REPORT

Habitat Area Requirements of the Golden-cheeked Warbler on the Edwards Plateau

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by

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INTRODUCTION

The breeding range of the Golden-cheeked Warbler (*Dendroica chrysoparia*) is restricted to Central Texas (predominantly on the Edwards Plateau) and is associated with the occurrence of Ashe juniper (*Juniperus ashei*). In fact, its breeding range coincides almost identically with the range of the Ashe Juniper (Pulich 1976). The widespread clearing of juniper as a range management practice coupled with urban encroachment into the breeding areas of the warbler has caused considerable concern for the future of the species.

Pulich (1976) described typical warbler habitat as "dense cedar brakes" but later descriptions indicate a mixture of Ashe Juniper with various species of deciduous plants is important (Kroll 1980, Ladd 1985, Wahl et al. 1988, Wahl et al. 1990). Although Kroll (1980) suggested that the Golden-cheeked Warbler was primarily an edge species, this assertion is not supported by later investigations (Ladd 1985). The bird is commonly parasitized by Brown-headed Cowbirds (*Molothrus ater*). Pulich (1976) found that 19 of 33 nests observed contained cowbird eggs.

Remaining Golden-cheeked Warbler habitat is undergoing constant fragmentation owing to human pressure to develop the Edwards Plateau for increased economic gain. It is commonly believed that this fragmentation will negatively impact the already limited population of breeding warblers. However, no investigation has attempted to characterize and quantify the life history relationship of the warbler to habitat area requirement or "patch size". What is the minimum patch size required to maintain a productive breeding territory? Recent work indicates that many bird species exhibit a marked relationship to habitat patch size (Robbins et al. 1989). An understanding of this relationship is crucial to conservation planning and management.

OBJECTIVES OF THIS STUDY

Planning for this project was coordinated by Mr. Rex Wahl at the Texas Parks and Wildlife Department, Austin, Texas. Several factors (long delay in getting contract signed at TPWD forcing work to begin late in the search, satellite images did not register properly with features on the ground, resignation of TPWD personnel that were to play a major role in completing some of the tasks, etc.) have caused the scope of this project to be reduced to the two major objectives listed below.

Objective 1: To determine the relationship of the occurrence of Golden-cheeked warblers to three measures (area, edge, fractal dimension) of habitat fragments or patches.

Objective 2: To measure the typical Golden-cheeked Warbler territory size, spatial and temporal utilization factors, and the temporal dynamics of territories during the breeding season. Instrumentation developed at Texas A&M University will be tested. The instrumentation records the location of vocalizing warblers through hyperbolic positioning.

STUDY AREA

The study area for the patch size/shape relationship investigations was the Edwards Plateau of central Texas. More than three hundred individual samples were taken in various areas in the hill country. Methods for taking samples are described elsewhere. Table I lists the Texas Highway Department aerial photographs which cover all the samples taken. These photographs are also included in the appendix. The locations of all study sites are marked on the photographs. A zero represents a sample taken where no Golden-cheeked Warblers were discovered. An "X" represents a sample taken where Golden-cheeked Warblers were present.

The study site for the hyperbolic positioning system test was a location in western Grimes County, Texas.

TABLE I.

County	Map Number	Sites on Photo
Bandera	1.21.346	21
"	1.8.94	17
Bell	1.9.125	9
Bexar	2.12.288	11
"	2.15.409	3
"	2.12.287	23
Blanco	1.4.45	6
Burnet	1.15.367	1
"	1.15.375	1
"	1.14.337	3
"	1.14.340	1
Comal	1.8.173	6
"	1.12.273	13
Hays	1.5.94	3
Kerr	1.11.265	10
"	1.6.131	2
"	1.7.160	32
"	1.10.235	11
"	1.10.237	10
"	1.11.260	11
Llano	1.13.324	1
Travis	1.12.215	4
"	1.11.202	14
"	1.11.201	3
"	1.11.200	14
"	1.10.164	5
"	1.12.216	2
"	1.12.220	8
"	1.13.241	5
"	1.13.244	10
"	1.14.267	3
"	1.15.302	2
"	1.20.408	8
"	1.16.319	7
"	1.13.246	4
"	1.14.263	8
"	1.17.340	5
"	1.17.338	1
Will.	1.15.340	4
"	2.22.441	2

FIELD METHODS

The methods used to accomplish the first objective were as follows. Field observers, in conjunction with the principal investigator, studied detailed maps and aerial photographs of the Edwards Plateau. Subsequently, field observers traveled to the Edwards Plateau in search of suitable sites (patches) in which to complete a sample. Sites were selected by fitting them to a structural profile which required the following criteria be met. Patches were composed of mixed oak and juniper and the junipers were at least 5 meters in height. The canopy cover was at least 50 percent, measured at the 4-meter level.

Patches were selected so that a sampling site was at least 45 meters from any part of the patch edge. In large patches, the observers were instructed to take multiple samples but these samples were always more that 150 meters apart.

Sampling began no earlier than 30 minutes after local sunrise and did not extend past 3:00 PM local time. Samples were not taken in rain nor in conditions where the temperature was below 40° F, nor when wind speed was greater than 15 mph during any portion of the survey.

Samples were taken using a modified circular plot method. The observer established a suitable sampling site, then sat quietly noting all sightings or vocalization of Golden-cheeked warblers. In the case of visual observations, distance classes were estimated as in the Emlen Method (Emlen, 1971). If time allowed, other bird species seen or heard during the 20 minute period were noted. The location of the sampling site was recorded on a USGS topographical map and sightings were recorded on a standard field data sheet for later analysis. A copy of the field data sheet is included in the appendix.

The second objective of this work was to test the feasibility of using a new technique developed by Robert Benson to study the range and movements of small vocalizing birds when hidden in heavy cover. The method uses four microphones deployed in a square array in or near the vocalizing bird's breeding territory. In general, the sound of the singing bird arrives in the four microphones at different times. By analyzing the delays between the arrival time of the various vocalizations, it is theoretically possible to calculate the position of the source of sound (i.e. the bird). The initial plan was to deploy this system in the territory of a Golden-cheeked Warbler. However, because the project got off to a very late start owing to contract problems, it was not possible to deploy the system as planned. Instead, the system was deployed near the Texas A&M University campus in the territory of a White-eyed Vireo. White-eyed Vireos tend to remain in heavy cover and provided a good test of the positioning system. Details of the system and the results obtained are elsewhere in this report.

METHODS OF ANALYSIS

Objective one

Field observers noted the number of Golden-cheeked Warblers seen or heard at each survey site and marked the exact location of the site on 1:24,000 U. S. Geological Survey topographic maps. Aerial photographs (at the same scale) of the survey sites were obtained from the Texas Highway Department in Austin, Texas. All sites were transcribed onto the aerial photographs. Sites where Golden-cheeked Warblers were discovered during the survey were marked with an "X". Sites where Golden-cheeked Warblers were not found were marked with"O".

In most cases, the perimeters of the patches were apparent on the aerial photographs. However, it was not possible to determine if all the vegetation enclosed by the perimeter properly fit the criteria mentioned above (tree height, presences of oaks, and canopy cover).

The outlines of all patches containing survey sites were digitized using a Hicomscan Data Tablet Digitizer Model HDG-1111B with a point resolution of 0.001 in. To assure that the same subjective rules for deciding what constituted the perimeter of a patch were used, one person completed the entire digitization. These data were collected and stored on a Hewlett-Packard Vectra Model RS/20 microcomputer.

I wrote computer software which used the vector representation of the patch perimeters collected by digitization and calculated the patch area in square meters, the total perimeter in meters, the ratio of the area to the perimeter and the fractal dimension of the patch. Fractal dimension was calculated using the following formula (Gardner et al. 1987),

$$D = \frac{\log A}{\log(.25\ P)}$$

where D is the fractal dimension, A is the patch area and P is the patch perimeter.

Reaching objective one required answering the following question. Is the probability for discovering Golden-cheeked Warblers in small patches significantly less than the probability of discovering Golden-cheeked Warblers in large patches? I planned to develop a logistic regression model to explain the relationship between probability of occurrence and patch size. However, if it could not be shown that small patches represented lower probabilities of occurrence, proceeding with logistic regression was not warranted.

I sorted the data by patch size in ascending order and chose five size classes. These classes were 0 to 44.99 ha, 45 to 93.99 ha, 94 to 141.99 ha, 142 to 185.99 ha, and 186 to 238 ha (to simplify tables and graphs, I have allowed overlap in stating the classes. For example, class 0 to 44.99 is shown as 0 to 45). The choice of five classes assured that the sample size was larger than 30 in each case. The probabilities of discovering a Golden-cheeked Warbler in the respective size classes were calculated by dividing the number of patches with warblers by the total number of patches sampled in the size class. Results of the classification are depicted in Table II and figure 1 below.

TABLE II.

Class	Patch size	Probability of Occurrence
I	00-45 ha	0.336
II	45-94 ha	0.395
III	94-142 ha	0.260
IV	142-186 ha	0.351
V	186-238 ha	0.552

To test whether the smallest size class represented a smaller probability of occurrence compared with the larger patches, classes II, III, IV, and V were lumped into one class and compared to class I. The probability of occurrence in the lumped class was p_1=0.337. The probability of occurrence in class I was p_2=0.336. A one tailed test at the P = 0.05 level of significance using pooled proportions (Arnold 1990) was used to examine the hypotheses $H_0:p_1=p_2$; $H_1:p_1>p_2$.

Similar tests were performed on data sorted by area/perimeter ratio (a measure of edge) and fractal dimension (a measure of shape). See figures 2 and 3.

Additionally, I applied Canonical Discriminate Function Analysis in an attempt to develop a model which could use the three measurements (area, area/perimeter, and fractal

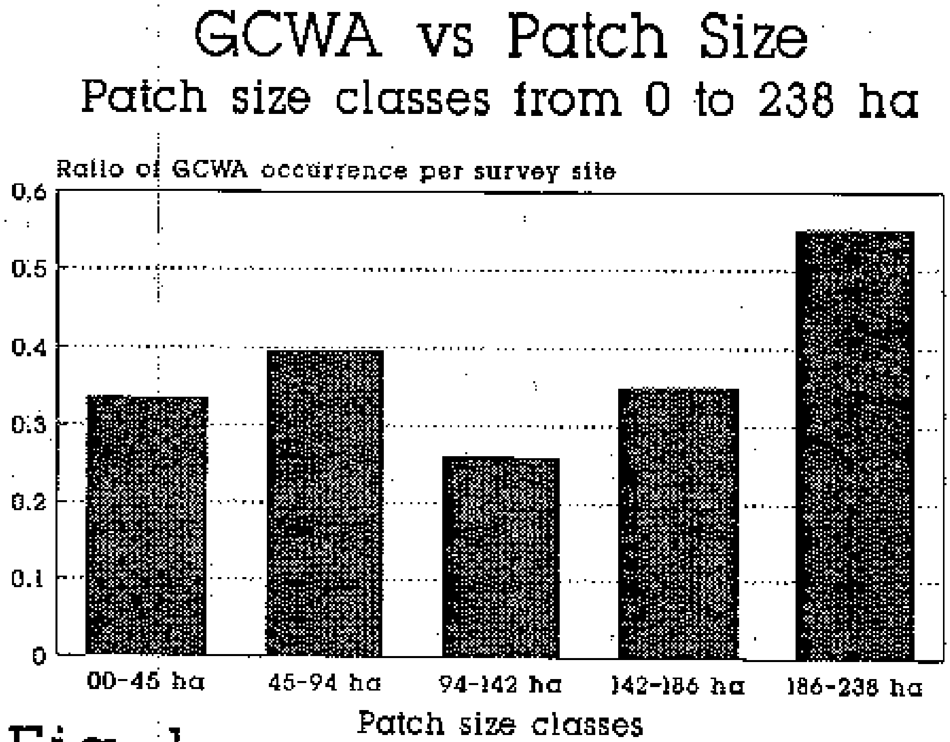
GCWA vs Patch Size
Patch size classes from 0 to 238 ha
Ratio of GCWA occurrence per survey site
0.6
0.5
0.4
0.3
0.2
0.1
0
00-45 ha
45-94 ha
94-142 ha
142-186 ha
186-238 ha
Patch size classes

Fig. 1.

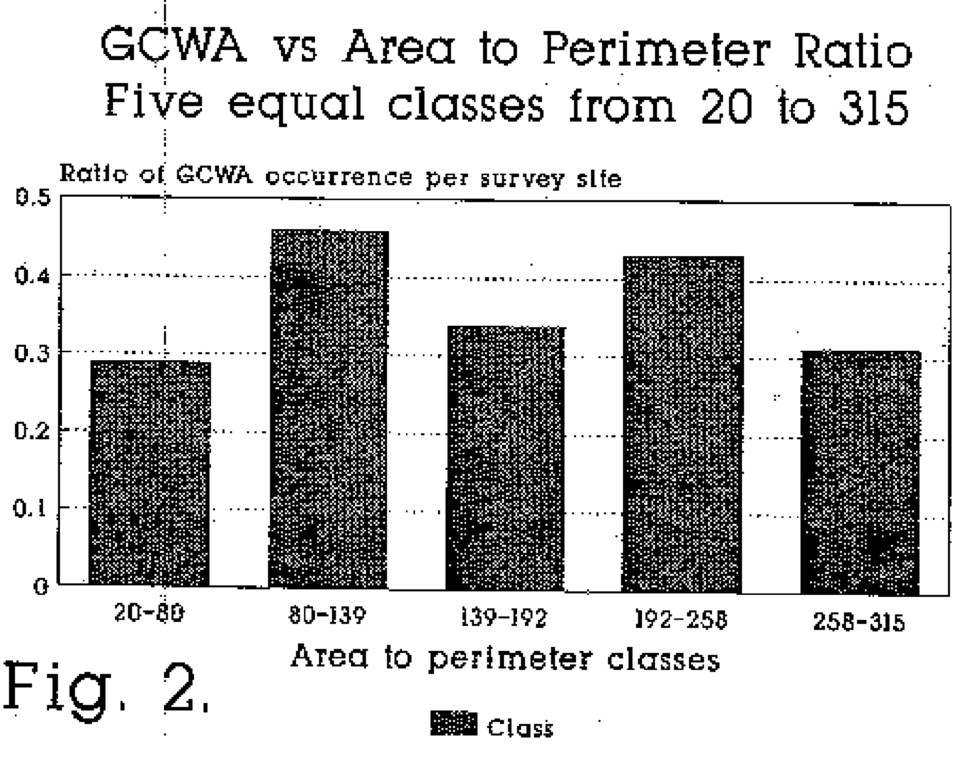
GCWA vs Area to Perimeter Ratio
Five equal classes from 20 to 315
Ratio of GCWA occurrence per survey site
0.5
0.4
0.3
0.2
0.1
0
20-80
80-139
139-192
192-258
258-315
Area to perimeter classes
Class

Fig. 2.

dimension) simultaneously. It should be noted that perimeter/area ratio and fractal dimension are correlated by a non-linear relationship. The model considered two classes; patches with warblers present during the survey and patches without warblers present during the survey.

Finally, I sorted the aerial photographs (subjectively) into three classes according to the perceived amount of urban development. Development types considered were housing subdivisions, industrial areas, roads, and other signs of human density. The classes were LOW urbanization, MODERATE urbanization, and HIGH urbanization. Each aerial photograph included a total area of 2982 ha (11.5 square miles).

TABLE III.

(Low urbanization)

Photo number	Sites on photo	Sites with GCWAs on photo
31	1	0
40	2	2
36	21	10
43	5	5
33	1	1
1	1	1
2	3	1
3	2	0
4	32	5
9	11	3
10	10	6
14	11	3
19	13	11
26	3	2
27	1	0

TABLE IV.

(Moderate urbanization)

Photo number	Sites on photo	Sites with GCWAs on photo
7	9	1
29	4	0
30	1	0
39	3	0
38	11	5
37	23	3
35	8	3
32	7	6
15	10	7
22	4	3
24	8	6

TABLE V.

(High urbanization)

Photo number	Sites on photo	Sites with GCWAs on photo
5	17	4
6	6	0
8	5	0
11	14	2
12	3	0
13	14	5
16	4	0
17	2	0
18	6	0
20	5	3
21	10	7
23	1	0
25	3	2
28	2	2

The aerial photographs from which these data are taken are included in the appendix.

To test whether the class with lowest urbanization represented a larger probability of occurrence compared with the class with highest urbanization, a one tailed test at the 0.05 level of significance using pooled proportions (Arnold 1990) was used to examine the hypotheses $H_0: p_1 = p_2$; $H_1: p_1 > p_2$. The proportion of sites with warblers in the low urbanization class p_1 was 0.40. The proportion of sites with warblers in the high urbanization class p_2 was 0.24.

Objective two

The positioning of vocalizing birds by acoustic hyperbolic positioning system depends on the measurement of time delays between the arrival of signals from an array of microphones. Consider a standard rectangular coordinate system with the y-axis vertical and the x-axis horizontal. A microphone is deployed at x, -x, y, -y where $|x| = |-x| = |y| = |-y|$. By measuring the time delay between the arrival of a signal at microphones x and -x and by noting in which microphone the sound arrives first, the position of the source lies on the hyperbola defined by the following equation.

$$\frac{X^2}{a^2} - \frac{Y^2}{b^2} = 1$$

Likewise, the delay measured between y and -y place the source on the hyperbola defined by this equation.

$$\frac{Y^2}{f^2} - \frac{X^2}{h^2} = 1$$

By solving these equations for an intersection, it is possible to determine the position of the source vocalization (figure 4). The velocity of sound (figure 5) is critical and can be determined if the air temperature is known. Any wind velocity will contribute error to the calculated position. However, if the wind velocity is less than 5 mph, the error is negligible. I wrote a computer program to automatically calculate source positions using time delays measured with the Kay 5500 spectrograph. Details of these calculations and the computer program are not included in this report but are available to the Texas Parks and Wildlife Department if needed.

RESULTS

Objective one

Within the limits of the measurements taken in this study (patch area, area/perimeter, fractal dimension) none of the parameters were found to be significant predictors of the presence or absence of Golden-cheeked Warblers at the selected study sites. The percentage of occurrence of warblers in patch-sizes below 45 ha was statistically no smaller than the percentage of occurrence of warblers in patches larger than 45 ha ($P = 0.05$). Furthermore, no clear relationship was observed when area/perimeter and fractal dimension were considered.

Discriminant Function Analysis was performed in an attempt to develop a model which could classify habitat patches into one of two classes: (1) patches with Golden-

GCWA vs Fractal Dimension
Five classes from 1.66 to 2.0

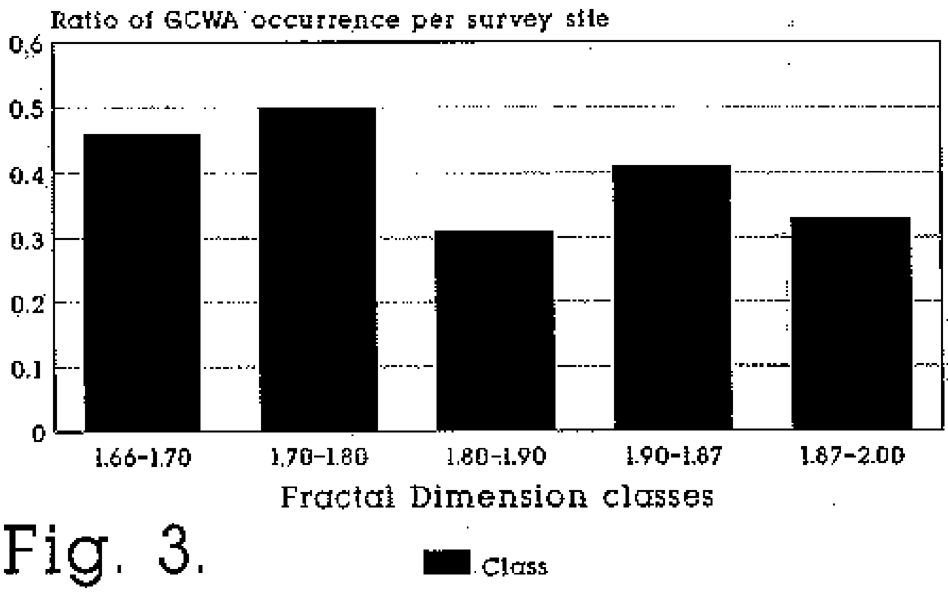

Fig. 3.

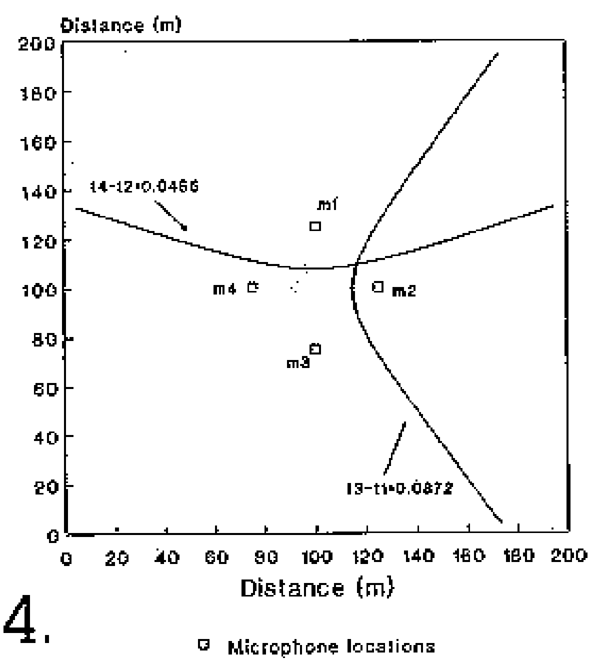

Fig. 4.

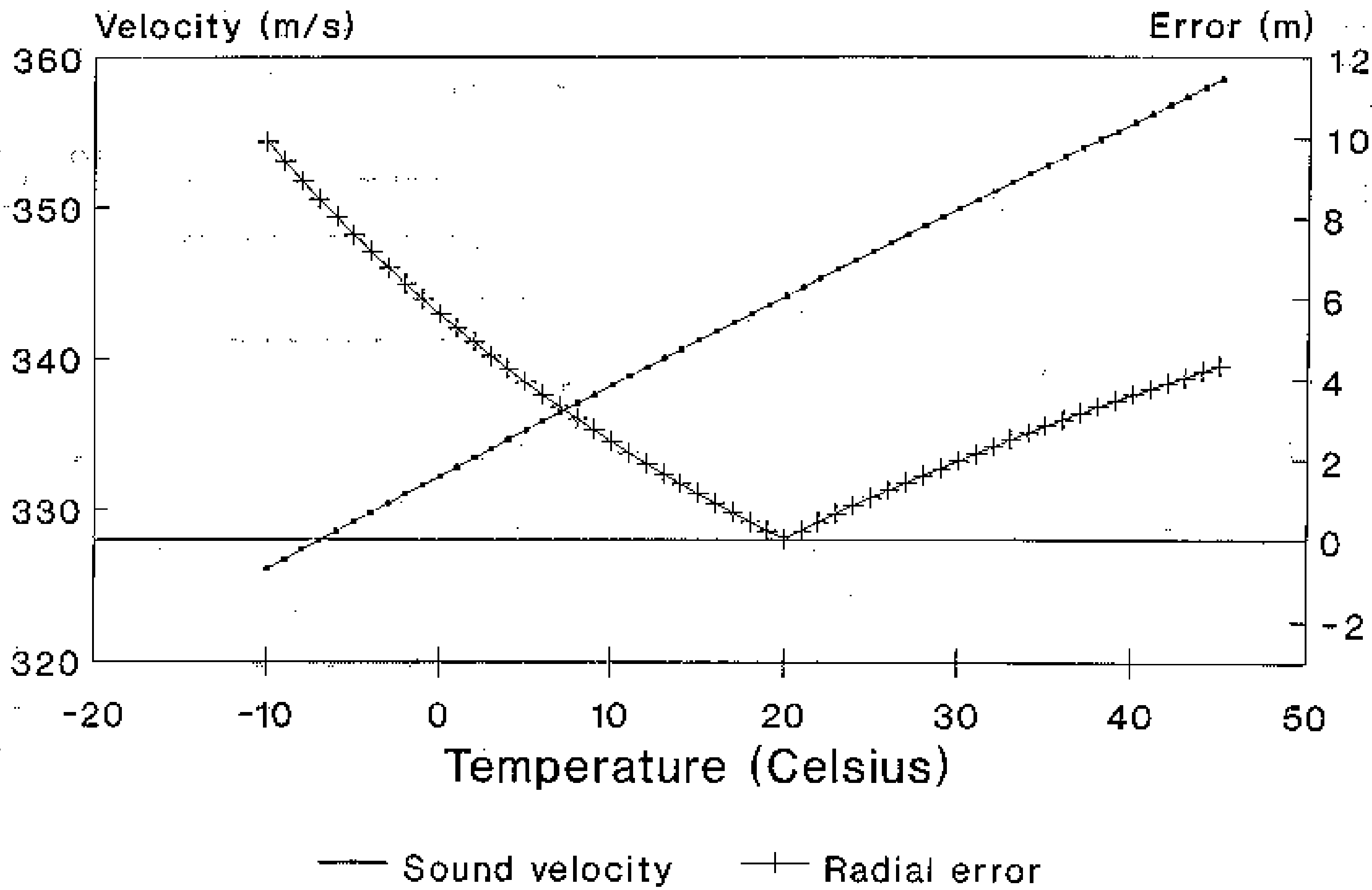

Fig. 5. Radial error made as a function of sound velocity.

cheeked Warblers and (2) patches without Golden-cheeked Warblers. The model was based on the parameters measured and calculated for each patch. Results indicate that the model derived from these measurements was not well suited for classifying patches. The model (when attempting to reclassify patches used to develop the model) had an overall error rate of 43.3 percent. In other words, the model failed to properly classify 43 percent of the patches even though the model was based on the same patches it was trying to classify.

Canonical DFA was also performed and plots of canonical axes CAN1 vs. CAN2, CAN1 vs. CAN3, and CAN2 vs. CAN3 were made. As expected, no clear separation was evident. A complete print-out of the analysis is in the Appendix.

When low urbanization verses high urbanization were tested, I determined that the proportion of occurrences of Golden-cheeked Warblers in the highly urbanized areas was significantly lower than the proportion occurrences in the least urbanized areas. Warblers were found at 40 percent of the least urbanized sites and only found on 24 percent of the highly urbanized sites and this difference was significant ($P = 0.05$).

<u>Objective two</u>

The results of the vocal positioning system were very promising. Figure 6 below is a plot of position calculated for a male White-eyed Vireo over a twenty minute period.

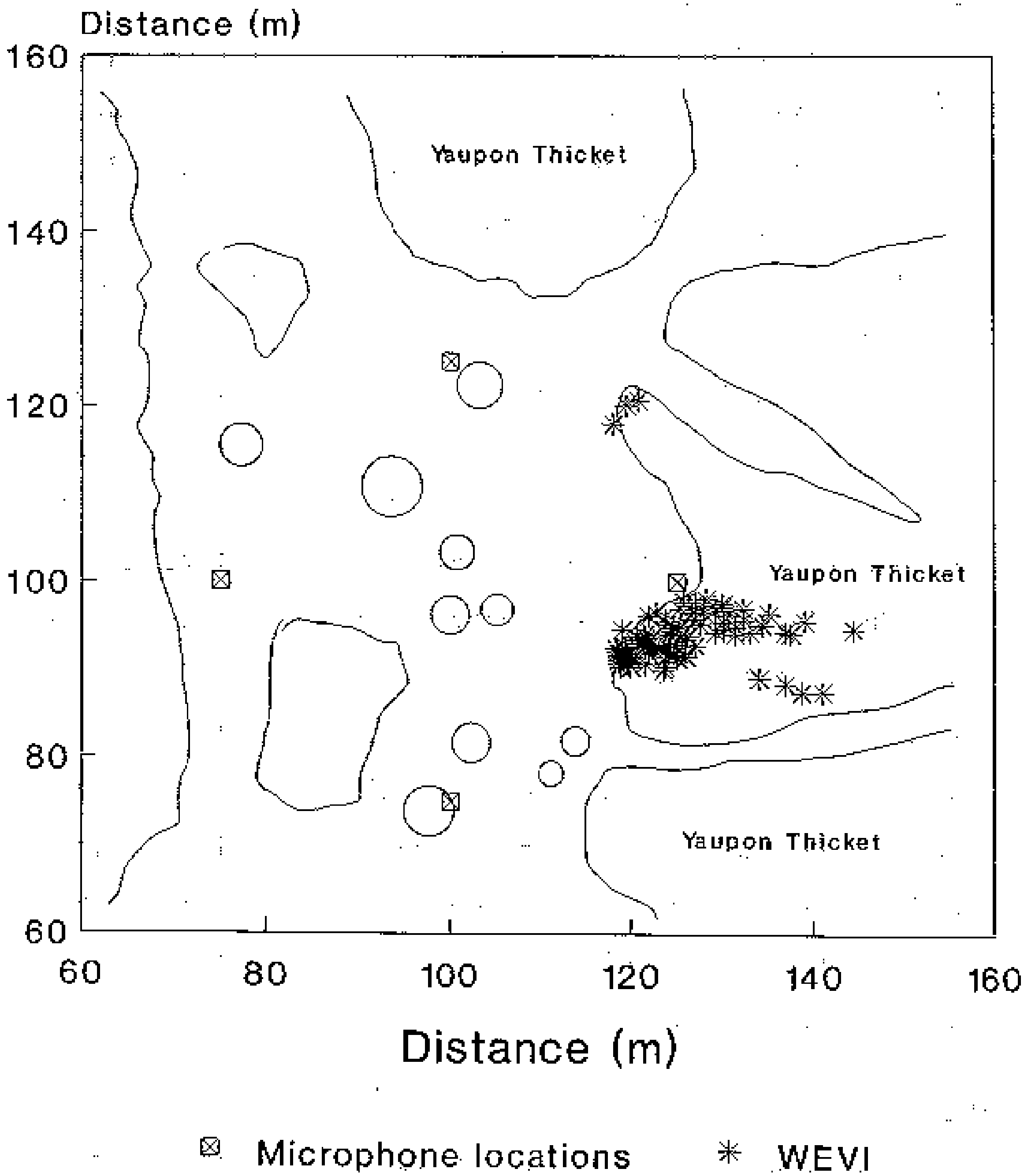
Distance (m)
160
140
120
100
80
60
Yaupon Thicket
Yaupon Thicket
Yaupon Thicket
60
80
100
120
140
160
Distance (m)
Microphone locations
WEVI

Fig. 6.

Notice that the bird did not leave the cover of the yaupon (*Ilex vomitoria*) thicket.

DISCUSSION

This study represents the first attempt to characterize the relationship (if any) between the occurrence of Golden-cheeked Warblers on the Edwards Plateau and various habitat patch parameters. My analyses indicate that there is no significant relationship between the probability of finding a Golden-cheeked Warbler in a given patch and patch size, amount of edge available, or the shape of the patch. Additionally, multivariate statistical techniques which use all measurements and calculated parameters simultaneously are not able to establish a classification model that can be relied on to predict if a patch is likely to be occupied by a warbler.

The standard wisdom among researchers working with Golden-cheeked Warblers has been that habitat fragmentation causes a decline in the population level. It cannot be argued that the elimination of prime habitat by development or other means has no effect on the survivability of warblers in their restricted range. However, my analyses show that habitat fragmentation alone does not have a significant impact on the bird. It must be understood that to fragment habitat, destruction of existing habitat must occur. Since this warbler will not utilize areas other than oak-juniper stands, fragmentation will reduce the available habitat and will have a negative impact on the bird. But it cannot be said that small patches are inferior to large patches as suitable habitat. The smallest patch we sampled (0.66 ha) did support at least one male Golden-cheeked Warbler.

My analyses do indicate that other habitat factors like urbanization can and do play a major role in the life history of the warbler. Golden-cheeked Warblers are 40 percent less likely to be found in the more urban areas of their range. This result may be considered evidence that urbanization causes a decline in population levels. But when considered on the scale of the entire range of the bird, the reduction in numbers is small. For example, if 10 percent of the total range has been urbanized, the reduction in the population would be 0.4 X .1 or 0.04 resulting in approximately a 4 percent reduction in population. I do not have exact numbers for the extent of urbanization on the Edwards Plateau. Consequently, this result is only an example meant to prevent casual readers from concluding that a 40 percent reduction in numbers in urban areas translates to a 40 percent reduction in the entire population.

A conclusion of this study is that habitat elimination and not habitat fragmentation will have a major impact on the long-term survival of the bird. If wildlife managers and planners seek to preserve Golden-cheeked Warbler habitat, it makes little difference whether habitat is set aside in large patches or small patches, as long as the preserved habitat is away from present or future areas of dense urbanization.

Another conclusion of this study is that the hyperbolic positioning system tested under this contract can provide an important new tool for the study of the utilization of the home range of the Golden-cheeked Warbler and other difficult to study passerines.

Much more work needs to be done before a complete understanding of the life history and habitat requirements of the Golden-cheeked Warbler is possible. All studies thus far have suffered from a poor knowledge of the population level of the bird. Without believable baseline information developed over time, we cannot document either a decline or increase in the population. This study is only suggestive. More work is needed to understand what factors associated with urbanization are limiting the occurrence of the bird in the eastern part of its range.

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APPENDIX

GCWA data sheet

Date: ____________ Time: __________ Quad name: _______________

Survey site number marked on quad map: ________ .

Assure that the selected survey site meets the following criteria: Patch must be mixed oak-juniper stand forming a patch. Junipers must be 5 m in height, and the canopy cover must be at least 50% at the 4 m level.

For each GCWA seen or heard, circle the following data entries if the information is obtainable.

GCWA (1) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

GCWA (2) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

GCWA (3) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

GCWA (4) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

GCWA (5) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

GCWA (6) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

GCWA (7) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

GCWA (8) : [seen heard] [male female] Distance class: [0 - 9 10 - 19 20 - 29 30 - 39 More]

Total number of Cowbirds seen or heard during the 20 minute survey period. ____________ .

Notes:

GCWA data sheet
Protocol

Site selection: A suitable initial site (patch) is to be selected by the following method. If a map overlay computed from satellite imagery is available, it should be used as a guide to patch selection. If an overlay is not available, initial patch selection should be based on the experience of the surveyor.

Once initial patch selection has be done, the proposed patch must fit the structure profile indicated on the reverse side of this data sheet or the site must be rejected as a suitable patch.

Sites should be large enough to allow the observer to be at least 45 m from any edge of the patch. When multiple sites or selected in large patches, the sites must be at least 150 m apart.

Time and conditions: Surveys should begin no earlier than 30 minutes after local sunrise and should extend no later than 3PM local time. Surveys should not be conducted in rain or in conditions where temperature is below 40 degrees or the wind velocity is greater than 15 mph.

Survey method: Surveys will be by a modified circular plot method. The surveyor will establish a suitable survey site which matches proper criteria as indicated on the reverse of this data sheet. Surveyor will sit quietly at a spot at least 45 m from the edge of the selected patch. The surveyor will make note of all GCWAs and BHCOs either seen or heard for the next 20 minutes. In the case of visual sightings, distance classes will be estimated as in the Emlen method. Use 10 m distance classes. For example, if a GCWA is seen at an estimated distance of 23 m, then this warbler will be assigned to the 20 - 29 m class. See other side of this form.

If time allows, other bird species seen or heard during the 20 minute survey period should be noted.

Survey strategy: As far as practical, equal numbers of sites should be selected in various size patches. The point of the investigation is to determine the relationship between patch size and occurrence of warblers in the patch. To do the analysis, equal area for each patch size should be surveyed. For example, if we survey five 3 ha patches, then we should survey five sites within 50 ha patches. Field effort will be coordinated on a weekly basis to assure field observers are achieving this equality.

SAS STATISTICS TABLES AND STUDY AREA MAPS AVAILABLE UPON REQUEST