

Purple Martins in Oak Woodlands¹

Brian D. C. Williams²

Abstract

Purple martins are cavity-nesting swallows that once nested fairly widely in California's oak woodlands but are now rare in that habitat. The old oaks of the Tehachapi Range (southern Sierra Nevada) may now host the last martins that nest in oak woodlands, with approximately 100-200 pairs or about 15 percent of the California population. In summer of 2000, we found 57 nests in 46 valley and blue oaks and measured over 20 variables at nest sites and random paired sites. Martins selected large-diameter trees [\bar{x} = 104.3 cm diameter at breast height (dbh)] that were more prominent than random trees. Among all trees with holes, martins chose nest trees that were prominently positioned in the upper third of the landscape, and had less canopy cover at nest height than random sites. European starlings were uncommon where martins concentrated, and starlings were not observed at one area with 18 martin nests; this was the only area >1 km from any residential development. Martins may persist in portions of the Tehachapi Range because of a unique set of habitat and landscape conditions, including factors that seem to limit starlings to low densities.

Introduction

The western purple martin (*Progne subis arboricola*) (Pyle 1997) is a large, social cavity-nesting swallow that is generally rare and local in California. It is currently designated by the State of California as a Bird Species of Special Concern (Remsen 1978), and I have estimated an extrapolated statewide population of 800-1,000 breeding pairs (Williams 1998). Most of the population breeds in open coniferous forests in northwestern California, but the species is also known from oak and riparian (primarily sycamore) woodlands throughout the remainder of the state's non-desert regions (Grinnell and Miller 1944, Small 1994, Williams 1998). Oak woodlands once supported widespread populations of martins, which have been reported from oak woodlands in at least 15 counties (*table 1*) (see Williams 1998 for references), and Miller (1951) ranked oak woodlands as the second-most important habitat for this species after coastal coniferous forests. My recent distributional review (Williams 1998), however, suggests that martins persist in oak woodlands in only one or two counties. One of the state's largest martin concentrations is a remnant population in oak woodlands of the Tehachapi Range at the southern tip of the Sierra Nevada. Though I had never visited the area prior to this study, notes and discussions with locals (e.g., Grantham 1993, Hightower 1995, Moore 1998) and study of habitat maps led me to estimate that the old oaks of the Tehachapi Range may host up to 100-200 pairs, or about 15 percent of the estimated California population (Williams 1998). This population offered an opportunity to study the

¹ An abbreviated version of this paper was presented at the Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape, October 22-25, 2001, San Diego, California.

² Wildlife and Conservation Ecologist, Williams Wildland Consulting, Inc., 8200 Turner Dr., Granite Bay, CA 95746 (e-mail: bwcal@sprynet.com)

Purple Martins in Oak Woodlands—Williams

distributional ecology of martins in oak woodlands, including the influence of European starlings (*Sturnus vulgaris*) which have been widely implicated in the decline of oak woodland and other lowland martin populations since their California arrival in the 1960s (e.g., Cabe 1993, Lehman 1994, Remsen 1978, Small 1994). Specifically, my objectives were to census the nesting population in this area and evaluate nesting habitat to determine which factors best predict martin nest sites.

Table 1—Locations where martins have nested in California oak woodlands (excluding remnant black oaks in conifer regions). A “?” indicates that nest sites were unspecified but almost certainly in oaks based on local conditions. The number of pairs is a conservative estimate, as I have indicated only 1+ pairs at many sites where “martins” (plural) were present. Regional boundaries are from Hickman (1993).

Region	Co.	Site	Pairs	Extant	Year
Central Valley	Butte	Sacramento River, near Chico	3+	no	1903-1906
Northwestern California	Sonoma	Sebastopol?	1+	no	1870s+
Central Western California	Marin	Nicasio?	1+	no	1920's
Central Western California	Sonoma	Petaluma?	1+	no	1856+
Central Western California	Alameda	Cedar Mtn.	1+	no	1938
Central Western California	Monterey	San Antonio River	3+	no	1894+
Central Western California	Monterey	Hastings Reservation	2+	no	1942-1950+
Central Western California	Santa Clara	San Antonio Valley Rd.	1+	no	1971
Central Western California	Santa Cruz	Ben Lomond Mtn.	3+	no	1898+
Central Western California	San Luis Obispo	Paso Robles	6	no	1912+
Central Western California	San Luis Obispo	Shandon district	1+	no	1914?, -32+
Central Western California	San Luis Obispo?	Mansfield, near Nacimiento River [exact county unknown]	4+	no	1894+
Central Western California	San Benito	Paicines?	2+	no?	1899+
Central Western California	San Luis Obispo	Salinas Valley?	6+	no	1908+
Sierra Nevada	Mariposa	Yosemite Valley	1+	no	1893
Sierra Nevada	Nevada	Grass Valley	4+	no	1920s
Sierra Nevada	Tulare	Sequoia NP, foothills below	2+	no?	1930s-50s?
Southwestern California	Los Angeles	San Fernando Valley, west of	2+	no	1890's
Southwestern California	Riverside	San Jacinto, lower ridges of range	1+	no	1910's
Southwestern California	San Diego	Cuyamaca, Green Valley	1+	no?	1954
Southwestern California	San Diego	Pine Valley	1+	no	1974

(Table 1 continued)

Region	Co.	Site	Pairs	Extant	Year
Southwestern California	San Diego	Laguna Ranch	2+	no?	1894+
Southwestern California	San Diego	Julian	2+	no?	1915
Tehachapi Range	Kern	Bear Valley Springs	30+	yes	190?-1998
Tehachapi Range	Kern	Tejon Ranch	15-50	yes	1891-1986+
Tehachapi Range	Kern	Castac	3+	no?	1912

Study Area

Our study area was centered in the northern portion of the Tehachapi Range, in and near the communities of Bear Valley Springs and Stallion Springs west of Tehachapi, Kern County, California (Bear Mountain and Tejon Ranch 7.5 ft. quad maps). Two large valleys, Bear Valley and Cummings Valley, defined our eastern boundary. The western boundary was primarily the Tejon Ranch. Topography in the area is varied, but is generally hilly to mountainous and rises fairly abruptly (600-1,200 m in 1.8-3.0 km) from the southern San Joaquin Valley floor at <300 m. Two large E-W canyons, Sycamore Canyon and Chanac Creek Canyon, are roughly aligned with prevailing winds, which are regular and sometimes very strong (C. Moore, personal communication). Climate is Mediterranean with very warm, dry summers and cool, wet winters (mean annual precipitation about 38 cm), but unusual in that the oak woodlands also receive >0.6 m of annual snowfall (Western Regional Climate Center data for Tejon Rancho and Tehachapi, web address: <http://www.wrcc.dri.edu/summary>; Block 1989, Clendenen 2001, Moore 1998). Habitats are dominated by valley (*Quercus lobata*) and blue oak (*Q. douglasii*) woodland/savannah with a mostly naturalized grassland or shrubby understory depending on slope, aspect, and elevation. Much of the area has been or is being developed as residential parcels (roughly 1-10 acres), and intensive agriculture is dominant in Cummings Valley.

Methods

Martin Nest Surveys

We searched for martin nests from 29 June to 5 July 2000, the predicted peak of food delivery to nestlings and hence nest detection. We located active nests by scanning and listening for martins until we observed direct evidence of nesting: feeding nestlings (41/56), nestlings seen/heard (6), carrying food to hole (3), or remaining in hole as if incubating (3); the status of three other nests was unrecorded. We surveyed all habitat with potential nest cavities within the study area, namely oak woodlands and limited amounts of ponderosa pine forest (west Bear Mountain) ranging from 1,030-1,830 m. We likely found and measured >90 percent of the active nests in the study area, exclusive of one area near Bear Valley Springs (where we probably found >70 percent of nests) due to lack of time. We determined this as follows: (1) almost every bird we followed was associated with a nest, (2) our maximum martin counts were consistent with the number of known nests in an area, and (3) we did not observe any fledglings during our visits (a few nests were within 1-2 days of fledging by 5 July). We conducted surveys during all parts of the day,

although martins were generally most active near the nest site in the morning hours. In addition to surveying for martins, we also noted the numbers of starlings, and the presence or absence of relatively large woodpeckers [smaller woodpeckers such as Nuttall's (*Picoides nuttallii*) and Downy Woodpeckers (*P. pubescens*) excavate cavity entrances that are typically too small for martins] and aerial foragers within or over each plot (roughly a 200-m radius—see below). We spent 0.6 - 2.0 + hrs at each plot (sometimes over two visits), sufficient to roughly characterize associations with ecologically important or indicator species (woodpeckers, swallows), or the relative abundance of starlings among areas used by martins.

Habitat Measurements

We recorded over 20 variables at 57 nests in 46 nest trees and at 38 random paired sites to analyze habitat selection (*table 2*). Data on seven additional random paired trees were recorded but not used for most analyses, as they would have constituted multiple pairs for one nest tree. We located random trees within a 200-m radius of the nest tree by a measuring two consecutive 100 m distances, with the compass direction of each 100 m each distance determined randomly (similar to Tietje and others 1997). Random tree selection excluded trees <28 cm in dbh, 8 cm smaller than the smallest nest tree reported for martins in California (Williams 1998). Random trees were not restricted to those with holes (thus potentially available for use by martins), although it would have been more meaningful for many tree- and plot-specific analyses. Similarly, we did not record variables at nonused holes, though recording such data would have been useful for studying selection of nest characteristics. We strategically avoided such measurements because doing so would have taken time from finding and measuring nest trees. As it was, the restricted duration of the study did not allow us to collect data on the remaining 11 random paired trees or additional suspected nests. All personnel were briefly trained to conduct field measurements which I occasionally checked in the field. Because visual estimates are known to be variable even among trained observers (Gotfryd and Hansell 1985), measurements at each paired site were conducted by the same observer; thus observer bias was controlled for when comparing nest sites and random sites which was the main objective of this study.

Table 2—Selected nest, tree, and plot variables measured in this study. Additional variables recorded in the field but not analyzed in this paper are not included.

Nest variable	Variable description
orient	Orientation of nest cavity opening, measured with a compass (degrees)
n-grd	Nest height above ground, measured with clinometer (m)
n-veg	Minimum distance from nest hole to nearest vegetation, usually visually estimated (m)
n-veghoriz	Horizontal distance from nest hole to vegetation in direction of cavity opening—a measure of the conspicuousness and accessibility of a cavity (m)
Tree variable	Variable description
tree sp.	Species of nest tree or random tree (=central tree)
dbh	Diameter at breast height (1.4 m) of the central tree (cm)
height	Height of central tree, measured with a clinometer or range finder (m)
width	Maximum canopy width of the central tree, measured through the trunk (m)
holes	Number of apparently suitable holes or cavities available for use by nesting martins, counted by scanning the tree from the ground

(Table 2 continued)

Plot variable	Variable description
rel ht 17	Height of central tree relative to other trees within a 17.8-m radius (0.1 ha): (1) tallest tree; (2) codominant; (3) within tallest 75 pct; (4) medium; (5) smallest 25 pct
prom 17	Prominence of central tree within a 17.8-m radius (0.1 ha), as determined by the maximum canopy elevation in comparison with other trees; this depends on both tree height and position in the landscape: (1) most prominent; (2) as prominent as any other tree; (3) more prominent than 75 pct of the other trees but not most prominent; (4) prominent 25-75 pct; (5) least prominent
rel ht 50	Height of central tree relative to other trees within a 50-m radius (0.785 ha): (1) tallest tree; (2) codominant; (3) within tallest 75 pct; (4) medium; (5) smallest 25 pct
prom 50	Prominence of central tree within a 50-m radius (0.785 ha), as determined by the maximum canopy elevation in comparison with other trees; this depends on both tree height and position in the landscape: (1) most prominent; (2) as prominent as any other tree; (3) more prominent than 75 pct of the other trees but not most prominent; (4) prominent 25-75 pct; (5) least prominent
No. trees	Number of trees >10 cm in dbh (minimum size used by cavity-nesting birds, Thomas and others 1979) within the 0.1-ha plot, excluding the central tree
Pct cover	Visual estimate of tree canopy cover within the 0.1-ha plot (estimates occasionally checked with densiometer): (1) <10 pct (2) 10-25 pct; (3) 25-50 pct; (4) 50-75 pct (5) >75 pct
Pct shrub	Visual estimate of shrub cover within the 0.1-ha plot: (0) 0 (1) <10 pct (2) 10-25 pct; (3) 25-50 pct; (4) 50-75 pct (5) >75 pct
Pct cover100	Visual estimate of tree canopy cover within 100 m of the central tree, estimated on a horizontal plane at nest height; or, for random trees, taken at ¾ tree height or to uppermost branch >15 cm diameter, whichever is lower: (1) <10 pct (2) 10-25 pct; (3) 25-50 pct; (4) 50-75 pct (5) >75 pct
maxdbh	Diameter of largest tree or snag within the 0.1-ha plot, excluding the central tree (cm)
slope	Slope of the 0.1-ha plot, measured with a clinometer through the central tree (0-90°)
aspect	Slope aspect of the 0.1-ha plot at the central tree (0-360°)
slp100	Relative slope position of the central tree within a circle described by a 100-m radius from the central tree (a tree on a peak is on top, a tree along a stream is usually on bottom, and a tree on the side of a long, even slope is in the middle): (1) upper 1/3, (2) middle 1/3, (3) bottom 1/3

Statistical Analysis

I used parametric and nonparametric paired-sample tests to analyze differences between variables measured at used and random sites, as it was likely that the variables were correlated by virtue of the proximity of the paired plots. Analyses of nest-specific variables were limited to descriptive statistics or chi-square (χ^2) tests. Other differences were tested using chi-square or log-likelihood chi-square for categorical variables and t-tests for continuous variables. I did not run any hypothesis tests on variables that were time-sensitive (e.g., the number of martins or starlings on a plot) since we generally spent less time at random sites vs. nest sites. A Bonferroni adjustment was used to control for experiment-wise error rates.

Results

Nests

Fifty-three of the 57 nests (93 percent) were in hollow portions of living branches that were abandoned woodpecker cavities, most of them probably from acorn woodpeckers (*Melanerpes formicivorus*). Most nests had vegetation within 0.5 m (43/57) and all had vegetation within 2.0 m. A few nests had vegetation within a meter of the entrance on a horizontal plane with the nest ($n = 5$), but this vegetation was typically sparse and/or well-spaced from other nearby vegetation; other distances were <7 m (27), 7-100 m (10), and 15 nests had completely unobstructed flight lines that extended from >100 m to as far as one could see. Nests were randomly distributed with respect to orientation (Rayleigh's $\bar{R} = 0.165$, $P = 0.217$) (Mardia 1972).

Nest Trees

Martins nested in 41 valley (50 nests) and four blue oaks (6 nests). Blue oaks were used only in the Stallion Springs portion of the study area. The species of oak for one nest was not recorded. Black oaks (*Q. kelloggii*) were not used, even though this species represented roughly 15 percent of all oaks in the study area. Nine trees had two nests and one valley oak had three nests. Nest trees were large ($\bar{x} = 104.3$ cm dbh): they averaged 16.3 cm larger than the largest tree in the plot (paired $t = 1.7$, $n = 23$, $P = 0.0949$) and were the largest diameter trees on 65 percent of the 0.1-ha plots with more than one tree. Valley oak nest trees tended to be larger than blue oak nest trees, although the relationship was not significant ($t = 0.94$, $df = 39$, $P = 0.353$). Martins used prominent trees, as most (35/40) were within the most prominent 75 percent of all trees within 50 m by relative height and position in the landscape. Martin nests were most often positioned on the upper third of the local slope (as measured within a 100-m radius of the nest tree) (Kolmogorov-Smirnov $d_{max} = 22.7$, $n = 55$, $P < 0.0001$), with only two nest trees positioned on the lower third of the local slope. This relationship also applied at a larger scale as most nests were in trees positioned on the upper third of the landscape (within a 1-km radius of the nest tree) ($P < 0.001$) and no nests were found on the lower third of the landscape. Of the 29 nest trees where we recorded the presence/absence of nearby woodpeckers, acorn woodpeckers were detected at 28 (97 percent), northern flickers (*Colaptes auratus*) at 13 (45 percent), and hairy woodpeckers (*Picoides villosus*) at 2 (7 percent). The most common aerial associates were violet-green swallows (*Tachycineta thalassina*) which occurred at 40 of 44 of sites where we recorded the presence of other aerial insectivores.

Nest Sites vs. Random Sites

Compared with random trees, nest trees were larger and wider (table 3). Holes were more than three times more numerous in nest trees (table 3), and only 12 of 38 of paired random trees had apparently suitable cavities. Random trees tended to be relatively shorter and less prominent in both 0.1- and 0.785-ha plots, although not significantly so (all $P > 0.10$) (table 3). Nest trees were more likely than random trees to occur on the upper third of a local slope (table 3). Overall canopy cover did not differ between nest trees and random trees, but canopy cover measured at nest height at 100 m was significantly lower at nest trees (table 3). Shrub cover was also lower at

nest sites ($P < 0.01$), but it was positively correlated with canopy cover at 100 m ($r = 0.41, P < 0.0001$).

Table 3—Descriptive statistics of continuous or categorical variables at nest sites and random sites. Paired measurements for nest variables were not taken.

Variable	Mean	SD	n	min	max	Mean	SD	n	min	max	Test ¹	N ²	P ³
Nest variable													
n-grd	8.0	2.3	46	4.0	15.5								
n-veg	0.5	0.4	46	0.1	2.0								
Tree variable													
dbh	104.3	23.8	42	57	175	73.5	32.0	35	28	151	t = 4.788	31	<0.0001
height	15.0	3.0	46	8.5	24.0	12.6	3.7	36	6.0	20.4	t = 2.867	36	0.0070
width	16.1	4.2	45	8.6	27.6	13.6	4.2	38	5.6	23.9	T = 3.635	38	0.0008
holes	3.5	1.9	44	1	9	1.0	2.0	38	0	9	T _{min} = 76	34	<0.001
Plot variable													
rel ht 17	1.5	0.8	35	1	4	2.2	1.5	38	1	5	T _{min} = 44.5	17	>0.10
prom 17	1.7	0.9	43	1	5	2.1	1.3	27	1	5	T _{min} = 57	17	>0.30
rel ht 50	2.2	1.2	34	1	5	2.7	1.4	31	1	5	T _{min} = 52	16	>0.40
prom 50	2.5	1.0	40	1	5	3.0	1.3	22	1	5	T _{min} = 41	14	>0.50
No. trees	3.8	3.0	45	0	13	4.1	4.6	37	0	18	t = -0.118	36	0.9069
Pct cover	2.8	0.8	46	2	5	2.6	1.1	38	1	5	T _{min} = 177	29	>0.20
Pct shrub	0.3	0.6	46	0	3	1.1	1.2	35	0	4	T _{min} = 27.5	19	<0.01
Pctcover100	1.3	0.5	46	1	3	2.4	1.1	38	1	5	T _{min} = 7.5	29	<0.001
max dbh	82.0	31.2	25	8	140	78.5	30.3	17	26	122	t = 0.638	13	0.5354
slope	20.1	7.9	44	6	55	17.7	7.8	31	4	38	T _{min} = 185	29	>0.40
slp100	1.3	0.5	45	1	3	1.9	0.8	36	1	3	T _{min} = 15.5	20	<0.001

¹ Paired-sample t-tests (t), or nonparametric paired-sample Wilcoxon signed-rank test (T).

² Denotes number of paired samples used for the t-test, or number of paired samples excluding differences of zero for the Wilcoxon T test.

³ Bonferroni adjustment for multiple comparisons requires a P-value of 0.0033 (0.05/15 tests) for significance at the 0.05 level or 0.0066 (0.10/15 tests) at the 0.10 level. Significant P-values are in bold.

Excluding random trees without holes (i.e., trees unavailable to martins), there were only two results at $P < 0.05$. The slope position of nest trees was higher (Wilcoxon $T_{min} = 0, n = 7, P = 0.02$), and canopy cover at 100 m was lower (Wilcoxon $T_{min} = 0, n = 8, P = 0.01$). Nest trees also tended to be larger than random trees with holes (121.8 ± 30.1 SD vs. 101.2 ± 17.7 SD cm dbh), but sample size was small ($n = 7$) and $P > 0.10$.

Starlings were uncommonly observed where martins concentrated. Starlings were not equally distributed among the three general areas where martins nested ($F = 3.92, df = 2, P = 0.0273$), as no starlings were observed on Black Oak Mountain – the only area >1 km from development. We did not find any starling nests in any trees we measured, partly due to the relatively late date of the study.

Discussion

Martin habitat selection appears to take place on at least four (but not mutually exclusive) levels. At the landscape level, martins may identify potential nesting areas by such factors as aerial insect availability and prevailing winds (Williams 1998), which are related to topographic position and elevation (Pedgley 1990). Elevation is also correlated with more rugged conditions and colder climates that may limit starling densities (see below).

At the broad habitat scale, martins appear to identify suitable habitat based on concentrations of suitable nest sites such as large oaks (Williams 1998) with relatively open (from above) and/or prominent positions. Martin distribution has always been patchy in California, even before starling colonization, and part of that patchiness seems to be related to the distribution of large oaks (Williams 1998).³ This hypothesis is supported by the observation that this area has some of the largest oaks in California (e.g., see Block 1989 for comparative size; B. Williams, personal observation), especially for such relatively high elevations. In an early account of oaks and martins from near Fort Tejon in the southern Tehachapi Range, Grinnell (1905) wrote “A few western martins had nests safely ensconced in holes of lofty oaks.” These oaks included “...an immense white oak, said to be the largest in California. It was 27 feet in circumference at the base, and was one of many others nearly as large...” The relative landscape position of nest trees is also important (this study; Williams 1998). Prominent and open habitat conditions may be selected because they enhance predator detection and also allow quick and efficient access to foraging areas which are usually high.

At the nest plot or tree level, martins look for concentrations of holes in prominent and/or easily accessible substrates (Williams 1998). Martins’ need of holes helps explain why they prefer large oaks, as larger trees had more holes than smaller ones (adjusted $R^2 = 0.13$, $P = 0.0002$). The number of holes, however, does not explain the total relationship with dbh. Other correlates that may help explain martin selection of large dbh trees include height and prominence: tall, prominent trees are likely to enhance predator detection and higher nests are probably less likely than lower nests to be depredated by terrestrial predators (see below). Martins, however, may simply be drawn by conspicuously large substrates.

On the nest cavity level, martins appear to prefer cavities that are easily accessible to martins and safe from predators. While some nests had vegetation within a meter of the entrance on a horizontal plane with the nest, this vegetation was usually sparse and/or well-spaced from other nearby vegetation, and martins clearly preferred unobstructed aerial pathways to visually conspicuous cavities. Nest heights averaged 8.0 m (minimum 4.0 m) above the ground, and nest height is often negatively associated with nest predation in other cavity-nesting species (e.g., Li and Martin 1991, Nilsson 1984, Rendell and Robertson 1989). Where martins nest over water (e.g., a snag with its base submerged in water), nests tend to be lower (Horvath 2000, Williams 1998), suggesting that avoidance of terrestrial predators is an important factor in nest-site selection (Horvath 2000, Williams 1998) as has been found for other cavity-nesting birds (e.g., Finch 1989, Li and Martin 1991, Nilsson 1984).

³ Unpublished data on file with Brian Williams, Granite Bay, California.

Considerable circumstantial evidence suggests that starlings have been a primary cause of martin declines in lowland California (summarized in Williams 1998). Starlings were abundant in Bear Valley and Cummings Valley near pastures, golf courses, parks, lawns, agricultural lands, corrals, etc., but were uncommon where we found martins, and at one area (Black Oak) with at least 18 martin nests, we saw no starlings in 3 days. The low numbers of starlings and absence of their nests may have been partly due to the relatively late date of the study, but the absence of starlings in any valley or blue oak woodland in California is unusual. Various factors may be involved here. First, only the Black Oak area was >1 km from development. Starlings were common to abundant in the urbanized valleys just 2 km to the east, but we saw no martins at Black Oak. The Black Oak area is also at 1,525 m and can be very cold during late winter and early spring (maximum snowfall occurs in March, and snow regularly occurs into April and May) when starlings usually begin nesting. Local naturalists have, in fact, observed that late (April) snows may cause starlings to abandon these high elevation oak woodlands (C. Moore, personal communication; Clendenen 2001). The high elevations of nearby Bear Valley Springs also have relatively few starlings, yet that area is residential. Another possibility may be that relatively high winds of ridgelines and canyon edges (where martin nests are concentrated) make such places energetically demanding for starlings traveling to and from foraging sites, yet favorable for the more dynamic flight behavior of martins. Much of the Black Oak area had poor-quality foraging habitat for starlings, as the area is surrounded by high canopy cover and relatively steep slopes. Furthermore, although at least part of the area is grazed by cattle, herbaceous vegetation is still relatively tall (evidenced by abundant stickers in our socks). Regardless, our observations are consistent with previous observations that starlings are generally uncommon or absent wherever martins persist. With starlings now common in most of lowland California, martins are almost exclusively found in fairly remote or rugged country (e.g., Gallagher 1997, Roberson 1993, Shuford 1993, Williams 1998). Troetschler (1976) predicted a similar distributional pattern for northern flickers as a result of competition with starlings.

Management Implications

Martins appear to persist in the Tehachapis because of a unique set of habitat and landscape conditions, including factors that seem to limit starlings to low densities. Because direct starling management (e.g., harassment, trapping) is not a practical solution (but see Weitzel 1988), martin conservation is likely to be successful only by conserving, promoting, and selecting for habitat and landscape conditions that are not only suitable for martins, but that also limit starlings. Because starlings and martins use and probably prefer similar oak woodland habitat characteristics, including nest cavity and tree conditions (multiple large holes, low canopy cover, large dbh, etc.) (Cabe 1993; see also Nilsson 1984 for habitat selection by starlings in Europe), management for martins in areas with suitable nest sites should focus on a combination of habitat (e.g., understory condition) and landscape-scale conditions (e.g., proximity to agricultural or suburban settings) that discourage starlings.

Perhaps most important, however, is the uniqueness of the oak woodlands there and their fate. The combination of large, prominent, and unusually high-elevation oaks is unique, but in most places the oaks do not appear to be replacing themselves. While regeneration is a widespread concern (e.g., Mensing 1991), the conversion of

oak woodland from a wildland setting to a residential one may be problematic—and essentially irreversible. While martins themselves are relatively tolerant of both human activities and suburban or rural residential features such as pastures, lawns, and fruit trees (Brown 1997; Williams, personal observation), such human-made structures or habitats promote the invasion of starlings into oak woodlands. We observed what appeared to be a starling invasion of Stallion Springs and Bear Valley Springs, where residential conversion has started but build out is incomplete. The future of the Black Oak area is unknown, but it could be critical for Purple Martins in the northern Tehachapis. I hope this is not true, but, as their distributional history has shown, martins have not persisted well in oak woodlands.

Finally, it should be mentioned that while most historic populations are indeed extirpated, it is possible that some fairly remote oak woodlands, probably with qualities similar to those described here, are still keeping their hidden martins a secret. I would appreciate information on any of these populations.

Acknowledgments

Clark and Jean Moore, local residents and field ornithologists, facilitated this study by arranging access and providing valuable data on local martin distribution. My field assistants Maria Cisneros, Cliff Hawley, Ed Pandolfino, and Phil Taylor provided hard work, enthusiasm, and great companionship. I also thank John Garcia of Garcia & Associates for use of a field vehicle. Partial funding was provided by a grant from the Purple Martin Conservation Association (web address: <http://www.purplemartin.org>).

References

- Block, William M. 1989. **Spatial and temporal patterns of resource use by birds in California oak woodlands**. Berkeley: University of California; 364 p. Ph.D. dissertation.
- Brown, Charles R. 1997. **Purple Martin (*Progne subis*)**. In: Poole, A.; Gill, F., eds. The birds of North America, No. 287. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.
- Cabe, Paul R. 1993. **European Starling (*Sturnus vulgaris*)**. In: Poole, A.; Gill, F., eds. The birds of North America, No. 48. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.
- Clendenen, David. [Letter to Brian Williams]. 2001 August 2. 1 leaf. Located at Brian Williams' Purple Martin files. Granite Bay, CA.
- Finch, Deborah M. 1989. **Relationships of surrounding riparian habitat to nest-box use and reproductive outcome in House Wrens**. Condor 91: 848-859.
- Gallagher, Sylvia Ranney. 1997. **Atlas of breeding birds, Orange County, California**. Irvine, CA: Sea and Sage Audubon Press; 264 p.
- Gotfryd, Arnie; Hansell, Roger I. C. 1985. **The impact of observer bias on multivariate analyses of vegetation structure**. Oikos 45: 223-234.
- Grantham, Jesse. [Letter to Brian Williams]. 1993 December 21. 7 pages including attached field notes. Located at: Brian Williams' Purple Martin files. Granite Bay, CA.
- Grinnell, Joseph. 1905. **Old Fort Tejon**. Condor 7: 9-13.

- Grinnell, Joseph; Miller, Alden H. 1944. **Distribution of the birds of California**. Pacific Coast Avifauna No. 27: 1-615.
- Hickman, James C., ed. 1993. **The Jepson manual: higher plants of California**. Berkeley, CA: University of California Press; 1,400 p.
- Hightower, Gayle. [Letter to Brian Williams]. 1995 May 9. 2 pages. Located at: Brian Williams' Purple Martin files. Granite Bay, CA.
- Horvath, Eric. 2000. **Distribution, abundance, and nest site characteristics of Purple Martins in Oregon**. Oregon Birds 26: 115-122.
- Lehman, Paul E. 1994. **The birds of Santa Barbara County, California**. Santa Barbara, CA: University of California, Vertebrate Museum; 337 p.
- Li, Pingjun; Martin, Thomas E. 1991. **Nest-site selection and nesting success of cavity-nesting birds in high elevation forest drainages**. Auk 108: 405-418.
- Mardia, K.V. 1972. **Statistics of directional data**. New York: Academic Press.
- Mensing, Scott. 1991. **The effect of land use changes on blue oak regeneration and recruitment**. In: Standiford, Richard B., technical coordinator. Proceedings of the symposium on oak woodlands and hardwood rangeland management; 1990 October 31-November 2; Davis, California. Gen. Tech. Rep. PSW-GTR-126. Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 230-232.
- Miller, Alden H., 1951. **An analysis of the distribution of the birds of California**. Univ. Calif. Publ. Zool. 50: 531-644.
- Moore, Clark, Bear Valley Bird Club. [Multiple telephone conversations with Brian Williams]. Undated: approximately 1998 or 1999.
- Nilsson, Sven G. 1984. **The evolution of nest-site selection among hole-nesting birds: the importance of nest predation and competition**. Ornis Scandinavica 15: 167-175.
- Pedgley, D. E. 1990. **Concentration of flying insects by the wind**. Philosophical Transactions of the Royal Society of London B 328: 631-653.
- Pyle, Peter. 1997. **Identification guide to North American birds. Part I**. Bolinas, CA: Slate Creek Press; 732 p.
- Remsen, J. V., Jr. 1978. **Bird species of special concern in California**. Wildlife Management Branch Administrative Report No. 78-1. Sacramento, CA: Nongame Wildlife Investigations, California Department of Fish and Game; 54 p.
- Rendell, Wallace B.; Robertson, Raleigh J. 1989. **Nest-site characteristics, reproductive success and cavity availability for Tree Swallows breeding in natural cavities**. Condor 91: 875-885.
- Roberson, Don. 1993. **Purple Martin**. In: Roberson, Don; Tenney, Chris, eds. Atlas of the breeding birds of Monterey County, California. Carmel, CA: Monterey Peninsula Audubon Society; 226-227, 250.
- Shuford, W. David. 1993. **The Marin County breeding bird atlas: a distributional and natural history of coastal California birds**. California Avifauna Series 1. Bolinas, CA: Bushtit Books; 479 p.
- Small, Arnold. 1994. **California birds: their status and distribution**. Vista, CA: Ibis Publishing Company; 342 p.
- Thomas, Jack Ward; Anderson, Ralph G.; Maser, Chris; Bull, Evelyn L. 1979. **Snags**. In: Thomas, Jack Ward, ed. Wildlife habitats in managed forests: the Blue Ridge Mountains of Oregon and Washington. Agric. Handbook No. 553. Portland, OR: Forest Service, U.S. Department of Agriculture; 512 p.

- Tietje, William D.; Bloom, Peter H.; Vreeland, Justin K. 1997. **Characteristics of Red-tailed Hawk nest sites in oak woodlands of central California.** In: Pillsbury, Norman H.; Verner, Jared; Tietje, William D., technical coordinators. Proceedings of a symposium on oak woodlands: ecology, management, and urban interface issues. 1996 March 19-22; San Luis Obispo, CA. Gen. Tech. Rep. PSW-GTR-160. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 365-372.
- Troetschler, Ruth G. 1976. **Acorn Woodpecker breeding strategy as affected by Starling nest-hole competition.** Condor 78: 151-165.
- Weitzel, Norman H. 1988. **Nest-site competition between the European Starling and native breeding birds in northwestern Nevada.** Condor 90: 515-517.
- Williams, Brian D. C. 1998. **Distribution, habitat associations, and conservation of Purple Martins breeding in California.** Sacramento: California State University Sacramento; 169 p. M.S. thesis.