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A CHARACTERIZATION OF VEGETATION IN NESTING AND NON-NESTING PLOTS FOR SOUTHWESTERN WILLOW FLYCATCHERS IN CENTRAL ARIZONA

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Abstract. We described habitat features at nesting plots of Southwestern Willow Flycatchers (*Empidonax traillii extimus*) in two study areas in central Arizona, and identified features that discriminated between nesting and non-nesting plots. Flycatchers showed preferences for nest placement close to breaks in the canopy and where there was more foliage at nest height and below; these preferences have also been described for Willow Flycatchers in other parts of the range. Other preferences we identified seemed unique to this region, reflecting the dominance of non-native saltcedar in nesting areas but also that the remaining native woody vegetation serves as an indicator of nesting habitat. High foliage density above the nest may be important for creating a suitable microclimate in the low desert landscape in which these birds nest.

Key Words: Arizona, canopy, *Empidonax traillii extimus*, nest height, nesting plots, Southwestern Willow Flycatcher, vegetation.

The endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*) breeds in riparian vegetation across the southwestern United States. Throughout this range, riparian habitat has been affected by the last century of land management practices. Prior to the 1880s, riparian habitats along low-elevation rivers and streams in Arizona were wetter than at present, and supported primarily native tree and shrub species (Minckley and Brown 1994). Since then, river channelization, impoundment and diversion, groundwater withdrawal (Stromberg 1993), and excessive livestock grazing (Amour et al. 1991) have created a less favorable environment for regeneration of native riparian plants. Overall, up to 90% of riparian habitat in Arizona has been degraded (Governor's Riparian Habitat Task Force 1990), which has restricted breeding Southwestern Willow Flycatchers to isolated sites within a few locations in the state. The future status of Arizona's Southwestern Willow Flycatcher populations is related to our ability to identify, protect, and conserve its breeding habitat.

Roosevelt Lake, at the confluence of Tonto Creek and the Salt River, hosts one of the largest breeding Southwestern Willow Flycatcher populations in Arizona (up to 115 territories; Paradzick and Woodward *this volume*), but current nesting habitat will flood and be destroyed when lake waters rise to the level of the newly renovated dam (U.S. Fish and Wildlife Service 1996). Characterization of nesting habitat at Roosevelt Lake is important as a description of nesting habitat in general, but also for comparison to vegetation in other areas to which these birds might relocate. The closest known breeding area to Roosevelt Lake is at the Gila/San Pedro River confluence, where at least 76 territories have been supported each year since 1997 (Paradzick and Woodward *this volume*). At both areas, nesting territories of Southwestern Willow Flycatchers are spatially clustered within patches of even-aged vegetation. This has led to speculation that some suitable nesting habitat remains unoccupied in each area, and that flycatchers displaced from Roosevelt Lake may relocate to the Gila/San Pedro River confluence (U.S. Fish and Wildlife Service 1996). It is also possible that characteristics within the patches of even-aged vegetation explain selective nest placement and clustering, and could inform wildlife managers about features to preserve and protect in these and other possible breeding areas.

Studies of nesting habitat of various subspecies of Willow Flycatchers have been conducted in California (*E. t. adastus*; Flett and Sanders 1987), along the Colorado River in the Grand Canyon (*E. t. extimus*; Brown 1988), and in Colorado (*E. t. adastus*; Sedgwick and Knopf 1992). These studies concluded that compared to other areas in the same vegetation patches, flycatcher nests were usually built closer to surface water and were surrounded by higher density of vegetation at nest height and below. Beyond these generalities, however, each study described different species of nesting tree, canopy structure, and nest placement within vegetation. Because Willow Flycatcher nesting habitat can vary substantially by region (Sedgwick 2000), data from central Arizona can yield insights into Willow Flycatcher habitat use in a desert landscape.

Here, we describe vegetation characteristics measured in Southwestern Willow Flycatcher nesting plots and in non-nesting plots within the same vegetation patches at two sites in central

Arizona. Our goals were to identify specific variables that describe potential Willow Flycatcher breeding habitat locally and to contribute to understanding of general features that characterize breeding habitat throughout the range. Our objectives were (1) to understand how plots within patches used by nesting Willow Flycatchers differ from those that are not used, (2) to describe how features of nesting habitat in the two study areas compare, and (3) to distinguish attributes shared by nesting Willow Flycatchers in other parts of their range from those that are specific to central Arizona. Because riparian vegetation is often modified by seasonal high water flow and is characterized by rapid growth, and because flycatchers often moved to new patches between years, we also use our data to describe how vegetation features around Southwestern Willow Flycatcher nests differ substantially from year to year.

METHODS

Selection of Sites and Data Collection

The study areas in central Arizona, Roosevelt Lake (Gila County) and the Gila/San Pedro River confluence (Pinal County), are between 555 and 658 m in elevation, and are riparian corridors within the arid Sonoran desertscrub biome (Minckley and Brown 1994). Roosevelt Lake includes one site at the Salt River inflow, and another at the Tonto Creek inflow. The Gila/San Pedro River confluence area included one site on the Gila River and six sites on the San Pedro River. Vegetation occurred in even-aged stands within each site; stands that contained one or more Southwestern Willow Flycatcher territories were called patches. Many sites consisted of only one patch; however, four sites (Salt River inflow, Tonto Creek inflow, Dudleyville, and Indian Hills) contained more than one patch, and although the same sites were used both years, not all patches were consistent between years. Saltcedar (*Tamarix ramosissima*) was the dominant woody plant at all 19 patches in this study. Canopy and woody shrub vegetation also included seepwillow (*Baccharis salicifolia*), Goodding willow (*Salix gooddingii*), velvet mesquite (*Prosopis velutina*), and Fremont cottonwood (*Populus fremontii*).

We described and measured vegetation and habitat features in 1998 and 1999. So that each nesting plot represented an independent sampling unit, we took precautions to identify and measure features of only the first active nest (i.e., containing eggs) each year for each female (Rourke et al. 1999; Paradzick et al. 1999, 2000). We treated nests of the same female in different years as independent attempts because females usually switch mates and territories between seasons (Luff et al. 2000). Females feed young within the territory for up to two weeks after fledging (C. Paradzick, pers. obs.); to avoid disrupting this activity, we measured vegetation in August when the nest, territory, and adjacent flycatcher territories had been inactive for at least this long.

We measured vegetation and habitat characteristics at non-nesting plots in August 1999. We assigned plot centers at the Gila/San Pedro River confluence by placing a gridline transparency over aerial photographs of each patch, randomly selecting grid intersections, and locating these points in the field. For the larger Roosevelt Lake patches, non-nesting plot centers were randomly selected from Universal Transverse Mercator (UTM) coordinates within patches. Because patch boundaries were delineated and non-nest plots were located in the field with global positioning units (which have inherent spatial error), some randomly chosen non-nesting plots were in obviously unsuitable vegetation. Use of these plots would have exaggerated differences between nesting and non-nesting plots within the same patch, so we only used non-nesting plots that contained a saltcedar, Goodding willow, Fremont cottonwood, or velvet mesquite tree over 5 m tall (approximate average nest hgt; Paradzick et al. 1999, 2000). Non-nesting plots in both breeding areas were only measured if canopy cover was at least 70%, if they were at least 25 m from any active flycatcher nest, and if they had no nesting flycatcher activity. Flycatcher activity was determined following the protocol of Sogge et al. (1997a); if flycatchers were present adjacent to a non-nesting plot, the plot was extensively searched multiple times to confirm the absence of nests.

We measured vegetation and habitat variables within an 11.3 m radius circle (0.04 ha; James and Shugart 1970) centered on the nest or, for non-nesting plots, centered on the randomly determined point. Plots of this size are likely to be large enough to describe variability within a territory without measuring areas outside the territory (Sedgwick and Knopf 1992). Vegetation and habitat variables measured were taken or modified from the BBIRD protocol (Martin et al. 1997, Rourke et al. 1999). We also measured vertical foliage density (MacArthur and MacArthur 1961), but used a color microvideo pin-hole camera (lens: 3.7 mm 90°) to estimate density as the percentage of a 0.5 × 0.5 m checkerboard obscured by vegetation. The camera and board were placed 2 m apart and raised in parallel, and measurements were recorded at various heights up to 7.6 m; above this height, poles were difficult to manipulate, so we recorded only whether vegetation was present.

We counted the number of stems of saltcedar, seepwillow, Goodding willow, velvet mesquite, Fremont cottonwood, and snags; other woody plant species that occurred in fewer than 5 plots were not analyzed. We also recorded nest height, vegetation measurements, and distance of the nest to nearest native shrub or tree, nearest break in the vegetation, and nearest surface water. Surface water included both the natural stream channel and any supplemental water present at the site (e.g., irrigation run-off).

Modification of Variables for Analysis

The number of variables measured at plots varied from 404 in 1998 to 314 in 1999 (Appendix). Thirteen of these variables could only be measured in conjunction with a nest, and were not reported for non-nesting plots. The number of descriptive variables far outnumbered the nesting plots, so some variables were modified or consolidated before any analysis (Appendix). (1) Vertical foliage measurements were averaged across all heights and cardinal directions at a given distance from the nest, across all distances and cardinal directions at a given height, or across all distances at a given cardinal direction and height. (2) Canopy cover was averaged across all cardinal directions. (3) To reduce the number of classes with zero counts, stem counts were summed across all quadrants. (4) Saltcedar stem count categories were further combined into three groups according to diameter of stem at breast height (dbh): small shrubs (<2.5 cm dbh), large shrubs (2.5–8.0 cm dbh), and trees (>8.0 cm dbh). (5) Each of the native species were described as either shrubs (<8.0 cm dbh) or trees (>8.0 cm dbh), and were scored as present or absent. The Appendix also identifies variables that departed strongly from normality and were appropriately transformed before principal components analysis and before any averaging was done to generate composite variables.

Statistical Analyses

Describing variability of vegetation at nesting plots

We used principal components analysis (PCA) to describe habitat variation at nesting plots. Because only continuous variables perform well in PCA, we excluded any species for which stem count was only reported as presence or absence. We examined a plot of decreasing eigenvalues (scree plot) to decide the number of components to extract (Dunteman 1989) and followed with varimax rotation to improve interpretation of components. For each principal component, scores were used to build ANOVA models to test whether variation could be accounted for as an effect of year or breeding area. Patches were included in the models as a factor nested within breeding areas.

Describing differences between nesting and non-nesting plots within a patch

Data from nesting and non-nesting plots were used to build a logistic regression model to classify future plots based on their potential to be used in a nesting territory. A best subsets technique was used to reduce the number of variables retained in the analysis. The procedure involved ranking the P-values of variables in the first model from lowest to highest, rebuilding the model without the variable with the lowest P-value, and repeating the process until four models had been explored. Variables were permanently removed from the model if the sum of their rank scores was higher than any variable that had ever scored in the lowest 20. The same procedure was followed again, using the lowest 15, then the lowest 10 ranking P-values.

Although application of logistic regression does not require assumptions about the underlying data distribution, some transformations facilitate interpretation of odds ratios. Odds ratios indicate the multiplicative effect on the odds for every unit change in an independent variable. Once the set of variables in the final model was identified, some were transformed to other units. For instance, because there were as many as 973 small-diameter saltcedar stems in a plot, we were more interested in describing how the odds change with a 10% increase in the number of stems, rather than with an increase of a single stem.

RESULTS

We gathered data from 85 first nests in 1998 and 130 in 1999, and measured vegetation and habitat characteristics at 123 non-nesting plots in 1999.

Variability of Vegetation at Nesting Plots

PCA identified six gradients that described variation in habitat at nesting plots. Sixteen variables had loadings $> |0.50|$ on these principal components (PC; Tables 1 and 4). Based on variable loadings, the first four PCs were similar for the full model (Table 1) and for models built separately with each year of data. Thus, correlations between variables were similar each year and overall. Combining data from both years resulted in description of an additional two PCs; overall the six PCs explained 66.6% of the variance between plots (Table 1).

PC1, PC2, and PC5 described the size classes of woody species and snags and the structure of this vegetation, represented by stem counts and canopy height and density (Table 1). PC1 described a gradient from plots with many small-diameter saltcedar stems and small snags to plots with a high, dense canopy. PC2 captured the fact that Southwestern Willow Flycatchers nested in plots with many native shrubs and trees but also in plots with many large-diameter saltcedar and small snags. As described by PC5, nesting plots in some patches were farther from water and had few large-diameter snags; those that were closer to water had more large-diameter snags.

PC1, PC3, PC4, and PC6 described the range of densities of foliage and canopy cover that characterized nesting plots (Table 1). PC1 reflected the range of canopy heights and densities, whereas PC3 and PC4 described vegetation density at or below average nest height (4.5 m $\pm$ 1.41 SD units, $N = 192$), either within 1 m of the nest (PC3) or averaged at three distances from 1 to 11 m from the nest (PC4). PC6 was attributable to variability in distance of each nest to the nearest break in the canopy.

ANOVAs for each of the six PCs indicated that nesting plots were more similar within than between patches except possibly for PC3 (Table 2). Species composition of woody vegetation did not change between years within a patch. However, because a different set of patches was used for nesting each year, statistically significant interaction effects for year-by-study area for PC1 and PC2 scores indicated that changes in patch use also resulted in use of areas with different species composition and structure. In 1999, patches used at Roosevelt Lake had shorter, less dense canopies and more small diameter saltcedar and snags (Fig. 1). This description also

TABLE 1. ROTATED PCA LOADINGS, EIGENVALUES, AND CUMULATIVE PERCENT VARIATION EXPLAINED IN VEGETATION AMONG SOUTHWESTERN WILLOW FLYCATCHER NESTING PLOTS IN 1998 AND 1999 AT ROOSEVELT LAKE AND THE GILA/SAN PEDRO RIVER CONFLUENCE IN ARIZONA

Variable	PC1	PC2	PC3	CP4	PC5	PC6
Vertical foliage >1 m N and S of the nest, 7.6 m high	−0.79	0.14	0.02	0.13	−0.11	0.06
Number of saltcedar stems <2.5 cm diam	0.77	−0.19	0.11	0.19	0.07	0.23
Vertical foliage <1 m N and S of the nest, 7.6 m high	−0.73	0.00	0.12	0.08	−0.01	0.17
Number of saltcedar stems 2.5–8.0 cm diam	0.72	−0.08	0.11	0.12	0.25	0.40
Canopy height	−0.64	−0.24	−0.21	−0.15	0.14	−0.13
Distance to nearest native over 5 m high	−0.09	0.82	−0.03	−0.22	−0.05	−0.17
Number of saltcedar stems greater than 8 cm diam	−0.35	0.76	−0.06	0.15	−0.07	0.13
Number of snags less than 8 cm diam	0.42	0.60	−0.10	0.16	0.30	0.07
Vertical foliage <1 m N and S of the nest, 2 m high	−0.02	−0.07	0.74	0.06	−0.14	−0.15
Vertical foliage <1 m N and S of the nest, 5 m high	0.05	−0.05	0.72	−0.03	0.17	0.16
Percent canopy cover	−0.20	−0.18	−0.23	0.77	0.03	0.03
Vertical foliage >1 m N and S of the nest, 5 m high	0.18	0.21	0.22	0.59	−0.02	0.22
Vertical foliage >1 m N and S of the nest, 2 m high	0.29	−0.01	0.36	0.52	0.21	−0.27
Number of snags greater than 8 cm diam	0.05	0.14	−0.15	−0.07	−0.82	−0.08
Distance to water	0.29	0.33	−0.19	−0.02	0.63	−0.14
Distance to canopy opening	0.09	−0.02	−0.02	0.06	0.00	0.86
Eigenvalue	3.6	2.0	1.6	1.3	1.2	1.0
Cumulative percent variance	22.6	35.2	45.0	53.0	60.5	66.6

fit nesting plots in patches at the Gila/San Pedro River confluence in 1998. Overall, Roosevelt Lake had fewer native woody plants and more large saltcedar and small snags (Fig. 1). As reflected by PC4, in both years, nests at Roosevelt Lake had more canopy cover and denser foliage at nest height and below, at least 1 m to the north and south of the nest than did nests at the Gila/San Pedro River confluence. Both study areas scored higher on PC4 in 1998 than in 1999. The statistically significant interaction effect of year and study area for PC1 and PC3 scores characterized nesting plots at Roosevelt in 1999 and Gila/San Pedro River confluence in 1998 for their greater canopy height, higher foliage density above average nest height, and denser foliage in the immediate vicinity of the nest, at and below average nest height (Fig. 2). The statistically significant effect on PC6 of patches and of the interaction effect of year and study area (Table 2) reflected the fact that nests were a similar distance from canopy openings both years at the Gila/San Pedro River confluence, whereas at Roosevelt Lake, nests were built much closer to canopy openings in 1998 than in 1999. Thus, the model reflects significant between-year differences due to use of different patches at Roosevelt.

DIFFERENCES BETWEEN NESTING AND NON-NESTING PLOTS WITHIN A PATCH

There were 15 variables in the final logistic regression model (Table 3). As distance to canopy opening doubled, the odds of a plot being occupied by Southwestern Willow Flycatchers decreased 44%. Doubling distance to water decreased the odds 24%, though the change was not significant at the $\alpha = 0.05$ level. For each meter in canopy height, odds of being occupied more than tripled. Foliage density, reflected by percent canopy cover and vertical foliage measurements at 2 and 5 m height, increased the odds of a tree being used for nesting. Plots were more attractive to nesting flycatchers if they held more small-diameter (≤8 cm) velvet mesquite, more mid-sized (2.5 cm–8.0 cm) saltcedar stems, fewer small diameter (≤2.5 cm) or large diameter (≥8 cm) saltcedar, velvet mesquite, and Goodding willow. Descriptive statistics for these variables are presented in Table 4.

Some variables in the final logistic regression model did not contribute to the description of nesting plots (Table 3), although all had performed well in interim models. Goodding willows with diameters less than 8 cm rarely occurred on our plots, were almost always associated with nesting plots (30 of 34 instances),

TABLE 2. UNIVARIATE ANOVA TESTS ON PCA SCORES DESCRIBING VEGETATION GRADIENTS BETWEEN SOUTHEASTERN WILLOW FLYCATCHER NESTING PLOTS IN CENTRAL ARIZONA

PC	Source	Sum of Squares	df	F	P
1	Study area	0.236	1	0.05	0.849
	Year	0.025	1	0.00	0.965
	Patch	55.177	15	7.42	<0.001
	Study area*Year	8.173	1	16.48	<0.001
	Error	85.809	173		
2	Study area	21.324	1	6.35	0.048
	Year	0.000	1	0.00	0.996
	Patch	79.770	15	17.42	<0.001
	Study area*Year	3.038	1	9.95	0.002
	Error	52.815	173		
3	Study area	0.133	1	0.06	0.827
	Year	1.238	1	0.37	0.653
	Patch	22.464	15	1.62	0.073
	Study area*Year	3.366	1	3.64	0.058
	Error	159.955	173		
4	Study area	6.000	1	3.53	0.070
	Year	6.236	1	7.87	0.006
	Patch	49.310	15	4.15	<0.001
	Error	137.835	174		
5	Study area	0.000	1	0.00	0.993
	Year	0.368	1	0.79	0.376
	Patch	83.873	15	11.96	<0.001
	Error	81.316	174		
6	Study area	1.088	1	0.08	0.821
	Year	22.764	1	0.78	0.540
	Patch	37.965	15	4.71	<0.001
	Study area*Year	29.238	1	54.46	<0.001
	Error	92.885	173		

Notes: Patches were nested within study areas. Interactions were retained in models when $P < 0.10$.

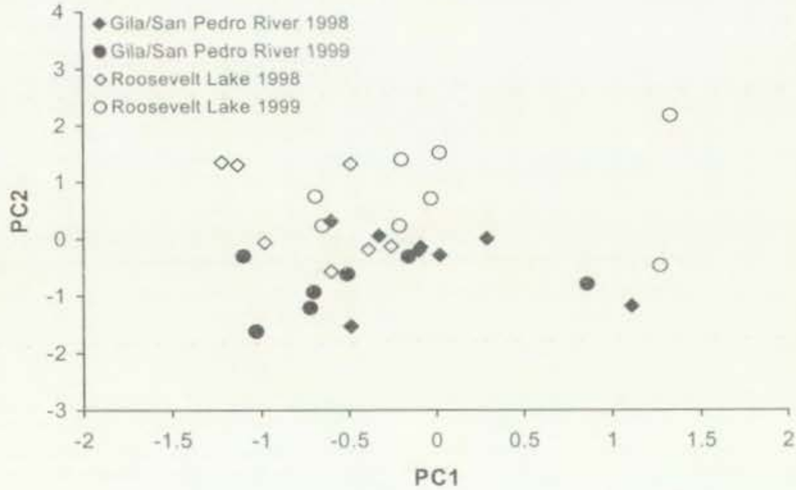

FIGURE 1. Average PC1 and PC2 scores within breeding patches for vegetation measurements at Southwestern Willow Flycatcher nest plots in central Arizona. Low PC1 scores described plots with high, dense canopy, while high scores indicated many small diameter saltcedar stems and snags. High PC2 scores indicated presence of many large saltcedars but few native shrubs and trees.

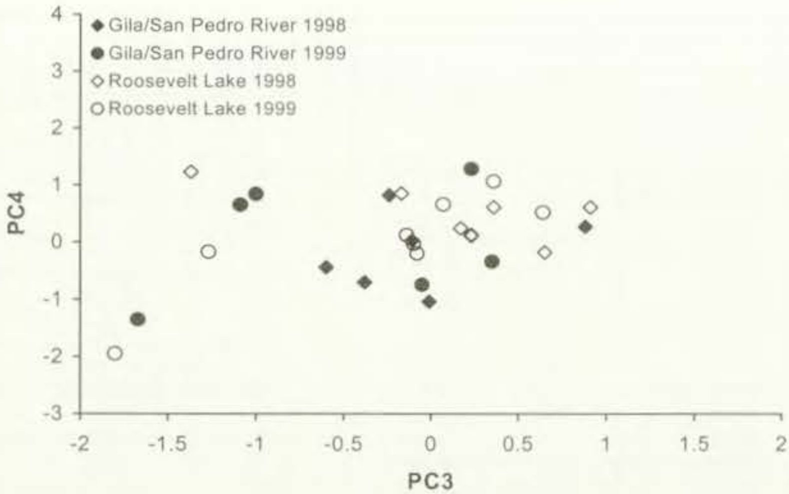

FIGURE 2. Average PC3 and PC4 scores within breeding patches for vegetation measurements at Southwestern Willow Flycatcher nest plots in central Arizona. Scores on both axes increased with density of vegetation at and below nest height within a one meter radius of the nest (PC3) or at a distance from one to 11 meters (PC4). PC4 was also positively correlated with percent canopy cover.

and were negatively correlated with presence of larger Goodding willows. As a result, the parameter estimate for Goodding willow was inflated and unstable. Two variables (vertical foliage to the south and 7.6 m high, and saltcedar stems larger than 8 cm diam) have high P-values and odds ratios so close to 1 that they do not add more information when combined with other variables in the model. These two variables were highly correlated with canopy height and vertical foliage to the north at 5 m high, respectively, so their lack of importance in the final model is best explained as a result of multicollinearity.

DISCUSSION

Habitat characteristics affect survival and reproductive success in birds; consequently, we expect species to have developed preferences for particular elements in their environment. Even for broad-ranging species like the Willow Flycatcher, we expect to uncover similar habitat features at nesting sites across their range. On the other hand, we also expect development of preferences that are not shared range-wide, but enable the species to exploit and accommodate each of the particular regions in which it breeds. Our description of habitat use in central Arizona clarifies common elements of flycatcher nesting habitat across its range, and focuses attention on nesting habitat preferences of Southwestern Willow Flycatchers within the desert landscape in particular.

Three types of variables characterized placement of nests within stands of even-aged vegetation: location, structural components, and floristic composition. Our finding that nests were located near canopy breaks matches the results of Flett and Sanders (1987), but differs from those of Sedgwick and Knopf (1992). The apparent difference in results may reflect differences in vegetation type and structure. Sedgwick and Knopf (1992) examined nests in shrub-willow clumps (mean height = 3.4 m) within larger herbaceous riparian stretches. In this study, nests were placed in large stands of trees (saltcedar, Fremont cottonwood, Goodding willow) that form a uniformly closed canopy (mean height at nest = 8.4 m; Table 4). Whereas Sedgwick and Knopf (1992) found that female-selected nest sites were more distant than randomly chosen points from openings in vegetation, in our more thickly vegetated sites, female Southwestern Willow Flycatcher selection of canopy breaks may reflect a foraging preference of aerial insectivores. In the relatively more open habitat described for other Willow Flycatcher populations, habitat structure that enables aerial foraging may be more readily available, and females can choose more closed nesting habitat but still be close to foraging habitat.

Nesting vegetation at our study sites was characterized by dense foliage up to 5 m high, approximately the same as the average nest height. Although plant species composition and height differed in specifics from that at our sites, both Flett and Sanders (1987) and Sedgwick and Knopf (1992) reported selection of high foliage density at nest height for other Willow Flycatchers. This preference may improve fledging success through enhanced concealment from pred-

TABLE 3. ODDS RATIOS FROM THE FINAL LOGISTIC MODEL DESCRIBING DIFFERENCES BETWEEN SOUTHWESTERN WILLOW FLYCATCHER NESTING AND NON-NESTING PLOTS IN THE SAME PATCH OF RIPARIAN VEGETATION IN CENTRAL ARIZONA.

Variable	Definition of unit increase	Odds ratio	95.0% C.I. Lower	95.0% C.I. Upper	P
Location in patch					
Distance to canopy opening	Doubling of distance	0.56	0.332	0.955	0.033
Distance to water	Doubling of distance	0.76	0.542	1.056	0.100
Amount of foliage					
Canopy height	1 m (up to 10)	3.19	1.776	5.740	<0.0005
Percent canopy cover	5% increments over 70%	1.45	0.920	2.281	0.110
Vertical foliage >1 m to the south, 7.6 m high	10%	1.22	0.916	1.622	0.173
Vertical foliage >1 m to the north, 5 m high	10%	1.45	1.077	1.951	0.014
Vertical foliage 9–11 m from the nest, 2 m high	10%	1.50	1.127	1.999	0.005
Species composition					
Distance to nearest native shrub/tree	5 m increments to 50 m	0.78	0.656	0.932	0.006
Saltcedar stems greater than 8 cm diam	Doubling of density	0.91	0.563	1.476	0.707
Saltcedar stems up to 2.5 cm diam	Doubling of density	0.34	0.171	0.670	0.002
Saltcedar stems 2.5–8.0 cm diam	Doubling of density	4.97	2.300	10.729	<0.0005
Velvet mesquite greater than 8 cm diam	Presence/absence	0.04	0.004	0.294	0.002
Velvet mesquite less than 8 cm diam	Presence/absence	9.92	1.899	51.864	0.007
Goodding willow greater than 8 cm diam	Presence/absence	0.04	0.006	0.320	0.002
Goodding willow less than 8 cm diam	Presence/absence	[a]			0.636

[a] Only 34 of 226 plots contained small-diameter Goodding willow; all but four of these were nesting plots. The odds ratio estimate for this variable therefore had high variance and changed dramatically as different logistic regression models were fitted; however, the odds ratio computed from a simple contingency table is 7.34.

TABLE 4. MEAN (AND SD) OF VEGETATION CHARACTERISTICS IN CENTRAL ARIZONA THAT CHARACTERIZED DIFFERENCES BETWEEN NESTING AND NONNESTING PLOTS AND/OR DESCRIBED CHARACTERISTICS THAT ARE HIGHLY VARIABLE BETWEEN NESTING PLOTS

Variable	Nesting plots	Non-nesting plots	Distinguished nesting and non-nesting plots	Source of variability among nesting plots
Distance to canopy opening (m)	9.2 (1.34)	13.7 (2.31)	X	X
Distance to surface water (m)	66.5 (5.22)	150.7 (2.07)		X
Distance to nearest native plant >5 m high (m)	12.9 (18.55)	24.4 (23.03)	X	X
Canopy height (m)	8.4 (0.32)	7.2 (0.41)	X	X
Percent canopy cover	95.0 (0.56)	88.9 (2.82)		X
Vertical foliage on north-south line at >1 m from nest tree (% of board obscured)				
2 m high	39.0 (13.70)	38.6 (17.90)	X	X
5 m high	49.8 (18.15)	31.6 (20.89)	X	X
7.6 m high	37.2 (24.28)	20.0 (23.33)		X
Vertical foliage bracketing nest tree on north-south line (% of board obscured)				
2 m high	38.0 (29.27)	37.2 (31.68)		X
5 m high	57.5 (31.56)	37.7 (32.94)		X
7.6 m high	46.4 (39.68)	21.7 (34.00)		X
Tree (diam >8 cm) count by species				
Saltcedar	24.7 (5.03)	16.4 (10.38)	X	X
Goodding willow	1.4 (3.46)	0.1 (1.00)	X	
Velvet mesquite	0.0 (0.39)	0.8 (2.49)		X
Snag	0.9 (3.17)	2.7 (3.08)		
Shrub (diam 2.5–8 cm) count by species				
Saltcedar	49.5 (7.88)	27.9 (11.84)	X	X
Goodding willow	0.4 (1.56)	0.0 (0.29)	X	
Velvet mesquite	0.8 (3.43)	1.3 (4.92)	X	
Snag	116.8 (23.75)	72.4 (32.63)		X

ators (Martin and Roper 1988) and/or by providing a more favorable microclimate at the nest (Walsberg 1981). One additional feature of nest placement at our study sites may provide improved microclimate at the nest. Nesting plots had higher canopy cover than non-nesting plots; this was not reported at other Willow Flycatcher breeding areas that experience lower average temperatures and less solar radiation during the breeding season.

Other elements of nesting plots in central Arizona are also revealing about the habitat available in this region. Saltcedar, a non-native plant, dominated all breeding patches in our study. However, Southwestern Willow Flycatcher females did not use all sizes/ages of saltcedar equally; nesting plots contained disproportionately more saltcedar stems that were 2.5–8 cm dbh, and fewer stems from both larger and smaller size classes. This is similar to the description of saltcedar use in the Grand Canyon (Brown 1988). We caution that selective use of a vegetation type or plant species (in this case, use of 2.5–8.0 cm dbh saltcedar) does not imply high quality habitat, perhaps associated with high reproductive rates (Van Horne 1983). Our study addressed flycatcher preferences but not habitat quality.

Note that although native trees and shrubs are not usually a dominant component of the vegetation at our study areas, presence of small-diameter Goodding willow or velvet mesquite nearby increased the odds of finding a Southwestern Willow Flycatcher nest (Table 3). We have no information to explain this association, but because younger shrubs require a higher water table than do larger trees, plants at this seral stage may indicate a particular humidity and/or microclimate that the birds prefer.

Some vegetation measurements were important for distinguish nesting and non-nesting plots in 1999, but also showed considerable variability among nesting plots that were measured in 1998 and 1999 (Table 4). For instance, in 1999, Southwestern Willow Flycatcher nest plots had denser vegetation at and below average nest height than non-nest plots. However, in a pattern that was also repeated with other variables, analysis of associated principal component scores from 1998 and 1999 indicated that there is considerable variation in foliage density among plots, arising from between-year differences in vegetation type and/or availability at each breeding area.

Overall, variation in available habitat at the two study areas was similar. Changes in reservoir level and seasonal flooding along the rivers have led to loss of some stands and new growth of others. This successional process is important for generating mid-sized saltcedar and Goodding willow stands that are apparently favored by Southwestern Willow Flycatchers. Such stands provide a possible example of habitat that is preferred but occasionally available only in limited quantities. Although our analyses showed that older trees generally characterize non-nesting plots, some nesting plots (especially at Roosevelt Lake) did include older trees. The between-year and between-area variation in habitat captured in our analysis might be related to the dynamic nature of riparian systems in central Arizona. We speculate that it is possible and expected that in some years there will be less preferred habitat available, so Southwestern Willow Flycatchers will nest in habitat that is available but not necessarily preferred. Spatial and temporal variability in habitat availability mean that in order to assure sufficient suitable nesting habitat in most years, managers may need to secure larger stretches of riparian vegetation than the nesting territories would actually cover in a given year. Habitat variability should be considered when determining the scale at which conservation efforts for this species will prove effective.

The scale at which we described habitat use by Southwestern Willow Flycatchers must also be carefully examined. This study was precipitated in part by the observation that nesting territories are often spatially clustered within what initially appeared to be homogeneous vegetation stands. Our analysis of variables centered on the nest represents one level of habitat selection and does not address selection questions at other scales. For instance, at the study area scale, use of only riparian habitat is evidence that distance to water is an important characteristic. However, distance to water did not differ significantly between nesting and non-nesting plots within a particular patch of riparian habitat. Study of stands that are used and those that are not may reveal that it is at this scale that distance to water describes habitat used by Southwestern Willow Flycatchers. Fine-scale habitat selection may also differ among sexes; Sedgwick and Knopf (1992) cautioned that nest placement describes only one aspect of breeding bird biology, and male Willow Flycatchers may select for different characteristics than do females, e.g., more exposed perch sites for advertisement and territorial defense. Our results provide insight into one scale of habitat use by Southwestern Willow Flycatchers in this dynamic, patchy, and fragmented landscape.

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APPENDIX. VARIABLES MEASURED IN PATCHES OCCUPIED BY SOUTHWESTERN WILLOW FLYCATCHERS IN CENTRAL ARIZONA

	Year		Measurement location		
Variable	1998	1999	Cardinal directions	Meters from plot center	Transformation[a]
Plot center relative to patch features					
Distance to open canopy	X	X			L
Distance to surface water	X	X			L
Distance to nearest native shrub/tree	X	X			
Canopy characteristics					
Height of canopy	X	X			
Seepwillow canopy cover >40%	X	X			
Fremont cottonwood canopy cover >40%	X	X			
Velvet mesquite canopy cover >40%	X	X			
Goodding willow canopy cover >40%	X	X			
Saltcedar canopy cover >40%	X	X			
Canopy cover	X	X	N, S, E, W		A, M
Foliage density at given height					
Vertical foliage at 2 m	X	X	N and S	2, 6, 10	M
Vertical foliage at 5 m	X	X	N and S	2, 6, 10	M
Vertical foliage at 7.6 m	X	X	N and S	2, 6, 10	M
Vertical foliage around nest tree at 2 m	X	X	N to S	0	
Vertical foliage around nest tree at 5 m	X	X	N to S	0	
Vertical foliage around nest tree at 7.6 m	X	X	N to S	0	
Foliage presence around nest tree at >7.6	X	X	N to S	0	
Vertical foliage around nest tree at 2 m	X		E to W	0	
Vertical foliage around nest tree at 5 m	X		E to W	0	
Vertical foliage around nest tree at 7.6 m	X		E to W	0	
Foliage presence around nest tree >7.6 m	X		E to W	0	
Vertical foliage at 2 m	X		[b]	2	M
Vertical foliage at 5 m	X		[b]	2	M
Vertical foliage at 7.6 m	X		[b]	2	M
Vertical foliage at 2 m	X		[b]	6	M
Vertical foliage at 5 m	X		[b]	6	M
Vertical foliage at 7.6 m	X		[b]	6	M
Vertical foliage at 2 m	X		[b]	10	M
Vertical foliage at 5 m	X		[b]	10	M
Vertical foliage at 7.6 m	X		[b]	10	M
Presence of canopy >7.6 m	X		[b]	2	
Presence of canopy >7.6 m	X		[b]	6	
Presence of canopy >7.6 m	X		[b]	10	
Stem counts					
Snag stems of diameter <8 cm	X	X	N, S, E, W		S, M
Snag stems of diam >8 cm	X	X	N, S, E, W		S, M
Goodding willow stems of diam <8 cm	X	X	N, S, E, W		M
Goodding willow stems of diam >8 cm	X	X	N, S, E, W		M
Fremont cottonwood stems of diam <8 cm	X	X	N, S, E, W		M
Fremont cottonwood stems of diam >8 cm	X	X	N, S, E, W		M
Velvet mesquite stems of diam <8 cm	X	X			M
Velvet mesquite stems of diam >8 cm	X	X			M
Seepwillow stems of diam <8 cm	X	X	N, S, E, W		M
Saltcedar stems of diam <2.5 cm	X	X	N, S, E, W		S, M
Saltcedar stems of diam 2.5–8 cm	X	X	N, S, E, W		S, M
Saltcedar stems of diam >8 cm	X	X	N, S, E, W		S, M

[a] L = Log 10, S = square root, A = Arcsine square root, M = Average over measurements taken in different cardinal directions or locations in the plot as indicated. Transformations were used before PCA and before creating variables by averaging.

[b] All four cardinal directions measured in 1998; only north and south measurements taken in 1999.