Demographics of the Golden-cheeked Warbler (Dendroica chrysoparia) on Fort Hood, Texas

by

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The Golden-cheeked Warbler (Dendroica chrysoparia) is a federally endangered migratory passerine that has its breeding range contained in the central Texas area that includes Fort Hood. Its listing as endangered in 1991 was a result of the rapid degradation and increasing fragmentation of habitat, causing a decline in their population. To assist in conservation and recovery of the Golden-cheeked Warbler and comply with the Endangered Species Act, environmental managers need information on the demographic parameters of the population on Fort Hood.

Researchers surveyed and documented the Golden-cheeked Warbler on Fort Hood, Texas between 1991 and 1996. The population remained relatively stable, with a slight decrease in 1996. The average return rate for males banded as adults was 45.5%; for males banded as juveniles the average was 16.9%. Dispersal distances for males banded as adults averaged 223 m. Dispersal distances for males banded as juveniles were significantly greater, with an average of 4,040 m. Densities of territorial males remained relatively stable between 1992 and 1996, with a peak density of 28 males per 100 ha (average of 18 males per 100 ha). Productivity of males within an intensive study area averaged 2.0 young per mated male.
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Foreword

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1 Introduction

Background

The Golden-cheeked Warbler (*Dendroica chrysoparia*) is a federally endangered migratory passerine that has its breeding range contained within the range of Ashe juniper (*Juniperus Ashei*) on the Edward’s Plateau of central Texas. Its listing as endangered in 1991 was a result of the rapid degradation and increasing fragmentation of habitat, causing a decline in their population (Benson 1990). Pulich (1976) estimated the breeding population to be approximately 14,950 birds. Wahl, Diamond, and Shaw (1990) believed that their estimation of 4,822 to 16,016 breeding pairs was “unrealistically” high. As of 1995, the species was believed to breed in at least 24 central Texas counties, a reduction of 23% since 1976 (31 counties; Pulich 1976; U.S. Fish and Wildlife Service [USFWS] 1996).

The species is entirely dependent upon the mature Ashe juniper forests of central Texas for its nesting and foraging substrates. The species builds its nests almost entirely from shredded juniper bark at a height of 4 to 5 meters, most commonly in Ashe juniper and occasionally in hardwoods common to the region (e.g., live oak, Texas oak; Pulich 1976). Only mature Ashe juniper trees shred their bark, limiting the Golden-cheeked Warbler to forests with a high proportion of juniper trees older than 40 to 50 years (Pulich 1976). Warblers, however, rarely exist in stands of pure juniper, as they also require hardwoods for foraging substrate. Early in the season, they forage most frequently in deciduous hardwood trees, primarily oaks, then switch to juniper as a principal foraging substrate later in the season (Beardmore 1994). For a more detailed description of the Golden-cheeked Warbler and its habitat, see Pulich (1976).

Fort Hood, Texas is located partially in both Bell and Coryell counties in east central Texas. Vegetative cover on the installation varies with slope, aspect, moisture, and previous use (e.g., cattle grazing and military activities), and consists of grassland, open savannah, hardwood thickets, and dense juniper-oak stands. For a more detailed habitat description of Fort Hood, see Tazik and Cornelius, 1993. Within its 87,890 hectares (ha) is approximately 16,000 ha of Golden-cheeked Warbler habitat.
The Golden-cheeked Warbler was listed as endangered in 1991 under the Endangered Species Act (ESA) of 1973, as amended. To assist in conservation and recovery of the Golden-cheeked Warbler and comply with the ESA, environmental managers need information on the demographic parameters of the population on Fort Hood. In 1991, these demographics were not available.

Quality and amount of warbler habitat appeared stable on Fort Hood between 1991 and 1995 (Figure 1). However, in February of 1996, a large wildfire destroyed approximately 4,300 ha (25%) of warbler habitat, mostly in the northern and northeastern sections of Fort Hood (Figure 2). A separate study was initiated to investigate the effects of this fire on warbler return rates and dispersal distance; males affected by the fire were not reported in this paper, and their numbers were not used in analyses of return rate or dispersal distance.

Figure 1. Map of Fort Hood, TX, showing approximate extent of Golden-cheeked Warbler habitat, including areas burned in February 1996. (1 cm ~ 2,900 meters.)
Objectives

The objectives of this work were to determine and document (1) demographic parameters (return rates, dispersal distances, productivity, and mated status) affecting population status and (2) occurrence of the Golden-cheeked Warbler on Fort Hood, Texas.

Approach

Research on the Golden-cheeked Warblers was conducted on Fort Hood, Texas between 1991 and 1996. Landsat MSS data were integrated with a Geographic
Information System (GIS) application, Geographic Resources Analysis Support System (GRASS), to suggest potential warbler habitat. Researchers then surveyed these areas, documenting the presence or absence of habitat, and numbers of birds seen or heard. Researchers also established an intensive study area in 1991, banding Golden-cheeked Warblers, and determining territory, mated status, and productivity. The research work consisted of systematically surveying possible Golden-cheeked Warbler habitat, color-banding adults, and monitoring an intensive study area to determine species productivity. Data from these studies were compiled and analyzed, and recommendations were made regarding the monitoring and management of the Golden-cheeked Warbler population on Fort Hood, Texas. Study methods are described in Chapter 2 of this report and in Hayden, Jetté, and Weinberg (in prep.).

Mode of Technology Transfer

This research contributes to a fundamental understanding of the ecology of the endangered Golden-cheeked Warbler, and serves as an example of a proactive approach to endangered species management on Army lands. This and other related reports are being transmitted to military, land, and wildlife managers at Fort Hood, TX; Headquarters, U.S. Army Forces Command (HQ FORSCOM); and the Department of the Army for use in ESA compliance efforts.
2 Methods

This chapter provides a brief overview of research methods between 1991 and 1996. For a detailed description of field methods used in this study, see Hayden, Jetté and Weinberg (in prep).

Data Collection

The research focus changed in the years following the project’s initiation in 1991. The focus shifted from a survey of the entire population of Golden-cheeked Warblers to documenting specific demographic and life history characteristics. This change of focus allowed collection of detailed information regarding return rates, dispersal distances, productivity, mated status, and age structures.

In 1991, a study area was established at the boundary of training areas 2 and 3A. It was necessary to change the location of the study area the following year due to difficulties accessing the site. A new intensive study area (13B, hereafter referred to as the Intensive Study Area [ISA], Figures 2 and 3) with an approximate area of 178 ha was established in 1992 in the eastern side of training area 13B. The 13B/ISA is relatively isolated from other patches of warbler habitat. It is enclosed on the north and northeast by Lake Belton, on the south by pasture, and on the southeast by savannah (open, partially wooded grassland). To the west of the study area is a combination of grassland (west) and stands of pure juniper (southwest) that were unoccupied by warblers. The northwestern section of the study area was attached to more extensive warbler habitat by a “corridor” of warbler habitat.

Golden-cheeked Warblers were captured using mistnets and playbacks of recorded songs and calls. Individuals were banded, aged, and sexed according to Pyle, et al. (1987) and Hayden, Jetté, and Weinberg (in prep). For a review of warbler-specific mistnetting techniques, see Hayden, Jetté, and Weinberg (in prep); and Weinberg, Jetté, and Cornelius (1996). The methods used to age and sex adult warblers during banding were refined during the course of this study. In 1992, it was found that adult plumage characteristics could reliably be used to age to the “second year” (SY) or “after-second-year” (ASY) age classes rather than the general age class of “after-hatch-year” (AHY) used by Pyle, et al. (1987).
Figure 3. Map of the ISA (training area 13B) with Golden-cheeked Warbler habitat shown by a thick white line. (1 cm ~ 100 m.)

However, the AHY age class was still used on Fort Hood after June 15 since most adults were in molt by then and could not be reliably aged. The majority of males banded in a given year were aged more specifically than “AHY” (i.e., to SY or ASY) beginning at 18% in 1992 and increasing to 96% in 1993, remaining high for the rest of the study.

Sex determination of “hatch year” (HY) birds was not as reliable as it was for adults, as individuals were captured at different stages of their sex-specific plumage development. Males could be reliably sexed much earlier than females, because at a young age males generally show the distinct beginning to the dark throat and chest that is characteristic of adult males. If the HY bird was captured late enough in the season (or late enough in the individual’s development), it could be reliably sexed, regardless of its sex. Table 1 shows the total number of HY birds captured between 1991 and 1996, separated by sex. The ratio of banded, known-sex hatch year birds was approximately 1.86:1 (male:female), with 17% of the total HY capture population labeled as “unknown-sex.” Since it is unknown if males and females return and disperse at the same rates, only known-sex hatch year individuals were used to analyze hatch year return rates and dispersal distances.

Return rates were estimated as the ratio of banded males that were found by searching to the total of those searched for (including both found and not found). Previously banded male Golden-cheeked Warblers were searched for by returning to the last location the bird was sighted (or banded). Males resighted by this method were categorized as having been “searched for.” If a banded male was resighted opportunistically (e.g., was not being searched for at the time it was found), the resighting was considered an “incidental” find. Dividing returning birds into categories was necessary to evaluate bias in different approaches to return rate estimations. The use of opportunistically resighted males would bias the estimated return rate toward a higher-than-realistic figure.

Table 1. Total number of HY Golden-cheeked Warblers captured yearly on Fort Hood, including the ISA and non-ISA training areas.

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
<th>Total Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>1992</td>
<td>27</td>
<td>8</td>
<td>20</td>
<td>55</td>
</tr>
<tr>
<td>1993</td>
<td>16</td>
<td>6</td>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td>1994</td>
<td>47</td>
<td>30</td>
<td>8</td>
<td>85</td>
</tr>
</tbody>
</table>
A third resighting category consisted of those territorial males within the ISA. The ISA was considered separately because of the increased detection rate due to the intensive monitoring procedures. Therefore, the inclusion of the ISA in the overall return rate estimation would also bias the results. All males resighted are listed in Appendix A, which is sorted by resight type. All males searched for and not found are listed in Appendix B.

Site fidelity was estimated by calculating dispersal distance between years. Dispersal distance was determined by Pythagorean’s theorem, using the original and resighting locations to obtain a straight-line distance. If a banded bird was resighted in more than one year, the dispersal distance for the first resighting was that between the original banding location and the resighting location; the dispersal distance for the second (and subsequent) resighting was between the first resighting location and the second (or third, etc.). Between 1992 and 1995, researchers chose males to search for, based upon location. For example, field technicians decided in which training area they were going to work on a particular day, and looked at previous years’ maps of banding and resighting locations within that training area to have a starting point for searching. In 1996, however, this protocol changed somewhat. A list was established prior to the season, with band combinations and locations of certain males to be searched for. This list included both older and newly banded males, in order to obtain a broader mix of specific age-class return rates, rather than just for those younger males banded in recent years.

Productivity within the intensive study area was estimated by documenting the number of hatch year warblers being fed (by both males and females) on each territory each year. In 1992, specific numbers of HY were not always recorded for each territory within the ISA, as was standard protocol in later years. As these methods differed from those in later years, these data were excluded when analyzing overall and age-specific productivity. Productivity for 1992 was gathered from Bolsinger and Hayden (1992). Also, data from the 1991 season was not used for overall and age-specific productivity because birds weren’t aged to specific age classes in 1991, different data were recorded in the baseline year, and because it was in a different location (Training Areas 2 and 3A vs. the ISA).

Data recorded for observations of males outside the ISA generally included only their location and band combination. For those males found within the ISA, however, more detailed demographic data were collected, including the following:

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<tbody>
<tr>
<td>1995</td>
<td>56</td>
<td>34</td>
<td>7</td>
<td>97</td>
</tr>
<tr>
<td>1996</td>
<td>22</td>
<td>12</td>
<td>4</td>
<td>38</td>
</tr>
<tr>
<td>Total</td>
<td>170</td>
<td>90</td>
<td>54</td>
<td>314</td>
</tr>
</tbody>
</table>
presence or absence of a female, number of HY birds observed (and whether or not they were being fed), location of a nest (whenever possible), and territory boundaries (determined by the males regularly visiting certain areas and engaging in singing bouts and fights with neighboring males).

Data Analysis

Differences in return rates and mated status were analyzed by chi-square tests of differences. Any chi-square test that violated Cochran’s rule of small sample sizes had data lumped into adjacent categories until it no longer violated this assumption. For all tests conducted, a chi-square test of heterogeneity was used before attempting to lump years together. If the calculated value in the heterogeneity test was not significant, the years were lumped, and were not considered to be statistically different. If the calculated value in the heterogeneity test was significant, the years were not lumped, as they were considered statistically different.

Second year male percentages were calculated by dividing the number of banded SY males in the population (including newly banded males and returning HYs) by the total number of known-age banded adult males in the population (e.g., AHY, HY, and U-age males were excluded from these calculations).

When analyzing dispersal distances, the age classes of 3-year (3Y) vs. 4-year (4Y) vs. “after 4-year” (A4Y+; which included A4Y, 5Y, A5Y, 6Y, and A6Y age classes) were tested by a Kruskal-Wallis test to determine whether the age classes dispersed differently. These age classes were chosen to reduce possible overlap between “unknown” ages; for example, the ASY age class may contain males in the 4Y, 5Y, etc. age classes. The Kruskal-Wallis test was also used to determine significance in dispersal distances between the following groups: (1) HY and adult males, (2) HY and adult females, and (3) ISA “chance” find and searched-for males.

Return rates for 1992 were not calculated, as a separate list of males searched for and not found was not maintained. It was also noted in 1992 if resighted males were found by “chance” or were searched for. “Annual return rate” refers to males banded one year that were searched for the next year.

All tests were performed in Excel 5.0 and/or SPSS, version 6.1 for the PC.
3 Results

Return rates

Annual Return Rates

Return rates were evaluated for the years 1992-93, 1993-94, 1994-95, and 1995-96. Overall annual return rate of adult Golden-cheeked Warbler males in the ISA was 51.8% (n = 83; Table 2, Figure 4; Appendices A, B, and C). Annual return rates ranged between 31.3% (n = 32) in 1996 to 72.2% (n = 18) in 1995. The return rate of 31.3% in the ISA in 1996 is considered low, as the return rate for 1992 through 1995 was 64.7% (n = 51, Table 2). When tested by chi-square, these differences were significant ($\chi^2 = 14.75$, df = 3, $P = 0.002$).

Annual return rates of males in non-ISA training areas were consistently and significantly lower than those within the ISA, with an overall rate of 42.7% (n = 185, $\chi^2 = 8.35$, df = 3, $P = 0.039$; Table 2, Figure 4; Appendices A and B). The highest annual return was 52.8% (n = 72) in 1994. The lowest rate was in 1996, with 29.8% (n = 57).

Table 2. Annual return rates for adult male Golden-cheeked Warblers.*

<table>
<thead>
<tr>
<th>Year banded</th>
<th>Year resighted</th>
<th>ISA return rate</th>
<th>Non-ISA return rate</th>
<th>Combined return rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>1993</td>
<td>60% (20)</td>
<td>48.6% (37)</td>
<td>52.6% (57)</td>
</tr>
<tr>
<td>1993</td>
<td>1994</td>
<td>61.5% (13)</td>
<td>52.8% (72)</td>
<td>54.1% (85)</td>
</tr>
<tr>
<td>1994</td>
<td>1995</td>
<td>72.2% (18)</td>
<td>31.6% (19)</td>
<td>51.4% (37)</td>
</tr>
<tr>
<td>1995</td>
<td>1996</td>
<td>31.3% (32)</td>
<td>29.8% (57)</td>
<td>30.3% (89)</td>
</tr>
</tbody>
</table>

| All years   | 51.8% (83)     | 42.7% (185)     | 45.5% (268)         |

* This table excludes AHY and HY males. (n) = Number of adult males banded that were searched for in the following year.
While the overall annual return rate was lower for non-ISA training areas than for the ISA (42.7%, \(n = 185\), and 51.8%, \(n = 83\), respectively), it was not statistically different (\(\chi^2 = 1.57, \text{df} = 1, P = 0.21\)). When the ISA and non-ISA return rates were lumped by year (test of heterogeneity: \(\chi^2 = 6.12, \text{df} = 4, P = 0.19\)), it was found that the difference between years was significant, with the 1996 overall return rate the lowest at 30.3% \((n = 89)\), and the 1994 overall return rate the highest at 54.1% \((n = 85, \chi^2 = 12.48, \text{df} = 3, P = 0.006)\).

Overall, 228 males were resighted at least one time; 51 males at least two times; 17 males at least three times; and four males were resighted four times (Appendix A).

**Overall Return Rates**

When looking at all adults present and territorial within the ISA one year that returned the next, the Golden-cheeked Warbler male had an overall return rate of 48% \((n = 127)\), with a low of 30% \((n = 50)\) in 1996 and a high of 65.6% \((n = 32)\) in 1995 (Table 3, Appendices A and C). This among year difference was significant (\(\chi^2 = 12.03; \text{df} = 3, P = 0.007\)). When the age classes were tested separately among years, SY and ASY return rates were both significantly different (SY: \(\chi^2 = 7.85, \text{df} = 3, P = 0.049\); ASY: \(\chi^2 = 10.67, \text{df} = 3, P = 0.014\); Table 3; Figure 5). SY males returned with the highest frequency in 1994, at 81.8%, and the lowest in 1996, with 30%. All ASY males returned with the highest frequency in 1995, at 76.5%, and the lowest in 1996 with 30%. Overall rates of return, however, did not differ significantly when divided into separate age classes: SY males returned at 49.1% \((n = 53)\) whereas all ASY lumped together
returned at 48.6% \((n = 70, \, \chi^2 = 1.017, \, df = 1, \, P = 0.90)\). When the age classes were further divided into specific age groups (of SY, 3Y, ASY, A3Y, and 4Y+), there were still no significant differences in overall return rates \((P > 0.05)\). ASY males returned most frequently at 57.7% \((n = 26)\), and A3Y males returned the least at 36.4% \((n = 11, \, \chi^2 = 1.50, \, df = 4, \, P = 0.83)\).

Table 3. Return rates for ISA males present and territorial for 1-year periods between 1992 and 1996.*

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<tbody>
<tr>
<td>SY</td>
<td>3/7 = 42.9%</td>
<td>9/11 = 81.8%</td>
<td>8/15 = 53.3%</td>
<td>6/20 = 30%</td>
<td>26/53 = 49.1%</td>
</tr>
<tr>
<td>All ASY</td>
<td>7/11 = 63.6%</td>
<td>5/12 = 41.7%</td>
<td>13/17 = 76.5%</td>
<td>9/30 = 30%</td>
<td>34/70 = 48.6%</td>
</tr>
<tr>
<td>ASY</td>
<td>7/9 = 77.8%</td>
<td>1/2 = 50%</td>
<td>3/3 = 100%</td>
<td>4/12 = 33.3%</td>
<td>15/26 = 57.7%</td>
</tr>
<tr>
<td>3Y</td>
<td>1/3 = 33.3%</td>
<td>6/8 = 75%</td>
<td>2/8 = 25%</td>
<td>9/19 = 47.7%</td>
<td></td>
</tr>
<tr>
<td>A3Y</td>
<td>0/2 = 0%</td>
<td>3/6 = 50%</td>
<td>1/1 = 100%</td>
<td>0/2 = 0%</td>
<td>4/11 = 36.4%</td>
</tr>
<tr>
<td>4Y+</td>
<td>3/4 = 75%</td>
<td>3/8 = 38%</td>
<td>6/12 = 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4Y</td>
<td>1/1 = 100%</td>
<td>2/5 = 40%</td>
<td>3/6 = 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>2/3 = 66.7%</td>
<td>0/1 = 0%</td>
<td>2/4 = 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td>1/1 = 100%</td>
<td>1/1 = 100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A5Y</td>
<td>0/1 = 0%</td>
<td>0/1 = 0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHY</td>
<td>1/4 = 25%</td>
<td>0/1 = 0%</td>
<td>1/1 = 100%</td>
<td>0/0 = 0%</td>
<td>2/6 = 33.3%</td>
</tr>
<tr>
<td>All ages</td>
<td>11/22 = 50%</td>
<td>14/23 = 60.9%</td>
<td>21/32 = 65.6%</td>
<td>15/50 = 30%</td>
<td>61/127 = 48%</td>
</tr>
</tbody>
</table>

* Numbers indicate those found divided by those present and territorial previous year. "Age Class" refers to age at banding or most recent observation. "ASY" in this table refers only to returning AHY males, and newly banded ASY males. "All ASY" is a total of all banded males, excluding SY and AHY.

Figure 5. Return rates for adult males within the ISA, by age and year.
As with the ISA, there was a significant difference among years in average return rates for males outside the ISA (all ages combined, $\chi^2 = 23.56$, df = 3, $P = 0.00003$), with an average of 32.9% ($n = 350$), and a range of 19.2% (1996, $n = 120$) to 51.1% (1994, $n = 88$, Table 4, Figure 6). Unlike the ISA, however, there was a significant difference in return rates between age classes outside the ISA for all years combined; SYs returned more frequently (47.2%, $n = 72$) than all ASYs combined (28%, $n = 225$, $\chi^2 = 8.31$, df = 1, $P = 0.004$). When all age classes were considered separately (SY, 3Y, 4Y, ASY, A3Y, A4Y+), the difference was still significant ($\chi^2 = 12.98$, df = 5, $P = 0.024$).

Table 4. Return rates for searched-for males in non-ISA training areas for 1-year periods between 1992 and 1996.*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SY</td>
<td>4/7 = 57.1%</td>
<td>15/27 = 55.6%</td>
<td>6/12 = 50%</td>
<td>9/26 = 34.6%</td>
<td>34/72 = 47.2%</td>
</tr>
<tr>
<td>All ASY</td>
<td>8/28 = 28.6%</td>
<td>24/42 = 57.1%</td>
<td>18/62 = 29%</td>
<td>13/93 = 14%</td>
<td>63/225 = 28%</td>
</tr>
<tr>
<td>ASY</td>
<td>5/17 = 29.4%</td>
<td>17/29 = 58.6%</td>
<td>5/26 = 19.2%</td>
<td>8/34 = 23.5%</td>
<td>35/106 = 33%</td>
</tr>
<tr>
<td>3Y</td>
<td>0/2 = 0%</td>
<td>2/4 = 50%</td>
<td>4/8 = 50%</td>
<td>1/11 = 9.1%</td>
<td>7/25 = 28%</td>
</tr>
<tr>
<td>A3Y</td>
<td>3/9 = 33.3%</td>
<td>4/8 = 50%</td>
<td>4/11 = 36.4%</td>
<td>0/19 = 0%</td>
<td>11/47 = 23.4%</td>
</tr>
<tr>
<td>4Y</td>
<td>1/1 = 100%</td>
<td>0/1 = 0%</td>
<td>0/12 = 0%</td>
<td>1/14 = 7.1%</td>
<td></td>
</tr>
<tr>
<td>A4Y+</td>
<td>4/6 = 67%</td>
<td>4/17 = 24%</td>
<td>4/23 = 35%</td>
<td>8/23 = 35%</td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>2/3 = 66.7%</td>
<td>2/11 = 18.2%</td>
<td>4/14 = 28.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td>0/1 = 0%</td>
<td>0/0 = 0%</td>
<td>0/1 = 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A5Y</td>
<td>2/2 = 100%</td>
<td>2/4 = 50%</td>
<td>4/6 = 66.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6Y</td>
<td>0/2 = 0%</td>
<td>0/2 = 0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHY</td>
<td>9/14 = 64.3%</td>
<td>8/19 = 42.1%</td>
<td>1/7 = 14.3%</td>
<td>1/1 = 100%</td>
<td>19/41 = 46.3%</td>
</tr>
<tr>
<td>U age</td>
<td>2/5 = 40%</td>
<td>2/5 = 40%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**All ages** 23/68 = 33.8% 45/88 = 51.1% 24/74 = 32.4% 23/120 = 19.2% 115/350 = 32.9%

* AAll males searched for, including those banded prior to previous season. Numbers listed are those found divided by those searched for. “Age Class” refers to age at first banding or most recent observation. “All ASY” is a total of all banded males, excluding SY, AHY, and those of unknown age at banding. “U age” refers to unknown age at banding.
Figure 6. Return rates for non-ISA adult males, by age class and year.

Adult female Golden-cheeked Warblers were resighted at 18.3% ($n = 60$ banded between 1991 and 1995; Table 5 for dispersal distances; Appendix D). Of the two females banded in 1991, one was resighted; the one female banded in 1992 was not resighted nor were any of the four banded in 1993. Three (15.8%) of the 19 females banded in 1994 were resighted, and 20.6% ($n = 34$) of those banded in 1995 were resighted. One female was resighted twice (Appendix D).

HY resighting rates were generally much lower than observed adult returns. HY males were resighted at an average of 16.9% ($n = 148$, Table 6 and Appendix E), ranging from 11.1% ($n = 27$) in 1993, to two of two HYs returning in 1992. HY females were resighted at an average of 9% ($n = 78$, Table 6 and Appendix F), with rates ranging from no returns in 1993 ($n = 8$) and 1994 ($n = 6$), to 11.8% ($n = 34$) in 1996.

Table 5. Dispersal distances for all female Golden-cheeked Warblers banded as adults.*

<table>
<thead>
<tr>
<th>Age at resight</th>
<th>n</th>
<th>Mean (m; S.D.)</th>
<th>Median (m)</th>
<th>Range (m)</th>
<th>Number located at each distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$\geq 300$ m</td>
</tr>
<tr>
<td>3Y</td>
<td>1</td>
<td>316 (47)</td>
<td>316</td>
<td>316</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>A3Y</td>
<td>4</td>
<td>135 (47)</td>
<td>141</td>
<td>100 - 200</td>
<td>0</td>
</tr>
<tr>
<td>A4Y</td>
<td>2</td>
<td>883 (172)</td>
<td>883</td>
<td>762 - 1005</td>
<td>2 (100%)</td>
</tr>
<tr>
<td>ASY</td>
<td>4</td>
<td>231 (95)</td>
<td>253</td>
<td>100 - 316</td>
<td>1 (25%)</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>322 (294)</td>
<td>224</td>
<td>100 - 1005</td>
<td>4 (36%)</td>
</tr>
</tbody>
</table>

* (%) = Percent of that age class resighted at or beyond that distance from either their banding location or observation in the previous year.
Table 6. Return rates for all hatch year (HY) Golden-cheeked Warblers.*

<table>
<thead>
<tr>
<th>Year banded</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>2/2 = 100%</td>
<td>0/0</td>
</tr>
<tr>
<td>1992</td>
<td>3/27 = 11.1%</td>
<td>0/8</td>
</tr>
<tr>
<td>1993</td>
<td>3/16 = 18.8%</td>
<td>0/6</td>
</tr>
<tr>
<td>1994</td>
<td>10/47 = 21.3%</td>
<td>3/30 = 10%</td>
</tr>
<tr>
<td>1995</td>
<td>7/56 = 12.5%</td>
<td>4/34 = 11.8%</td>
</tr>
<tr>
<td>All years</td>
<td>25/148 = 16.9%</td>
<td>7/78 = 9.0%</td>
</tr>
</tbody>
</table>

* Numbers indicate those found divided by total number banded. Intensive study area-banded HY birds are included in this list, regardless of where they were resighted. Unknown-sex HY birds are not included in this list.

Dispersal Distances

Observed dispersal distances for all male Golden-cheeked Warblers banded as adults (including the second resighting of four HY males that were resighted twice (i.e., from 3Y to 4Y) ranged from 0 m to 3,523 m, with an average distance of 223 m (n = 268, median = 141, S.D. = 307, Table 7). While the dispersal distance differences for the 3Y, 4Y, and A4Y+ (A4Y, 5Y, A5Y, 6Y, A6Y) age classes were not significant (Kruskal-Wallis test $\chi^2 = 3.93$, 1 df, $P = 0.14$), there was a trend toward 3Y males being resighted farther (n = 80, average = 268 m, median = 141, S.D. = 282) from their original banding locations than the 4Y males (n = 20, average = 162 m, median = 100, S.D. = 157). Although A4Y+ males were resighted at an average distance of 262 m (n = 43, median = 121, S.D. = 552), this may have been due to three males that were found at much greater distances than the others (Appendix A). Excluding these three males, the average resighting distance for A4Y+ males was 152 m (n = 40, median = 100, S.D. = 120).

Dispersal distances were classified into three groups: ISA resightings, searched-for males, and those males that were “chance” finds (Table 8 and Appendix A). These three groups showed a significant difference in dispersal distance that was most likely due to the methods used to find them (Kruskal-Wallis test $\chi^2 = 14.16$, df = 2, $P = 0.0008$). “Chance” find males were observed at the greatest average distance (304 m, median = 200 m, S.D. = 480, n = 66); ISA males were resighted at an average distance of 277 m (median = 200 m, S.D. = 310, n = 65); searched-for males were resighted at the shortest average distance of 146 m (median = 100 m, S.D. = 141, n = 137).
Table 7. Dispersal distances summarized by age class for male Golden-cheeked Warblers banded as adults on Fort Hood.*

<table>
<thead>
<tr>
<th>Age at resight</th>
<th>n</th>
<th>Mean (m; S.D.)</th>
<th>Median (m)</th>
<th>Range (m)</th>
<th>Number located at each distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt; 300 m</td>
</tr>
<tr>
<td>ASY</td>
<td>37</td>
<td>193 (191)</td>
<td>141</td>
<td>0 - 1000</td>
<td>9 (24%)</td>
</tr>
<tr>
<td>3Y</td>
<td>80</td>
<td>262 (282)</td>
<td>141</td>
<td>0 - 1746</td>
<td>29 (36%)</td>
</tr>
<tr>
<td>A3Y</td>
<td>86</td>
<td>167 (209)</td>
<td>100</td>
<td>0 - 1456</td>
<td>15 (17%)</td>
</tr>
<tr>
<td>4Y</td>
<td>20</td>
<td>162 (157)</td>
<td>100</td>
<td>0 - 510</td>
<td>4 (20%)</td>
</tr>
<tr>
<td>A4Y+</td>
<td>43</td>
<td>268 (552)</td>
<td>121</td>
<td>0 - 3523</td>
<td>8 (19%)</td>
</tr>
<tr>
<td>A4Y</td>
<td>23</td>
<td>353 (734)</td>
<td>141</td>
<td>0 - 3523</td>
<td>5 (22%)</td>
</tr>
<tr>
<td>5Y</td>
<td>5</td>
<td>125 (55)</td>
<td>100</td>
<td>100 - 224</td>
<td>0</td>
</tr>
<tr>
<td>A5Y</td>
<td>9</td>
<td>126 (116)</td>
<td>100</td>
<td>0 - 316</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>6Y</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A6Y</td>
<td>5</td>
<td>277 (147)</td>
<td>224</td>
<td>200 - 539</td>
<td>1 (20%)</td>
</tr>
<tr>
<td>AHY</td>
<td>2</td>
<td>193 (191)</td>
<td>549</td>
<td>0 - 1000</td>
<td>2 (100%)</td>
</tr>
<tr>
<td>Overall</td>
<td>268</td>
<td>223 (307)</td>
<td>141</td>
<td>0 - 3523</td>
<td>67 (25%)</td>
</tr>
</tbody>
</table>

* Known dispersal distances only. This table also includes four HY “second” resightings incorporated into their respective resight-age categories – i.e., they were resighted as SY, then as 3Y (or later). This table excludes 1996 fire-displaced males. (%) = % of that age class resighted at, or beyond that distance from a previous resighting location, or from their original banding location (whichever occurred later).

Table 8. Dispersal distances for adult males banded in the intensive study area (ISA), banded males searched for, and banded males observed opportunistically (“chance-find”).*

<table>
<thead>
<tr>
<th>Resight type</th>
<th>n</th>
<th>Mean (m; S.D.)</th>
<th>Median (m)</th>
<th>Range (m)</th>
<th>Number located at each distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt; 300 m</td>
</tr>
<tr>
<td>ISA</td>
<td>65</td>
<td>277 (310)</td>
<td>200</td>
<td>0 - 1746</td>
<td>24</td>
</tr>
<tr>
<td>Chance</td>
<td>66</td>
<td>304 (480)</td>
<td>200</td>
<td>0 - 3523</td>
<td>22</td>
</tr>
<tr>
<td>Search</td>
<td>137</td>
<td>146 (141)</td>
<td>100</td>
<td>0 - 781</td>
<td>21</td>
</tr>
</tbody>
</table>

* This table excludes fire-displaced males and HY first resights. It includes only males with known dispersal distances.

The average resighting distances for male Golden-cheeked Warblers banded as HY (4,040 m, median = 3317, S.D. = 4,777, n = 25) was significantly greater than for adult males (223 m, S.D. = 308, n = 284, Kruskal-Wallis test $\chi^2 = 53.68$, df = 1, $P = 0.000$; Tables 7 and 9, and Appendix E). Nineteen (76%) of the resighted HY males were observed 1 kilometer or more from their original banding locations ($n = 25$) compared with only 2% of adult males ($n = 268$, Table 7). This difference in proportion dispersing farther than 1 km was significant ($\chi^2 = 155.60$, df = 1, $P = 0.000$).

The average resighting distance for adult females was 322 m (median = 224 m, S.D. = 294, n = 11; Table 5 and Appendix D). The range of these resighted
females was 100 m to 1,005 m. The average resighting distance for female Golden-cheeked Warblers that were banded as HY was 1,525 m ($n = 7$, median = 856, S.D. = 1,388, range of 0 m to 3,448 m; Table 10 and Appendix F) from their original banding locations. This difference in resighting distances between adult and HY females was significant (Kruskal-Wallis test $\chi^2 = 5.62$, df = 1, $P = 0.018$).

Detection of Territorial Males

Density within the ISA steadily increased from 1992 through 1995, peaking at 28.1 males per 100 ha in 1995 (50 territorial males within 178 ha, Table 11), then dropping to 18.0 males per 100 ha in 1996 (32 territorial males). The annual average between 1992-1996 was 18.8 males per 100 ha (S.D. = 6.91).

Numbers of territorial males detected postwide (including the ISA) also fluctuated between 1991 and 1996, averaging 584 males (S.D. = 219.79, Table 12). The highest number detected was 915 males, in 1996; the lowest was 383 males, in 1992. The number of training areas in which males were detected also fluctuated somewhat, with an average of 37.7 (S.D. = 4.46), and a range of 31 (1994) to 41 (1991 and 1996).

<table>
<thead>
<tr>
<th>Age at 1st resight</th>
<th>n</th>
<th>Mean (m; S.D.)</th>
<th>Median (m)</th>
<th>Range (m)</th>
<th>Number located at each distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td># &gt; 300 m</td>
</tr>
<tr>
<td>SY</td>
<td>17</td>
<td>2461</td>
<td>1720</td>
<td>60 - 10004</td>
<td>16 (95%)</td>
</tr>
<tr>
<td>3Y</td>
<td>5</td>
<td>7864 (7982)</td>
<td>5906</td>
<td>906 - 20082</td>
<td>6 (100%)</td>
</tr>
<tr>
<td>4Y</td>
<td>1</td>
<td>5573</td>
<td>5573</td>
<td>5573</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>5Y</td>
<td>1</td>
<td>5557</td>
<td>5557</td>
<td>5557</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>4040 (4777)</td>
<td>3317</td>
<td>60 - 20082</td>
<td>24 (96%)</td>
</tr>
</tbody>
</table>

* This table includes only initial resights. The 3 cases in which a male was originally banded as HY and was resighted >1 time are listed in the table of adult male dispersal distances (Table 7). (%) = % of that age class resighted at, or beyond that distance away from either a previous resighting location, or their original banding location.

<table>
<thead>
<tr>
<th>Age at 1st resight</th>
<th>n</th>
<th>Mean (m; S.D.)</th>
<th>Median (m)</th>
<th>Range (m)</th>
<th>Number located at each distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td># &gt; 300 m</td>
</tr>
<tr>
<td>SY</td>
<td>6</td>
<td>1785 (1379)</td>
<td>906</td>
<td>0 - 3448</td>
<td>5 (83%)</td>
</tr>
<tr>
<td>3Y</td>
<td>1</td>
<td>224</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>1525 (1388)</td>
<td>856</td>
<td>0 - 3448</td>
<td>5 (71%)</td>
</tr>
</tbody>
</table>

* (n) = % of that age class resighted at, or beyond that distance away from either a previous resighting location, or their original banding location (whichever occurred later).
### Table 11. Number of territorial Golden-cheeked Warblers present in the ISA.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of territorial males (in 178 ha)</th>
<th>Density per 100 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>24</td>
<td>13.5</td>
</tr>
<tr>
<td>1993</td>
<td>25</td>
<td>14.1</td>
</tr>
<tr>
<td>1994</td>
<td>36</td>
<td>20.2</td>
</tr>
<tr>
<td>1995</td>
<td>50</td>
<td>28.1</td>
</tr>
<tr>
<td>1996</td>
<td>32</td>
<td>18.0</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>33.4</strong></td>
<td><strong>18.8</strong></td>
</tr>
</tbody>
</table>

### Table 12. Number of male Golden-cheeked Warblers detected in all training areas (including the ISA), and the total number of training areas in which males were detected.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of males</th>
<th>Number of training areas in which males were detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>515</td>
<td>41</td>
</tr>
<tr>
<td>1992</td>
<td>383</td>
<td>40</td>
</tr>
<tr>
<td>1993</td>
<td>399</td>
<td>33</td>
</tr>
<tr>
<td>1994</td>
<td>499</td>
<td>31</td>
</tr>
<tr>
<td>1995</td>
<td>797</td>
<td>40</td>
</tr>
<tr>
<td>1996</td>
<td>915</td>
<td>41</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>584.7</strong></td>
<td><strong>37.7</strong></td>
</tr>
</tbody>
</table>

### Age Structures

The percentage of SY males within the ISA averaged 41.7%, ranging from 30.3% to 57.1%. The differences did not vary significantly among years ($\chi^2 = 4.27$, df = 4, $P = 0.37$; Table 13). Observed percentage of SY males was consistently and significantly higher within the ISA than in non-ISA training areas (ISA average = 41.7%, non-ISA average = 27.5%, $\chi^2 = 12.40$, df = 1, $P = 0.0004$; Tables 13 and 14; Figure 7). Although rates in the non-ISA training areas did not vary as widely among years as those within the ISA, the differences were statistically significant (range: 18.5% to 34.7%, average of 27.5%, $\chi^2 = 15.97$, df = 5, $P = 0.007$). When the annual captures of the ISA and non-ISA training areas were lumped together, SY males were captured at a significantly lower rate than ASY males ($\chi^2 = 13.54$, df = 5, $P = 0.019$; Table 15).
Table 13. Age structure of male Golden-cheeked Warblers present in ISA.*

<table>
<thead>
<tr>
<th>Age class</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>SY (%SY)</td>
<td>6 (35.3%)</td>
<td>12 (57.1)</td>
<td>17 (44.7)</td>
<td>25 (42.4)</td>
<td>10 (30.3)</td>
<td>70 (41.7)</td>
</tr>
<tr>
<td>ASY</td>
<td>9</td>
<td>2</td>
<td>5</td>
<td>13</td>
<td>7</td>
<td>36</td>
</tr>
<tr>
<td>3Y</td>
<td>2</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>A3Y</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>4Y</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A5Y</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6Y</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHY</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>HY</td>
<td>8</td>
<td>4</td>
<td>10</td>
<td>32</td>
<td>11</td>
<td>59</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>21</td>
<td>38</td>
<td>59</td>
<td>33</td>
<td>168</td>
</tr>
</tbody>
</table>

* Includes all males identified within the intensive study area, regardless of territory status. Neither AHY nor HY are included in % SY calculation.

Table 14. Age structure of male Golden-cheeked Warblers observed outside the ISA.*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SY (%SY)</td>
<td>23 (33.3%)</td>
<td>23 (31.1)</td>
<td>33 (34.7)</td>
<td>32 (21.9)</td>
<td>72 (33.0)</td>
<td>29 (18.5)</td>
<td>212 (27.5)</td>
</tr>
<tr>
<td>ASY</td>
<td>46</td>
<td>34</td>
<td>48</td>
<td>64</td>
<td>97</td>
<td>69</td>
<td>358</td>
</tr>
<tr>
<td>3Y</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>17</td>
<td>10</td>
<td>22</td>
<td>59</td>
</tr>
<tr>
<td>A3Y</td>
<td>12</td>
<td>4</td>
<td>22</td>
<td>16</td>
<td>20</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>4Y</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td>3</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A5Y</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A6Y</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7Y</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHY</td>
<td>15</td>
<td>24</td>
<td>43</td>
<td>20</td>
<td>13</td>
<td>13</td>
<td>128</td>
</tr>
<tr>
<td>HY</td>
<td>2</td>
<td>19</td>
<td>12</td>
<td>37</td>
<td>23</td>
<td>11</td>
<td>104</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>74</td>
<td>95</td>
<td>146</td>
<td>218</td>
<td>157</td>
<td>770</td>
</tr>
</tbody>
</table>

* Includes both resighted and newly banded males. Neither AHY nor HY are included in % SY calculation. ISA males are not included in this table. See Table 13 for age classes of ISA males.
Mated Status Within the Intensive Study Area

Males within the intensive study area mated at an overall frequency of 89% \((n = 167, \text{ Table 16, Figure 8})\). SY males mated consistently and significantly less often, at 79% \((n = 61, 1992-1996)\) than ASY males, at 97% \((n = 88, \chi^2 = 14.20, \text{ df } = 1, P = 0.0005)\). SY mating percentage ranged from 70% in 1993 to 85% in 1995. ASY mating percentage ranged from 82% in 1992 to 100% in 1993, 1995, and 1996. There was no significant heterogeneity among years, allowing the years to be lumped \((\chi^2 = 2.75, \text{ df } = 4, P = 0.60)\).
Figure 8. Percent of mated males within the ISA, by age class and year.

Table 16. Percent of ISA males mated, by age class.*

<table>
<thead>
<tr>
<th>Age class</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>SY</td>
<td>71% (7)</td>
<td>70 (10)</td>
<td>79 (14)</td>
<td>85 (20)</td>
<td>80 (10)</td>
<td>79 (61)</td>
</tr>
<tr>
<td>All ASY</td>
<td>82 (11)</td>
<td>100 (12)</td>
<td>94 (16)</td>
<td>100 (30)</td>
<td>100 (19)</td>
<td>97 (88)</td>
</tr>
<tr>
<td>ASY</td>
<td>78 (9)</td>
<td>100 (2)</td>
<td>100 (3)</td>
<td>100 (12)</td>
<td>100 (4)</td>
<td>93 (30)</td>
</tr>
<tr>
<td>3Y</td>
<td>100 (3)</td>
<td>100 (8)</td>
<td>100 (8)</td>
<td>100 (7)</td>
<td>100 (26)</td>
<td></td>
</tr>
<tr>
<td>A3Y</td>
<td>100 (2)</td>
<td>100 (7)</td>
<td>100 (1)</td>
<td>100 (2)</td>
<td>100 (16)</td>
<td></td>
</tr>
<tr>
<td>4Y</td>
<td>100 (1)</td>
<td>100 (5)</td>
<td>100 (1)</td>
<td>100 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>67 (3)</td>
<td></td>
<td>100 (1)</td>
<td>75 (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td></td>
<td>100 (1)</td>
<td>100 (2)</td>
<td>100 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A5Y</td>
<td></td>
<td>100 (1)</td>
<td></td>
<td>100 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6Y</td>
<td></td>
<td></td>
<td>100 (1)</td>
<td>100 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHY</td>
<td>100 (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UB</td>
<td>75 (4)</td>
<td>100 (3)</td>
<td>67 (6)</td>
<td>100 (2)</td>
<td>80 (15)</td>
<td></td>
</tr>
<tr>
<td>All ages</td>
<td>79 (24)</td>
<td>88 (25)</td>
<td>83 (36)</td>
<td>94 (50)</td>
<td>94 (32)</td>
<td>89 (167)</td>
</tr>
</tbody>
</table>

* (n) = total number of territorial males in that age class. **All ASY** is a total of all banded males, excluding SY and AHY. **UB** = unbanded male.

Productivity

Fecundity within the ISA averaged 2.23 HY per successful male \((n = 118)\) successful males including unknown-age and unbanded males, 263 fledglings; excludes 1992), and ranged between 2.08 (1996, \(n = 25\) successful males) to 2.29 (1995, \(n = 45\) successful males; Table 17). Numbers of HY per territorial male
averaged 1.84 HY per territorial male (n = 143 territorial males), ranging from 1.63 (1996, n = 32 territorial males) to 2.06 (1995, n = 50 territorial males, Table 18).

Table 17. Mean number of young fledged by successful ISA males, by age class and year.*

<table>
<thead>
<tr>
<th>Age class</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>SY</td>
<td>2.83 (17)</td>
<td>2.00 (20)</td>
<td>2.06 (16)</td>
<td>2.17 (13)</td>
<td>2.18 (83)</td>
<td></td>
</tr>
<tr>
<td>All ASY</td>
<td>2.00 (24)</td>
<td>2.36 (33)</td>
<td>2.41 (29)</td>
<td>2.12 (36)</td>
<td>2.26 (163)</td>
<td></td>
</tr>
<tr>
<td>ASY</td>
<td>1.50 (3)</td>
<td>2.33 (7)</td>
<td>2.33 (12)</td>
<td>1.75 (7)</td>
<td>2.14 (45)</td>
<td></td>
</tr>
<tr>
<td>3Y</td>
<td>2.67 (8)</td>
<td>2.29 (16)</td>
<td>2.63 (8)</td>
<td>2.00 (10)</td>
<td>2.39 (55)</td>
<td></td>
</tr>
<tr>
<td>A3Y</td>
<td>1.86 (13)</td>
<td>3.00 (3)</td>
<td>1.00 (1)</td>
<td>2.00 (8)</td>
<td>1.92 (25)</td>
<td></td>
</tr>
<tr>
<td>4Y</td>
<td>3.00 (3)</td>
<td>2.20 (11)</td>
<td>2.00 (2)</td>
<td>2.29 (16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>2.00 (4)</td>
<td>4.00 (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td></td>
<td>2.00 (2)</td>
<td>3.00 (6)</td>
<td></td>
<td>2.67 (8)</td>
<td></td>
</tr>
<tr>
<td>A5Y</td>
<td></td>
<td>3.00 (3)</td>
<td></td>
<td></td>
<td>3.00 (3)</td>
<td></td>
</tr>
<tr>
<td>6Y</td>
<td></td>
<td>3.00 (3)</td>
<td></td>
<td></td>
<td>3.00 (3)</td>
<td></td>
</tr>
<tr>
<td>AHY</td>
<td></td>
<td>2.00 (2)</td>
<td></td>
<td></td>
<td>2.00 (2)</td>
<td></td>
</tr>
<tr>
<td>UB</td>
<td>2.00 (4)</td>
<td>2.50 (10)</td>
<td>1.00 (1)</td>
<td></td>
<td>2.14 (15)</td>
<td></td>
</tr>
<tr>
<td>All ages</td>
<td>1.69 (27)</td>
<td>2.25 (45)</td>
<td>2.25 (63)</td>
<td>2.29 (103)</td>
<td>2.08 (52)</td>
<td>2.23 (263)</td>
</tr>
</tbody>
</table>

*(n) = total number of young fledged. “All years” column excludes 1992 data. “All ASY” is a total of all banded males, excluding SY and AHY. “UB” = unbanded males.

Table 18. Mean number of young fledged by territorial ISA males, by age class and year.*

<table>
<thead>
<tr>
<th>Age class</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>SY</td>
<td>1.70 (17)</td>
<td>1.43 (20)</td>
<td>1.65 (33)</td>
<td>1.30 (13)</td>
<td>1.54 (83)</td>
<td></td>
</tr>
<tr>
<td>All ASY</td>
<td>2.00 (12)</td>
<td>2.06 (33)</td>
<td>2.33 (70)</td>
<td>1.89 (36)</td>
<td>2.12 (163)</td>
<td></td>
</tr>
<tr>
<td>ASY</td>
<td>1.50 (3)</td>
<td>2.33 (7)</td>
<td>2.33 (28)</td>
<td>1.75 (7)</td>
<td>2.14 (45)</td>
<td></td>
</tr>
<tr>
<td>3Y</td>
<td>2.37 (8)</td>
<td>2.00 (16)</td>
<td>2.63 (21)</td>
<td>1.43 (10)</td>
<td>2.12 (55)</td>
<td></td>
</tr>
<tr>
<td>A3Y</td>
<td>1.86 (13)</td>
<td>3.00 (3)</td>
<td>0.50 (1)</td>
<td>2.00 (8)</td>
<td>1.79 (25)</td>
<td></td>
</tr>
<tr>
<td>4Y</td>
<td>3.00 (3)</td>
<td>2.20 (11)</td>
<td>2.00 (2)</td>
<td>2.29 (16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>1.33 (4)</td>
<td>4.00 (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td></td>
<td>2.00 (2)</td>
<td>3.00 (6)</td>
<td></td>
<td>2.67 (8)</td>
<td></td>
</tr>
<tr>
<td>A5Y</td>
<td></td>
<td>3.00 (3)</td>
<td></td>
<td></td>
<td>3.00 (3)</td>
<td></td>
</tr>
<tr>
<td>6Y</td>
<td></td>
<td>3.00 (3)</td>
<td></td>
<td></td>
<td>3.00 (3)</td>
<td></td>
</tr>
<tr>
<td>AHY</td>
<td></td>
<td>2.00 (2)</td>
<td></td>
<td></td>
<td>2.00 (2)</td>
<td></td>
</tr>
<tr>
<td>UB</td>
<td>1.33 (4)</td>
<td>1.67 (10)</td>
<td>1.00 (1)</td>
<td></td>
<td>1.36 (15)</td>
<td></td>
</tr>
<tr>
<td>All ages</td>
<td>1.13 (27)</td>
<td>1.80 (45)</td>
<td>1.75 (63)</td>
<td>2.06 (103)</td>
<td>1.63 (52)</td>
<td>1.84 (263)</td>
</tr>
</tbody>
</table>

*(n) = total number of young fledged. “All years” column excludes 1992 data. “All ASY” is a total of all banded males, excluding SY and AHY.
Productivity of mated males did not differ significantly between age classes. The average fecundity for mated SY males was 1.93 young per mated SY ($n = 43$ mated SY; Table 19). The average for mated ASY males was 2.15 young per mated ASY ($n = 76$ mated ASY excluding 1992, $t = 0.77$, df = 1, $P = 0.50$; Table 19). Productivity per successful male was also very similar between SY (2.18 HY per successful SY, $n = 38$ successful SY excluding 1992) and ASY males (2.26 HY per successful ASY, $n = 72$ successful ASY excluding 1992, $t = 0.77$, df = 1, $P = 0.50$; Tables 17 and 20). The difference between age classes in productivity per territorial male was statistically significant, however, with an average of 1.54 HY per territorial SY ($n = 54$ territorial SY excluding 1992; Tables 16 and 18) and 2.12 young per territorial ASY ($n = 77$ territorial ASY excluding 1992, $t = 6.45$, df = 1, $P = 0.008$, Tables 16 and 18), due to the lower mating success of SY males versus ASY males. Once mated, however, SY males appeared to be equally successful as ASY males (see success rate information below). See Figure 9 for SY productivity by year.

Although sample sizes were small, there was a slight trend toward males producing more young as they aged. Third-year mated males’ productivity was the same as all ASY mated males, with 2.12 HY per mated male ($n = 26$ 3Y males, Table 16). Fourth-year males produced 2.29 HY per mated male ($n = 7$ 4Y males, Table 16), fifth-year males, 2.67 ($n = 3$ 5Y males; Table 16), and the 1 sixth-year male present in the intensive study area produced 3 HY.

![Figure 9. Productivity for ISA SY males, by year.](image-url)
Table 19. Mean number of young fledged by mated ISA males, by age class and year.\(^*\)

<table>
<thead>
<tr>
<th>Age class</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>SY</td>
<td>2.43 (17)</td>
<td>1.82 (20)</td>
<td>1.94 (33)</td>
<td>1.63 (13)</td>
<td>1.93 (83)</td>
<td></td>
</tr>
<tr>
<td>All ASY</td>
<td>2.00 (24)</td>
<td>2.20 (33)</td>
<td>2.33 (70)</td>
<td>1.89 (36)</td>
<td>2.15 (163)</td>
<td></td>
</tr>
<tr>
<td>ASY</td>
<td>1.50 (3)</td>
<td>2.33 (7)</td>
<td>2.33 (28)</td>
<td>1.75 (7)</td>
<td>2.14 (45)</td>
<td></td>
</tr>
<tr>
<td>3Y</td>
<td>2.67 (8)</td>
<td>2.00 (16)</td>
<td>2.63 (21)</td>
<td>1.43 (10)</td>
<td>2.12 (55)</td>
<td></td>
</tr>
<tr>
<td>A3Y</td>
<td>1.86 (13)</td>
<td>3.00 (3)</td>
<td>0.50 (2)</td>
<td>2.00 (8)</td>
<td>1.79 (25)</td>
<td></td>
</tr>
<tr>
<td>4Y</td>
<td>3.00 (3)</td>
<td>2.20 (11)</td>
<td>2.00 (2)</td>
<td>2.29 (16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4Y</td>
<td>2.00 (2)</td>
<td>4.00 (4)</td>
<td></td>
<td></td>
<td>2.67 (8)</td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td></td>
<td>2.00 (2)</td>
<td>3.00 (6)</td>
<td></td>
<td></td>
<td>2.67 (8)</td>
</tr>
<tr>
<td>A5Y</td>
<td></td>
<td>3.00 (3)</td>
<td></td>
<td></td>
<td></td>
<td>3.00 (3)</td>
</tr>
<tr>
<td>6Y</td>
<td></td>
<td></td>
<td>3.00 (3)</td>
<td></td>
<td></td>
<td>3.00 (3)</td>
</tr>
<tr>
<td>AHY</td>
<td></td>
<td></td>
<td>2.00 (2)</td>
<td></td>
<td></td>
<td>2.00 (2)</td>
</tr>
<tr>
<td>UB</td>
<td>1.33 (4)</td>
<td>2.50 (10)</td>
<td></td>
<td>1.00 (1)</td>
<td></td>
<td>1.67 (15)</td>
</tr>
<tr>
<td>All ages</td>
<td>1.42 (27)</td>
<td>2.05 (45)</td>
<td>2.10 (63)</td>
<td>2.19 (103)</td>
<td>1.73 (52)</td>
<td>2.04 (263)</td>
</tr>
</tbody>
</table>

\(^*\)\(n\) = total number of young fledged. "All years" column excludes data for 1992. "All ASY" is a total of all banded males, excluding SY and AHY.

Table 20. Success rate of ISA Golden-cheeked Warbler males.\(^*\)

<table>
<thead>
<tr>
<th>Age class</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
<th>All years</th>
</tr>
</thead>
<tbody>
<tr>
<td>SY</td>
<td>5/5</td>
<td>6/7</td>
<td>10/11</td>
<td>16/17</td>
<td>6/8</td>
<td>43/48</td>
</tr>
<tr>
<td>All ASY</td>
<td>8/9</td>
<td>12/12</td>
<td>14/15</td>
<td>29/30</td>
<td>17/19</td>
<td>80/85</td>
</tr>
<tr>
<td>AHY</td>
<td>0/2</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>1/1</td>
<td>1/3</td>
</tr>
<tr>
<td>UB</td>
<td>3/3</td>
<td>2/3</td>
<td>4/4</td>
<td>0/0</td>
<td>1/2</td>
<td>10/12</td>
</tr>
<tr>
<td>All ages</td>
<td>16/19</td>
<td>20/22</td>
<td>28/32</td>
<td>45/47</td>
<td>25/30</td>
<td>133/145</td>
</tr>
</tbody>
</table>

\(^*\)Proportion of mated males that were also successful. "All years" column includes 1992 data.

Success rate (mated males that also reproduced) between the age classes was very consistent. SY males had an overall success rate of 90% \((n = 48\) successful SY males [including 1992 data], ranging from 75% in 1996 to 100% in 1992; Table 20). ASY males had an overall success rate of 94% \((n = 85\) successful ASY males [including 1992 data], ranging from 89% in 1992 and 1996 to 100% in 1993). This difference between SY and ASY male mating success was not significant \((\chi^2 = 0.37, \text{df} = 1, P = 0.54)\).

Parasitism

Seven incidents of brown-headed cowbird (BHCO) parasitism of Golden-cheeked Warbler nests were reported since 1991. In 1991, three of six Golden-cheeked Warbler nests located were parasitized (at least two of which fledged cowbird
young, Table 21), and an adult male was seen feeding a juvenile BHCO in a cowbird trap. The one nest located in 1992 was not parasitized; in 1993, none of the four nests whose contents were observed were parasitized. There was one instance in 1993, however, of a pair of Golden-cheeked Warblers feeding one BHCO young, as well as at least one (and possibly two) Golden-cheeked Warbler young. In 1994, none of the ten nests were parasitized, and no feeding of BHCO fledglings was observed. Similarly, in 1995, none of the seven nests found were parasitized, and no feeding of BHCO fledglings was observed. In 1996, none of the 11 nests found were parasitized, but there were two occasions during which an adult Golden-cheeked Warbler was found in association with a juvenile BHCO. In one instance, an adult female was seen within inches of the BHCO HY, but did not feed it even though it was begging. In another instance, an adult female was seen feeding a juvenile BHCO.


<table>
<thead>
<tr>
<th>Year</th>
<th>No. found</th>
<th>No. fledged successfully</th>
<th>No. depredated or abandoned</th>
<th>No. parasitized</th>
<th>No. fate unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
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<td>1993</td>
<td>7</td>
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<td>7</td>
<td>4</td>
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<td>2</td>
</tr>
<tr>
<td>1996</td>
<td>11</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>27</td>
<td>5</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>
4 Discussion

Population Trends

Results indicate that the Golden-cheeked Warbler population on Fort Hood, Texas steadily increased through 1995, when most population measurements were at their peak. Return rates were at their highest within the intensive study area in 1995, and were average for non-ISA training areas. Territorial males were at their greatest density within the ISA, and above average for all training areas combined. The proportion of the population that was SY was above average for both inside and outside the study area, indicating a young, growing population. All measurements of productivity within the study area were at their highest since the study began, also indicating a growing population. However, 1996 showed decreases in many population indices. Return rates and proportions of SY in the population were at their lowest for all males, both within and outside the study area. Similarly, all measurements of productivity, including success rate, were also at their lowest since 1992. Because no baseline warbler demographic data was available before 1991, and because of the steady increase between 1992 and 1995, followed by the sharp decrease in 1996, no long term population trends can be discerned at this time. Data collected in the years 1991 through 1996 on Fort Hood demonstrate a capacity for high annual variability. While there were several possible reasons for the observed decreases in population parameters in 1996, there was no apparent cause for the increases between 1991 and 1995.

One possible explanation for the decreases of 1996 may be the stress caused by severe weather in the spring and summer of 1996. According to the Palmer Drought Severity Index, there was a “severe to extreme drought” in the spring and summer of 1996 (Figure 10, Appendix G). When these drought conditions were combined with the slightly cooler than average temperatures and significantly lower than average relative humidity that were prevalent when the Golden-cheeked Warblers were migrating north, and when they returned to Fort Hood in March, a higher death rate might be expected due to stress caused by food and water shortages (see Table 22 for weather data). This hypothesis, though, is not supported, as the return rate in a Texas Parks and Wildlife Department (TPWD) study less than 100 miles south of Fort Hood did not show a similar decrease, although they generally had similar weather patterns.
PSDI Classifications for Dry and Wet Periods

<table>
<thead>
<tr>
<th>Classification</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely wet</td>
<td>4.00 or more</td>
</tr>
<tr>
<td>Very wet</td>
<td>3.00 to 3.99</td>
</tr>
<tr>
<td>Moderately wet</td>
<td>2.00 to 2.99</td>
</tr>
<tr>
<td>Slightly wet</td>
<td>1.00 to 1.99</td>
</tr>
<tr>
<td>Incipient wet</td>
<td>0.50 to 0.99</td>
</tr>
<tr>
<td>Near normal</td>
<td>0.49 to –0.49</td>
</tr>
<tr>
<td>Incipient dry spell</td>
<td>-0.50 to –0.99</td>
</tr>
<tr>
<td>Mild drought</td>
<td>-1.00 to –1.99</td>
</tr>
<tr>
<td>Moderate drought</td>
<td>-2.00 to –2.99</td>
</tr>
<tr>
<td>Severe drought</td>
<td>-3.00 to –3.99</td>
</tr>
<tr>
<td>Extreme drought</td>
<td>-4.00 to –4.99</td>
</tr>
</tbody>
</table>

Figure 10. Monthly averages of the Palmer Drought Severity Index (PDSI) for Texas, Division 7 (of which Fort Hood is a part), from 1895 to 1996. For a detailed description of this index, see Appendix G.
Table 22. Mean daily temperatures and relative humidities for the month of March for Fort Hood from 1994-1996.*

<table>
<thead>
<tr>
<th></th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean March daily temperature</td>
<td>68.7°</td>
<td>64.0°</td>
<td>63.4°</td>
<td>65.4°</td>
</tr>
<tr>
<td>Temperature range</td>
<td>40.5° - 86.2°</td>
<td>33.1° - 89.4°</td>
<td>41.5° - 83.5°</td>
<td>33.1° - 89.4°</td>
</tr>
<tr>
<td>S.D. = 13.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean March daily Relative Humidity*</td>
<td>48.7%</td>
<td>58.5%</td>
<td>38.2%</td>
<td>48.5%</td>
</tr>
<tr>
<td>Relative Humidity range</td>
<td>21% - 99%</td>
<td>22% - 91%</td>
<td>16% - 99%</td>
<td>16% - 99%</td>
</tr>
<tr>
<td>S.D. = 21.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = significant difference by ANOVA ($F_{(2,92)} = 7.714; P = 0.001$). Data compliments of Natural Resources Branch, Fort Hood (unpublished data).

Another hypothesis concerns the stress and damage caused by the extensive fire that destroyed nearly 4,300 ha of Golden-cheeked Warbler habitat (approximately 25% of the warbler habitat on Fort Hood; Figures 1 and 2) in the northeastern section of Fort Hood in February, 1996. Upon their return, many birds would have found that their territories were either entirely or partially burned. Locating and establishing new territories may have taken valuable time and resources (i.e., fat stores) that the birds may not have had after their migration. Some of the more dominant, newly displaced males that had previously held territories within the area of the fire may have displaced less dominant males that had held territories within nearby areas. All of these sudden movements and displacements may have increased territory border fights, and the need for males to increase “patrols” of their territory borders. This, in turn, may have decreased foraging time and efforts to attract and defend a mate and or care of nestlings and fledglings. Males that maintained partially burned territories may have experienced a shortage of food. Any of these scenarios could cause an increase in mortality.

This hypothesis, however, does not explain population dynamics observed in other areas across Fort Hood. For example, there was no evidence that fire-displaced warblers affected demographic parameters in the ISA (a dispersal distance of 3 to 4 kilometers). The percentage of SY males did not decrease significantly within the study area due to the influx of older, more dominant fire-displaced males (assuming that SYs were less dominant than older males). While the percentage did decrease slightly, it was not significant (Table 13). Secondly, some of the males within the fire region were color-banded in years prior to the fire; if a significant number of these males moved south into the study area and nearby regions, their chance of detection was high, and only one
of these males was found there. (This male was found in habitat adjacent to the study area. He was originally banded as an HY, however, so his movement may be accounted for equally as well by HY dispersal patterns as by fire-related dispersal). Thirdly, if fire-displaced males in turn displaced study area males, it is assumed that these newly displaced males from within the study area would also establish a territory in the nearest suitable habitat. Researchers did not find this to be true, however, as all adjacent habitat was searched, and no males previously territorial within the study area were found.

Productivity within the intensive study area remained relatively stable between 1992 and 1996, suggesting that fecundity may not have a strong effect on the adult population of the immediate area, which varied during the same time period. One possible explanation for this lack of strong effect may be caused by the biology of the species, particularly the dispersal of the young away from their natal territories. One possible hypothesis for their dispersal pattern is inbreeding avoidance (Greenwood 1984). It may be inherent in many birds to disperse away from their natal territories in order to not breed with close kin (i.e., parents or siblings). Juveniles disperse much farther than do adults. Therefore, local productivity likely does not affect adult populations of the natal area in succeeding years. Judging by the long dispersal distances of juveniles and high estimates of juvenile emigration (see Relevance/Application to Predictive Models), there may be a significant proportion of Fort Hood-produced young that may not return to Fort Hood.

The significant differences in adult return rate between the ISA and other training areas can possibly be attributed to search effort and detection rate. The monitoring of the ISA was extensive, with near-daily coverage; the detection rate of males within this area probably approached 100%. Outside this area, however, most males were searched for only once or twice. Many things may have occurred during these search times to alter the probability of detection, including circumstances of their breeding cycle, time of day, presence of other singing males, females or HYs, weather effects, lighting, and canopy cover. It may not be uncommon to search for a specific male and consider him “not found” even though he may have been present and neither singing nor responding to the playback tape. Due to the intensive monitoring effort within the ISA, many of these factors were canceled, yielding the most reliable data.

While the cause of the decreased return rate within the intensive study area was unknown, there was a possible explanation for the decrease in other training areas. There was a slight change in searching protocol in 1996. Rather than searching for males picked from all previously banded males (as had been done in 1992 through 1995), it was decided that field technicians would search for pre-
chosen males, which were, in general, older than those that would have been chosen randomly (see Methods section). In general, passerine survival rates level off after the first year, and remain essentially constant, but the probability of surviving to a particular age decreases as the bird ages, due to annual mortality rates (Gill 1990). This leads to a small sample size of older birds, in turn decreasing the possibility of locating survivors.

There are two possible reasons for the fact that female band returns were generally lower than that of males. First, adult females may disperse to a greater extent than males (Tables 5 and 7; Gill 1990). Secondly, females are generally very quiet and secretive in their behaviors, making it difficult to observe and determine their identity.

**Age-related Differences**

While return rates within the ISA did not differ between age classes when years were lumped, those in other training areas did (Tables 3 and 4). This may be partially explained by the differences in detection rates between the areas. Field observations suggest that older males may sing less than younger males, resulting in a lower detection rate for older males outside the ISA; older males within the ISA had the same probability of detection as younger males due to the intense monitoring regimen. Older males returning to non-ISA training areas, therefore, may not have been detected by researchers.

Although not statistically significant, younger males (age 3Y) had the tendency to disperse farther than older males (ages 4Y and A4Y+, Table 3). This idea also had support from data gathered concerning territory boundaries of returning males within the ISA. Three-year-old males seldom defended the same territory as they did during their SY year (42% [10 of 24] of 3Y territories overlapped their SY territory). Most of these SY-3Y territory connections were tenuous though, as only 20% (n = 10) of the overlapping territories actually overlapped at the center (see Figures 11 through 15). Returning ASY males, however, generally defended the same territory as their previous year (85% [22 of 26] of their territories overlap their previous territory). The majority (68%, n = 22) of these connections between years overlapped at their centers. This difference in the frequency of territory overlap by age class was statistically significant (SY vs. ASY, territory overlap: $\chi^2 = 8.21$, df = 1, $P = 0.0041$, SY vs. ASY, centers overlap: $\chi^2 = 4.62$, df = 1, $P = 0.03$).

Observed results indicate that SY males had the capacity to reproduce at the same rate as ASY males. Productivity per successful SY was very similar to
productivity per successful ASY male (Table 17). Similarly, success rate of mated SY and ASY males was virtually identical (Table 20). The difference, then, in SY fitness can be attributed to difficulty in finding, securing or defending a mate. SY males mated significantly less often than did ASY males (Table 16).
Relevance/Application to Predictive Models

Results from a regional population viability workshop (U.S. Fish and Wildlife Service 1996) estimated that HY Golden-cheeked Warbler survival rate must be above 50%, given observed annual fecundities of 0.8 and 1.01 HY per adult male (SY and ASY, respectively), and an estimated average adult survival rate of 57% (AHY) to maintain a stable population. In population viability analysis (PVA) models simulating time until extinction, the use of any HY survival rate below 50% caused the model’s population to decline dramatically and become extinct well within the 100 years of simulation (U.S. Fish and Wildlife Service 1996).

The observed return of HYs to their natal area in the ISA was 14.2% (Table 6). Assuming HY survival of 50% to maintain a stable population, the observed HY return rate in the ISA would indicate that at least 76% of surviving HYs must emigrate from their natal area. The greater observed dispersal distance of HYs compared with adult Golden-cheeked Warblers suggests a 76% HY emigration rate is realistically possible. The average dispersal distance for returning HY males was over 4 kilometers, with 41% of all HY resightings at a distance greater than 3 km, and one actually being resighted 20 km from its original banding location. This compares with a mean dispersal distance for adult males of 217 m.

Comparison With Similar Species

Although the overall intensive study area return rate for the Golden-cheeked Warbler (48%) was lower than that for the Kirtland’s Warbler (approximately 65%, Mayfield 1992), their ranges were similar. The Kirtland’s Warbler return rate ranged between 29% and 82% (Mayfield 1992) whereas the Golden-cheeked Warbler return rate has ranged from 30% to 65.5% within the study area. The Golden-cheeked Warbler's observed return rate was also lower than that of the Black-throated Green Warbler (67%, Morse 1989), the Prairie Warbler (65%, Nolan 1978), the Common Yellowthroat (54%, Roberts 1971) the Black and White Warbler (71%, Roberts 1971) and the American Redstart (71%, Roberts 1971).

The observed Kirtland’s Warbler HY return rate of 2.7% (n = 296 as of 1968; Berger and Radabaugh 1968) was much lower than the Golden-cheeked Warbler’s (17%, overall HY male return rate). The Golden-cheeked Warbler HY return rate was also high compared to that documented in other species (i.e., 5.8% in the Indigo Bunting [Payne and Payne 1990], 5.0% in the Wood Thrush
[Roth and Johnson 1993], and 0.6% in the American Redstart [Sherry and Holmes 1992]).

There are few published studies concerning survival rates of first-year birds. Loery, et al. (1987) reported an average 44% (range of 24% to 66%) HY survival rate for the Black-capped Chickadee (Parus atricapillus), a figure that was similar to the estimates for the Golden-cheeked Warbler. This study also stated that the adult chickadee survival rate was, on average, 23% higher than that for HYs, with an overall average of 69% (and a range of 45% to 100%) for 3Y individuals. Loery, et al. (1987) attributed this difference in survival to increased mortality within the first year and/or to increased dispersal. Ryel (1981) calculated the Kirtland’s Warbler adult survival rate to be at least 35%. These figures were similar to the warbler’s estimated 57% survival for adult males (USFWS 1996).

Golden-cheeked Warbler productivity (2.04 HY per mated male within the ISA) was similar to that documented in several other species. Mayfield (1992) reported the Kirtland’s Warbler productivity to be 2.2 fledglings per nest (without Brown-headed Cowbird parasitism). The Prairie Warbler had an estimated productivity of 2.2 fledglings per territory (Nolan 1978), slightly higher than Fort Hood’s Golden-cheeked Warbler average of 1.84 HY per territory. Black-throated Green Warbler productivity was also higher, with three (and sometimes four) fledglings per territory (Morse 1993).

Mated status for the Golden-cheeked Warblers within the ISA (89% of the territorial males mated) was comparable to the 92% of the Kirtland’s Warbler within prime, wildfire-regrown areas, and 72% of Kirtland’s Warblers within plantations (Bocetti 1994).

Average Golden-cheeked Warbler density (0.13 pairs per ha) was much lower than that documented for the Black-throated Green Warbler. Morse (1993) reported that the maximum density was 2.0 pairs per ha in prime habitat. He also reported, however, a minimum of 0.6 pairs per ha in a year of high mortality. The Kirtland’s Warbler had a density lower than either species, ranging from 0.048 pairs per ha to 0.07 pairs (Probst and Weinrich 1989, Bocetti 1994). Contrary to highly variable densities found within Fort Hood’s ISA between 1992 and 1996, Morse (1989) stated that “Populations of most warblers are surprisingly constant in density from year to year, although they experience temporary and short-term depressions, probably in response to environmental factors....” Holmes et al. (1986) also found that periods of stability were punctuated by pulses in response to outbreaks of caterpillars.
Incidence of Cowbird Parasitism

Rates of parasitism of the Golden-cheeked Warbler on Fort Hood may be misleading, as cowbird control began in 1988, whereas Golden-cheeked Warbler studies did not begin until 1991; no pre-control, baseline data is available. Even though Pulich (1976) reports a very high parasitism rate (58%, 19 of 33 nests parasitized), data suggest that cowbirds currently do not play a major role in Fort Hood warbler nest success. There were seven incidents concerning Golden-cheeked Warblers and cowbirds on Fort Hood since 1991, including three parasitized nests (no parasitized nests since 1991, 9% nest parasitism rate; Table 21).
5 Conclusions and Recommendations

Fort Hood supports a substantial population of the endangered Golden-cheeked Warbler (915 maximum documented males). This population is vital to the survival of the species because it resides under a single land management authority. This continuity of management will assist in the preservation of the remaining habitat and the species as a whole.

A substantial conclusion stemming from this data analysis is the high variability of the Golden-cheeked Warbler population on Fort Hood. During the first 4 years of the study, it appeared that the population was growing, at first slowly, then more rapidly. During 1996, however, this trend reversed, and the population appeared to decline. The long-term trends for this species cannot yet be determined.

Currently, habitat availability is considered the primary limiting factor for warbler populations on Fort Hood. Other potential limiting factors (e.g., cowbird parasitism or predation) appear to be of secondary importance at this time. If cowbird control on the installation is discontinued in the future, this relationship will need to be reevaluated.

It is recommended that demographic parameters are best estimated from data obtained in intensively monitored areas.

It is recommended that these data be collected and updated annually to monitor long-term population changes on Fort Hood. It is also recommended that managers be cautious in making decisions regarding this species based on short-term demographic variability.
References


Appendix A: List of all Adult Males Resighted on Fort Hood

This list is presented by resighting type ("Search type": ISA, incidental, searched for), in order by band number and the number of times each was resighted. For explanation of search types, see Methods section. "Distance (m)" is the distance between observations, either between banding and resighting, or between consecutive resightings.

<table>
<thead>
<tr>
<th>Band number</th>
<th>Search Type</th>
<th>No. times resighted</th>
<th>Banding Information</th>
<th>Resighting Information</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Year</td>
<td>Age</td>
<td>East</td>
</tr>
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<td>92</td>
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<td>342</td>
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<td>92</td>
<td>AHY</td>
<td>344</td>
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<td>1290-90819</td>
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<td>3</td>
<td>92</td>
<td>AHY</td>
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<td>93</td>
<td>SY</td>
<td>346</td>
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Appendix B: List of all Adult Males

Searched for and Not Found on Fort Hood

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Appendix C: List of all Males Located Within the ISA Including Non-territorial Birds

Territory numbers correspond to those listed in Figures 11-15. Two separate numbers listed in the “No. HY” column indicate double brooding. “UK” = unknown male or missing data. “UB” = unbanded male.

### 1996

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Appendix D: List of all Adult Females Resighted on Fort Hood

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This list is presented by resight type (ISA, incidental, searched for), in order by band number.

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Appendix F: List of all HY Females Resighted on Fort Hood.

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<td>485</td>
<td>1995</td>
<td>SY</td>
<td>341</td>
<td>475</td>
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<td>341</td>
<td>479</td>
<td>1996</td>
<td>SY</td>
<td>342</td>
<td>488</td>
<td>905</td>
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<tr>
<td>1960-03897</td>
<td>1995</td>
<td>339</td>
<td>482</td>
<td>1996</td>
<td>SY</td>
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<td>462</td>
<td>3124</td>
</tr>
<tr>
<td>2060-20812</td>
<td>1995</td>
<td>310</td>
<td>497</td>
<td>1996</td>
<td>SY</td>
<td>314</td>
<td>504</td>
<td>806</td>
</tr>
<tr>
<td>2060-20816</td>
<td>1995</td>
<td>310</td>
<td>497</td>
<td>1996</td>
<td>SY</td>
<td>310</td>
<td>497</td>
<td>*0</td>
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</table>
Appendix G: Description of Palmer Drought Severity Index

Source: National Oceanic and Atmospheric Administration, National Climate Data Center, Asheville, NC.

Palmer Drought Severity Index (PDSI)

In 1965, Palmer developed an index to “measure the departure of the moisture supply” (Palmer 1965). Palmer based his index on the supply-and-demand concept of the water balance equation, taking into account more than only the precipitation deficit at specific locations. The objective of the Palmer Drought Severity Index (PDSI), as this index is now called, was to provide a measurement of moisture conditions that were “standardized” so that comparisons using the index could be made between locations and between months (Palmer 1965).

The PDSI is a “meteorological” drought index and responds to weather conditions that have been abnormally dry or abnormally wet. When conditions change from dry to normal or wet, for example, the drought measured by the PDSI ends without taking into account streamflow, lake and reservoir levels, and other longer-term hydrologic impacts (Karl and Knight 1985). The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content (AWC) of the soil. From the inputs, all the basic terms of the water balance equation can be determined, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer. Human impacts on the water balance, such as irrigation, are not considered. Complete descriptions of the equations can be found in the original study by Palmer (1965) and in the more recent analysis by Alley (1984).

Palmer developed the PDSI to include the duration of a drought (or wet spell). His motivation was as follows: an abnormally wet month in the middle of a long-term drought should not have a major impact on the index, or a series of months with near normal precipitation following a serious drought does not mean that the drought is over. Therefore, Palmer developed criteria for determining when a drought or a wet spell begins and ends, which adjust the PDSI accordingly. Palmer (1965) described this effort and gave examples, and it is also described in detail by Alley (1984). In near-real time, Palmer’s index is no longer a...
meteorological index but becomes a hydrological index referred to as the Palmer Hydrological Drought Index (PHDI) because it is based on moisture inflow (precipitation), outflow, and storage only, and does not take into account the long-term trend (Karl and Knight 1985). In 1989, a modified method to compute the PDSI was begun operationally (Heddinghaus and Sabol 1991). This modified PDSI differs from the PDSI during transition periods between dry and wet spells. Because of the similarities between these Palmer indices, the terms “Palmer Index” and “Palmer Drought Index” have been used to describe general characteristics of the indices.

The Palmer Index varies roughly between -6.0 and +6.0. Palmer arbitrarily selected the classification scale of moisture conditions (Table 23) based on his original study areas in central Iowa and western Kansas (Palmer 1965). Ideally, the Palmer Index is designed so that a -4.0 in South Carolina has the same meaning in terms of the moisture departure from a climatological normal as a -4.0 in Idaho (Alley 1984). The Palmer Index has typically been calculated on a monthly basis, and a long-term archive of the monthly PDSI values for every Climate Division in the United States exists with the National Climatic Data Center from 1895 through the present. In addition, weekly Palmer Index values (actually modified PDSI values) are calculated for the Climate Divisions during every growing season and are available in the Weekly Weather and Crop Bulletin. These weekly Palmer Index maps are also available on the World Wide Web from the Climate Prediction Center.

The Palmer Index is popular and has been widely used for a variety of applications across the United States. It is most effective measuring impacts sensitive to the soil moisture conditions, such as agriculture (Willeke et al. 1994). It has also been useful as a drought monitoring tool and has been used to start or end drought contingency plans (Willeke et al. 1994). Alley (1984) identified three positive characteristics of the Palmer Index that contribute to its popularity: (1) it provides decision makers with a measurement of the abnormality of recent weather for a region; (2) it provides an opportunity to place current conditions in an historical perspective; and (3) it provides spatial and temporal representations of historical droughts. Several states, including New York, Colorado, Idaho, and Utah use the Palmer Index as one part of drought monitoring systems.

There are considerable limitations when using the Palmer Index, and these are described in detail by Alley (1984) and Karl and Knight (1985). Drawbacks of the Palmer Index include:
• The values quantifying the intensity of the drought and signaling the beginning and end of a drought or wet spell were arbitrarily selected based on Palmer’s study of central Iowa and western Kansas and have little scientific meaning.

• The Palmer Index is sensitive to AWC of a soil type. Thus, applying the index for a Climate Division may be too general.

• The two soil layers within the water balance computations are simplified and may not be accurately representative for a location.

• Snowfall, snow cover, and frozen ground are not included in the index. All precipitation is treated as rain, so that the timing of PDSI or PHDI values may be inaccurate in the winter and spring months in regions where snow occurs.

• The natural lag between when precipitation falls and the resulting runoff is not considered. In addition, no runoff is allowed to take place in the model until the water capacity of the surface and subsurface soil layers is full, leading to an underestimation of the runoff.

• Potential evapotranspiration is estimated using the Thornthwaite method. This technique has wide acceptance, but it is still only an approximation.

Several other researchers have presented additional limitations of the Palmer Index. McKee et al. (1995) suggested that the PDSI is designed for agriculture, but does not accurately represent the hydrological impacts resulting from droughts of longer time scales. The Palmer Index is also applied within the United States and has little acceptance elsewhere (Kogan 1995). One explanation for this is provided by Smith et al. (1993), who suggested that it does not do well in regions where there are extremes in the variability of rainfall or runoff. Examples in Australia and South Africa were given. Another weakness in the Palmer Index is that the “extreme” and “severe” classifications of drought occur with a greater frequency in some parts of the country than in others (Willeke et al. 1994). “Extreme” droughts in the Great Plains occur with a frequency greater than 10%. This limits the accuracy of comparing the intensity of droughts between two regions, as well as planning response actions based on a certain intensity more difficult.
Table 23: PDSI classifications for Dry and Wet Periods

<table>
<thead>
<tr>
<th>PDSI Range</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.00 or more</td>
<td>Extremely wet</td>
</tr>
<tr>
<td>3.00 to 3.99</td>
<td>Very wet</td>
</tr>
<tr>
<td>2.00 to 2.99</td>
<td>Moderately wet</td>
</tr>
<tr>
<td>1.00 to 1.99</td>
<td>Slightly wet</td>
</tr>
<tr>
<td>0.50 to 0.99</td>
<td>Incipient wet spell</td>
</tr>
<tr>
<td>0.49 to -0.49</td>
<td>Near normal</td>
</tr>
<tr>
<td>-0.50 to -0.99</td>
<td>Incipient dry spell</td>
</tr>
<tr>
<td>-1.00 to -1.99</td>
<td>Mild drought</td>
</tr>
<tr>
<td>-2.00 to -2.99</td>
<td>Moderate drought</td>
</tr>
<tr>
<td>-3.00 to -3.99</td>
<td>Severe drought</td>
</tr>
<tr>
<td>-4.00 or less</td>
<td>Extreme drought</td>
</tr>
</tbody>
</table>