CHAPTER 7

NEST MICROCLIMATE

INTRODUCTION

Innate selection of beneficial nest-site microclimate by birds can moderate extreme environmental conditions and has the potential to improve reproductive success and increase fitness (Webb and King 1983, Walsberg 1985). Although nest microclimate may influence avian reproductive success, other factors such as habitat and food availability also are important (Cody 1985, Gloutney and Clark 1997). Potential covariance with other evolutionary forces such as predation further complicates any investigation of microclimatic nest-site selection (Martin 1995).

Most studies of microclimatic nest-site selection have concentrated on non-passerines. Waterfowl (Gloutney and Clark 1997), hummingbirds (Calder 1973), and woodpeckers (Connor 1975, Inouye 1976, Inouye et al. 1981) in particular have been evaluated with respect to various aspects of microclimatic regulation. Selected species from each of these groups have demonstrated a preference for specific physical attributes within their nesting habitat as strategies to maximize heat gain, minimize heat loss, or manipulate wind exposure, depending on the situation. Several species of woodpeckers excavate cavities whose entrance holes are oriented toward or away from the sun, again depending on the situation and the need to regulate nest microclimate.

Microclimatic selection by passerines has received less attention than that by non-passerines, with most investigations of passerines directed at either ground-nesters or those building covered nests. Horned Lark (*Eremophila alpestris*) is probably the most thoroughly studied ground-nesting passerine, and numerous studies indicate that it selects nest locations based on compass orientation as a way to manipulate wind exposure, solar insolation, and resulting nest microclimate (Cannings and Threlfall 1981, With and Webb 1993, Hartman and Oring 2003). Cactus Wren (*Campylorhynchus brunneicapillus*) and Verdin (*Auriparus flaviceps*) orient the entrances to their covered nests either away from or toward prevailing winds in different parts of the nesting season to moderate nest microclimate (Austin 1974, 1976).

Microclimatic nest-site selection has been investigated in only a few open-cup, shrub- or tree-nesting passerines. The Warbling Vireo (*Vireo gilvus*) is very sensitive to fluctuations in nest microclimate (Walsberg 1981), and the San Miguel Island Song Sparrow (*Melospiza melodia micronyx*) may benefit from microhabitats that maintain higher nest relative humidity (Kern et al. 1990).

Gloutney and Clark (1997) pointed out that nonrandom distribution of nests strongly supports the microhabitat (i.e., microclimate) selection hypothesis. For example, nest-site selection for thermal advantages has been offered as an explanation as to why nonrandom nest-site placement occurs in many species (Kern and van Riper 1984, Bekoff et al. 1987, van Riper et al. 1993).

Nests placed in dense vegetation have been suggested to be less susceptible to predation (Cody 1985), and may also benefit from protection from wind, nocturnal heat loss, and diurnal heat gain (Walsberg 1981, 1985). Because the microhabitat of an individual can influence energy expenditure (Warkentin and West 1990), calories conserved through beneficial nest-site selection can aid reproductive efforts and improve fitness (Gloutney and Clark 1997).

Air temperature alone cannot portray the microclimate of an incubating bird (Gloutney and Clark 1997). Solar insolation, vapor pressure (i.e., relative humidity), and wind speed interact in a complex manner with temperature to define microclimate (McArthur 1990), so that many physiological investigators instead calculate *operative temperature* in a complex formula that integrates all of the above factors (Gloutney and Clark 1997).

The purpose of this microclimate investigation was to document temperature, relative humidity, and soil moisture at nests of Southwestern Willow Flycatchers, an open-cup nesting passerine. We tested the null hypothesis that no difference existed between (1) a flycatcher nest site, (2) a randomly located adjacent site within that flycatcher territory, and (3) unoccupied riparian habitat outside of that territory. Air temperature, relative humidity, and soil moisture were used as indices to microclimate, although it was recognized that substantial interaction likely occurred between those three variables.

METHODS

OVERVIEW

We located active flycatcher nests at four life history study areas (Pahranagat, Mesquite, Mormon Mesa, and Topock) between May and July 2004. Temperature, relative humidity, and soil moisture were measured at three locations relative to each nest for the purpose of examining microclimate at three levels of potentially increasing differences in flycatcher nesting habitat use, as follows:

1. Within 2 m of a nest (i.e., the nest site).
2. Within the territory associated with that nest (but 5–10 m from the nest; i.e., within-territory site).
3. Within unoccupied riparian habitat 50–200 m from the nearest known nest or territory (i.e., non-use site).

We began collecting microclimate data simultaneously at nest, within-territory, and non-use sites within 48–72 hours of the time an active nest was vacated. A nest was defined as vacated if it met one of the following criteria: (1) it had been abandoned for any reason (including brood parasitism) at any stage of the nesting cycle after the first flycatcher egg was laid, (2) it had fledged young and was no longer active, or (3) it had been depredated after an egg was laid. This technique minimized disturbance due to equipment placement or increased human activity near the nest as recommended by Hartman and Oring (2003), while still allowing for quantitative post-use comparisons of microclimate.

Temperature and relative humidity data were collected over a period of at least 14 full days (midnight to midnight), after which time we transferred the equipment and effort used to collect microclimate data to the nest, within-territory, and non-use sites for another recently vacated nest (i.e., including a second brood or second nesting attempt). The 14-day study period for each nest became the focus of all final analyses. Renests, or second nests of a known pair, were treated as independent data points because nests were the unit of analysis of this study and not individuals or pairs. All equipment used to collect microclimate data was removed after 14 full days from the time the last active nest had been vacated.

TEMPERATURE AND RELATIVE HUMIDITY MEASUREMENTS

Measurements of temperature and relative humidity (T/RH) were recorded automatically every 15 minutes using a HOBO H8 Pro (Onset Computer Corporation, Pocasset, MA) that combines a thermometer (degrees Celsius), relative humidity monitor, and digital data logger (hereafter referred to as a sensor array). We camouflaged all HOBO sensor arrays by placing them in an inverted small, plastic bowl coated with spray adhesive and local vegetation. The opening at the bottom was covered with shadecloth, allowing free air circulation around the sensor array. The HOBO sensor arrays were placed in four different location types in a manner consistent with an overall randomization design, as follows:

(1) Seasonal-variation (SV) sensor arrays: When field personnel arrived at the four life history study areas in early May, they placed SV sensor arrays at representative locations within the riparian and adjacent desertscrub habitat. The riparian SV sensor arrays were designed to monitor T/RH fluctuations throughout the nesting season within the riparian zone to document ambient environmental conditions throughout the study period. Riparian SV sensor arrays were placed in the nearest tree or woody shrub at their representative sites using a prearranged random number selection sequence (see 3C–3E below). The desertscrub SV sensor arrays at each study area were placed in desert habitat outside the riparian zone to document local extremes in T/RH.

(2) Nest site (NS) sensor arrays: Once a known nest was vacated, an NS sensor array was placed less than 1 m from the nest, preferably hanging directly below it. Sensor arrays were camouflaged so as not to disturb birds that may have returned to the nest to recycle nesting material. Canopy closure was visually estimated as < 25%, 25–75%, or >75% at all nest, within-territory, and non-use sites, and habitat type was identified as native (cottonwood/willow), exotic (tamarisk), mixed native, or mixed exotic (see data forms in Appendix A).

(3) Within-territory (WT) sensor arrays: A WT sensor array was placed at a location within the territory of the pair that attended the corresponding nest. The WT sensor array sites were determined by means of the following instructions and the use of random number sequences:

A. The compass direction to walk from the nest, given in degrees from north, was determined from a random number sequence.
B. The distance (between 5 and 10 m) to walk in the designated direction was determined from a random number sequence. Once that distance was traveled, the closest woody tree or shrub was selected for sensor array placement. If several trees were tied for closest, one of the field crew tossed a rock over his or her shoulder and the woody tree or shrub closest to its resting place was the one in which the sensor array was placed.

C. The sensor array was placed within the documented range of flycatcher nest heights (Sogge et al. 1997), and maximum height depended upon local tree or shrub maximum height at each of the four life history study areas. Sensor arrays were placed at a height between 1.5 and 5.0 m, as determined from a random number sequence, at Mesquite, Mormon Mesa, and Topock, and between 1.5 and 10.0 m (or as high as reasonably possible) at Pahranagat. If the random number at Pahranagat was greater than approximately 7 m, the sensor array was placed as close to the random height as reasonably possible. If the tree or shrub chosen for a sensor array location was of insufficient height to accept the height from the random number sequence, then field personnel placed the sensor array at the first height in the sequence that was less than the height of the tree or shrub.

D. The distance (0–3 m) at which the sensor array was placed from the bole of the tree or center of the shrub was determined from a random number sequence. If the tree or shrub was of insufficient radius to accept the distance from the random number sequence, then field personnel placed the sensor array at the first number in the sequence that was less than the radius of the tree or shrub.

E. The compass direction, given in degrees from north, at which the sensor array was placed from the bole of the tree or center of the shrub was determined from a random number sequence. If there was no branch in this compass direction that would support the sensor array at the height and distance specified in (C) and (D), field personnel proceeded clockwise around the tree or shrub until a suitable branch was located.

If, as presented in C and D, a number from a subsequent random number sequence (sequence meaning a row in the random number table) was used because the number in the initial sequence was too high, then both sequences were considered used and no longer available for future use. If these directions took field personnel outside of the riparian zone or to a site without trees or shrubs, they returned to the nest site and used the next sequence of random numbers.

(4) Non-use (NU) habitat sensor arrays: At all life history study areas, we identified NU habitat after the first territories and nests were located. We used ArcView® GIS 3.3 software to generate two circles that were centered on each nest site or territory center, one 50 m in radius and one 200 m in radius. The area between the two circles that was within the study area boundaries and was at least 50 m from all other nests or territory centers was classified as NU. Specific locations for non-use sensor were selected by superimposing a 25 × 25–m grid on the NU habitat, numbering the grid blocks, selecting blocks by using a random number generator, and using the centroid of each selected block. The NU site was located in the field using the UTM coordinates and a Rino 110 GPS unit. The exact location of the sensor array was determined by selecting the closest woody tree or shrub and using the procedures in 3C–3E above. If the NU site was inaccessible (e.g., impenetrable vegetation or deep water) or was in clearly unsuitable habitat (e.g., open marsh), the next UTM coordinate for a random NU site was used.

Soil Moisture Measurements

We recorded soil moisture (SM) measurements using two methods: (1) SV SM sensor arrays were placed at representative locations throughout the four study areas at the same sites as the SV T/RH arrays in riparian habitat to document daily range and rate of change, and (2) hand-held probes were used to document soil moisture at NS, WT, and NU sites at the time the T/RH sensor arrays were placed, and at the time the T/RH sensor arrays were removed 14 days later. No SV SM sensor arrays were placed in desertscrub habitat because soil moisture at those locations was assumed to be at or near zero.

(1) In mid-May, field personnel placed SV sensor arrays at representative sites within the riparian zone at each of the four life history study areas. If the locations for any of the SV SM sensor arrays were inundated or exhibited completely saturated soils, field personnel placed the sensor array 5 m beyond the edge of the inundated or saturated area in a compass direction determined by a random number sequence. The decision rule for completely saturated soil was as follows: a 1-cm-deep trench (created with a stick) filled with water or unstable mud in less than one minute.

The SM data were collected at 1-hour intervals using a Smart Soil Moisture Sensor connected to a 4-channel HOBO Micro Station data logger (both by Onset Computer Corp., Pocasset, MA). All SM sensor arrays were buried horizontally with the flat side perpendicular to the ground surface and the top edge of the sensor 1 cm beneath the soil surface. A trench slightly narrower than the probe was excavated with a putty knife to ensure good soil-to-probe contact.

(2) Hand-held probes, the ThetaProbe ML2x coupled to an HH2 Moisture Meter Readout (Macaulay Land Use Research Institute, Aberdeen, UK, and Delta-T Devices, Cambridge, UK, respectively) were used to gather volumetric water content data at NS, WT, and NU sites during the 14-day period after nests were vacated. Measurements were taken between 0700 to 1000 hours to eliminate the potential bias of time-of-day changes in the soil capillary fringe. The SM readings (17 per site) were recorded at the plot center and at estimated 0.5-m intervals from 0.5 to 2.0 m in each cardinal direction for each NS, WT, and NU site. If the soil was too wet (above ~50% volumetric water content, which represents saturated soil) or too dry (below ~0.5%) to obtain a volumetric SM reading, the logger read "above" or "under," respectively. If soil was completely saturated or inundated, "sat" was recorded. Readings of "above" and "sat" occurred for approximately 2% of the data points; readings of "under" occurred for approximately 3%. These results were converted to continuous values for the final analysis: 50% for "above" and "sat" values and 0% for "under" values. For the final analysis, the SM readings were combined into two comparison groups: plot center to 1.0 m, and greater than1.0 m to 2.0 m.

Soil samples were collected at each SM site (SV, NS, WT, NU sites) when sensor arrays were initially set up. Samples were approximately the size of a medium apple, collected from the surface down to and including a depth of 5 cm, and placed in a heavy zip-lock plastic bag labeled with the site designation. Because soil texture strongly influences capillary action and therefore overall soil moisture (Sumner 2000), analysis of soil composition may be conducted in future years as time and funding allow.

STATISTICAL ANALYSES

We downloaded data from the T/RH and SM sensor arrays at SV, NS, WT, and NU sites into databases at the end of the field season. We merged all data to create one dataset for further analysis, with the exception of the SV dataset, which was summarized separately for descriptive purposes and was not included in any of the analyses. We calculated the following variables for each sensor array by overall study period:

- Mean soil moisture from plot center to 1.0 m from plot center
- Mean soil moisture from greater than 1.0 m to 2.0 m from plot center
- Mean distance to saturated/inundated soil
- Mean diurnal temperature
- Mean maximum diurnal temperature
- Mean diurnal relative humidity
- Mean nocturnal temperature
- Mean minimum nocturnal temperature
- Mean nocturnal relative humidity
- Mean daily temperature range (diurnal maximum minus nocturnal minimum)

The overall study period constituted the entire season for SV sensor arrays and the 14 days of monitoring for sites (NS, WT, and NU) associated with nests. We determined diurnal and nocturnal periods by using the actual daily sunrise and sunset times reported for the region by the National Weather Service (2004).

We used Tukey's multiple comparison test with a one-way Analysis-of-Variance (ANOVA) to determine whether placing the sensor arrays *after* the nest had been vacated was appropriate, by testing the mean weekly diurnal temperature and mean soil moisture of the SV sensor arrays at each study area. Any consecutive weeks at a study area that were significantly different would be an indication that placing the sensor arrays after nests had been vacated was inappropriate.

We used probability plots and other distribution tests to test the response variables for normality. Chi-square (X^2) and one-way ANOVA tests were used to test the single effects of the three location types (NS, WT, NU) and other predictor variables for all response variables. If significant differences were found ($P<0.05$), we used Tukey's multiple comparison test to determine pairwise differences.

We used multiple factor ANOVA (MANOVA) analyses with and without interaction terms to determine significant differences in means between location types for all temperature, humidity, and soil moisture variables. MANOVA tests for a difference in means, while controlling for the variance by study area, habitat, and canopy closure. The full model is:

> Response Variable = Location Type + Study Area + Habitat + Canopy + Significant Interaction Term(s)

The R^2 value for the MANOVA analyses identifies the extent of the variation in the response variable that was explained by the predictor variables in each analysis. Tukey's multiple comparison test was used to determine pairwise differences for significant predictor variables. The *P* values presented in the MANOVA analyses were for type III sum of squares.

Correlated values were determined using the Pearson correlation coefficient (R). Analyses were conducted using SAS® Version 9.1 (SAS Institute 2003) and Stata® Version 8.2 (StataCorp LP 2004).

RESULTS

SEASONAL VARIATION

Twenty SV T/RH sensor arrays and 16 SV SM sensor arrays were placed at the four life history study areas beginning May 11 and remained in place until late August. One T/RH sensor in desertscrub at Mormon Mesa failed to function. The results from all SV sensor arrays indicated desertscrub sites were substantially hotter and drier than riparian sites (Tables 7.1 and 7.2).

Table 7.1. Seasonal Variation in Riparian Habitat by Study Area for Southwestern Willow Flycatcher Microclimate Data from along the Virgin and Lower Colorado Rivers, May–August, 2004*

Descriptive Statistics	Pahranagat	Mesquite	Mormon Mesa	Topock
N (Temperature/Humidity)	3	3	3	3
N (Soil Moisture)	4	4	4	4
Mean soil moisture (% volume)	20.9 (3.8)	18.9 (3.2)	16.9 (3.2)	30.3 (3.8)
Mean diurnal temperature (°C)	25.5 (1.7)	29.5 (1.6)	32.9 (2.5)	27.1 (1.2)
Mean maximum diurnal temperature (°C)	32.4 (2.1)	39.5 (2.3)	45.8 (3.3)	33.6 (1.2)
Mean diurnal relative humidity (%)	32.5 (6.8)	40.4 (5.1)	33.5 (4.3)	62.9 (6.7)
Mean nocturnal temperature (°C)	20.2 (1.7)	23.0 (2.0)	20.0 (2.4)	22.7 (1.7)
Mean minimum nocturnal temperature (°C)	15.3 (2.0)	17.4 (2.3)	14.7 (2.5)	19.0 (2.2)
Mean nocturnal relative humidity (%)	38.0 (6.2)	51.8 (8.1)	59.2 (7.0)	68.8 (5.3)
Mean daily temperature range (°C)	17.2 (2.3)	22.1 (2.8)	31.1 (3.9)	14.6 (2.3)

*All values are means (standard error in parentheses).

Table 7.2. Seasonal Variation in Desertscrub Habitat by Study Area for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado Rivers, May–August, 2004*

Descriptive Statistics	Pahranagat	Mesquite	Mormon Mesa	Topock
N (Temperature/Humidity)	2	2	1	2
Mean diurnal temperature (°C)	33.0 (2.4)	38.9 (2.7)	38.6 (5.1)	38.6 (2.9)
Mean maximum diurnal temperature (°C)	48.2 (3.4)	48.3 (3.5)	52.0 (7.7)	49.3 (3.7)
Mean diurnal relative humidity (%)	21.7 (7.6)	10.9 (4.0)	14.5 (5.4)	23.3 (7.4)
Mean nocturnal temperature (°C)	19.8 (2.5)	28.3 (2.5)	25.6 (4.2)	26.3 (2.9)
Mean minimum nocturnal temperature (°C)	14.3 (2.9)	22.0 (2.9)	19.7 (4.7)	20.2 (3.4)
Mean nocturnal relative humidity (%)	34.6 (10.3)	17.4 (7.1)	27.1 (6.6)	42.7 (11.0)
Mean daily temperature range (°C)	33.9 (3.9)	26.4 (3.5)	32.3 (8.3)	29.2 (3.4)

*All values are means (standard error in parentheses). No SM data were gathered in desertscrub habitat.

DATA COLLECTION AFTER NESTS WERE VACATED

Mean diurnal temperature differed significantly ($P<0.05$) during four pairs of weeks: the first and second week in August at Mormon Mesa and, at Pahranagat, the last week in May and the first week in June, the first and second weeks in June, and the second and third weeks in August. Mean soil moisture differed at Topock between the second and third weeks in June.

LOCATION TYPES: DESCRIPTIVE STATISTICS AND SINGLE EFFECTS ANALYSIS

Data on T/RH were successfully collected for 70 NS, 70 WT, and 63 NU sites (Tables 7.3–7.6). Sample sizes for the three location types were unequal because of the random failure of some data loggers. The location type data were normally distributed for all response variables, so no transformations or elimination of outliers were needed.

The single effects analyses indicate that the NS, WT, and NU sites were significantly different at all four study locations for the three diurnal temperature values: mean diurnal temperature, mean maximum diurnal temperature, and mean daily temperature range. The pairwise differences demonstrated that NU sites on average were significantly hotter during the day than either NS or WT sites. Figures 7.1 through 7.4 show box plots comparing mean diurnal temperature and other response variables for NS, WT, and NU sites by study area.

Mean soil moisture was significantly lower at NU sites compared to NS or WT sites at plot center to 1.0 m from the plot center and from 1.5 to 2.0 m from plot center at Pahranagat and Topock. Mean diurnal relative humidity was significantly higher at NS sites compared to NU sites at Pahranagat and Mesquite. Mesquite and Mormon Mesa had more native habitat at NS and WT sites than at NU sites. Mesquite had greater canopy cover at NS and WT sites than at NU sites, and Topock exhibited a greater mean distance to water from NU sites than from either NS or WT sites.

INDIVIDUAL EFFECT OF PREDICTOR VALUES

The single effects analyses (Tables 7.7 through 7.10) illustrate the individual effect that each predictor had on response variables across study areas. The NU sites were significantly different from both NS and WT sites for both soil moisture measures, mean distance to water, the three diurnal temperature values, and mean diurnal relative humidity. The WT and NS sites differed for only the three diurnal temperature values.

All response variables differed significantly among study areas. In 2003, Topock exhibited the highest diurnal and nocturnal temperatures, but Mormon Mesa was consistently the hottest and driest study area in 2004. Pahranagat in 2004, like 2003, consistently exhibited the lowest diurnal and nocturnal temperatures and the highest soil moisture values.

Table 7.3. Descriptive Statistics (Chi-square) and Single Effects (ANOVA) for Southwestern Willow Flycatcher Microclimate Data by Location Type at Pahranagat NWR, June–August, 2004*

Response Variable	Nest Site	Within Territory	Non-Use	*P*	Significant Pairwise Differences 2004	Significant Pairwise Differences 2003
N (Temperature/Humidity Sensor Arrays)	16	14	15	N/A	N/A	N/A
Habitat						
Native (cottonwood or willow)	16 (100.0)	14 (100.0)	15 (100.0)	N/A	N/A	N/A
Exotic (tamarisk)	0 (0.0)	0 (0.0)	0 (0.0)			
Mixed (native and exotic)	0 (0.0)	0 (0.0)	0 (0.0)			
Canopy Cover						
Less than 25%	0 (0.0)	1 (7.14)	3 (20.0)	0.187	N/A	N/A
25–75%	9 (56.3)	8 (57.1)	10 (66.7)			
More than 75%	7 (43.8)	5 (35.7)	2 (13.3)			
Soil Moisture						
Mean soil moisture (% volume) plot center to 1.0 m	40.0 (3.0)	40.0 (2.2)	24.7 (4.2)	0.002	WT>NU, NS>NU	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	40.8 (2.3)	39.5 (2.4)	24.5 (3.9)	0.001	WT>NU, NS>NU	N/A
Mean distance to saturated/ inundated soil	35.0 (8.3)	41.3 (10.3)	86.9 (19.9)	0.030	NU>NS	N/A
Temperature/Humidity						
Mean diurnal temperature (°C)	26.1 (0.2)	27.6 (0.5)	28.6 (0.5)	<0.001	NU>NS, WT>NS	NU>NS
Mean maximum diurnal temperature (°C)	35.8 (0.5)	40.9 (1.5)	41.2 (1.4)	0.003	NU>NS, WT>NS	N/A
Mean diurnal relative humidity (%)	43.4 (2.2)	39.1 (1.8)	33.8 (2.5)	0.013	NS>NU	NS>WT>NU
Mean nocturnal temperature (°C)	21.8 (0.3)	22.0 (0.4)	22.6 (0.6)	0.410	N/A	N/A
Mean minimum nocturnal temperature (°C)	12.8 (0.4)	12.3 (0.4)	13.3 (0.6)	0.291	N/A	N/A
Mean nocturnal relative humidity (%)	46.2 (2.1)	42.7 (1.4)	40.4 (2.7)	0.150	N/A	N/A
Mean daily temperature range (°C)	16.3 (0.7)	20.7 (1.4)	19.2 (0.9)	0.014	WT>NS	N/A

*Results of pairwise comparisons for similar data in 2003 are included. Habitat and canopy cover variables are presented as N followed by % of column totals (in parentheses), while soil moisture and temperature/humidity values are means (standard error in parentheses). N/A = data not available or not applicable.

Table 7.4. Descriptive Statistics (Chi-square) and Single Effects (ANOVA) for Southwestern Willow Flycatcher Microclimate Data by Location Type at Mesquite, June–August, 2004*

Response variable	Nest Site	Within Territory	Non-Use	*P*	Significant Pairwise Differences 2004	Significant Pairwise Differences 2003
N (Temperature/Humidity Sensor Arrays)	14	15	11	N/A	N/A	N/A
Habitat						
Native (cottonwood or willow)	10 (71.4)	9 (60.0)	1 (9.1)	0.019	NS>NU, WT>NU (more native)	N/A
Exotic (tamarisk)	3 (21.4)	3 (20.0)	4 (36.36)			
Mixed (native and exotic)	1 (7.14)	3 (20.0)	6 (54.6)			
Canopy Cover						
Less than 25%	0 (0.0)	1 (6.7)	7 (63.6)	<0.001	NS>NU, WT>NU	NS>NU, WT>NU
25–75%	11 (78.6)	13 (86.7)	4 (36.4)			
More than 75%	3 (21.4)	1 (6.7)	0 (0.0)			
Soil Moisture						
Mean soil moisture (% volume) plot center to 1.0 m	40.7 (3.2)	39.8 (3.2)	37.0 (3.2)	0.714	N/A	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	40.2 (3.0)	39.6 (3.0)	32.3 (4.8)	0.259	N/A	N/A
Mean distance to saturated/ inundated soil	7.0 (2.3)	8.4 (2.3)	18.5 (4.7)	0.030	NU>NS	N/A
Temperature/Humidity						
Mean diurnal temperature (°C)	29.0 (0.4)	30.7 (0.5)	33.4 (1.1)	<0.001	NU>NS, NU>WT	NU>NS, NU>WT
Mean maximum diurnal temperature (°C)	39.1 (0.7)	44.0 (1.0)	52.2 (1.6)	<0.001	NU>WT> NS	NU>NS, NU>WT
Mean diurnal relative humidity (%)	52.0 (1.8)	47.9 (2.2)	42.2 (1.8)	0.006	NS>NU	NS>NU, WT>NU
Mean nocturnal temperature (°C)	22.7 (0.5)	22.8 (0.5)	22.3 (0.6)	0.786	N/A	N/A
Mean minimum nocturnal temperature (°C)	14.8 (0.6)	14.4 (0.6)	13.8 (1.1)	0.699	N/A	N/A
Mean nocturnal relative humidity (%)	63.1 (2.1)	61.8 (2.0)	64.2 (3.4)	0.786	N/A	N/A
Mean daily temperature range (°C)	18.4 (0.6)	22.9 (0.8)	28.7 (2.5)	<0.001	NU>NS, NU>WT	NU>NS, NU>WT

*Results of pairwise comparisons for similar data in 2003 are included. Habitat and canopy cover variables are presented as N followed by % of column totals (in parentheses), while soil moisture and temperature/humidity values are means (standard error in parentheses). N/A = data not available or not applicable.

Table 7.5. Descriptive Statistics (Chi-square) and Single Effects (ANOVA) for Southwestern Willow Flycatcher Microclimate Data by Location Type at Mormon Mesa, June–August, 2004*

Response Variable	Nest Site	Within Territory	Non-Use	*P*	Significant Pairwise Differences	
					2004	2003
N (Temperature/Humidity Sensor Arrays)	6	6	5	N/A	N/A	N/A
Habitat						
Native (cottonwood or willow) – 2 missing Habitat values	3 (75.0)	3 (50.0)	0 (0.0)	0.016	NS>NU, WT>NU (more native)	N/A
Exotic (tamarisk)	0 (0.0)	0 (0.0)	4 (80.0)			
Mixed (native and exotic)	1 (25.0)	3 (50.0)	1 (20.0)			
Canopy Cover – 1 missing canopy value						
Less than 25%	0 (0.0)	0 (0.0)	2 (40.0)	0.128	N/A	WT>NU
25–75%	4 (80.0)	6 (100.0)	3 (60.0)			
More than 75%	1 (20.0)	0 (0.0)	0 (0.0)			
Soil Moisture						
Mean soil moisture (% volume) plot center to 1.0 m	25.5 (5.6)	26.0 (8.6)	6.2 (5.2)	0.262	N/A	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	20.3 (7.7)	21.8 (9.0)	5.7 (5.1)	0.497	N/A	N/A
Mean distance to saturated/ inundated soil	48.0 (8.5)	50.6 (7.5)	68.1 (19.2)	0.488	N/A	N/A
Temperature/Humidity						
Mean diurnal temperature (°C)	33.5 (0.7)	34.8 (1.0)	37.0 (0.5)	0.027	NU>NS	N/A
Mean maximum diurnal temperature (°C)	45.2 (1.3)	51.4 (1.9)	53.9 (1.6)	0.006	NU>NS, WT>NS	N/A
Mean diurnal relative humidity (%)	37.6 (1.6)	36.0 (2.1)	30.1 (3.1)	0.095	N/A	N/A
Mean nocturnal temperature (°C)	24.9 (1.0)	24.6 (1.0)	23.4 (1.1)	0.588	N/A	N/A
Mean minimum nocturnal temperature (°C)	17.2 (1.0)	16.8 (0.9)	14.4 (1.2)	0.147	N/A	N/A
Mean nocturnal relative humidity (%)	60.2 (1.6)	60.3 (1.3)	55.2 (4.0)	0.276	N/A	N/A
Mean daily temperature range (°C)	21.4 (1.0)	27.3 (1.3)	31.6 (1.4)	<0.001	NU>NS, WT>NS	N/A

*Results of pairwise comparisons for similar data in 2003 are included. Habitat and canopy cover variables are presented as N followed by % of column totals (in parentheses), while soil moisture and temperature/humidity values are means (standard error in parentheses). N/A = data not available or not applicable.

Table 7.6. Descriptive Statistics (Chi-square) and Single Effects (ANOVA) for Southwestern Willow Flycatcher Microclimate Data by Location type Topock, June–August, 2004*

Response Variable	Nest Site	Within Territory	Non-use	*P*	Significant pairwise differences 2004	Significant pairwise differences 2003
N (Temperature/Humidity Sensor Arrays)	34	35	32	N/A	N/A	N/A
Habitat						
Native (cottonwood or willow)	0 (0.0)	1 (2.9)	0 (0.0)	0.566	N/A	N/A
Exotic (tamarisk)	33 (97.1)	31 (88.6)	30 (93.8)			
Mixed (native and exotic)	1 (2.9)	3 (8.6)	2 (6.3)			
Canopy Cover – 1 missing canopy value						
Less than 25%	1 (2.9)	3 (8.6)	7 (22.6)	0.116	N/A	WT>NU
25–75%	26 (76.5)	26 (74.3)	21 (67.7)			
More than 75%	7 (20.6)	6 (17.1)	3 (9.7)			
Soil Moisture						
Mean soil moisture (% volume) plot center to 1.0 m	41.9 (1.1)	39.2 (1.5)	28.8 (2.3)	<0.001	NS>NU, WT>NU	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	41.9 (1.3)	38.9 (1.7)	28.1 (2.4)	<0.001	NS>NU, WT>NU	N/A
Mean distance to saturated/ inundated soil	22.6 (2.2)	23.7 (1.9)	36.0 (2.2)	<0.001	NU>NS, NU>WT	N/A
Temperature/Humidity						
Mean diurnal temperature (°C)	30.3 (0.3)	30.9 (0.3)	32.0 (0.7)	0.025	NU>NS	N/A
Mean maximum diurnal temperature (°C)	41.4 (0.7)	42.1 (0.8)	44.9 (1.1)	0.012	NU>NS	N/A
Mean diurnal relative humidity (%)	59.2 (1.6)	57.5 (1.6)	56.1 (1.9)	0.439	N/A	N/A
Mean nocturnal temperature (°C)	24.6 (0.3)	24.4 (1.6)	23.7 (0.4)	0.219	N/A	N/A
Mean minimum nocturnal temperature (°C)	17.2 (0.5)	16.9 (0.4)	15.8 (0.5)	0.095	N/A	N/A
Mean nocturnal relative humidity (%)	69.3 (1.6)	69.9 (1.3)	73.5 (1.3)	0.089	N/A	N/A
Mean daily temperature range (°C)	17.4 (0.7)	18.8 (0.7)	21.9 (0.8)	<0.001	NU>NS, NU>WT	N/A

*Results of pairwise comparisons for similar data in 2003 are included. Habitat and canopy cover variables are presented as N followed by % of column totals (in parentheses), while soil moisture and temperature/humidity values are means (standard error in parentheses). N/A = data not available or not applicable.

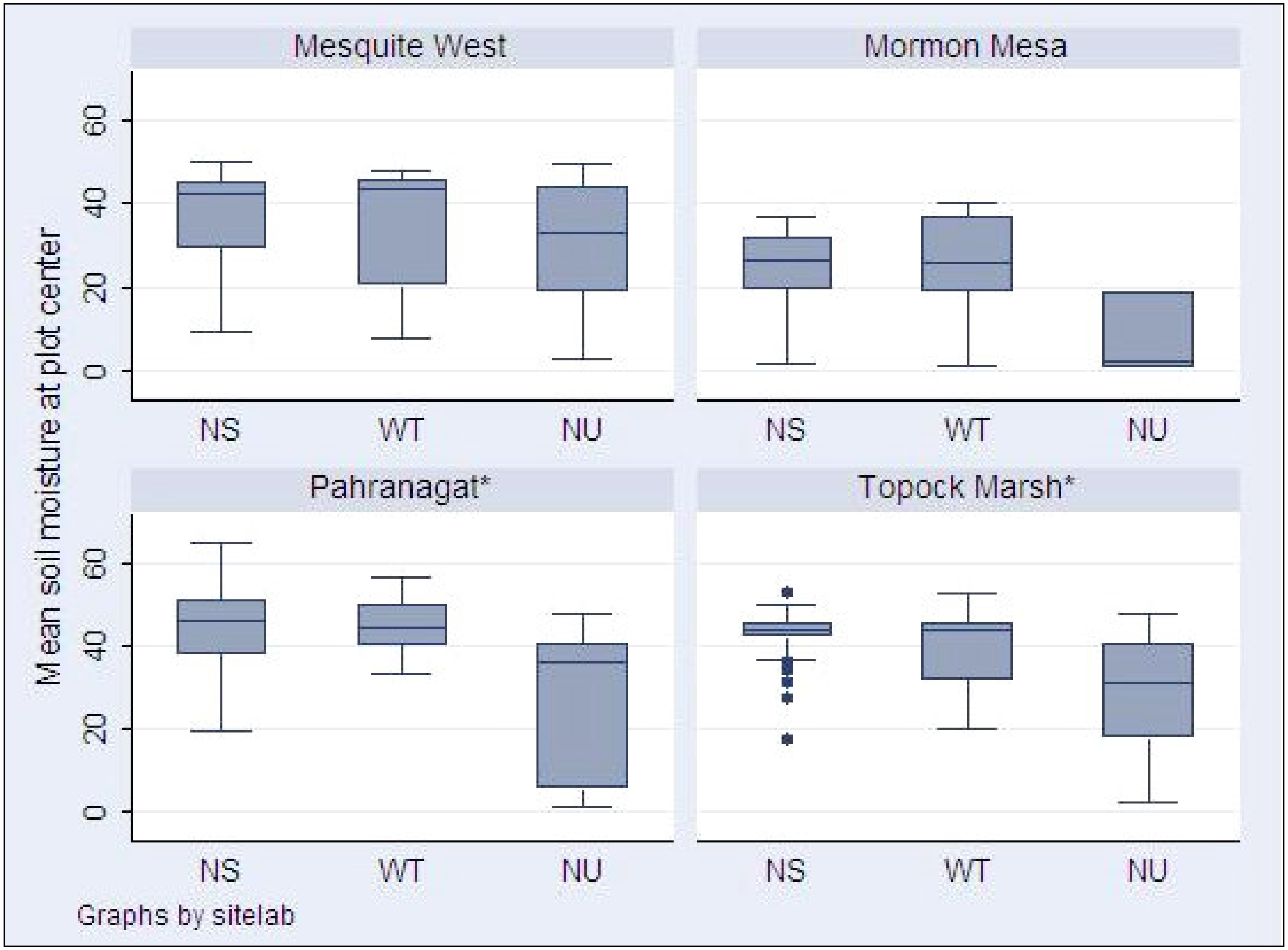

Figure 7.1. Box plots for the mean percent soil moisture plot center to 1.0 m from plot center by study area and location type for Southwestern Willow Flycatcher microclimate data along the Virgin and lower Colorado River regions, June–August, 2004. (Lines = minimum and maximum values; Box = 25th to 75th quartiles; Dots = outliers; and Center line = Median; * = $P<0.05$.)

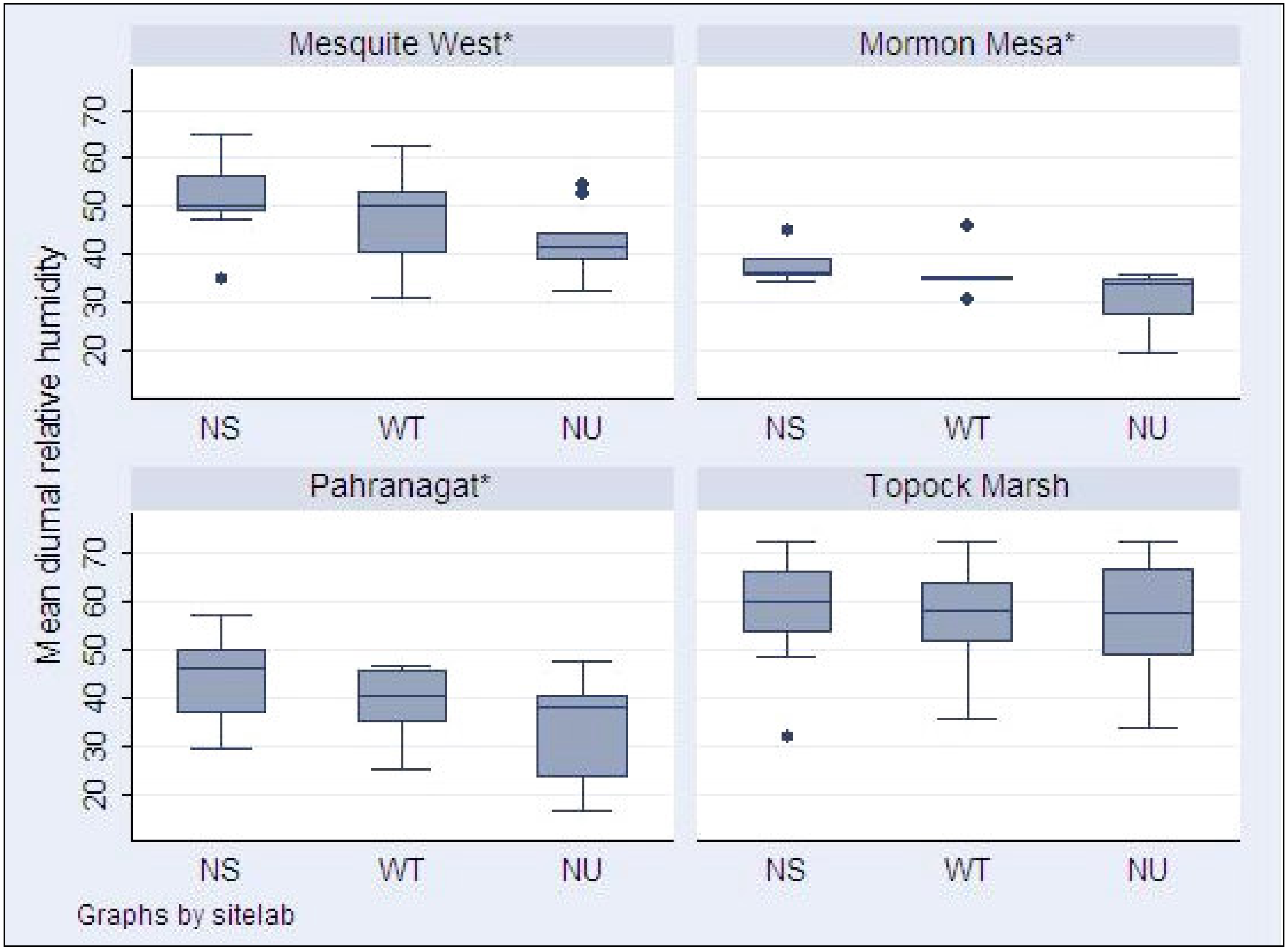

Figure 7.2. Box plots of the mean diurnal relative humidity by study area and location type for Southwestern Willow Flycatcher microclimate data along the Virgin and lower Colorado River regions, June–August, 2004. (Lines = minimum and maximum values; Box = 25th to 75th quartiles; Dots = outliers; and Center line = Median; *=P<0.05.)

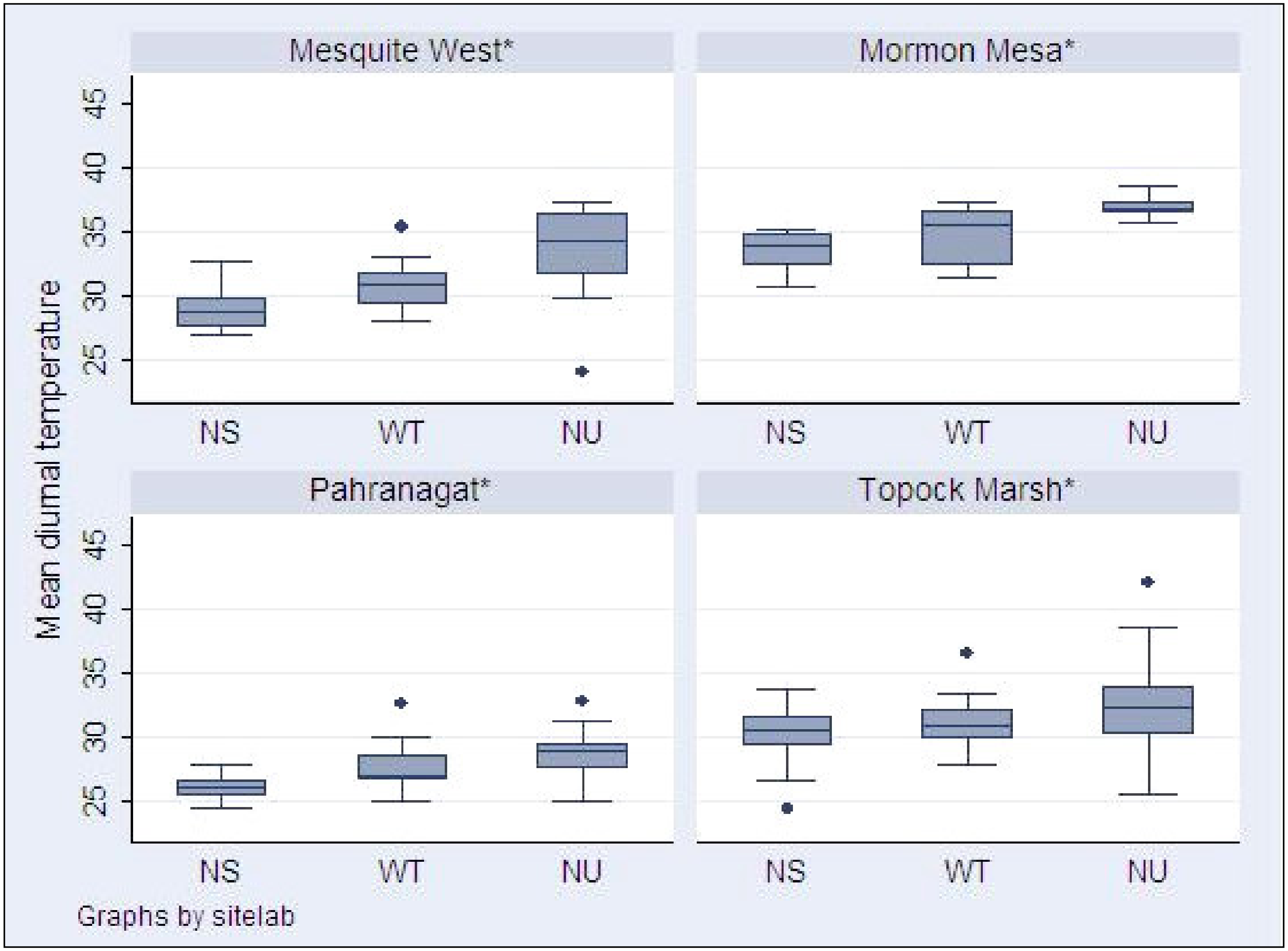

Figure 7.3. Box plots of the mean diurnal temperature by study area and location type for Southwestern Willow Flycatcher microclimate data along the Virgin and lower Colorado River regions, June–August, 2004. (Lines = minimum and maximum values; Box = 25th to 75th quartiles; Dots = outliers; and Center line = Median; *=P<0.05.)

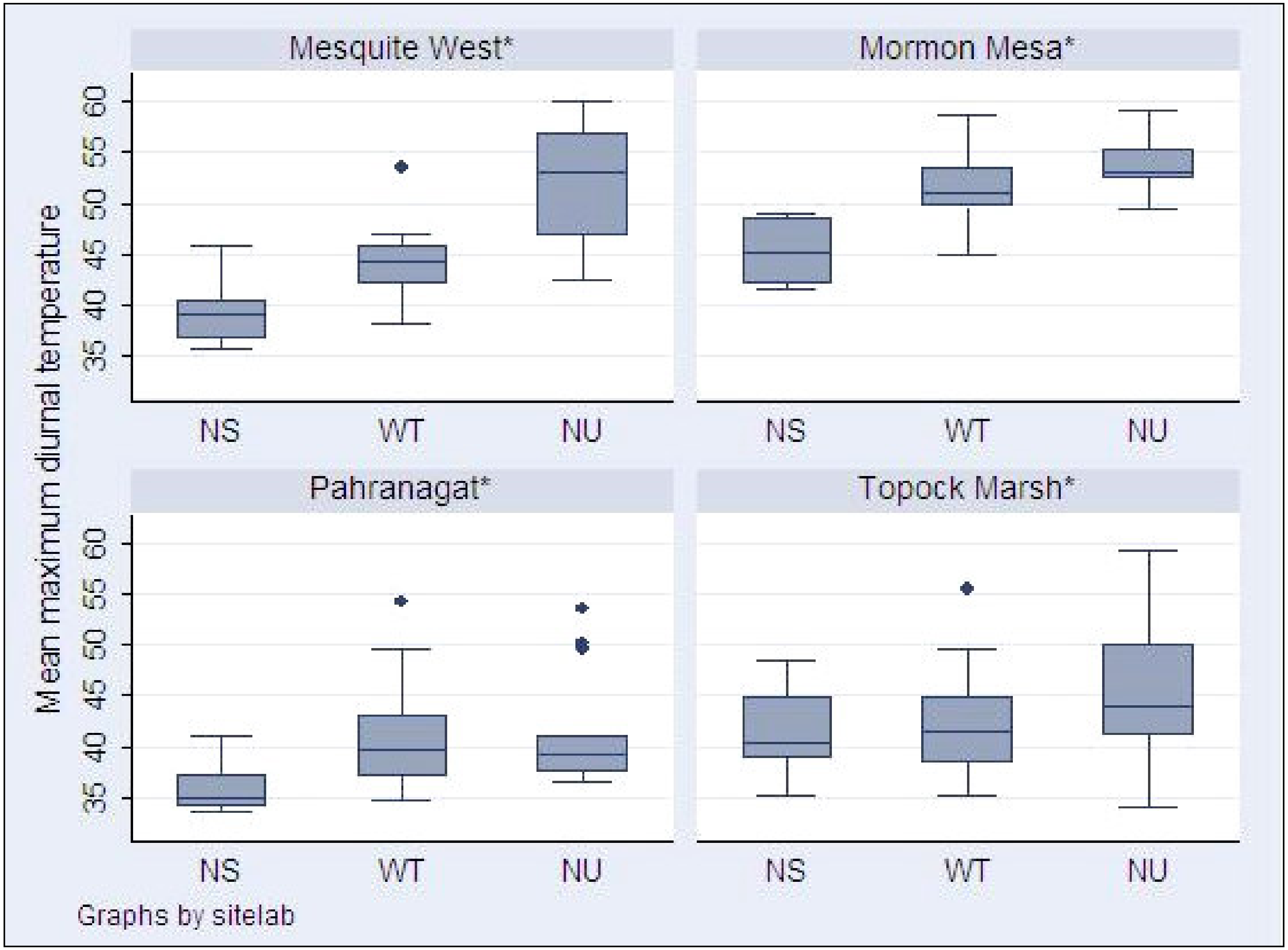

Figure 7.4. Box plots of the mean maximum diurnal temperature by study area and location type for Southwestern Willow Flycatcher microclimate data along the Virgin and lower Colorado River regions, June–August, 2004. (Lines = minimum and maximum values; Box = 25th to 75th quartiles; Dots = outliers; and Center line = Median; *=P<0.05.)

Table 7.7. Single Effects ANOVA Response Variables by Location Type for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado River Regions, June–August, 2004*

Response Variable	Location Type			*P*	Significant Pairwise Differences	
	Nest Site	Within Territory	Non-Use		2004	2003
Soil Moisture						
Mean soil moisture (% volume) plot center to 1.0 m	40.2 (1.2)	38.7 (1.2)	28.1 (1.9)	<0.001	NS>NU, WT>NU	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	40.0 (1.3)	38.1 (1.4)	27.1 (1.9)	<0.001	NS>NU, WT>NU	N/A
Mean distance to saturated/ inundated soil	23.7 (2.6)	25.0 (2.7)	47.8 (6.3)	<0.001	NU>WT, NU>NS	N/A
Temperature/Humidity						
Mean diurnal temperature (°C)	29.3 (0.3)	30.5 (0.3)	31.9 (0.5)	<0.001	NU>WT>NS	NU>WT>NS
Mean maximum diurnal temperature (°C)	39.9 (0.5)	43.1 (0.6)	46.1 (0.9)	<0.001	NU>WT>NS	NU>WT>NS
Mean diurnal relative humidity (%)	52.2 (1.3)	49.9 (1.4)	46.2 (1.8)	0.021	NS>NU	NS>WT>NU
Mean nocturnal temperature (°C)	23.5 (0.3)	23.6 (0.3)	23.1 (0.3)	0.417	N/A	N/A
Mean minimum nocturnal temperature (°C)	15.7 (0.4)	15.4 (0.4)	14.7 (0.4)	0.175	N/A	N/A
Mean nocturnal relative humidity (%)	61.9 (1.5)	61.9 (1.5)	62.6 (2.0)	0.953	N/A	N/A
Mean daily temperature range (°C)	17.7 (0.4)	20.8 (0.6)	23.3 (0.8)	<0.001	NU>WT>NS	NU>WT>NS

*Results of pairwise comparisons for similar data in 2003 are included. All values are means (standard error in parentheses); N/A = data not available or not applicable.

Table 7.8. Single Effects ANOVA Response Variables by Study Area for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado River Regions, June–August, 2004*

Response Variable	Study Area				*P*	Significant Pairwise Differences	
	Pahranagat (PA)	Mesquite (MW)	Mormon Mesa (MM)	Topock (TM)		2004	2003
Soil Moisture							
Mean soil moisture (% volume) plot center to 1.0 m	35.1 (2.1)	39.3 (1.8)	21.9 (4.6)	36.9 (1.1)	<0.001	PA>MM, TM>MM, MW>MM	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	35.2 (2.0)	37.6 (2.1)	18.0 (4.8)	36.6 (1.2)	<0.001	PA>MM, TM>MM, MW>MM	N/A
Mean distance to saturated/ inundated soil	56.3 (9.2)	10.7 (1.9)	55.0 (7.0)	27.2 (1.4)	<0.001	PA>TM, PA>MW, MM>TM, MM>MW, TM>MW	N/A
Temperature/Humidity							
Mean diurnal temperature (°C)	27.4 (0.3)	30.9 (0.5)	35.0 (0.5)	31.0 (0.3)	<0.001	MM>TM, MM>MW, MM>PA, TM>PA, MW>PA	MM>PA, MW>PA, TM>PA
Mean maximum diurnal temperature (°C)	39.2 (0.8)	44.6 (1.0)	50.0 (1.3)	42.7 (0.5)	<0.001	MM>MW, MM>TM, MM>PA, MW>PA, TM>PA	MM>PA, MW>PA
Mean diurnal relative humidity (%)	38.9 (1.4)	47.8 (1.3)	34.8 (1.5)	57.6 (1.0)	<0.001	TM>PA, TM>MW, TM>MM, MW>PA, MW>MM	TM>MW, TM>PA, TM>MM, MW>MM
Mean nocturnal temperature (°C)	22.1 (0.2)	22.6 (0.3)	24.3 (0.6)	24.2 (0.2)	<0.001	MM>MW, MM>PA, TM>MW, TM>PA	TM>MW, TM>PA, TM>MM, PA>MM

Table 7.8. Single Effects ANOVA Response Variables by Study Area for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado River Regions, June–August, 2004*, continued

Response Variable	Study Area				*P*	Significant Pairwise Differences	
	Pahranagat (PA)	Mesquite (MW)	Mormon Mesa (MM)	Topock (TM)		2004	2003
Mean minimum nocturnal temperature (°C)	12.8 (0.3)	14.4 (0.4)	16.2 (0.6)	16.6 (0.3)	<0.001	TM>MW, TM>PA, MM>PA, MW>PA	TM>MW, TM>PA, TM>MM
Mean nocturnal relative humidity (%)	43.2 (1.3)	62.9 (1.4)	58.8 (1.4)	70.9 (0.8)	<0.001	TM>MW, TM>PA, TM>MM, MW>PA, MM>PA	TM>MW, TM>PA, TM>MM, MW>PA, MM>PA
Mean daily temperature range (°C)	18.6 (0.6)	23.0 (1.0)	26.5 (1.2)	19.3 (0.5)	<0.001	MM>TM, MM>PA, MW>TM, MW>PA	MM>TM, MM>PA, MW>PA, MW>TM

*Results of pairwise comparisons for similar data in 2003 are included. All values are means (standard error in parentheses); N/A = data not available or not applicable.

Table 7.9. Single Effects ANOVA Response Variables by Habitat Type for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado River Regions, June–August, 2004*

Response variable	Habitat Type			*P*	Significant Pairwise Differences	
	Native (Cottonwood or Willow)	Exotic (Tamarisk)	Mixed (Native and Exotic)		2004	2003
Soil Moisture						
Mean soil moisture (% volume) plot center to 1.0 m	36.2 (1.6)	35.5 (1.2)	40.4 (1.7)	0.397	N/A	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	35.4 (1.6)	35.2 (1.3)	40.3 (1.9)	0.384	N/A	N/A
Mean distance to saturated/ inundated soil	38.7 (6.4)	28.3 (1.7)	28.4 (6.0)	0.152	N/A	N/A
Temperature/Humidity						
Mean diurnal temperature (°C)	28.7 (0.3)	31.3 (0.3)	32.2 (0.5)	<0.001	Mix>Nat, Tam>Nat	Mix>Nat, Tam>Nat
Mean maximum diurnal temperature (°C)	40.7 (0.7)	43.4 (0.6)	47.5 (1.3)	<0.001	Mix>Tam>Nat	Mix>Nat
Mean diurnal relative humidity (%)	42.2 (1.2)	55.0 (1.2)	49.0 (2.4)	<0.001	Mix>Nat, Tam>Nat	Tam>Nat> Mix
Mean nocturnal temperature (°C)	22.5 (0.2)	24.1 (0.2)	23.3 (0.5)	<0.001	Tam>Nat	Tam>Mix, Tam>Nat
Mean minimum nocturnal temperature (°C)	13.7 (0.3)	16.3 (0.3)	15.2 (0.8)	<0.001	Tam>Nat	Tam>Mix, Tam>Nat
Mean nocturnal relative humidity (%)	50.7 (1.5)	69.0 (1.0)	66.7 (1.7)	<0.001	Tam>Nat, Mix>Nat	Tam>Mix, Tam>Nat
Mean daily temperature range (°C)	19.9 (0.6)	20.0 (0.6)	24.4 (1.2)	0.002	Mix>Tam, Mix>Nat	Mix>Tam, Mix>Nat

*Results of pairwise comparisons for similar data in 2003 are included. All values are means (standard error in parentheses); N/A = data not available or not applicable.

Table 7.10. Single Effects ANOVA Response Variables by Canopy Closure for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado River Regions, June–August, 2004*

Response Variable	Canopy Closure Categories			*P*	Significant Pairwise Differences	
	< 25%	25–75%	> 75%		2004	2003
Soil Moisture						
Mean soil moisture (% volume) plot center to 1.0 m	31.9 (2.9)	35.8 (1.1)	39.4 (1.9)	0.095	N/A	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	31.3 (2.9)	35.1 (1.1)	40.3 (1.9)	0.029	GT75>LT25	N/A
Mean distance to saturated/ inundated soil	35.8 (5.9)	33.2 (3.4)	23.7 (3.9)	0.345	N/A	N/A
Temperature/Humidity						
Mean diurnal temperature (°C)	33.6 (0.7)	30.4 (0.3)	28.6 (0.4)	<0.001	LT25>25-75>GT75	LT25>25-75>GT75
Mean maximum diurnal temperature (°C)	50.2 (1.2)	42.4 (0.4)	39.4 (0.8)	<0.001	LT25>25-75>GT75	LT25>25-75>GT75
Mean diurnal relative humidity (%)	43.7 (2.2)	50.3 (1.1)	50.8 (2.3)	0.046	25-75>LT25	N/A
Mean nocturnal temperature (°C)	22.8 (0.5)	23.6 (0.2)	23.0 (0.3)	0.113	N/A	N/A
Mean minimum nocturnal temperature (°C)	13.9 (0.6)	15.7 (0.3)	14.4 (0.4)	0.005	25-75>LT25	N/A
Mean nocturnal relative humidity (%)	64.5 (2.7)	62.4 (1.1)	58.6 (2.7)	0.212	N/A	LT5>GT75, 25-75>GT75
Mean daily temperature range (°C)	27.8 (1.1)	19.8 (0.4)	18.0 (0.6)	<0.001	LT25>25-75, LT25>GT75	LT25>25-75>GT75

*Results of pairwise comparisons for similar data in 2003 are included. All values are means (standard error in parentheses); N/A = data not available or not applicable.

All temperature and humidity response variables differed significantly among habitat types. There was no significant difference in soil moisture or mean distance to water between habitat types. Native habitats consistently exhibited the lowest diurnal and nocturnal temperature and humidity, and the lowest mean daily temperature range as compared to exotic or mixed habitats. However, the majority of sites with native habitat occur at Pahranagat, which has the highest latitude and elevation of the sites and exhibited the lowest diurnal and nocturnal temperatures. Thus, habitat type and study area are likely confounded.

The following variables differed significantly among canopy closure levels: soil moisture at plot center to 1.0 m from the plot center and from 1.5 to 2.0 m from plot center, mean diurnal temperature, mean maximum diurnal temperature, mean diurnal relative humidity, mean minimum nocturnal temperature, and mean daily temperature range. These results are similar to those obtained in 2003.

MANOVA MODEL

Location type remained a significant predictor for soil moisture at plot center to 1.0 m from the plot center and from 1.5 to 2.0 m from plot center, mean distance to water, the three diurnal temperature measures, and mean diurnal relative humidity, even after adjusting for study area, habitat, and canopy closure (Table 7.11). No significant interaction terms remained in the stepwise analyses, so the models with these terms, which were shown for the 2003 analysis, have not been included here.

Because NU sites were the source of much of the significant difference in the single effects of location, NU sites were removed from the models to make a discrete comparison between only NS and WT sites at all study areas (Table 7.12). This MANOVA showed that NS sites remained significant predictors of mean diurnal temperature, mean maximum diurnal temperature, and mean daily temperature range. In 2003, only mean maximum diurnal temperature remained significantly different between NS and WT sites.

The response variables were often correlated (Table 7.13). For example, higher soil moisture at plot center to 1.0 m was significantly correlated with the following: higher soil moisture from 1.5 to 2.0 m, lower distance to water/saturated soil, lower mean diurnal temperatures, lower mean maximum diurnal temperatures, higher mean diurnal and nocturnal relative humidity, and lower mean diurnal temperature range. However, soil moisture at plot center was not significantly correlated with nocturnal temperature or minimum nocturnal temperature. Of note is that all three measures of diurnal temperature were directly and significantly correlated.

DISCUSSION

SEASONAL VARIATION

The 2004 finding that riparian habitat was cooler and more humid than adjacent desertscrub habitat was consistent with data collected in 2003 and with what would be expected.

Table 7.11. MANOVA Response Variables by Location Type, Adjusting for Study Area, Habitat, and Canopy Closure for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado River regions, June–August, 2004*

Response Variable	*P* for Overall Model	R^2 (%)	*P* for Location Type		Other Significant Predictors 2004	Significant Pairwise Differences	
			2004	2003		2004	2003
Soil Moisture							
Mean soil moisture (% m^3/m^3) plot center to 1.0 m	<0.001	31.7	<0.001	N/A	Study area, Habitat	NS>NU, WT>NU, MW>MM, PA>MM, TM>MM, Mix>Tam	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	<0.001	35.1	<0.001	N/A	Study area, Habitat	NS>NU, WT>NU, MW>MM, PA>MM, TM>MM, Nat>Mix, Mix>Tam	N/A
Mean distance to saturated/ inundated soil	<0.001	37.3	<0.001	N/A	Study area	NU>NS, NU>WT, MW>MM, PA>MW, TM>MM, PA>TM	N/A
Temperature/Humidity							
Mean diurnal temperature (°C)	<0.001	55.4	0.001	0.008	Study area, Canopy	NU>NS, WT>NS, MM>MW, MM>PA, MM>TM, TM>PA, MW>PA, 25-75-LT25, GT75-LT25	NU>NS, Mix>Nat, LT25>25-75>GT75
Mean maximum diurnal temperature (°C)	<0.001	49.0	<0.001	0.008	Study area, Canopy	NU>NS, WT>NS, MM>MW, MM>PA, MM>TM, TM>PA, LT25>25-75, LT25>GT75	NU>NS, LT25>25-75>GT75
Mean diurnal relative humidity (%)	<0.001	54.5	0.020	0.002	Study area, Habitat, Canopy	NS>NU, MW>MM, TM>MM, MW>PA, TM>MW, TM>PA, Mix>Tam, 25-75>LT25, GT75>LT25	NS>NU, WT>NU, MW>MM, TM>MM, MW>PA, TM>PA, Nat>Mix
Mean nocturnal temperature (°C)	<0.001	20.4	0.597	0.354	Study area	TM>MW, TM>PA	PA>MM, TM>MM
Mean minimum nocturnal temperature (°C)	<0.001	32.4	0.351	0.188	Study area	MM>PA, TM>MW, TM>PA	TM>MM, TM>MW, TM>PA
Mean nocturnal relative humidity (%)	<0.001	65.4	0.601	0.484	Study area	MM>PA, TM>MM, MW>PA, TM>MW, TM>PA	MM>PA, MW>PA, TM>PA, Mix>Nat, Tam>Mix
Mean daily temperature range (°C)	<0.001	48.1	<0.001	<0.001	Study area, Canopy	NU>NS, WT>NS, MM>MW, MM>PA, MM>TM, MW>PA, MW>TM, LT25>25-75, LT25> GT75	NU>NS, NU>WT, MM>PA, MM>TM, MW>TM, LT25>25-75, LT25>GT75

*Results of pairwise comparisons for similar data in 2003 are included. N/A = data not available or not applicable.

Table 7.12. MANOVA Response Variables by Location Type (NS and WT only), Adjusting for Study Area, Habitat, and Canopy Closure for Southwestern Willow Flycatcher Microclimate Data along the Virgin and Lower Colorado River Regions, June–August, 2004*

Response Variable	*P* for Overall Model	R^2 (%)	*P* for Location Type		Other Significant Predictors 2004	Significant Pairwise Differences	
			2004	2003		2004	2003
Soil Moisture							
Mean soil moisture (% volume) plot center to 1.0 m	<0.001	16.5	0.246	N/A	Study area, Habitat	MW>MM, PA>MM, TM>MM, Mix>Tam	N/A
Mean soil moisture (% volume) 1.5–2.0 m from plot center	<0.001	25.9	0.187	N/A	Study area, Habitat	MW>MM, PA>MM, TM>MM, Mix>Tam	N/A
Mean distance to saturated/ inundated soil	<0.001	44.8	0.569	N/A	Study area, Canopy	MM>MW, MM>TM, PA>MW, PA>TM, 25-75>GT75	N/A
Temperature/Humidity							
Mean diurnal temperature (°C)	<0.001	58.3	0.001	0.060	Study area	WT>NS, MM>MW, MM>PA, MM>TM, MW>PA, TM>PA	N/A
Mean maximum diurnal temperature (°C)	<0.001	36.5	<0.001	0.017	Study area	WT>NS, MM>MW, MM>PA, MM>TM, MW>PA	MM>TM, Mix>Nat, Tam>Nat
Mean diurnal relative humidity (%)	<0.001	50.3	0.053	0.127	Study area	MW>MM, TM>MM, MW>PA, TM>MW, TM>PA	MW>MM, TM>MM, MW>PA, TM>PA, Nat>Mix
Mean nocturnal temperature (°C)	<0.001	33.0	0.701	0.951	Study area, Canopy	TM>MW, TM>PA, 25-75>LT25	N/A
Mean minimum nocturnal temperature (°C)	<0.001	44.2	0.424	0.335	Study area, Canopy	MM>PA, MW>PA, TM>MW, TM>PA, 25-75>LT25, GT75>LT25	TM>MM, TM>MW, TM>PA
Mean nocturnal relative humidity (%)	<0.001	63.2	0.407	0.236	Study area	MM>PA, TM>MM, MW>PA, TM>MW, TM>PA	N/A
Mean daily temperature range (°C)	<0.001	35.1	<0.001	0.771	Study area, Canopy	WT>NS, MM>MW, MM>PA, MM>TM, LT25>25-75, LT25>GT75	N/A

*Results of pairwise comparisons for similar data in 2003 are included. N/A = data not available or not applicable.

Table 7.13. Correlations (R) among response variables for Southwestern Willow Flycatcher microclimate data along the Virgin and lower Colorado River regions, June–August, 2004[1]

Predictor Variables	SM Plot Center	SM 2.0 m	Distance to Water	Mean Day Temp	Mean Max Day Temp	Mean Day Rel. Hum.	Mean Night Temp	Mean Min Night Temp	Mean Night Rel. Hum.	Mean Day Temp Range
Mean soil moisture (% volume) plot center to 1.0 m	1.0	0.96*	-0.16*	-0.35*	-0.28*	0.33*	-0.13	-0.04	0.16*	-0.21*
Mean soil moisture (% volume) 1.5–2.0 m from plot center	-	1.0	-0.17*	-0.38*	-0.32*	0.33*	-0.13	-0.03	0.14	-0.25*
Mean distance to saturated/ inundated soil at setup	-	-	1.0	-0.04	-0.02	-0.25*	-0.04	-0.09	-0.27*	0.01
Mean diurnal temperature (°C)	-	-	-	1.0	0.80*	-0.18*	0.51*	0.38*	0.28*	0.65*
Mean maximum diurnal temperature (°C)	-	-	-	-	1.0	-0.27*	0.20*	0.12	0.16*	0.81*
Mean diurnal relative humidity (%)	-	-	-	-	-	1.0	0.19*	0.33*	0.79*	-0.40*
Mean nocturnal temperature (°C)	-	-	-	-	-	-	1.0	0.87*	0.13	-0.24*
Mean minimum nocturnal temperature (°C)	-	-	-	-	-	-	-	1.0	0.26*	-0.32*
Mean nocturnal relative humidity (%)	-	-	-	-	-	-	-	-	1.0	0.08
Mean daily temperature range (°C)	-	-	-	-	-	-	-	-	-	1.0

[1]Positive numbers = direct correlation; negative numbers = inverse correlation; * = *P*<0.05)

DATA COLLECTION AFTER NESTS WERE VACATED

Because so few differences were found in 2004 (as in 2003) between consecutive weeks for T/RH and SM measurements, we were again confident in the validity of measuring nest microclimate after nests were vacated. A total of 88 pairs of weeks were possible: 11 weeks from mid-May to mid-August, in the four study areas, with two measures each. Of these, only five pairs of weeks (or 6%) differed significantly for SV measurements of mean diurnal temperature and mean soil moisture; three were at the peak of the nesting season (June); and two were outside the peak.

LOCATION TYPES: DESCRIPTIVE STATISTICS AND SINGLE EFFECTS ANALYSIS

Soil moisture at NS and WT sites was higher than at NU sites at Pahranagat and Topock. Canopy cover at this level of analysis was generally not a significant factor in the 2004 data as it had appeared to be in the 2003 data. The three measures of diurnal temperature differed among location types in 2004, with NU sites consistently hotter than NS sites, NU sites usually hotter than WT sites, and WT sites sometimes hotter than NS sites. Diurnal relative humidity was higher at NS sites than at NU sites at Pahranagat and Mesquite, as it was in 2003. As in 2003, nocturnal variables generally did not differ between location types.

INDIVIDUAL EFFECT OF PREDICTOR VALUES

Results of single effects analyses in 2004 were generally similar to those from 2003, with the exception that reliable soil moisture data were available in 2004. The NS and WT sites exhibited higher soil moisture, were closer to open water, and were cooler and more humid during the day than NU sites. The finding that study areas differed significantly for all variables was identical to findings from 2003. Again, as in 2003, most temperature and humidity variables differed among habitat types. Soil moisture variables, however, did not differ. Those sites with greater canopy closure exhibited a pattern similar to that detected in 2003 by being cooler during daytime and exhibiting greater soil moisture.

MANOVA MODEL

The first MANOVA analysis for all three location types for the 2004 data validated the results from 2003 by showing the same pattern of significance: NS sites during the daytime were cooler, had smaller temperature fluctuations, and were more humid than NU sites. In addition, the 2004 data revealed that NS and WT sites exhibited greater soil moisture and were closer to water than NU sites. These findings indicate that Southwestern Willow Flycatchers established territories and built their nests at sites with significantly cooler, more humid, and wetter microclimates.

The second MANOVA analysis comparing only NS and WT sites revealed that Southwestern Willow Flycatchers were building nests at sites within their territories that were cooler and exhibited smaller temperature fluctuations. Soil moisture, diurnal relative humidity, and all nocturnal T/RH variables were similar among NS and WT sites.

Our findings indicate that Southwestern Willow Flycatchers nest in habitats exhibiting lower mean diurnal temperatures, lower mean maximum diurnal temperatures, and lower mean daily temperature ranges. These three measures were highly correlated and likely incorporate different perspectives on the same question: how hot does it get at the nest site? These results corroborate the 2003 findings that the largest difference between nest sites and non-nest sites is mean maximum diurnal temperature.

For this analysis, we split the soil moisture measurements into those measurements closest to plot center and those farther away. The results were essentially the same for both measures, suggesting that it might be more efficient and make the analysis less complicated by combining them into one measure in future analyses.

COMPARISON WITH OTHER FINDINGS

Allison et al. (2003) reported that habitat within Southwestern Willow Flycatcher nesting territories exhibited greater canopy closure than non-nesting plots in Arizona, a relationship they suggested might provide a more favorable (i.e., more moderate) microclimate at nests. Our finding that NS and WT sites had greater canopy closure than NU sites at two study areas was consistent with Allison et al. (2003). Our vegetation analyses (see previous chapter), which used a quantitative, continuous measure rather than a categorical measure of canopy closure, parallel this, in that canopy closure was greater at NS sites than at NU sites in all study areas.

At the four life history study areas, McKernan and Braden (2001a, 2001b) reported that mean daily temperature range (they used the term "variation in temperature") was significantly greater at NU sites than at either NS or WT sites, but that NS and WT sites were similar. However, their difference between NU and NS sites was small, which was apparently the reason they discounted the difference as biologically insignificant and reported the following: "Selection of nest sites or territories by the…flycatcher was not found to be affected by specific requirements in temperature, relative humidity, or stability in these microclimate variables. Therefore, the microclimate variables are unlikely to limit habitat suitability for the species" (McKernan and Braden 2001b:78). They also reported that "…microclimate variables between native and non-native habitat types, under the same hydrological conditions, do not limit habitat suitability for the …flycatcher" (McKernan and Braden 1999:58, McKernan and Braden 2001b:81).

The 2004 findings supported our earlier assertion (Koronkiewicz et al. 2004) that the differences among our mean diurnal temperature measures at the three location types, although small (only 2.6 degrees C), appear to be biologically meaningful since they paralleled significant vegetative differences identified in the previous chapter and reported by Allison et al. (2003). Therefore, it continues to appear that microclimate limits nesting habitat suitability, territory location, and nest placement. This key difference between our findings and those of McKernan and Braden (2001b) should be interpreted with caution as we were unable to replicate their field methods, and we used a different approach to statistical analysis. Additional microclimate data collected in subsequent years will continue to show whether the patterns observed to date are consistent across years and will help clarify whether suitable nesting habitat for willow flycatchers is limited by microclimate.

This page intentionally left blank.