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The Influence of Temperature on Black-Capped Vireo Nest-site Selection

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Abstract - Reproductive success is highly influenced by nest-site selection for avian species in breeding habitats, and variation in the physical environment can drive small-scale changes in the nest-site selection process. We examined the influence of temperature on *Vireo atricapilla* (Black-capped Vireo; hereafter Vireo) nest-site selection at Kerr Wildlife Management Area (KWMA) in Kerr County, TX (March–July 2013 and 2014). We measured ambient temperature across points that represented the continuum of vegetation characteristics used by Vireos at our study sites during the breeding season. We also found and monitored 181 Vireo nests, collected vegetation data, and compared vegetation characteristics between areas used and not used by Vireos. Finally, we investigated whether Vireo nest-site characteristics changed over the course of the breeding season in relation to the temperature profile of vegetation at our study sites. As expected, temperature increased over the course of the breeding season. Vireo nest sites had higher percent shrub cover than areas not used for nesting by Vireos. Vireos selected different vegetation characteristics for nesting as the breeding season progressed, but we did not find differences in temperature across vegetation types, suggesting that temperature is not the driving factor in Vireo nest-site selection in locations where temperatures remain consistently high throughout the breeding season. However, we could not directly measure temperature at nest-site locations. Therefore, Vireos may exhibit some degree of thermal preference at smaller spatial scales. Additionally, our results suggest that Vireos may require nesting habitat with more shrub cover than previously recommended.

Introduction

Factors including microclimate, food availability, and vegetation composition and structure within an organism's breeding habitat can influence the survival of adults and young, and ultimately, impact persistence of the species. For avian species in breeding habitats, reproductive success is highly influenced by nest-site selection, and variation in the physical environment can drive small-scale changes that influence the nest-site selection process. Thus, changes in the physical environment, such as elevated seasonal and climatic temperatures, can influence patterns of habitat use for some species (Barnagaud et al. 2013, Cox et al. 2013a, Martin et al. 2015).

Guthery's (1997) useable-space hypothesis (i.e., based on an area that physically and physiologically supports the adaptations of a species) combines principles of habitat selection and use, while considering changes in environmental constraints, to determine the influence of these factors on animal behavior and reproductive

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success over time. Changes in temperature can act as an environmental constraint that can reduce the availability and potential quality of habitat space (Forrester et al. 1998, Tieleman et al. 2008). This potential loss of useable habitat space is an important concept for the management of species of concern.

Evidence suggests that temperature variation may contribute to habitat loss and degradation; thus, it is imperative that we consider the influence of temperature—both locally within a season and across longer time spans (i.e., climatic change)—on threatened and endangered bird species (Huntley et al. 2006). *Vireo atricapilla* Woodhouse (Black-capped Vireo; hereafter, Vireo) is a federally endangered neotropical migratory songbird threatened by habitat loss and other anthropogenic factors. Vireos breed in central Oklahoma, central and southwest Texas, and northeastern Mexico (Grzybowski 1995).

In Texas, the Vireo breeds from April through July in shrubland vegetation, including deciduous and non-deciduous woody cover, comprised of *Quercus virginiana* Mill (Live Oak), *Quercus havardii* Rydb. (Sand Shinnery Oak), and *Juniperus asheii* J. Buchholz (Ashe Juniper) mottes (Graber 1961). Vireos nest from 0.2 m to 3.0 m (usually 0.5 m to 2.0 m) above the ground (Graber 1961, Grzybowski 1995) with ~30–50% cover around the nest (Grzybowski 1995), although variation exists among different areas within the breeding range (Grzybowski et al. 1994; Pope et al. 2013a, b; Wilkins et al. 2006).

Previous studies suggest Vireos have a preference for specific nest heights (Grzybowski 1995) and amount of concealment around the nest (Pope et al. 2013a, b). Colon et al. (2017) found that Vireo nest placement changed in relation to drought conditions, with Vireos using the evergreen Ashe Juniper as a nest substrate more often when conditions were dry and deciduous substrates under moderate conditions. Our goal was to explore how temperature may influence nest-site selection of the Black-capped Vireo in central Texas across the breeding season.

Study Area

We conducted our study at the Kerr Wildlife Management Area (KWMA), located in the Edwards Plateau ecoregion of central Texas, which consists of savanna grassland, oak shrubland, oak–juniper woodland, and deciduous woodland. Vegetation management at KWMA includes prescribed burning, slash and burn, bulldozing, understory thinning, and occasional cattle grazing. Vireos at KWMA inhabit mid-successional Live Oak and Sand Shinnery Oak mottes, and oak–juniper woodlands of varying densities and heights (Pope et al. 2013a, b). The habitat-management activities at KWMA maintain suitable vegetation for Vireos, and land managers conduct extensive *Molothrus ater* (Boddaert) (Brown-headed Cowbird) trapping efforts to minimize the negative effect of brood parasitism on nesting Vireos and other breeding birds.

Study-site selection

We chose study sites at KWMA based on known occurrence of Vireos and specifically sought areas with variation in vegetation height, canopy cover, and shrub cover (Graber 1961, Pope et al. 2013b). In 2013, we selected a 59-ha study site on the west side of KWMA that was last burned in 1999. Personal observations (R.S. Holden) prior to data collection indicated that vegetation on the study site was variable, but that overall, shrubs were taller and canopy cover was higher when compared to other areas of known Vireo occupancy at KWMA. In 2014, we selected 2 study sites: one 22-ha study site last burned in 2007 that had substantial woodland and little grassland cover; and one 60-ha study site last burned in 2011 that consisted of shorter vegetation than the 2013 study site. We selected different sites between years because we were interested in the overall adaptive responses of Vireos to changes in temperature and vegetation, and not differences between sites.

Methods

Ambient temperature

We recorded temperature across each study site using Lascar EL-USB temperature-data loggers (Lascar Electronics, Erie, PA). We created a grid network of points using ArcGIS at 200-m spacing (200 m x 200 m grid) within which we systematically placed the temperature-data loggers at each grid point. This spacing allowed complete coverage of each study site. We attached the data loggers to 1-m wooden stakes and covered them with green plastic cups to protect the loggers from direct sunlight. If a point location along the grid was bare ground or only covered in a herbaceous ground layer, we placed the data logger in a random position within the nearest clump of vegetation to better represent potential Vireo nesting and foraging substrates and to avoid temperature spikes from direct sunlight; random-point locations were no more than 10 m away from the original location. The data loggers recorded temperature in degrees Celsius (°C) every hour between late March and late July during the 2013 and 2014 Vireo breeding seasons.

Site vegetation

Using the grid network of points created for temperature-data logger placement, we measured vegetation across each site once during the Vireo breeding season to quantify vegetation characteristics within areas that were used and not used by Vireos for nesting (see below). At each grid point, and at 4 points located 5 m from the grid point in each cardinal direction, we recorded canopy cover to the nearest 10% using a tubular densitometer. We also used a 3-m range pole to measure height of the vegetation at each of these 5 points. We established a 5-m–radius circle around the center point and divided the circle into 4 quadrants based on the 4 cardinal directions. Within each quadrant, we visually estimated the percent woody-shrub cover to the nearest 10% for shrubs <2 m tall.

Territory establishment and monitoring

To locate Vireos on each study site, we again used the grid network to conduct transect surveys. We walked at a ~1-km/hr pace from point to point from sunrise to 13:00 to detect singing male Vireos, and marked their locations with a Garmin Rino GPS unit. We surveyed each transect 3 times between early March and late April, and used the GPS point locations of Vireo detections to relocate birds for subsequent monitoring. We revisited each detection location at 3–5-d intervals to map territories, and considered males territorial if we detected them within a specific location for ≥4 weeks. These surveys were not designed to estimate abundance, but rather as a focus for nest searching (see below).

Nest searching

We conducted nest searching within Vireo territories (see above) from late March to late July in 2013 and 2014. We used behavioral cues of the birds (e.g., alarm calls, food carries, territorial behavior) to locate nest sites. We monitored nests every 2–3 d and determined nest fate (i.e., nest failed or fledged). After a nest failed or fledged, we continued to monitor and search the territory, every 3–5 d, looking for subsequent nesting attempts. Data on nest success are not presented in this paper.

Nest vegetation

To identify the vegetation characteristics of each active nest, we recorded measurements at all nests within monitored territories in which we found at least 1 Vireo or Brown-headed Cowbird egg or young. We recorded nest height, canopy height, percent shrub-cover, and percent canopy-cover only after all nests had fledged or failed at the end of the season. Nest-vegetation measurement methods followed the procedures used for the above-mentioned vegetation measurements at temperature-data logger locations.

Data analysis

Ambient temperature. We calculated the mean temperature, maximum temperature (i.e., highest temperature recorded at each data-logger point location), and the average maximum temperature (i.e., mean of daily maximum temperatures on each data logger) for all temperatures recorded at site-vegetation locations for each temperature-data logger.

Vegetation. We obtained average values for the vegetation-metrics measurements of canopy height, percent canopy-cover, and percent shrub-cover in Vireo breeding vegetation across all sites at each temperature-data logger location. We took a mean of the 5 measurements for each vegetation metric at each temperature-data logger grid-point location. We also took the mean canopy height, percent canopy-cover, and percent shrub-cover at nest sites. We used analysis of variance (ANOVA, $\alpha = 0.05$) to determine differences in mean vegetation characteristics at the sites between the 2013 and 2014 Vireo breeding seasons. Lastly, we conducted ANOVA on all vegetation metrics to assess differences between site vegetation at temperature-data logger locations and nest-site vegetation during each year.

Relationship of vegetation and ambient temperature. We used linear-regression analyses to evaluate the relationships between temperature (mean, maximum, and average maximum) and the associated vegetation measurements (canopy height, and canopy and shrub cover) at temperature-data logger locations for each site during the 2013 and 2014 breeding seasons.

Temporal changes in nest characteristics. We employed linear regression for each nest characteristic to determine if nest-vegetation characteristics changed relative to time of season. To standardize analyses across the breeding season, we analyzed all nest-site characteristics from nest-start date, defined as the day the first egg was laid. If we located a nest with more than 1 egg or one with nestlings, we estimated the nest-start date based on known Vireo nesting parameters. Vireos usually lay 1 egg per day after the first egg is laid, and incubate eggs for ~15–17 d. After hatching, nestlings remain in the nest for 10–12 d before fledging (Graber 1961).

We performed all analyses in the R statistical software program, version 2.15.3 (R Development Core Team, Vienna, Austria).

Results

Temperature

We deployed 18 temperature-data loggers from 15 April to 1 August 2013 that recorded 44,723 hourly temperature readings. From 10 April to 31 July 2014, we deployed 21 temperature-data loggers that recorded in 54,408 temperature readings. Temperatures varied from -1.5 to 45 °C (mean = 24.2 °C, SD = 6.9) in 2013 and from -3 to 48 °C (mean = 24.3 °C, SD = 7.3) in 2014. The means for the 2 years were similar; thus, we combined temperature data across years for subsequent analyses.

Site vegetation

We measured vegetation at 39 temperature-data logger locations during the 2013 (n = 18) and 2014 (n = 21) Vireo breeding seasons (Table 1). We found that shrub-cover percentages and canopy height were significantly different at temperature-data logger locations for the 2013 site than at both sites for 2014 (ANOVA: $F_{1, 37} = 4.16$, $P = 0.04$; and $F_{1, 37} = 4.29$, $P = 0.04$; respectively). Shrub cover was higher and canopy height was lower at the 2013 site than at both 2014 sites. However, canopy cover was statistically similar between sites (ANOVA: $F_{1, 37} = 0.57$, $P = 0.45$).

Ambient temperature and vegetation. We found no relationships between average temperature, maximum temperature, or average maximum temperature at temperature-data logger locations and average canopy cover, average canopy height, or average shrub cover (linear regression: all P-values = 0.12–0.76; see Holden 2016:figs. 2–4).

Table 1. Site vegetation metrics at temperature-data logger locations at Kerr Wildlife Management Area, Kerr County, TX.

	2013 (n = 18) site				2014 (n = 21) sites			
Vegetation variable (units)	Mean	Min	Max	SD	Mean	Min	Max	SD
Canopy cover (%)	21.0	0.0	66.0	21.79	27.0	0.0	72.0	24.53
Shrub cover (%)	38.0	17.5	75.0	18.07	26.0	0.0	68.0	18.74
Canopy height (m)	3.0	0.0	10.0	2.73	5.5	0.0	11.0	3.61

Nest-site vegetation

We measured vegetation at 181 Vireo nest sites during the 2013 (n = 55) and 2014 (n = 126) Vireo breeding seasons (Table 2). Nest height ranged from 0.2 m to 4.0 m, with the mean of 1.0 m (Table 2). Nest height did not differ between sites (ANOVA: $F_{1,179} = 1.52$, $P = 0.22$). Mean shrub cover at Vireo nests was 47% across years, with no large differences between years (ANOVA: $F_{1,179} = 3.291$, $P = 0.07$). Mean percent canopy-cover at nest sites was ~24% (SD = 17.7) across years. Canopy cover at nest locations was significantly different between years (ANOVA: $F_{1,179} = 4.12$, $P = 0.04$) due to differences in vegetation at sites. In 2013, mean percent canopy-cover was higher at nest sites than in 2014 (mean = 28.04%, SD = 20.90 in 2013; mean = 22.22%, SD = 16.13 in 2014). Mean canopy height above nests was 4.0 m (SD = 2.3; Table 2) and was similar between years (ANOVA: $F_{1,179} = 0.42$, $P = 0.51$).

We found that average nest canopy-cover and average site canopy-cover (ANOVA: $F_{1,218} = 0.02$, $P = 0.89$) and average nest canopy-height and average site canopy-height (ANOVA: $F_{1,218} = 0.16$, $P = 0.69$) did not differ. However, average nest shrub-cover (~45%) was ~15% higher than average site shrub-cover (~30%; ANOVA: $F_{1,218} = 21.41$, $P < 0.01$; Holden 2016:fig. 5).

Temporal changes in nest characteristics

Over both study years, linear regression indicated there was no significant change in mean nest height as the Vireo breeding season progressed ($F_{1,179} = 3.89$, $P = 0.06$), although the result was close to statistical significance. However, mean canopy cover at nest sites decreased by ~15% (from ~35% to ~20%) over time ($F_{1,179} = 5.16$, $P = 0.02$). In contrast, there was an increase of approximately 15% (~45% to 60%) in percent shrub cover over the breeding season ($F_{1,179} = 9.40$, $P <$ 0.01). In addition, canopy height above nests decreased by an average of 1.5 m over the course of the breeding season ($F_{1,179} = 8.53$, $P < 0.01$; Holden 2016:fig. 6).

Discussion

Although we cannot conclude that temperature was a limiting factor for Vireo useable habitat space at Kerr Wildlife Management Area, we found that Vireos nested in areas with different vegetation characteristics in relation to time of season. As the useable-space hypothesis is stated, changes in an organisms' needs should be supported in respective habitat space (Guthery 1997). Vireos used areas of habitat

Table 2. Black-capped Vireo nest-vegetation metrics at Kerr Wildlife Management Area, Kerr County, TX.

	2013 (n = 55) site				2014 (n = 126) sites			
Nest vegetation variable (units)	Mean	Min	Max	SD	Mean	Min	Max	SD
Nest height (m)	1.0	0.3	2.6	0.6	1.1	0.2	4.3	0.6
Canopy cover (%)	28.0	0.0	92.0	20.9	22.0	0.0	72.0	16.1
Shrub cover (%)	50.0	10.0	90.0	20.0	45.0	0.0	97.5	18.1
Canopy height (m)	4.0	0.0	11.0	1.9	4.5	0.0	12.0	2.4

with higher amounts of shrub cover at nest sites than at the random temperature-data logger locations. We did not detect a difference in temperature within areas with contrasting vegetation characteristics; however, there could still be some thermal preferences by Vireos at nest sites that were not apparent because we could not measure temperature at nest-site locations due to permit restrictions and because we wanted to avoid disturbing nesting birds.

We found only a small difference in temperature between years, but the 2014 breeding season had a higher maximum temperature and lower average minimum temperature. This difference in measured temperature between both years may be due to differences in site vegetation in addition to annual variation. In previous studies, temperature increases as small as 2–3 °C during bird breeding seasons resulted in changes in reproductive success (Cox et al. 2013b). Furthermore, although we did not study operative temperatures for the Vireo, evidence shows that operative temperatures above 40 °C can be harmful for various bird species (Cox et al. 2013b, Forrester et al. 1998). In our study, not only did maximum ambient temperatures exceed 40 °C, but, the majority of data loggers placed across sites experienced readings over 40 °C in both years.

Although Vireo habitat is managed with similar management treatments (i.e., cattle grazing, prescribed fire) across the KWMA, differences in time since last treatment has resulted in varied vegetation characteristics across sites. Although not statistically significant, the vegetation we measured at the 2013 site had higher percentages of canopy cover but lower canopy heights than 2014 the sites. Site vegetation and nest-site vegetation were very similar, but there was a difference between nest-site shrub cover and site-vegetation shrub-cover percentages. Vireos nested and used vegetation that was denser than surrounding areas within the site, supporting previous claims that Vireos on the Edwards Plateau avoid more open areas (Grzybowski et al. 1994). This observation could lead to further study about foraging preferences, predator avoidance, and thermal needs of the species.

We could not identify a relationship between any vegetation characteristics and the ambient temperature at our sites. Although we did not measure airflow, densely packed vegetation in woodland interiors can cause a still and warm thermal environment (Adams 2010). Thus, additional study is warranted to better understand the relationship between temperature under higher percentages of canopy cover and the amount of shrub or ground cover under the trees.

Differences in nest height were not statistically significant, but Vireos in our study area placed nests lower as the breeding seasons progressed; nest height remained within the known range (Conkling et al. 2012, Graber 1961, Grzybowski 1995). Furthermore, the tradeoff between avoiding predation and finding a thermal refuge may also change during the breeding season, where predator avoidance (including Brown-headed Cowbird predation on young) may prevail in the early portion of the breeding season, but the need for thermal refugia prevails towards the end of the breeding season, when temperatures begin to increase (Tieleman et al. 2008). Also, because Brown-headed Cowbird parasitism decreases as the breeding season progresses (M.L. Morrison, unpubl. data), the birds might be able to later focus more on thermal factors rather than avoiding predators. Variation among individuals adds additional factors to the study of predation risk versus thermal-refuge preferences because body conditions and learned actions may cause individuals to alter behaviors accordingly (Amat and Masero 2004). Colon et al. (2017) found that during a drought, Vireos had lower pairing and territory success, delayed nest-initiation, fewer re-nesting attempts, and lower nest-success relative to a more moderate rainfall year.

We do not fully understand how expected climatic variation will change the Vireo's environment; however, we must consider the observed trends and adjust management strategies accordingly. Shrublands with higher percent shrub-cover may provide the necessary cover options and appropriate thermal refuge for Vireo as seasonal temperatures increase. Our results suggest that Vireos may need shrub-cover options that are higher than previously recorded percentages (30−50%; Grzybowski et al. 1994), particularly as temperatures increase over the course of the Vireo breeding season. The availability of woodland vegetation may also provide thermal cover in the absence of shrub cover, but an excess of woodland should be avoided. This suggestion corresponds with previous studies that report Vireo breeding habitat needs (Graber 1961, Grzybowski et al. 1994, Wilkins 2006).

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