ASSESSING BLACK-CAPPED VIREO (*VIREO ATRICAPILLUS*) BREEDING HABITAT BASED ON SIZE, SPATIAL DISTRIBUTION, AND PLANT SPECIES IN SHRUB MOTTES AT KERR WILDLIFE MANAGEMENT AREA, TEXAS

THESIS

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by

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ABSTRACT

ASSESSING BLACK-CAPPED VIREO (*VIREO ATRICAPILLUS*) BREEDING HABITAT BASED ON SIZE, SPATIAL DISTRIBUTION, AND PLANT SPECIES IN SHRUB MOTTES AT KERR WILDLIFE MANAGEMENT AREA, TEXAS

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The Black-capped Vireo (*Vireo atricapillus*) (hereafter, BCV), an endangered Neotropical, migrant songbird, inhabits semi-open areas ranging from a maturing scrubland to more open habitats. An important

factor of BCV habitat is heterogeneity. BCVs inhabit areas with greater heterogeneity in vegetative cover. Vegetative cover in BCV habitat is composed of low deciduous shrubs with lateral branching to the ground. Openness, or distance between shrubs, is another important feature of heterogeneity as well as BCV habitat. The objective of my study was to determine suitable and unsuitable BCV habitat based on the size, spatial distribution, and plant species found in shrub mottes. The study took place at Kerr Wildlife Management Area (KWMA). Three pastures, Middle Trap, Plot 2 and Plot 3, were designated as unsuitable BCV habitat (LDBCV habitat) based on low BCV densities. North Rock, Fawn, and Doe were the three pastures designated as suitable habitat (HDBCV habitat) based on high BCV densities. I used the quadrat method to measure 5 response variables-- canopy cover, distance between shrub mottes, number of shrub mottes, number of favorable mottes, and species richness. I examined differences between the LDBCV and HDBCV habitats using a multivariate analysis of variance (MANOVA). Five univariate ANOVAs were used to determine the extent of the main effects of the treatments on the response variables. Correlations using Pearson's product moment correlations were made regarding canopy cover, distance between shrub mottes, and number of mottes. A t-test was used to examine differences between overall canopy cover per quadrats based on the mean canopy cover and number of mottes. During data collection, GPS locations of each shrub motte were recorded and downloaded into ArcGIS to emphasize the results of the statistics on maps. Suitable BCV habitat was considered heterogeneous and semi-open containing frequent mottes of various small sizes closely spaced with several plant species. Unsuitable BCV habitat was characterized as less heterogeneous and dense containing few, large mottes spaced far apart with few species.

CHAPTER 1

INTRODUCTION

The Black-capped Vireo (*Vireo atricapillus*) (hereafter, BCV), a Neotropical, migrant songbird, was listed by United States Fish and Wildlife Service (USFWS) as an endangered species in October 1987 (Grzybowski 1995, Leyva et al. 2002). Historically, the breeding range extended from southern Kansas through central Oklahoma, central Texas, and Big Bend National Park into northern and central Coahuila, Mexico (Bunker 1910, Graber 1961, Barlow 1966, Benson and Benson 1990, Grzybowski 1995). The species was extirpated in Kansas in the 1930's, and currently, the breeding range is much smaller, consisting of fragmented habitat in central Texas and isolated patches in western Oklahoma and parts of Coahuila, Mexico (Graber 1961, Benson and Benson 1990, Grzybowski et al. 1994, Grzybowski 1995). The winter range of the BCV is less well-known, but encompasses western Durango, southern Sinaloa, Nayarit, Jalisco, Colima, with a few sightings in Oaxaca and southern Sonora, Mexico (Graber 1961, Benson and Benson 1990, Grzybowski 1995). BCV populations in Texas were declining until recently, but are now stable in the Edwards Plateau and Trans-Pecos area (Levya et al. 2002). BCVs are endangered for 3 reasons-- nest parasitism by the Brown-headed cowbird (*Molothrus ater*), direct habitat destruction and fragmentation, and control of natural processes such as fire (USFWS 1991, Grzybowski et al. 1994, Grzybowski 1995, Barber and Martin 1997, Stake and Cimprich 2003).

Habitat loss and fragmentation over much of the BCV's range has resulted from the conversion of habitat into urban, suburban, and agricultural areas (Grzybowski 1995). Brush management destroys habitat by removing low, woody vegetation pertinent to BCV nesting habitat. Overgrazing of forage by livestock and subsequent browsing on low-growing shrubs damage BCV habitat. Overbrowsing by goats (*Capra hircus*) and white-tailed deer (*Odocoileus virginianus*) on the lower limbs of shrubs in BCV habitat reduces the number of potential nesting sites.

Suppression of wild fires is another factor in the decline of BCVs. The presence of suitable habitat may be altered by human activity or natural phenomenon affecting plant succession (Benson and Benson 1990, Grzybowski 1995). Fires retard plant succession pertinent to maintaining early successional BCV habitat (O'Neal et al. 1996). Relationships exist between bird species and points along habitat gradients or successional stages of vegetation (Grzybowski et al. 1994). Suitable habitat for BCVs occurs on landscapes with transitional stages of succession that result in openness. Habitat becomes unsuitable for

BCVs as a community matures into a closed-canopy forest (Graber 1961, Leyva et al. 2002, Cimprich and Kostecke 2006). BCV habitat has diminished because of invasive plant encroachment since the suppression of fire (O'Neal et al. 1996).

Natural disturbances, such as fire, in areas of rocky substrate and shallow soils generate and maintain BCV habitat (Grzybowski 1995). Grzybowski (1995) noted that fire stimulated the regrowth of multistemmed, fire-adapted oak and sumac species and produced substantial patches of favorable BCV habitat. Leyva et al. (2002) suggested the best BCV habitat occurred 10-15 years after a fire intense enough to kill Ashe juniper (*Juniperus ashei*) (Koloszar and Horne 2000). Ashe juniper, a common shrub in Texas Hill Country, is an undesirable component of BCV habitat (USFWS 1991, Grzybowski et al. 1994, Guilfoyle 2002). Fire, rotational grazing, and low stocking regimes help maintain suitable BCV habitat (Graber 1961, O'Neal 1996, O'Neal et al. 1996).

In order to recover an endangered species, guidelines are developed in a management or recovery plan. An understanding of the relationship between BCV distributions and critical habitat requirements are necessary in developing effective management plans (Grzybowski et al. 1994). USFWS drafted and implemented a recovery plan for the BCV in 1991. Several parameters of BCV habitat were assessed. In general, strong correlations exist between the distributions of BCVs and structural features of vegetation (Grzybowski et al. 1994). Assessing habitat requirements involves characterization of the structure and composition of vegetation.

BCVs occupy semi-open habitats ranging from maturing scrubland to more open areas (Graber 1961, Grzybowski et al. 1994, Grzybowski 1995). Low deciduous cover is a key feature. Overall heights of the vegetation in suitable BCV habitat are 2 to 3 m tall. Breeding habitat for BCVs is a shrubby landscape with shrubs usually no more than 3-5 m in height with branches extending laterally to the ground (Grzybowski et al. 1994, Grzybowski 1995). Heterogeneity of vegetation is another important factor. BCVs inhabit areas with greater heterogeneity in the density of woody vegetation or vegetative cover (Grzybowski et al. 1994). Distance between shrubs, or openness, is another component of heterogeneity (USFWS 1991). BCVs occur in semi-open areas with an irregular matrix of shrubs closely spaced, but separated enough to allow light penetration and dense cover at a height of roughly 3 m (USFWS 1991). This suggests openness (no greater than 65% with at least 35% woody cover), which is also a necessary component in BCV habitat (USFWS 1991, Grzybowski 1995). BCVs also occupy areas with fewer Ashe juniper saplings and trees and abundant deciduous cover (USFWS 1991, Grzybowski 1995, Leyva et al. 2002). A diverse array of plant species is also indicative of suitable habitat with oaks, such as Shin oak (*Quercus sinuata*), Texas oak (*Quercus buckleyi*), and Live oak (*Quercus* *fusiformis*), occurring more frequently (Graber 1961, Grzybowski 1995, Hayden et al. 2001). Woody plant species such as Texas persimmon (*Dyosporis texana*), Flameleaf sumac (*Rhus lanceolata*), and Texas redbud (*Cercis canadensis*) also make up large portions of the habitat (Grzybowski et al. 1994, Grzybowski 1995).

While much is known about BCV habitat, there are specific features of habitat at a landscape level lacking definition and relevance to breeding habitat. The objective of my study was to characterize suitable and unsuitable BCV breeding habitat based on the size, spatial distribution, and plant diversity of shrub mottes.

CHAPTER 2

MATERIALS AND METHODS

Study Site

My study was conducted at Kerr Wildlife Management Area (KWMA). KWMA, a 2,628 ha (6,493 acre, 34 pastures) research facility owned and operated by the Texas Parks and Wildlife Department, is located at the headwaters of the North Fork of the Guadalupe River near Hunt, Texas (TPWD 1998). Presently, KWMA is an educational and research facility for the development and management of native wildlife habitat and populations using a holistic management program, entailing the use of prescribed burning, rotational grazing, brush control, deer harvest, and cowbird trapping (TPWD 1998). This type of management allows better food, water, and cover increasing the overall quality of wildlife such as endangered species. BCVs are a recent inhabitant of prescribed burn pastures on KWMA. The species has increased in abundance since the first documented record of their occurrence in 1986 (TPWD 1998). In 1988, the KWMA began rotational cattle grazing and cowbird trapping to alleviate nest parasitism. The BCV population increased from 27 in 1986 to 422 in 2002 (TPWD 2003). BCVs occur in the 27 of the 34 pastures (TPWD 2003).

BCV Surveys

TPWD personnel and public volunteers conducted presence/absence counts yearly at KWMA in the first 2 weeks of May for 3 to 5 days (Nelka 1999, Dufault 2004). Counters were assigned to pastures in groups of 2 to 3 individuals. Each group was given a GPS unit, recording of BCV song, and map of known BCV locations from the previous year. Counters walked all or part of each pasture stopping periodically at or near known locations to listen for BCVs. After listening for 3 minutes, a tape recording of the BCV song was played for 15 to 30 seconds, and counters listened for BCV calls for another 1.5 minutes (Nelka 1999). Once the BCVs were located, waypoints of singing males were marked in the GPS unit. The waypoints were downloaded into ArcView and a shapefile created of BCV locations. I used the 2004 BCV survey data for selecting pastures and building maps of suitable and unsuitable BCV habitat.

Selection of pastures

I used 6 pastures for my study-- 3 pastures for unsuitable BCV habitat and 3 pastures for suitable BCV habitat. I decided on a replication of 3 for each treatment because that would give sufficient information for analysis. The criteria for choosing pastures were based on the density of BCVs per pasture. I obtained data on pastures and number of BCVs in the pastures from current KWMA GIS file. I obtained the necessary GIS data from KWMA that included pastures, BCV densities, Ashe juniper breaks, and roads shapefiles. I calculated the number of BCVs in each pasture and divided by the pasture area. I chose the 3 pastures with the lowest density of BCVs for the unsuitable habitat and 3 highest for suitable habitat assuming that the density of BCVs in a pasture was indicative of suitable habitat. Plot 2, Plot 3, and Middle Trap had the lowest density and were designated as low-density BCV (LDBCV) habitat (Fig. 1). Doe, Fawn, and North Rock pastures had the highest density and were designated high-density BCV (HDBCV) habitat (Fig. 1). I excluded pastures with BCVs and large amounts of Ashe juniper because BCVs do not nest in Ashe juniper (USFWS 1991, Grzybowski 1995, Leyva et al. 2002).

Measuring vegetative components

I estimated horizontal patchiness by incorporating shrub density and canopy cover (Rottenberry and Wiens 1980). My sampling units

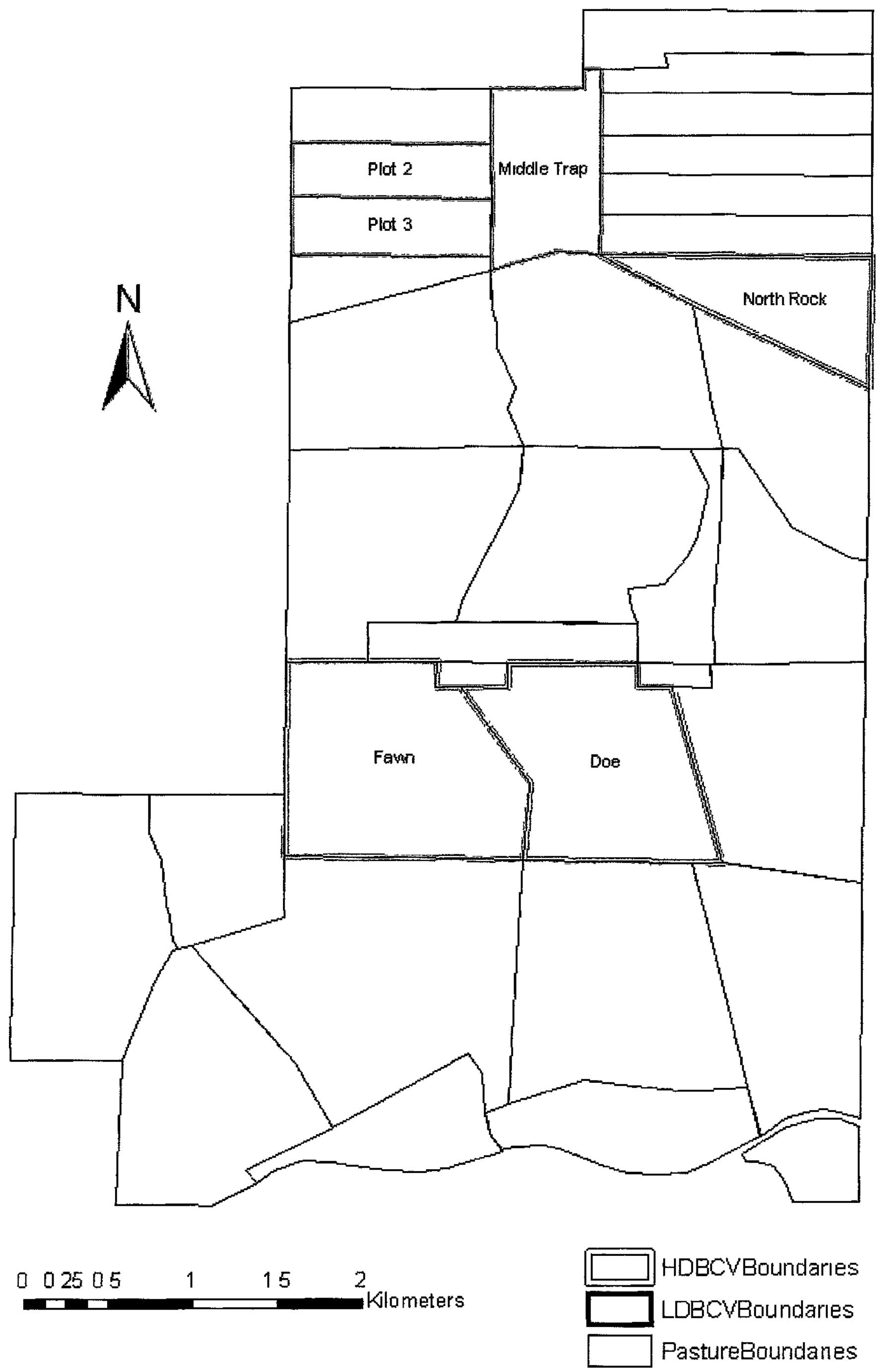


Figure 1. Map of Kerr Wildlife Management Area, Kerr County, Texas showing the pastures selected for analysis during the study in 2005.

were 50 X 50 m quadrats. I used large quadrats because I was interested in a landscape view of the habitat and needed to record measurements on the total canopy area of a shrub motte and not on a single species of shrub where a smaller quadrat would be adequate. I sampled 15 quadrats for LDBCV habitat and 15 for the HDBCV habitats. In the LDBCV habitat, 5 quadrats were selected for each pasture because pastures were small (< 66 ha). In the HDBCV habitat, Doe and Fawn pastures were larger (125.4 ha and 147.8 ha respectively), and were assigned 6 and 7 quadrats, respectively. North Rock (65.5 ha) was assigned 2 quadrats. Using the editor toolbar in ArcVIEW 9.1 (ESRI, Redlands, California), I placed a grid of 50 m X 50 m cells over the pastures and numbered each cell. Each 50 m X 50 m cell represented the size of a quadrat, or experimental unit, for vegetative measurements and GPS locations. I entered the cell numbers into S-PLUS 7.0 (Insightful Corportation, Seattle, Washington) to generate randomly selected quadrats for sampling.

Once the quadrats were randomly selected, I recorded from ArcMap the coordinates of the north corner closest to the road to ensure correct placement of quadrats within the pastures. I located each quadrat in the pastures using a Garmin Etrex GPS unit (Garmin International, Inc., Olathe, Kansas). To ensure that one quadrat did not influence another and was independent, no quadrats overlapped. I measured mottes within a 2-m buffer outside the quadrat boundary to account for any vegetative unit occurring on the boundary line.

I measured 5 variables in each quadrat-- number of shrub mottes, number of favorable mottes, distance between each shrub motte, canopy cover and plant species richness of each shrub motte. I defined a shrub motte (MOTTE) as any cluster of woody species separated from other mottes by light penetration to the ground on all exterior margins. Canopy cover (CA) was the vertical projection of the exterior perimeters of the crown to the ground of the entire motte. Each observation of canopy cover was the circular average of the perpendicular measurements in the 4 cardinal directions of the distance between the farthest edges of the canopy. Favorable mottes (FAVMOTTE) were shrub mottes with lateral branching to the ground. Distance between mottes (DIST) was the shortest path to the exterior perimeters of the crown between 2 mottes without any obstruction between the mottes. I counted the number of woody species in each motte to determine plant species richness (SPP). Density of woody species was not recorded because the error involved in differentiating individuals of multistemmed shrubs propagated by prescribed fires.

During data collection, variances between means of the canopy cover/per quadrat and distance between mottes/quadrat were graphed to assess whether 15 quadrats would be sufficient sample sizes. Variances for the LDBCV habitat leveled off between quadrats 8 and 9 for

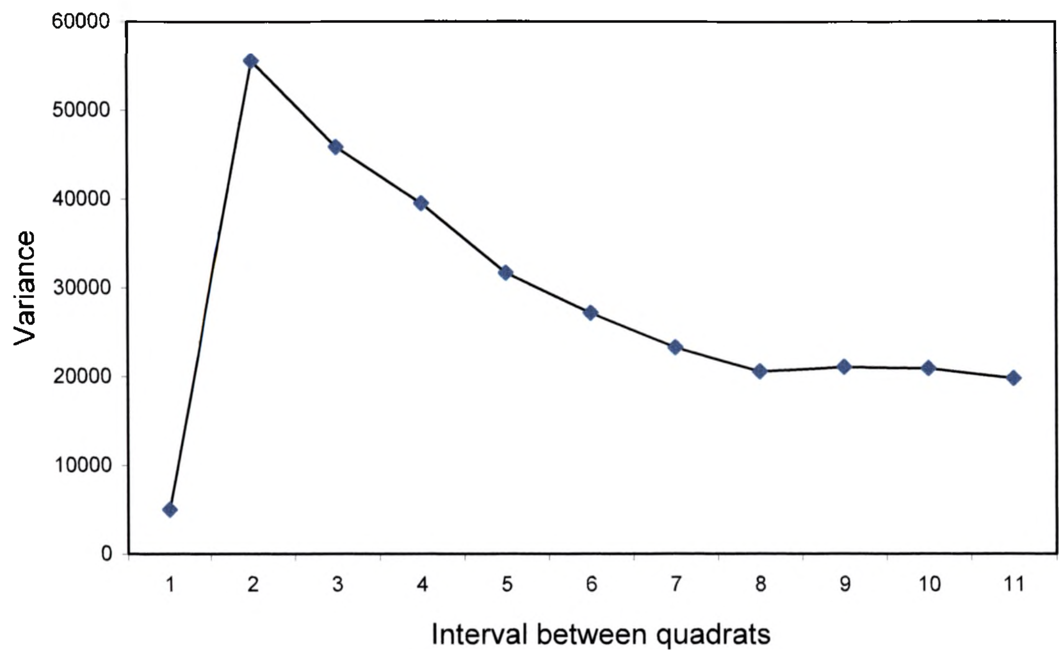


Figure 2. Variance for mean canopy cover/quadrat in low density Black-capped Vireo habitat leveled off at 8 quadrats indicating that 15 quadrats were an adequate sample size for distinguishing this habitat variable at Kerr Wildlife Management Area, Texas in 2005.

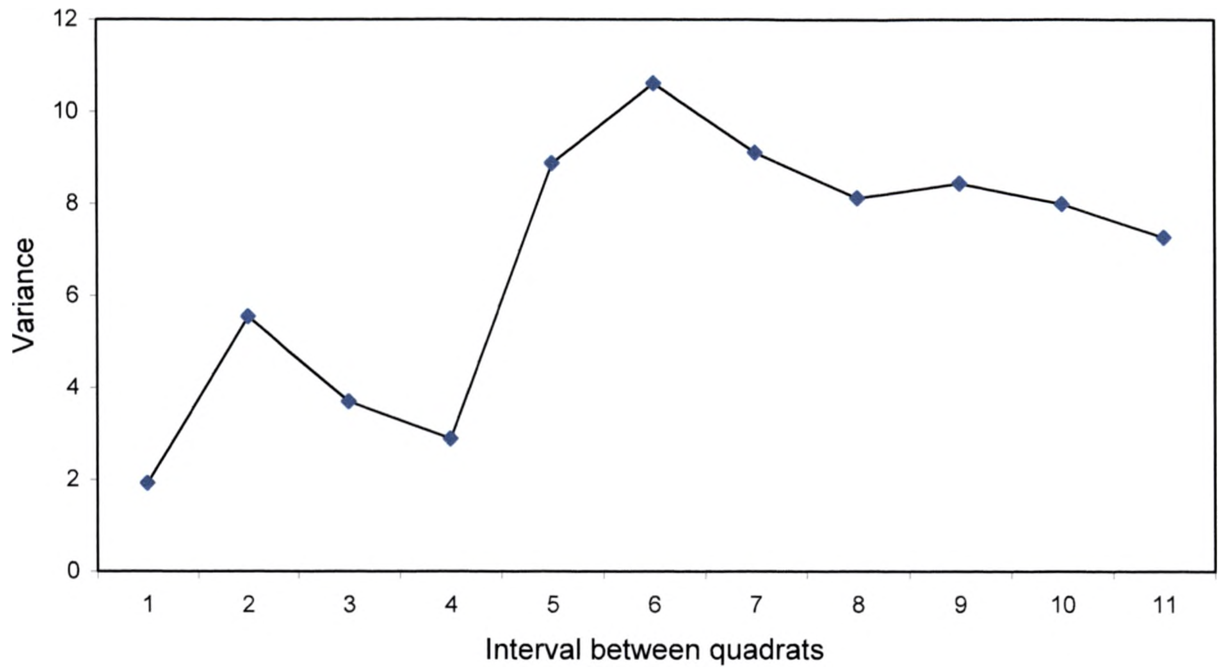


Figure 3. Variance of mean distance for mottes/quadrat in low density Black-capped Vireo habitat leveled off at 8 quadrats indicating that 15 quadrats were an adequate sample size for distinguishing this habitat variable at Kerr Wildlife Management Area, Texas in 2005.

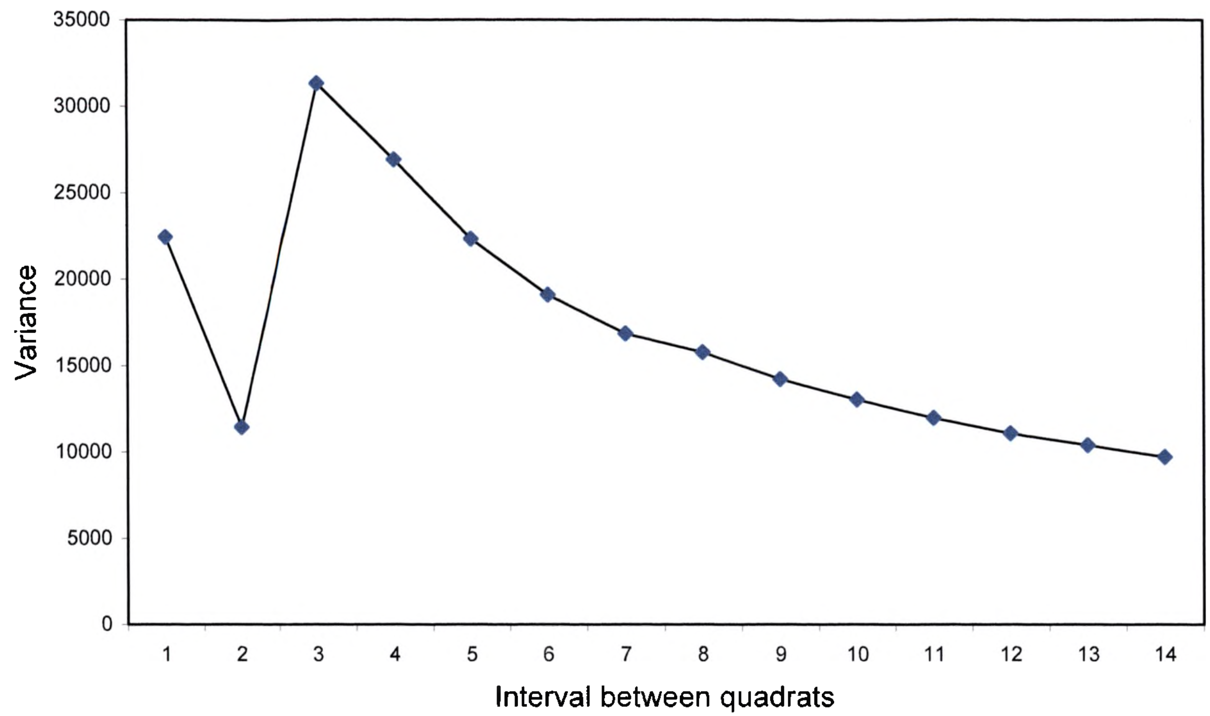


Figure 4. Variance between mean canopy cover/quadrat in high density Black-capped Vireo habitat leveled off at 8 quadrats indicating that 15 quadrats for were adequate sample size for distinguishing this habitat variable at Kerr Wildlife Management Area, Texas in 2005.

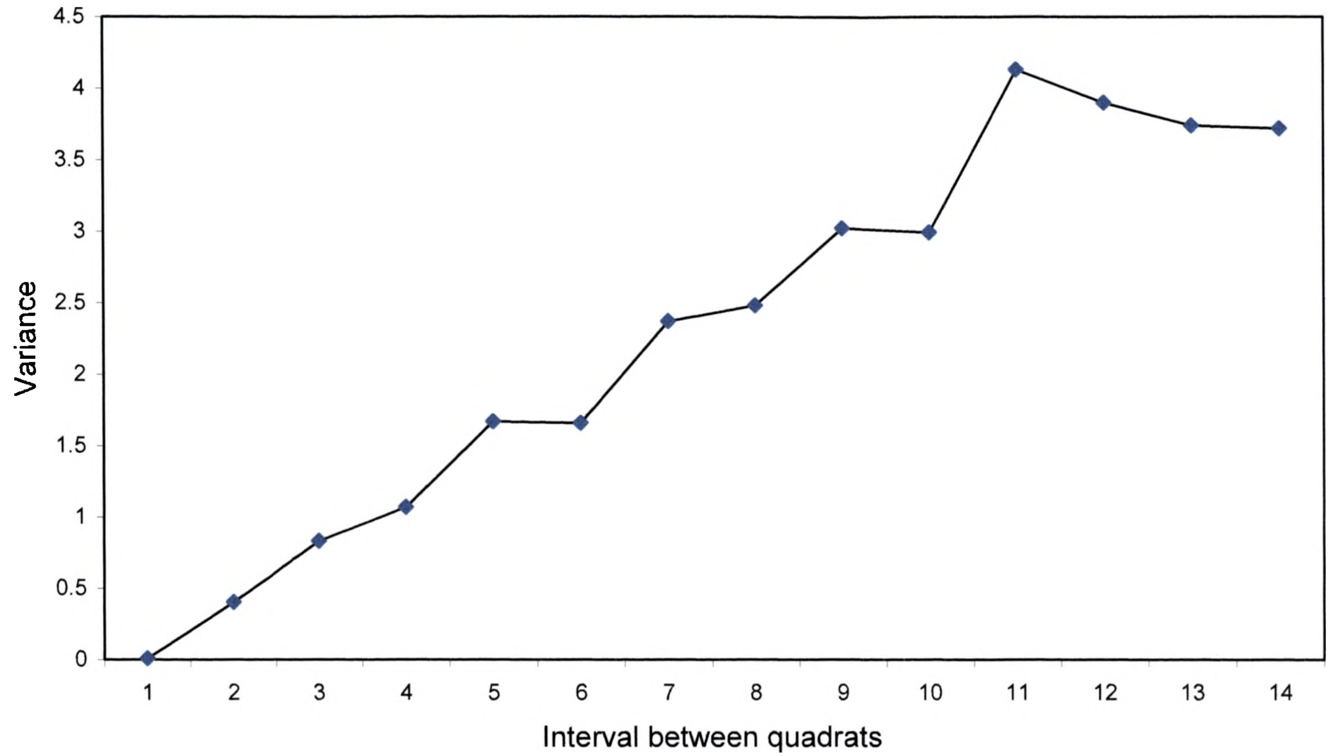


Figure 5. Variance of mean distance between mottes/quadrat in high density Black-capped Vireo habitat leveled off at 11 quadrats indicating that 15 quadrats were adequate sample size for distinguishing this habitat variable at Kerr Wildlife Management Area, Texas in 2005.

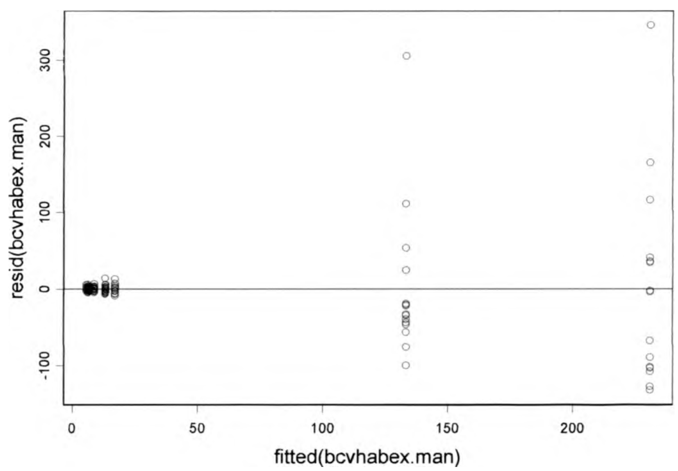
both canopy cover and distance indicating that at least 8 quadrats were needed for sampling in this habitat (Fig. 2, 3). Canopy cover variance in HDBCV habitat leveled off 8 at quadrats and distances variance leveled off between 11 and 12 quadrats (Fig. 4, 5). The graphs indicated at least 12 quadrats were necessary in the HDBCV habitat. I concluded that 15 quadrats were a sufficient sample size.

GPS readings (accuracy of 5-8 m) were also recorded to create maps. The GPS readings were taken as close to the center of the shrub motte as possible. The GPS unit was set to Universal Transverse Mercator (UTM) and units were meters.

Statistical Analysis

Statistical analyses were conducted using S-PLUS 7.0. I analyzed data using a single factor multivariate analysis of variance (MANOVA). MANOVAs are designed for use in situations with more than 1 dependent variable (Weinfurt 1995). I had 2 treatments--LDBCV and HDBCV (independent variables) and 5 dependent variables-- CA, DIST, MOTTE, FAVMOTTE, and SPP (response variables). Data were transformed (natural log) because the assumption of homoscedascity was violated as shown by an apparent megaphone pattern in a residual plot (Fig. 6a). The residual plot of transformed data showed no pattern, therefore, the assumption was validated (Fig. 6b). There were 2 other

(a)



(b)

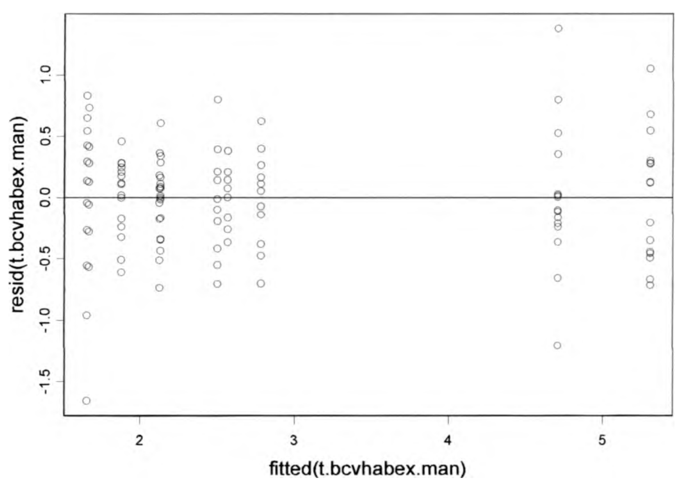


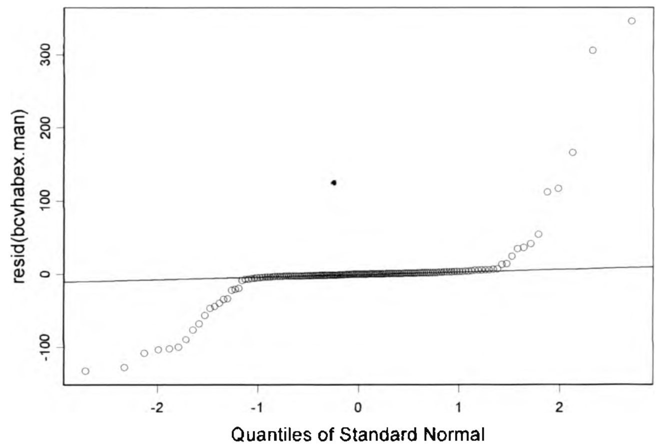
Figure 6. (a) Graph shows the violation of the assumption of homoscedascity by a megaphone pattern of data recorded on canopy cover, distance, shrub mottes, favorable shrub mottes, and plant species in both the unsuitable and suitable Black-capped Vireo habitat at Kerr Wildlife management Area, Kerr County, Texas in 2005. (b) This graph shows the absence of the megaphone pattern after the log transformation.

assumptions I addressed, multivariate normality and independence. Weinfurt (1995) stated that MANOVAs tend to be used even if data violate the multivariate normality assumption because MANOVAs are fairly robust to Type I errors. I checked the assumption with a normality plot and my data were in violation (Fig. 7a). Data points adhered to the line after the transformation (Fig. 7b). My study design validated the assumption of independence because one quadrat did not have an affect on the other. Each quadrat was separated by at least 50 m. The means of response variables for each quadrat were used for analyses to avoid the possibility of observations influencing each other. In such situations, MANOVAs help control TYPE I error by keeping the error rate at the nominal alpha level (Weinfurt 1995). I used an alpha of 0.05 for statistical tests.

The MANOVA tested whether vectors of means for dependent variables of the LDBCV habitat was equal to those of the HDBCV habitat (Weinfurt 1995). However, MANOVAs do not indicate how each treatment affects each dependent variable, just that there are main effects. I conducted univariate analyses of variances (ANOVAs) when multivariate main effects were indicated by the MANOVA. I conducted 5 univariate ANOVAs to determine whether treatments affected or influenced dependent variables (Weinfurt 1995).

Pearson's product-moment correlation was used to compare the degree of association between the 5 response variables (Rodgers and

(a)



(b)

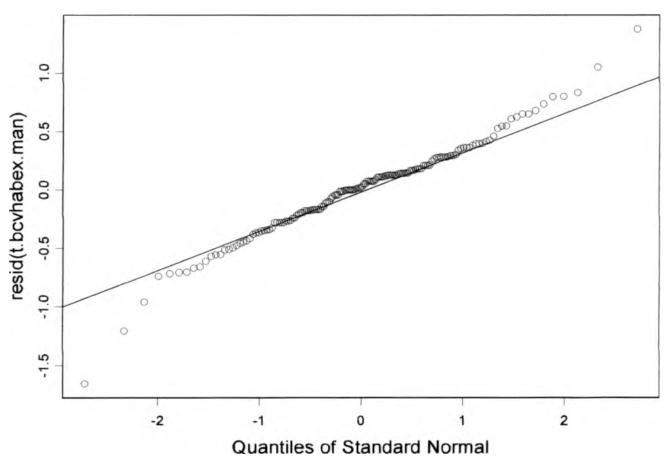


Figure 7. (a) Graph shows violation of the assumption of normality because the data points collected in unsuitable and suitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005 do not fit the line. (b) After the log transformation, the data points fit the line or within close enough proximity to be considered normal.

Nicewander 1988, Sokal and Rohlf 1995). Correlations are made between 2 variables at a time and ranged from -1 to +1. Values equal or close to -1 indicate an inverse relationship between 2 variables meaning as one variable increases the other decreases. Values equal to 0 indicate no correlation. Correlations equal or close to +1 means that as one variable increases the other increases (Rodgers and Nicewander 1988, Sokal and Rohlf 1995).

I used an unpaired t-test to compare the average canopy cover/quadrat in HDBCV and LDBCV habitat. Average canopy cover/quadrat was calculated by multiplying the number of mottes/quadrat times the corresponding canopy cover. The t-test was performed to give a clearer understanding of the magnitude of openness in each habitat type.

Geographic Information Systems

I used ArcView 9.1 to help determine the characteristics of suitable and unsuitable BCV habitat. I analyzed the data using ArcGIS 9.1 in a fashion that allowed me to further emphasized differences in number of mottes per quadrat and size of mottes between unsuitable and suitable BCV habitat. Maps were using BCV density and pasture shapefiles retrieved from KWMA files in conjunction with information from my data. I modified tables created earlier in S-plus by adding UTM coordinates of the center-most shrub mottes or centroids. The tables contained coordinates with attribute information. I saved the table as a database file (dbase) and entered it into ArcMap as X, Y coordinates. A shapefile was created of the BCV habitat. I selected high density and low density pastures and created layers. Then the BCV density, which encompassed much of KWMA, was intersected with pastures to create shapefiles of the BCV locations within each habitat type. BCVs in LDBCV habitat were labeled BCV_lowdensity and symbolized with red points. BCVs in HDBCV habitat were labeled BCV_highdensity and symbolized with yellow points. I also created a shapefile of quadrats. Quadrats were symbolized with an X and their assigned number in Table 1. I used the kernel density tool under Spatial Analyst to represent 3 of 5 variables,-- CA, DIST, and MOTTE. The kernel density tool is useful for showing concentrations of points or lines based on specified criteria. In this case, the criteria were the 3 variables that best portrayed openness-- CA, DIST, and MOTTE. I created layers for each of these kernels and then overlayed them with the BCV density shapefiles and quadrat shapefiles to create maps of suitable and unsuitable BCV habitat. They were overlayed in a fashion that showed relationships of statistical tests. A model was created of the 2 habitat types using mean canopy cover and mean distance. Using the editor toolbar, point shapefiles were created to represent the canopy cover. Each point was spaced by using the mean distance.

CHAPTER 3

RESULTS

Results of the MANOVA confirmed significant differences between LDBCV and HDBCV habitats for means of response variables (MANOVA: Pillai trace = 0.60, $P < 0.0003$). The canopy cover per quadrat for LDBCV habitat (Mean = 230.9 m^2, SE = 34.1) was significantly higher than HDBCV habitat (Mean = 133.3 m^2, SE = 25.6; Univariate ANOVA: $F_{1, 28}$ = 8.3, $P = 0.007$). Also, fewer mottes occurred in LDBCV habitat (Mean = 13.27, SE = 0.69) than in HDBCV habitat (Mean = 17.00, SE = 1.43; $F_{1, 28}$ = 4.48, $P = 0.043$). An inverse correlation was found between mottes and canopy cover (Pearson's Product Moment Correlation: r = -0.71, $P < 0.0001$; Fig. 8). Habitat with greater canopy cover per quadrat had fewer shrub mottes. In LDBCV habitat, there was greater canopy cover per quadrat and fewer shrub mottes; whereas, in HDBCV habitat there was less canopy cover per quadrat with more shrub mottes. In HDBCV habitat, there were about 68 mottes/ha compared to only 53 mottes/ha in LDBCV habitat. The distance between shrub mottes was greater in

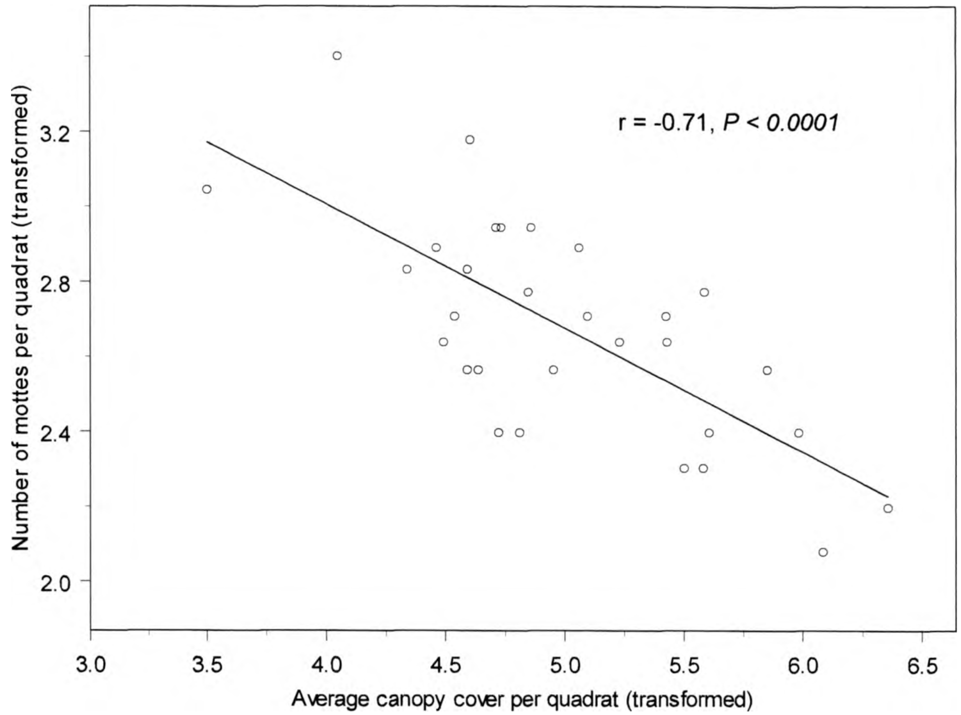


Figure 8. Pearson's product-moment correlation indicates that as canopy cover increases, the number of mottes decrease in both the unsuitable and suitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

LDBCV habitat (Mean = 8.8 m, SE = 0.69) than HDBCV habitat (Mean = 6.8 m, SE = 0.50; $F_{1, 28}$ = 5.3, *P = 0.029*). An inverse correlation existed between distance and number of mottes (r = -0.42, *P = 0.021*; Fig. 9). Twice as many favorable mottes occurred in HDBCV habitat (Mean = 13.1, SE = 1.36) compared to LDBCV habitat (Mean = 6.1, SE = 0.86; $F_{1, 28}$ = 17.7, *P = 0.0002*). The number of plant species in each quadrat was higher in HDBCV habitat (Mean = 8.3, SE = 0.54) than in LDBCV habitat (Mean = 5.6, SE = 0.52; $F_{1, 28}$ = 14.6, *P = 0.001*). LDBCV habitat (Mean = 0.29 ha, SE = 0.032) had larger canopy cover/quadrat than HDBCV habitat (Mean = 0.19 ha, SE = 0.019; Unpaired t-test: t_{28}= 2.51, *P = 0.0179*).

Maps developed from GIS and GPS data coincided with statistical results. The map of canopy cover and distance for HDBCV habitat had relatively no dark shading around the majority of quadrats showing that canopy cover and distance were smaller for HDBCV habitat (Fig. 10, 11). Quadrat 22 was the most apparent exception with the darkest shade (Fig. 10). Quadrat 22 had the second highest average canopy cover of all quadrats (Table 1). However, a BCV inhabited the center of the quadrat (Fig. 10). The presence of BCVs can be explained by the distance between mottes, number of mottes, and species richness. Quadrat 22 had one of the shortest distances between mottes. Six of 8 mottes present in Quadrat 22 were designated favorable and had higher species richness than LDBCV habitat (Table 1). Statistically, there were more

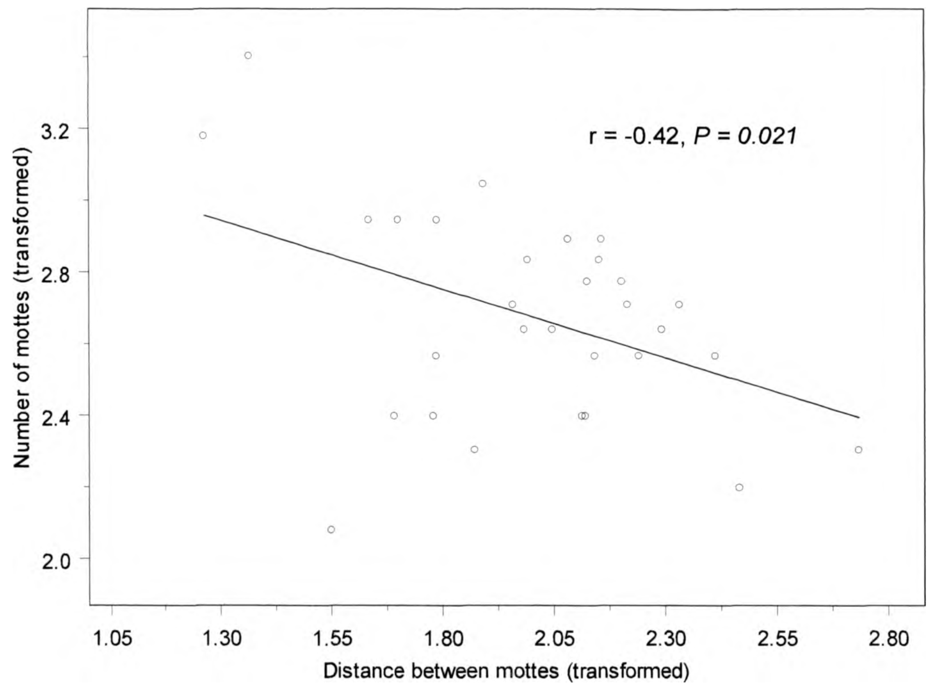


Figure 9. Weak inverse correlation between distance and number of mottes found in both unsuitable and suitable Black-capped Vireo habitat indicating that as the distance between mottes increase the number of mottes decrease at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

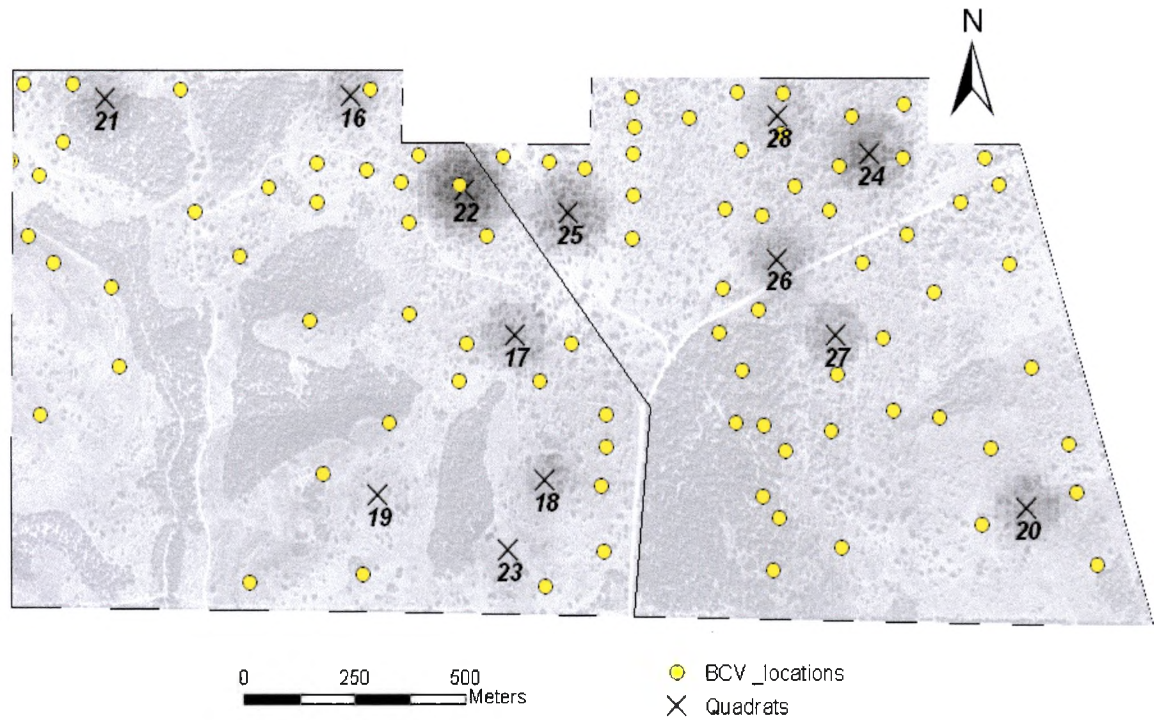


Figure 10. The darker shading around quadrats the greater the canopy cover and distance between the mottes in Fawn and Doe pastures designated as suitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr county, Texas in 2005.

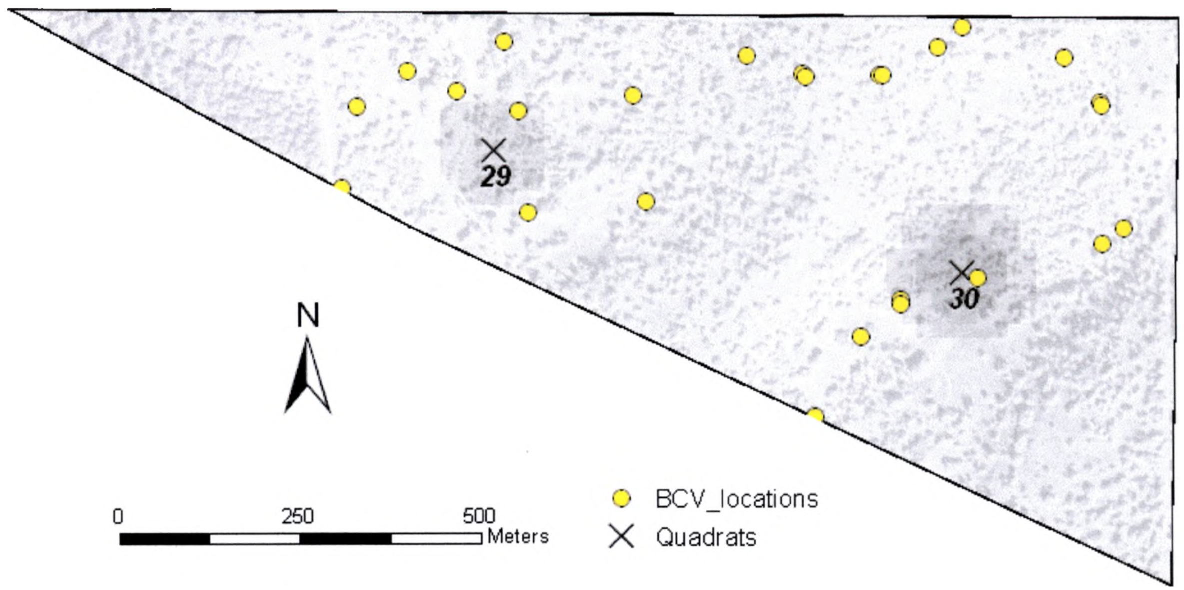


Figure 11. The darker the shading around quadrats the greater the canopy cover and distance between the mottes in North Rock pasture designated as suitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

Table 1. Averages of the canopy cover (CA), distance between shrub mottes (DIST), number of shrub mottes (MOTTES), number of favorable shrub mottes (FAVMOTTES), percent of favorable mottes to mottes (%), and plant species richness/quadrat (RICHNESS) for low density and high density Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

Site	Quadrat	CA (m^2)	DIST (m)	MOTTES	FAVMOTTES	RICHNESS
LDBCV	1	98.49	11.17	13	0 (0.00)	4
LDBCV	2	576.06	11.78	9	7 (77.78)	6
LDBCV	3	347.34	9.40	13	5 (38.46)	4
LDBCV	4	228.06	9.90	14	7 (50.00)	4
LDBCV	5	103.16	8.52	13	4 (30.77)	3
LDBCV	6	265.14	15.40	10	5 (50.00)	4
LDBCV	7	226.91	7.09	15	2 (13.33)	6
LDBCV	8	266.51	8.38	16	8 (50.00)	5
LDBCV	9	163.14	9.17	15	9 (60.00)	6
LDBCV	10	396.13	5.93	11	10 (90.91)	4

Table 1 — *Continued.*

Site	Quadrat	CA (m^2)	DIST (m)	MOTTES	FAVMOTTES	RICHNESS
LDBCV	11	127.14	9.05	16	3 (18.75)	7
LDBCV	12	122.64	5.43	11	6 (54.55)	6
LDBCV	13	128.75	5.98	19	12 (63.16)	8
LDBCV	14	141.46	5.97	13	10 (76.92)	6
LDBCV	15	271.76	8.28	11	4 (36.36)	11
HDBCV	16	89.23	7.75	14	10 (71.43)	4
HDBCV	17	112.30	8.34	11	10 (90.91)	5
HDBCV	18	76.69	7.33	17	7 (41.18)	9
HDBCV	19	57.26	3.92	30	27 (90.00)	10
HDBCV	20	98.59	8.61	17	11 (64.71)	11
HDBCV	21	86.65	8.03	18	14 (77.78)	7
HDBCV	22	438.48	4.71	8	6 (75.00)	9
HDBCV	23	33.11	6.64	21	18 (85.71)	9
HDBCV	24	157.56	8.65	18	15 (83.33)	9

Table 1 — *Continued.*

Site	Quadrat	CA (m^2)	DIST (m)	MOTTES	FAVMOTTES	RICHNESS
HDBCV	25	244.91	6.51	10	8 (80.00)	7
HDBCV	26	93.44	10.31	15	14 (93.33)	8
HDBCV	27	99.75	3.54	24	18 (75.00)	9
HDBCV	28	113.66	5.48	19	14 (73.68)	7
HDBCV	29	111.17	5.13	19	12 (63.16)	9
HDBCV	30	186.78	7.26	14	12 (85.71)	12

favorable mottes with higher richness in HDBCV habitat. It this case, it appears favorable variables offset unsuitable variables. Quadrats 24, 25, and 30 could have been exceptions as well because their canopy covers were similar to LDBCV habitat, but they still had more favorable mottes (≥ 80%) and higher species richness than LDBCV habitat (Fig. 10, 11; Table 1). BCVs inhabited Quadrat 30 and several occurred near Quadrat 24 (Fig. 10, 11). In comparison, the map for LDBCV habitat had more quadrats with dark shading, especially Plots 2 and 3 (Fig. 12). Quadrat 1 was an exception, but it was designated unsuitable habitat despite the light shading on the map. Quadrat 1 had the lowest canopy cover of all LDBCV quadrats, one of the largest distances between mottes, no favorable mottes, and low richness (Fig. 12; Table 1). I rated Quadrat 5 as unsuitable despite light shading because of characteristics similar to Quadrat 1 (Fig. 12; Table 1). Middle Trap had more lightly shaded quadrats. Middle Trap also contained the most BCVs for LDBCV habitat (Fig. 12). One BCV occurred near Quadrat 14, which was the only quadrat in LDBCV habitat with characteritisics similar to HDBCV habitat (Table 1). Quadrats 11 and 12 were also lightly shaded, but I rated them unsuitable based on low percentage (≤ 50%) of favorable mottes and lower richness values than HDBCV habitat. Quadrat 9 had a BCV present, most likely because it had low canopy cover relative to the other LDBCV quadrats and 60% favorable mottes (Fig. 12; Table 1). Quadrat

13 had low canopy cover, short distances between mottes, high number of mottes, 63% favorable mottes, and moderate number richness. I considered Quadrats 9 and 13 borderline suitable habitat based on the percentage of favorable mottes to total mottes (60 % and 63 %, respectively; Table 1). The percent of favorable mottes to total mottes for Quadrats 9 and 13 was higher than the mean percent (46 %) for LDBCV habitat.

The number of mottes in HDBCV habitat with darker shading exceeded those of LDBCV habitat (Fig. 13-15). Quadrats in LDBCV habitat had the same intensity of shading (Fig. 15; Table 1); whereas, mottes in the HDBCV habitat had more variability in shading (Fig. 13, 14; Table 1). This can further be seen by comparing standard deviations between the 2 habitat types. The standard deviation for HDBCV habitat (SD = 5.55) was greater than LDBCV habitat (SD = 2.65). This indicates more variability in the number of mottes in the HDBCV habitat. This is also apparent in a comparison of coefficients of variation (CV) between the 2 habitat types. HDBCV habitat had a higher CV (33%) than LDBCV habitat (20%). This indicates more spatial variability in HDBCV habitat. The univariate ANOVA showed fewer mottes in LDBCV habitat (Mean = 13.27, SE = 0.69) than the HDBCV habitat (Mean = 17.00, SE = 1.43; $F_{1, 28} = 4.48$, $P = 0.043$).

Mottes in quadrats of HDBCV habitat had 6 plant species present

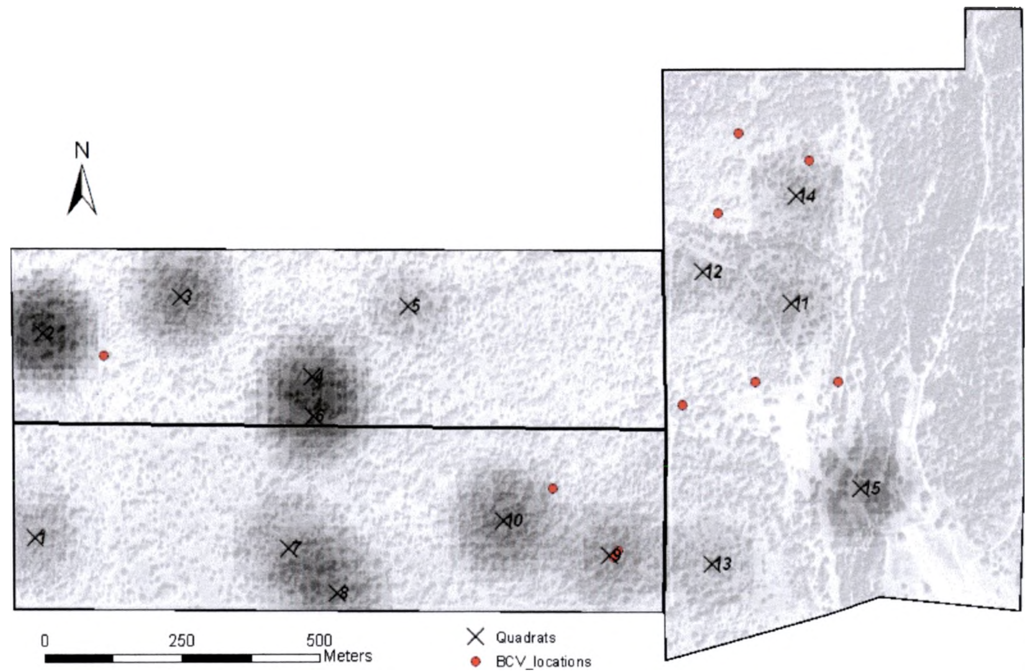


Figure 12. Increasing canopy cover and distance is indicated by the dark shading around quadrats in Plot 2, Plot 3, and Middle Trap pastures designated as unsuitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

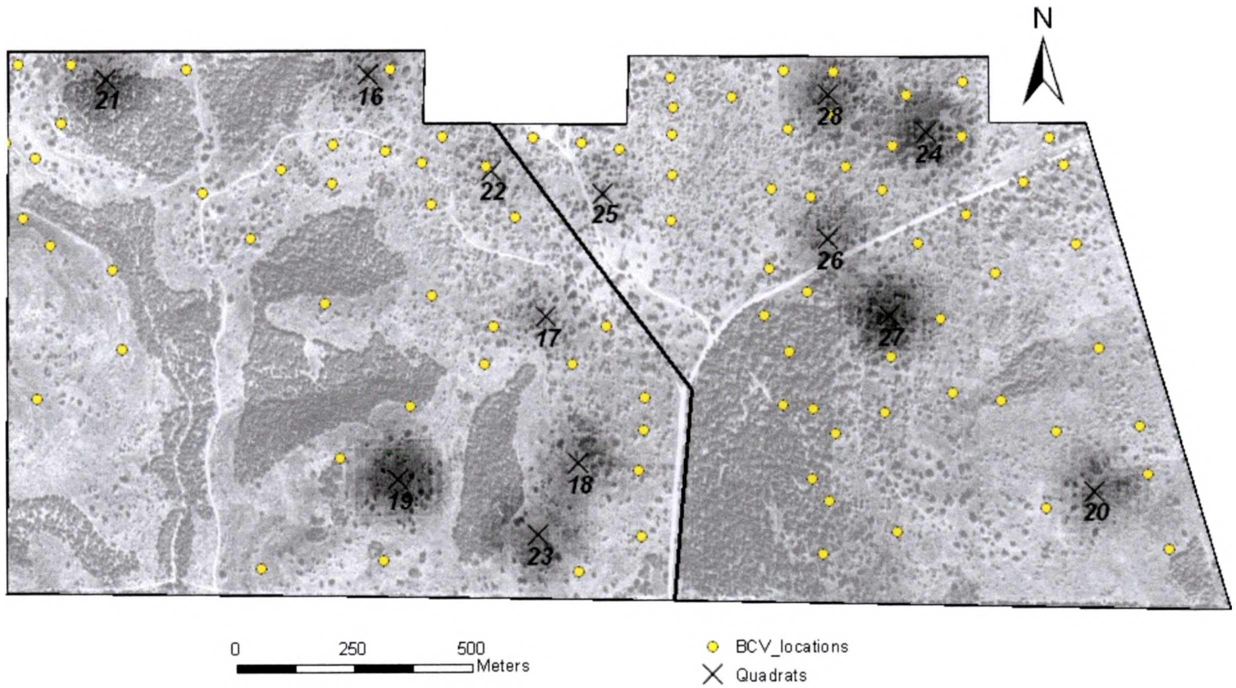


Figure 13. Dark shading around quadrats indicate higher average number of mottes per quadrat in Fawn and Doe pastures designated as suitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

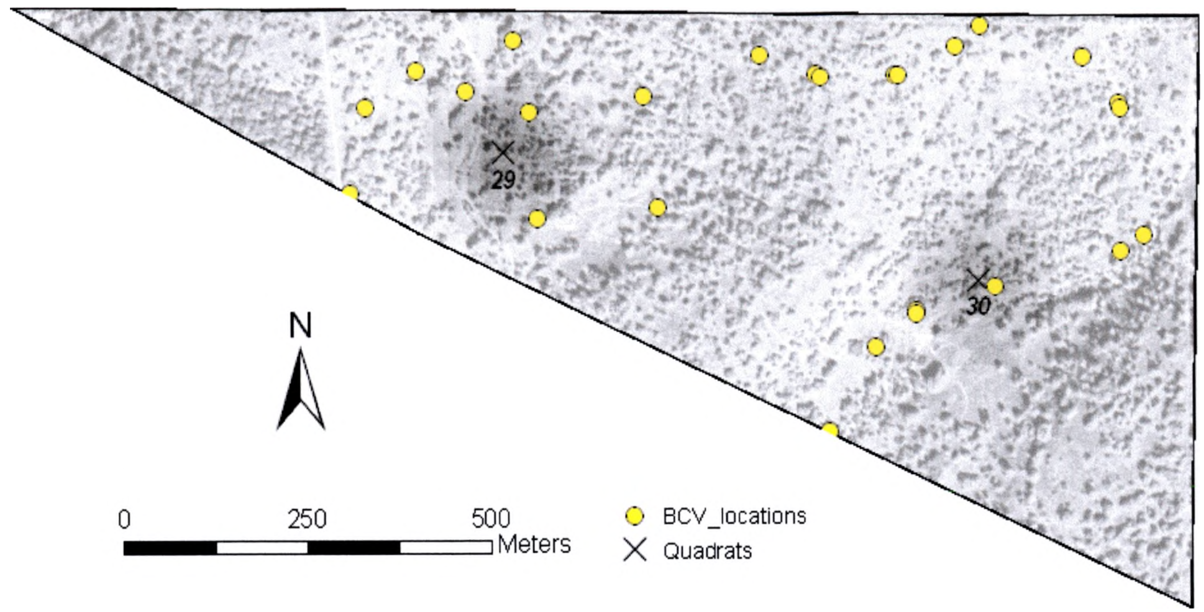


Figure 14. The greater the number of mottes present, the darker the shading around quadrats in North Rock pasture designated as suitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

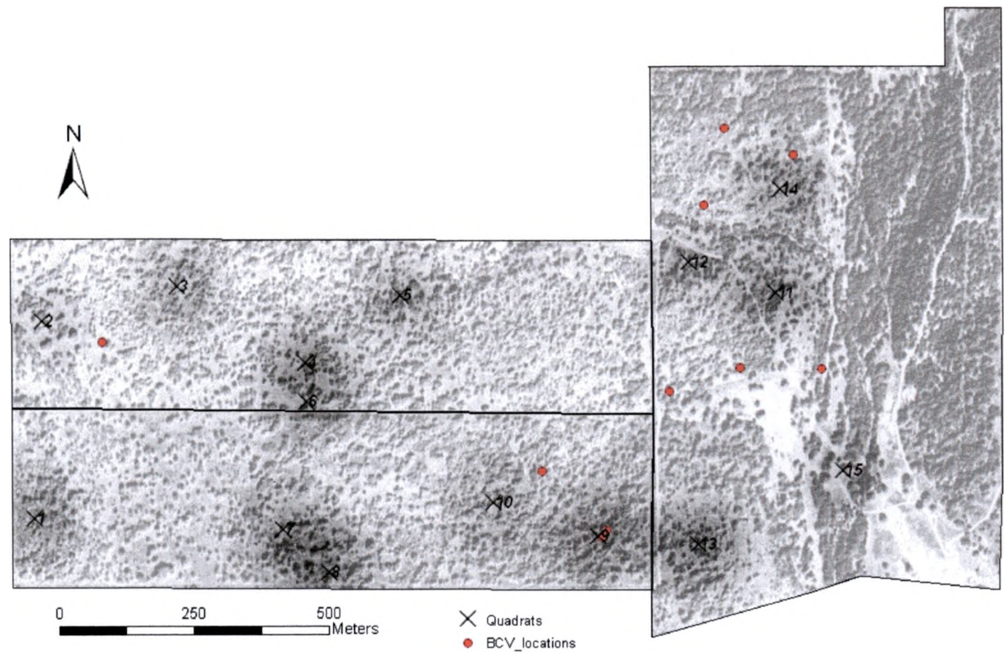


Figure 15. The darker shading around quadrats, the more mottes per quadrat in Plot 2, Plot 3, and Middle Trap pastures designated as unsuitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

Table 2. Woody plant species present and frequency of occurrence (%) by quadrat in suitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

Plant	Quadrat															Total	Frequency
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Acacia greggi			X	X						X						3	20.00
Berberis trifoliolata			X	X	X	X	X	X	X	X	X	X		X	X	12	80.00
Celtis spp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15	100.00
Cercis canadensis				X	X		X	X	X	X			X			7	46.67
Condalia hookeri					X				X		X			X	X	5	33.33
Diospyros texana	X	X	X	X	X	X	X	X	X		X		X	X	X	13	86.67
Forestiera pubescens											X	X		X	X	4	26.67
Ilex decidua							X	X	X	X						4	26.67
Juniperus ashei	X	X	X	X	X	X	X	X	X	X	X	X	X		X	14	93.33
Lonicera albiflora												X				1	6.67
Prosopis glandulosa													X			1	6.67

Table 2 — *Continued.*

Plant	Quadrat															Total	Frequency
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Prunus caroliniana		X														1	6.67
Prunus serotina												X		X	X	3	20.00
Quercus buckleyi				X	X	X	X	X							X	6	40.00
Quercus fusiformis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15	100.00
Quercus laceyi				X												1	6.67
Quercus marilandica					X							X				2	13.33
Quercus sinuata			X	X	X	X	X	X						X	X	8	53.33
Quercus stellata															X	1	6.67
Rhus lanceolata					X				X		X	X	X	X	X	7	46.67
Rhus virens																0	0.00
Sophora affinis			X													1	6.67
Ulmus crassifolia																0	0.00

Table 3. Woody plant species present and frequency of occurrence (%) by quadrat in unsuitable Black-capped Vireo habitat at Kerr Wildlife Management Area, Kerr County, Texas in 2005.

	Quadrat																
Plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	Frequency
Acacia greggi												X				1	6.67
Berberis trifoliolata									X	X	X	X	X			5	33.33
Celtis spp.							X				X	X	X	X	X	6	40.00
Cercis canadensis																0	0.00
Condalia hookeri													X	X		2	13.33
Diospyros texana													X			1	6.67
Forestiera pubescens											X	X		X	X	4	26.67
Ilex decidua																0	0.00
Juniperus ashei	X	X	X	X		X	X	X	X	X	X		X	X	X	13	86.67
Lonicera albiflora																0	0.00
Prosopis glandulosa		X						X			X				X	4	26.67

Table 3 — *Continued.*

Plant	Quadrat 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	Frequency
Prunus caroliniana																0	0.00
Prunus serotina															X	1	6.67
Quercus buckleyi	X	X	X		X		X		X						X	7	46.67
Quercus fusiformis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15	100.00
Quercus laceyi									X	X						2	13.33
Quercus marilandica		X						X			X					3	20.00
Quercus sinuata	X			X	X	X	X					X	X	X	X	9	60.00
Quercus stellata		X	X	X		X	X	X					X		X	8	53.33
Rhus lanceolata															X	1	6.67
Rhus virens																0	0.00
Sophora affinis																0	0.00
Ulmus crassifolia									X						X	2	13.33

with a frequency of occurrence > 50% (Table 2); whereas, LDBCV habitat had 4 species with a frequency of occurrence >50% (Table 3). Overall, 21 plant species occurred in mottes in HDBCV habitat and 17 in LDBVC habitat (Table 2, 3).

CHAPTER 4

DISCUSSION

BCV habitat has been characterized, in general terms, as mostly low, deciduous vegetation irregular in height and distribution containing a diversity of plant species (Graber 1961, Grzybowski 1995, Gryzybowski et al. 1994). It was also described as early successional habitat with areas of deciduous scrub containing several oak species interspersed with open areas and dense thickets (Graber 1961). Heterogeneity is another component of BCV habitat. Adler et al. (2001) found heterogeneity measured with non-spatial statistics, such as mine, corresponds to spatial variability. Heterogeneity is an interspersion concept, which includes the number of landscape changes between woody vegetation and openings between shrubs. This is further described as an irregular matrix of closely spaced, but separated shrubs with lateral branching to the ground (Graber 1961, Grzybowski et al. 1994). I addressed heterogeneity and openness from a horizontal perspective as a function of canopy cover, distance between shrub mottes, and number of mottes within each habitat type, LDBCV and

HDBCV. No measurements were taken on height of shrubs or density of understory. I was more interested in the horizontal landscape perspective of habitat rather than vertical strata. I felt it imperative to include 2 other characteristics of BCV habitat, woody plant species composition and lateral branching to the ground (in consideration of favorable or unfavorable mottes). I also used GIS in characterizing BCV breeding habitat. GIS was used in the recovery of endangered species, such as the California Condor *(Gymnogyps californianus),* by providing an inventory of recent California Condor habitats, measuring the association of activity patterns and mapped habitat variables, and examining spatio-temporal patterns in the distribution of wild populations (Stoms et al. 1993). The conservation and management of endangered species and their habitats requires the collection and analysis of information such as habitat analysis through vegetative sampling.

The results of my statistical analyses showed the 2 habitat types were different not only as whole, but in all 5 variables included in my analysis-- canopy cover, distance, number of mottes, number of favorable mottes, and plant species richness. Thus, I characterized suitable and unsuitable BCV habitat based on these 5 variables.

Suitable Habitat versus Unsuitable Habitat

From my results, suitable BCV habitat has more spatial variability indicative of heterogeneity (Adler et al. 2001). This was emphasized by the CV of 33% for number of mottes/quadrat in suitable habitat and 20% for the unsuitable habitat (Table 4). The canopy cover in suitable habitat had a CV of 74% indicating much more spatial variability than unsuitable habitat with a CV of 57% (Table 4). Heterogeneity can also be assessed by observing trends found in correlations. The correlations indicated openness, which is a component of heterogeneity. I found that as canopy cover within mottes and distance between mottes increase, number of mottes decrease (Fig. 8, 9; Table 4). Suitable BCV habitat is more open than habitat considered unsuitable, however, it cannot be considered closed either for there were 68 mottes/ha. In suitable BCV habitat, there is less canopy cover, less distance, and more shrub mottes (Fig. 16). Unsuitable BCV habitat has greater canopy cover, greater distance between mottes, and fewer mottes (Fig. 16). There is 30% fewer mottes (53 mottes/ha) in the unsuitable habitat (Table 4). Despite larger canopy cover in unsuitable habitat, the distance and number of mottes still insinuate larger areas of open habitat (Fig. 13; Table 4). This is not preferred habitat by BCVs (Graber 1961, Grzybowski 1995). Suitable BCV habitat has open areas, but they are small (Table 4).

Table 4. Results summarized by suitable and unsuitable habitat at Kerr Wildlife Management Area in 2005.

Variable	Suitable BCV Habitat	Unsuitable BCV Habitat
Heterogeneity (Spatial variability)		
Number of Mottes	CV 33%	CV 20%
Canopy cover	CV 74%	CV 57%
Openness		
Pearson's Correlations	CA and DIST ↓, number of mottes ↑	CA and DIST ↑ , number of mottes ↓
Mottes/ha	68	53
Open areas	small	large
Favorable Mottes	76% (13fav/17total)	46% (6fav/13total)
Species Richness		
Number of species	8	6
Frequency of occurrence	6 w/FOC > 50%	4 w/FOC > 50%
Ashe juniper	93% (sapling, sporadic)	86% (older)

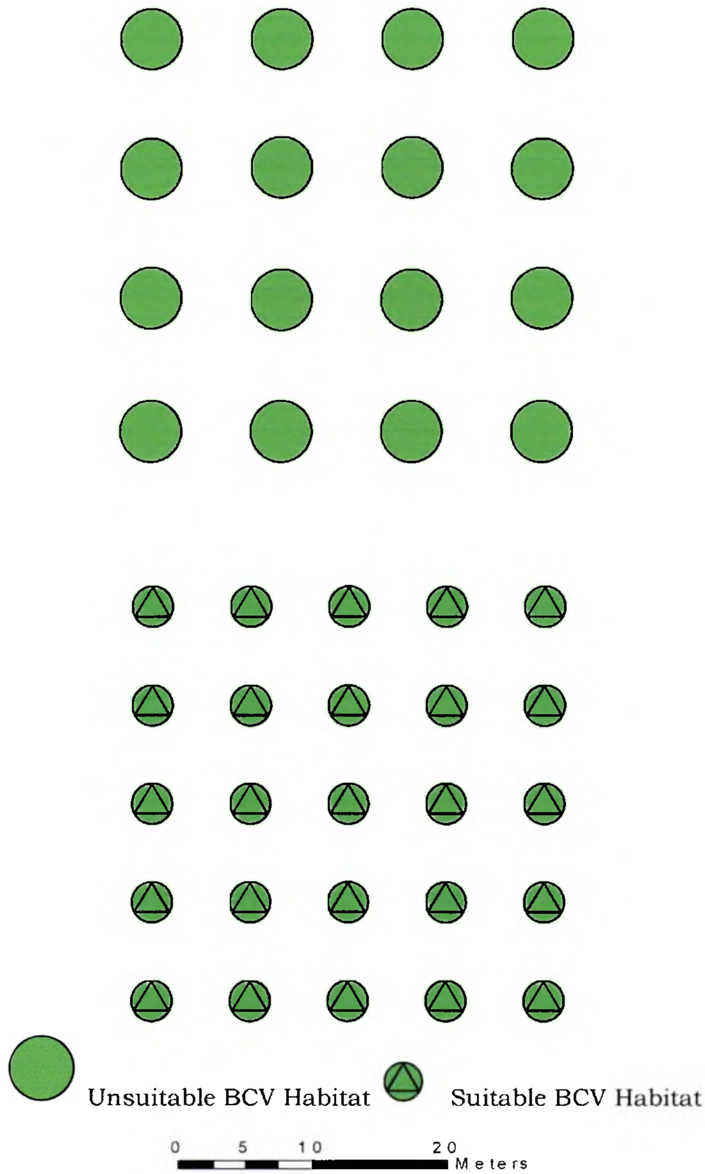


Figure 16. Model shows the apparent differences in average canopy cover and distance between the 2 habitat types at Kerr Wildlife Management Area, Kerr County, Texas in 2005. The size of the large green circle is 1.8 times the size of the smaller circle which is proportionate to the size differences of the actual canopy covers for each habitat type. Both schematics are equal in area (45 m X 45 m).

Some quadrats were outliers or did not conform to the aforementioned descriptions of suitable and unsuitable BCV habitat. These quadrats can be explained by the variables--number of favorable mottes and plant species richness. There were significant differences in the number of favorable mottes between the 2 habitat types. The average mottes/quadrat in suitable BCV habitat was 17 with 13 mottes having lateral branching to the ground (76%); whereas, the average mottes/ quadrat in unsuitable BCV habitat was 13 with 6 favorable mottes/quadrat (46%) (Table 4). In the suitable habitat, quadrats with a larger canopy cover (Quadrats 22, 24, 25, and 30) had more favorable mottes (82%) and higher plant species richness (Table 1). In unsuitable BCV habitat, there were 2 quadrats (Quadrats 9 and 14) with BCVs present (Fig. 12, 15). These quadrats were the ones in LDBCV habitat most like quadrats in HDBCV habitat (Table 1).

Suitable BCV habitat had higher mean plant species richness (8) than unsuitable BCV habitat (6). Six plants occurred with a frequency greater than 50% in suitable BCV habitat; whereas, 4 occurred in unsuitable BCV habitat (Table 4). Grzybowski (1995) reported BCVs occupy areas with fewer Ashe juniper saplings or trees. Ashe juniper occurred frequently in suitable BCV habitat and unsuitable BCV habitat (93.33% and 86%, respectively; Table 4). Ashe junipers were mostly very small, regrowth saplings dispersed sporadically in the understory of 14 quadrats in suitable BCV habitat; while Ashe junipers were a larger tree form and less sporadically dispersed in 13 quadrats of unsuitable BCV mottes. Gryzbowski et al. (1994) found juniper (*Juniperus spp.*) densities higher in vireo plots than non-vireo plots. Grzybowski (1995) also found that BCVs underutilize juniper relative to its availability for nesting.

Overall, suitable BCV habitat can be characterized as having frequent mottes of various small sizes spaced closely with lateral branching to the ground and higher plant species richness. The heterogeneity in suitable BCV habitats results from the number and size of shrub mottes and not necessarily from the distance between each motte (Fig. 17). Unsuitable habitat contains fewer mottes of large size with more substantial open spaces between mottes and lower species richness (Fig. 18). The majority of mottes were not favorable to BCVs. BCVs found in the unsuitable habitat could be a result of Fretwell's Ideal Free Distribution model. The Ideal Free Distribution model states that populations will inhabitat less suitable habitats if the best habitat or intermediate habitat is saturated or crowded (Krebs 2001). Fitness of the habitat declines as population density increases, so individuals are forced to live in optimal conditions with crowding, suboptimal conditions under less crowding, or unsuitable conditions with no crowding (Krebs 2001). Fawn, Doe, and North Rock pastures are near saturated with BCVs in optimal habitat with crowding. BCVs in Plot 2, Plot 3, and Middle Trap are optimizing their fitness by living in unsuitable quality

Figure 17. Picture represents suitable Black-capped Vireo habitat having frequent small mottes of various sizes spaced closely at Kerr Wildlife Management Area, Texas in 2005.

Figure 18. This is a picture of unsuitable Black-capped Vireo habitat having large unfavorable mottes spaced far apart at Kerr Wildlife Management Area, Texas in 2005.

habitat without crowding. BCVs in this situation have no choice but to treat the suitable and unsuitable habitats equals.

I characterized BCV habitat as heterogeneous based mainly on measurements of canopy cover and number of shrub mottes. Heterogeneity has been said to occur in areas where bushes are closely spaced but still separated allowing light to penetrate to ground level providing suitable deciduous cover at lower height zones (Grzybowski 1995). However, heterogeneity is a secondary component of BCV habitat with low deciduous cover being the primary component (USFWS 1991). I identified heterogeneity and openness as parameters of BCV habitat with limited information. Heterogeneity has been considered one of several important features in determining the distribution and abundance of birds by guiding habitat selection (Rotenberry and Wiens 1980).

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VITA

Stephanie Lynn Myers was born in Biloxi, Mississippi, on June 28, 1977, the daughter of Jenny McQuade and Michael Myers. Stephanie was able to travel to many places including Iceland and England because her father was in the Air Force. Towards the end of her father's tour of duty in the military, her family settled in Clovis, New Mexico. Stephanie attended Clovis High School where she graduated with honors in May 1996. Stephanie began her college education as biology major at Eastern New Mexico University in the small town of Portales, New Mexico in August 1996. She transferred to the University of Colorado, Colorado Springs in January 1997 to be closer to family. In May 2001, she graduated cum laude with a bachelors of arts in biology.

She returned to school 2 years later to pursue a career as a wildlife ecologist. She was accepted into the Wildlife Ecology Masters degree program at Texas State University in August 2003. While attending Texas State University, she taught Modern Biology and General Ecology laboratories. She was a member of the Wildlife Society. In February 2006, she became an intern as a Natural Resource Technician for Travis

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