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NESTING ECOLOGY OF SCISSOR-TAILED FLYCATCHERS IN SOUTH TEXAS

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ABSTRACT.—We examined nest-site selection and nesting success of the Scissor-tailed Flycatcher (*Tyrannus forficatus*) on the Rob and Bessie Welder Wildlife Foundation Refuge, San Patricio County, Texas in 1992–1993. Mesquite (*Prosopis glandulosa*) comprised 22% of available shrubs; however, Scissor-tailed Flycatchers used shrubs out of proportion to their availability, placing 91% of their nests in mesquite. Scissor-tailed Flycatcher nests were placed in taller shrubs with less vertical cover and patchiness, with less total horizontal cover, and with greater heterogeneity than in random sites. The majority of nests were oriented to the northwest (18%), north (17%), and northeast (23%). Successful nests were in shrubs with less vertical patchiness and horizontal cover and with greater vertical cover ($\leq$1 m) and horizontal heterogeneity than unsuccessful nests. Nest-site selection appeared to be a tradeoff between orienting nests to provide protection from abiotic factors while minimizing horizontal cover to allow sufficient visibility for nest defense. *Received 7 April 1995, accepted 1 Dec. 1995.*

Nest-site selection is closely tied to fitness (Martin and Roper 1988) by influencing losses caused by predators and weather. Tyrant flycatchers (*Tyrannus* spp.) breed later (Robins 1970) and have longer nesting cycles than most other open-nesting passerines. Except for three species of phoebes (*Sayornis* spp.), the Vermilion Flycatcher (*Pyrocephalus rubinus*), and the Acadian Flycatcher (*Empidonax virescens*), most flycatchers raise only one brood per year (Bent 1942, Robins 1970, Murphy 1989). Scissor-tailed Flycatchers (*T. forficatus*) tend to have the largest clutch size among the tyrannids (Murphy 1989), slower growth rates for nestlings, and more time spent in the nest (Murphy 1988). Scissor-tails breed throughout the south-central United States, with the core nesting range being located in north-central Texas (Fitch 1950). Like other flycatchers, Scissor-tailed Flycatchers typically place nests in relatively conspicuous locations, often near the canopy edge (Bent 1942) and at heights ranging from 1.5 to 12.2 m (Fitch 1950). Scissor-tailed Flycatchers tend to forage and nest along roadways in open prairies dotted with few trees (Bent 1942). Use of roadways and ditches by mammalian predators may render Scissor-tailed Flycatcher nests more susceptible to predation as well as increasing the possibility of predation on adults while foraging. The inherently greater diversity of snakes and avian predators in southern lati-

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tudes may impose an additional cause of potential nest failure. These factors, combined with the intense heat, high winds, heavy rainfall, and high humidity typical of the summer months in south Texas, are predominant factors influencing the environment and, therefore, nesting success. This leads to the prediction that Scissor-tailed Flycatchers have evolved specialized nest placement to mitigate these influences. Scissor-tailed Flycatchers should select the largest available shrubs within an area as nest sites because tall shrubs with greater volume facilitate placement of nests at locations inaccessible to terrestrial predators, provide protection from abiotic factors, and allow for nest defense from reptilian and avian predators and avian nest parasites.

Our objectives were to quantify nesting ecology and to test the hypothesis that nest-site selection and nesting success of the Scissor-tailed Flycatcher is a positive function of vertical cover and a negative function of horizontal cover of the nest shrub. Predictions based on this hypothesis were that (1) successful Scissor-tailed Flycatcher nests are placed in shrubs with greater vertical cover than shrubs containing unsuccessful nests; (2) successful nests are placed in shrubs with less horizontal cover than at unsuccessful nests; and (3) nests are placed within shrubs at locations inaccessible to mammalian and reptilian predators, i.e., a negative relationship should exist between relative nest height and relative horizontal distance of nest from main stem to shrub canopy.

STUDY AREA AND METHODS

We conducted this study on the Rob and Bessie Welder Wildlife Foundation Refuge which encompasses 3156 ha and is 80 km northeast of Corpus Christi in northern San Patricio County, Texas. The primary habitat associated with the study area was a mesquite-mixed grass community (Drawe et al. 1978) and was composed of moderately dense stands of honey mesquite interspersed with dense clusters of chaparral and interstitial areas of grass. Other common brush species include huisache (*Acacia smallii*), spiny hackberry (*Celtis pallida*), agarito (*Berberis trifoliata*), lotebush (*Ziziphus obtusifolia*), and lime pricklyash (*Zanthoxylum fagara*). The soil associated with the mesquite-mixed grass community is Victoria clay (0–1% slope). Prevailing winds are from the southeast and may reach average speeds of 56 km/h (Guckian and Garcia 1979). Peak periods of rainfall occur during April, May, and June.

We found Scissor-tailed Flycatcher nests from May through August 1992 and 1993 by traversing pastures and by using an extensive network of unimproved roads. Nests were located by observing Scissor-tailed Flycatchers and by visually inspecting shrubs. We marked nests, using florescent flagging placed on a shrub or structure adjacent to the nest shrub, and we revisited at three-day intervals, recording the number of eggs and/or young at each nest to determine nest fates. An extendible mirror-and-pole device was used to view the contents of nests. Evidence of nest success included observations of young fledging from a nest or the presence of young near a nest. Nests were considered successful if ≥ 1 nestling fledged. Failure was assumed when nest contents disappeared before the anticipated fledging date or when the nest was damaged or blown out of the shrub. Not all nests were found before the onset of egg-laying or incubation; therefore, success was quantified by using Mayfield's method (Mayfield 1961, 1975) to compensate for exposure. We tested for a difference in nest success between years with an *F*-test (Johnson 1979).

Nest sites were revisited to conduct vegetation measurements following fledging of young or upon nest failure. Since some nests were lost because of abiotic factors or predation or because some nests were inaccessible, only 60 nest sites were measured. Vegetation measurements were also taken at randomly selected sites ($N = 30$ each year) to represent available nest sites. Available shrubs were selected by pacing 100 m in a random direction from each Scissor-tailed Flycatcher nest site and then choosing the shrub nearest the end of the 100-m distance. We recorded shrub species and determined proportions of each species at used and at available sites for preference/avoidance analysis. Frequency of nest placement among available shrubs was compared using chi-square analysis. If a chi-square test resulted in rejecting the null hypothesis that a species was used in proportion to availability, a Bonferroni z-statistic was used (Neu et al. 1974) to estimate whether a Scissor-tailed Flycatcher selected or avoided that shrub species.

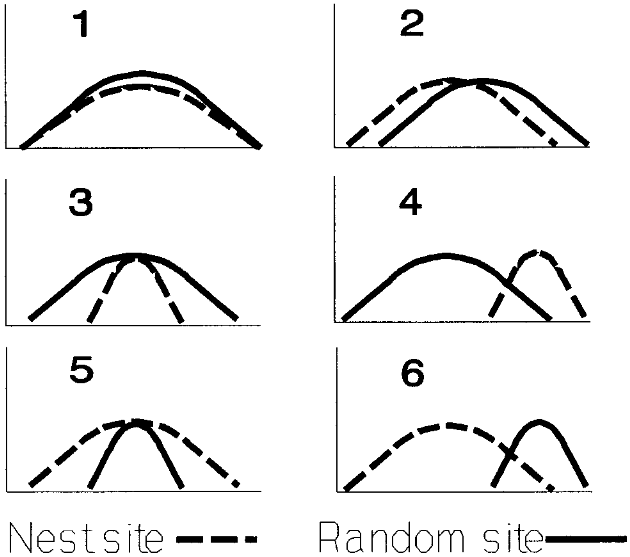
Variables were grouped into two levels of resolution: nest placement within the shrub and vertical and horizontal structure of the nest shrub to six m from the nest (Table 1). A 6-m-radius from the nest was selected to describe horizontal structure, since most nests were in uniform habitats composed of mesquite trees with canopies <10 m in diameter. We quantified horizontal and vertical structure (cover) and patterning (patchiness) of the vegetation using a method similar to the "bird centered view" described by (Weins and Rotenberry 1985). We quantified vertical and horizontal cover using a 2-cm diameter rod marked at 0.1 m increments. We recorded the number of 0.1 m increments touching vegetation out of the total possible number of increments within each of three height (vertical) or distance (horizontal) classes (0–1 m, 1–3 m, and 3–6 m). For example, within the 1–3 m class (a distance of 2 m) there were 20 possible increments. If vegetation touched 10 of the 20 increments, cover was 50%. Vertical cover was measured by extending the rod from the ground to the canopy projecting through the nest. Horizontal structure was quantified by extending the rod parallel to the ground, at nest height, in each of the four cardinal directions from the nest. Cover was calculated from the mean of the four cover estimates within each of the three distance classes. If the nest was too high to be reached from the ground or it could not be reached by climbing the tree, a ladder was used to measure horizontal cover. At the nest placement level, we determined average three-dimensional cover surrounding the nest. The structure rod was oriented vertically to nest height and structure measurements were recorded at 0.5-m increments moving away from the nest in each of the four cardinal directions. Mean percent cover was determined within each of three distance classes (0–1 m, 1–3 m, and 3–6 m) horizontally from the nest and extending from the ground to the outer canopy of the shrub. The coefficient of variation (CV) for structure variables represented an index of the patchiness of the measured variable. We also calculated a horizontal heterogeneity index (HHI) (Rotenberry and Weins 1980) using horizontal structure data.

We compared means and variances for statistical differences between nest sites and random sites and between successful and unsuccessful nests to explore the relationship between nest success and nest-site selection, (Ratti et al. 1984). Homogeneity of variance tests can indicate aspects of nest-site selection not readily detectable by comparing sample means alone. We considered nest-site selection to have occurred when (1) Scissor-tailed Flycatchers selected nest-site characteristics with different means but similar variance as random sites, (2) nest sites had similar means but less variance than at random sites, and (3) nest sites had different means and less variance than at random sites (Fig. 1). In the second situation, traditional comparisons of sample means would not have detected habitat selection, whereas,

TABLE 1
MEASURED AND CALCULATED VEGETATION VARIABLES USED TO QUANTIFY NEST SITES AND AVAILABLE RANDOM SITES

Variable	Description
Shrub characteristics[a]	
TOTHT	Total height of the shrub (m)
VI	Shrub vigor (1 = ≤25%, 2 = 26 ≤ 50%, 3 = 51 ≤ 75%, 4 = 76 ≤ 100%) based on the percent of living material
NSDIAM	Average diameter of the shrub at nest height (m)
NSVOL	Shrub volume (*pi*/3) (NSDIAM*NSDIAM*TOTHT/2) (m^3)
VCOV01	Vertical cover projected through nest from 0–1 m (%)
VCOV13	Vertical cover projected through nest from 1–3 m (%)
VCOV36	Vertical cover projected through nest from 3–6 m (%)
TVCOV	Total vertical cover 0–6 m (%)
CVVCOV	Coefficient of variation (CV) for the three vertical cover variables
HCOV01	Average horizontal cover 0–1 m from nest (%)
HCOV13	Average horizontal cover 1–3 m from nest (%)
HCOV36	Average horizontal cover 3–6 m from nest (%)
THCOV	Total horizontal cover (%)
CVHCOV	Coefficient of variation (CV) for the three horizontal cover variables
HHI	Horizontal heterogeneity
AVEDNW	Average distance to the nearest shrub (m)
CVDNW	Coefficient of variation (CV) of distance to the nearest shrub in each of the four compass directions
Placement characteristics	
NESTHT	Height of nest (m)
RELHT	Ratio between nest height and total height of shrub
TOPDIST	Vertical distance from nest to canopy of shrub (m)
ORIENT	Orientation of the nest within the shrub (degrees)
DTRK	Horizontal distance from the main stem to the nest (m)
TOTTRK	Distance from main stem to the canopy through nest (m)
RELDIST	Relative horizontal distance of nest between main stem and shrub canopy
NSTANGL	Angle of main branch supporting nest (degrees)
COV01	Three dimensional cover from 0–1 m around the nest (%)
COV13	Three dimensional cover from 1–3 m around the nest (%)
COV36	Three dimensional cover from 3–6 m around the nest (%)
TCOV	Total cover in a 6-m radius cube around the nest (%)
CVCOV	CV for the three cover measurements

[a] All shrub variables were used to compare flycatcher nests and random sites.



	Mean value	
Variance	not different	different
not different	1. no selection	2. selection
less at nest site	3. selection	4. selection
less at random site	5. no selection	6. no selection

FIG. 1. Possible combinations of means and variances at nest sites and random sites that indicate habitat selection or random choice.

an instance when sample means were different but variance was less at random sites would not indicate habitat selection.

Treatment means (nest vs random, successful vs unsuccessful) for nest-site variables were compared with a completely random design and a two-way factorial treatment structure with the general linear model (GLM) procedure (SAS 1988). When an interaction occurred between years, contrasts were used to compare treatments by year. Percentage or proportional data were arc-sine transformed before statistical analyses (Sokol and Rohlf 1973). Analyses were performed with SAS (Statistical Analysis Institute 1988) and conclusions were based on $\alpha = 0.05$ unless otherwise indicated.

RESULTS

Reproductive success.—Forty-eight nests were monitored during 1992–1993, resulting in 789 nest-days of observations (Table 2). The first nest-

TABLE 2
ESTIMATES OF NEST SUCCESS, CONFIDENCE INTERVALS, AND SOURCES OF NEST FAILURE FOR SCISSOR-TAILED FLYCATCHERS BREEDING

	1992	1993
Nest days	186	603
Number of eggs ($\bar{x}$ ± SD) (N)	4.4 ± 0.5 (12)A	4.5 ± 0.5 (19)A
Number of young ($\bar{x}$ ± SD) (N)	3.2 ± 1.6 (7)A	3.0 ± 1.0 (10)A
Daily mortality rate	5.9%	2.2%
Mayfield estimate (N)	94.1% (17)	97.8% (31)
95% confidence interval	90.6–97.6%	96.6–99.0%
Probability of survival to fledging	15.6%A	50.7%B
95% confidence interval	4.9–26.3%	34.8–66.6%
Sources of nest failure		
Weather (N)	45.5% (5)	7.7% (1)
Predation (N)	36.4% (4)	15.4% (2)
Abandonment (N)	18.1% (2)	7.7% (1)
Unknown (N)	0.0% (0)	69.2% (9)

[a] Means followed by the same letter are not significantly different ($P > 0.05$).

ing activity was recorded on 5 May 1992 and 3 May 1993. Egg laying began on 28 May 1992 and 25 May 1993. Mean fledging dates respectively were 1 July 1992 (N = 7) and 3 July 1993 (N = 10). Based on complete nests, the number of eggs/nest and number of fledglings/nest did not differ ($P \geq 0.05$) between years (Table 2). Nineteen nests were destroyed during storms or were removed (used as nesting material) by other birds before vegetation could be quantified. These and all other nests that could not be visually inspected because they were inaccessible were excluded. Of the remaining 48 nests (17 in 1992, 31 in 1993) used to calculate success, 31 were found before initiation of egg-laying. Probability of nesting success was greater ($P = 0.03$) during 1993 than 1992. Nest success was 39% when years were pooled. There was a year × nest success interaction for the number of eggs/nest ($P = 0.03$) and for the number of young/nest ($P = 0.0001$) between successful and unsuccessful nests. Both the number of eggs/nest ($P = 0.09$) and the number of young/nest were similar ($P = 0.06$) at successful and unsuccessful nests during 1992. Number of eggs/nest and young/nest were greater ($P = 0.01$, $P = 0.0001$, respectively) at successful nests than at unsuccessful nests during 1993.

Rainfall during 1992 (128.4 cm) and 1993 (102.8 cm) was above the annual average of 88.9 cm for the Welder Refuge and therefore may not reflect average conditions. Abiotic factors accounted for the largest percentage (46%) of nest failures in 1992. All five nests lost to abiotic factors were found on the ground near the shrub following storms. Predation accounted for 36% of nest failures, and the remaining 18% of failures were because of abandonment. Predation was assumed when nest contents disappeared under suspicious circumstances, i.e., eggs or young disappeared between consecutive visits or when contents disappeared following observations of predators near the nest site. In 1993, the majority (69%) of nest failures were because of unknown causes.

Frequency of shrub selection.—Scissor-tailed Flycatcher nests (N = 60) were placed nonrandomly among the available shrub species ($\chi^2 = 170.46$, df = 4, $P < 0.0001$). Frequency of available shrubs in the habitat was mesquite (22%), huisache (20%), spiny hackberry (18%), lime pricklyash (20%), brazil (*Ziziphus obtusifolia*) (8%), agarito (5%), Texas persimmon (*Diospyros texana*) (3%), sugar hackberry (*Celtis laevigata*) (2%), and wolfberry (*Lycium berlandieri*) (2%). Scissor-tailed Flycatchers selected mesquite and avoided all other shrubs during 1992 and 1993. Ninety-one percent of the nests (N = 55) were placed in mesquite. Nests were also placed in huisache (N = 1), lime pricklyash (N = 2), sugar hackberry (N = 1), and under a transformer on a telephone pole (N = 1).

Nest-site characteristics.—Nests were placed 2.8 ± 0.8 m high and 1.9 ± 1.0 m ($\bar{x}$ ± 1 SD; N = 60) from the main stem of the shrub. Relative height of the nest within the shrub and relative horizontal distance from main stem to the shrub canopy were 0.60 ± 0.11 and 0.49 ± 0.18, respectively. There was no correlation ($r = -0.15$, $P = 0.26$) between relative nest height and relative horizontal distance. Average height, diameter, and volume of nest shrubs were 4.7 ± 0.9 m, 7.6 ± 2.7 m, and 172.0 ± 133.0 m^3, respectively. Mean nest orientation was to the southeast; however, a majority (58%) of nests were oriented northwest (18%), north (17%), and northeast (23%) (Fig. 2).

Flycatcher vs random comparisons.—Thirteen of the 17 vegetation characteristic means differed ($P < 0.05$) between flycatcher nests and random sites (Table 3). The year × treatment (used or random) interaction was significant ($P = 0.0001$) for total horizontal cover. Total horizontal cover was greater ($P < 0.05$) at random sites than at nest-sites during 1992 but was not different ($P > 0.05$) during 1993. Scissor-tailed Flycatchers chose shrubs that were taller ($P < 0.001$), greater in diameter ($P < 0.001$) and volume ($P < 0.001$), and had less ($P < 0.001$) variation in vertical cover than random shrubs. They also chose shrubs with less vertical cover from 0–1 m ($P < 0.001$), from 1–3 m ($P = 0.001$), and from 0–6 m (total vertical cover) ($P \leq 0.001$). However, there was more ($P < 0.001$) vertical cover from 3–6 m at their nests than at random shrubs. Scissor-tailed Flycatchers selected sites that were more ($P = 0.002$) open, i.e., a greater distance to the nearest shrub and shrubs that were patchier

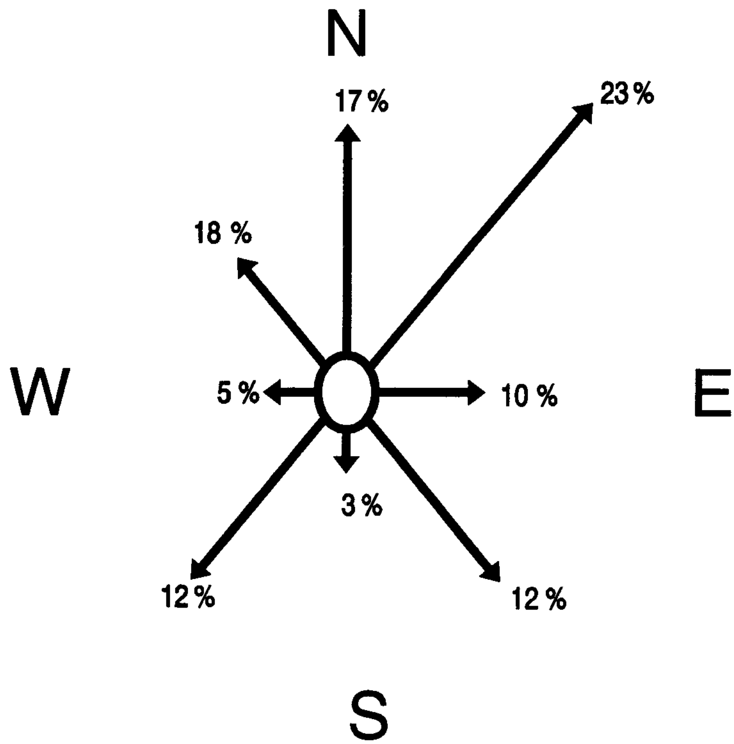


FIG. 2. Percent of Scissor-tailed Flycatcher nests (N = 60) oriented within each of the eight cardinal compass directions on the Rob and Bessie Welder Wildlife Refuge, 1992–1993.

($P < 0.001$), i.e., greater variation in the amount of horizontal cover, than random sites. Nests were also placed in shrubs with greater ($P < 0.001$) horizontal heterogeneity than random sites.

Tests for homogeneity of variance indicated differences ($P < 0.05$) for seven characteristics (Table 3). Scissor-tailed Flycatchers selected shrubs with greater variation in shrub diameter ($P < 0.001$) and volume ($P < 0.001$) than random shrubs. Random shrubs had greater ($P < 0.001$) variance for vertical cover from 0–1 m, from 1–3 m and for total vertical cover, with less ($P < 0.001$) variance for vertical cover from 3–6 m than shrubs selected by flycatchers. The variance of average distance to the nearest woody vegetation was greater ($P < 0.001$) at nests than at random sites.

Successful vs unsuccessful nest comparisons.—There was no difference ($P > 0.05$) between relative height or relative horizontal distance at suc-

TABLE 3

COMPARISON OF VEGETATION CHARACTERISTICS AT SCISSOR-TAILED FLYCATCHER NESTS (N = 60) VS RANDOM SITES (N = 60)

Variable	Flycatcher		Random		Ho: equal means	Ho: equal variance
	$\bar{x}$	SD	$\bar{x}$	SD	P-value	P-value
Shrub characteristics						
TOTHT*	4.7	0.9	2.0	0.9	0.000	0.841
V1	3.3	0.9	3.6	0.7	0.051	0.060
NSDIAM	7.6	2.7	2.0	1.5	0.000	0.000
NSVOL	172.0	133.0	10.3	27.0	0.000	0.000
VCOV01*	0.23	0.15	0.70	0.26	0.000	0.000
VCOV13*	0.19	0.12	0.39	0.30	0.001	0.000
VCOV36	0.33	0.17	0.04	0.10	0.000	0.000
TVCOV*	0.25	0.08	0.39	0.15	0.000	0.000
CVVCOV*	64.4	33.4	108.2	40.0	0.000	0.170
HCOV01	0.53	0.27	0.59	0.21	0.199	0.083
HCOV13	0.37	0.21	0.34	0.27	0.345	0.075
HCOV36*	0.20	0.25	0.26	0.23	0.037	0.466
THCOV*[a]	0.32	0.20	0.41	0.19	0.000	0.674
CVHCOV*	73.5	43.0	65.4	38.0	0.000	0.351
HHI*	1.7	0.6	1.0	0.5	0.000	0.239
AVEDNW	13.8	24.7	3.8	2.4	0.002	0.000
CVDNW	40.0	25.2	47.1	26.9	0.129	0.624

[a] Significant ($P < 0.05$) interaction between year and treatment (used and random). THCOV at used and random sites differed ($P < 0.0001$) for 1992 and was similar ($P = 0.6545$) for 1993.
* Habitat selection.

cessful and unsuccessful nests. Analysis of cover measurements at Scissor-tailed Flycatcher nests indicated vertical cover from 0–1 m was greater ($P = 0.036$) at successful nests (Table 4). Successful nests were also placed in shrubs with less ($P = 0.013$) patchiness of vertical cover than unsuccessful nests. The year × treatment (nest success) interaction was significant ($P < 0.05$) for horizontal cover from 1–3 m and from 3–6 m and for total horizontal cover. Contrasts indicated that three cover attributes at successful and unsuccessful nests differed for 1993 ($P < 0.05$) but not for 1992 ($P > 0.05$).

Tests for homogeneity of variance indicated differences for four characteristics (Table 4). Successful nests were placed in shrubs with less variation in vertical cover from 0–1 m ($P = 0.027$), CV of mean distance to the nearest shrub in each of the four cardinal compass directions ($P = 0.005$), and horizontal heterogeneity ($P = 0.005$). Variance for average distance to the nearest shrub ($P = 0.009$) was greater at successful nests.

TABLE 4

COMPARISON OF VEGETATION CHARACTERISTICS AT SUCCESSFUL (N = 17) AND UNSUCCESSFUL (N = 39) SCISSOR-TAILED FLYCATCHER NESTS ON THE ROB AND BESSIE WELDER WILDLIFE REFUGE, SAN PATRICIO COUNTY, TEXAS, 1992–1993

	Successful		Unsuccessful		Ho: equal means	Ho: equal variance
Variable	$\bar{x}$	SD	$\bar{x}$	SD	*P*-value	*P*-value
Shrub characteristics						
TOTHT	4.6	0.8	4.7	0.9	0.220	0.668
V1	3.4	1.0	3.2	0.9	0.801	0.648
NSDIAM	7.7	2.7	7.7	2.7	0.426	0.939
NSVOL	173.0	128.0	175.0	137.0	0.368	0.797
VCOV01*	0.29	0.12	0.21	0.16	0.036	0.027
VCOV13	0.20	0.12	0.18	0.11	0.342	0.953
VCOV36	0.31	0.15	0.33	0.18	0.172	0.131
TVCOV	0.27	0.06	0.24	0.09	0.218	0.231
CVVCOV*	48.8	25.7	71.6	32.6	0.047	0.304
HCOV01	0.45	0.25	0.56	0.27	0.200	0.811
HCOV13*[a]	0.33	0.22	0.39	0.21	0.003	0.686
HCOV36*[a]	0.15	0.19	0.24	0.28	0.000	0.153
THCOV*[a]	0.26	0.16	0.36	0.22	0.000	0.232
CVHCOV	73.6	49.0	72.5	42.5	0.812	0.453
HHI*	1.6	0.3	1.8	0.6	0.285	0.005
AVEDNW	17.9	34.6	12.7	20.8	0.401	0.009
CVDNW*	37.4	14.8	40.6	29.3	0.776	0.005
Placement characteristics						
NESTHT	2.8	0.9	2.8	0.8	0.176	0.643
RELHT	0.60	0.13	0.60	0.11	0.409	0.326
TOPDIST	1.8	0.6	1.9	0.5	0.912	0.373
ORIENT	171.0	68.0	113.0	68.0	0.066	0.867
DTRK	1.7	1.1	2.1	1.0	0.466	0.900
TOTTRK	3.8	1.4	3.9	1.4	0.426	0.939
RELTRK	0.46	0.21	0.50	0.18	0.775	0.243
NSTANGL	37	27	31	22	0.483	0.324
COV01	0.27	0.07	0.23	0.08	0.066	0.326
COV13	0.23	0.06	0.23	0.07	0.140	0.672
COV36	0.20	0.13	0.19	0.11	0.208	0.394
TCOV	0.24	0.06	0.23	0.06	0.279	0.685
CVCOV	32.7	35.7	31.8	25.1	0.463	0.077

[a] Significant ($P < 0.05$) interaction between year and treatment (successful and unsuccessful). HCOV13, HCOV36, and THCOV at successful and unsuccessful nests differed ($P < 0.05$) during 1993 but were similar ($P > 0.05$) during 1992.
* Habitat selection.

DISCUSSION

The nesting success rate (39%) for Scissor-tailed Flycatchers on the Welder Refuge was less than that reported for other flycatchers except Eastern Kingbirds (25.6%) in Kansas (Murphy 1986). Scissor-tailed Flycatchers had the highest success rate 81% (N = 16) (Murphy 1983) and clutch size 4.69 (N = 16) (Murphy 1988) of all tyrannids reported. Mean clutch size on the Welder Refuge was similar to that reported by Murphy (1988), suggesting Fitch's (1950) estimate of nest success was low, possibly because of the inclusion of incomplete nests. Similarities between clutch sizes indicate nests on the Welder Refuge suffered a greater mortality rate during the post-laying period. Above-average rainfall during the 1992 and 1993 breeding seasons was partially responsible for lower nesting success because high winds and heavy rains dislodged nests from shrubs. Murphy (1986) reported losses caused by weather were mostly from wind blowing nests from trees. Abiotic factors were also believed to have accounted for many of the nest failures from unknown causes during 1993. However, since most of the these nests could not be found, or the nest contents had disappeared, the exact cause of failure remains uncertain.

Nest success may be affected at two spatial scales: habitat in the immediate vicinity of the nest (shrub characteristics) and habitat surrounding the nest (characteristics of the nest patch) (MacKenzie and Sealy 1981, Martin and Roper 1988). This study focused on nesting success and nest-site selection at the nest shrub scale. We believe this degree of resolution was sufficient to describe nest-site selection by Scissor-tailed Flycatchers. Nests were placed, on average, 2.8 m high in shrubs 4.7 m tall. Mean height of available shrubs was only 2 m and therefore would not provide much horizontal obstruction for their nests placed in adjacent shrubs. Because of the nest height, conspicuous nest placement, and orientation away from prevailing winds, it appears that Scissor-tailed Flycatchers select attributes related to nest shrubs rather than the surrounding habitat.

Site selection for Scissor-tailed Flycatchers may have been a function of selecting characteristics that allowed adults to monitor and defend the nest site since horizontal cover was less at successful nests. Ricklefs (1977) found that a strong correlation existed between nest conspicuousness and intensity of nest defense in tropical passerines. Scissor-tailed Flycatcher nests were generally found >100 m apart and were located in open stands of mesquite on the Welder Refuge. Fitch (1950) noted that nests were never found within 76 y of each other. Spacing of Scissor-tailed Flycatcher nests is partially a function of the open habitat selected and partially because of the size and aggressive defense of individual territories. Placing nests in open shrubs (less vertical and horizontal cover) would allow for sufficient air space in which the birds can maneuver to attack intruders. However, less total cover may also increase the risk of nest failure from abiotic factors.

Nest orientation relative to the center of the shrub should influence losses of nests because of abiotic factors, including prevailing southeast winds and numerous thunderstorms originating in the Gulf of Mexico during the nesting season. Since only 25% of the nests were oriented to the east, southeast, or south (toward prevailing winds), the birds appeared to place nests so as to minimize the effects of abiotic factors. Placement of Scissor-tailed Flycatcher nests within shrubs appeared to minimize horizontal cover while favorable nest orientation may have provided some respite from the wind, rain, and sun, thus partially mitigating the effects of mortality from overexposure to the sun. Murphy (1985) described nestling deaths from overexposure to sun in Eastern Kingbirds, as a source of mortality.

Murphy (1983) noted that predation was the driving force behind nest-site selection in Eastern Kingbirds, as nests placed extremely low or extremely high within trees had the lowest probability of fledging young. He added that maximum success occurred at relative nest heights and relative horizontal distances from the tree center to the shrub canopy edge of about 0.5. Our results differ somewhat from the above. Although nests were placed at relative heights and horizontal distances of 0.6 and 0.5, respectively, there was no difference between successful and unsuccessful nests for either variable.

Nest concealment was greater at low predation nests than at high predation nests for woodland birds including the Hermit Thrush (*Hylocichla guttata*), Prairie Warbler (*Dendroica discolor*), Mourning Dove (*Zenaida macroura*), and Eastern Kingbird (Murphy 1983, Westmoreland and Best 1985, Martin and Roper 1988). Great-tailed Grackles (*Cassidix mexicanus*) appeared to be the primary avian predator of Scissor-tailed Flycatcher nests. Large groups of grackles were observed harassing Scissor-tailed Flycatchers at their nest sites on numerous occasions. Raccoons (*Procyon lotor*), and opossums (*Didelphis virginianus*) were the only common mammalian predators present on the study site capable of depredating the flycatcher nests. We documented no incidence of mammalian predation on nests during the two years of this study; however, these mammalian predators are nocturnal and direct observations would be unlikely. Vertical cover ≤ 1 m was greater at successful nests than at unsuccessful nests. Greater ground cover may inhibit some terrestrial predators from locating nests, although reptilian predators may actually benefit.

Nineteen nests were abandoned before egg-laying for unknown reasons.

Frequent visitation to nests has been documented to affect nesting success. However, daily intrusions, including removal of young for measurements, did not adversely affect nesting success of Scissor-tailed Flycatchers (Fitch 1950). Because nests of unknown fate were often found intact although empty, snake predation likely contributed to nest failure. Had mammalian and avian predators been responsible, it is likely that shell fragments or other signs would have been left at the nest site. Several species of snakes known to prey on eggs and nestlings were present throughout the study area. Kingsnakes (*Lampropeltis* spp.), yellow-bellied racers (*Coluber constrictor flaviventris*), and western coachwhips (*Masticophis flagellum testaceus*) were observed at nest sites on several occasions and were observed or suspected to be the source of nest failure on numerous other occasions for Dickcissels (*Spiza americana*), Mourning Doves, Northern Mockingbirds (*Mimus polyglottos*), and Northern Cardinals (*Cardinalis cardinalis*) on the Welder Refuge (Nolte, pers. observ.).

Strength of attachment of the nest to the shrub may be an important component of nest success. Many nests failed before hatching or fledging because they were dislodged from the nest shrub following storms. Conspicuous placement of nests may render them more vulnerable to unpredictable, heavy rainfall and wind events than those of most other passerines which nest in short, dense shrubs in south Texas. Additional research should be conducted to determine if the firmness of nest attachment is related to nesting success.

On the Welder Refuge, randomly available shrubs appeared to be of insufficient size to accommodate placement of flycatcher nests. Mesquite seemed to afford the best compromise by providing optimal cover and by allowing nests to be placed at locations inaccessible to terrestrial predators. Previous investigators have reported that Scissor-tailed Flycatchers nest in any species of tree that is isolated and is open-foliaged (Bent 1942, Fitch 1950). The structural attributes provided by mesquite may be only partially responsible for nest-site selection by Scissor-tailed Flycatchers. They selected for total height of nest shrubs; therefore, size relative to other available shrubs may also have a role in shrub selection on the Welder Refuge.

Based on the results of this study, we accept the hypothesis that Scissor-tailed Flycatchers select nest sites based on horizontal structure of the shrub. Our results indicate that nest-site selection in Scissor-tailed Flycatchers appears to be a trade-off between providing air space around the nest (less horizontal cover) for defense from predators and at the expense of increasing exposure to abiotic influences such as wind, rain, and solar radiation. Results did not, however, support the predictions that nest-site selection was a function of vertical cover or that a negative relationship existed between relative nest height and relative horizontal distance within the nest shrub.

About 400,000 ha of rangelands in Texas are annually treated with herbicides, often with the goal of decreasing the density of mesquite. Brush management practices, to one degree or another, result in setting back succession. We found evidence that Scissor-tailed Flycatchers show shrub-specific site tenacity. In 1993, six nests were placed in shrubs that contained a Scissor-tailed Flycatcher nest in 1992. Subsequent observations in 1994 indicated that 25 nests were in shrubs containing Scissor-tailed Flycatcher nests in at least one of the two previous years. If areas used as nest-sites are subsequently altered via some brush management practice, returning pairs of Scissor-tailed Flycatchers may attempt to renest in dead shrubs. We documented eight occasions when nests were placed in shrubs that were dead before initiation of nesting activity, and in all eight cases the nests failed. The widespread use of such practices could decrease the available nesting habitat for Scissor-tailed Flycatchers. Our results indicate this will undoubtedly result in a greater rate of nest mortality. Other passerine species, including cavity nesters or those that require larger shrubs for nest placement and support, could be equally affected. Managers should consider leaving strips or patches of untreated brush when large acreages of rangeland are managed. Another management strategy could be to leave dispersed mature mesquite in an area following treatment. Brush control on sites without mesquite should allow for the preservation of individuals or loose clumps of the largest trees available.

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