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WINTER HABITAT ASSOCIATIONS OF DIURNAL RAPTORS IN CALIFORNIA'S CENTRAL VALLEY

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ABSTRACT: The wintering raptors of California's Central Valley are abundant and diverse. Despite this, little information exists on the habitats used by these birds in winter. We recorded diurnal raptors along 19 roadside survey routes throughout the Central Valley for three consecutive winters between 2007 and 2010. We obtained data sufficient to determine significant positive and negative habitat associations for the White-tailed Kite (*Elanus leucurus*), Bald Eagle (*Haliaeetus leucocephalus*), Northern Harrier (*Circus cyaneus*), Red-tailed Hawk (*Buteo jamaicensis*), Ferruginous Hawk (*Buteo regalis*), Rough-legged Hawk (*Buteo lagopus*), American Kestrel (*Falco sparverius*), and Prairie Falcon (*Falco mexicanus*). The Prairie Falcon and Ferruginous and Rough-legged hawks showed expected strong positive associations with grasslands. The Bald Eagle and Northern Harrier were positively associated not only with wetlands but also with rice. The strongest positive association for the White-tailed Kite was with wetlands. The Red-tailed Hawk was positively associated with a variety of habitat types but most strongly with wetlands and rice. The American Kestrel, Northern Harrier, and White-tailed Kite were positively associated with alfalfa. Nearly all species were negatively associated with urbanized landscapes, orchards, and other intensive forms of agriculture. The White-tailed Kite, Northern Harrier, Red-tailed Hawk, Ferruginous Hawk, and American Kestrel showed significant negative associations with oak savanna. Given the rapid conversion of the Central Valley to urban and intensive agricultural uses over the past few decades, these results have important implications for conservation of these wintering raptors in this region.

The Central Valley of California supports both large numbers and a broad variety of wintering diurnal raptors. From the early 1960s to the present, Christmas Bird Counts (CBC) circles in the valley have consistently recorded numbers of the White-tailed Kite (*Elanus leucurus*), Northern Harrier (*Circus* *cyaneus*), Red-tailed Hawk (*Buteo jamaicensis*), and American Kestrel (*Falco sparverius*) among the highest for the United States and Canada (Root 1988, Pandolfino 2006, Pandolfino and Suedkamp-Wells 2009). At least 15 species of diurnal raptors winter commonly in the Central Valley, more than in any other region of the United States or Canada, with the possible exception of the coastal plains of Texas. Despite this, there are no regionwide and only a handful of localized studies of winter habitat use by raptors in the Central Valley. The latter include studies restricted to one or two counties (Koplin 1973, Warner and Rudd 1975, Wilkinson and Debban 1980, Temeles 1986, Goerrissen 2005), to specific taxa or groups of raptors (Erichsen et al. 1996, Smallwood et al. 1996), to specific habitat types such as rice field (Elphick 2004), or to a single watershed (Reeves and Smith 2004).

During the past few decades, the Central Valley has lost agricultural land to urbanization at a rate higher than any other region of the United States (Johnson and Hayes 2004, Lubell et al. 2009), and projections of human population growth in the valley suggest that trend will continue well into this century (State of California 2007). In addition, from the 1980s to the present, large portions of Central Valley farmland have been converted from cattle ranching and other relatively passive uses to more intensive agricultural practices like vineyards and orchards (California Department of Conservation 2008, Volpe et al. 2010). Because of these changes in land use, combined with the high abundance and diversity of wintering raptors found in this region, it is important to understand the relative importance of the Central Valley's habitats to raptors. We assessed habitat associations of wintering raptors with monthly roadside surveys over three consecutive winters.

STUDY AREA AND METHODS

The Central Valley is one of the California's dominant geographic features, stretching over half the length of the state and constituting 14% of its land area (Figure 1). For our study, we defined the Central Valley as the valley floor up to 300 m above sea level and including a portion of the delta region in Sacramento, Solano, and San Joaquin counties (Figure 1).

Land cover in the Central Valley has changed drastically since 1850. Most of its historic wetlands, perennial grasslands, and riparian systems have been altered through intensive agriculture, urbanization, and grazing (Frayer et al. 1989, Noss et al. 1995). Cities, notably Sacramento, Stockton, Modesto, Fresno, and Bakersfield, continue to expand. What remains is a complex mosaic of mostly open habitats with varying types of agriculture on the valley floor, transitioning into open grasslands at the valley's edges and into oak savanna in the foothills.

Survey Routes and Methods

To assess habitat associations of wintering raptors in the Central Valley we established 19 roadside survey routes throughout the valley (Figure 1). Routes were not distributed randomly but instead selected on the basis of (1) broad geographic coverage and representation of all the valley's major land-cover types, (2) roads bisecting mostly open country so birds could be

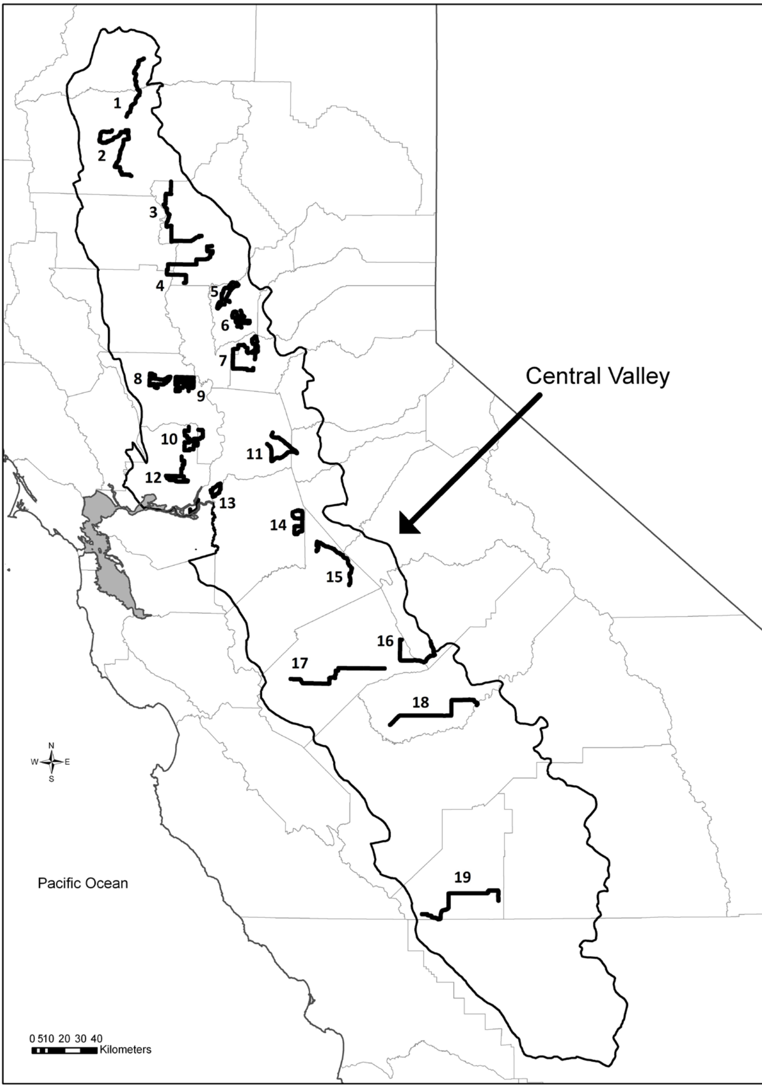

Figure 1. The 19 survey routes from which we assessed habitat associations of diurnal raptors wintering the Central Valley of California, 2007–2010.

detected more easily, and (3) roads having low to moderate traffic so observers could devote the time needed to detect and identify perched and flying raptors. The routes' average length was 59 km (range 44–81).

Two volunteer observers, at least one having experience at raptor identification, conducted each survey. Surveys took place monthly from December through February over three winters, 2007–2010. Surveys began between 08:00 and 10:00 PST and ended no later than 15:00 PST. Observers drove each route in the same direction each time at an average speed of 15 km/hr (range 11–25, standard deviation 4) and occasionally stopped to identify birds or allow traffic to pass. Surveys were postponed or interrupted for heavy fog, precipitation, high winds (>30 km/hr or Beaufort scale 4) or any condition that limited visibility to less than 500 m. Observers recorded all raptors seen within 500 m of the survey road and, to allow assessment of any roadside bias in habitat associations, assigned each to one of two distance categories: (1) roadside, if the bird was perched immediately along the survey road, or (2) beyond out to 500 m, including flying and perching birds. For each raptor seen, we noted where possible the species, age, sex, behavior (perched or flying), color morph, perch type, side of the road it was seen on, and distance (to the nearest 0.1 mile on the basis of odometer readings) from the start of the survey. The bird's behavior and location along the survey route (shortest perpendicular distance from the bird to the road) were recorded instantaneously.

Habitat Assessment

In order to assign each raptor observed to a specific habitat we defined habitat blocks on both sides of each survey road, beginning from the start of each route. Blocks measured 500 m × 800 m, with one of the 800-m sides abutting the road, and were spaced continuously along the survey route. We recorded UTM coordinates and odometer readings at the center point of the roadside leg of each block. We assigned a dominant habitat type to each block as defined by the categories described below. At the start of each winter survey period we drove each route and noted any change in the dominant habitat type in each block. So that observations were assigned to the correct habitat block, odometers of each survey vehicle were calibrated to the odometer of the vehicle used for habitat assessment.

Habitat Categories

We categorized each block into one of 12 habitats defined to describe the dominant land-cover types along the routes. The habitats covered were generally representative of the Central Valley as a whole (Figure 2; California GAP Analysis Project 1998, California Department of Conservation 2008, U.S. Department of Agriculture 2008, 2009). For planted crops our assessments did not differentiate the stage of development, which ranged from recently planted to post-harvest stubble. In general, the Central Valley consists of flat, open country, and this was the case in nearly all blocks. Only in some areas of oak savanna and mature orchards was the visibility within the block limited.

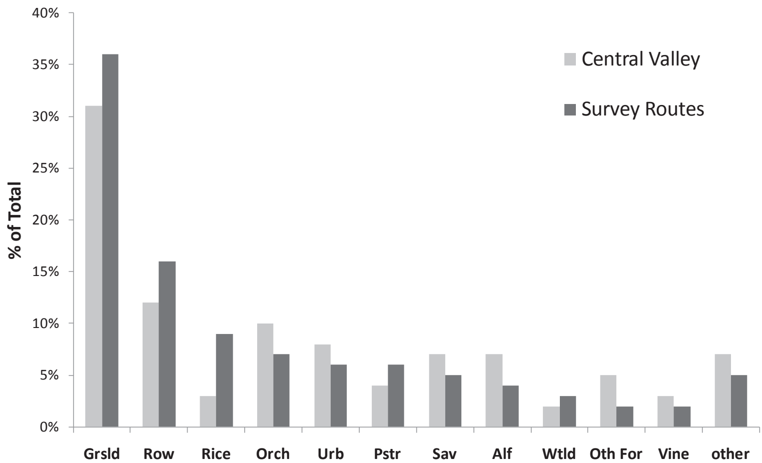

Figure 2. The proportion of habitat types in the Central Valley as a whole versus those sampled during our assessment of habitat associations of diurnal raptors wintering the Central Valley of California, 2007–2010. Grsld, grassland; Row, row crop; Orch, orchard; Urb, urbanized; Pstr, irrigated pasture; Sav, savanna; Alf, alfalfa; Wtld, wetland; Oth For, other forage; Vine, vineyard.

Grassland. Included grazed, ungrazed, and burned stands of annual grasses and, in the San Joaquin Valley portion of the Central Valley, small amounts of grasslands interspersed with salt-tolerant shrubs (mainly *Atriplex* spp.). We characterized grassland as ungrazed if the area had not been grazed for at least a year and the grasses were >15 cm tall.

Row crop. This category included row crops grown mainly in the spring and summer. Often the crop was unknown, and many fields were plowed for winter and consisted of bare dirt during our surveys.

Rice. Consistent with the distribution of this crop in the Central Valley, all routes containing rice fields were in the southern Sacramento Valley. In the Central Valley, most rice is flooded in the winter (Central Valley Joint Venture 2006). Nonflooded rice fields were either burned or contained dry stubble.

Orchard. Included stands of trees such as walnuts, almonds, and apricots of various ages.

Urbanized. Included mainly residential and rural residential areas and small areas of industrial development or office complexes.

Pasture. Included only irrigated pasture.

Savanna. Scattered oaks (mainly blue oaks, *Quercus douglasii*) in a matrix of grassland with 10–30% tree canopy, mostly along routes along the eastern edge of the Central Valley.

Alfalfa. Included both harvested and unharvested fields at all stages of development.

Wetland. Included both natural and man-made wetlands.

Other forage. Included mainly hay and winter wheat in a range of stages of development from recently planted to post-harvest stubble.

Vineyard. Included vineyards of varying ages, most with typical supporting structures.

Other. Diverse habitats such as fallow fields, mowed grass, open water, golf course, oak forest, eucalyptus stands, landfill, and riparian areas.

Statistical Analyses

We used generalized linear models (McCullagh and Nelder 1989) with an assumed Poisson distribution and density (number of individuals per block) as the response variable. We limited our fixed effects to habitat and year. For each species, we ran all possible combinations of models (including the interaction of habitat and year). Results presented were calculated as the averaged values for predictions from all five of the alternative models, each model's predictions weighted according to its score by Akaike's information criterion (AIC_c score). Therefore, these predictions incorporate not only the variation around the prediction of the model but also uncertainty of selection of the model (Burnham and Anderson 2002). We considered a species to be associated positively with a given habitat when the average predicted density across years in that habitat was significantly greater than the average density of that species over all habitats and to be associated negatively when the density in that habitat was significantly less than the average.

RESULTS

During the three winters encompassing 2007–2010 we recorded 16,033 observations of diurnal raptors in the Central Valley with 15,546 (97%) of these identified to species (Table 1). Our surveys covered more than 112,000 ha or about 1.7% of the entire valley. However, the distribution of surveyed versus total habitat in the valley was significantly disproportional ($\chi^2_{11\ \mathrm{df}}$ = 510, n = 2818, $P < 0.001$), with oversampling of rice the main contributor to the discrepancy.

For all eight species of raptors modeled, by all potential models considered, variation in density was best explained by habitat (Table 2). Densities varied annually by as much as 10-fold (for the Rough-legged Hawk) (Table 1), and year was strongly supported as an explanatory variable for all species except the Bald Eagle and Prairie Falcon, for which there was only a weak support (Table 2). There also was strong support for an interaction between year and habitat in densities of the White-tailed Kite, Northern Harrier, Red-tailed Hawk, and American Kestrel, but habitat associations were quantitatively similar each year for all species. That is, no species in any habitat showed a positive association one year and a negative association in another year.

Three species, the Ferruginous Hawk, Rough-legged Hawk, and Prairie Falcon, were strongly associated with grasslands and tended not to occur in urbanized areas and areas of intensive agriculture such as orchards, rice, and row crops (Figure 3). These same species occurred in grazed grassland at densities higher than in ungrazed grassland (Figure 4). However, this difference was insignificant for the Prairie Falcon. Rough-legged Hawks were

Table 1 Numbers and Densities of Diurnal Raptors Observed during a Study of Habitat Associations in the Central Valley of California, Winter 2007–2010.

			Birds/block (×100; mean ± standard error)		
Species	Observations	%	2007–2008	2008–2009	2009–2010
Red-tailed Hawk (*Buteo jamaicensis*)	7950	51%	29 ± 1	27 ± 1	34 ± 1
American Kestrel (*Falco sparverius*)	3622	23%	13 ± 1	13 ± 1	16 ± 1
Northern Harrier (*Circus cyaneus*)	1396	9.0%	4.9 ± 0.3	4.0 ± 0.3	7.0 ± 0.4
Ferruginous Hawk (*Buteo regalis*)	630	4.1%	2.4 ± 0.2	2.2 ± 0.2	2.1 ± 0.2
White-tailed Kite (*Elanus leucurus*)	468	3.0%	1.8 ± 0.2	1.5 ± 0.2	1.8 ± 0.2
Red-shouldered Hawk[a] (*Buteo lineatus*)	444	2.9%	—	—	—
Bald Eagle (*Haliaeetus leucocephalus*)	276	1.8%	1.0 ± 0.2	0.9 ± 0.1	1.0 ± 0.1
Prairie Falcon (*Falco mexicanus*)	232	1.5%	0.7 ± 0.1	0.9 ± 0.1	0.7 ± 0.1
Accipiter spp.[a]	144	0.9%	—	—	—
Rough-legged Hawk (*Buteo lagopus*)	143	0.9%	0.8 ± 0.1	0.5 ± 0.1	0.06 ± 0.03
Golden Eagle[b] (*Aquila chrysaetos*)	95	0.6%	—	—	—
Merlin[b] (*Falco columbarius*)	80	0.5%	—	—	—
Peregrine Falcon[b] (*Falco peregrinus*)	33	0.2%	—	—	—
Osprey[b] (*Pandion haliaetus*)	33	0.2%	—	—	—

[a]Excluded from analyses because of strong association with woodlands, making consistent detection difficult.

[b]Excluded from analyses because of low numbers.

never observed in ungrazed grasslands. The White-tailed Kite and Northern Harrier were significantly more abundant in ungrazed than in grazed grassland (Figure 4). We observed no significant differences for the Bald Eagle, Red-tailed Hawk, or American Kestrel with respect to grazed vs. ungrazed grasslands.

The White-tailed Kite, Northern Harrier, and Bald Eagle were strongly associated with wetlands (Figure 5), and the harrier and eagle also showed a positive association with rice. The White-tailed Kite and Northern Harrier were also positively associated with alfalfa and other forage.

The Red-tailed Hawk and American Kestrel, the two species which accounted for nearly three-fourths of all observations, were both positively associated with irrigated pasture and alfalfa and negatively associated with

Table 2 Species-specific AIC_c model selection results used to predict densities by habitat of diurnal raptors in the Central Valley of California in winter.

Species and variables appearing in model(s) best predicting its habitat associations	K^a	AIC_c	Δi^b	w_i^c
White-tailed Kite				
Habitat + year + habitat × year	36	4680	0	1
Northern Harrier				
Habitat + year + habitat × year	36	10,880	0	0.50
Habitat + year	14	10,880	0.015	0.50
Bald Eagle				
Habitat	12	2966	0	0.7
Habitat + year	14	2967	1.6	0.3
Red-tailed Hawk				
Habitat + year + habitat × year	36	37,858	0	1
Ferruginous Hawk				
Habitat + year	14	5511	0	0.8
Habitat	12	5514	3	0.2
Rough-legged Hawk				
Habitat + year	14	1593	0	1
American Kestrel				
Habitat + year + habitat × year	36	21,948	0	0.96
Habitat + year	14	21,955	6	0.04
Prairie Falcon				
Habitat	12	2530	0	0.7
Habitat + year	14	2532	2	0.3

[a]Number of parameters estimated by the model.

[b]Difference between AIC_c value of the specified model and the lowest AIC_c value (best model); models with Δi values greater than 10 not shown.

[c]Model weight; relative weight of given model used to predict densities based on AIC_c values.

urbanized areas, row crops, orchards, and savanna (Figure 6). The American Kestrel had the strongest positive association with alfalfa, with density in that habitat more than twice the overall average. The Red-tailed Hawk's strongest positive associations were with wetlands and rice.

We compared habitat associations of birds along the roadside to those of birds away from the road, finding no significant difference for any species in any habitat with the single exception of the American Kestrel in rice. Along roads, kestrels were associated positively with rice, away from the road they were negatively associated with this habitat.

DISCUSSION

Geographically, our coverage of the Sacramento Valley and northern portions of the San Joaquin Valley was better than that of the southern half of the San Joaquin Valley, where we had only one route. Because of an intentional bias for open areas, habitats like grassland and rice were over-

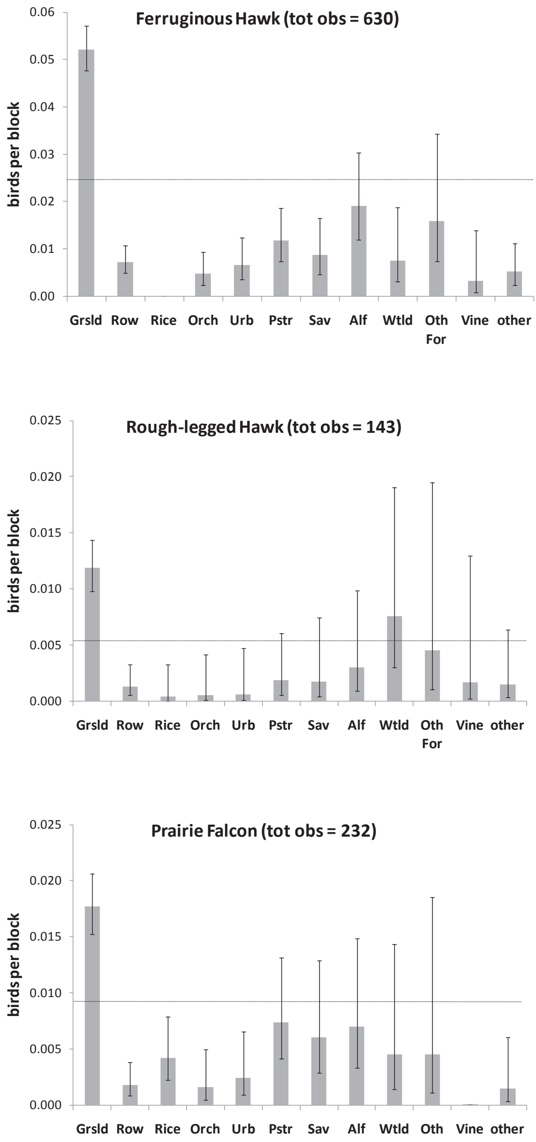

Figure 3. Predicted density (birds per 40-ha block) of the Ferruginous Hawk, Rough-legged Hawk, and Prairie Falcon in various habitat types in the Central Valley in winter. The horizontal line represents the average density over all habitats for each species. Error bars represent 95% confidence intervals. Tot obs, total observations; Grsld, grassland; Row, row crop; Orch, orchard; Urb, urbanized; Pstr, irrigated pasture; Sav, savanna; Alf, alfalfa; Wtld, wetland; Oth For, other forage; Vine, vineyard.

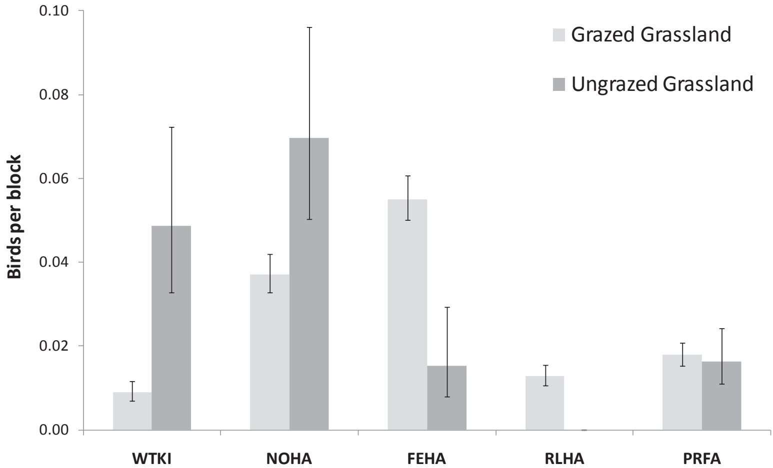

Figure 4. Comparison of predicted density (birds per 40-ha block) in grazed versus ungrazed grasslands. WTKI, White-tailed Kite; NOHA, Northern Harrier; FEHA, Ferruginous Hawk; RLHA, Rough-legged Hawk; PRFA, Prairie Falcon.

represented in our sample, whereas areas of urbanization, oak savanna, and orchard were under-represented with respect to their coverage of the Central Valley as a whole. With the exception of the work of Erichsen et al. (1996) and Smallwood et al. (1996), which included five routes in the Sacramento Valley, all prior studies of winter raptors in the Central Valley focused on one or two counties. No prior work examined winter raptor associations in this region on the scale or for the variety of species or habitats we addressed.

Wetland and Rice

Our results suggest that wetland is an important winter habitat for the White-tailed Kite, Bald Eagle, Northern Harrier, and Red-tailed Hawk in the Central Valley. The positive association of three of these species with rice is consistent with this crop possibly serving in winter as a surrogate for wetland (Sterling and Buttner 2009). The wetland association for the Northern Harrier is consistent with prior studies (Collopy and Bildstein 1987, Preston 1990, MacWhirter and Bildstein 1996). Elphick (2004) found the Northern Harrier the most abundant raptor in rice in the Central Valley in winter. Bald Eagles are most likely attracted to Central Valley wetlands and rice in the winter because of the concentrations of waterfowl found in those habitats (McWilliams et al. 1994, Sterling and Buttner 2009).

The positive association of the White-tailed Kite with wetland was unexpected, but there are few studies of this species' winter habitat preference. Waian and Stendall (1970) noted marsh as one of a variety of foraging habitats suitable for this species but did not differentiate by season. Erichsen et al. (1996) observed White-tailed Kites in winter in the Sacramento Valley more than expected in rice stubble and in a habitat category they defined as upland/wetland.

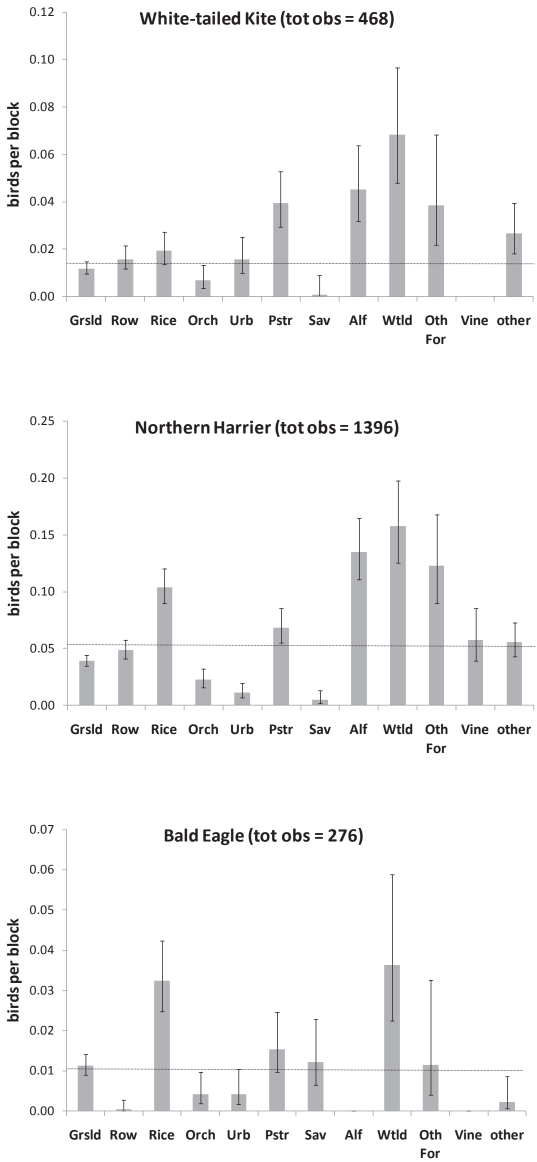

Figure 5. Predicted density (birds per 40-ha block) of the White-tailed Kite, Northern Harrier, and Bald Eagle in various habitat types in the Central Valley in winter. The horizontal line represents the average density over all habitats for each species. Error bars represent 95% confidence intervals. Tot obs, total observations; Grsld, grassland; Row, row crop; Orch, orchard; Urb, urbanized; Pstr, irrigated pasture; Sav, savanna; Alf, alfalfa; Wtld, wetland; Oth For, other forage; Vine, vineyard.

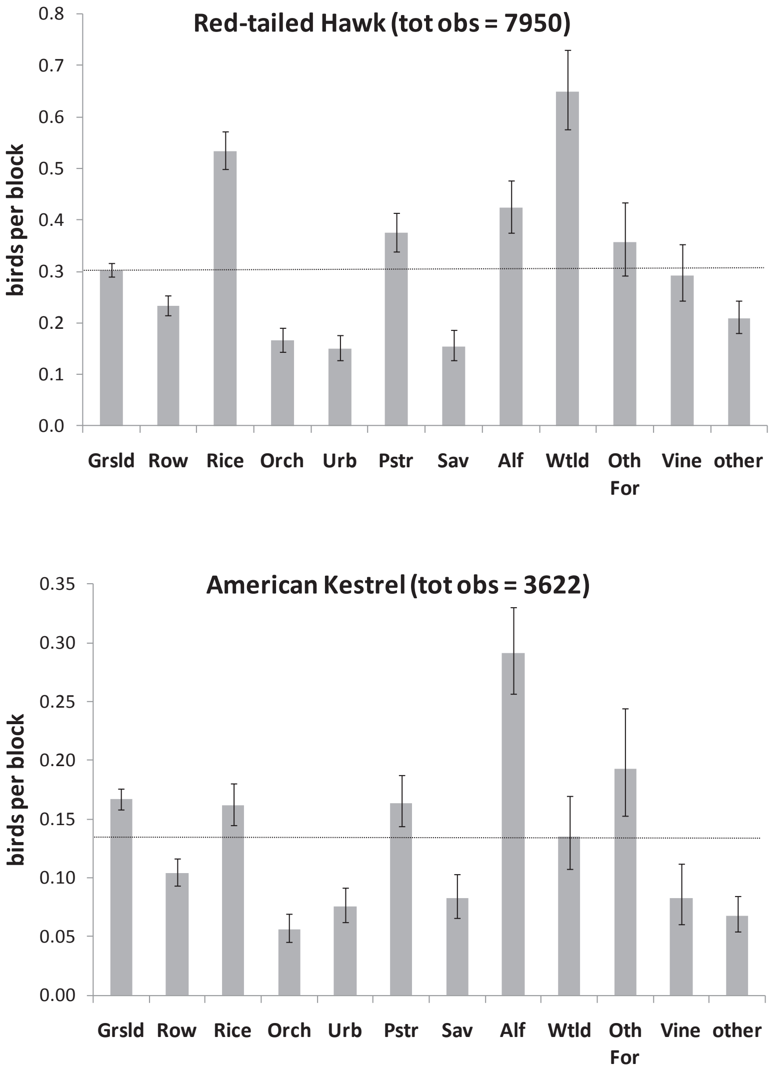

Figure 6. Predicted density (birds per 40-ha block) of the Red-tailed Hawk and American Kestrel Falcon in various habitat types in the Central Valley in winter. The horizontal line represents the average density over all habitats. Error bars represent 95% confidence intervals. Tot obs, total observations; Grsld, grassland; Row, row crop; Orch, orchard; Urb, urbanized; Pstr, irrigated pasture; Sav, savanna; Alf, alfalfa; Wtld, wetland; Oth For, other forage; Vine, vineyard.

The Red-tailed Hawk is a habitat generalist and, although wetland is one of a wide variety of habitats it uses in winter (Preston and Beane 2009), no prior studies demonstrated a strong preference for wetland or rice (Preston 1990, Garner and Bednarz 2000, Pearlstine et al. 2006). The only report of a strong association of any *Buteo* species with winter rice is from the Po Valley of Italy, which revealed high densities of the Common Buzzard (*Buteo buteo*) in this habitat (Boano and Toffoli 2002).

Elphick (2004) observed that in the Central Valley the White-tailed Kite, Northern Harrier, and Red-tailed Hawk all preferred unflooded over flooded rice. Most (approximately 67%) of the valley's rice is flooded in winter (Central Valley Joint Venture 2006, P. Buttner pers. comm.). Because flooding of rice varies both within a winter and from year to year, we did not differentiate between flooded and unflooded rice for raptor observations. Even when a rice field is flooded, the berms bordering it may harbor concentrations of rodent prey that are accessible to raptors. Further studies are needed on prey taken and foraging strategies used in rice.

Grassland

The strong association with grassland we observed for the Ferruginous Hawk, Rough-legged Hawk, and Prairie Falcon is consistent with other studies throughout North America (Bechard and Schmutz 1995, Steenhof 1998, Bechard and Swem 2002). A positive association of the American Kestrel with grassland has also been widely reported in California and elsewhere (Fischer et al. 1984, Bildstein 1987, Reeves and Smith 2004).

Among the species we analyzed, only the Northern Harrier showed a significant negative association with grassland, consistent with Erichsen et al. (1996) and Williams et al. (2000) but not other studies (MacWhirter and Bildstein 1996, Reeves and Smith 2004, Littlefield and Johnson 2005). This apparent contradiction may relate to the preference for ungrazed over grazed grassland we observed for this species. Prior studies also found the harrier prefers ungrazed grasslands (Bildstein 1987, Littlefield and Johnson 1987, Johnson and Horn 2008) or areas with higher vegetative cover (Temeles 1986, Massey et al. 2009). The large majority of the grassland we surveyed was grazed (93%), explaining the overall negative association we observed for this habitat. The other species we observed in significantly higher density in ungrazed than in grazed grassland, the White-tailed Kite, showed this same preference in two California studies (Bammann 1975, Johnson and Horn 2008).

Because of differences between species and regions, it is difficult and usually unwise to generalize about the effects of grazing on raptors (Snyder and Snyder 1975, Severson 1990, Kirby et al. 1992). In the Central Valley, grasslands are dominated by non-native annual grasses and bear little resemblance to the habitats that existed prior to European settlement (Stromberg et al. 2007). When unmanaged by grazing, mowing, or burning, most of these grasslands are susceptible to invasion by aggressive introduced species like the star thistle (*Centaurea solstitialis*) and medusa head (*Taeniatherum caput-medusae*), which can become dominant. We found the vegetative structure of grazed and ungrazed grassland very different, ungrazed areas having tall, thick, weedy vegetation, grazed grassland more open. Thus one would expect prey to be more easily seen in these grazed grasslands. However, we do not know the relative density of prey in grazed versus ungrazed grasslands, and the interplay between rodent abundance and susceptibility to predation by raptors can be extremely complex, as demonstrated by a long history of studies from Craighead and Craighead (1956) to Baker and Brooks (1981) to Johnson and Horn (2008). Therefore, one cannot assume that increased visibility of prey represents better foraging for raptors.

The differences we observed may be related to the species' styles of hunting. The grassland specialists, the Ferruginous and Rough-legged hawks, spend much of their time hunting from an elevated perch or from the ground, while the Northern Harrier and White-tailed Kite forage primarily in flight, rarely from a perch (Bildstein 1987, Johnsgard 1990, Wheeler 2003). Therefore, these last two species may be able to take advantage of prey that are difficult to detect from a perch. However, the Red-tailed Hawk, another perch-hunter, showed no preference for grazed or ungrazed grassland. Perhaps the greater variety of prey taken and hunting styles used by this species (Preston and Beane 2009) allows it to take advantage of the ungrazed grasslands in ways not available to the other perch-hunting species.

Irrigated Pasture, Alfalfa, and Other Forage Crops

There are few data available on winter use of alfalfa by raptors. Warner and Rudd (1975) observed White-tailed Kites foraging over alfalfa in Yolo and Solano counties, California. Erichsen et al. (1996) found fewer than expected White-tailed Kites in alfalfa in the Sacramento Valley, contrary to our results.

As we did, Reeves and Smith (2004) found that hay (included in our "other forage" category) and irrigated pasture were used more than expected by the White-tailed Kite, Northern Harrier, Red-tailed Hawk, and American Kestrel. Erichsen et al. (1996), however, found the White-tailed Kite using irrigated pasture in the Sacramento Valley less than expected, contrary to our observations. Results from Wilkinson and Debban (1980) suggest that the White-tailed Kite, Northern Harrier, and Red-tailed Hawk use hay more than expected, the American Kestrel less than expected. In Ohio, Bildstein (1987) reported use of hay less than expected for the Red-tailed Hawk and American Kestrel but more than expected for the Northern Harrier. He also found that the Northern Harrier used unharvested winter wheat less than expected but wheat stubble more than expected, the Red-tailed Hawk showing the opposite tendency, and the Rough-legged Hawk and American Kestrel associated negatively with both types. In Texas, Littlefield and Johnson (2005) found the Northern Harrier using winter wheat less than expected. The Prairie Falcon has been reported using winter wheat more than expected in Colorado, Utah, and Wyoming (Enderson 1964, White and Roseneau 1970, Beauvais et al. 1992), whereas we found no significant association.

Orchard, Vineyard, and Row Crops

Most studies of raptors in areas of intensive agriculture are consistent with our finding that none of the species analyzed was positively associated with any of these habitats and all species were associated negatively with one or more. Previous studies also noted such associations. The White-tailed Kite, for example, is found less often than expected in row crops and in orchards (Erichsen et al. 1996, Reeves and Smith 2004), the Northern Harrier less often than expected in orchards and vineyards (Reeves and Smith 2004) and row crops (Bildstein 1987, Leptich 1994, and Reeves and Smith 2004)—with corn stubble being a possible exception (Temeles 1986, Preston 1990). The Red-tailed Hawk also appears to avoid most types of row crops (Garner and Bednarz 2000, Reeves and Smith 2004) and orchards (Fischer et al. 1984, Reeves and Smith 2004), as does the Rough-legged Hawk (Fischer et al. 1984). Others have reported the American Kestrel to occur less often than expected in row crops (Toland 1987, Reeves and Smith 2004) and orchards (Reeves and Smith 2004), but Koplin (1973) found more male kestrels than females in orchards, consistent with orchards being an inferior winter habitat for the species. Exceptions to this pattern come from Erichsen et al. (1996), who reported a positive association of the White-tailed Kite with row crops, Reeves and Smith (2004), who found the Red-tailed Hawk and American Kestrel more often than expected in vineyards, and Bildstein (1987) and Preston (1990), who found the Red-tailed Hawk more than expected in corn stubble and soybean stubble. The only report of a positive association of any of these species with orchards is that of Fischer et al. (1984), who found the American Kestrel more abundant than expected.

Urbanized Areas

Consistent with our results, nearly all published work on habitat associations of these open-country raptors concludes that they tend to avoid areas of urbanization (Fischer et al. 1984, Sferra 1984, Bildstein 1987, Berry et al. 1998, Reeves and Smith 2004, Rodriguez-Estrella 2007). In Colorado, Berry et al. (1998) found the Red-tailed Hawk and American Kestrel tolerated urbanization better than other grassland raptors. However, the only studies suggesting any affinity for urbanized areas are those of Bildstein (1987), who observed the kestrel in residential areas more often than expected, and Kimsey and Conley (1988), who found relatively high numbers of this species in residential areas.

Oak Savanna

Our findings that no species was positively associated with savanna and five species were negatively associated with it is somewhat surprising but consistent with the observations of Reeves and Smith (2004). In blue oak woodland, which they characterized as being mostly savanna, they observed numbers fewer than expected of the White-tailed Kite, Northern Harrier, Red-tailed Hawk, and American Kestrel. There are no other comparable studies of these species in this habitat type. Because raptors are less detectable in this habitat than in most others we surveyed, it is possible that the negative associations we observed were due to this factor. However, our finding of no significant difference in habitat associations between roadside raptors (where detectability is not an issue) and raptors away from the roadside in this habitat type supports our conclusion that these species' association with savanna is negative.

Roadside Effects

From the early 20th century (Nice and Nice 1921) to the present, roadside surveys have been a valuable method for the study of raptors (Andersen 2007). However, such surveys are subject to limitations and potential bias (Fuller and Mosher 1987), including issues like concentration of habitat elements and perch sites along roadways (Williams and Colson 1989) and limits on detectability of some species in some habitats (Millsap and Lefranc 1988). In assessment of habitat associations, a major issue is the fact that the narrow strip of habitat along the edges of roadways may differ from the adjacent habitat and influence the abundance and species composition of raptors. Adams and Geis (1983) in the U.S. and Meunier et al. (1999) in France found the density and species composition of the population of small mammals along roadways differ from those of the adjacent habitats, with density generally higher along the roads. The relative abundance of road-killed carrion along roadways can attract scavengers (Knight and Kawashima 1993, Lambertucci et al. 2009). Meunier et al. (2000) observed the Common Buzzard and Eurasian Kestrel (*Falco tinnunculus*) preferring roadsides over adjacent habitats.

Our observation that roadside American Kestrels were positively associated with rice, whereas kestrels observed away from the road were negatively associated with rice, suggests that conditions along the road may be the key element for this species in this habitat. Prey may be abundant on the berms separating the rice field from the road, while the rice fields themselves, most of which are flooded in winter, may not provide opportunities for the kestrel's foraging.

Year Effects

It is not surprising that, although the strongest habitat associations remained qualitatively consistent from year to year, year was a significant factor in predicted densities of most species. That is, numbers and densities of these species varied from year to year. The Bald Eagle, Prairie Falcon, and Ferruginous and Rough-legged hawks are found in the Central Valley exclusively or almost exclusively in winter. The great majority of Red-tailed Hawks, American Kestrels, and Northern Harriers in the Central Valley in winter are also migrants. Factors that could account for year-to-year variations include reproductive success in the breeding range, relative quality of alternative wintering areas outside the Central Valley, and variations in winter prey abundance within the valley.

Year-to-year variation in density was largest for the Rough-legged Hawk (Table 1), with that in the third winter a fraction of that in the first two winters of the study. Data from Central Valley Christmas Bird Counts during these three winters (Pandolfino, unpublished data) mirror our findings. Such variations in winter density are well-known throughout the Rough-legged Hawk's winter range (Bechard and Swem 2002) and are thought to be a response to local weather conditions such as snow depth (Thiel 1985, Watson 1986). Pandolfino and Suedkamp Wells (2009) documented a long-term northward shift in the species' winter range in North America correlated with lower average snow depths in the northern parts of the range; they did not, however, detect correlation with annual variation in snow depth. For this study, we examined weather patterns in the Great Plains and Great Basin (where most Rough-legged Hawks winter) to see if conditions in those areas might have influenced the densities we observed. In both areas temperatures were close to normal in all three winters (http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html). Snowfall in the Great Plains was well below normal in the first winter, well above normal in the second and third winters. If deep snow in the Great Plains causes some Rough-legged Hawks to move to the Central Valley, then we should have seen higher densities in our last winter, but we did not. The Great Basin had very dry winters during the first two years of our study, whereas the third year was near normal. Again, this pattern is inconsistent with this species moving from the Great Basin into the Central Valley in response to increased snowfall. The reason for large fluctuations in numbers of the Rough-legged Hawk in the Central Valley remains a mystery.

Northern Harrier density in the second winter was down approximately 18% from the first, and in the third winter density was nearly 1.5 times higher than in the first winter. Rainfall in the Central Valley was near normal during the first two winters of our study but approximately 20% above normal in the third winter. As a result, large areas of the Yolo and Butte Sink bypasses in Yolo, Sutter, Colusa, and Butte counties in the southern Sacramento Valley were inundated for flood control (*fide* Peter Fickenscher). This flooding creates wetlands at the edges but also makes large areas of wetland unsuitable for raptor foraging. None of our survey routes pass directly through or adjacent to these areas, but eight of our routes are within 50 km of these bypasses. It is possible that Northern Harriers displaced by this flooding concentrated in higher numbers along our survey routes. It is also possible that wetter conditions throughout the Central Valley in the third winter caused more harriers to winter here, although data from Central Valley Christmas Bird Counts show no apparent pattern.

Densities of the Red-tailed Hawk and American Kestrel were slightly (<20%) higher in the third winter. Any combination of the factors noted above could have contributed to this. It is also possible that our observers became more adept at detecting raptors by the third year of the study. This explanation seems unlikely, however, because nearly all our observers had many years of prior birding and survey experience and such a factor should result in increases in density of all species in the third year, which we did not observe.

Conservation Implications

Given the importance of the Central Valley to wintering raptors and the rapid changes in land use occurring there, conservation planning in this region must be informed by data on the relative importance of existing habitats to these raptors. Our results support the conclusion that some current agricultural land uses may be critical to preservation of some raptors in the Central Valley in winter. Over the past three decades, more than 100,000 ha of grassland in the Central Valley have been lost to urbanization and conversion to orchards and vineyards (Pandolfino 2006, California

Department of Conservation 2008, Volpe et al. 2010). Our results suggest that, for the Ferruginous Hawk, Rough-legged Hawk, and Prairie Falcon, this trend is of concern because grassland is the only habitat with which we found these species positively associated and all had a negative association with urbanization and intensive agriculture. Grassland birds as a guild are in continent-wide decline (Sauer et al. 2008), and the Ferruginous Hawk and Prairie Falcon are considered species of conservation concern by the U.S. Fish and Wildlife Service.

Our results suggest that rice fields, as well as wetlands, may be more important to wintering raptors in the Central Valley than previously thought. Our observation that species attracted to wetlands are also attracted to rice is consistent with the suggestion of Sterling and Buttner (2009) that this crop may serve as a surrogate wetland habitat. It would be worth identifying the prey taken by White-tailed Kites, Northern Harriers, and Red-tailed Hawks in Central Valley wetlands and rice fields in winter. The Northern Harrier is a California species of special concern (Davis and Niemela 2008), and the White-tailed Kite, whose population plunged to very low levels early in the 20th century (Grinnell and Miller 1944), enjoys "fully protected" status in the state (California Department of Fish and Game 2009).

In the breeding season, alfalfa provides a key foraging habitat for the Central Valley's population of Swainson's Hawk (*Buteo swainsoni*), designated threatened by the California Department of Fish and Game (Estep 1989, Babcock 1995, D. Anderson pers. comm.). Our results suggest that alfalfa may be an important crop to some raptors in the Central Valley in winter as well. This crop may support high densities of rodents (Getz et al. 2005). The relatively low and open structure of alfalfa, combined with the fact that it is harvested multiple times per year in this area, may make prey accessible to raptors (Estep 1989). Alfalfa appears to be particularly attractive to the American Kestrel, a species in widespread, long-term decline in North America (Sauer et al. 2008, Farmer and Smith 2009, Smallwood et al. 2009) and in the Central Valley (Pandolfino 2006, Sauer et al. 2008).

Urbanization and conversion of more passive forms of agriculture to orchards and vineyards are among the fastest growing land uses in the Central Valley. This trend is alarming given that most of the species we studied were associated negatively with these increasing land uses and no species was associated positively. In addition, with the supply of water limited and many interests competing for that supply, decisions about allocation of water may affect the habitat available for raptors in the Central Valley. Our results suggest that, to the extent water for urban uses, orchards, vineyards, and row crops takes precedence over crops like rice and alfalfa, important winter habitat for some species of raptors may be lost.

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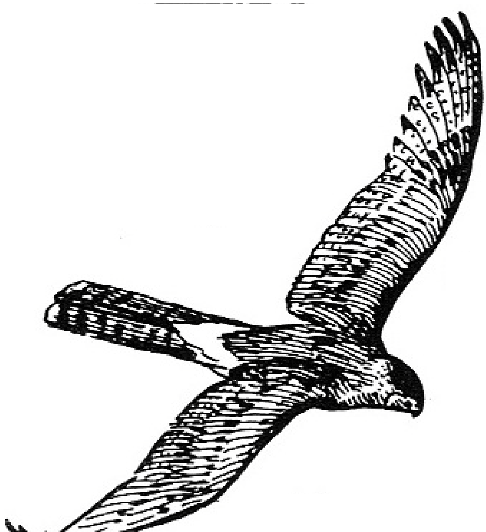

Northern Harrier

Sketch by Bob Hines, courtesy U. S. Fish and Wildlife Service