STATISTICAL TRENDS OF GOLDEN-CHEEKED WARBLERS ON BALCONES CANYONLANDS PRESERVE,
CITY OF AUSTIN, TEXAS

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A goal for the conservation of federally endangered golden-cheeked warblers (GCWA, *Dendroica chrysoparia*) on Balcones Canyonlands Preserve (BCP) is to maintain and, if possible, increase populations that breed in the BCP (BCP 1999). To assess whether the goal is met, the City of Austin (COA) established eight 100 acre plots throughout the BCP in 1998. In each plot, data on territory density and productivity is collected annually or biannually so that GCWA population trends can be estimated. Population trend refers to whether a population over a specified period of time has increased, declined, or remained stationary (Anthony et al. 2007). The purpose of this report is to determine GCWA population trend on City of Austin BCP lands by analyzing the data collected by COA biologists between 1998 and 2007.

Specific objectives of this analysis are to:

1) Assess the reliability of measures of GCWA territory density;
2) Estimate trend in GCWA territory density on each of 8 plots;
3) Determine whether trend on the BCP can be assessed by pooling data among plots or whether trend should be assessed on a plot-by-plot basis;
4) Estimate the spatial and temporal variance in territory density and use this information to assess the number of 100 acre plots needed to estimate trend in territory density throughout the BCP;
5) Investigate trends in productivity and assess whether productivity trends match trends in territory density.

Reliability of territory density involved determining a) which measure of territory density to analyze (number of full, full plus edge or full plus one-half the number of edge territories), b) whether the existing survey effort (60 hours/plot) detects the number of singing males in a 100 acre plot when they are present, and c) whether the experience of the surveyor (which has varied among years and plots) has influenced population trends. Pairing success, breeding success, and productivity were assessed in each plot. Pairing success was the proportion of territories where females paired with singing males. Pairing of males with females was inferred from locating an active nest or observing a male tending fledglings within the perimeter of a territory. A ‘successful territory' was a territory that produced nestlings or fledglings. Average productivity was reported in two ways: the number of young fledged divided by the number of successful territories, and number of young fledged divided by the total number of full territories.

Estimating pairing and productivity requires the detection (usually by sight not sound) of females, nests, and fledglings; entities that are more cryptic than the brightly colored male that is singing. Consequently, in all likelihood the productivity data is biased low; fewer females, nests, and fledglings are detected than actually exist in 100 acre plots. If productivity data is biased then it may manifest as trends in territory density that do not match trends in productivity.

METHODS

100 acre plots.—In 1998, five square-shaped plots (Barton Creek, Emma Long, Forest Ridge, Ivanhoe, 3M/St. Edwards) were established in prime GCWA habitat (Fig. 1). Prime habitat for GCWA is defined on the basis of at least 75 percent of the area containing more than 70 percent canopy cover (Abbruzzese, 1999). A sixth plot was established in an area of Bohls Hollow that had close to 75 percent prime habitat but the plot shape was a polygon to encompass as much prime habitat as possible (Fig. 1). Two additional plots were placed in transitional habitat (Fig. 1), plots that had noticeably less than 75 percent prime habitat (Abbruzzese 1999). The shape of one transitional plot was a polygon (Canyon Creek) and the shape of the other was rectangular (Double J & T). To remain consistent with annual reports, the Bohls Hollow plot was also considered a prime habitat plot (e.g., Abbruzzese 1999, 2001; Becker 2004, 2005, 2006).

Territory density analysis.—Details of field work to collect data on territory density of GCWA is given in annual reports and will not be repeated here (e.g., Abbruzzese 1999, 2001; Abbruzzese and Koehler 2002, 2003; Becker and Koehler 2004, 2005; Becker 2006). Before a formal trend analysis was conducted there were two issues to resolve; first, what measure of territory density should be used and, second, how reliable is the measure of territory density. Territory density data is reported by COA each year in three ways; the number of territories that are entirely within the boundaries of the plot (full territories), the number of full territories plus the number of territories in which a portion is outside the plot boundary (edge territories), and the number of full territories plus one-half the number of edge territories. Because one-half the number of edge territories is a constant of the number of edge territories; both measures will reflect identical changes or trends in territory density. Verner (1985) suggests that the number of full territories plus one-half the number of edge territories is a realistic measure of territory density because, on average, one-half of the territories that intersect the plot boundary will be within the plot. A potential complication to using the number of full territories plus one-half the number of edge territories as a measure of territory density is change in ratios of plot perimeter to plot area among the five square-, one rectangular-, and two polygonal-shaped plots. Possibly, more edge territories would be found in polygon-shaped plots because they have higher perimeter:area ratios than square-shaped plots. Thus far yearly surveys have implicitly assumed no relationship between plot shape and number of edge territories. To test this assumption we examined the relationship between number of full territories and the proportion of edge territories (one-half the number of edge territories divided by number of full plus one-half the number of edge territories) in each plot. If the shape of the plot does not influence number of edge territories then there should be two predictable patterns in the relationships between the number of full territories and proportion of edge territories. First, the relationship should be negative. When there are more full territories there should be proportionally fewer edge territories because the area of a 100 acre plot is much greater than length of the plot perimeter. Second, there should be an inverse relationship between the intercept and slope of regressions estimated in each of the eight plots. Plots with more full territories among all nine years should have smaller intercepts and shallower negative slopes and plots with fewer full territories among all nine years should have larger intercepts and steeper negative slopes (smaller values).

We used mixed-effect regression models to estimate the relationship between number of full territories and proportion of edge territories and to test whether regressions differed among plots (Hedeker and Gibbons 2006). Regressions were estimated using the ten years of data collected in the prime plots and the seven years of data gathered from the transitional plots. Plot was a random predictor, number of full territories was a fixed predictor and proportion of edge territories was the response variable. We compared two models using likelihood ratio tests (Pinheiro and Bates 2000). The intercept model examined whether the relationship between number of full territories and proportion of edge territories varied among plots in intercepts. The intercept and slope model examined whether regressions varied among plots in intercept and slope. The intercept and slope model also estimated the correlation between intercept and slope among plots to test whether intercepts and slopes were inversely related (Hedeker and Gibbons 2006).

Spot mapping to determine territory location and boundaries of breeding pairs of songbirds may or may not detect all singing males that establish territories in a plot (Holmes and Sherry 2001, Kery et al. 2005, Toms et al. 2006). Whether all singing males in a plot are detected using the spot mapping technique may be associated with the spatial extent of the plot surveyed and the time taken to survey the plot (Kery et al. 2005, Toms et al. 2006). All parts of each 100 acre plot are searched by COA biologists during the ≥ 60 hour survey conducted during each breeding and fledging season. To determine whether this length of time is adequate to detect all singing males we tested whether the relationship between survey effort (hours/acre) and observed territory density increased nonlinearly with a decelerating rate indicating a threshold of diminishing returns. Realized survey effort beyond the threshold suggests sufficient survey effort.

We tested whether COA effort was adequate using an independent data set provided by Travis County (Travis County 2002, 2003, 2004, 2005, 2006). Travis County has been conducting tract territory mapping in portions of the BCP that they manage. Tract territory mapping refers to spot mapping to delineate territory boundaries of singing males but the ratio of survey effort to plot size varies from the effort used by COA (60 hours/100 acres = 0.6 hrs/acre). From tract territory mapping conducted between 2002 and 2006, there were 24 possible sites (Appendix). Ideally, survey effort – territory density relationships should be estimated at a site where territory density is constant and survey effort is varied. That way the changes in estimated territory densities are not confounded with variation in survey effort. Because it was likely that true territory density differed among sites the data was first screened. If two or more sites had similar survey effort but one site had estimates of territory density that was one-half or less of the other sites, the data from that site was discarded from analysis. We selected 21 sites for the analyses, among these sites survey effort ranged from 0.04 to 0.71 hrs/acre and territory density ranged from 0.004 to 0.11 territories/acre (Appendix). We compared the coefficients of determination (r^2) of a simple linear regression between hrs/acre (X) and territories/acre (Y) to an asymptotic regression with an offset (Pinheiro and Bates 2000). The equation of this nonlinear regression is

$$Y = A * [1 - e^{-e^{B} * (X - C)}]$$

where X and Y are the same variables as used in the simple linear regression and parameter A estimates the asymptote; the point at which territory density does not increase with greater survey effort. Parameters B and C inform where the regression crosses the X axis when Y is 0 (parameter C) and the survey effort that is one-half the asymptote ($[\log(2)/e^B] + C$). We chose this form of a nonlinear regression because an initial view of the scatterplot of data indicated that the regression would not pass through the origin when X equals 0 (see below).

Territory density trend.—We assessed trend in territory density using mixed-effect regression analysis. The random predictor was plot, year was the fixed predictor, and territory density was the response variable. Analyses were conducted in steps. First, we estimated the intercepts model (see above) and calculated the intraclass correlation coefficient. An intraclass correlation coefficient close to zero indicates that one regression characterizes trend for data pooled among plots, whereas an intraclass correlation coefficient near one suggests trend should be estimated in each plot. Second, we determined whether trends estimated from the intercept model differed between prime and transitional plots. Prime plots presumably provide more high quality GCWA habitat than transitional plots. Consequently, territory densities may vary between the two types of plots. Third, we tested whether regressions estimating trend in each plot differed in intercepts and slopes. If regression coefficients differ among plots then trends should be examined in each plot. Fourth, we tested whether the intercepts and slopes model differed between prime and transitional plots, a likely expectation given differences in availability of high quality GCWA habitat between the two plot types. At steps two through four, alternative models were compared using the likelihood ratio test. Trend was assessed as increasing, stationary, or declining by interpreting t-tests of slopes. For example, if from 1998 to 2006, territory density appeared to increase numerically for a given plot and the slope coefficient was positive and the t-test was statistically significant ($P < 0.05$) then trend was considered to be positive. In contrast, trend would be considered stationary, indicating no change in territory density between 1998 and 2006, if the t-test of the slope was statistically nonsignificant. We estimated variance components for the selected model to provide another measure of model fit to the data that was also intuitive. From the variance components we estimated the proportion of variation in territory density that was not accounted for by regressions and the proportion of variation in territory density among 100 acre plots that was accounted for by the regressions (Fox 2002).

Surveyor experience.—Over the ten years that data was collected, all plots (except Ivanhoe) were surveyed by more then one biologist. The number of years of experience of the biologist may influence spot mapping skill. For each year we coded indicator variables for the years of experience the observer had surveying the 100 acre plot or plots. Years of experience was categorized as one, two, and more than two years experience. We then conducted a single factor analysis of variance on the residuals from the trend regressions (Pinheiro and Bates 2000). If, for example, fewer territories are delineated by surveyors with one year experience, then mean residuals for category one should be less than categories two and more than two years experience.

Spatial and temporal variance.—Because of unequal number of years that prime and transitional plots were surveyed, a single factor analysis of variance using a restricted maximum likelihood estimator was conducted to estimate variance among (spatial) and within plots (temporal) in territory density (Pinheiro and Bates 2000). If spatial variance is greater than temporal variance, then variation in territory density is greater across space then it is within plots. The implication is that if COA wants to obtain reliable estimates of GCWA territory density throughout BCP lands, then how many 100 acre plots are needed? To address this question, we conducted a nonparametric bootstrapping simulation to assess the number of 100 acre plots that would be needed to stabilize variance in territory density (Manly 1997). In other words this analysis addresses the question: how many 100 acre plots are needed to estimate the variability in territory density on BCP? Each simulation generated 1000 bootstrapped samples of constant size. The first simulation had bootstrap samples of size eight (the number of plots presently surveyed) and in subsequent simulations, sample sizes increased in increments of two until the last simulation had 1000 bootstrapped samples of n = 26 plots surveyed. The actual territory densities (territories/acre) were gleaned from COA and Travis County data sets. Territory densities estimated in COA 100 acre plots were gathered from 2005 (transitional plots) and 2006 (prime plots) and from Travis County tract territory mapping plots where we did not detect a correlation between survey effort and territory density. We summarized the variability among these 1000 bootstrapped samples by plotting box plots of the variances of territory densities (territories/acre).

Productivity.—Because productivity has historically been low in transitional plots (Abbruzzese 2001, Becker 2006), trend analyses of pairing success, breeding success, number of young fledged in successful territories, and number of young fledged in all full territories were confined to data collected in prime plots. We approached trend analyses of productivity variables similar to how we analyzed trends in territory density (Hedecker and Gibbons 2006). We first estimated the intercepts model and calculated the intraclass correlation coefficient to assess if data could be pooled among plots. For each productivity variable, intraclass correlation coefficients ranged from 0.33 to 0.48 suggesting that productivity data could be pooled among the six prime plots. Therefore, we examined the intercepts model to assess trend in the relationship between year and each productivity variable with data pooled among the six prime plots.

RESULTS AND INTERPRETATION

Measure of Territory density.—The mixed-effect model that estimated separate intercepts and slopes for regressions summarizing the number of full territories and proportion of edge territories fit the data better than the mixed-effect model that estimated separate intercepts for regressions in each plot (χ^2 = 13.03, *d.f.* = 2, *P* = 0.0015). In each plot there was an inverse relationship between number of full territories and proportion of edge territories (Fig. 2, Table 1). Moreover, among regressions the steeper the estimated slope, the larger the intercept (*r* = -0.77, 95% confidence interval: -0.96 to -0.09). In plots with greater numbers of full territories among the ten years, changes in numbers of full territories did not result in dramatic changes in the proportion of edge territories.

We expected, and found, a strong inverse correlation between regression slopes and intercepts as predicted if plot shape did not influence the number of edge territories. Therefore, territory density expressed as number of full plus one-half the number of edge territories is probably not an artifact or influenced to a high degree by the shape of the plot. Thus for all subsequent analyses we used the number of full plus one-half the number of edge territories as the measure of territory density.

Survey effort and territory density.—Both the simple linear regression ($F_{1,19}$ = 28.61, *P* < 0.001) and asymptotic regression with an offset ($F_{3,\ 17}$ = 14.4, *P* < 0.001) fit the data. However, the nonlinear regression (r^2 = 0.71), more than the simple linear regression (r^2 = 0.60), summarized the relationship between survey effort (X = hours/acre) and territory density (Y = territories/acre) (Fig. 3). Parameter estimates for the nonlinear regression were

$$Y = 0.1268 * (1 - e^{[-e^{1.42153} * (X - 0.05449)]}),$$

and the standard errors of A, B, and C were 0.01801, 0.35292, and 0.02798, respectively. The survey effort at which one-half the asymptote was reached was 0.22. Interpreting the 95% confidence interval of parameter A (0.09047 – 0.16315) suggests little increase in number of territories after 0.35 hours/acre. The existing survey effort of 0.6 (60 hrs/plot) may be sufficient to detect males that establish territories in 100 acre plots.

Trend in territory density.—The intraclass correlation coefficient for the intercepts model was 0.75 suggesting that a single estimate of trend in territory density across the entire set of eight plots should not be estimated. Trend in territory density should be estimated in each plot. When we compared an intercepts model with another intercepts model that determined if the intercepts differed between prime and transitional plots (intercepts habitat model), the intercepts model was selected ($\chi^2 < 0.01$, *d.f.* = 1, $P > 0.999$). We next compared the intercepts model to a model that allowed the intercepts and slopes to vary in each plot. The intercepts and slopes model was chosen ($\chi^2 = 5.73$, *d.f.* = 2, $P = 0.0284$). Finally, we determined whether the intercepts and slopes of regressions differed between prime and transitional plots; they did not ($\chi^2 < 0.01$, *d.f.* = 3, $P > 0.999$). For the variability due to random components (intercepts, slopes, residuals), 65 percent of that variability in territory density was accounted for by the regression coefficients and 35 percent of the variability in territory density was residual or not accounted for by regressions. In other words, the selected intercepts and slopes model estimated regressions in each plot that summarized the relationships between year and territory density.

Plot specific regressions indicated an increasing trend in two of the plots and stationary trends in the remaining plots (Table 2, Fig. 4). In plots with increasing trend, the slopes suggest that, on average, between 0.75 (Emma Long) and 1.53 (Ivanhoe) new territories were added each year. Also, the two plots with increasing trend were in prime habitat.

Increasing trends in GCWA from 1992 to 2001 were also reported on Ft. Hood (Anders and Dearborn 2004). For this study, data was collected from point count surveys and relative abundance was reported. There were between 206 and 428 points surveyed each year. Across the 10 years, Anders and Dearborn (2004) reported a 40 percent increase in relative abundance. Comparing Anders and Dearborn's (2004) findings to COA territory density trends are difficult because of different methodologies and metrics of abundance (Ft. Hood: detections per point, COA: number of territories per 100 acres).

Biologists with Travis County have also measured territory density using the same spot mapping technique as COA. In three 100 acre plots situated in Bunten, Hamilton Preserve, and Lake Perspectives areas of the BCP, territory density data was collected annually from 2002 to 2006 (Travis County 2002, 2003, 2004, 2005, 2006). Although the number of plots and number of years of data in each plot is too sparse for a formal mixed-effect regression analysis, viewing territory densities among the three plots suggests that trends in territory density are probably similar to what we documented on the eight COA plots (Fig. 5). In two of the plots territory density was probably stationary whereas there was probably an increasing trend in the Bunten plot from 2003 to 2006.

The reasons for increasing trends in territory density detected in two plots (Emma Long, Ivanhoe) are unclear. Attributes in and around these two plots such as patch size, configuration, quality, and surrounding land use may result in productivity and immigration exceeding mortality and emigration. Greater ingress of birds than egress of individuals because of conditions outside the plots and BCP lands may have contributed to the increasing territory densities in Emma Long and Ivanhoe plots. At Ft. Hood, Anders and Dearborn (2004) speculated that the increasing population trend may be due, in part, to immigration of juveniles and adults from areas undergoing conversion to agricultural land or urban development.

Observer experience.—We detected no influence of observer experience when categorized as one, two, and more than two years experience on the residuals from the trend regressions ($F_{2,71}$ = 0.24, P = 0.784). This finding indicated that the experience of the observer did not influence the number of territories detected in 100 acre plots.

Spatial and temporal variation.—The estimate of spatial variance (deviation in territory density from plot-to-plot) was 26.85 and temporal variance (deviation in territory density from year-to-year in a plot) was 11.61. The variance components, expressed as a proportion of the total variance in territory density (26.85 + 11.61 = 38.46), were 0.70

and 0.30 for spatial and temporal variances, respectively. Clearly, there is more variation in territory density from plot-to-plot than from year-to-year within plots.

The variance components analysis indicated that most variation in territory density was among plots. An implication of this analysis is whether 8 plots are adequate to sufficiently capture variation in territory densities across the entire BCP lands and, if not, how many additional plots would be needed. To address these points we conducted bootstrapping simulations to ascertain the number of 100 acre plots needed to stabilize variance in territory density. When territory densities vary widely among plots as shown herein, then sampling few plots will result in variances that are noticeably larger than when an adequate number of plots are measured. In the bootstrap simulation we modeled hypothetical number of plots from 8 – 26 in increments of two. For each bootstrap simulation, we summarized finding using boxplots (Fig. 6). It was difficult to determine the number of plots where variances stabilized because variance in territory densities declined gradually from 8 to 26 plots in both range (largest minus smallest variance) and IQR (InterQuartile Range = 75th percentile of variances minus 25th percentile of variances). To aid in interpretation we plotted the range and IQR of variances for each bootstrap simulation (Fig. 7). There was a noticeable decline in range of variances between 8 and 10 plots, thereafter the decline was gradual. For IQR, a decline was evident between 10 and 12 plots; thereafter the decline was also gradual. Because no stabilization or flattening out was evident (e. g., range and IQR's of variances of 14 to 26 number of plots were similar and the smallest) a clear recommendation is unwarranted.

Productivity.— In the two transitional plots we pooled productivity data because it was sparse and reported means and standard deviations (Table 3). The coefficients of variation (standard deviation divided by mean) for each variable in the transitional plots were >1.0 indicating much variability from year-to-year and between plots in all variables used to track productivity.

Pairing success showed an increasing trend across the nine years in prime plots (t = 2.16, d.f. = 53, P = 0.0364). However, the trend was not strong as evidenced by the scatter about the regression line (Fig. 8). The regression suggested that pairing success in 1998 was 0.58 and increased to 0.81 in 2007. No trend was detected in breeding success (*t* = 1.75, d.f. 52, *P* = 0.086), number of young fledged in successful territories (*t* = -0.57, d.f. 52, *P* = 0.573), and number of young fledged in all full territories (*t* = 1.37, d.f. 52, *P* = 0.177). For these variables, means and standard deviations of variables are in Table 4. Plots that appeared to have high productivity were Barton Creek, Forest Ridge, Emma Long, and Ivanhoe.

There are two lines of evidence to suggest that productivity data is biased low. One, there was clear evidence of trends in territory density in two of the 100 acre plots yet there was little suggestion of trend in productivity data. Trend in productivity may in reality be present but a bias in the productivity data may preclude detecting the trend in statistical analyses. The lack of trends in territory density and productivity data may also be due to movement of birds to different areas among years. In spite of this possibility, it is still possible that the lack of similar trends in territory density and productivity data is influenced by biased productivity data. Two, Reidy (2007) studied nest predation in GCWA nests at BCP and Ft. Hood that were continuously filmed when there was activity in the nest. She estimated that 64 percent of nests fledged young. With the exception of the Barton Creek plot, proportion of nests that fledged young was much less than 64 percent in most years in 100 acre plots (Table 4).

SUMMARY OF RESULTS

Objective (1): Assess the reliability of measures of GCWA territory density.

a. We found that the number of full territories plus one-half of the edge territories was not influenced by the different shapes of the 100 acre plots.
b. Survey effort was nonlinearly related to territory density. Interpretation of the 95 percent confidence interval of the estimate asymptote parameter indicated the survey effort of 60 hours/100 acre plots may be adequate to detect all territories of singing males.
c. Experience of the surveyor did not appear to influence trends in territory density.

Objective (2): Estimate trends in GCWA territory density.

a. There was an increasing trend in two plots and stationary trend in the remaining plots.

Objective (3) Determine whether trends can be assessed by pooling data among plots or whether trends should be assessed in each plot.

a. We found that trends in territory density were highly variable among 100 acre plots. Consequently, based on the observed results, adherence to strict statistical convention dictates that overall trend across the BCP should not be determined from data pooled among plots but rather that trends should be determined in each of the 8 plots.
b. We found that trends in productivity variables were less variable among the six 100 acre plots. Consequently, we analyzed productivity data pooled among these plots.

Objective (4): Estimate the spatial and temporal variance in territory density and use this information to assess the number of 100 acre plots needed to reliability estimate trend in territory density throughout BCP.

a. There was more variation in territory densities among plots than within plots; spatial variance was much larger than temporal variance.
b. Our bootstrap simulation, however, did not result in clear suggestions about the number of additional 100 acre plots to survey. There is a suggestion of a stepped reduction in variance at n =14 plots from inspection of figure 6.

Objective (5): Investigate trends in productivity.

a. There was weak evidence that pairing success increased from 1998 – 2007.
b. No trend was detected in breeding success, number of young fledged in successful territories, and number of young fledged in all full territories.

RECOMMENDATIONS

A. Use number of full plus one-half the number of edge territories as the measure of territory density.

B. Analyses of territory density trends should be assessed in each 100 acre plot and not by pooling data among plots.

C. Further study is strongly recommended into whether pairing and productivity data is biased low (detecting less females and reporting fewer fledglings than actually exists).

D. More intensive study into demography and movement is recommended to determine factors that drive trends in territory density. Such study would require banding and attaching radio transmitters to numerous individuals and intensive monitoring of many nests. Without information on movement and demography of individual birds within and among years questions pertaining to how GCWA respond to habitat loss on BCP remain unanswered.

E. Using spot mapping to estimate territory density may be reliable. However, further work is needed to specifically address the reliability (detect all territories in 100 acre plots) of territory density estimates.

F. Because the goal is to obtain BCP area wide estimates of density and productivity, it is strongly recommended that COA sample a larger part of COA. Surveying eight 100-acre plots is probably inadequate to capture the spatial heterogeneity in territory density and productivity.

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Table 1. Intercepts and slopes of linear regressions of the relationships between numbers of full territories and proportion of edge territories from each 100-acre plot. Standard errors (SE) of each coefficient are also provided. Plot initials are: EL-Emma Long, FR-Forest Ridge, IH-Ivanhoe, SE-3M/St. Edwards, BH-Bohls Hollow, BC-Barton Creek, JT-Double J & T, CC-Canyon Creek. Plots are listed in a sequence to show intercepts from small to large and the corresponding decrease in slopes.

Plot	Intercept	SE	Slope	SE
EL	0.47	0.08	-0.02	0.01
FR	0.51	0.09	-0.02	0.01
IH	0.66	0.07	-0.02	0.01
SE	0.68	0.07	-0.04	0.02
BH	0.74	0.06	-0.09	0.02
BC	0.75	0.08	-0.08	0.02
JT	0.91	0.05	-0.17	0.02
CC	0.98	0.05	-0.13	0.03

Table 2. Intercepts and slopes of regressions between year (coded 0-1998, 1-1999, so on to 9-2006) and territory density (territories per 100 acres) in each plot. Standard errors (SE) of the intercept and t-test of slopes are provided. Trend of "o" means that the null hypothesis of stationary population could not be rejected, and a "+" trend means territory density increased. Plot initials are listed in Table 1.

Plot	Intercept	SE	Slope	SE	t	P	Trend
BC	5.70	1.93	0.18	0.31	0.58	0.562	o
SE	9.43	1.93	0.30	0.31	0.97	0.335	o
BH	3.90	1.93	0.30	0.31	0.96	0.339	o
CC	3.90	2.01	0.31	0.35	0.90	0.374	o
FR	10.83	1.93	0.47	0.31	1.50	0.139	o
JT	-0.09	2.01	0.55	0.35	1.56	0.123	o
EL	11.83	1.93	0.75	0.31	2.40	**0.019**	+
IH	8.17	1.93	1.53	0.31	4.92	**<0.009**	+

Table 3. Means and standard deviations of productivity variables of Golden-cheeked warblers measured in two transitional plots.

Estimate	Pairing Success	Fledged young*	Number successful*	Number fledged*
Mean	0.23	0.14	0.49	0.44
Standard deviation	0.40	0.32	1.14	1.01

*Fledged young-Proportion of territories with females that fledged young, number successful-number of young fledged in successful territories (territories with females), and number fledged-number of young fledged in all territories

Table 4. Means and standard deviations (s) of proportion of territories with females that fledged young (Fledged young), number of young fledged in successful territories (Number successful), and number of young fledged in all territories (Number fledged) in each 100 acre plot in prime habitat. Plot initials are listed in Table 1.

	Fledged young		Number successful		Number fledged	
Plot	mean	s	mean	s	mean	s
BC	0.72	0.22	2.07	0.49	1.55	0.68
SE	0.43	0.30	1.76	0.79	0.91	0.73
BH	0.08	0.12	0.83	1.32	0.20	0.33
FR	0.61	0.14	2.40	0.45	1.49	0.31
EL	0.59	0.25	2.22	0.45	1.20	0.49
IH	0.48	0.25	2.66	0.43	1.31	0.74

Fig. 1. Map showing locations of the eight 100 acre plots in the Balcones Canyonlands Preserve, Travis County, Texas.

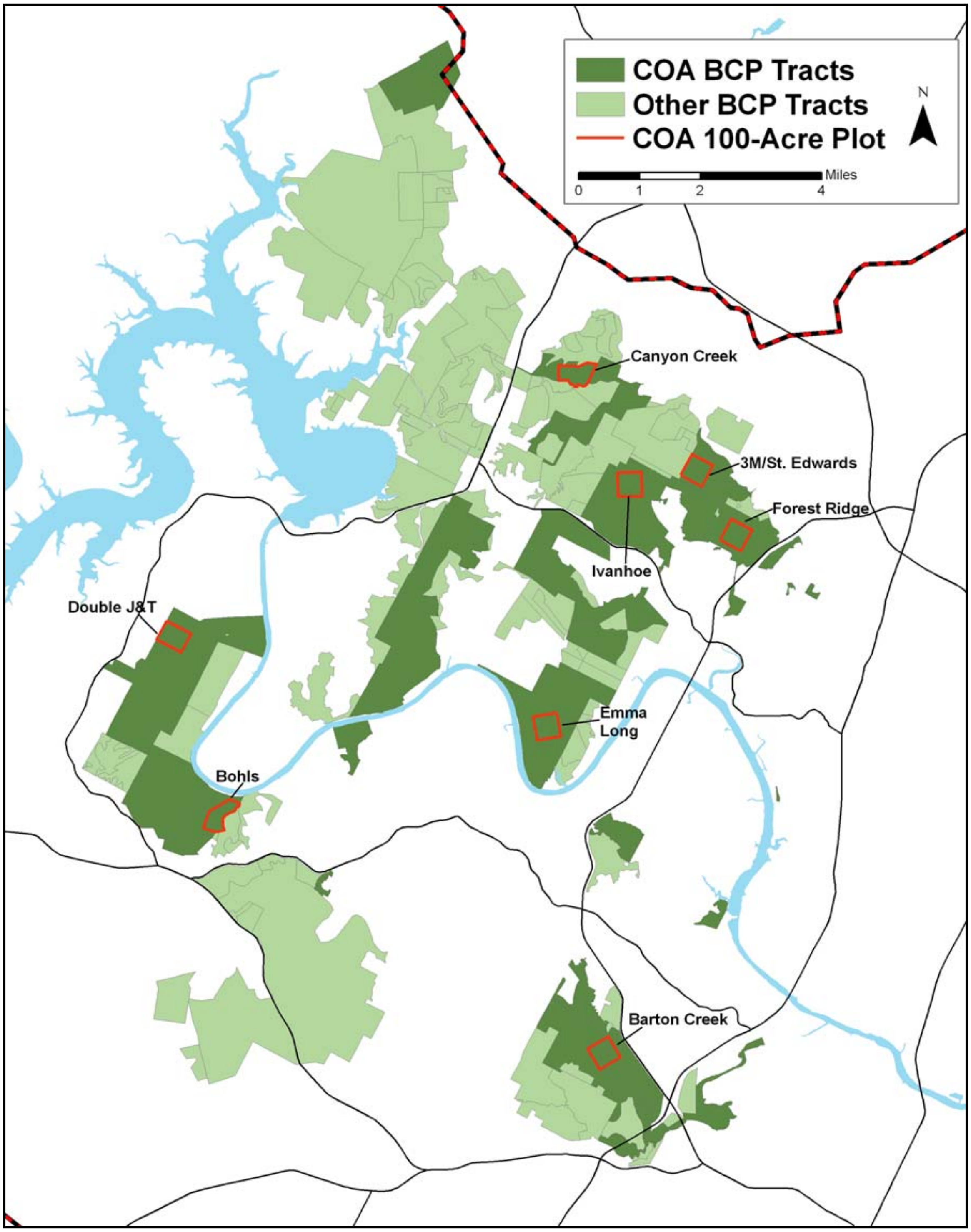


Fig. 2. Trellis plot showing the relationship between number of full territories and proportion of edge territories (one-half edge territories). Panels have the intercept for the relationship and the plot label. Prime and trans (transitional) refer to habitat of the plot and the plot label after the period. Plot initials are provided in Table 1. The display of relationships in each plot shows that smaller intercepts (and greater numbers of full territories) corresponded with shallower slopes.

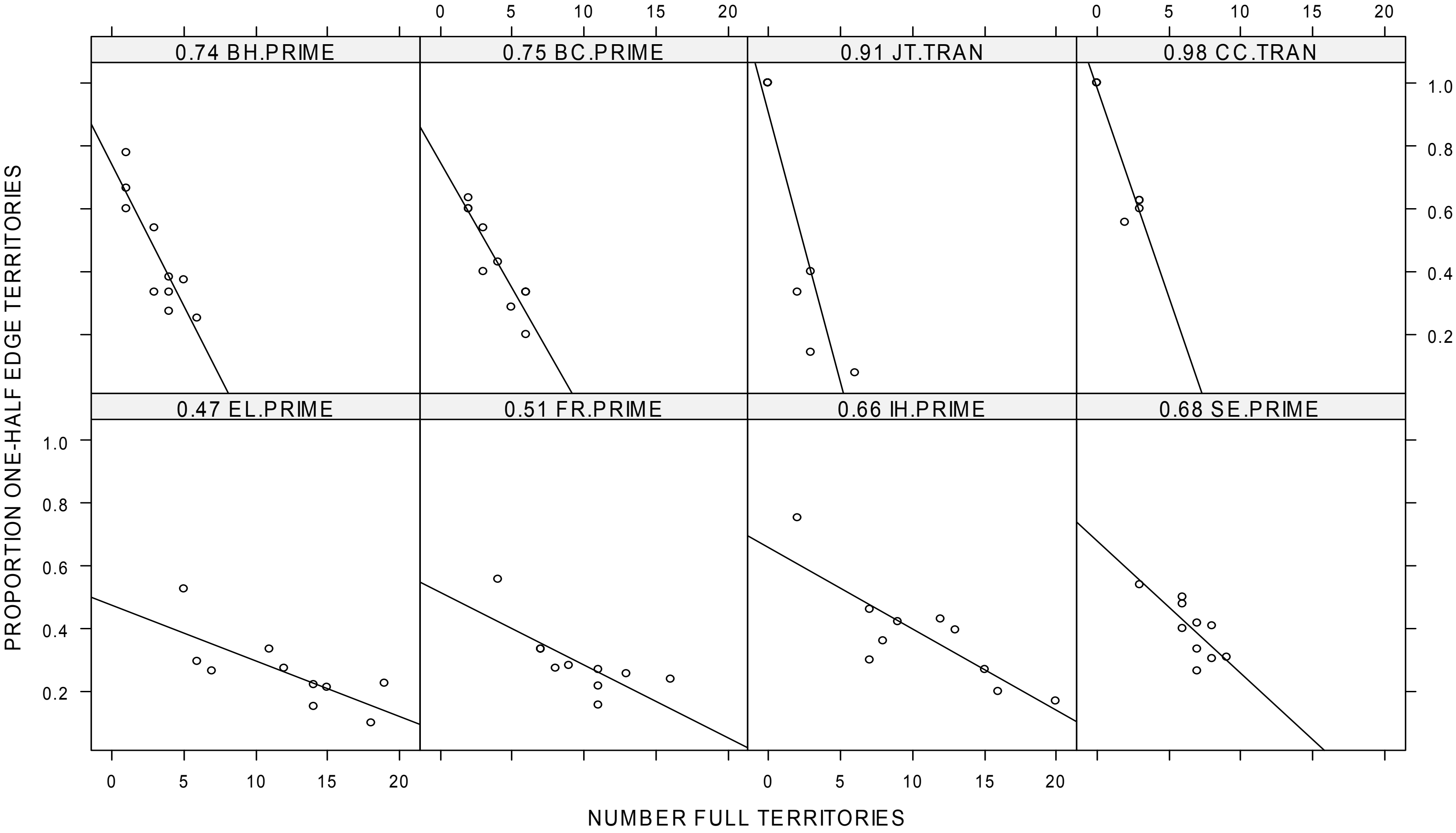


Fig. 3. Scatter plot of survey effort (hours per acre), territories per acre, and the nonlinear regression summarizing the relationship. The vertical line is the survey effort in 100 acre plots and the shaded area reveals the estimated asymptote (parameter A) and the lower bound of its 95 percent confidence interval. Parts of the regression within the shaded area may indicate sufficient survey effort to estimate territory density.

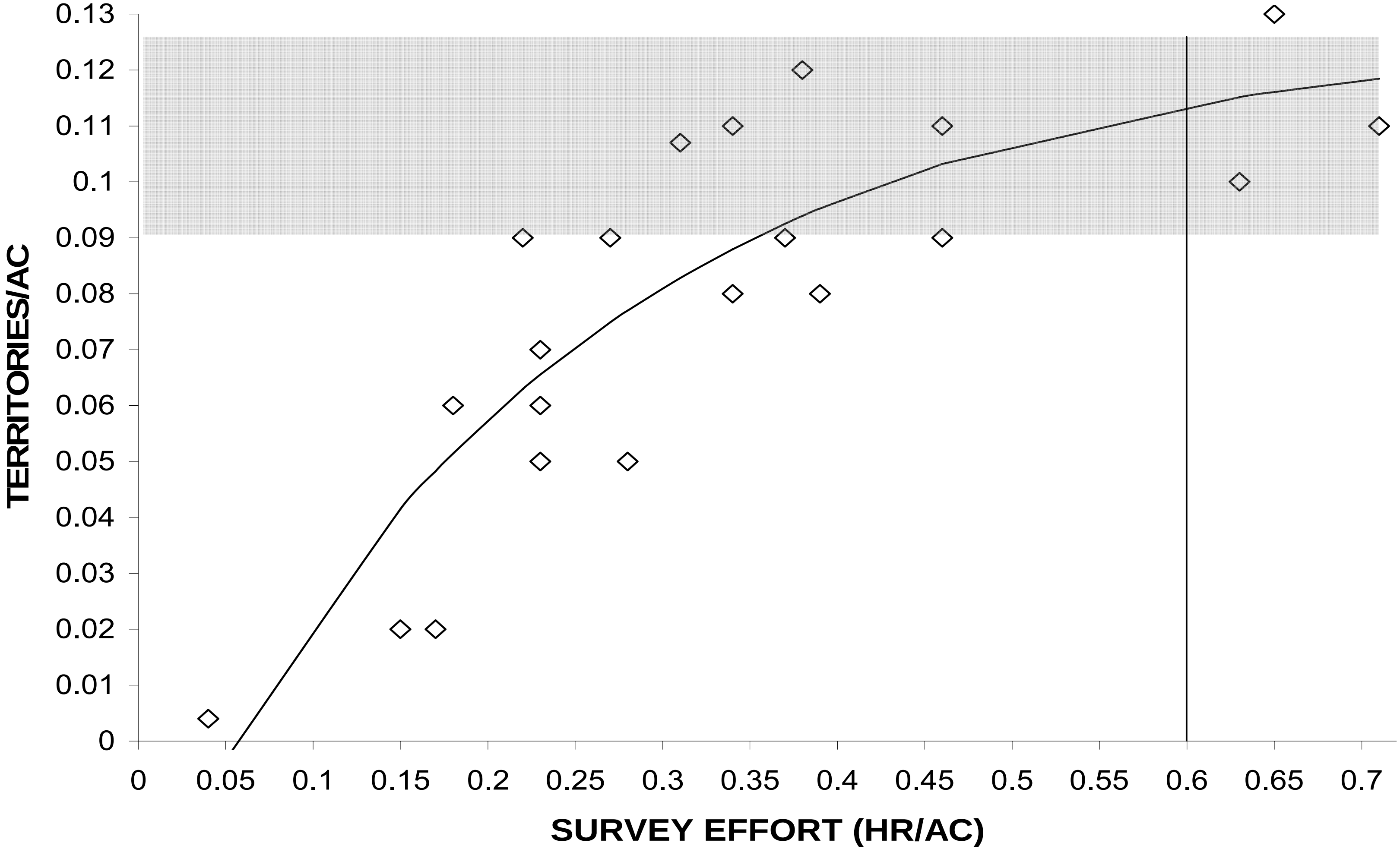


Fig. 4. Trellis plot of trend (regression) between year (0-1998, 1-1999, so on to 9-2006) and territory density in 8-100 acre plots. The panels list slope estimates in 100-acre plot, the habitat type (prime, tran-transitional) and the plot initial (see Table 1) after the period.

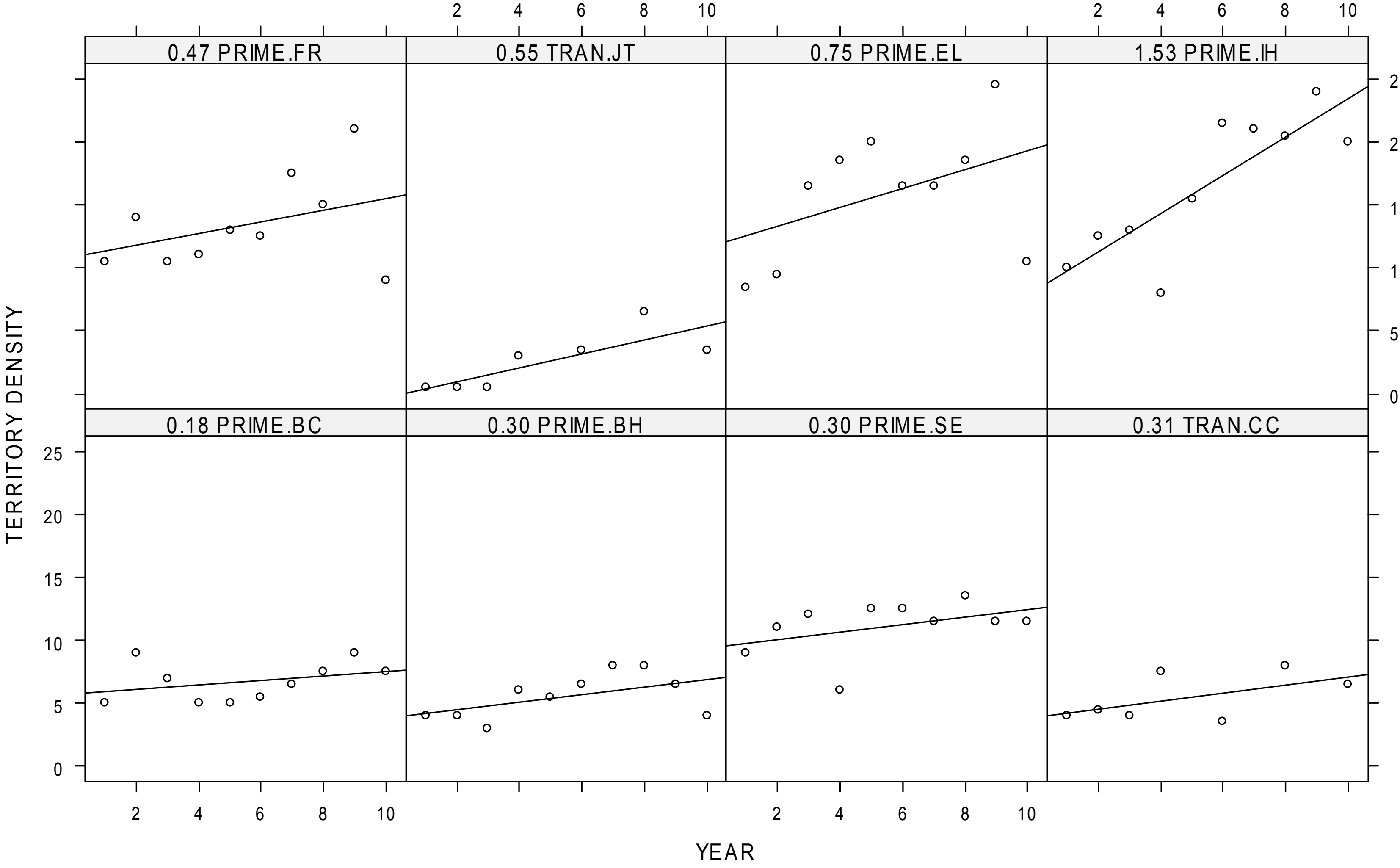


Fig. 5. Line plot showing territory densities of GCWA in three 100 acre plots measured by biologists with Travis County from 2002 to 2006. Data was not collected in 2002 in the Bunten plot.

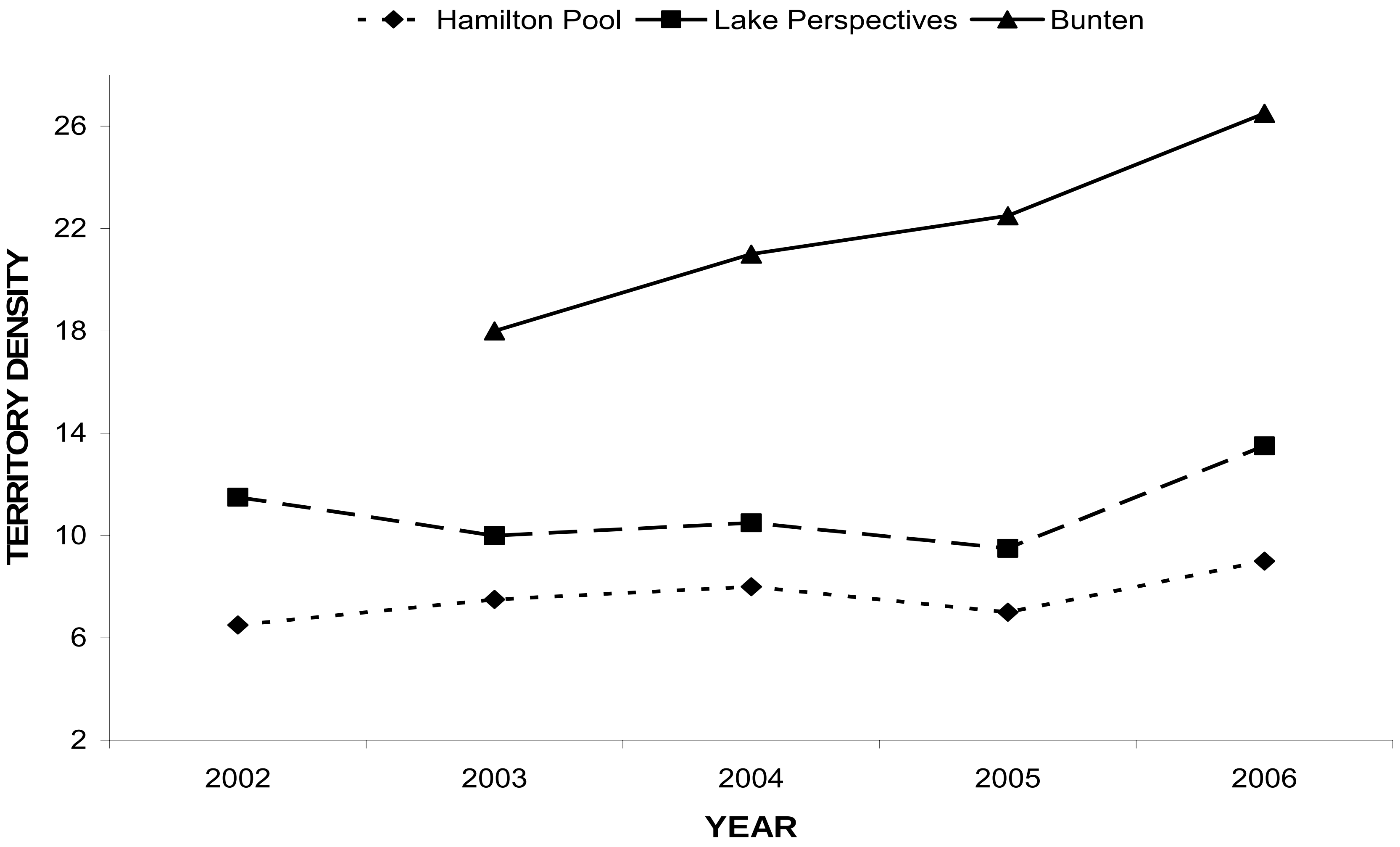


Fig. 6. Bootstrapping simulations summarized with boxplots of variance in territory densities. Each simulation generated 1000 bootstrapped samples. The rectangles of the boxplots reveal the 25th, 50th, and 75th percentiles in variances for a particular simulation. The lines extending below and above the rectangles identify the smallest and largest variances in a simulation except when outliers are denoted with dots.

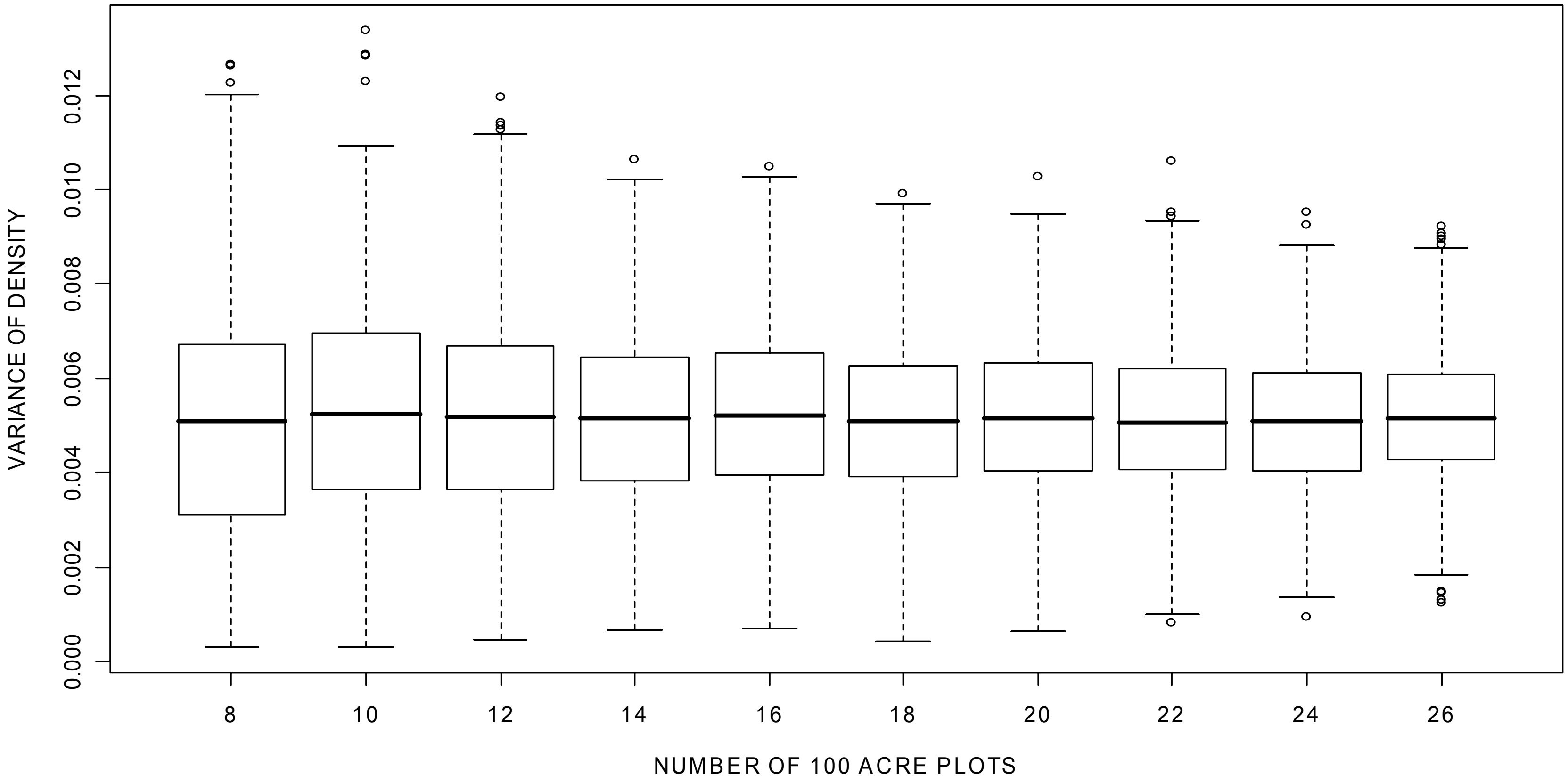


Fig. 7. Line plots of decline in ranges and IQR's of variance in territory densities reported in Figure 4.

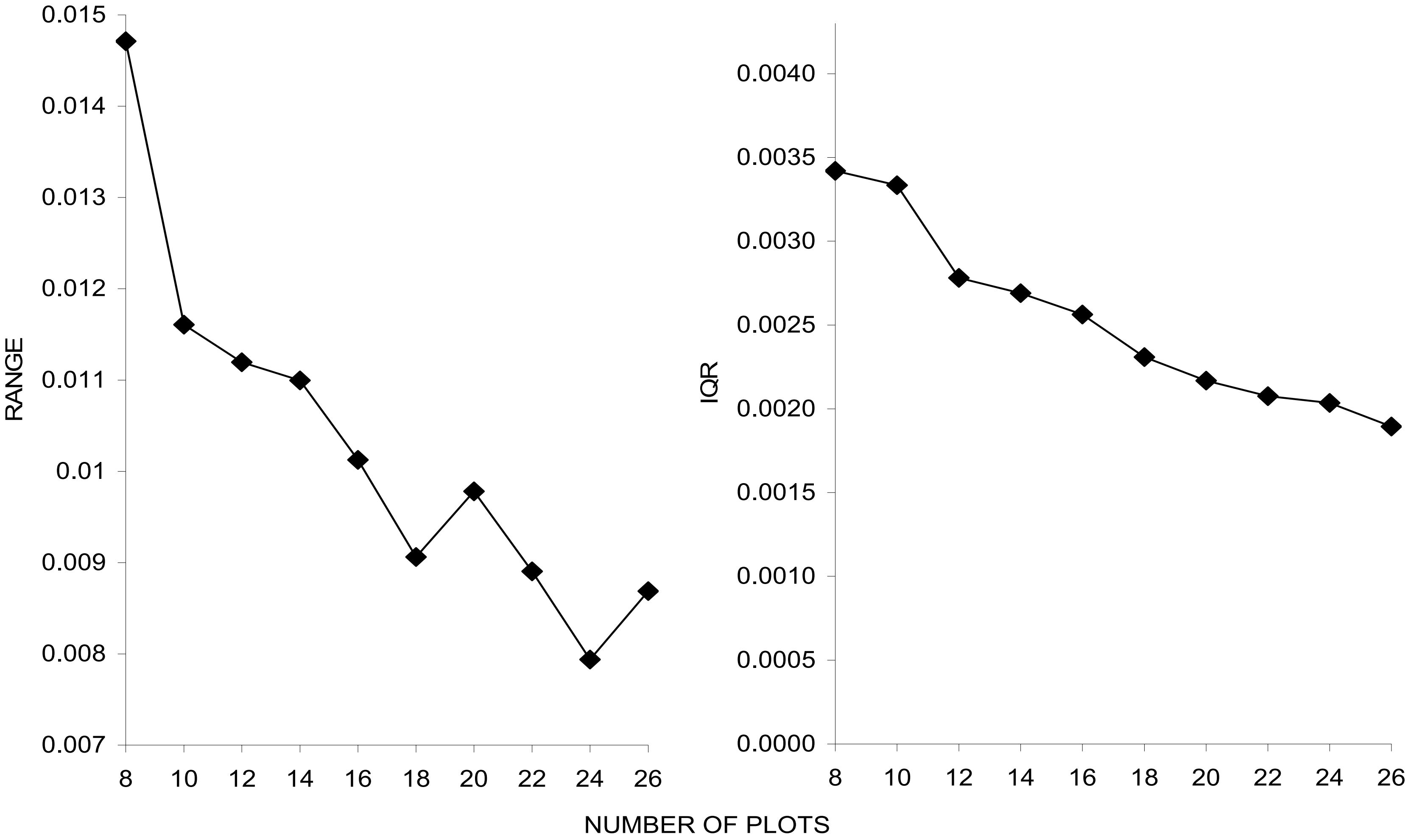
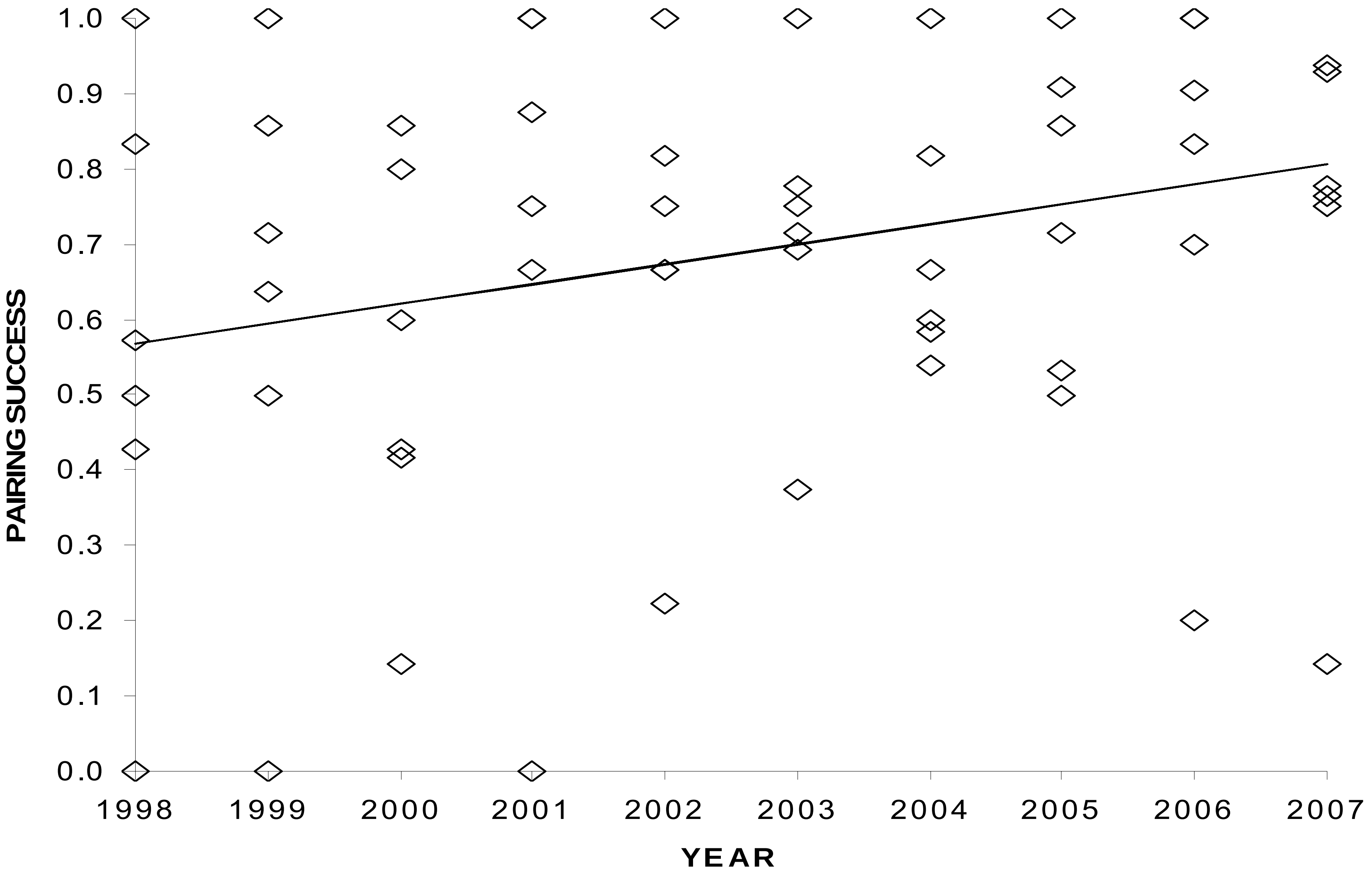


Fig. 8. Scatter plot showing the trend (regression) between year (1998 to 2007) and pairing success in the100 acre plots in prime habitat. The regression was Y = 0.57 + 0.03X.



APPENDIX

Data used to estimate relationship between survey effort (hours/acre surveyed) and territory density (territories/acre) and reported in figure 2. Data was extracted from Travis County annual reports (2002 – 2006). Sites in bold face were not included in data analysis because territory densities were one-half or less of sites with similar survey efforts, possibly confounding a survey effort – territory density relationship.

Site	Year	Survey effort	Territory Density
Bunten	2002	0.46	0.11
Grandview Hills – North	2002	0.46	0.09
Steiner Ranch (VMA, tract 2)	2002	0.17	0.02
Vista Point	2002	0.37	0.09
Grandview Hills – South	2003	0.63	0.10
Steiner Ranch (All)	**2003**	**0.18**	**0.02**
Toops	2003	0.27	0.09
Vireo Ridge	2003	0.34	0.11
Beck	2004	0.34	0.08
Cuenas	2004	0.71	0.11
King-Attwood-Blake	**2004**	**0.27**	**0.03**
Canyon Vista	2005	0.39	0.08
Grandview Hills – North	2005	0.28	0.05
Greenshores	2005	0.23	0.06
Medway Ranch	2005	0.04	0.004
Nootsie	2005	0.65	0.10
Ribelin	2005	0.38	0.12
Franzetti	2006	0.23	0.05
Grandview – South	2006	0.22	0.09
Greenshores	2006	0.23	0.07
King-Attwood-Blake	**2006**	**0.35**	**0.02**
Steiner Ranch J Canyon	2006	0.15	0.02

Appendix - Continued

Toops	2006	0.18	0.06
Vista Point	2006	0.31	0.11