Characteristics of Red-tailed Hawk Nest Sites in Oak Woodlands of Central California[1]

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***Abstract**: Characteristics of nest sites of red-tailed hawks (*Buteo jamaicensis*) have not been described for the 3.1 million ha of California oak (*Quercus *spp.) woodlands. From 1992 to 1995, we located 44 active red-tailed hawk nests in oak woodlands in San Luis Obispo and Monterey Counties, California. We measured 19 characteristics that describe the nest, nest tree, vegetation, and topography within 0.04-ha circular plots centered on the nest tree and on randomly-selected, paired plots. Thirty-four nest trees were oaks. Tree diameter at breast height (dbh), height, and maximum canopy width were significantly greater (all* $P \leq 0.0001$*) for nest trees than for random trees (85.3 ± 4.1 cm [mean ± SE] vs. 62.6 ± 3.7 cm in dbh, 19.9 ± 1.1 m vs. 13.3 ± 0.7 m in height, and 11.4 ± 0.5 m vs. 9.1 ± 0.4 m trunk to drip line, respectively). Anthropogenic activities, including grazing, firewood cutting, and housing development should maintain a component of the largest trees in oak woodlands to conserve red-tailed hawk nest sites.*

Nesting habitat of red-tailed hawks (*Buteo jamaicensis*) has been described for several parts of North America (Bednarz and Dinsmore 1982, Belyea 1976, Bohm 1978, Gates 1972, Petersen 1979). One other study examined nesting habitat of red-tailed hawks in tropical habitats at the southeastern-most limit of their range (Santana and others 1986). These studies identified particular characteristics of nesting substrate and the landscape selected for nesting sites. To our knowledge, no study has yet evaluated nesting requirements of red-tailed hawks in California's 3.1 million ha of oak (*Quercus* spp.) woodlands.

Californians value their state's oak woodlands for livestock and wood production, esthetics, recreation, watershed protection, and wildlife habitat. In some areas of California, poor regeneration of some native oak species, urbanization, wood cutting, and poor land-management practices have raised concern about the long-term sustainability of oak woodlands (Pavlik and others 1991). If these woodlands continue to be degraded or destroyed, shortages of acceptable nest sites may limit nesting populations of red-tailed hawks.

Our objectives were to describe nest trees and associated vegetation and topographical characteristics of nest-sites of red-tailed hawks in oak woodlands of central California, and to determine if red-tailed hawks are selecting nest sites with particular characteristics. These data may serve as baseline information to aid managers in evaluating human effects on red-tailed hawk habitat and in its conservation.

Study Area

From 1992 to 1995, we located active nests of red-tailed hawks on three private livestock ranches (Avenales, Camatta, and Canyon) and on Camp Roberts Military Facility (CRMF) of the Army National Guard (*fig. 1*). The ranches were chosen primarily on the basis of an active livestock production enterprise on the ranch and the ability to gain access. These ranches are typical of central California oak woodlands and represent a continuum of stand densities and tree species compositions. Since the late 1800's, the primary land use on the ranches has been

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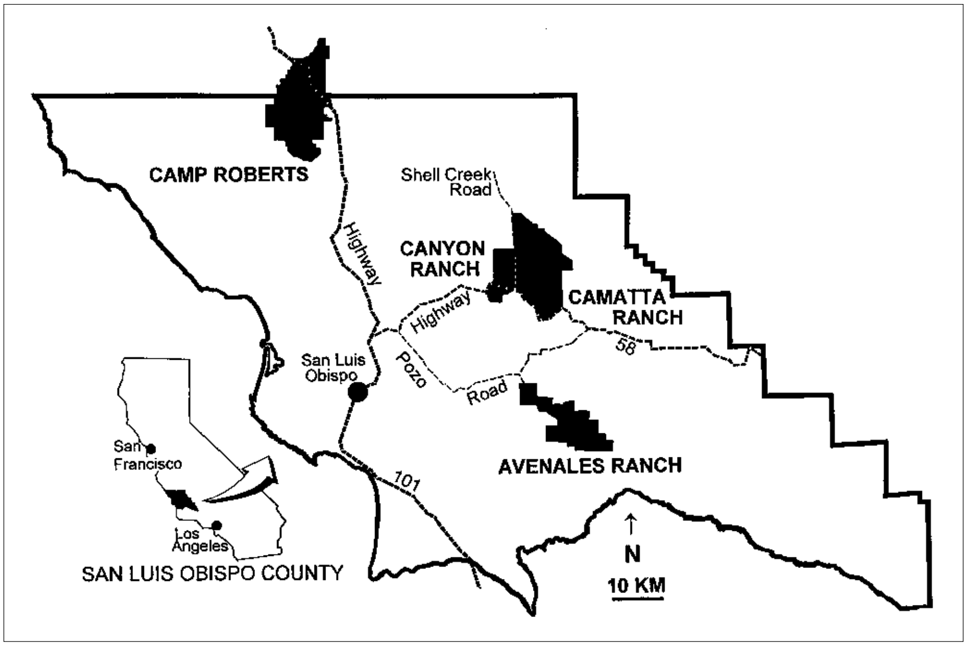

Figure 1—Location of the Avenales, Canyon, and Camatta Ranches and the Camp Roberts Military Facility on which 44 red-tailed hawk nests were located in oak woodlands, central California, 1992 to 1995.

cattle grazing. Livestock are grazed seasonally on the grasslands and open woodlands of the CRMF.

Topography on the four sites generally is hilly. The climate of the area is Mediterranean, characterized by warm, dry summers and cool, wet winters. Nearly all precipitation occurs during October to May. Snowfall is rare. The dominant tree species in the oak woodlands on these study sites are blue oak (*Quercus douglasii*) and coast live oak (*Q. agrifolia*). Gray pine (*Pinus sabiniana*) is interspersed with the blue oak, except at CRMF where gray pine does not occur. Valley oak (*Q. lobata*) occurs as solitary trees or small groups of trees in valley bottoms or associated with western sycamore (*Platanus racemosa*) and cottonwood (*Populus* spp.) in intermittent and perennial riparian areas. When present, understories of these oak woodlands consist mostly of toyon (*Heteromeles arbutifolia*), redberry (*Rhamnus crocea*), bigberry manzanita (*Arctostaphylos glauca*), and poison oak (*Toxicodendron diversilobum*). Chaparral (*Adenostoma* spp.) predominates on many south-facing slopes. Wild oats (*Avena* spp.), bromes (*Bromus* spp.), and fescues (*Festuca* spp.) occupy woodland floors and grassy openings; filaree (*Erodium* spp.), deerweed (*Lotus scoparius*), and hummingbird sage (*Salvia spathacea*) are common forbs.

Methods

Nest Location

During January to March from 1992 to 1995, we located active red-tailed hawk nests by searching along roads and by visually observing red-tailed hawks carrying nesting material or prey to nests. Additionally, several nests on CRMF were located during April to June, incidental to another field study on the facility. Frequent visits were made to nests with sign (e.g., sign of nest repair or nest-defense behaviors) of activity that year. We considered a red-tail nest active only when an adult red-tailed hawk was observed incubating on the nest anytime during the nesting season. A single exception was a nest seen being repaired by a hawk in February and a fledgling observed perched on the nest in June. Location, tree species, and hawk activity at nest trees was recorded during these initial visits. Nests were not approached closer than 100 m during the nesting period.

Plot Measurements

Nest Plots

We defined a nest plot as a 0.04-ha circular plot (11.3-m radius) centered on the nest tree (Titus and Mosher 1981). We collected 11 numerical and two categorical variables on nest plots and on associated random plots (*table 1*). Variables 1-5 describe the nest, nest tree, and associated random "nest tree." Variables 6-11 describe the vegetation structure of the 0.04-ha plots. Variables 12 and 13 describe topographic features of the 0.04-ha plots. Field measurements of these trees were taken during summer to winter after young had fledged.

Random Plots

We located a random plot approximately 200 m from each nest tree to evaluate characteristics of sites used versus sites available. For this comparison, a quadrant was selected by two flips of a coin, the first for the N or S radius and the second for the E or W radius of the NE (1-90), SE (91-180), SW (181-270), or NW (271-360) quadrant. Two specific azimuths within the selected quadrant were then picked from a random numbers table; the first azimuth was used for the first 100 m of travel from the nest tree, the second for the second 100 m. This procedure was repeated in several cases when the direction of travel would have led to a large

***Table 1**—Description of two categorical and 11 numerical variables measured at nest sites of red-tailed hawks and at associated random sites, central California, 1992-1995.*

Mnemonic code	Variable description (units)
1. CNTR SPP	Species of central tree.
2. CNTR CAN POS	Canopy position of central tree, ocularly estimated from the ground—dominant: the tallest tree within 30 m of the central tree; codominant: almost equal in height to the dominant tree; intermediate: shorter than codominant trees and ≤ 75 pct under the canopy of another tree; and suppressed: ≥ 75 pct under the canopy of another tree.
3. CNTR DBH	Diameter (cm) at breast height (dbh) of central tree, measured with a diameter tape.
4. CNTR HT	Height (m) of central tree, measured with a clinometer.
5. CNTR DRIPLIN WID	Maximum distance (m) from trunk to dripline, measured with a tape.
6. PLOT TREE STMS	Number of living trees ≥ 5 cm dbh in a 0.04-ha plot centered on the central tree.
7. PLOT TREE COV	Tree canopy cover (pct) of a plot, averaged from 20 measurements taken with a spherical densiometer (Lemmon 1956): one reading in each of the cardinal directions at the central tree and at 7 m from the trunk in each of the cardinal directions.
8. PLOT SHRUB STMS	Number of living individual shrubs or clumps of living shrubs in a plot.
9. PLOT SHRUB COV	Ocular estimate of shrub cover (pct) in a plot.
10. PLOT GRND COV	Ocular estimate of herbaceous material cover (pct) in a plot.
11. PLOT DOWN WOOD	Ocular estimate of downed woody material (≥ 5 cm diameter and 1 m length) cover (pct) in a plot.
12. DIS VAL BOT	Distance (m) from central tree to nearest valley bottom (usually a perennial or seasonal stream), measured by pacing.
13. PLOT SLOPE	Slope (0˚-90˚) of a plot, measured with a clinometer.

treeless opening. At the end point of the travel, the nearest tree of at least 43 cm diameter at breast height (dbh; 1.4 m above the ground) (43 cm dbh was the size of the smallest nest tree of the study) was selected. This tree was called the "nest tree" and formed the center of the 0.04-ha random plot. This approach to select random plots discouraged the preselection of "representative" or "typical" nesting areas in the oak woodlands, while it excluded trees and habitat types that were obviously unsuitable for nesting by red-tailed hawks (e.g., small trees and non-woodland habitats such as chamise and grassland). Not all measurements were made on each plot; therefore, some sample sizes differ.

Data Analysis

Descriptive statistics were calculated for six nest-specific variables: nest height, number of limbs supporting the nest and their average diameter, horizontal distance from the trunk to the nest, the percent of nest tree height at which the nest was located, and nest plot azimuth. Before analyses, the remaining 11 numeric variables (*table 1*) were tested for normality using Shapiro-Wilks tests (Conover 1980: 363) in PROC UNIVARIATE of SAS (SAS Institute Inc. 1988: 627-628; Schlotzhauer and Littell 1987: 117-119). We compared features of nest plots and associated random plots using paired-sample t-tests (for normally distributed variables), and Wilcoxon signed ranks tests (T, for non-normally distributed or small sample size variables). The log likelihood ratio (G) test for independence was used to detect hawk preference for trees of certain species or status, and for azimuth preference for nest trees only. Differences were considered significant when $P \leq 0.10$. Statistical procedures were conducted in PROC UNIVARIATE of PC-SAS (SAS Institute Inc. 1988: 617-634; Schlotzhauer and Littell 1987: 201-210).

Results

Nest Trees

We located 44 active red-tailed hawk nests, all but three during 1993 and 1994: 6, 16, and 22 on the Camatta/Canyon, Avenales, and Camp Roberts areas, respectively (*fig. 1*). In a study conducted in Orange County, California, Wiley (1975) located red-tailed hawk nests an average of 0.84 km apart (0.15 to 2.09 km) in intensively searched areas. With the conservative approach of using approximately twice that distance (i.e., 1.6 km) as our minimum distance for distinguishing nests of different pairs of red-tailed hawks, and our knowledge of the years the nests were active, we estimate that 39 of the 44 nests (89 percent) on our study sites were built by different pairs of hawks. Nests were in seven species of trees: 25, eight, and one in blue, valley, and coast live oaks, respectively; four in western sycamore, three in gray pine, two in eucalyptus (*Eucalyptus* spp.), and one in cottonwood. Proportions of tree species used for nest trees versus the proportions of random "nest tree" species available were similar ($G = 3.82$, df = 3, $P = 0.2817$).

Mean height and nest height of nest trees were 19.9 m ± 1.1 m (mean ± SE) and 15.8 m ± 0.8 m, respectively; 60 percent of nests were in the top 20 percent of the nest tree. Mean distance from the nest to the trunk (4.5 m ± 0.6 m, n = 22) was approximately 40 percent of the distance between the trunk of the nest tree and the maximum distance from the trunk to the dripline (11.4 m ± 0.5 m, n = 44). The number of limbs supporting nests and the average diameter of those limbs averaged 3.3 ± 0.1 and 6.9 cm ± 0.5 cm, respectively. Of 33 0.04-ha plots in which trees other than the central tree occurred, height of the nest tree (19.7 m ± 1.4 m) was approximately twice the height of surrounding trees within the plot (9.6 m ± 0.9 m) (Wilcoxon $T = 280.5$, df = 33, $P < 0.0001$).

Of the 44 nest plots, 70 percent were on hillsides and 30 percent were on valley floors. Of all nest plots on hillsides, slopes averaged 13.7°. The aspect frequencies in each of four categories of the azimuth of nest plots on hills differed from equiprobable frequencies (G = 14.42, df = 3, P = 0.0024) (*fig. 2*).

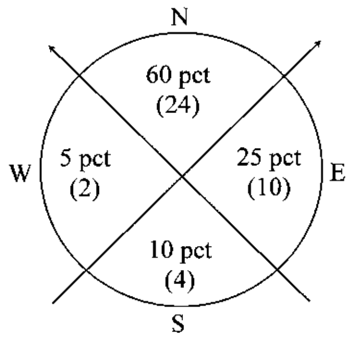

Figure 2—Slope aspects of 40 red-tailed hawk nests located on hillsides on four sites in oak woodlands, central California, 1992 to 1995.

Nest Versus Random Plots

The 11 numerical central tree and plot variables tested between nest and random plots (plot azimuth was not compared between nest and random plots) revealed three significant differences (*table 2*). All significant differences were measures of tree size. Central tree dbh (85.3 cm ± 4.1 cm vs. 62.6 m ± 3.7 cm, Wilcoxon T = 402, n = 44, P < 0.0001), height (19.9 m ± 1.1 m vs. 13.3 m ± 0.7 m, Wilcoxon T = 455, n = 44, P < 0.0001), and maximum canopy width (11.4 m ± 0.5 m vs. 9.1 m ± 0.4 m, paired t = 4.38, df = 43, P < 0.0001) were greater for nest trees than for random trees. Canopy position of central trees was dominant more often (G = 18.98, df = 1, P < 0.0001) on nest plots (38 of 44) than on random plots (19 of 44). All other nest versus random plot comparisons tested were not significant (all P > 0.10) (*table 2*).

Discussion

As in several other studies of red-tailed hawk nesting habitats, we found that red-tailed hawks in California oak woodlands use large trees for nesting (Bednarz and Dinsmore 1982, Belyea 1976, Santana and others 1986, Titus and Mosher 1981). Data from this study indicate this predilection clearly, despite our conservative approach of selecting "nest trees" on random plots that were at least the size of the smallest nest tree (43 cm dbh) measured. In another research project (Tietje and others, these proceedings) in which measurements were taken of 1,233 randomly selected trees in dense oak woodland on the Camp Roberts Military Facility, only 5.6 percent (69) were 43 cm dbh, indicating the limited occurrence and, therefore, strong preference for large trees on the area used in this study.

Tall trees likely afford several advantages to nesting red-tailed hawks and other *Buteo* species, including protection from predators, a substantial and safe base for the nest (Solonen 1982), and placement above the surrounding understory trees, which facilitates vigilance and accessibility to hunting areas. Red-tailed hawks (*Buteo jamaicensis* spp.) occur throughout the United States (Bent 1937). In some geographic areas within the range of the red-tailed hawk where large trees are unavailable, other substrates are used. For example, in Arizona, the western red-tailed hawk (*B. j. jamaicensis*) nests in the saguaro (*Carnegiea gigantea*) and paloverde (*Cercidium macrum*) at heights of only 1.8 to 9.1

Table 2—Central tree and 0.04-ha plot characteristics of nest plots of red-tailed hawks and associated random plots, central California, 1992-1995.

Variable[1]	Statistic	Nest site	Random site	Test statistic[2]	n^3	*P*
CNTR DBH (cm)	Mean	85.3	62.6	*T* = 402	44	<0.0001
	SE	4.1	3.7			
	Range	43.2-166.9	40.4-163.3			
CNTR HT (m)	Mean	19.9	13.3	*T* = 455	44	<0.0001
	SE	1.1	0.7			
	Range	11.0-43.9	7.3-29.3			
CNTR DRIPLIN WID (m)	Mean	11.4	9.1	*t* = 4.38	44	<0.0001
	SE	0.5	0.4			
	Range	6.4-23.2	4.6-18.0			
PLOT TREE STMS (no.)	Mean	6.6	4.7	*T* = 35	44	0.6175
	SE	1.3	0.6			
	Range	0-38.0	0-15.0			
PLOT TREE COV (pct)	Mean	65.0	64.7	*t* = 0.942	44	0.9254
	SE	2.2	2.6			
	Range	28.3-94.5	28.0-98.3			
PLOT SHRUB STMS (no.)	Mean	2.1	3.3	*T* = 9	41	0.5525
	SE	0.7	1.6			
	Range	0-21.0	0-55.0			
PLOT SHRUB COV (pct)	Mean	2.9	4.2	*T* = 7.5	44	0.6586
	SE	1.1	2.1			
	Range	0-30.0	0-75.0			
PLOT GRND COV (pct)						
	Mean	81.6	78.3	*T* = 25	42	0.5778
	SE	4.1	4.7			
	Range	<1-100.0	<1-100.0			
PLOT DOWN WOOD (pct)	Mean	5.0	4.5	*T* = 0	13	1.0000
	SE	1.6	0.9			
	Range	0-20.0	0-10.0			
DIS VAL BOT (m)						
	Mean	88.1	96.1	*t* = -0.5664	42	0.5742
	SE	15.2	15.2			
	Range	0-450.0	0-350.0			
PLOT SLOPE (°)	Mean	13.7	14.3	*T* = -51	43	0.4996
	SE	2.0	1.9			
	Range	0-67.0	0-55.0			

[1]See *table 1* for description of variables.
[2]Test statistics are paired sample *t*-tests (*t*) for normally distributed variables or Wilcoxon signed rank tests (nonparametric paired samples) (*T*) for non-normally distributed or low sample size variables.
[3]*n* is the number of pairs in which values for both nest and random sites were available for testing.

m (Bent 1937: 168). Whether removal of large trees in oak woodlands would prompt use of remaining small trees, and whether their use would adversely affect red-tailed hawk populations, is unknown.

Tree species probably is unimportant to nest-site selection, as long as the tree's growth form, size, and location in the landscape permit accessibility and vigilance. The method we used to select random plots provided little opportunity for selection of trees outside the stand that contained the nest tree. Therefore, this method might have biased selection of random trees towards the same species as the nest tree. This may have masked selection for uncommon species of trees on the study areas, such as valley oak, gray pine, and eucalyptus trees, which were usually larger than trees of other species. Moreover, relatively little searching was conducted in riparian areas. Our observations suggest that riparian areas may have been disproportionately used by red-tailed hawks.

Common measurements in other studies of nesting habitat of *Buteo* and *Accipiter* hawks are distance to water, valley bottom, and forest edge. These measures may not be meaningful in oak woodlands because the woodlands are not large expanses of contiguous forest and valley bottoms are frequently wide, flat expanses with few trees. Additionally, we found a difference among aspect frequencies of nest plots. This difference may be attributed to the occurrence of most oak trees on more mesic north and east slopes rather than any preference by red-tailed hawks for aspect of nest sites.

Management Implications

The sustainability of much of California's 3.1 million ha of oak woodland is currently problematic. In some areas, some of the 19 native oak species are not regenerating well (Bolsinger 1988; Brown and Davis 1991; Griffin 1971, 1976). Two species of highest concern, valley oak and blue oak, were among those most used by red-tailed hawks in this study. Most (80 percent) California oak woodland is privately owned and used primarily for livestock production (Tietje and Schmidt 1988). Livestock grazing may affect use by red-tailed hawks to the extent that it impedes tree regeneration and affects rodent populations. Grazing selectively decreases certain rodent (*Peromyscus* spp.) populations and increases others (Linsdale 1946). It may enhance red-tailed hawk habitat by increasing population size and availability of ground squirrels (*Spermophilus beecheyi*), which are likely an important prey species for red-tailed hawks, and whose populations generally fare well in grazed areas (Linsdale 1946).

Other land-use activities likely are more serious threats than livestock grazing to woodland sustainability. Larger trees are sometimes cut for firewood (McCreary 1996); however, firewood generally is not being cut on a large scale in California oak woodlands (Bleier 1991). The primary concern within the past decade over the loss of oak trees is the permanent removal of trees and degradation of habitat by urbanization and intensive agriculture. Home building and other types of development converted approximately 40,500 ha of the 3.1 million ha of oak woodland during 1969 to 1982 and, as of 1985, 110,000 ha were in the process of conversion (Bolsinger 1988).

Red-tailed hawks generally are tolerant of housing and other human development. In Puerto Rico, Santana and others (1986) located nests within 300 m of dwellings, though they speculated that hawks would decline in numbers with the expected development of woodlands in Puerto Rico. In California oak woodlands, large-parcel development might be tolerated by red-tailed hawks, but increased noise, pets, road construction, removal of large trees, and potential prey reduction make this tolerance unlikely.

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