Distribution, Abundance, and Habitat Associations of Nesting Swainson's Hawks in the Central San Joaquin Valley, California

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ABSTRACT

We conducted a census of nesting Swainson's Hawks (*Buteo swainsoni*) across a large section of Fresno and Kings counties in 2011. Surveys determined the distribution and abundance of Swainson's Hawk and other stick nest-building raptors, documented nesting and foraging habitats, and determined reproductive rates. We documented 90 occupied Swainson's Hawk nesting territories within the approximately 1 million-acre study area. Of the 80 territories where nesting outcomes were determined, 52 pairs (65%) nested successfully, 22 (28%) nested but failed to successfully nest, and 6 (8%) occupied nesting territories but did not nest. Nesting raptors, including Swainson's Hawks, were unevenly distributed within the survey area, with the highest nesting densities along the Kings River-Fresno Slough corridor and within and near the Mendota Wildlife Area. Availability of suitable trees for nesting appeared to be the primary factor determining distribution. The greatest proportion of nesting Swainson's Hawks (40%) nested in riparian woodland habitat, with the remaining 60% divided among seven other nesting habitat types. Eucalyptus was the most commonly used nest tree (34%) followed by cottonwood (28%) and willow (28%). Reproductive rate (0.91 fledged young per occupied nest) was consistent with other Central Valley locales for the 2011 breeding season.

INTRODUCTION AND STUDY AREA

The breeding range of the Swainson's Hawk extends throughout most of the Central Valley from near Red Bluff in the north to Bakersfield in the south, and from the Coast Range foothills in the west to the Sierra Nevada foothills in the east. Most large, regional survey efforts over the past 30 years since the 1983 state listing of this species as Threatened have occurred north of Stanislaus County in the Sacramento Valley and northern San Joaquin Valley regions of the Central Valley where the species is relatively abundant. Most of

this work has been conducted as basic research on the distribution, abundance, and life history of the Swainson's Hawk or to support large regional conservation planning (Estep 1989, 2007, 2008, Babcock 1995, ICF International 2012, 2013). Although localized surveys have been conducted in the southern and central San Joaquin Valley, no regional census-level surveys have been conducted recently. As a result, information is lacking on the distribution and abundance of the Swainson's Hawk throughout much of the San Joaquin Valley.

In the San Joaquin Valley, most surveys have been conducted on state and federal wildlife refuges and in response to proposed development, infrastructure, and energy projects. Additional incidental data have been reported over the years, some of which have been submitted to the California Department of Fish and Wildlife's (CDFW) Natural Diversity Data Base (CNDDB). In 2005 and 2006, CDFW funded a statewide survey of the species that included several randomly selected 1-square mile survey blocks in the San Joaquin Valley (Anderson et al. 2007). Although this effort was useful in estimating the regional and statewide populations, it was less useful in describing the distribution and abundance of the species across the regional landscape and the habitat conditions in areas where the species occurs.

In 2011, we surveyed a large portion of Fresno and Kings counties. These surveys were conducted in response to eight proposed photovoltaic solar generation facilities and the need to assess the effects of these projects on the distribution and abundance of the Swainson's Hawk. Reliable and current information on hawk nesting in the area was lacking. Therefore, we established a study area by encompassing 10-mile radius areas extending from the edges of each of the proposed solar project sites. The individual survey areas overlapped to varying degrees creating a single contiguous survey area (Figure 1).

Because the project sites are irregularly shaped, the study area boundaries were expanded outward until a circular-shaped area was achieved. As a result, the total irregularly-shaped study area encompassed 416,739 ha (1,029,785 acres or 1,609 sq. mi) extending from approximately Kettleman City on the south to Mendota on the north, and from Coalinga on the west to Hanford on the east.

The study area is primarily an agricultural landscape; however, several small and medium-sized urban areas are present including the towns of San Joaquin, Tranquility, Huron, and Stratford, and the small cities of Lemoore and Coalinga. Lemoore Naval Air Station is also within the study area, much of which is also actively farmed. The CDFW's Mendota Wildlife Area also is within the study area just south of Mendota, most of which is maintained as managed seasonal wetland. In addition to portions of the Mendota Wildlife Area, the most prominent natural feature in the study area is the Kings River-

Fresno Slough corridor, in the central-east portion of the study area. Fresno Slough extends from the northernmost portion of the study area, through the Mendota Wildlife Area and along with the James Bypass (a water conveyance canal paralleling the Fresno Slough) continues southeast until it connects with the Kings River. The Kings River continues southward until it terminates at the Tulare Lakebed south of Stratford (Figure 1).

We conducted surveys for nesting Swainson's Hawks to determine distribution and abundance relative to the location of the eight proposed photovoltaic solar facilities and to assess the effects of the facilities on the local and regional Swainson's Hawk population. The survey, however, also provides a broader landscape perspective on the distribution and abundance of this species in the central San Joaquin Valley.

METHODS

Distribution and Abundance

Our primary objective was to record all active Swainson's Hawk nests within the study area and document nesting and foraging habitat associations. While the survey focused primarily on nesting Swainson's Hawks, our secondary objective was to collect similar data on several other species that may compete for nesting or foraging habitat and that may influence the distribution and abundance of Swainson's Hawks, including the Red-tailed Hawk (*Buteo jamaiscensis*), Red-shouldered Hawk (*Buteo lineatus*), White-tailed Kite (*Elanus leucurus*), and Great-horned Owl (*Bubo virginianus*). We determined how these species were distributed within the study area and described the habitat conditions that influence distribution and abundance.

The survey was designed as a complete census. We surveyed all potential nesting areas equally according to the protocol described below regardless of past survey effort or existing information on Swainson's Hawk nesting locations.

Surveys were conducted in two phases, once during the incubation/early nestling phase from 12-29 April, and again during late nestling/early fledging phase from 6 June to 1 July. Conducting early and later surveys ensures that all active nesting territories are documented and that failed nests and nests abandoned later in the breeding season are not missed as they may be if only a single survey were conducted. It also provides an opportunity to resurvey all areas in the event that any active sites were missed during the first survey, and allows for documentation of reproductive outcome.

Surveys were conducted by systematically driving all available roads within the study area. Where roads were not available to drive or where there were no roads to access potential nest trees, the survey was conducted on foot unless access to private property was not granted. In general, access in the study area was very good; we were provided with access to state lands

and to all levees maintained by the Kings River Conservation District. Access onto private farmlands was also regularly granted or provided through numerous public roadways. Therefore, overall access and survey coverage throughout the study area was excellent.

Using binoculars and spotting scopes, we checked all suitable nesting habitats for the presence of active nests and adult Swainson's Hawks and to note nesting activity and behavior (e.g., nest construction, courtship flights, and defensive behavior). We searched all trees for active nests. We recorded nest site and habitat data on a standardized field form. Activity was noted and mapped on field maps; locations of active nests were documented on 7.5 minute USGS quadrangle maps, and a hand-held GPS unit was used to record latitude-longitude coordinates of each nest. We took photographs of each active nest site and surrounding land use.

We conducted follow-up surveys as needed until all potential habitats were inspected. As necessary, each active nest was revisited to determine activity and reproductive status and to record the number of fledged young: the metric used to report reproductive performance. Many nesting territories were visited multiple times to collect the necessary data. Activity data were recorded based on the following standard definitions (Postupalsky 1983):

- *Occupied Nesting Territory:* a nesting area in which a pair of raptors showed activity indicating territory establishment. Territories were considered occupied when the following activities and behaviors were observed: regular presence and activity of adults, courtship displays, circling low above the nest tree or nesting stand, defensive behavior, prey exchanges and prey delivery to the nest. The nesting territory location was plotted based on the location of the nest, or if the nest was not located, based on the primary area of observed activity within potential nesting habitat.
- A*ctive Nest:* An occupied nesting territory at which egg laying was confirmed through direct observation of incubating adults.
- *Occupied Inactive Nesting Territory:* an occupied nesting territory in which multiple observations confirmed that adults did not lay eggs.
- *Occupied Nesting Territory with Unconfirmed Nesting Status:* an occupied nesting territory for which reproductive outcome was not confirmed. This category includes occupied nesting territories where access was inadequate to determine nesting activity (in some cases the actual nest was not observed) or where repeat visits were inconclusive in determining if the nest was active.
- *Successful Nest*: an active nest that fledged at least one young.
- *Unsuccessful Nesting Attempt:* an occupied territory in which the pair did not lay eggs, or an active nest that failed to produce fledged young.

We measured productivity of the populations as the average number of fledged young produced per occupied nesting territory with confirmed nesting status (active nests plus occupied nesting territories that did not nest). Brood size was measured as the average number of fledged young produced per successful nest.

Each active nest was characterized with regard to nesting habitat type, tree species, condition, and location within the nesting habitat. A chi-square (χ^2) analysis was conducted to statistically compare the similarity of use of nest tree species among species with significance levels set at $\alpha \leq 0.05$.

Distribution of Nesting and Foraging Habitats

We mapped and characterized land uses and habitat types in the field throughout the study area on 7.5 minute USGS quadrangle base maps. Fifty quad maps were used during the study. We documented the current 2011 land use in the field according to the land cover type categories listed below. Field boundaries were recorded, confirmed, or adjusted as needed on the USGS base maps.

We assessed raptor foraging habitat associations based on broad agricultural land use categories rather than the specific crop type. The crop pattern mosaic is diverse in the study area and subject to change annually and seasonally through typical crop rotation practices. Therefore, with the exception of perennial and long-term crop types (e.g., vineyards, orchards, pasturelands), and semi-perennial types (e.g., alfalfa hay), specific crop types were grouped into the following broad categories that represent long-term land use patterns in the study area.

- Rotated cropland (annually cultivated and rotated crops, including fields that were idle at the time of the survey)
- Alfalfa and other hay crops
- Irrigated pastureland
- Orchards and vineyards
- Managed wetland
- Natural land (includes all uncultivated grassland and scrub natural communities)
- Developed land (excluding rural residential less than one acre, which were subsumed into the land use category within which they occurred).

These types are described in more detail, along with use by Swainson's Hawks and other raptors, in ***Results and Discussion***.

Nesting habitats were limited to those woody land cover types that could be reasonably mapped and quantified including riparian, tree rows, and tree groves. However, several other nesting habitat types, such as isolated trees and small groups or rows of trees too small to effectively map, were recognized (see ***Results and Discussion***) and their use was reported.

Following the initial field mapping of habitat/land use categories, the data were then re-mapped using aerial photos to confirm field boundaries. These maps were then converted to graphic maps using Adobe Illustrator. Habitat/land use cover type acreages were calculated from the graphic maps using a plug-in filter from Telegraphics Inc. Although this process provided a reasonably accurate mapping representation, and particularly for calculating the relative abundance of the mapped types across the landscape, it did not exclude roads and other edge features. As a result, the acreage totals reported may exceed the actual acreage for most types. These inclusions, however, were considered to have a negligible effect on meeting the study purposes of characterizing raptor responses at a broader landscape scale. Using the mapped and quantified habitat/land use information, we then characterized and described the distribution and abundance of nesting Swainson's Hawks in the study area with regard to these broad habitat associations.

RESULTS AND DISCUSSION

Distribution and Abundance

We documented a total of 90 occupied Swainson's Hawk nesting territories during the survey effort (Figure 1). Table 1 summarizes nesting activity and reproductive results for Swainson's Hawk and other raptors.

The density of Swainson's Hawk nesting territories within the study area was 0.16 per km^2 (0.06 per mi^2). This nesting density is very low compared with the Sacramento Valley breeding population (i.e., Yolo and Sacramento counties), but similar to nesting densities reported elsewhere in the breeding range (Table 2).

The nesting distribution was uneven across the study area, with most Swainson's Hawk nesting territories (68%) concentrated in the vicinity of the DFW Mendota Wildlife Area and along and east of Fresno Slough and the Kings River (Figure 1). Fourteen of the 90 nest sites (16%) were on or immediately adjacent to the Mendota Wildlife Area, where riparian woodland, tree groves, tree rows, and many isolated trees provide abundant suitable nesting habitat. Twenty-four nest territories were along Fresno Slough or the Kings River where suitable riparian nesting habitat is also abundant. An additional 23 territories were east of the Fresno Slough/Kings River corridor where nesting habitat is abundant and crop patterns are highly suitable for Swainson's Hawk foraging.

The remaining 29 territories were scattered throughout the western portion of the study area, where available nesting habitat is scarce and is limited primarily to trees around farm houses, tree rows, isolated trees, and small patches of riparian woodland.

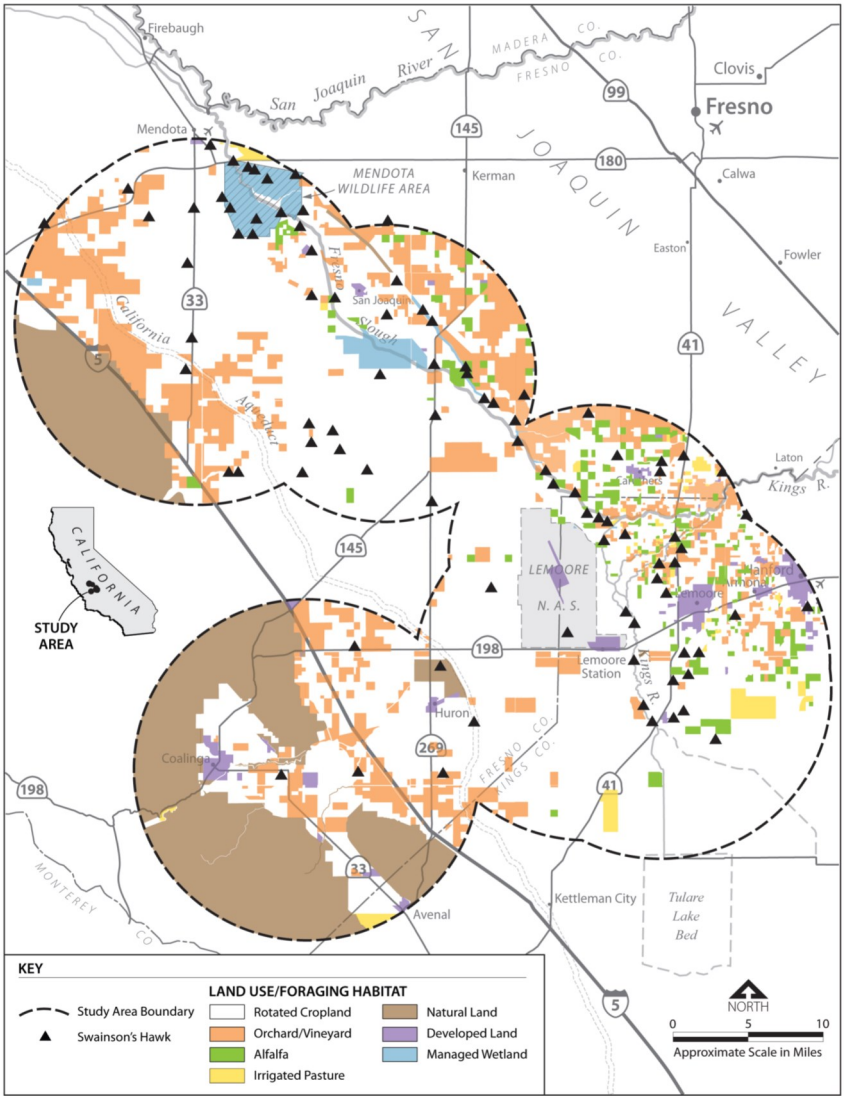

Figure 1. Distribution of nesting Swainson's Hawks and land use/foraging habitat with the Central San Joaquin Valley study area. 2011.

Table 1. Nesting success and reproduction of Swainson Hawks and other nesting raptors in Fresno and Kings counties, San Joaquin Valley, California.

A. Nesting Success								
	Swainson's Hawk		Red-tailed Hawk		Red-shouldered hawk		Great-horned owl	
	# Territories	%	# Territories	%	# Territories	%	# Territories	%
Successful	52	58	80	83	2	67	23	92
Unsuccessful	22	24	5	5	0	0	0	0
Not nesting	6	7	0	0	0	0	0	0
Unconfirmed	10	11	12	12	1	33	2	8
Total	90	100	97	100	3	100	25	100

B. Reproduction				
	Swainson's Hawk	Red-tailed Hawk	Red-shouldered hawk	Great-horned owl
Young fledged	73	129	3	48
Fledglings/ occupied nest	0.91	1.52	1.5	2.10
Fledglings/ successful nest	1.40	1.61	1.5	2.10

We documented a similar distribution and abundance for Red-tailed Hawk (Table 1, Figure 2). The 97 active Red-tailed Hawk nesting territories represent a survey area-wide nest density of 0.17 territories per km^2 (0.07 nests per mi^2), also quite low relative to the Sacramento Valley (Estep 2007, 2008). Nest distribution for Red-tailed Hawks followed the same general pattern as for Swainson's Hawks, with most nest territories occurring along and east of the Fresno Slough/Kings River corridor.

Results for Red-shouldered Hawk and Great-horned Owl were similar to other species (Table 1, Figure 2). However, we found only three Red-shouldered Hawk nests during the survey, indicating a very low nest density compared with the Sacramento Valley. While all three were found along or east of the Fresno Slough/Kings River corridor, additional nesting pairs were expected given the extent of available nesting habitat in that area. We also documented a total of 25 Great-horned Owl nests, which probably under-represents the breeding population of this species since the surveys were conducted too late in the season to ensure detection of all Great-horned Owl nests. Nonetheless, the distribution of the Great-horned Owl follows that of the other species (Figure 2). Notable also was the lack of any confirmed White-tailed Kite territories. While this species also occurs in low densities in the Sacramento Valley, particularly compared with Swainson's Hawk and Red-tailed Hawk (Estep 2007, 2008), we were surprised that none were detected even though a substantial amount of apparently-suitable nesting and foraging habitat occurred in the eastern portion of the study area.

Table 2. Swainson's Hawk nest density in the study area compared with other geographic areas.

Location	Nesting Territories per km^2 (/mi^2)	Source
Yolo Co., CA	0.98 (0.38)	Estep 2008
Sacramento Co., CA	0.96 (0.37)	Estep 2007
Butte Valley, Siskiyou Co., CA	0.37 (0.14)	Woodbridge et al. 1995
Alberta, Canada	0.23 (0.09)	Schmutz 1987
New Mexico	0.17 (0.07)	Bednarz et al. 1990
Fresno and Kings county, CA	0.16 (0.06)	This study

Activity and Reproduction

Most of the Swainson's Hawk pairs in the study area were confirmed to have attempted nesting (82%). The proportion of active nests that failed to produce young (24%), however, was high compared with other years of record in other areas, but consistent with those of other Central Valley locales during the 2011 breeding season (ICF International 2012). The proportion of pairs that did not attempt to nest (6.7%) was lower than other areas in 2011 and other recent survey efforts, whereas the proportion of occupied nesting territories with unconfirmed nesting status (11%) was similar or lower than in other areas (Estep 2007, 2008, ICF International 2012).

Red-tailed Hawks, possibly due to a more diverse diet, were more successful than Swainson's Hawks, with 88% of pairs confirmed nesting and only 5% confirmed to have failed. Such success is typical of Red-tailed Hawk reproductive performance in other areas. While no failed Great-horned Owl nests were confirmed, the high proportion (92%) of active and successful nests does not include nests that may have failed prior to the first survey and so the calculated success may be inflated (Table 1).

We recorded 73 fledged Swainson's Hawk young, equating to averages of 0.91 young per occupied nest (the total of active nests and non-nesting active territories) and 1.40 young per successful nest (Table 1). While the number of young per successful nest is generally consistent with other past and ongoing studies of Swainson's Hawk in the Central Valley (Estep 2007, 2008, unpub. data; ICF International 2012), the number of young per occupied nests is lower than typically reported due to the high number of nest failures in 2011. Both indicators are also lower than for most populations outside of the Central Valley (Briggs 2007, Alsup 2012).

One possible explanation for lower reproduction in Fresno and Kings counties and the rest of the Central Valley is the dynamic nature of valley agricultural systems. While the diverse matrix of cover types and the planting and harvesting regimes can produce periodic high prey abundance, the growth and harvesting of crops also can create an inconsistent forage base, forcing birds to hunt further from the nest during some portions of the breeding season and possibly contributing to lower reproductive success per nesting pair (England et al. 1995).

Reproductive performance for the other three species (Table 1) was more robust and typical of most years elsewhere for these species (Stout et al. 2006, Estep 2007, 2008).

Habitat Associations

The distribution and abundances of land cover types across the entire 1,029,785-acre study area are shown in Figure 1 and Table 3. Descriptions of each type that are considered foraging and nesting habitats follow.

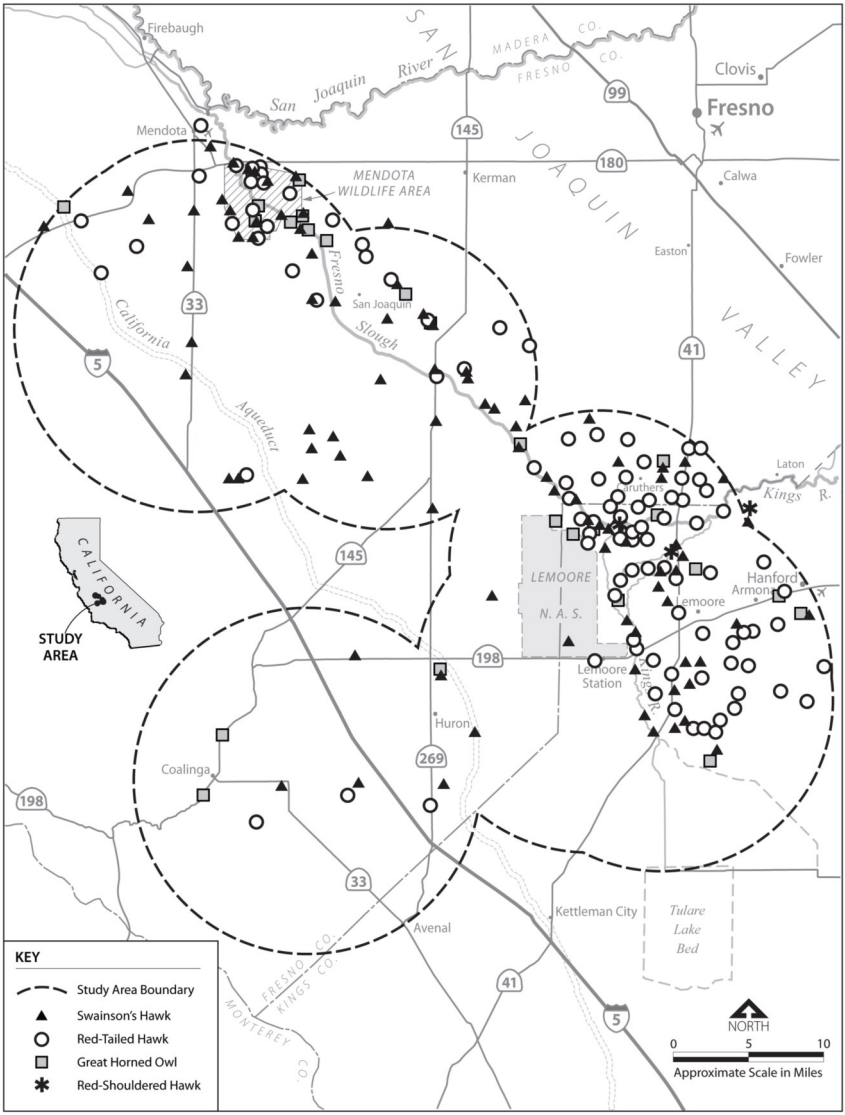

Figure 2 Distribution of Swainson's Hawks in relation to other nesting raptors within the Central San Joaquin Valley study area, 2011.

Foraging Habitat. Within a diverse agricultural landscape, as occurs through most of the Central Valley, raptor foraging habitat tends to be spatially dynamic throughout the breeding season. Where irrigated hay, row, and grain crops dominate, hawk use of cultivated lands is primarily affected by vegetation structure (i.e., height and density; Bechard 1982, Swolgaard et al. 2008, Estep 2009), which changes seasonally and annually based on planting, growth, and harvesting regimes of the many crops grown. Therefore, the agricultural crop matrix present in any given year influences Swainson's Hawk foraging use and behavior. A similar relationship likely exists for other raptor species, but the relationship appears to be much more pronounced in Swainson's Hawk, which relies primarily on cultivated lands.

Within the study area, land uses considered suitable for Swainson's Hawk foraging, including rotated croplands, alfalfa and other hay fields, irrigated pastures, and natural lands, occupy 332,547 ha (821,742 ac) or 80% of the study area. The term 'suitable', however, is not synonymous with 'available'. Within the broad agricultural matrix, most suitable crop types are available to foraging Swainson's Hawks only during a portion of the season due to seasonal changes in vegetation structure, which influences the accessibility of prey to foraging hawks (Estep 2009). The following sections describe the land use/cover type categories in the study area that are considered suitable Swainson's Hawk foraging habitat and generally describe their seasonal availability.

Rotated Cropland. This type includes crops that are annually or seasonally cultivated and rotated. This is the dominant cover type in the study area comprising 62% of the land area (Table 3, Figure 1). Most of this type included cotton, tomatoes, wheat, and corn. It has likely declined in overall acreage due to recent and ongoing conversion of rotated cropland to orchards. While individual crop types within this category were not mapped or evaluated, cotton, tomato, wheat, and corn comprised approximately 75% and 55% of the total irrigated cropland area in Kings and Fresno counties, respectively (Kings County 2012, Fresno County 2012). A typical crop rotation includes cotton, wheat, and tomatoes. With milk products as important commodities in Kings and Fresno counties, dairies support the cultivation of a variety of silage and hay crops including corn, wheat, sorghum, and triticale (Kings County 2012). Alfalfa is also an important part of this rotation, but as noted below alfalfa hay remains in fields for several consecutive seasons, and thus is not included in this category.

Rotated crops generally have seasonal or fluctuating foraging habitat value depending on the planting, growth, and harvesting regime and resulting vegetation structure (Estep 2009). For example, tomatoes are planted in the spring and vegetation height and density increases throughout the breeding season. Rodent populations increase during this period, but prey accessibility (and thus hawk foraging use) decreases as vegetation height and density

increases (Bechard 1982, Estep 1989, 2009). When tomatoes are harvested in August, prey accessibility increases when rodent populations are at their highest; therefore, the value and foraging use of tomato fields reaches its peak then.

Each crop type within the rotated category undergoes a similar temporal change in value and use; however, the timing is different for each. Some crops, including cotton and corn have limited value because their vegetation structure precludes foraging early in the breeding season, prey populations are generally low, and harvesting often occurs after Swainson's Hawks have begun fall migration.

In general, however, rotated croplands as a whole are considered to have at least moderate foraging value due to the matrix of different crop types across the agricultural landscape, the seasonal value of certain types such as tomatoes and wheat, and the seasonal or annual rotation practices.

Table 3. Land area and relative abundance of mapped land use types.

Land Use Type	Hectares (Acres)	Percent of Total
Rotated Cropland	256,456 (633,716)	62
Orchard/Vineyard	67,603 (167,050)	16
	63,141 (156,025)	15
Alfalfa Hay	10,059 (24,857)	2.4
Managed Wetland	7,816 (19,313)	1.9
Developed Land	6,093 (15,056)	1.5
Irrigated Pasture	2,891 (7,144)	0.7
Riparian	1,870 (4,620)	0.4
Tree Grove	413 (1,021)	0.1
Tree Row	398 (983)	0.1
Total	416,739 (1,029,785)	100

Alfalfa. Alfalfa is an ungrazed irrigated hay crop used for livestock feed. The nutritional benefits alfalfa provides to livestock, including high protein content, also benefits the abundant rodent and insect prey populations found in alfalfa fields (Putnam et al. 2001, Ball 2005). Alfalfa typically remains uncultivated for 3 to 5 years, and occasionally longer, without being rotated to other crops. Alfalfa is considered the cover type with the highest foraging value to Swainson's Hawks due to its relatively low vegetation structure, lack of seasonal cultivation, and the practice of regular mowing and flood-irrigating during the breeding season, which exposes and concentrates prey

(Estep 1989, 2009, Swolgaard et al. 2008, Anderson et al. in preparation). Following its multi-year growth, alfalfa is often converted back to rotated cropland. Alfalfa is interspersed throughout the agricultural matrix. It constitutes approximately 2.4% of the total land area (Table 3, Figure 1) with the largest proportion occurring east of the Fresno Slough/Kings River corridor.

Irrigated Pasture. Irrigated pastures grow irrigated grasses or forbs grazed by livestock or periodically cut for hay. These include large pasturelands such as those south of the city of Lemoore and east of the Kings River, smaller pastures associated with dairy operations scattered throughout the study area, and small pastures associated with farm residences. Depending on rodent availability and grazing intensity, irrigated pastures can provide moderate to high value foraging habitat for Swainson's Hawk and other raptors because they usually maintain low vegetation cover and are available for foraging throughout the breeding season. Approximately 0.7% of the study area consists of this cover type (Table 3, Figure 1) with the largest proportion east of the Fresno Slough/Kings River corridor.

Natural Land. Natural land consists of uncultivated areas that have retained some natural topography, vegetation characteristics, or other values. These lands are rare on the valley floor and are usually associated with remnant patches of native salt scrub community, other uncultivated grazing land, or river bottom along the edges of the Kings River. Most natural land consists mainly of annual grassland in the western portion of the study area in the eastern foothills of the Coast Ranges. Natural lands constitute 15% of the study area (Table 3, Figure 1). Although annual grasslands provide suitable foraging habitat that is available throughout the season, Swainson's Hawks are generally associated with flat landscapes, so foraging use of the more topographically diverse foothill areas in the western portion of the study area is expected to be substantially less than in the cultivated habitats on the valley floor.

Managed Wetland. In the Central Valley, most managed wetlands are agricultural fields or former agricultural fields periodically flooded to provide wintering waterfowl habitat. During summer, these areas are typically dry and provide upland habitat for foraging raptors and other wildlife. Managed wetlands constitute 2% of the study area (Table 3, Figure 1), most of which is associated with the Mendota Wildlife Area and a waterfowl management area near the town of Helm.

The following cover types in the study area provide limited to no suitable foraging habitat for Swainson's Hawks.

Vineyards and Orchards. These perennial crops develop a vegetative overstory that usually precludes access by foraging Swainson's Hawks and most other raptors. Although Swolgaard et al. (2008) found some limited use

of vineyard habitats, both types are generally considered incompatible with Swainson's Hawk foraging. These types occur throughout the study area, with the largest proportions east of the Fresno Slough/Kings River corridor and in the western portion of the study area, particularly immediately east of Interstate 5 (Figure 1). The type constitutes 16% of the total study area and is the second most abundant land cover type in the study area (Table 3).

Developed Lands. Developed lands include urban, industrial, and rural residential areas greater than 1 acre. These types generally consist of high density developed areas that lack natural or cultivated landscapes and provide no foraging habitat value. Rural residential is lower density urbanization that fragments natural or cultivated landscapes. Most developed lands are found east of the Fresno Slough/Kings River corridor, including the cities of Lemoore, Hanford, and San Joaquin. Other smaller developed areas are scattered throughout the study area and include small towns such as Huron, and large farming or packing facilities. Both high density urban areas and lower density rural residential or commercial areas, constituting 1.5% of the total study area (Table 3, Figure 1), are considered unsuitable habitat areas.

Of the seven defined foraging cover types, two (Vineyards/Orchards and Developed Lands) represent distinct land uses or cover types that provide limited to no suitable Swainson's Hawk foraging habitat. These types comprise 18% of the study area (Table 3). The remaining 82% of the study area is considered suitable Swainson's Hawk foraging habitat, but with variable value.

Nesting Habitat. We found Swainson's Hawk nests in eight of the nesting habitat types (Table 4). Red-tailed Hawks used these and also utility poles and electrical transmission towers. Not surprisingly, due to its relative abundance, riparian was the most commonly used nesting habitat for all species combined. Swainson's Hawk and Red-tailed Hawk nesting habitat use was similarly diverse. Each type is described below.

Riparian. Riparian is streamside vegetation that generally supports an overstory of Fremont cottonwood (*Populus fremontii*), willow (*Salix* spp.), and valley oak (*Quercus lobata*) trees, which are commonly used for nesting by Swainson's Hawks and other raptors. Eucalyptus (*Eucalyptus* spp.), salt cedar (*Tamarix* spp.), and other non-native trees also occur within riparian zones. Thirty-six of the 90 occupied Swainson's Hawk territories (40%) were associated with riparian habitat (Table 4). The Kings River (North Fork, South Fork, and Clarks Fork) supports a relatively continuous corridor of mature riparian forest, and Fresno Slough, which supports intermittent, patchy willow -cottonwood riparian woodland. Other riparian vegetation is associated with small sloughs, creeks, or other channels.

Table 4. Nesting habitat types of four raptor species in Fresno & Kings county.

	Swainson's Hawk		Red-tailed Hawk		Red-shouldered hawk		Great-horned Owl	
Nesting Habitat	Occupied territories	% of Total	Occupied territories	% of Total	Occupied territories	% of Total	Occupied territories	% of Total
Riparian	36	40	28	29	2	67	13	52
Rural Residential	17	19	31	32	0	0	3	12
Isolated Tree	13	14	12	12	0	0	5	20
Tree Row	10	11	5	5	0	0	0	0
Grove	5	6	12	12	0	0	2	8
Isolated Roadside Tree	5	6	2	2	0	0	1	4
Roadside Tree Row	2	2	2	2	1	33	1	4
Farmyard	2	2	2	2	0	0	0	0
Utility Pole/Tower	0	0	3	3	0	0	0	0
Total	90	100	97	100	3	100	25	100

Rural Residential. Rural residential includes trees planted for windbreak cover, shade, or ornamentals around rural farmsteads. These trees are of a variety of species, but are predominantly eucalyptus. Nesting Swainson's Hawks can be quite tolerant of human activities and often use trees associated with rural farm residences or farmyards (Estep 2007, 2008). Seventeen of the 90 occupied Swainson's Hawk territories (19%) were associated with rural residential areas, with all nests in eucalyptus trees (Table 4).

Isolated Tree. Isolated trees are single trees (and occasionally two or three trees) that are not associated with roadsides, residences, or other features. Many are large, mature valley oak trees within agricultural fields that are remnants of pre-agricultural oak woodlands or trees that have grown along field edges. Thirteen Swainson's Hawk nest territories (14%) were associated with isolated trees (Table 4).

Tree Row. Tree row consists of planted rows of trees not associated with roadsides. These often occur along field borders or rural driveways and were usually planted as windbreaks. Most tree rows consist of eucalyptus trees. Ten occupied Swainson's Hawk territories (11%) were associated with this habitat type (Table 4).

Grove. Groves were defined as at least six trees in a planted or remnant native stand. While there are several small valley oak and cottonwood groves in the northern and central portions of the study area east of the Fresno Slough/Kings River corridor, most groves are planted eucalyptus or other non-native tree species. Eucalyptus groves are common in the study area, planted as windbreaks or as sound and visual barriers. Five (6%) occupied Swainson's Hawk territories were associated with this habitat (Table 4).

Isolated Roadside Tree. Isolated roadside trees were distinguished from other isolated trees because they generally receive a substantially greater amount of noise and other human disturbances. This type includes any naturally occurring or planted native or nonnative tree. Isolated roadside trees include eucalyptus, willow, cottonwood, and valley oak trees. Five occupied Swainson's Hawk territories (6%) were in isolated roadside trees (Table 4).

Roadside Tree Row. Roadside tree rows are planted rows of trees along roadsides, which were planted as visual barriers or windbreaks. Most of these rows are eucalyptus trees. They are distinguished from isolated roadside trees because they provide additional cover, perching and roosting opportunities, and nest security from vehicle traffic. Two Swainson's Hawk nests (2%) were associated with roadside tree rows (Table 4).

Farmyard Tree. Farmyards are sites along the edges of agricultural fields that are used for equipment staging for planting and harvesting operations or storage of farm equipment. They are usually less than 1 acre in size and often

Table 5. Nest tree species used by four raptor species in Fresno and Kings counties.

	Swainson's Hawk		Red-tailed Hawk		Red-shouldered Hawk		Great-horned Owl	
Tree Species/ Other substrate	No. Nest Sites	% of Total	No. Nest Sites	% of Total	No. Nest Sites	% of Total	No. Nest Sites	% of Total
Eucalyptus	28	34	47	48	1	33	7	28
Cottonwood	23	28	24	25	1	33	8	32
Willow	23	28	7	7	0	0	7	28
Valley Oak	7	8	11	11	1	33	1	4
Pine sp.	2	2	3	3	0	0	0	0
Locust	0	0	2	2	0	0	0	0
Sycamore	0	0	0	0	0	0	1	4
Beefwood	0	0	0	0	0	0	1	4
Utility Pole	0	0	2	2	0	0	0	0
Transmission Tower	0	0	1	1	0	0	0	0
Total	83	100	97	100	3	100	25	100

have trees within or around their perimeter, which provide nesting opportunities for Swainson's Hawks, particularly where nesting habitat is otherwise limited. Two Swainson's Hawk nest territories (2%) were associated with farmyards (Table 4).

Nesting Swainson's Hawks and other raptors used a variety of tree species (Table 5). Swainson's Hawks nested in five different tree species. Eucalyptus was the predominant nest tree species used by both Swainson's Hawk and Red-tailed Hawk. Both species also used cottonwood, willow, and valley oak, and to a lesser extent ornamental pine. Eucalyptus nest trees were mainly within tree rows, roadside tree rows, or rural residences. Cottonwood and willow trees were the most commonly used trees in riparian areas. Valley oak nest trees were mostly isolated trees in fields or along field edges. While there were similarities in relative use among most tree species, the difference in use of willow resulted in an overall pattern of use that differed significantly between Swainson's Hawks and Red-tailed Hawks ($\chi^2_{1.d.f.} = 3.84$ $P<0.025$). Red-tailed Hawks typically construct larger more robust nests than Swainson's Hawks and willow trees often are not capable of supporting their nests.

Relationship between Hawk Distribution and Habitat Associations

Swainson's Hawks forage widely over agricultural landscapes, and foraging has been documented to regularly occur greater than 10 miles from nest sites (Estep 1989, Babcock 1995). Foraging ranges, however, are highly elastic and change seasonally as fields are prepared, planted, mature, and are harvested. These changes thereby result in seasonal changes in prey populations and in vegetation structure and density that influences prey abundance and accessibility (Bechard 1982, Estep 2009). Swainson's Hawks have proven to be very adaptable to this dynamic foraging landscape and have learned to opportunistically exploit suitable foraging conditions as they become available over the season. Using the information on general crop patterns throughout the study area and data on Swainson's Hawk foraging use patterns in the Central Valley (Estep 1989, Babcock 1995, Anderson et al. in preparation), it is possible to qualitatively describe the likely use of the study area by the 90 nesting pairs that reside within it.

The distribution of nesting Swainson's Hawks and other raptors in the study area suggests differences between habitat conditions east of the Fresno Slough/Kings River corridor, where nesting density is most concentrated, and the larger western portion of the study area where nesting territories are sparsely distributed across a broad agricultural landscape. Figure 1 illustrates the distribution of Swainson's Hawk nesting territories relative to the distribution of land use/cover types in the study area. The figure suggests a relationship between the distribution of hawks and land cover based on two primary factors: the distribution of nesting habitat and the distribution of high value foraging habitat.

Because of the greater extent of alfalfa and other higher value crop types east of the Kings River; it is reasonable to assume that most foraging activity also occurs east of the Kings River. However, Swainson's Hawks readily travel significant distances from their nest sites to forage when opportunities occur. For example, high quality foraging conditions occur during wheat harvest (June), and tomato harvest (August), when these crop types are used extensively by foraging Swainson's Hawks. Because these crop types are among the most common in the study area and throughout Kings and Fresno counties, the area west of the Kings River likely also receives a substantial amount of foraging activity.

As previously noted, there are very few nesting opportunities west of the Fresno Slough/Kings River corridor. This area supports an abundance of moderate value foraging habitat, but the paucity of trees restricts nesting opportunities to relatively few locations. East of the Fresno Slough/Kings River corridor, nesting habitat is relatively abundant and includes nearly continuous riparian woodland along the three forks of the Kings River, sparse and intermittent riparian along Fresno Slough, and remnant valley oak trees, eucalyptus tree rows, groves, and isolated trees between Stratford and Riverdale. Few suitable nest trees exist south of Stratford toward the Tulare Lakebed, and no nesting territories occur in this area. Relatively few nest trees and Swainson's Hawk nesting territories occur west of the Fresno Slough/ Kings River corridor, including the area south of State Route 198 west to Interstate 5, west of the Lemoore Naval Air Station and, with the exception of the Mendota Wildlife Area, west of Fresno Slough to Interstate 5 in the northern portion of the study area (Figure 1). West of Interstate 5, the landscape changes to include rolling grassland hills, where suitable nest trees are also largely absent, and thus support few Swainson's Hawk nesting territories. Only two nesting territories were documented west of Interstate 5, one near the western edge of the valley floor and one further west in Pleasant Valley near Coalinga.

Interestingly, in the open agricultural landscape between Interstate 5 and the Fresno Slough/Kings River corridor, Swainson's Hawks occupied much of the available nesting habitat. A large proportion of the isolated trees, eucalyptus tree rows, and small riparian corridors, such as Cantua Creek, supported nesting Swainson's Hawks. This pattern suggests that the agricultural landscape in this area, while only moderately suitable compared with the eastern portion of the study area, could support additional Swainson's Hawk nesting pairs and that the lack of nesting habitat may be the primary factor limiting population size in that area.

While nesting habitat distribution is likely the key factor affecting the distribution of nesting Swainson's Hawks, the more diverse agricultural landscape and the presence of higher value foraging habitat types (e.g., alfalfa and irrigated pasture) east of the Kings River also influences the distribution

and abundance of nesting Swainson's Hawks and other raptors. Virtually all of the dairies, and the associated alfalfa hay fields and irrigated pastureland occur east of the Kings River. The combination of abundant nesting habitat and a more diverse agricultural pattern with higher value crop types supports a greater abundance of nesting Swainson's Hawks in this area and illustrates the strong relationship between habitat availability and suitability in an agricultural landscape and the resulting distribution and abundance of Swainson's Hawk.

ACKNOWLEDGEMENTS

We thank Recurrent Energy, in particular Aimee Epstein, Seth Israel, and Elizabeth Brady, for initiating and supporting this project; the Kings River Conservation District for access along the Kings River and tributaries; the staff at CDFW's Mendota Wildlife Area for access to refuge lands; and to the many farmers who permitted access onto their lands. We also thank Mary Estep for preparing the graphics and Dan Airola for his thorough review and insightful comments.

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