

BREEDING SWAINSON'S HAWKS IN THE CENTRAL COAST RANGE OF CALIFORNIA

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ABSTRACT: During the 20th century the Swainson's Hawk (*Buteo swainsoni*) was an infrequent migrant through the central Coast Range of California with no breeding documented. Since 2005, however, several breeding pairs have established nest sites in the region. We studied Swainson's Hawks during the breeding seasons of 2019 and 2020 in a portion of the central Coast Range to estimate their abundance and distribution there. We observed individual hawks systematically and monitored their nesting activity and breeding outcomes in suitable habitat in Alameda, Santa Clara, and San Benito counties within the Coast Range and sought to characterize the habitat of this small outlying population. From 2019 to 2020 the numbers of nesting pairs increased from 3 to 5, of young fledged from 1 to 6, and of individual adults from 15 to 22. Swainson's Hawks were more closely associated with farmland than with grassland, and nests were located in areas that were closely associated with both grassland and farmland. The increase of this species in the central Coast Range and its use of agricultural areas is of conservation significance for land managers and wildlife and conservation agencies, given that the California Department of Fish and Wildlife has designated it as threatened.

The Swainson's Hawk (*Buteo swainsoni*) is a long-distance migrant that spends the boreal spring and summer in western North America (Bechard et al. 2010). It once bred widely through the valleys of California, but by the mid-20th century its population had declined precipitously (Bloom 1980). In 1983, the species was accorded "threatened" status under the California Endangered Species Act (California Natural Diversity Database 2020). Since the early 2000s, the number of Swainson's Hawks breeding in California has increased, especially in the middle latitudes of the Central Valley where 95% of the state's population currently nests (Battistone et al. 2019). Breeding pairs have also recently nested in areas where they have long been absent, including the valleys of the central Coast Range in Santa Clara and San Benito counties. A pair of Swainson's Hawks has nested in Coyote Valley, San Jose, Santa Clara County, since 2013, the first pair nesting in the area since 1894 (Phillips et al. 2014). Also in 2013, the first San Benito County nest was found (Phillips et al. 2014). In 2018, another pair began nesting in Santa Clara County at Gilroy. Swainson's Hawks have similarly nested for the first time in decades just to the north in Napa and Sonoma counties, where the Golden Gate Raptor Observatory monitored eight nests in 2013 (Phillips et al. 2014; Allen Fish pers. comm.).

During 2019 and 2020, we estimated the abundance and distribution of Swainson's Hawks and assessed their breeding in Santa Clara, San Benito, and Alameda counties. We surveyed the landscape systematically to record occupancy, the number of Swainson's Hawks, and their habitat use. We also monitored all active nest sites to determine how many individuals were breeding and the nests' characteristics, status, and success rate. To our knowledge,

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

this was the first systematic survey and monitoring of the Swainson's Hawks in this region, generating information that should prove useful to wildlife and land-management agencies and organizations in assessing the suitability of habitat for this species.

STUDY AREA

The study area extended from El Cerrito (Alameda County) in the north to Paicines (San Benito County) in the south (Figure 1). It was bordered by San Francisco Bay and the Santa Cruz Mountains on the west and the Diablo Range on the east. This area comprises highly developed urban and suburban areas near San Francisco Bay and in the Santa Clara Valley, open space (largely open grassland) and private land (used for cattle ranching or golf courses) in the surrounding hills, and scattered residential development, light industrial facilities, and agricultural areas in the less developed valleys. Dominant native trees within the valleys include Valley Oak (*Quercus lobata*), Coast Live Oak (*Q. agrifolia*), Western Sycamore (*Platanus racemosa*), Fremont Cottonwood (*Populus fremontii*), and various willows (*Salix* spp.). Agriculture included row crops, hayfields, orchards of fruit and nut trees, and vineyards.

METHODS

Landscape and Occupancy Survey

Drawing on methods established for surveying Swainson's Hawks and associated habitat (Gifford et al. 2012) and expert advice, we overlaid a map of the study area with a grid of 5 × 5 km plots in ArcGIS Online (version 2.0, ESRI, Redlands, CA). Since in California breeding Swainson's Hawks are restricted primarily to valleys at lower elevations (Gifford et al. 2012), we omitted plots with a largely mountainous topography (>300 m elevation on average), giving us a sampled area containing 153 plots that totaled 3825 km².

We used a conceptual model of Swainson's Hawk's habitat associations and nesting behaviors to stratify the sampled area into habitat types and to inform our selection of plots to survey. Preferred habitat included open, flat, or hilly grasslands and certain types of agricultural fields, especially of alfalfa and other low-growing crops (Bloom 1980, Estep 1989, Babcock 1995, Fleishman et al. 2016). To aid in stratifying the plots, we overlaid our map with a layer from the National Land Cover Database (NLCD16), dated 2016 and available from the Multi-Resolution Land Characteristics Consortium (U.S. Geological Survey data release, <https://doi.org/10.5066/P96HHBIE>), and estimated the percentages of grassland and farmland (preferred habitat) in each of the plots. Grassland in the NLCD16 included areas of herbaceous and graminoid vegetation. Farmland included the categories of cultivated crops and areas of pasture and hay. The NLCD16 land-cover layer did not distinguish crop types within agricultural uses, so our estimations of the percentages of farmland may have included unsuitable areas such as orchards and vineyards (Swolgaard et al. 2008). We then categorized the sampled area by the percentages of grassland and cropland and calculated a suitability index for each plot based on its combined percentage of these habitat types.

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

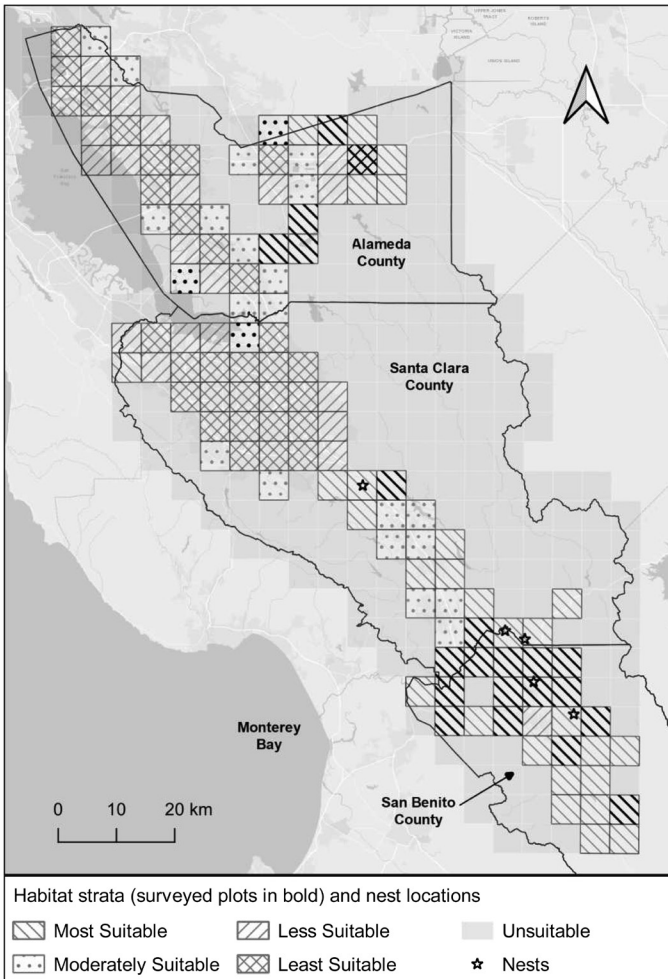


FIGURE 1. Habitat suitability of the plots within the study area. Plots in boldface were surveyed in 2020. Stars indicate nests monitored in 2020, named from north to south as follows: Coyote Valley, Ortega Creek, San Felipe Road & 152, San Felipe Road & 156, and Santa Ana Valley Road.

We plotted our observations of nesting Swainson's Hawks in 2018 as well as observations of individual Swainson's Hawks reported through eBird (<http://ebird.org>) between March and August in 2018. In all plots where Swainson's Hawks were observed in 2018 the combined coverage of grassland and farmland was >40%, so we defined that percentage as the threshold above which suitability was high. Seventy (46%) of the 153 total plots in the study area contained $\geq 40\%$ of these types of land cover. We categorized the remaining 83

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

plots by percent coverage of grass and farmland into three additional strata, defined as moderately suitable (25–40%; $n = 17$), less suitable (10–25%; $n = 11$), and least suitable (<10%; $n = 55$). For field surveys, we randomly selected 18 plots characterized as most suitable, five characterized as moderately suitable, three characterized as less suitable, and one characterized as least suitable, for a total of 27 survey plots. We increased the total to 31 by adding four further plots after colleagues and reporters to eBird observed pairs likely nesting in them. We surveyed each plot one to three times over the course of the breeding season from April through mid-September (Table 1).

Following our 2019 field surveys, we transferred our GIS maps to the program QGIS (version 3.10 a Coruña, <https://qgis.org>) and made some changes to the sampled area. We identified additional plots as unsuitable or unavailable for sampling (e.g., too mountainous or inaccessible) and eliminated them from the sampled area, leaving 123 plots (3075 km²) in the area sampled during the 2020 survey. We added a covariate for urban development because in 2018 and 2019 Swainson's Hawks were more frequently observed in relatively undeveloped areas, defined by the NLCD16 as less than 20% covered with nonpermeable surfaces, and all Swainson's Hawks confirmed nesting were in undeveloped areas or areas developed at low intensity (i.e., coverage of impermeable surface 20–49%). Using the NLCD16 data layer we estimated the percentage of developed area in each plot, then used the percentage of developed area in each plot as a habitat deficit for Swainson's Hawks. Subtracting the percentage of developed areas from the percentage of suitable areas for each plot gave an index of suitability ranging from 1.0 to -1.0. Dividing this range into four equal intervals gave us the following habitat categories. Highly suitable plots were those with an index greater than 0.5 ($n = 48$) and made up 39% of the total number of plots, moderately suitable plots ranged from 0.0 to 0.5 ($n = 23$), less suitable plots from -0.5 to 0.0 ($n = 20$), and least suitable plots less than -0.5 ($n = 32$) (Figure 1). We then randomly chose a total of 30 plots to survey without regard to whether they were

TABLE 1 Numbers of Plots Surveyed and Occupied and Swainson's Hawks Observed by Phase of the Nesting Cycle in the Central Coast Range, California, 2019 and 2020

Year and phase	Plots surveyed (n)	Plots occupied (n)	Percent occupied	Hawks counted (n)
2019				
Arrival/courtship	30	7	23	12
Incubation/brooding	31	5	16	9
Fledging	22	3	14	6
Season ^a	31	9	29	15
2020				
Arrival/courtship	4	2	50	2
Incubation/brooding	22	8	36	8
Fledging	21	8	38	20
Season ^a	23	8	35	22

^aCounts of the plots surveyed or occupied at least once during the season. Season totals reflect adjustments for duplicate counting.

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

surveyed in 2019. This resulted in 21 plots from the highly suitable category, and three plots each from the moderately, less, and least suitable categories.

Using the well-documented phenology of Swainson's Hawk's nesting cycle (Bechard et al. 2010), we divided our survey schedule into three phases: phase 1 (arrival/courtship) from 15 March to 30 April, phase 2 (incubation/brooding) from 1 May to 14 July, and phase 3 (fledging) from 15 July to 15 September. Our goal was to survey each selected plot three times during the breeding season, once during each phase of the cycle. In 2019, we were able to visit each selected plot at least twice. In 2020, because of the public-health restrictions imposed during the covid-19 outbreak, we focused our efforts on the selected highly suitable plots and visited those at least twice (Table 1).

In 2019, we drove all major roads looking for nests and individual Swainson's Hawks. We also did point-count surveys for a minimum of 30 minutes from vantage points that gave unobstructed views of large portions of the plot. The survey protocol changed in 2020. During each survey, observers located riparian corridors within the plot and observed for 30 minutes at 1-km intervals along roadsides or public trails at the edge of the riparian corridor. It was impossible to view the entirety of each plot or riparian corridor because of obstructions such as dense development, tree canopy, and inaccessible areas. We categorized each plot as 0 (unoccupied) or 1 (occupied by one or more individuals), recording the number of Swainson's Hawks and, when discernible, their sex, age (Crossley et al. 2013), and morph, following Palmer's (1988) classification. We plotted their location, flight pattern, direction, and behavior, specifying the hawks' locations by measuring the distance from the center of their activity to the observation point in Google maps. To minimize the risk of double counting, we assumed that hawks seen in a given plot on more than one date were the same individuals. We used the maximum number of hawks seen in a plot on any one date as the total count of individuals for that plot. If a nest was discovered, we added it to the nest-monitoring schedule and monitored it biweekly to determine its outcome.

After the completion of surveying in 2020, we analyzed habitat characteristics in the occupied plots within the surveyed area. We refined the habitat characteristics of each plot in the sampled area by generating a histogram of NLCD16 land-cover types within each plot by using a raster layer zonal histogram tool in QGIS a Coruña. We then analyzed the mean percentages of grassland, cultivated crops, and development in each of the plots surveyed in 2020 and compared the landscape characteristics of occupied and unoccupied plots. We used a chi-squared test to evaluate the relationship among the three land-cover types in the occupied and unoccupied plots. We also counted the number of times Swainson's Hawks were observed circling directly over each habitat type (grassland, farmland, or urban).

Nest Monitoring and Habitat

We monitored all active nests from April through August every 14 days until fledging, nest abandonment, or failure was confirmed. If new active nests were discovered during the season, we added those to our monitoring schedule. During visits, we recorded the plumage characteristics (morph) of the adult hawks (Palmer 1988) and the nest's stage, noting the presence of adults, incubation or brooding behavior, prey deliveries, the appearance of

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

young in the nest, and fledging. To avoid disturbance of the nesting pair, our monitoring sessions lasted only long enough to confirm that the nest was still active and to count adults and young. We considered a nesting attempt to be successful if at least one young fledged. Fledging was defined as branching from the nest, not the first flight. After monitoring was completed in 2020, we analyzed the area within a 2.5-km radius around each nest and calculated the percentage of grassland, farmland, and urban development within each circle. We did a *t* test to characterize the relationship between the different habitat types surrounding the nests.

RESULTS

Landscape and Occupancy Survey

Table 1 summarizes the number of occupied plots per phase in each year. In 2020, we observed an increase in the percentage of occupied plots in all three phases of the survey and a seasonal increase of 21%. We estimated the number of individual Swainson's Hawks seen over the season in 2019 and 2020 as 15 (0.39/100 km²) and 22 (0.72/100 km²), respectively. The majority of the hawks observed during the survey were foraging (i.e., circling, kiting, or diving) over agriculture in southern Santa Clara County and northern San Benito County, but other behaviors were also observed, including soaring, undulating, pursuit of an intruder, and courtship.

In 2020 Swainson's Hawks showed a strong preference for farmland over grassland or urban development, as evidenced by a chi-squared test comparing land cover in occupied and unoccupied plots ($n = 23$, $\chi^2 = 54.88$, $p < 0.001$). Of the 23 plots that were surveyed in 2020, the 8 occupied plots had a larger mean percentage of farmland (59%) than of grassland (27%) or urban development (13%), while the 15 unoccupied plots had a larger mean percentage of grassland (69%) than of farmland (9%) or urban areas (8%). Also, we observed more instances of Swainson's Hawks using fields that were fallow, tilled, or in a phase of crop growth ($n = 22$) than instances of grassland use ($n = 10$).

Nest Monitoring and Habitat

Figure 1 shows the locations and names of all sites of nesting in 2020, which were clustered in southern Santa Clara and northern San Benito counties. Table 2 presents the data on each nest's success.

The Coyote Valley pair, both of the intermediate morph, were observed soaring together and rebuilding a nest in a Western Sycamore in the courtyard of two wings of a K-8 public school on 14 April 2019. The surrounding habitat includes lawns and playing fields, impermeable surfaces, various cultivated trees such as Deodar Cedar (*Cedrus deodara*) and pines (*Pinus* spp.), fallow fields of non-native forbs and shrubs, bare crop fields, and a riparian corridor lined with willows, oaks, cottonwoods, California Black Walnut (*Juglans californica*), and English Black Walnut (*J. regia*). The nest was situated ~10 m above the ground and ~2 m below the canopy. The female sat briefly on the nest and made soaring flights over the nest tree and adjacent bare farm fields on 14 April. On 21 April both individuals were at the nest site, soaring above

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

TABLE 2 Outcomes of Swainson's Hawk Nests in Southern Santa Clara and Northern San Benito Counties

Site	County	2019		2020	
		Nests attempted	Fledglings	Nests attempted	Fledglings
Coyote Valley	Santa Clara	1	0	2	2
San Felipe & 152	Santa Clara	1	1	1	2
Santa Ana Valley	San Benito	1	0	1	1
Ortega Creek	San Benito	?	?	1	?
San Felipe & 156	San Benito	?	?	1	1
Total		3	1	6	6
Success rate ^a			0.33		1.0

^aFledglings per nest attempted.

the nest tree and foraging over a bare field to the west. Only one Swainson's Hawk, the presumed male, was seen during each subsequent visit from 4 May to 30 July 2019, and the nest appeared to be abandoned. Since the presumed female was never observed incubating and subsequently disappeared, we considered this nesting attempt to have failed.

The San Felipe Road nest was the only successful nest in 2019. Both adults, an intermediate-morph female and a light-to-intermediate-morph male, were seen on 2 April 2019, soaring together and building a nest in a Valley Oak adjacent to a busy road and a hilly area of rangeland to the north. The nest was located ~10 m above the ground in one of the branches of the canopy. The habitat around the nest consists of pasture on the hillsides and vineyard and orchards in the flatter areas to the south. There are several farmsteads and homes nearby as well as a small vegetable market. Dominant trees are Valley Oak, eucalyptus (*Eucalyptus* sp.), and pine along with ornamental trees around the houses. The riparian area of Pacheco Creek is ~1 km to the south. On 19 July, the female Swainson's Hawk was perched at the edge of the nest, which contained two young. A fledgling was observed on 3 August, and the second young was not observed on that date. We considered this a successful nest that fledged one young.

The Santa Ana Valley Road pair was discovered on 29 April 2019. A light-to-intermediate-morph bird, presumably the female, was sitting in a nest in a grove of several eucalyptus trees, and a dark-morph individual, the presumed male, was perched below the nest. The nest was situated ~15 m from the ground and ~2 m below the top of the tree. The immediate surroundings of the eucalyptus grove consist of rolling hills of grassland made up of native and non-native grasses, forbs, and scattered fields in which wheat, barley, or hay grow to varying heights through the season. Land use includes a couple of isolated farmsteads with shelterbelts of pine trees surrounded by large tracts of pastureland. The male was seen again on 13 June, but only remnants of the nest remained. No Swainson's Hawks were present on the last day of observations (27 July), and we presumed the nest was abandoned.

Early in the 2020 breeding season we returned to the locations of the nests that had been active in 2019 (Figure 1). We observed pairs at the Coyote Valley and San Felipe Road nest sites during 10 visits between 7 April and 31 July

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

2020. We visited the Santa Ana Valley Road site and found evidence of nesting in late June and revisited that nest on six subsequent occasions. A fourth nest near Ortega Creek in San Benito County was located by S. Rottenborn (pers. comm.) and was monitored by us on four occasions. A probable pair was observed on 6 May 2020 near Highway 156 and San Felipe Road in San Benito County, and we monitored this site for a total of five times.

We assumed all the individual hawks associated with active sites from the previous year were the same individuals returning in 2020, except for the female of the Coyote Valley pair, as its female was differently plumaged (light to intermediate morph) and over the entire season the original female was never observed. In 2020, the Coyote Valley pair fledged two young (Figure 2), which were observed branching from the nest on 11 July. Two young fledged from the San Felipe Road nest as well and were seen flying on 17 July. The Santa Ana Valley Road pair successfully fledged one young, seen flying on 26 June.

The Ortega Creek pair, both of a dark to intermediate morph, was observed by S. Rottenborn (<https://ebird.org/checklist/S66681390>) building a nest and copulating on 4 April 2020. The nest tree is east of San Felipe Lake in a wetland that is fed by Ortega Creek, Pacheco Creek, and the Tequisquita Slough. The lake and wetland are adjacent to barren fields, cultivated cropland, and pastures interspersed with small groups of willows and shrubs. On 12 June we observed one dark-to-intermediate individual perched in a willow at the location reported by Rottenborn. It was perched for 25 minutes, then flew to the southeast and began soaring above the wetland with Turkey Vultures (*Cathartes aura*). The nest was not visible from our observation point. We visited the site twice more on 19 June and 17 July but observed no adult or young Swainson's Hawks at or near the nest so could not determine its success.

An additional pair of Swainson's Hawks, one dark and one intermediate, was seen consistently near the intersection of Highway 156 and San Felipe Road in Hollister, San Benito County. The pair was seen soaring together and exchanging prey on 29 May. This area is made up of grass and pastureland,



FIGURE 2. Young Swainson's Hawks in nest in Coyote Valley, Santa Clara Co., California, 3 July 2020.

Photo by Larry Baer

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

a mix of cultivated crops (oats, winter wheat, alfalfa, and other hay), small almond orchards, and a few farmsteads. A small creek or irrigation canal borders some of the fields and is lined with shrubs, scattered Valley Oaks, and ornamental trees. A nest was not located, but on 26 July, the pair was seen flying and interacting with a juvenile intermediate-morph Swainson's Hawk, which we consider evidence of a successful nesting with one young fledged.

Within the 2.5-km radius around each nest, the average percentage of grassland (50%) was somewhat higher than that of farmland (41%), while the average percentage of development (i.e., <20% of surface permeable) was low (6%). A two-sample *t* test revealed no statistically significant difference between the percentage of grassland and the percentage of farmland in the circle around each nest ($t = 0.6$, $p = 0.3$).

DISCUSSION

This survey of Swainson's Hawks in three valleys of the central Coast Range of California was the first systematic survey of nesting success and patterns of habitat use in that region. Habitat stratification proved to be a fruitful approach for predicting the presence of Swainson's Hawks, and we confirmed a minimum number of breeding pairs and individuals in the study area. We observed an increase in the number of breeding Swainson's Hawks and occupied plots in the survey area from 2019 to 2020, but changes in the survey protocol in 2020 could have enhanced our ability to detect the birds. Further monitoring will be necessary for an estimate of the population size in the study area and elsewhere in the central Coast Range. Continued surveying is also needed to identify population trends in this region and possible causes for this seeming expansion outside of the hawk's typical range in California.

In their usage of habitat, Swainson's Hawks were more strongly associated with farmland than with grassland, information relevant to wildlife-management agencies and land conservancies that work with farmers and urban planners. Grassland and farmland were also important for nesting Swainson's Hawks. In this region both types of habitat, therefore, need to be protected from further urban, industrial, and residential development.

These preliminary data on the Swainson's Hawks in a portion of the central Coast Range do not shed light on the reasons for the expansion into peripheral areas of the Central Valley. Possible reasons include the hawk population in the Central Valley reaching carrying capacity, detrimental land-use changes, or both. Since 1979, the California Department of Fish and Wildlife has conducted three statewide surveys of this species (CDFW 2016), the most recent in 2005 and 2006 (Battistone et al. 2019). Together they indicate that the Central Valley population has grown, but differences in the surveys' methods and intensity make establishing a trend difficult (CDFW 2016). Data from the North American Breeding Bird Survey, 1967–2019, tend to verify an upward trend in Swainson's Hawk abundance statewide (<http://www.pwrc.usgs.gov/BBS/>), though the numbers recorded on this survey are so low the trend is poorly supported statistically. Further study is necessary if the Central Valley's carrying capacity is to be estimated.

In California Swainson's Hawks appear to be diverging in behavior from populations elsewhere (Airola et al. 2019, Battistone et al. 2019). These be-

SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

havioral changes coincided with significant land-use change in the primary breeding range, which could have driven the species' adaptation to agriculture and human proximity.

The California Environmental Quality Act (Public Resources Code, section 21000 *et seq.*), requires mitigation at a ratio of 1:1 for destruction of suitable habitat of threatened or endangered species, overriding circumstances notwithstanding. In practice, this requirement could increase the patchiness of suitable habitat in the Central Valley, where pressure for development continues. The Multi-Resolution Land Characteristics Consortium now provides a tool that calculates changes in land cover over time by county, which could reveal how suitable habitat in the Central Valley has been modified. Swainson's Hawks have been known to abandon territories and nests because of disturbance (Estep 1989). Despite the availability of patches set aside through mitigation, these displaced hawks could choose to establish new nesting territories farther afield, establishing small, vulnerable subpopulations in peripheral areas. Also, a greater understanding of the behavior, migration patterns, pair bonding, and nest-site selection of first- and second-year Swainson's Hawks would help clarify the reasons for the recent changes in the species' distribution.

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SWAINSON'S HAWKS BREEDING IN CALIFORNIA'S COAST RANGE

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