

POPULATION TRENDS OF THE ENDANGERED GOLDEN-CHEEKED WARBLER AT FORT HOOD, TEXAS, FROM 1992-2001

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ABSTRACT—We assessed population trends of the endangered golden-cheeked warbler (*Dendroica chrysoparia*) at Fort Hood, Texas, using point-count data from 1992 through 2001. We assessed the effect of a large-scale fire in 1996 on these population trends and the effect of military training activities on relative abundance of golden-cheeked warblers. Results indicated that the population has increased steadily at Fort Hood during the 10-yr period. The 1996 fire might have caused a decrease in detections from 1996 through 2001, but excluding any localized effects of the fire, population size continued to increase. Analyses of data from areas with and without military training detected no effect of these activities on the relative abundance of golden-cheeked warblers. Habitat protection and a cowbird-control program might have contributed to the increasing population of golden-cheeked warblers at Fort Hood during the period of study. Data on population trends, demography, and factors limiting population size are needed from other areas to understand more fully the threats to and management needs of the golden-cheeked warbler.

RESUMEN—Evaluamos las tendencias poblacionales de la reinita pechinegra (*Dendroica chrysoparia*) en Fort Hood, Texas, usando conteos por puntos desde 1992 hasta el 2001. Evaluamos el efecto que tuvo un incendio a gran escala en 1996 en las tendencias de esta población y el efecto de actividades de entrenamiento militar en la abundancia relativa de la reinita pechinegra. Los resultados indican que el tamaño de la población ha aumentado consistentemente en Fort Hood durante 10 años. El incendio de 1996 puede haber causado una disminución en detecciones desde 1996 hasta el 2001, pero fuera de cualquier efecto local del incendio, el tamaño de la población siguió aumentando. Los análisis de los datos de áreas con entrenamiento militar, o sin este, no detectaron ningún efecto de estas actividades en la abundancia relativa de la reinita pechinegra. La protección del hábitat y el programa de control de los pájaros vaqueros pueden haber contribuido al aumento de la población de la reinita pechinegra en Fort Hood durante el estudio. Se necesitan datos de otras áreas sobre las tendencias poblacionales, demografía y factores que limitan el tamaño de la población para entender mejor las amenazas a y las necesidades de manejo de la reinita pechinegra.

Information on population trends is important for identifying populations of concern and for assessing effects of management actions (Ralph et al., 1995; DeSante and Rosenberg, 1998). Programs to monitor population trends have identified long-term changes in populations of many songbird species (Robbins et al., 1989; Peterjohn et al., 1995; James et al., 1996). Identification of changes in population size is particularly critical in the management and conservation of endangered species.

The golden-cheeked warbler (*Dendroica*

chrysoparia) is an endangered Neotropical migrant songbird that breeds in the United States and winters in Mexico and Central America. The breeding range of this species is restricted to central Texas, and its breeding habitat is restricted to mature oak-juniper forest (*Quercus-Juniperus ashei*; Ladd and Gass, 1999). Due to an increasing rate of loss of breeding habitat, primarily from urban expansion and conversion to agricultural land, the golden-cheeked warbler was emergency-listed as federally endangered in 1990 (United States Fish and Wildlife Service, 1990, 1992).

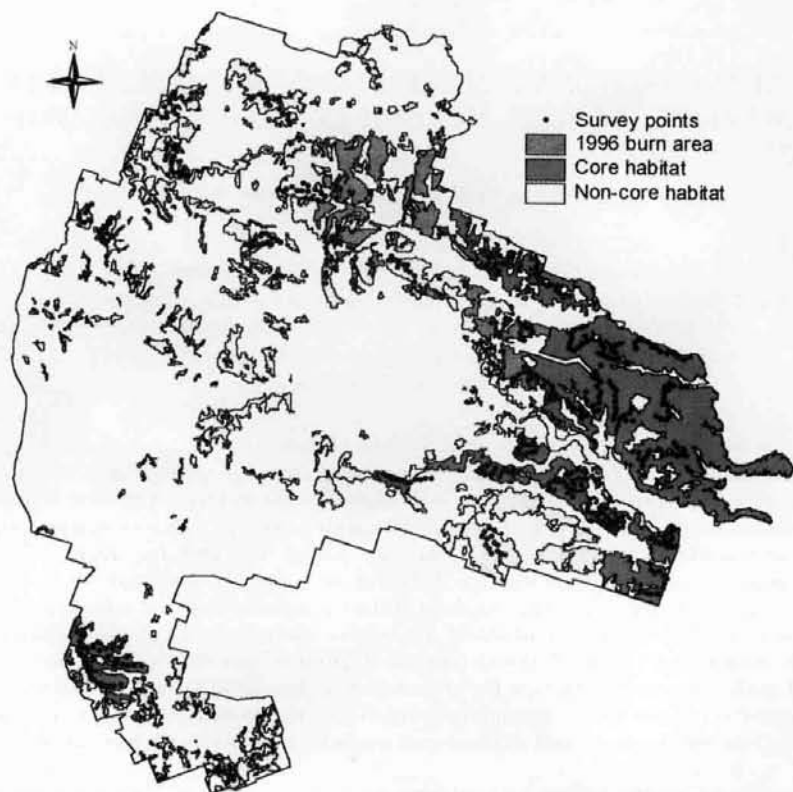


FIG. 1—Golden-cheeked warbler point-count survey routes, the 1996 burn area, and “core” and “non-core” habitats at Fort Hood, Texas.

The majority of breeding habitat occurs on private lands (Ladd and Gass, 1999). The largest population of this species under a single management agency on public land occurs at Fort Hood, Texas (Ladd and Gass, 1999). Fort Hood, an active United States Army installation, covers 88,500 ha and contains approximately 21,500 ha of golden-cheeked warbler breeding habitat. Territory density data (based on spot-map surveys) indicate that Fort Hood supports approximately 4,500 breeding pairs of golden-cheeked warblers (Anders, The Nature Conservancy, unpubl. data). Fort Hood is critical to the viability of golden-cheeked warblers for 2 reasons: 1) it contains the largest breeding population of golden-cheeked warblers under single management authority, and 2) because Fort Hood is managed by a federal agency, activities on the installation currently are restricted by provisions of the Endangered Species Act.

Following the federal listing of golden-

checked warblers, the Department of Defense began monitoring this species at Fort Hood in 1991 (Hayden and Tazik, United States Army Construction Engineering Research Laboratory, unpubl. data). This monitoring program has yielded the largest and longest-term point-count survey data set for golden-cheeked warblers anywhere on their breeding grounds. Analyses of this data set allow for the examination of population trends on Fort Hood from 1992 through 2001 and of potential effects of military training activities on this species.

In February 1996, fires sparked by military ordnance burned 4,015 ha of Fort Hood, destroying 2,108 ha of oak-juniper forest and decreasing the amount of golden-cheeked warbler habitat on Fort Hood by approximately 15% (Fig. 1; Sanchez, The Nature Conservancy, unpubl. data). Although the fire occurred before golden-cheeked warblers returned from their wintering grounds, the loss of such a

large amount of breeding habitat would have affected territorial settlement patterns, forcing returning breeders to establish territories in other areas. Several of the permanent golden-cheeked warbler survey points on Fort Hood are located in the area burned in 1996. Analyses of survey data that include and exclude these survey points allows for an examination of the effect of the fire on population trends from 1996 through 2001.

In addition to directly impacting breeding habitat, military training activities can affect the behavior and physiology of animals, potentially leading to changes in population viability. Military activity has been shown to alter patterns of abundance, space use, or behavior in a variety of birds and mammals (caribou: Maier et al., 1998; eagles: Stalmaster and Kaiser, 1997; mule deer: Stephenson et al., 1996; ducks: Conomy et al., 1998; Mexican spotted owls: Delaney et al., 1999), and the residual chemicals from munitions or other military devices can impact reproductive success of wildlife long after military use of an area has stopped (Anthony et al., 1999; Dudley et al., 2002). However, several studies of birds have found no apparent effect of military activity on site occupancy (loggerhead shrikes: Michaels and Cully, 1998; Henslow's sparrows: Cully and Michaels, 2000), abundance (raptors: Lehman et al., 1999; Schueck et al., 2001), or reproductive success (red-cockaded woodpeckers: Doresky et al., 2001; raptors: Lehman et al., 1999). Thus, any hypothesized impact of military activity requires testing.

At Fort Hood, the combination of live munitions fire, aircraft overflight, tracked vehicles, and infantry maneuvers has the potential to impact settlement patterns and breeding-site fidelity by golden-cheeked warblers. From 1991 through 1999, all habitat of the golden-cheeked warbler at Fort Hood was protected from direct military training activities during the breeding season. In 2000, the Fort Hood Endangered Species Management Plan was implemented. Under this plan, areas of "core" habitat remain under military training restrictions, while areas of "non-core" habitat are open to training activities during the breeding season. Core areas consist of relatively large blocks of contiguous habitat, while non-core areas consist of smaller, more isolated habitat patches (Fig. 1; Hayden et al., United States

Army Construction Engineering Research Laboratory, unpubl. data). After the implementation of the Fort Hood Endangered Species Management Plan, military training activities occurred in non-core habitat in 2000 and 2001, with ground vehicle maneuvers, artillery firing, and aviation training activities being highly visible. Golden-cheeked warbler survey points were located on both core and non-core areas of Fort Hood; an assessment of the relationship between training activities and the relative abundance of golden-cheeked warblers based on survey data provides one measure of the effects of military training activity on the species.

In this study, we assessed the long-term population trends of golden-cheeked warblers at Fort Hood by analyzing point-count survey data from 1992 through 2001. We examined whether population trends were affected by a large-scale fire that destroyed breeding habitat in 1996, and we examined whether military training activities affected the relative abundance of golden-cheeked warblers at Fort Hood in 2000 and 2001.

METHODS—Study Area—Fort Hood is an 88,500-ha United States Army installation in Bell and Coryell counties, spanning the Edwards Plateau Ecoregion and the Cross Timbers and Southern Tallgrass Prairie Ecoregion in central Texas. Fort Hood was established in 1942 and now comprises the largest army installation in the United States. A full range of military activities is conducted at Fort Hood, including large-scale troop and ground vehicle maneuvers, live-fire weapons training, and aviation training, by over 40,000 active military personnel. Because Fort Hood was established on property that originally was privately held ranchland, grazing agreements were arranged to allow the continued use of this area for cattle grazing. The current grazing lease with the Central Texas Cattlemen's Association permits the presence of 3,500 animal units on a free-range area that encompasses 65,560 ha. In addition to cattle grazing, sections of Fort Hood are open for public recreation, including mountain biking, off-road vehicle use, hunting, fishing, and hiking.

The habitat at Fort Hood consists of approximately 65% perennial grassland and 30% forest, dominated by oaks and junipers (United States Army, unpubl. data). The majority of the wooded areas, including breeding habitat of golden-cheeked warblers, currently exist on the tops and sides of rolling hills and mesas.

In 1991, permanent survey points were estab-

lished in oak-juniper forests throughout Fort Hood (Hayden and Tazik, United States Army Construction Engineering Research Laboratory, unpubl. data). Pilot point-count surveys were conducted in 1991, and in 1992, a standard point-count survey protocol was established (Hayden, United States Army Construction Engineering Research Laboratory, pers. comm.). Over time, as money and personnel allowed, additional permanent survey points were established to increase the power to detect changes in population size (Niven, United States Army Construction Engineering Research Laboratory, unpubl. data) and to increase survey coverage of the installation. The numbers of points surveyed each year were: 1992: 206 points along 19 routes; 1993 and 1994: 228 points along 21 routes; 1995: 217 points along 21 routes; 1996: 342 points along 27 routes; 1997: 365 points along 27 routes; and 1998 through 2001: 428 points along 31 routes (Fig. 1; United States Army, unpubl. data). Point-count routes consisted of 10 to 18 points situated approximately 300 m apart along trails, and all survey points (both within and between routes) were located at least 300 m apart. Intervals of 300 m ensured independence among points, such that the survey point was considered the sampling unit (Pendleton, 1995).

Data Collection—Point-count routes were sampled between 25 March and 11 June from 1992 through 2001. In 1992, routes were each sampled once. To decrease between-year detection variability due to observer variability (Sauer et al., 1994), from 1993 through 2001 each route was sampled at least twice, once each by 2 different observers. From 1996 through 1999, a subset of routes was sampled 6 times within a season. In all years prior to 2000, 2 observers sampled each route on the same day. In 2000 and 2001, observers sampled routes on separate days to ensure independence among counts and to reduce daily biases due to weather or other factors. In all years, routes were sampled in opposite directions by the 2 observers to reduce time-of-day bias in detection rates (Palmeirim and Rabaca, 1994).

From 1992 through 1995, point-count sampling consisted of 10-min unlimited-radius counts at each point. The 10-min period was broken into intervals consisting of the first 3 minutes, the second 3 minutes, and the final 4 minutes. In 1996, counts were reduced to 6-min unlimited-radius counts, because that count length provided a better compromise between power to detect population changes and number of points that could be surveyed in a single morning (Niven, United States Army Construction Engineering Research Laboratory, unpubl. data). Because the 10-min counts in 1992 through 1995 were broken into 3-min intervals, detections that occurred within the first 6 minutes of the counts can

be used in analyses with the 6-min counts from 1996 through 2001.

Counts generally began within 20 min of sunrise and ended by 1100 CST. Counts were not conducted during periods of wind or rain strong enough to interfere with detection of birds. At each point, observers recorded date, time, observer, route number, and point number. All golden-cheeked warblers detected at the point were recorded and identified to sex, and the time interval in which each bird was detected was noted.

Data Analysis—To determine whether golden-cheeked warbler population size at Fort Hood changed between 1992 and 2001, we conducted linear regression analyses. In these analyses, we used the first 6 minutes of point-count data from all points surveyed within each year. For routes that were sampled more than twice per year prior to 2000, we used a subsample of 2 independent surveys for each route, choosing dates that were similar among years for each route. For each point within a year, the numbers of male golden-cheeked warblers detected at that point during each survey were averaged, providing a mean number of detections at each point within each year.

We used 2 analytical approaches. First, we conducted a regression analysis using as a datum the average number of detections across all points surveyed in a given year, yielding a single measure of relative abundance per year (i.e., the mean number of detections was summed for all points within a year then divided by the total number of points surveyed during that year). Secondly, we conducted a regression analysis using as a datum the average number of detections across the points in each route in a given year, yielding 19 to 31 data points per year.

Because the mean detection values were Poisson-distributed in both of these analyses, mean detection values were transformed by adding 0.5 to each mean detection and taking the square root of this value (Zar, 1999).

In 1993, information was available only for the entire 10-min point count. Because 6-min count data were not available for 1993, we used the ratio of 10-min to 6-min total mean detections per point for 1992, 1994, and 1995 to estimate 6-min total mean detections per point for 1993 (mean of the 10-min to 6-min total mean detection per point ratios for 1992, 1994, and 1995 was 1.082, range = 1.077 to 1.086). If we excluded the 1993 data entirely from all analyses of population trends over time, there was no meaningful change in the test statistics, *P*-values, or slopes of the regression models.

To examine the effect of the 1996 fire on population trends, we conducted an additional regression analysis. This analysis was identical to the regression analyses described above, with the exception that all data (1992 through 2001) from the 25 survey points

located within the 1996 burn area were excluded. For both data sets (with and without the 25 survey points in the burned area), we fitted regression models using 2 predictor variables: year and a categorical variable for pre-burn and post-burn. If the fire significantly reduced the mean number of detections across all points, the categorical variable should be significant in the analysis of the full data set, but not in the analysis that excluded the burned area.

To determine whether military training was associated with a decreased abundance of golden-checked warblers, we analyzed point-count data from 89 survey points along 6 routes in non-core habitat and from 230 points along 17 routes in core habitat from 1998 through 2001 (Fig. 1). Military training was restricted in all areas in 1998 and 1999; training restrictions were then lifted in the non-core areas in 2000 and 2001. Within each year, we first calculated mean number of detections per point based on 2 surveys. As in the previous analyses, for routes that were sampled more than twice a year, we chose a subset of 2 independent surveys that most closely matched the dates those routes were surveyed in 2000 and 2001. Because the mean detection values were Poisson distributed, mean detection values were transformed by adding 0.5 to each mean detection and taking the square root of this value (Zar, 1999). We used these transformed data in a repeated-measures analysis of variance (ANOVA) in SPSS (SPSS, Inc., Chicago, Illinois). In this analysis, we used habitat type (i.e., core and non-core) as a between-subjects factor and year as a within-subjects repeated-measures factor. We tested for differences between core and non-core habitats in numbers of detections from 1998 through 2001 by testing for a year \times habitat interaction.

RESULTS—A regression analysis of the transformed data showed a significant positive relationship between mean detections per point and year, whether based on overall mean detections (2-tailed $t_8 = 5.96$, $P < 0.001$, $r^2 = 0.84$; Fig. 2a) or on mean detections per point-count route ($t_{255} = 3.90$, $P < 0.0005$, $r^2 = 0.056$), indicating that the golden-checked warbler population size at Fort Hood increased significantly between 1992 and 2001. This finding was not affected by exclusion of the 1993 data nor by restricting our dataset to only those 206 points established in 1992 (using route means: $t_{185} = 3.87$, $P < 0.0005$, $r^2 = 0.075$).

A regression analysis excluding all data from survey points within the 1996 burn area also indicated a significant positive relationship between mean detections per point and year

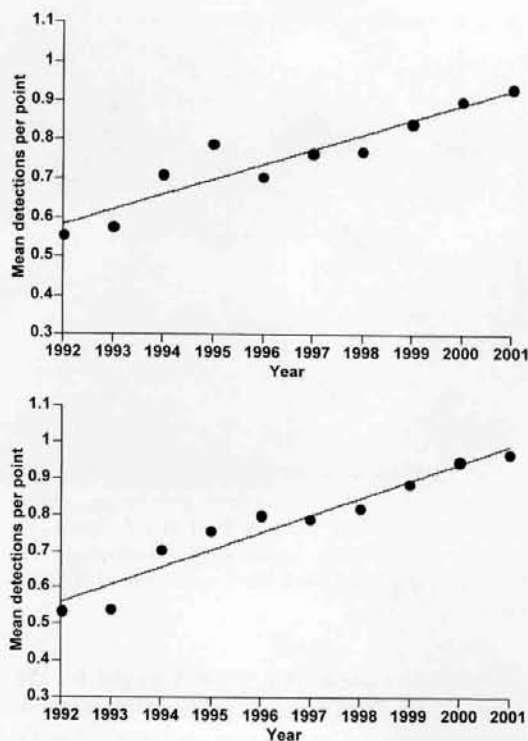


FIG. 2.—Top) mean numbers of golden-checked warbler detections per survey point at Fort Hood, Texas, from 1992 through 2001. Bottom) mean numbers of golden-checked warbler detections per survey point, excluding points in habitat burned by the 1996 fire, from 1992 through 2001. Although values were square-root transformed for analysis, they have been back-transformed for presentation here.

(overall mean detections: $t_8 = 8.20$, $P < 0.001$, $r^2 = 0.91$); however, unlike the above analysis, this relationship indicated no decline in point-count detections in 1996 (Fig. 2b). Golden-checked warblers were completely absent from the burned area from 1996 through 2001 (i.e., there were 0 detections of golden-checked warblers at all survey points within the burned area). In multiple regression models using a categorical variable for pre-burn and post-burn years, the categorical variable was significant in the model that included all survey points ($t_8 = -2.41$, $P = 0.05$) and not significant in the model that excluded survey points in the burned area ($t_8 = -0.45$, $P > 0.6$), suggesting that the 1996 fire significantly reduced the mean number of detections per point in the burned area from 1996 through 2001.

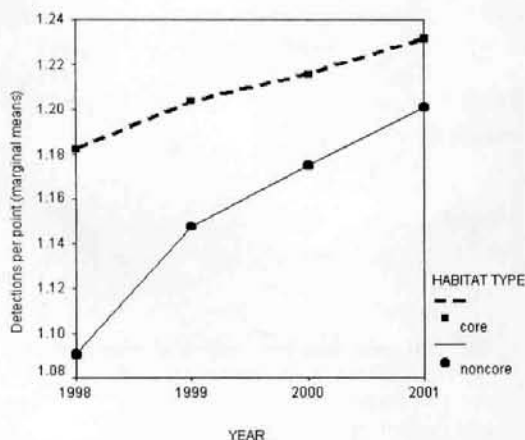


FIG. 3.—Mean number of golden-cheeked warbler detections at core and non-core point-count points from 1998 through 2001 at Fort Hood, Texas. Although values were square-root transformed for analysis, they have been back-transformed for presentation here.

A repeated-measures ANOVA to test for differences in detections of golden-cheeked warbler in core habitat versus non-core habitat over time revealed a difference between habitats that was not statistically significant ($F = 3.285$, $P = 0.071$), with more detections in core habitat than in non-core habitat (Fig. 3). However, a test for year \times habitat interaction indicated no interaction effect ($F = 2.056$, $P = 0.153$), suggesting that any differences in detections that existed between core and non-core habitat existed before military training restrictions were lifted. In addition, numbers of detections within both habitat types increased each year from 1998 through 2001 (Fig. 3).

DISCUSSION—Analysis of golden-cheeked warbler point-count survey data from 1992 through 2001 indicated a significant increase in population size at Fort Hood. During this 10-yr period, the mean number of golden-cheeked warblers detected at each survey point almost doubled. The increase in population size has not yet leveled off, suggesting that breeding habitat at Fort Hood might not yet be saturated.

Between 1992 and 1995, the mean number of golden-cheeked warblers detected at each survey point increased steadily each year. Overall detection rate, but not mean detections on each route, declined in 1996 and again in-

creased steadily from 1997 through 2001. An analysis of the overall point-count data excluding all survey points within habitat burned by the 1996 fire showed no decline in detections of warblers in 1996. In addition, because golden-cheeked warblers were completely absent from the burned area from 1996 through the end of this study in 2001, exclusion of survey points within the burned area also resulted in an increase in mean number of detections per point from 1997 through 2001. These results suggested that the 1996 fire caused a decrease in overall detections of golden-cheeked warblers through 2001. However, excluding the localized effects of the fire, the population of golden-cheeked warblers continued to increase over time.

A long-term increase in population size at Fort Hood is potentially encouraging, but an accurate interpretation of this trend requires an understanding of the underlying demographic processes. For instance, an increase in population size at Fort Hood might indicate an increased rate of immigration of young or adults from other areas. While most golden-cheeked warbler breeding habitat is under extreme development pressure from urban expansion and conversion to agricultural land (United States Fish and Wildlife Service, 1992), the habitat at Fort Hood remains relatively well protected from continued fragmentation and destruction. As breeding habitat continues to be destroyed in other areas, the stability of habitat at Fort Hood might contribute to increased immigration of young or adults from other areas.

An increase in population size also might have resulted from increased productivity and recruitment at Fort Hood. A program to control brood parasitism by brown-headed cowbirds (*Molothrus ater*) has been in place at Fort Hood since 1988 (Eckrich et al., 1999). Golden-cheeked warblers are susceptible to cowbird parasitism, with a parasitism rate of 68% documented in a population in Kendall County, Texas (Pulich, 1976). Rates of parasitism on golden-cheeked warbler nests at Fort Hood were not documented prior to 2000, but we found no signs of cowbird parasitism in 83 golden-cheeked warbler nests nor on 349 monitored golden-cheeked warbler territories in 2000 and 2001 (Anders, The Nature Conservancy, unpubl. data). Parasitism of black-

capped vireo (*Vireo atricapillus*) nests at Fort Hood has been reduced from >90% in 1987 to <10% in 2001 (Eckrich et al., 1999; Summers and Sterling, The Nature Conservancy, unpubl. data). Based on territory-monitoring data, the proportion of golden-cheeked warbler pairs producing young at Fort Hood has not increased over time (Department of Defense, unpubl. data). However, because the cowbird-control program at Fort Hood has virtually eliminated the threat of brood parasitism on the installation, it is possible that the number of fledglings per pair or the proportion of pairs producing second broods has increased over time. Ongoing research on pairing success, production of first and second broods, and survival rates at Fort Hood will further contribute to our understanding of population dynamics of golden-cheeked warblers.

Other potentially confounding factors that might require additional investigation include effects of smaller fires, changes in recreational activity at Fort Hood, and brush clearing on the installation and on adjoining private land. Military activity increases the incidence of fire, but most of these fires are grass fires that do not impact golden-cheeked warbler habitat. Although the impact of recreation is likely small relative to any effects of military training, study of this impact is currently underway. Brush clearing might be a more important issue, but the history of brush clearing is not quantified well enough to test for impacts on population dynamics of golden-cheeked warblers. Much of this clearing has been of monotypic juniper stands that are not suitable for warblers. If destruction of small patches of suitable habitat went undetected, it would represent a net loss of protected breeding area. However, when destruction of any potential breeding habitat (i.e., mature oak-juniper forest) is detected at Fort Hood, the United States Army is required to protect additional habitat in mitigation, regardless of whether habitat destruction was due to brush-clearing, fire, or military training maneuvers.

In 2000, the Fort Hood Endangered Species Management Plan was put into effect, in which areas of core golden-cheeked warbler habitat were protected from military training during the breeding season, while areas of non-core habitat were open to training activities (Hayden et al., United States Army Construction

Engineering Research Laboratory, unpubl. data). Although large-scale vehicle maneuvers, artillery fire, and aviation training did occur in non-core habitat in 2000 and 2001, potentially increasing disturbance to breeding birds, analysis of point-count data from core and non-core habitats showed no difference in detections of golden-cheeked warblers after the lifting of military training restrictions. Because this finding constitutes a failure to reject the null hypothesis, caution is warranted when interpreting the lack of apparent difference between core and non-core areas. Also, because core designations were applied to predominantly contiguous habitat (rather than to fragments), there could be intrinsic differences in the quality of core and non-core areas that could be more important than any effects of military training.

Despite the apparent lack of effect of military training, we have tested only for differences in relative abundance of birds. If training activities discouraged birds from establishing territories in an area, our analysis would indicate that type of disturbance. However, ecologically important disturbance in the form of decreased pairing success or decreased productivity would not be evident from analysis of point-count data alone. For this reason, research was initiated in 2000 to study these demographic factors on a study site in non-core habitat. Pairing success and productivity, as well as return rates and direct measures of territory density, will be assessed for comparison between non-core and core habitats. Examination of these demographic parameters provides a way to study less obvious but potentially important effects of military training on golden-cheeked warblers.

Although trend data from other populations of golden-cheeked warblers were not available for comparison, populations of this species might be declining in other parts of its breeding range. Fragmentation and destruction of breeding habitat is occurring in many areas, and populations likely are declining due simply to a decrease in available breeding habitat (United States Fish and Wildlife Service, 1992). In addition, cowbird parasitism might be reducing productivity in areas without cowbird-control programs. Finally, much of the warbler habitat outside of Fort Hood is adjacent to urban areas or surrounded by agricul-

tural land. In those areas, large mammalian predators, such as coyotes (*Canis latrans*) and bobcats (*Lynx rufus*), are less prevalent, and smaller mammals, such as house cats (*Felis domesticus*), raccoons (*Procyon lotor*), and opossums (*Didelphis virginiana*), consequently might pose a greater nest-predation threat for golden-cheeked warblers (Estes, 1996; Henke and Bryant, 1999). Overall, the warbler population at Fort Hood likely is in better condition than populations in other areas, and the persistence of viable populations at other sites will be necessary for recovery of this species.

Current research on demography of golden-cheeked warblers at Fort Hood, including the study of productivity and adult survival and the identification of nest predators, will contribute further to our understanding of population dynamics. Research on population trends, demographic parameters, brood parasitism, and nest predation in other areas of the range of the species is needed to more fully understand the threats to golden-cheeked warblers and the management actions that can be taken to protect them.

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