LANDSCAPE CHARACTERISTICS SURROUNDING WHITE-TAILED KITE NEST SITES IN SOUTHWESTERN CALIFORNIA

By

Chris Anne Niemela

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

In Natural Resources: Wildlife Emphasis

December 2007

LANDSCAPE CHARACTERISTICS SURROUNDING WHITE-TAILED KITE

NEST SITES IN SOUTHWESTERN CALIFORNIA

By

Chris Anne Niemela

Approved by the Master's Thesis Committee:

Dr. T. Luke George, Major Professor   Date

Peter H. Bloom, Committee Member   Date

Dr. David W. Kitchen, Committee Member   Date

Dr. Gary Hendrickson, Graduate Coordinator   Date

Dr. Chris A. Hopper, Interim Dean Research & Graduate Studies   Date

ABSTRACT

LANDSCAPE CHARACTERISTICS SURROUNDING WHITE-TAILED KITE NESTS IN SOUTHWESTERN CALIFORNIA

Chris Anne Niemela

I quantified landscape variables surrounding 31 white-tailed kite (*Elanus leucurus*) nest sites and compared them with 31 unused sites in an undeveloped landscape in southwestern California. Using a geographic information system, I combined landcover data from Orange County with aerial photography to produce a landcover map surrounding white-tailed kite nest sites. Habitat types were quantified and landscape pattern indices were computed within circular plots of 300, 500, 700 and 1000 m radii centered on nests. At all circular scales, kite nests had significantly more agriculture, grassland, riparian, and woodland habitat, and significantly less chaparral habitat than unused sites ($P \leq 0.01$). The landscape surrounding nest sites also had significantly greater patch density than unused sites, suggesting a preference for patchier landscapes. All nests were within 307 m of a riparian corridor, and were located at elevations below 314 m, and on slopes less than 25 degrees. I used logistic regression analysis to develop a predictive model of landscape variables that best discriminated between white-tailed kite nest sites and unused sites within my study area. Largest patch index and perimeter density were used to further interpret the landscape surrounding white-tailed kite nests. The final model incorporated distance to nearest stream, percent grassland, and percent woodland, and correctly classified 97% of kite nest sites within the study area. While

landscape variables were significantly different between nest sites and unused sites, some variables varied widely among individual kite nest sites. These results suggest that the quality of similar habitat types varied widely across the landscape, and that the quantity of habitat necessary to support a pair of nesting kites may vary as well. For white-tailed kites in California, habitat quality is largely dependent on abundance and availability of California voles (*Microtus californicus*).

ACKNOWLEDGMENTS

First and foremost I would like to thank Peter H. Bloom - my mentor, advisor, boss, and friend - for taking me under his wing, so to speak, and for giving me unconditional access to his endless pit of knowledge of raptors and of the natural world. Many thanks to T. Luke George, my graduate advisor, for all your help and patience, and for giving me my first break as an inexperienced undergraduate. I would like to thank my thesis committee member David Kitchen for many helpful comments on my final thesis draft. A special thank you goes to Richard and the late Donna O'Neill and the Moiso family of Rancho Mission Viejo for access to the study area. Without their support I would not have had access to some of the last remaining natural areas in Orange County. Thanks to Pete and Sandy DeSimone for unlimited access to Starr Ranch Audubon Sanctuary, and to Tim Miller for unlimited access to all county parks, and to the County of Orange Planning and Development Services Department and Albert Lucero for providing me with Orange county GIS data. Endless thanks to Scott Thomas for help with fieldwork, and especially for being such a staunch conservationist for the local flora and fauna. My gratitude goes out to Jeff Kidd for bringing me into Peter's research and teaching me how to make traps and trap hawks. I thank Steven Steinberg for help with GIS, and Jeff Manning for help with GIS and statistics. Thanks to Jeep Pagel for helpful comments and support, as well as to Craig Milewski for motivational support and jokes. Thank you Emil and Jesse for 24 breaks from reality. Thanks to Karly Moore for your friendship, fun times, and for following the birds with me. Thanks

to all of my friends for your support, patience, and encouragement along the way. And finally, endless love and thanks to my parents for supporting my pursuits even though they sometimes didn’t understand them.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Appendix Page

INTRODUCTION

The white-tailed kite (*Elanus leucurus*) has had a tenuous existence in California over the last decade. Once a common raptor throughout California's open country lowlands and marshlands, it is believed that habitat loss, shooting, and egg-collecting brought white-tailed kites to the brink of extinction by the 1930s (Grinnel 1914, Fry 1966, Waian and Stendell 1970). Following this decline, population numbers appeared to increase and distribution expanded from the 1940s to the 1970s (Eisenmann 1971, Pruett-Jones et. al. 1980). Expansion was attributed in part to state and federal protection (kites were granted California State Fully Protected Species status in 1957) and to increased agricultural development (Fry 1966, Waian and Stendell 1970, Eisenmann 1971). However, based on Breeding Bird Survey data collected in California between 1980 and 2006 (Sauer 2007) and on the disappearance of local nesting pairs and communal roost sites between 1970 and the present (Bloom, P. 2006. Personal Communication. Western Foundation of Vertebrate Zoology, 439 Calle San Pablo, Camarillo, CA 93012), it is apparent that population numbers of white-tailed kites in southwestern California are declining. The recent decline in kite populations is attributed to the conversion of natural and agricultural lands to urban development and commercial properties (Dunk 1995). At least seven traditional kite territories in Orange County, California have been lost to urban development in the last two decades (Bloom, P. 2006. Personal Communication. Western Foundation of Vertebrate Zoology, 439 Calle San Pablo, Camarillo, CA 93012). Kites are thought to be a nomadic species, moving in response to fluctuating prey densities (specifically *Microtus californicus*) (Stendell 1972). However, the evidence for this claim is circumstantial and is based on changes in kite numbers in response to changes in *Microtus* abundance at local (several km^2) scales. No studies of marked kites have confirmed that these temporal changes in abundance represent movements rather than mortality and recruitment. Therefore, the decrease in kite observations in this region may indicate a permanent downward population trend or, less likely, a shift in geographical range.

White-tailed kites generally inhabit low elevation open grasslands, oak-woodland, wetland, and savannah-like habitats, as well as some types of agricultural fields. In California, these plant communities are limited to areas west of the Sierra Nevada Mountains, from the Oregon border south into Baja California (Clark 1987). Grassland and wetland habitats in California are being lost to urban development and agriculture at an alarming rate. An estimated 64% of historic grasslands and 91% of wetlands in California have been lost (California Partners in Flight 2000, Dahl 1990). Changes in land use and loss of kite foraging habitat poses a threat to the persistence of local as well as regional kite populations. Knowledge of habitat requirements of nesting kites may help reduce further loss of suitable kite habitat and the possibility of extirpation of local populations.

Foraging ecology of white-tailed kites has been studied throughout portions of the species range by Dixon et al. (1957), Stendell and Meyers (1973), Bammann (1975), Warner and Rudd (1975), and Dunk and Cooper (1994). Territoriality in kites has been studied by Watson (1940), Waian (1973), Henry (1983), and Dunk and Cooper (1994).

However, despite a broad knowledge of kite natural history and ecology, little is known about nest site preference. In particular, little is known about landscape characteristics surrounding occupied nest sites. Erichsen et al. (1996) examined habitat characteristics around white-tailed kite nest sites in an agricultural setting in the Sacramento Valley, California. However, most kites in southwestern California nest in more natural landscapes rather than the agricultural type landscapes studied by Erichsen et al. (1996). Habitat and landscape characteristics surrounding white-tailed kite nests in natural landscapes have not been examined in detail.

A host of variables may be involved in nest site selection in raptors, including, but not limited to: prey density and (or) availability, conspecific and interspecific competition, availability of perch and nesting substrate, vegetation structure and composition, ground cover, water, and topography (Newton 1979). While prey availability appears to be the ultimate factor affecting the density and distribution of white-tailed kites (Stendell 1972, Dunk 1992), habitat variables such as soil moisture or water and hence vegetation structure and composition, and ground cover may ultimately be affecting prey abundance and availability.

Although there are many ecological and evolutionary constraints that influence an individual’s behavior and ultimately its choice of habitat (Wiens 1989), I examined only the influence of landscape variables on nest site preference. The ultimate objective of my study was to determine what constitutes suitable white-tailed kite nesting habitat in a relatively natural area of southwestern California using GIS and other tools. Specific objectives included:

1) Describe habitat and physiographic (aspect, slope, elevation, and distance to nearest stream) characteristics around white-tailed kite nests,
2) quantify and compare landscape variables surrounding white-tailed kite nest sites with unused sites using a GIS,
3) identify landscape variables useful in predicting white-tailed kite nesting sites,
4) explore methods for quantifying nesting habitat preference of raptors at a landscape level, and
5) use the information gathered from this study in future land-use planning and habitat management, specifically in, though not limited to, southwestern California.

STUDY AREA

This study was conducted in southern Orange County, in southwestern California (Figure 1), and encompassed 30,258 ha of open space: including Casper's Wilderness Park, National Audubon Society Starr Ranch Sanctuary, and privately owned Rancho Mission Viejo. The study site boundaries were determined by availability of reliable kite census data, availability of geographic information system (GIS) data layers, and urban development. The study site was bordered by urban development on the west and northwest, rural development along the north, Cleveland National Forest on the east, and mostly undeveloped private land on the south. Elevation ranged from 41 to 1379 m, and included rolling terrain, steep canyons, and riparian corridors of perennial and intermittent stream flow. The study site falls within the San Juan Creek and San Mateo Creek watersheds. Climate in the region is Mediterranean, with an average annual rainfall of 36 cm (County of Orange 2002).

The study site was comprised of 14 different general habitat classes based on the Orange County Habitat Classification System (Gray and Bramlet 1992). The county's classification of native habitats was based on Holland's (1986) statewide system. The study site was dominated by chaparral, scrub, and grassland, but also included smaller percentages of other landcover types (Figure 2). Additional land use types within the study area included nurseries, orchards, corrals, horse stables, and scattered human dwellings and facilities. Each habitat type was further divided into subtypes using the Orange County Habitat Classification System. All GIS and statistical analyses were

Figure 1. Location of study area, Orange County, California.

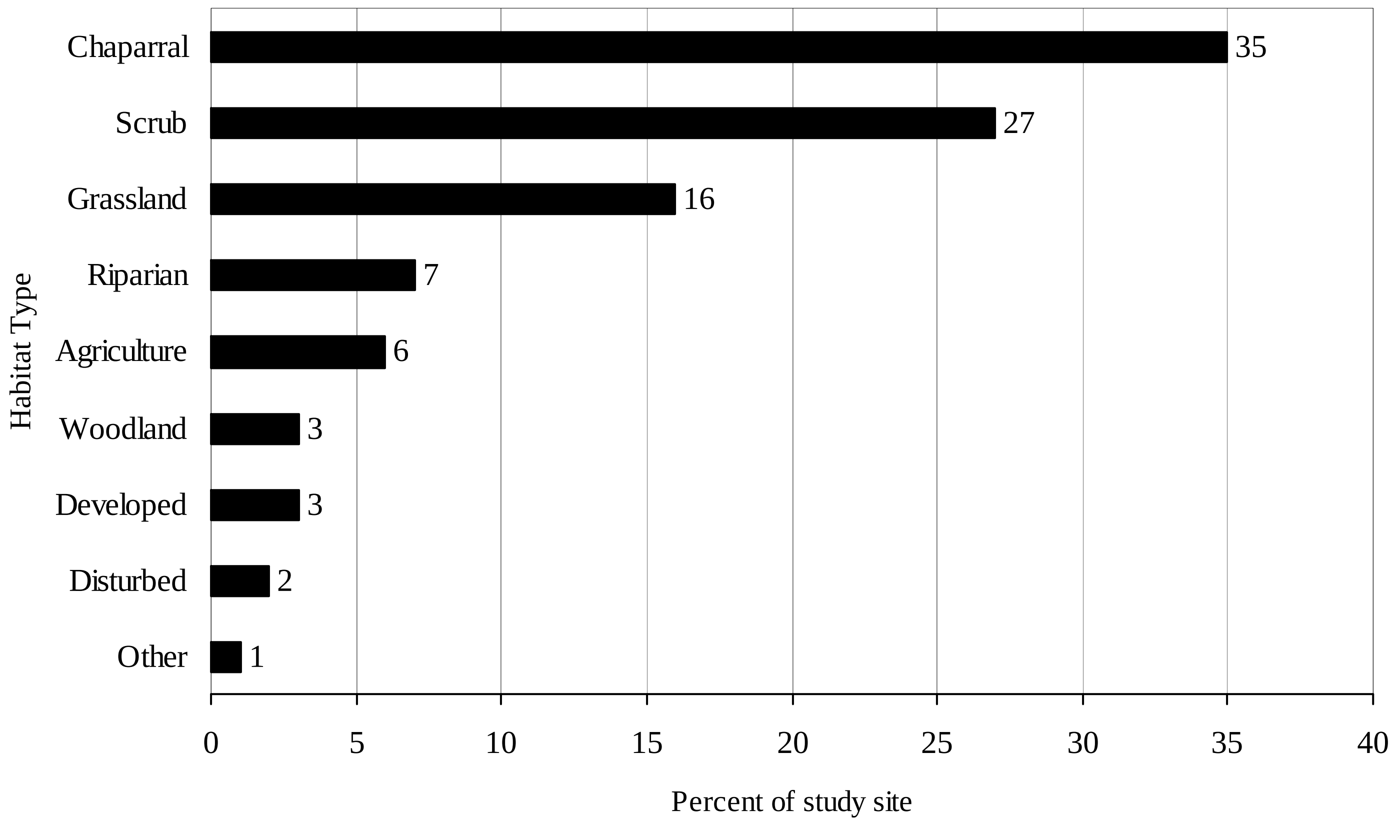


Figure 2. Habitat composition within the study site, Orange County, California.

based on general habitat types, however, habitat subtypes of scrub, grassland, riparian, and woodland were examined non-statistically.

METHODS

White-tailed kite nest site locations were mapped between 1980 and 2000 during studies of other raptors in southwestern California (Bloom et al. 1993, Chiang 2004, Bennett and Bloom 2005). The study area was surveyed yearly by experienced biologists searching for raptor nests. Although all kite nests in the survey area were not active every year, they were traditional territories, meaning they were occupied during at least six years over the course of two decades. Kites frequently used the same nest tree or nest grove from year to year. The most consistently used nest tree, or nest grove, was used as the nest point in analyses. All traditional nest sites that fell within my study area, were known to be active within the last 20 years, and were not surrounded by landscape that had been dramatically altered within 1 km of the nest site were used in my analysis. Because the study area was surveyed every year for the last 20 years, and no new sites were identified after the first five years of surveys, it was likely that all kite territories were known. Therefore, the nest sites used in my analysis did not merely represent a sample, but a census of kite territories within the study area.

In addition to traditional nest sites, I located all active nests within the study area in years 2001 and 2002. All known traditional nest sites and surrounding areas were visited a minimum of five times over the course of the nesting season from 1 February through 15 August to check for activity. In addition, the entire study area was searched for new nesting locations at least once per month by driving and (or) walking along canyons and ridgelines that offered a wide-ranging view of the study area.

Active nest sites from 2001 and 2002 were pooled and combined with traditional nest sites for comparison with unused sites. Since birds were not marked it was impossible to tell whether it was the same pair using closely located nests in separate years. Therefore, each nest was considered a separate sampling point as long as it was more than 420 m from a previous year's nest, which was the distance of the closest simultaneously active nests during 2001 and 2002. Because all nest sites were located within 307 m of the center of a stream corridor, it was evident that nests were strongly associated with the presence of streams. I therefore chose random points in two ways. First, to examine the distance of nests from streams, I selected points randomly without respect to distance from streams. Second, to examine landcover differences, I restricted random points to be within 307 m of a stream. In both cases random points were restricted to 2000 m or more from nest points, so that circular plots did not overlap. Random points were also restricted to 1000 m or more from other random points to minimize overlap, and 1000 m or more from the study site boundary. Since kites nest only in trees, the nearest tree to each random point, determined from a digital orthophoto quadrangle (DOQ) (United States Geological Survey 1998), was selected as the final random point, hereafter referred to as unused point. All known kite nest locations within the study area were mapped, thus allowing comparison of used versus unused sites, as opposed to used versus random sites (Johnson et al. 2006, MacKenzie 2006). Coordinates for all nest sites were obtained in the field using a Global Positioning System (GPS), and subsequently matched with the DOQ to check for accuracy of location.

Data were compiled and analyzed using a vector-based geographical information system (GIS) (ArcGIS 9.1, ESRI). A digital habitat layer was provided by the County of Orange Planning and Development Services Department. This detailed habitat layer was created in 1992 from aerial photos and ground surveys, and had a ground resolution of 1 m. Polygons were classified by general habitat class as well as by habitat subtype. Minor updates were required to reflect changes in habitat class. Streams were digitized using a combination of blue lines from USGS 7.5' topographic maps (1988), vegetation from the digital habitat layer, and DOQs (United States Geological Survey 1998). Any drainage or canyon that contained riparian vegetation class was digitized as a stream, regardless of surface water flow. Surface water within these stream corridors varied from intermittent to perennial. Distance to nearest stream corridor was estimated for all nest sites and random points using GIS. Elevation, slope, and aspect for each nest and unused point were extracted from raster (grid) layers derived from a 30 m-resolution digital elevation map (DEM) (United States Geological Survey 2001).

Landscape Analysis

Landscape variables and amount of each habitat class were computed at four different scales based on four concentric circular plots centered around each nest and unused point. Concentric circles with radii of 300 m (28.3 ha), 500 m (78.5), 700 m (78.5 ha), and 1 km (314.2 ha) were used for all analyses. Circle sizes were based on average distances white-tailed kites have been observed foraging from the nest, and on home range estimates of nesting kites from previous studies. Henry (1983) observed breeding kite territories ranging from 17 – 120 ha in southwestern California. Waian (1973) noted kite territories ranging from 19 – 52 ha in Santa Barbara coastal plains. Hawbecker (1940) reported that breeding male kites rarely hunted more than 1 km from the nest. Erichsen (1993) observed kites frequently using hunting areas immediately adjacent to the nest (<0.5 km) and out to approximately 1.6 km, although she found that the significance of land-use types diminished at greater distances from the nest. Kites on my study site were casually observed hunting up to 1 km from their nests.

Landscape composition and configuration within each circular plot was compared between nest sites and unused sites using various class-level landscape indices calculated for each habitat class. Landscape indices were based generally on those presented in FRAGSTATS (McGarigal and Marks 1995), but were calculated in an Excel spreadsheet using area and perimeter measurements obtained from ArcGIS. Indices computed for each habitat class within circular plots included total area, percent area, largest patch index, patch density, perimeter density, and patch total. Landscape patch density and landscape patch total of all patches within each circle was also computed. Some variables were obviously redundant and highly correlated, and therefore not all were included in the model selection analyses. However, some variables, though correlated, measured the landscape in slightly different ways, and thus added to landscape interpretation when used in conjunction with each other. Rather than analyze the whole gamut of landscape variables, I limited analyses to those variables that would be biologically meaningful to kites, and easily calculated, interpreted, and used in future raptor landscape analyses. All patch sizes were included in analyses no matter how small. Unlike other raptors that hunt from perches, the hover-hunting technique used by kites allows them to exploit even the smallest patches of habitat in search of food. Forty-two landscape variables were measured and compared between kite nest sites and unused sites (Table 1).

Landscape Variables

To facilitate comparisons across different spatial scales, I quantified total area of all habitat types around all points as the percentage of the total landscape, with landscape referring to the area within the circular plot centered on nest point. The following landscape variables were computed within each circular plot around nest sites and unused sites to aid in interpreting the configuration of habitat patches across the landscape. Largest patch index, which is the percentage of the landscape occupied by the largest patch of a habitat type, is useful in comparing landscapes with similar habitat areas. Low largest patch index values indicate a more fragmented habitat. Patch density, which is measured as the number of patches per 100 ha, is used as an index of fragmentation. A higher patch density in areas of similar habitat area indicates more fragmentation. Landscape patch density, calculated as the number of all patches of all habitat types, can be used as an index of spatial heterogeneity of the entire landscape. Perimeter density is measured as the total length of habitat edge divided by total landscape (circle) area, and is another index of fragmentation. However, perimeter density is only meaningful when interpreted in conjunction with total percent area of the same habitat. Holding percent area constant, a higher perimeter density indicates a more highly fragmented landscape.

Table 1. Physiographic and landscape variables measured around white-tailed kite nest sites and unused sites in southwestern California 2001-2002.

Variable Code	Description
D_STRM	Distance to nearest stream (m)
ELEV	Elevation at point (m)
SLOPE	Slope at point (degrees)
ASPECT	Aspect (degrees)
*AREA_X	Total area of habitat class x (ha)
PCT_AG	Percent agriculture
PCT_CHP	Percent chaparral
PCT_GR	Percent grassland
PCT_RIP	Percent riparian
PCT_SCR	Percent scrub
PCT_WDL	Percent woodland
*LPI_AG	Percent of largest agricultural patch per circular plot
*LPI_CHP	Percent of largest chaparral patch per circular plot
*LPI_GR	Percent of largest grassland patch per circular plot
LPI_RIP	Percent of largest riparian patch per circular plot
*LPI_SCR	Percent of largest scrub patch per circular plot
*LPI_WDL	Percent of largest woodland patch per circular plot
PCHDN_AG	Number of agricultural patches per 100 ha
PCHDN_CHP	Number of chaparral patches per 100 ha
PCHDN_GR	Number of grassland patches per 100 ha
PCHDN_RIP	Number of riparian patches per 100 ha
PCHDN_SCR	Number of scrub patches per 100 ha
PCHDN_WDL	Number of woodland patches per 100 ha
*PERDN_AG	Total agricultural perimeter per circular plot (m/m2)
*PERDN_CHP	Total chaparral perimeter per circular plot (m/m2)
*PERDN_GR	Total grassland perimeter per circular plot (m/m2)
PERDN_RIP	Total riparian perimeter per circular plot (m/m2)
PERDN_SCR	Total scrub perimeter per circular plot (m/m2)
*PERDN_WD	Total woodland perimeter per circular plot (m/m2)
*PT_X	Total number of patches of habitat x within circular plot.
*LPT	Total number of all patches within circular plot
LPCHDN	Number of all patches in the landscape per 100 ha

* Variable not included in logistic regression analysis because of collinearity with other variables.

Statistical Analysis

Spatial autocorrelation among nest points was assessed using Moran's I tool within ArcGIS. I compared habitat variables between nest sites and unused sites using Mann-Whitney U-tests (Daniel 1990). Habitat variables were summarized using mean and standard error. I ran a Spearman-rank correlation matrix on all variables to check for collinearity among variables. Highly correlated variables were removed from the modeling process since including both variables at the same time dilutes their individual effects. I removed one variable of correlated pairs ($r^2 \geq \pm 0.70$), keeping the variable that was most easily interpretable in relation to kite natural history. This produced a reduced set of variables for model analyses. For each of the four scales (circle sizes), a separate forward stepwise logistic regression comparing used and unused sites (Afifi and Clark 1984) was conducted to identify landscape variables that best predicted the presence of kite nest sites. All statistical analyses were performed using statistical software package NCSS (Hintze 2004). The probability of a type I error (alpha) was 0.05 for all analyses.

Predictive accuracy of the models was assessed using classification tables and the area under the curve (AUC) of a receiver operating characteristic (ROC) plot. The ROC curve is a plot of sensitivity (true positive cases) and 1-specificity (false positive cases) across a range of threshold values (Fielding and Bell 1997). In other words, the percent correct predictions of species presence are plotted as a function of the percent false predictions of species presence (Hand 1997). The area under the curve is a convenient measure of overall fit of the model, and varies from 0.5 for a model no better than random chance discrimination between groups, to 1.0 for a perfect discriminatory ability between groups (Pearce and Ferrier 2000). The ROC curve can also be used to identify cutoff values between occupied and unoccupied areas based on desired thresholds of error rates. Thresholds can be adjusted depending on individual species circumstances. For instance, false positives would be more desirable than false negatives in determining habitat suitability for rare species.

RESULTS

Nine active white-tailed kite nests were located within the study area in 2001, and eight active nests were located in 2002. Five of the nine nests (55.5%) in 2001 successfully fledged 3-4 young, and seven of the eight nests (87.5%) in 2002 successfully fledged 2-3 young. Of the four unsuccessful nests in 2001, one nest was abandoned before eggs were laid, two failed during incubation, and one failed due to predation during nestling stage. The final outcome of one nest in 2002 was uncertain beyond the incubation period, but all other nests were successful. Eighteen traditional nests were located within the study area boundaries and were used in analyses. All active nest sites located in 2001, plus all additional 2002 active nest sites located more than 420 m (the minimum distance of two simultaneously active nest sites in 2001) from an active 2001 nest were used in my analyses. Four active nests in 2002 were less than 420 m (16, 18, 40, and 164 m) from a 2001 active nest, and thus were not included in the analysis. This resulted in 13 active nest points for analysis. Thirty nests (12 active and 18 traditional) were located in coast live oaks (*Quercus agrifolia*), and one active nest was consistently located in a southern arroyo willow (*Salix lasiolepis*).

White-tailed kite nests within the study area occurred at elevations between 65 and 314 m, on slopes ranging from flat to 24° slope, and no further than 307 m from a stream corridor (Figure 3). Fifty-two percent of nests were on slopes facing 171° (south) to 286° (west).

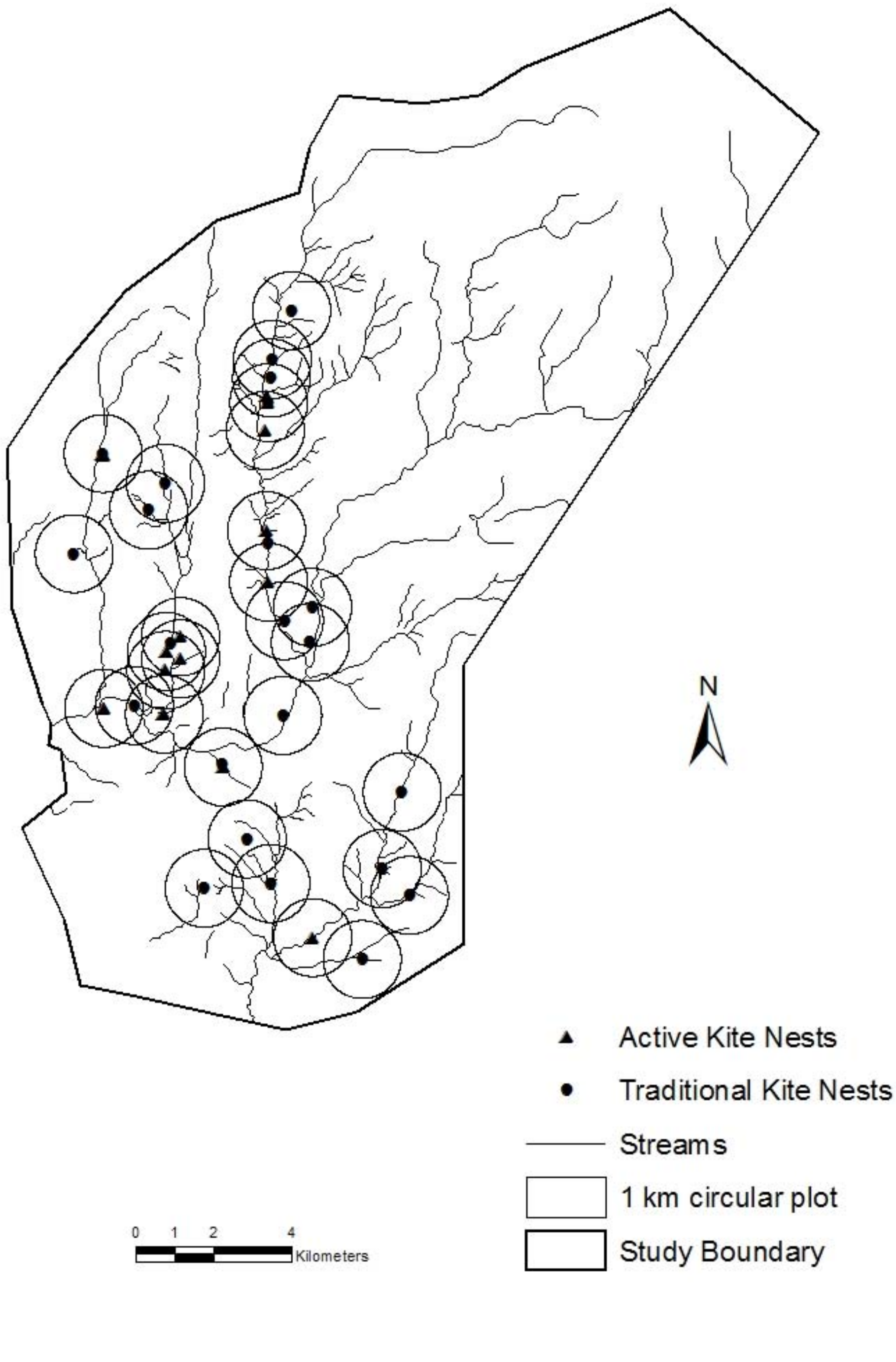


Figure 3. Location of active and traditional white-tailed kite nest sites within the southwestern California study area, 2001-2002.

Univariate Analyses

Kite nest points did not exhibit significant spatial autocorrelation (Moran's I index = -0.43, z-score = -0.6 SD). Significant differences in several physiographic and landscape variables were found when comparing kite nest sites and unused sites across all four circular scales using a two-tailed Mann-Whitney U-test (Table 2). In comparing distance to nearest stream between nest sites and unrestricted random points, nests were significantly closer to streams ($\bar{x}$ = 94 m; SE = 15; $P < 0.001$). In comparing landscape variables around nest sites and unused sites ($\leq$ 307 m from a stream), nest sites had significantly more ($P < 0.01$) agricultural, grassland, riparian, and woodland habitat, and significantly less chaparral habitat compared to unused sites at all scales (Table 2, Figure 4). Patch density of agriculture, grassland, riparian, scrub, and woodland was significantly greater around nest sites than unused sites at all scales (Table 2). In addition, largest patch index and perimeter density of agriculture, grassland, riparian, and woodland were significantly greater around nest sites at all scales, and landscape patch density was greater around nest sites than unused sites at all circular scales. Results of all univariate tests are presented in Appendix A. Habitat surrounding two active nest sites is shown in Appendices B and C.

The percentage of grassland around individual kite nests varied widely from 2.7% to 47.8% (Figure 5). Agriculture ranged from 0 – 48%, grassland from 2.7 - 47.8%, scrub from 12 - 57.8%, and woodland from 0.2 - 11.5%. Agriculture, grassland, and scrub habitat (all potential foraging habitat) together accounted for 35-91% of the habitat

Table 2. Comparison of white-tailed kite nest sites and unused sites at four different circular scales in southwestern California 2001-2002. Only uncorrelated statistically significant variables are shown. AREA variables in terms of total hectares are also presented even though they were correlated with PCT variables. Two-tailed Mann-Whitney U-test. (see Table 1 for definitions of variables)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	*z*	*P*
	D_STRM	94.2	14.83	0.1	306.9	407.8	66.16	9.4	1716.9	-4.52	0.000
	ELEV	150.3	9.75	64.6	313.6	415.0	43.84	87.2	973.5	-5.37	0.000
	SLOPE	7.8	1.14	1.0	24.3	19.6	2.06	0.4	41.7	-4.24	0.000
300 m	AREA_AG	2.4	0.96	0.0	23.9	1.0	0.74	0.0	20.9	2.35	0.019
	AREA_CHP	1.7	0.63	0.0	13.5	12.9	1.86	0.0	27.2	4.59	0.000
	AREA_GR	6.5	0.87	0.0	19.1	2.4	1.03	0.0	22.1	4.67	0.000
	AREA_RIP	7.0	0.72	0.2	18.7	3.9	0.76	0.0	21.8	3.73	0.000
	AREA_WDL	1.5	0.37	0.0	7.3	0.3	0.15	0.0	3.1	3.90	0.000
	PCT_AG	8.6	3.40	0.0	84.4	3.5	2.60	0.0	74.1	2.35	0.019
	PCT_CHP	6.1	2.22	0.0	47.7	45.5	6.57	0.0	96.4	-4.59	0.000
	PCT_GR	22.9	3.09	0.0	67.7	8.5	3.66	0.0	78.0	4.67	0.000
	PCT_RIP	24.8	2.56	0.8	66.2	13.8	2.69	0.0	77.0	3.73	0.000
	PCT_WDL	5.2	1.30	0.0	25.7	1.1	0.53	0.0	11.0	3.90	0.000
	LPI_RIP	23.2	2.62	0.5	66.2	12.9	2.56	0.0	77.0	3.39	0.001
	PCHDN_AG	1.8	0.49	0.0	7.1	0.5	0.27	0.0	7.1	2.42	0.016
	PCHDN_GR	10.6	1.12	0.0	28.3	2.3	0.65	0.0	10.6	5.39	0.000
	PCHDN_RIP	7.0	0.69	3.5	17.7	4.5	0.37	0.0	10.6	3.18	0.001
	PCHDN_SCR	13.7	1.20	3.5	28.3	5.6	0.88	0.0	17.7	4.59	0.000
	PCHDN_WDL	5.0	0.88	0.0	17.7	1.6	0.56	0.0	10.6	3.49	0.000
	LPCHDN	47.8	2.82	17.7	81.3	23.0	1.97	7.1	53.0	5.40	0.000

Table 2. Comparison of white-tailed kite nest sites and unused sites at four different circular scales in southwestern California 2001-2002. Only uncorrelated statistically significant variables are shown. AREA variables in terms of total hectares are also presented even though they were correlated with PCT variables. Two-tailed Mann-Whitney U-test. (see Table 1 for definitions of variables) (continued)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	*z*	*P*
500 m	AREA_AG	7.8	2.39	2.4	52.4	2.3	1.52	0.0	39.8	2.59	0.010
	AREA_CHP	6.5	1.85	1.8	45.2	37.3	5.07	0.0	74.4	-4.26	0.000
	AREA_GR	17.5	2.25	2.2	44.4	6.8	2.72	0.0	57.9	4.57	0.000
	AREA_RIP	15.8	1.33	1.3	35.0	7.7	1.25	1.1	36.5	4.49	0.000
	AREA_WDL	3.6	0.69	0.7	14.5	0.7	0.23	0.0	4.1	4.49	0.000
	PCT_AG	9.9	3.04	0.0	66.8	2.9	1.93	0.0	50.7	2.59	0.010
	PCT_CHP	8.2	2.35	0.0	57.5	47.4	6.46	0.0	94.7	-4.26	0.000
	PCT_GR	22.2	2.86	0.0	56.5	8.6	3.46	0.0	73.7	4.57	0.000
	PCT_RIP	20.2	1.69	2.2	44.6	9.8	1.59	1.4	46.5	4.49	0.000
	PCT_WDL	4.6	0.88	0.0	18.5	0.8	0.29	0.0	5.2	4.49	0.000
	LPI_RIP	17.4	1.86	1.0	43.0	8.8	1.50	1.4	46.5	3.51	0.000
	PCHDN_AG	0.8	0.20	0.0	2.5	0.2	0.10	0.0	2.5	2.73	0.006
	PCHDN_GR	7.1	0.61	0.0	12.7	1.8	0.47	0.0	10.2	5.33	0.000
	PCHDN_RIP	4.7	0.54	1.3	11.5	2.1	0.25	1.3	6.4	4.11	0.000
	PCHDN_SCR	9.6	0.76	2.5	17.8	3.7	0.64	0.0	15.3	5.01	0.000
	PCHDN_WDL	4.2	0.68	0.0	17.8	1.0	0.28	0.0	5.1	4.50	0.000
	PERDN_RIP	72.2	4.19	29.2	130.7	52.1	4.07	12.2	87.8	2.65	0.008
	PERDN_SCR	104.2	6.59	29.7	193.6	58.9	9.51	0.0	163.0	3.30	0.001

Table 2. Comparison of white-tailed kite nest sites and unused sites at four different circular scales in southwestern California 2001-2002. Only uncorrelated statistically significant variables are shown. AREA variables in terms of total hectares are also presented even though they were correlated with PCT variables. Two-tailed Mann-Whitney U-test. (see Table 1 for definitions of variables) (continued)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	*z*	*P*
500 m	LPCHDN	34.2	2.06	15.3	64.9	14.0	1.47	2.5	33.1	5.81	0.000
700 m	AREA_AG	15.8	4.30	0.0	84.9	4.5	2.93	0.0	77.0	2.76	0.006
	AREA_CHP	15.1	3.86	0.0	94.9	73.6	9.84	0.0	146.0	-4.06	0.000
	AREA_GR	33.9	4.25	0.6	79.0	14.0	5.17	0.0	111.5	4.45	0.000
	AREA_RIP	25.9	2.17	2.2	54.9	12.2	1.67	2.3	48.1	4.62	0.000
	AREA_WDL	6.3	1.06	0.4	21.3	1.0	0.33	0.0	8.1	5.19	0.000
	PCT_AG	10.2	2.80	0.0	55.1	2.9	1.90	0.0	50.0	2.76	0.006
	PCT_CHP	9.8	2.50	0.0	61.6	47.8	6.39	0.0	94.9	-4.06	0.000
	PCT_GR	22.0	2.76	0.4	51.3	9.1	3.36	0.0	72.4	4.45	0.000
	PCT_RIP	16.8	1.41	1.4	35.7	7.9	1.08	1.5	31.2	4.62	0.000
	PCT_WDL	4.1	0.69	0.3	13.9	0.7	0.21	0.0	5.3	5.19	0.000
	LPI_RIP	13.5	1.51	0.5	33.3	6.8	1.02	0.9	30.7	3.41	0.001
	PCHDN_AG	0.7	0.17	0.0	3.2	0.1	0.05	0.0	1.3	3.08	0.002
	PCHDN_GR	5.7	0.41	0.6	9.7	1.3	0.33	0.0	5.8	5.78	0.000
	PCHDN_RIP	3.7	0.44	0.6	9.1	1.7	0.26	0.6	6.5	3.76	0.000
	PCHDN_SCR	7.5	0.52	1.9	14.9	3.1	0.52	0.0	13.6	5.09	0.000
	PCHDN_WDL	3.6	0.41	0.6	11.0	0.8	0.18	0.0	3.9	5.64	0.000
	PERDN_RIP	61.2	4.09	19.4	105.0	44.2	3.61	11.8	86.2	2.39	0.017
	PERDN_SCR	102.9	5.13	63.1	168.9	57.6	8.75	0.0	156.5	3.72	0.000

Table 2. Comparison of white-tailed kite nest sites and unused sites at four different circular scales in southwestern California 2001-2002. Only uncorrelated statistically significant variables are shown. AREA variables in terms of total hectares are also presented even though they were correlated with PCT variables. Two-tailed Mann-Whitney U-test. (see Table 1 for definitions of variables) (continued)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	*z*	*P*
700 m	LPCHDN	27.8	1.58	12.3	48.7	11.0	1.20	1.3	26.0	5.90	0.000
1 km	AREA_AG	34.3	8.44	0.0	145.1	9.5	6.06	0.0	158.9	2.94	0.003
	AREA_CHP	34.5	7.40	0.0	173.5	147.3	19.30	0.0	291.1	-3.96	0.000
	AREA_GR	67.2	7.90	8.5	150.1	30.5	10.73	0.0	246.9	4.20	0.000
	AREA_RIP	43.7	3.29	4.5	75.5	21.3	2.29	4.6	68.4	4.87	0.000
	AREA_WDL	11.1	1.77	0.5	36.2	2.5	0.65	0.0	18.6	4.87	0.000
	PCT_AG	10.9	2.69	0.0	46.2	3.0	1.93	0.0	50.6	2.94	0.003
	PCT_CHP	11.0	2.35	0.0	55.2	46.9	6.14	0.0	92.7	-3.96	0.000
	PCT_GR	21.4	2.52	2.7	47.8	9.7	3.42	0.0	78.6	4.20	0.000
	PCT_RIP	13.9	1.05	1.4	24.0	6.8	0.73	1.4	21.8	4.87	0.000
	PCT_WDL	3.5	0.56	0.2	11.5	0.8	0.21	0.0	5.9	4.87	0.000
	LPI_RIP	9.6	1.12	0.4	22.0	5.1	0.65	0.5	18.3	3.01	0.003
	PCHDN_AG	0.5	0.11	0.0	2.2	0.1	0.03	0.0	0.6	3.34	0.001
	PCHDN_CHP	4.4	0.51	0.0	9.9	2.2	0.33	0.0	7.3	3.18	0.001
	PCHDN_GR	4.6	0.30	1.9	8.9	1.2	0.25	0.0	5.4	5.94	0.000
	PCHDN_RIP	3.0	0.31	0.3	6.4	1.4	0.23	0.3	5.7	4.15	0.000
	PCHDN_SCR	6.2	0.49	1.0	13.7	2.8	0.42	0.0	10.8	4.62	0.000
	PCHDN_WDL	3.0	0.30	0.3	8.9	0.8	0.15	0.0	3.5	5.67	0.000
	PERDN_RIP	53.9	3.65	17.2	96.8	38.3	2.66	9.3	71.6	2.76	0.006

Table 2. Comparison of white-tailed kite nest sites and unused sites at four different circular scales in southwestern California 2001-2002. Only uncorrelated statistically significant variables are shown. AREA variables in terms of total hectares are also presented even though they were correlated with PCT variables. Two-tailed Mann-Whitney U-test. (see Table 1 for definitions of variables) (continued)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	*z*	*P*
1 km	PERDN_SCR	101.9	4.61	59.5	149.3	56.3	7.71	0.0	133.9	4.10	0.000
	LPCHDN	23.7	1.30	11.8	38.2	9.3	1.00	1.6	21.3	5.96	0.000

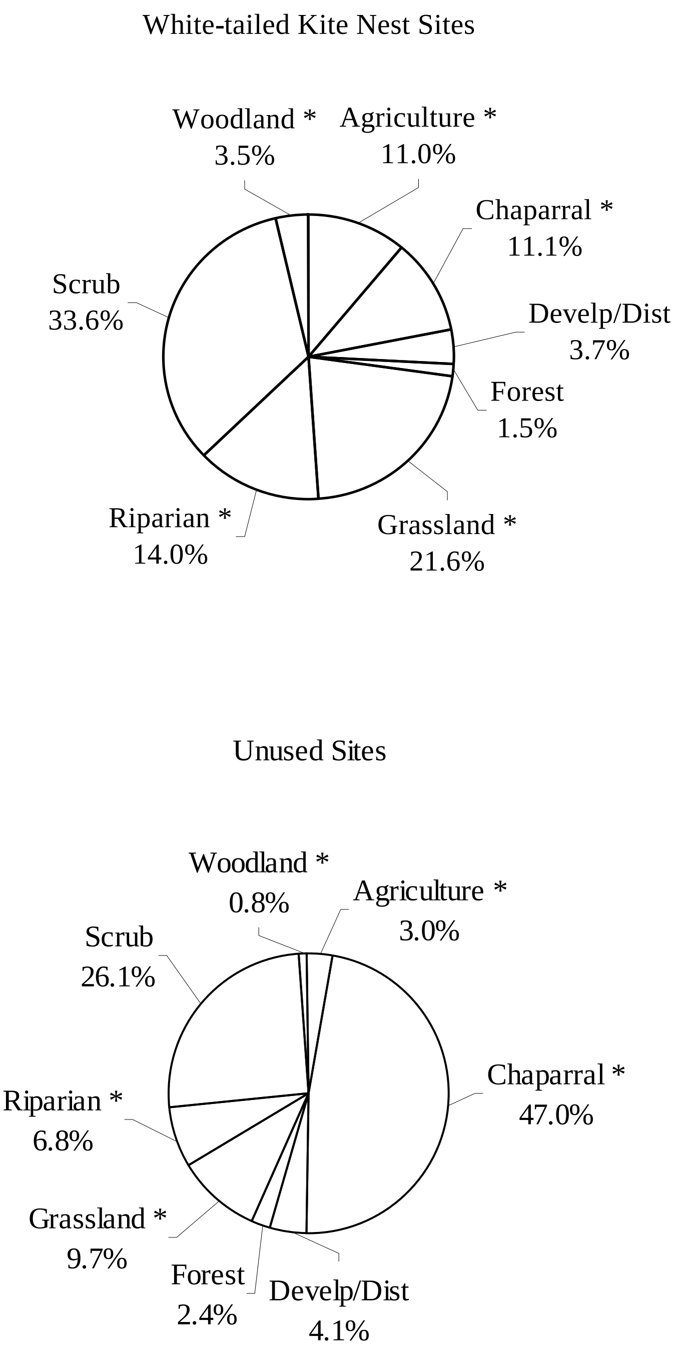


Figure 4. Habitat composition within 1 km circular plots centered on white-tailed kite nests and unused sites in southwestern California 2001-2002. Variables that differed significantly ($P < 0.05$) using two-tailed Mann-Whitney U-test are indicated with an asterisk (*).

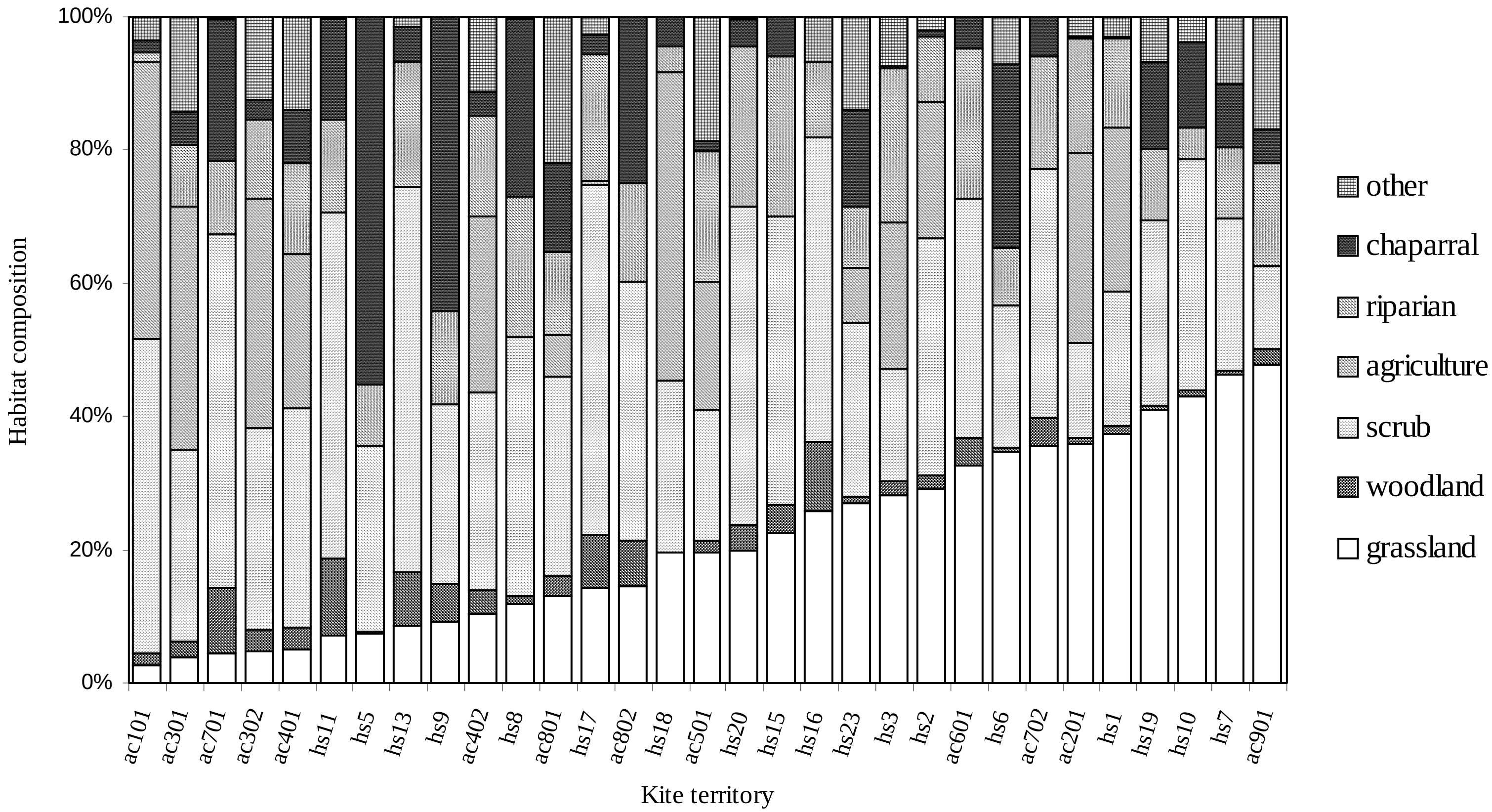


Figure 5. Habitat composition within 1 km circular plot around each of 31 active and traditional white-tailed kite nest sites in southwestern California, 2001-2002. Territories are arranged in order of proportion of grassland habitat. “Other” category includes disturbed, developed, and forest habitat.

surrounding kite nest sites ($\bar{x}$ = 66, SE = 2.37) at 1 km-radius scale. Similar patterns were found at 300, 500, and 700 m scales. In cases where grassland was at a low percentage, scrub was at a large percentage, and vice versa (Figure 6).

Model Selection

Distance to nearest stream, percent grassland, and percent woodland habitat were the most useful variables for discriminating between kite nest sites and unused sites across all four circular scales (Table 3). Percent correctly classified nests ranged from 94-97% across scales. ROC analyses revealed a high level of predictability by the final model at each scale, based on the area under the curve (AUC). In comparing the performance of the model between scales, the model at 700 m scale, followed by 1 km scale, had the greatest predictive power in discriminating between kite nest sites and unused sites. At 300 m scale, distance to nearest stream, percent grassland, and percent woodland habitat correctly classified 94% of nest sites and 90% of unused sites (Table 3). The ROC plot for the model had an AUC of 0.96. At 500 m scale, the same three variables correctly classified 94% of nest sites and 100% of unused sites, and had an AUC of 0.98. At 700 m scale, these three variables correctly classified 100% of nest sites and 100% of unused sites, and had an AUC of 1.00. At 1000 m scale, the same three variables correctly classified 97% of nest sites and 100% of unused sites, and had an AUC of 0.99. A quasi-complete separation of kite nests and unused points occurred during logistic regression analyses for 300 m and 500 m scale, and a complete separation of the data points occurred for the 700 m scale, thus questioning the validity of the

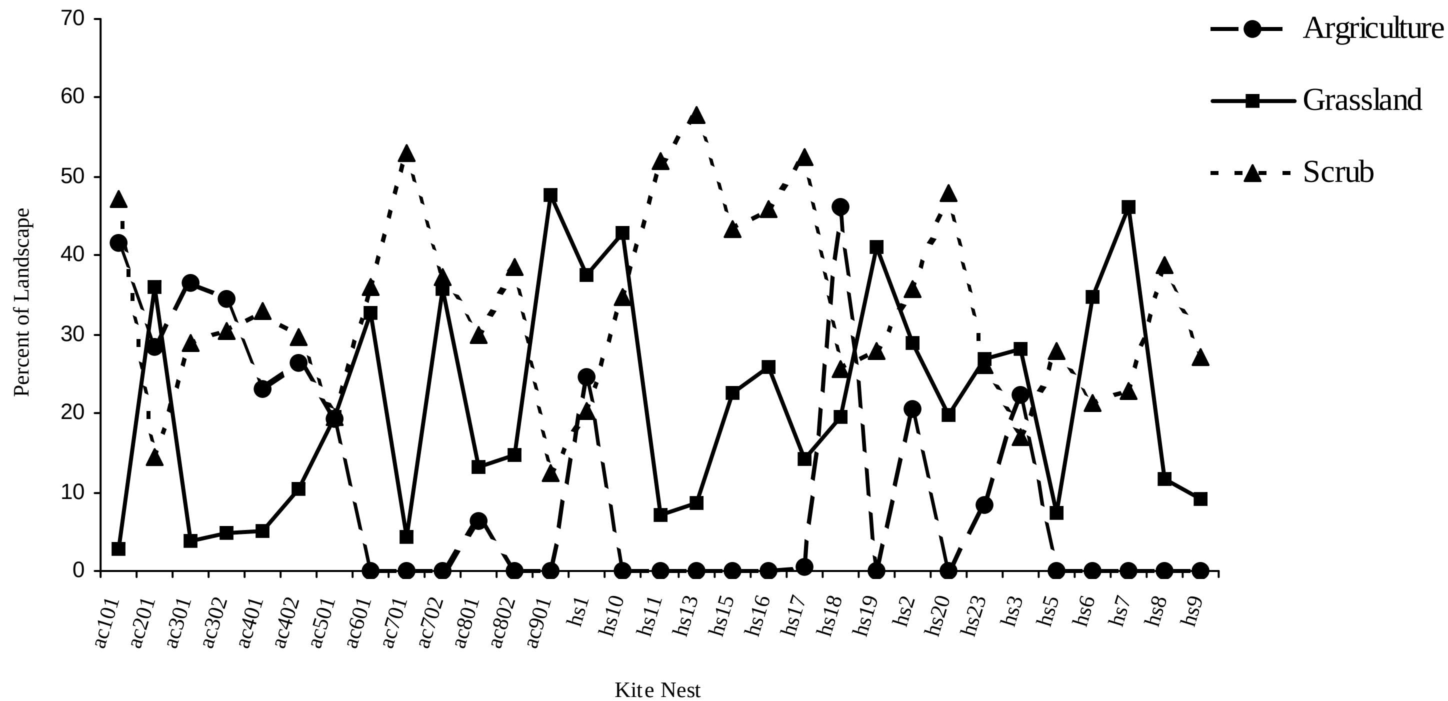


Figure 6. Comparison of percent agriculture, grassland, and scrub habitats within 1 km circular plot around white-tailed kite nest sites in southwestern California, 2001-2002.

Table 3. Results of forward stepwise logistic regression analysis of white-tailed kite nest sites and unused sites at four different circular scales. (see Table 1 for definition of variables).

Landscape Variable	Likelihood-ratio test			
300 m radius scale	Coefficient	Odds ratio	x^2	*P*
Intercept	1.167			
D_STRM	-0.022	0.978	39.185	0.000
PCT_GR	0.152	1.164	16.156	0.000
PCT_WDL	0.570	1.768	8.952	0.003
Correctly classified = 92% (94 nests, 90 unused)				
Model AUC*: 0.96				
500 m radius scale				
Intercept	0.120			
D_STRM	-0.026	0.975	39.767	0.000
PCT_GR	0.194	1.214	17.043	0.000
PCT_WDL	1.720	5.583	17.787	0.000
Correctly classified = 97% (94 nests, 100 unused)				
Model AUC: 0.98				
700 m radius scale				
Intercept	-5.749			
D_STRM	-0.424	0.655	50.063	0.000
PCT_GR	2.851	17.304	21.960	0.000
PCT_WDL	63.078	10000+	32.160	0.000
Correctly classified = 100% (100 nests, 100 unused)				
Model AUC: 1.00				
1 km radius scale				
Intercept	-2.888			
D_STRM	-0.061	0.941	47.569	0.000
PCT_GR	0.481	1.618	23.567	0.000
PCT_WDL	6.216	500.577	29.331	0.000
Correctly classified = 98% (97 nests, 100 unused)				
Model AUC: 0.99				

*area under the curve from ROC plot

models. Analysis results for 1 km scale were normal. Quasi-complete and complete separation of data often occurs because the sample size is too small. While these models correctly classify this dataset, they may not do so for other observations.

DISCUSSION

Nesting white-tailed kites on my study site showed a strong affinity for low elevation riparian corridors. All nests were below 314 m elevation and within 307 m of a riparian corridor. More than half of all nests were less than 150 m from a riparian corridor. I frequently observed kites foraging in grassland and open scrub habitats surrounding these riparian corridors. In addition, all occupied kite territories had significantly more riparian habitat with adjacent grassland habitat than did unused sites. Kites have also shown a preference for riparian areas in other studies (Henry 1983, Erichsen et al. 1996). Nine of 22 white-tailed kite nests (41%) in an agricultural setting in the Sacramento Valley were located in riparian corridors and the remaining nests were in hedgerows (Erichsen et al. 1996). Distance to nearest stream was included in models at multiple scales around eagle owl (*Bubo bubo*) nests (Ortega and Diaz 2004). Ortega and Diaz suggested that these owls were selecting for either protected nest locations and (or) areas of high prey availability.

White-tailed kites are known to nest in a variety of different tree species (Pickwell 1930, Dixon et al. 1957). Since coast live oaks were abundant throughout the study site and not just within riparian corridors, it is unlikely that nest substrate was the main reason why kites showed a preference for riparian corridors. Within my study site, wetter areas such as riparian corridors and marshes had the greatest amount of grass and herbaceous cover, and therefore had the potential to support an abundance of prey. Adjacent to these riparian areas were grassland and open scrub habitats where prey may immigrate and be more available to foraging kites. Thus, kites may be nesting within the riparian corridors because of the proximity to foraging areas rather than the availability of nesting substrate.

Univariate results comparing kite nests and unused points were the same across all scales. White-tailed kite nests in my study area were surrounded by significantly more agriculture, annual grassland, riparian, and woodland habitat than were unused sites. In addition, the landscape surrounding nest sites was patchier (more fragmented) than unused sites. Mean percent grassland was the most consistent across all scales at 21-23%. Percent agriculture, chaparral, and scrub increased slightly with increase in scale size. Riparian and woodland habitat decreased with increase in scale. For all habitats, patch density decreased as scale increased, with the greatest decrease seen in patch density of scrub, suggesting a patchier landscape closer to the nest.

Though habitat composition was significantly different between nest sites and unused sites, the degree and direction of change in habitat variables with increase in scale were similar at nest and unused sites. This suggests that similarities in variables across scales could be a result of sampling technique (concentric circles), thus making it difficult to extract biological meaning from the observed scale patterns. The scale patterns could also be a reflection of the distance from riparian corridors. As distance from a riparian corridor increased, the amount of riparian habitat decreased, the amount of agriculture, chaparral, and scrub increased, and patch density of all habitats decreased. Perimeter density of grassland showed the greatest difference between kite nests and unused sites across scales, suggesting an importance of this variable to kites. Perimeter density, which is an index of fragmentation, decreased considerably (from 90 to 64 m/m^2) around nest sites with an increase in scale, as compared to a slight decrease (from 25 to 20 m/m^2) around unused sites. This indicates that the habitat closer to nest sites was more fragmented, or patchier.

May and Gutierrez (2002) showed that important habitat variables specific to Mexican spotted owls (*Strix occidentalis lucida*) were most significant at smaller scales. Erichsen et al. (1996) found that the significance of land-use types diminished at larger distances from white-tailed kite nests in an agricultural environment. On the other hand, Finn et al. (2002) found that the relationship between Northern goshawk (*Accipiter gentillis*) occupancy and important habitat variables increased proportionately with an increase in scale. This suggests that habitat farther from the nest may be more important than the immediate area for goshawks. On my study site, important habitat variables were significant at all scales around kite nests.

Distance to stream, percent grassland, and percent woodland were the most useful landscape variables in distinguishing between white-tailed kite nest sites and unused sites. The greatest percent of correctly classified kite nest sites occurred at the 700 m-radius circle (153 ha), though the most statistically valid model occurred at the 1 km scale. Distance to stream was the most important variable in the model at all scales, and the percent correct classification of the model varied only slightly among scales. Models produced for eagle owl nest sites also included the same variables across all four scales and had equally high classification rates at all scales (Ortega and Diaz 2004). The inclusion of the same variables at all scales indicates a strong selection for these variables. White et al. (2005) found consistency of certain variables in models at multiple scales surrounding Northern Bobwhite nests, and suggested scale independence of these variables.

The consistency of habitat composition and predictive power of models across all scales around kite nests in my study suggests that grassland and riparian habitats may be equally as important within 1 km from the nest as they are within 300 m from the nest. However, other variables suggested that a patchier landscape is more important closer to the nest. Most kite nests were within riparian corridors that ran right through the middle of all circular plots, which meant that kites had access to riparian habitat and adjacent grasslands immediately around the nest, as well as 1 km from the nest. Centering nests within a riparian corridor may give kites the best central location to search for quality foraging habitat at a variety of distances and directions from the nest.

Agricultural habitat may play an important role as foraging habitat for nesting white-tailed kites, depending upon crop type. Ninety percent of agricultural habitat within the landscape surrounding kite nests was classified as dryland field crops (e.g., wheat and barley). These fields are known to provide prey for foraging raptors on this study site depending on the crop stage (Bloom, P. 2006. Personal Communication. Western Foundation of Vertebrate Zoology, 439 Calle San Pablo, Camarillo, CA 93012). Within the study area dryland fields go through different stages over the course of a year and over several years. The productivity of each stage, as it relates to profitable foraging habitat for kites, also fluctuates. For instance, a fallow crop field could provide a substantial amount of prey for kites, but a recently disked or planted crop field would contain few prey. Irrigated crops also vary in their value to foraging raptors. Alfalfa and sugarbeets provide substantial foraging habitat for raptors (Erichsen et al. 1996). Active strawberry fields on the other hand provide no habitat for kites, but a strawberry field gone fallow could provide additional foraging areas. Orchards that contain little to no ground cover contain few prey, and therefore, provide little to no foraging habitat at anytime of the year. Landscape studies on raptors should distinguish between the different types of agriculture so that the importance, or unimportance, of this habitat to raptors is not overlooked.

While the amount of grassland around kite nests was significantly greater than unused sites, it was variable among individual kite nests. There are several possible explanations for the wide range. First, variability in habitat quality as it pertained to abundance and availability of prey could be a factor. Several of the kite circles containing the least amount of grassland were located adjacent to marshy areas that had a high density of prey that may have dispersed into adjacent grassland patches. This suggests that a small amount of high quality prey habitat may be adequate to support nesting kites. Second, some kites may have had foraging areas beyond 1 km from the nest. Waian (1973) and Henry (1983) each observed a breeding male foraging regularly at a grassland patch 2 km and 1.9 km from the nest, respectively. Third, kites may be foraging in other habitats beside grassland. Henry (1983) observed a nesting kite foraging regularly over coastal sage scrub habitat.

Cattle grazing may have significantly affected white-tailed kite nest site use. Of the 13 active nests on my study site, nine were centered in ungrazed areas and included ungrazed patches of grassland. Eight of these nine nests successfully fledged young, and one nest failed due to predation of young in the nest. Four of the total 13 active nests were located in grazed areas. Three of these nests failed due to abandonment and failed incubation. The one successful nest was surrounded by 36% grassland and 28% agriculture habitat. Evans et al. (2006) showed that livestock grazing negatively affected abundance of *Microtus* sp. Grazing may ultimately lower the quality of kite nesting habitat by decreasing the abundance of prey.

White-tailed kites on my study site nested almost exclusively in coast live oaks, usually in small groves within a riparian corridor. The significance of woodland habitat in the model was likely due to its association with riparian corridors, although, depending on the density of the woodland, this habitat could provide additional foraging patches for kites.

The greatest percentage of habitat surrounding nest sites was scrub. This is likely a reflection of the abundance of this habitat within the study site. However, while the amount of scrub habitat was not significantly different between nest sites and unused sites, it may serve as important foraging habitat for kites in this region. Most of the scrub habitat within the study site is coastal sage scrub and southern cactus scrub, both of which can be open, patchy, and intermingled with patches of native grasses. Coastal sage scrub habitat has the highest diversity of small mammals of any habitat in this region (Schoenherr 1992). The hover-hunting technique used by kites allows them to utilize even the smallest patches of habitat, thus allowing them to hunt small grassy patches within coastal sage scrub, and to exploit patchy landscapes.

Patch density of coastal sage scrub and grassland was greatest around nest sites at the smallest scale (300 m), thus indicating more edge habitat near nest sites. Edge habitat between grassland and coastal sage scrub could be highly valuable in terms of prey availability. Small mammals moving between coastal sage scrub patches may be more vulnerable to kites. Austin et al. (1996) noted that forest edge created a region of spillover of voles into open habitat, creating optimal hunting conditions for buzzards (*Buteo buteo*). It is possible that surplus rodents from coastal sage scrub spill over into adjacent grassland.

Upon reviewing studies of hunting behavior and food habits of all *Elanus* species worldwide, Mendelsohn and Jaksic (1989) found that grasslands, low shrubs, open woodlands, and cultivated areas were consistently favored for hunting. There appeared to be a balance or interplay among the proportion of these foraging habitats surrounding kite nest sites on my study site. In instances where grassland was at a minimum around nest sites ($\leq$5%), agriculture was high (20-40%). In instances where grassland and agriculture together accounted for less than 10% of habitat surrounding kite nests, scrub occurred at its greatest percentage (27-58%).

While the scale at which habitat or landscape affects site occupancy in kites is unknown, observations of nesting kites have revealed an array of estimated home range sizes. Home range from several studies range from 17 – 120 ha. Watson (1940) determined an average kite home range of 68 ha for 10 pairs. Breeding kites have also been observed foraging more than 1km from the nest (Waian 1973, Henry 1983). Erichsen (1993) observed kites frequently using hunting areas immediately adjacent to the nest (<500 m) and out to approximately 1.6 km. In addition, Dunk and Cooper (1994) reported year-round hunting territories ranging from 1.6 to 21.5 ha.

Mendelsohn and Jaksic (1989) stated that kites usually select microhabitats within a heterogeneous landscape. Henry (1983) observed nesting kites spending a disproportionate amount of time over small areas within their home range. For example, one kite was observed spending 68% of foraging activities within 8 ha of its 62 ha home range; another kite spent 81% of its foraging over 2 ha; and a third kite spent 94% of its foraging within 32 ha of its 35 ha home range. Another kite had two main foraging areas: one 47 ha coastal sage scrub patch approximately 350 m from the nest, and one 6 ha grassland patch at 1.9 km from the nest. This kite used an area of about 53 ha within its 120 ha home range. Thus, while habitat immediately surrounding the nest may be influential, it may not always include all important foraging areas. Kites appear willing to fly extended distances from nests to a good foraging patch (Waian 1973, Henry 1983, Erichsen et al. 1996).

Using information on white-tailed kite home range and territory sizes from other studies in combination with my results from univariate and logistic regression analyses of landscape around nest sites, I suggest that a 700 m-radius scale (153 ha) is an appropriate scale for examining kite nesting habitat. The model for this scale had the greatest number of correctly classified nest sites, and this scale generously covers all currently known white-tailed kite home range sizes. In terms of potential foraging habitat, the mean total amount of agriculture, grassland, and scrub habitat around nest sites at this scale was 16, 34, and 48 ha, respectively.

While this scale may be appropriate for landscape analysis, this is not to say that a 700 m circle around a nest site will preserve an adequate amount of foraging habitat for nesting kites in all cases. The amount of foraging habitat needed depends ultimately on the quality of habitat in terms of prey abundance and availability. Hawbecker (1940) stated that kite populations were governed by the relationship of food to suitable nesting places, and a high population of voles were necessary for successful kite nesting. Dixon et al. (1957) suggested that an area of about 8 ha of “mouse pasture” is sufficient to support a pair of nesting kites if prey is abundant. Dunk and Cooper (1994) noted that the abundance of voles within fluctuating kite territories remained fairly consistent over time, and suggested that kites need about 1500 voles within their territory. Estimates of vole density in specific locations would help to determine the quality of habitat patches, and thus help to determine the amount of habitat necessary to support a pair of nesting kites in that location.

Circular plots centered on nest sites have been used as a simplistic but effective way of representing a species home range and habitat use area for various raptor species. However, it should be remembered that the location of the nest may be on the periphery of the territory rather than in the center, and that birds may adjust the shape of their range to incorporate disjunct suitable habitat patches. In addition, while this method may be suitable for analyzing habitat of raptors such as Buteos, Accipiters, Falcons, and some owls, which prey upon evenly distributed and stable prey populations, it may not be the best method for habitat analysis of raptor species such as Northern harriers (*Circus* *cyaneus*), short-eared owls (*Osio flammeus*), and white-tailed kites, which prey upon patchy rodent populations that undergo large localized fluctuations.

CONCLUSION AND RECOMMENDATIONS

Studies have shown that both micro and macrohabitat variables play an important role in habitat selection by raptors. However, thorough analysis of microhabitat requires labor-intensive on-site field efforts, while macrohabitat variables can be examined relatively easily from satellite images and digitized map data within a geographic information system.

Occupied white-tailed kite nest sites within this study site had several common landscape characteristics. Nests were located within or near undisturbed riparian corridors or marsh and surrounded by a patchy landscape. Riparian corridors had areas of dense grass cover and herbaceous vegetation and contained small stands of coast live oaks and(or) mature willows for nests. Adjacent to nesting riparian corridors was undisturbed open foraging habitat, in the form of grassland, open scrub, and some agriculture types.

Nesting white-tailed kites would benefit from the following land management considerations: 1) preserve and maintain areas that promote an abundant prey base, 2) maintain open areas where prey is available to foraging kites, such as grasslands, open coastal sage scrub, and certain types of agriculture (e.g., alfalfa, sugarbeets); 3) maintain proximity between high density prey habitat and open foraging areas; and 4) keep development and disturbance to a minimum near riparian and adjacent grassland habitats. In addition, kite territories should be monitored annually, and those that are occupied most consistently should receive priority when designing habitat reserves. Future research on white-tailed kites should include extensive observations of nesting kites and their habitat use across the landscape; combination of home range study and small mammal trapping; and comparison of habitat analysis results between circular plots and known home range polygons.

LITERATURE CITED

Afifi, A. A. and V. Clark. 1984. Computer-aided multivariate analysis. Wadsworth Press, Belmont, California.

Austin, G. E., C. J. Thomas, D. C. Houston, and D. B. A. Speiser. 1996. Predicting the spatial distribution of buzzard *Buteo buteo* nesting areas using a Geographical Information System and remote sensing. Journal of Applied Ecology 33:1541-1550.

Bammann, A. R. 1975. Ecology of predation and social interactions of wintering white-tailed kites. Master's thesis. Department of Natural Resources, Humboldt State University, Arcata, California.

Bennett, J. R. and P. H. Bloom. 2005. Home range and habitat use by great horned owls in southern California. Journal of Raptor Research 39:119-126.

Bloom, P. H., M. D. McCrary, and M. J. Gibson. 1993. Red-shouldered hawk home range and habitat use in southern California. Journal of Wildlife Management 57:258-265.

California Partners in Flight. 2000. Version 1.0. The draft conservation plan: a strategy for protecting and managing grassland habitats and associated birds in California. Point Reyes Bird Observatory, Stinson Beach, California. Available at http://www.prbo.org/calpif/plans.html. Contacted on September 15, 2007.

Chiang, S. N. 2004. Home range and habitat use of Cooper's hawks in urban and natural areas of southern California. Master's thesis. Department of Environmental Studies, California State University, Fullerton, California.

Clark, W. S. and B. K. Wheeler. 1987. Peterson Field Guides - Hawks. Houghton Mifflin Company, Boston, Massachusetts.

County of Orange. 2002. Orange County facts and figures. County of Orange, Planning and Development Services and Public Facilities and Resources Departments, Santa Ana, California.

Dahl, T. E. 1990. Wetland losses in the United States: 1780's to 1980's. U.S. Fish and Wildlife Service, Washington, DC. 13 p.

Daniel, W. W. 1990. Applied Non-parametric statistics. PWS-Kent Publishing Co., Boston, Massachusetts.

Dixon, J. B., R. E. Dixon, and J. E. Dixon 1957. Natural history of the white-tailed kite in San Diego County, California. Condor 59:156-166.

Dunk, J. R. 1992. Black-shouldered kite – small mammal – vegetation relationships in northwestern California. Master's thesis. Department of Natural Resources, Humboldt State University, Arcata, California.

Dunk, J. R. 1995. White-tailed kite (*Elanus leucurus*). No. 178 in A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences and The American Ornithologists' Union, Philadelphia, Pennsylvania and Washington, D.C.

Dunk, J. R. and R. J. Cooper. 1994. Territoriality size regulation in Black-shouldered Kites. Auk 111:588-595.

Eisenmann, E. 1971. Range expansion and population increase in North and Middle America of the white-tailed kite (*Elanus leucurus*). American Birds 25:529-536.

ESRI (Environmental Systems Research Institute). 2005. ArcGIS. Version 9.1. Environmental Systems Research Institute, Redlands, California.

Erichsen, A. L. 1993. The white-tailed kite (*Elanus leucurus*): Nesting success and seasonal habitat selection in an agricultural landscape. Master's thesis. Department of Avian Sciences, University of California, Davis, California.

Erichsen, A. L., K. S. Smallwood, A. M. Commandotore, B. W. Wilson, and D. M. Fry. 1996. White-tailed kite movement and nesting patterns in an agricultural landscape. Pages 165-176 in D. M. Bird, D. E. Varland, and J. J. Negro, editors. Raptors in human landscapes. Academic Press and Raptor Research Foundation. London, United Kingdom.

Evans, D. M., S. M. Redpath, D. A. Elston, S. A. Evans, R. J. Mitchell, and P. Dennis. 2006. To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. Journal of Applied Ecology 43:499-505.

Fielding, A. H. and J. F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation 24:38-49.

Finn, S. P., J. M. Marzluff, and D. E. Varland. 2002. Effects of landscape and local attributes on Northern Goshawk site occupancy in western Washington. Forest Science 48:427-436.

Fry, D. R., Jr. 1966. Recovery of the white-tailed kite. Pacific Discovery 19:27-30.

Gray, J. and D. Bramlet. 1992. Habitat classification system: Orange County natural resources geographic information system (GIS) project. Prepared for the County of Orange, Environmental Management Agency, Santa Ana, California.

Grinnell, J. 1914. Occurrence of the white-tailed kite in Central California in 1913. Condor 16:41.

Hand, D. J. 1997. Construction and assessment of classification rules. John Wiley & Sons, Chichester, United Kingdom.

Hawbecker, A. C. 1940. The nesting of the white-tailed kite in Southern Santa Cruz County, California. Condor 42:106-111.

Henry, M. E. 1983. Home range and territoriality in breeding white-tailed kites. Master's thesis. Department of Biology, San Diego State University, San Diego, California.

Hintze, J. L. 2004. Number cruncher statistical system (NCSS). Kaysville, Utah.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. California Department of Fish and Game, unpublished report, Sacramento, California.

Johnson, C. J., S. E. Nielsen, E. H. Merrill, T. L. McDonald, and M. S. Boyce. 2006. Resource selection functions based on use-availability data: theoretical motivation and evaluation methods. Journal of Wildlife Management 70:347-357.

MacKenzie, D. I. 2006. Modeling the probability of resource use: the effect of, and dealing with, detecting species imperfectly. Journal of Wildlife Management 70:367-374.

May, C. A. and R. J. Gutierrez. 2002. Habitat associations of Mexican Spotted Owl nest and roost sites in central Arizona. Wilson Bulletin 114:457-466.

McGarigal, K. and B. J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. United States Department of Agriculture, Forest Service, General Technical Report PNW-351, Washington, D.C.

Mendelsohn, J. M. and F. M. Jaksic. 1989. Hunting behaviour of black-shouldered kites in the Americas, Europe, and Australia. Ostrich 60:1-12.

Newton, I. 1979. Population Ecology of Raptors. Poyser, United Kingdom.

Ortega, J. and M. Diaz. 2004. Habitat preference models for nesting Eagle Owls *Bubo bubo*: How much can be inferred from changes with spatial scale? Ardeola 51:385-394.

Pearce, J. and S. Ferrier. 2000. Evaluating the predictive performance of habitat models developed using logistic regression. Ecological Modelling 133:225-245.

Pickwell, G. 1930. The white-tailed kite. Condor 32:221-239.

Pruett-Jones, S. G., M. A. Pruett-Jones, and R. L. Knight. 1980. The white-tailed kite in North and Middle America: current status and recent population changes. American Birds 34:682-688.

Sauer, J. R., J. E. Hines, and J. Fallon. 2007. The North American breeding bird survey, results and analysis 1966-2006. Version 7.23.2007. United States Geological Society, Patuxent Wildlife Research Center, Laurel, Maryland.

Schoenherr, A. A. 1992. A natural history of California. University of California Press, Berkeley, California.

Stendell, R. C. 1972. The occurrence, food habits, and nesting strategy of white-tailed kites in relation to a fluctuating vole population. Doctoral dissertation. Department of Zoology, University of California, Berkeley, California.

Stendell, R. C. and P. Meyers. 1973. White-tailed kite predation on a fluctuating vole population. Condor 75:359-360.

United States Geological Society. 1988. 7.5-minute topographical quadrangles: Canada Gobernadora and San Clemente, California. United States Geological Society, Denver, Colorado.

United States Geological Society. 1998. Digital Ortho-photo Quads (DOQQ). Obtained from United States Fish and Wildlife Service, Carlsbad, California.

United States Geological Society. 2001. Digital Elevation Maps (DEMS). Available at www.gisdatadepot.com. Contacted on December 10, 2006.

Waian, L. B. 1973. The behavioral ecology of the North American white-tailed kite (*Elanus leucurus majusculus*) of the Santa Barbara coastal plain. Doctoral dissertation. Department of Biology, University of California, Santa Barbara, California.

Waian, L. B. and R. C. Stendell. 1970. The white-tailed kite in California with observations of the Santa Barbara population. California Fish and Game 56:188-198.

Warner, J. S. and R. L. Rudd. 1975. Hunting by the white-tailed kite. Condor 42:295-304.

Watson, F. G. 1940. A behavior study of the white-tailed kite. Condor 42:295-304.

Wiens, J. A. 1989. The ecology of bird communities, Vol. 1. Foundations and patterns. Cambridge Studies in Ecology. Cambridge University Press, Cambridge, United Kingdom.

White, C. G., S. H. Schweitzer, C. T. Moore, I. B. Parnell III, L. A. Lewis-Weis. 2005. Evaluation of the landscape surrounding Northern Bobwhite nest sites: a multiscale analysis. Journal Wildlife Management 69:1528-1573.

Appendix A. Summary of two-tailed Mann-Whitney U-test tests comparing all landscape variables measured within 500 m and 1 km radii circular plots around white-tailed kite nest sites and unused sites in southwestern California 2000-2001. (many variables are highly correlated.)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	z	*P*
500 m	ASPECT	215.8	17.85	24.7	349.6	164.5	20.86	0.0	353.2	1.68	0.094
	AREA_AG	7.8	2.39	0.0	52.4	2.3	1.52	0.0	39.8	2.59	0.010
	AREA_CHP	6.5	1.85	0.0	45.2	37.3	5.07	0.0	74.4	-4.26	0.000
	AREA_GR	17.5	2.25	0.0	44.4	6.8	2.72	0.0	57.9	4.57	0.000
	AREA_RIP	15.8	1.33	1.7	35.0	7.7	1.25	1.1	36.5	4.49	0.000
	AREA_SCR	23.1	1.91	3.3	47.8	19.5	3.63	0.0	59.4	1.56	0.118
	AREA_WDL	3.6	0.69	0.0	14.5	0.7	0.23	0.0	4.1	4.49	0.000
	PCT_AG	9.9	3.04	0.0	66.8	2.9	1.93	0.0	50.7	2.59	0.010
	PCT_CHP	8.2	2.35	0.0	57.5	47.4	6.46	0.0	94.7	-4.26	0.000
	PCT_GR	22.2	2.86	0.0	56.5	8.6	3.46	0.0	73.7	4.57	0.000
	PCT_RIP	20.2	1.69	2.2	44.6	9.8	1.59	1.4	46.5	4.49	0.000
	PCT_SCR	29.4	2.44	4.2	60.8	24.9	4.62	0.0	75.7	1.56	0.118
	PCT_WDL	4.6	0.88	0.0	18.5	0.8	0.29	0.0	5.2	4.49	0.000
	LPI_AG	8.5	2.75	0.0	58.8	2.9	1.91	0.0	50.7	2.57	0.010
	LPI_CHP	3.9	1.17	0.0	30.6	37.7	5.93	0.0	94.7	-4.31	0.000
	LPI_GR	13.1	1.80	0.0	36.4	7.4	3.24	0.0	72.4	4.40	0.000
	LPI_RIP	17.4	1.86	1.0	43.0	8.8	1.50	1.4	46.5	3.51	0.000
	LPI_SCR	18.7	2.40	1.3	55.5	19.6	4.17	0.0	75.7	1.23	0.221
	LPI_WDL	2.9	0.66	0.0	15.8	0.6	0.19	0.0	4.5	4.40	0.000

Appendix A. Summary of two-tailed Mann-Whitney U-test tests comparing all landscape variables measured within 500 m and 1 km radii circular plots around white-tailed kite nest sites and unused sites in southwestern California 2000-2001. (many variables are highly correlated.) (continued)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	z	*P*
500 m	PCHDN_AG	0.8	0.20	0.0	2.5	0.2	0.10	0.0	2.5	2.73	0.006
	PCHDN_CHP	4.9	0.77	0.0	15.3	3.7	0.55	0.0	11.5	0.87	0.382
	PCHDN_GR	7.1	0.61	0.0	12.7	1.8	0.47	0.0	10.2	5.33	0.000
	PCHDN_RIP	4.7	0.54	1.3	11.5	2.1	0.25	1.3	6.4	4.11	0.000
	PCHDN_SCR	9.6	0.76	2.5	17.8	3.7	0.64	0.0	15.3	5.01	0.000
	PCHDN_WDL	4.2	0.68	0.0	17.8	1.0	0.28	0.0	5.1	4.50	0.000
	PERDN_AG	24.4	6.92	0.0	135.7	7.9	4.99	0.0	124.9	2.55	0.011
	PERDN_CHP	38.8	9.15	0.0	169.6	74.2	7.69	0.0	140.8	-2.96	0.003
	PERDN_GR	75.7	7.40	0.0	158.7	21.7	6.66	0.0	118.7	4.77	0.000
	PERDN_RIP	72.2	4.19	29.2	130.7	52.1	4.07	12.2	87.8	2.65	0.008
	PERDN_SCR	104.2	6.59	29.7	193.6	58.9	9.51	0.0	163.0	3.30	0.001
	PERDN_WDL	24.2	3.98	0.0	106.6	4.7	1.41	0.0	28.5	4.73	0.000
	LPCHDN	34.2	2.06	15.3	64.9	14.0	1.47	2.5	33.1	5.81	0.000
1 km	AREA_AG	34.3	8.44	0.0	145.1	9.5	6.06	0.0	158.9	2.94	0.003
	AREA_CHP	34.5	7.40	0.0	173.5	147.3	19.30	0.0	291.1	-3.96	0.000
	AREA_GR	67.2	7.90	8.5	150.1	30.5	10.73	0.0	246.9	4.20	0.000
	AREA_RIP	43.7	3.29	4.5	75.5	21.3	2.29	4.6	68.4	4.87	0.000
	AREA_SCR	104.9	6.84	39.1	181.4	82.0	12.20	0.0	220.4	1.68	0.094
	AREA_WDL	11.1	1.77	0.5	36.2	2.5	0.65	0.0	18.6	4.87	0.000

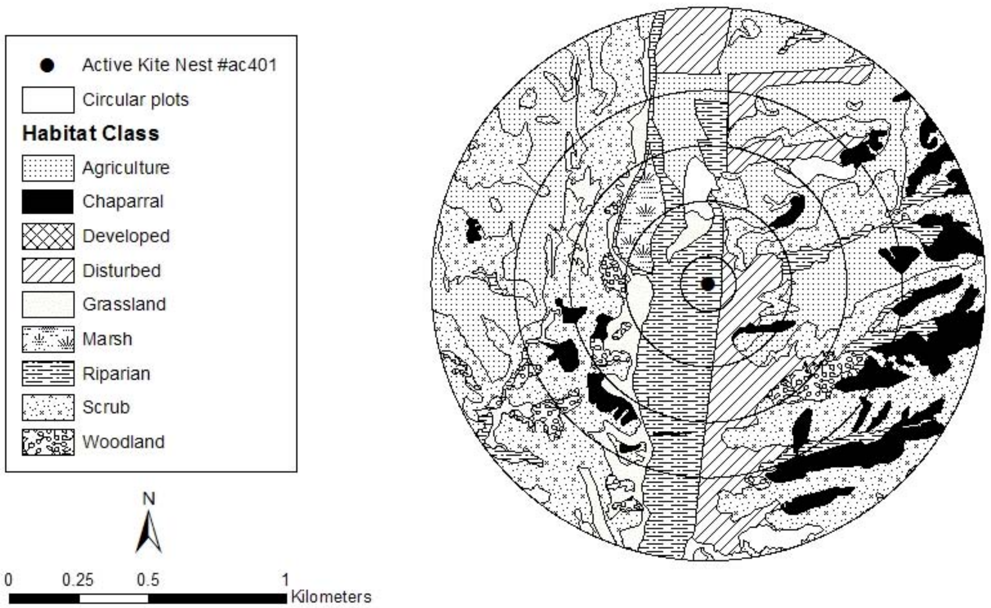
Appendix A. Summary of two-tailed Mann-Whitney U-test tests comparing all landscape variables measured within 500 m and 1 km radii circular plots around white-tailed kite nest sites and unused sites in southwestern California 2000-2001. (many variables are highly correlated.) (continued)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	z	*P*
1 km	PCT_AG	10.9	2.69	0.0	46.2	3.0	1.93	0.0	50.6	2.94	0.003
	PCT_CHP	11.0	2.35	0.0	55.2	46.9	6.14	0.0	92.7	-3.96	0.000
	PCT_GR	21.4	2.52	2.7	47.8	9.7	3.42	0.0	78.6	4.20	0.000
	PCT_RIP	13.9	1.05	1.4	24.0	6.8	0.73	1.4	21.8	4.87	0.000
	PCT_SCR	33.4	2.18	12.4	57.7	26.1	3.88	0.0	70.2	1.68	0.094
	PCT_WDL	3.5	0.56	0.2	11.5	0.8	0.21	0.0	5.9	4.87	0.000
	LPI_AG	7.8	2.04	0.0	44.6	3.0	1.92	0.0	50.6	2.87	0.004
	LPI_CHP	4.3	1.21	0.0	25.9	34.2	5.69	0.0	92.7	-4.05	0.000
	LPI_GR	10.4	1.53	0.9	30.9	7.4	3.17	0.0	78.1	3.99	0.000
	LPI_RIP	9.6	1.12	0.4	22.0	5.1	0.65	0.5	18.3	3.01	0.003
	LPI_SCR	15.7	1.89	2.3	42.7	16.3	3.36	0.0	69.5	1.18	0.237
	LPI_WDL	1.4	0.27	0.2	5.2	0.4	0.10	0.0	2.8	3.56	0.000
	PCHDN_AG	0.5	0.11	0.0	2.2	0.1	0.03	0.0	0.6	3.34	0.001
	PCHDN_CHP	4.4	0.51	0.0	9.9	2.2	0.33	0.0	7.3	3.18	0.001
	PCHDN_GR	4.6	0.30	1.9	8.9	1.2	0.25	0.0	5.4	5.94	0.000
	PCHDN_RIP	3.0	0.31	0.3	6.4	1.4	0.23	0.3	5.7	4.15	0.000
	PCHDN_SCR	6.2	0.49	1.0	13.7	2.8	0.42	0.0	10.8	4.62	0.000
	PCHDN_WDL	3.0	0.30	0.3	8.9	0.8	0.15	0.0	3.5	5.67	0.000
	PERDN_AG	24.1	6.11	0.0	100.9	7.4	4.60	0.0	118.1	2.90	0.004

Appendix A. Summary of two-tailed Mann-Whitney U-test tests comparing all landscape variables measured within 500 m and 1 km radii circular plots around white-tailed kite nest sites and unused sites in southwestern California 2000-2001. (many variables are highly correlated.) (continued)

		Nest Sites				Unused Sites					
Radius	Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	z	*P*
1 km	PERDN_CHP	40.9	6.89	0.0	147.1	58.8	5.67	0.0	114.6	-2.44	0.015
	PERDN_GR	63.6	5.72	15.9	125.4	20.4	5.43	0.0	115.1	4.85	0.000
	PERDN_RIP	53.9	3.65	17.2	96.8	38.3	2.66	9.3	71.6	2.76	0.006
	PERDN_SCR	101.9	4.61	59.5	149.3	56.3	7.71	0.0	133.9	4.10	0.000
	PERDN_WDL	17.8	2.21	1.1	52.4	4.1	0.87	0.0	20.2	5.37	0.000
	PT_AG	1.5	0.34	0.0	7.0	0.2	0.09	0.0	2.0	3.34	0.001
	PT_CHP	13.9	1.59	0.0	31.0	6.8	1.05	0.0	23.0	3.18	0.001
	PT_GR	14.4	0.96	6.0	28.0	3.7	0.80	0.0	17.0	5.94	0.000
	PT_RIP	9.5	0.97	1.0	20.0	4.3	0.72	1.0	18.0	4.15	0.000
	PT_SCR	19.5	1.54	3.0	43.0	8.8	1.32	0.0	34.0	4.62	0.000
	PT_WDL	9.5	0.94	1.0	28.0	2.4	0.46	0.0	11.0	5.67	0.000
	LPT	74.6	4.09	37.0	120.0	29.4	3.13	5.0	67.0	5.96	0.000
	LPCHDN	23.7	1.30	11.8	38.2	9.3	1.00	1.6	21.3	5.96	0.000

Appendix B. Habitat composition and circular plots around active white-tailed kite nest #ac401.



Appendix C. Habitat composition and circular plots around active white-tailed kite nest #ac701