FORAGING AND NESTING HABITAT ASSOCIATION OF SWAINSON'S HAWK (*BUTEO SWAINSONI*) ALONG LOWER CACHE CREEK, YOLO COUNTY, CALIFORNIA

A Thesis

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by

Kevin Paul Cahill

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Kevin Paul Cahill

Approved by:

__________________________________, Committee Chair
William E. Avery, Ph.D.

__________________________________, Second Reader
Ronald M. Coleman, Ph.D.

__________________________________, Third Reader
Robert G. Titus, Ph.D.

____
Date

Student: Kevin Paul Cahill

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____________________________, Graduate Coordinator ____________________
Jamie M. Kneitel, Ph.D. Date

Department of Biological Sciences

Abstract

of

FORAGING AND NESTING HABITAT ASSOCIATION OF SWAINSON'S HAWK ALONG LOWER CACHE CREEK, YOLO COUNTY, CALIFORNIA

by

Kevin Paul Cahill

Swainson's hawk (*Buteo swainsoni*) has experienced population declines throughout much of its range and the most drastic decline has occurred in California. Once abundant throughout California, the range of the Swainson's hawk has been reduced. Two disjunct populations remain in the state. A small population occurs in the Modoc Plateau and a larger population is concentrated in the four county region of Sacramento, San Joaquin, Yolo, and Solano Counties. This is considered the core breeding area for the species in California. Swainson's hawk is listed as a State Threatened Species by the California Department of Fish and Wildlife and a bird of conservation concern by the United States Fish and Wildlife Service. Loss of suitable foraging and nesting habitat are major contributors to the hawk's protected status in the state. Understanding how Swainson's hawk utilizes the landscape for foraging and nesting is a critical aspect in the effort to recover the species.

The purpose of this study was to determine foraging habitat preference in a 194 square kilometer study area in the Lower Cache Creek Resources Management Area in central Yolo County and to identify predictive factors of nest presence. A secondary objective was to identify and measure nest tree characteristics.

From March 2010 through August 2010 strip-transect road surveys were conducted to observe and document Swainson's hawk foraging behavior and the land use with which it was

associated. Six routes were driven twice a week. All observed raptors were recorded as well as their associated behavior, and associated land use. Only the Swainson's hawk foraging observations were analyzed.

An attempt to census the nesting population was done by intensively searching the study area by vehicle and on foot. Land use within 500 m and 1600 m buffers were analyzed around nest trees with ArcView GIS 10.1 and then compared to nest buffers established around random trees to determine if predictors of nest presence existed.

Swainson's hawks preferred to forage in hayfields, alfalfa, and tomato-row crops in greater proportion than their availability. They used almond orchards, walnut orchards, grain crops, residential, and "other" cover types significantly less than expected based on their availability. Nest trees were significantly closer to paved roads, human dwelling and red-tailed hawk nests than random trees. Diameter at breast height (DBH), crown width, and height were all significantly greater that random trees.

Several habitat categories predicted nesting presence including agricultural-industry, annual grass, natural habitats, eucalyptus-conifer, idle fields, and hay. Negative predictors included; increased distance from roads, human dwellings, and red-tailed hawk nests, as well as row crops, agricultural-urban, aggregate mining, irrigated field crops, corn, and grain crops.

The study area has a good proportion of high quality foraging habitat and preferred crops for Swainson's hawk. While land use influences where Swainson's hawks nest, it may not be the only determinant of nest presence. Nesting may also be limited by availability of large trees and competition with other species. Further investigation should be conducted to determine additional factors that influence Swainson's hawk nest presence.

________________________, Committee Chair
William E. Avery, Ph.D.

____
Date

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INTRODUCTION

Swainson's hawk (*Buteo swainsoni*) in California experienced a sharp population decline early in the twentieth century and a drastic reduction in range (Bradbury 2009). A 1979 statewide census suggested a 91 percent decline in population from estimated historical levels of 4,284 - 17,136 pairs to approximately 375 pairs (Bloom 1983). This reduction resulted in the hawk's listing as a State Threatened species in 1983 by the California Fish and Game Commission (Bloom 1980, Bradbury 2009). A more recent inventory conducted from 2005 to 2006 adjusted this estimate to between 1,770 and 2,393 pairs, still well below historical levels (Anderson et al. 2007). Swainson's hawk remains a State Threatened species and is also considered a Bird of Conservation Concern in California by the United States Fish and Wildlife Service (CDFG 2011, USFWS 2008). The decline of Swainson's hawk population is attributed to many factors including harassment, injury and death from collisions, pesticide use, and disease in the hawk's summer and winter ranges (Bradbury 2009). The greatest threats in California, however, are the loss of nesting and foraging habitat due to urbanization, conversion of natural habitats to agriculture, and other anthropogenic changes (Bloom 1980, Estep 1989, Estep 2008, Bradbury 2009). These impacts have reduced the range of Swainson's hawk which was once throughout most of California to two disjunct populations in the Great Basin and Central Valley, small breeding numbers in Mono and Inyo Counties, and a handful of breeding pairs in Antelope Valley (Woodbridge et al. 1995a, Peters and Peters 2005, Bradbury 2009).

Outside of California, Swainson's hawks breeds throughout most of the mid-western United States and from Central Canada to Northern Mexico. It was historically one of the most abundant raptor species in western North America but has experienced a decline since European settlement increased in the 20th century (England et al. 1997, Hull et al. 2008). More recently, declines have been noted in southeastern Oregon and Nevada as well as in parts of Canada, however, California's decline has been the most drastic (Bloom 1980, England et al. 1997).

Swainson's hawk winters in South America, primarily in Argentina. Birds from Canada can travel over 10,000 kilometers (km), making one of the longest migrations of any raptor species (England et al. 1997). In its winter range, Swainson's hawk is associated with permanent pastureland, fallow, natural, and alfalfa fields and its primary food source consists of insects, particularly dragonflies (Jaramillo 1993, Canavelli et al. 2003). Swainson's hawk roosts communally in Argentina in groups of 35 to 7,000 individuals mainly in eucalyptus groves (Woodbridge et al. 1995b, Canavelli et al. 2003). Groups of foraging Swainson's hawk in La Pampa, Argentina are made up mostly of adults and can range from 50 to 1,000 but reach upwards of 4,000 individuals. Juveniles dominate foraging flocks in Buenos Aires Provence which can reach 5,000 to 10,000 individuals (Woodbridge et al. 1995b, Jaramillo 1993, England et al. 1997). The biggest threat to these birds in Argentina is the use of organophosphate pesticides to control insect populations which has been responsible for massive die-off events of up to 6,000 birds, however, conversion of agricultural practices from range-based livestock production to intensive cultivation is also an emerging threat (Woodbridge et al. 1995b, Goldstein et al. 1999, Canavelli et al. 2003, Kochert et al. 2011).

California Swainson's hawks are mainly associated with large, open agricultural and grassland habitats in proximity to riparian zones, but occur in desert and shrubsteppe habitats as well (Woodbridge 1998, Estep 2008). Historical declines are attributed to conversion of natural habitats such as seasonal wetlands and grasslands to agriculture and settlements as well as the loss of suitable nest trees (Schlorff and Estep 1993, Bradbury 2009). California wetlands have declined from an estimated 5 million acres (2 million hectares) in the late 1700's, 4 million of which were in the Central Valley, to less than 500,000 acres (202,343 hectares) today. Fewer than 205,000 acres (82,961 hectares) of managed wetland exists in the Central Valley. Nearly one million acres (404,686 hectares) of alfalfa are grown in California, mostly in the Central Valley, and have taken the place of historical wetland habitats (Hartman and Kyle 2010). More than 90 percent of the riparian areas in the Central Valley have been destroyed over the last 200 years due to agricultural and urban conversion, yet 95 percent of the state's Swainson's hawks still breed in the Central Valley (Katibah 1984, Schlorff and Estep 1993, Anderson et al. 2007). The lack of suitable nesting and foraging habitat has limited their distribution and abundance and concentrated the largest number of breeding pairs and the highest breeding densities in Yolo, Sacramento, Solano, and San Joaquin Counties where narrow riparian corridors along rivers and streams, remnant oak groves and trees, and roadside trees provide nesting habitat (Bloom 1980, Woodbridge et al. 1995a, Anderson et al. 2007, Estep 2008).

While conversion of natural habitat to agriculture has had a large impact on Swainson's hawk numbers, certain crops such irrigated hay, dryland grain, such as wheat and barley, and many row crops have become key foraging habitat for the Central Valley population which is now highly dependent on agricultural practices (Babcock 1995, Swolgaard et al. 2008, Bradbury 2009). Several Central Valley studies have found that irrigated hay, particularly alfalfa, is preferred disproportionately to all other crop types (Estep 1989, Babcock 1995, Smallwood 1995, Swolgaard et al. 2008). Eighty-five percent of Central Valley Swainson's hawks still nest within riparian forests or in remnant riparian trees, however, high quality agricultural lands are incorporated into the majority of home ranges and are determinants of habitat suitability for the birds (Bloom 1980, Woodbridge et al. 1995a).

Alfalfa may have the highest individual value as a foraging cover type, however, Estep (2008) found that an agricultural matrix of irrigated cropland and alfalfa was considered the highest value foraging landscape. Many agricultural cover types such as vineyards, corn, and safflower, may not be conducive to foraging, due to crop height, which impedes vision, or the inability to support food sources such as microtine rodents, which make up a large portion of the Swainson's hawk diet during the breeding season (Woodbridge et al. 1995a). However, when planted proportionately with a variety of other annually rotated high value crops, foraging value as a whole may increase due to a more diverse agricultural system (Bloom 1980, Estep 1989, Briggs 2007, Estep 2009). Determining the proportionality of Swainson's hawk land cover use and the relative value of these covers is a critical element to maintaining a viable and productive agricultural landscape which will also sustain existing Swainson's hawk populations into the future (Estep 2008).

Yolo County supports a large population of Swainson's hawks and is included in the core breeding area for the species in the Central Valley (Bloom 1980, Anderson et al. 2007). The most recent California state inventory of Swainson's hawk resulted in a combined estimate of 346 pairs for Yolo County between 2005 and 2006 (Anderson et al. 2007). Estep (2008) identified a total of 290 active Swainson's hawk nesting territories in Yolo County with a nesting territory density of 0.98 pairs per square km, among the highest in the species' range. Approximately half of the nesting sites were associated with riparian woodland habitat (Estep 2008). Yolo County has experienced among the largest amount of urban growth relative to the rest of the Central Valley yet with its narrow riparian strips and diverse crop matrix, it still provides season-long availability of high value foraging in proximity to preferred nesting habitat (Estep 2009).

Cache Creek runs through the heart of Yolo County. Its history is full of extreme anthropogenic change. Conversion of native lands to Mexican ranchos in the 1840's led to some of the state's first water diversions in the 1850's and 1860's for agricultural irrigation. More recently intensive in-channel gravel mining carved out the creeks precious aggregate from the 1950's through the mid-1990's until in-channel mining was banned (CCRMP 2002). In its recent history, this area has also experienced urban expansion in areas such as Esparto, Madison, and the Watts-Woodland Airport along the highway 16 corridor. Still, a large portion of the land continues to be used for mixed agricultural purposes and remnant riparian corridors remain.

Yolo County has taken measures to improve riparian habitat along Lower Cache Creek and in 1994 adopted a framework of goals which in 2002 became the Cache Creek Resources Management Plan. Due in large part to aggregate mining operations, long stretches of riparian habitat have been removed and noticeable degradation and fragmentation has occurred along Lower Cache Creek (CCRMP 2002). Major goals of the Cache Creek Resources Management Plan include restoring a diverse riparian ecosystem within the Cache Creek Channel that is self-sustaining and capable of supporting wildlife, as well as monitoring and collecting data that can be used to measure the success of re-vegetation efforts. Among these efforts is the establishment of a continuous riparian corridor as well as a series of wildlife preserves, some of which have already been created, to provide core areas for wildlife with an emphasis on high quality existing habitat (CCRMP 2002).

Conservation lands alone will not successfully sustain the existing Swainson's hawk population (Estep 2009). Determining the value of individual cover types is important to the management of Swainson's hawks in agricultural areas and can be used in the development of management strategies designed to enhance foraging value while retaining agricultural productivity not only in Yolo County but throughout the range of the species in California (Estep 2008, Estep 2009).

In 2002, Yolo County and the cities of Davis, West Sacramento, Woodland, and Winters entered into an agreement for the purposes of implementing the "Agreement Regarding Mitigation Impacts to Swainson's Hawk Foraging Habitat in Yolo County" and assisting in the planning, preparation and subsequent administration and implementation of the Yolo County Habitat Conservation and Natural Community Conservation Plan (YCHCP/NCCP). This agreement formed the joint powers agency known as the Yolo County Natural Community Conservation Plan Joint Powers Agency (Joint Powers 2002). As part of the planning process, a report was prepared for the Joint Powers Agency by an independent science advisory committee recommending a series of goals and objectives, based on the best available science, prior to drafting the YCHCP/NCCP (Spencer et al. 2006).

Swainson's hawk and its associated habitat, including valley oak stands and woodland and Yolo County's rich agricultural matrix, were emphasized throughout as topics of high priority. Recommendations included intensive nest monitoring to emphasize population size and nest success as well as increased survey effort in areas that had received little historical survey effort to determine the extent of Swainson's hawk distribution and suitable habitat. A major limiting factor identified by the committee was availability of suitable nest trees within suitable foraging areas. They suggested that investigating agricultural practices in the vicinity of nest territories could help to determine correlations between the presence and absence of nesting Swainson's hawk. Additionally, the committee stressed the ecological importance of the extensive agricultural mosaic and the need to maximize wildlife friendly mosaics and practices. They recommended retaining or increasing high-quality Swainson's hawk foraging habitat especially alfalfa and certain row crops within 1 mile (1.6 km) of existing or potential nest trees (Spencer et al. 2006).

Objectives and Hypothesis

The primary objective of this study is to determine how Swainson's hawks currently utilize Lower Cache Creek and the surrounding area encompassed in the Cache Creek Resources Management Plan. This information will be an important tool for managers attempting to balance guidelines for Swainson's hawk conservation while still retaining a viable productive agricultural landscape in the Management Plan study area as well as throughout the Central Valley.

More specifically my objectives were to 1) determine which land-use types are available to Swainson's hawks during the survey period and if certain crops are favored for foraging relative to the proportion of their occurrence, 2) attempt to census the nesting population of Swainson's hawk, document nest trees, and determine land use in proximity of active nests, 3) investigate if certain habitat features or land uses were important predictors for nest presence or absence, 4) identify nest trees and compare them to randomly available trees to determine if certain features, specifically diameter at breast height (DBH), average crown diameter, and height were significant factors in nest tree selection.

- I hypothesize that Swainson's hawks will prefer to forage in certain land-use types, particularly alfalfa and hay crops, and avoid others disproportionately to their availability in the study area.
- I hypothesize that nest sites will be distinctive from random sites and similar to other Swainson's hawk nest sites in the study area.
- I hypothesize that nest tree morphometrics will be distinctive from random trees.

METHODS

Study Area

The study area, in Yolo County, California, west of the city of Woodland, is roughly based on the Cache Creek Area Resources Management Plan Boundary as defined in the Cache Creek Resources Management Plan (2002) and its area is roughly 194 square km (Figures 1-2). The highly anthropogenic landscape is primarily agricultural but includes open pit gravel mining, natural riparian, oak woodland, and grassland habitats, and the towns of Capay, Esparto, Madison, a portion of Woodland, the suburban golf course community of Wild Wings as well as several agricultural-urban communities expanding from highway 16 near Woodland and Esparto.

Interstate 5, at County Road 17, and County Road 98 form the eastern border of the study area and the southern border parallels Gibson Road, County Road 24, and County Road 23 to the junction of County Road 23 and County Road 22 in the west at a distance of 1 km south. The western border follows, one km west, County Road 22 and County Road 85B until extending further west to parallel State Highway 16 to County Road 82 in the Capay Valley. West of the town of Capay the border is defined by the ridge crest south of highway 16. The western border in Capay Valley is one km west of County Road 82 and the northern border is defined by Cache Creek from County Road 82 to one km west of County Highway E4. At County Highway E4 the Western border goes north to County Road 16A. The border in the north is formed by County Road 16A and parallels County Road 17 1 km north.

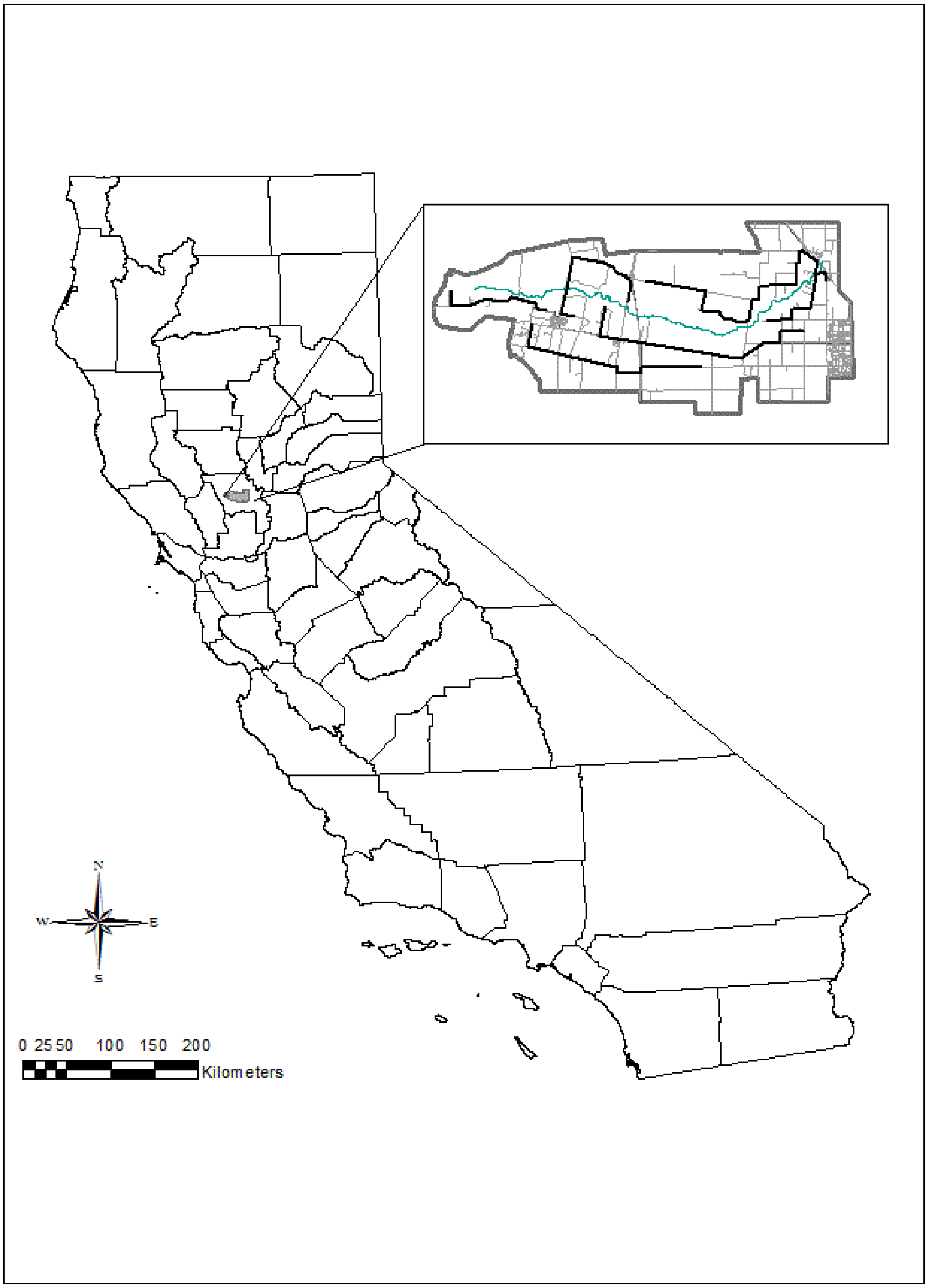

Figure 1. Lower Cache Creek study area (inset) in Yolo County, California, U.S.A. In the inset are the six routes (black lines) that were surveyed for Swainson's hawk and Cache Creek (blue line).

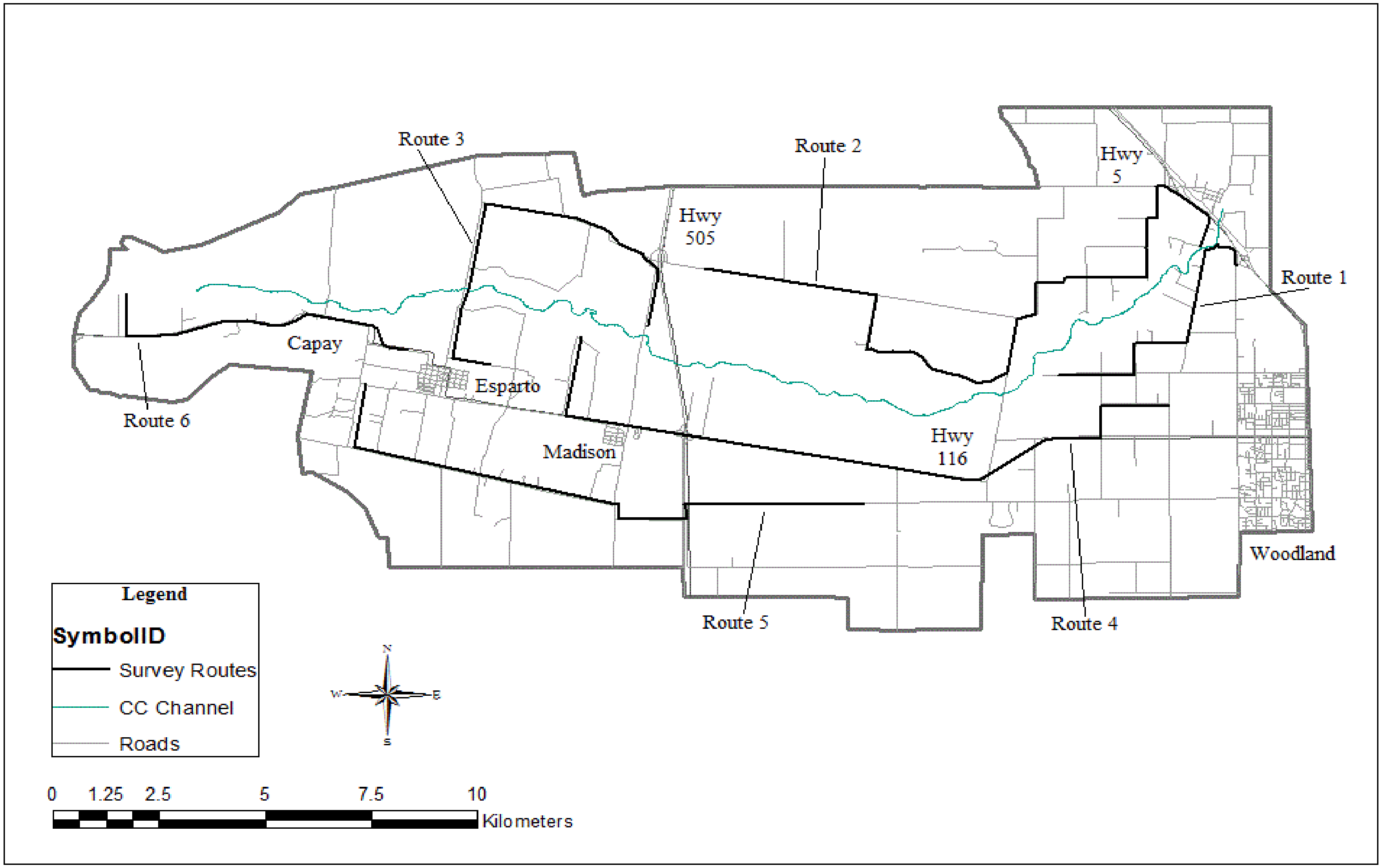

Figure 2. Detailed map of the Lower Cache Creek study area and survey routes in Yolo County, California

Road Surveys

Swainson's hawk foraging and habitat association data were collected by strip transect road survey techniques (Craighead and Craighead 1969, Hardey et al. 2009). Road surveys were initiated 23 March 2010 and continued through 17 August 2010. Six survey routes were planned to attempt uniform coverage of the study area. Systematic surveys were conducted twice a week by the same observer between 0800 h and 1630 h. A total of 138 surveys were conducted on 23 days and 110.58 hours were spent conducting surveys. A total of 1,923 km were driven.

Each survey day began with the second route traveled during the previous day and subsequent surveys were completed in numerical order to insure that each route was driven at different times during the day therefore avoiding any temporal bias. Initial direction was determined by a flip of a coin and surveys were then completed in either descending or ascending numerical order depending on the direction so that each route was also driven in multiple directions. All raptor species detected within an 800 meter (m) transect were recorded (400 m on either side of the road). When a raptor was spotted, the car was stopped long enough to identify and record on survey sheets raptor species, activity, approximate distance from the road, odometer reading, time, bearing, habitat, land use, approximate height, and pertinent notes. Raptor activities were categorized as foraging, perching on the ground, perching on objects, flying, agonistic behavior, breeding behavior, and present at nest. Only foraging behavior was analyzed for the purposes of this study. Swainson's hawk foraging was defined as searching from a low soaring flight or kiting 30 to 90 m above the ground, stooping for prey, following farm equipment actively working a field, in-flight foraging on insects, or when birds were observed on the ground looking for prey (Estep 1989).

Nest Searches

Nest searches were conducted to determine the location of all Swainson's hawk nests for comparison to random trees for habitat selection analysis (Litvaitis et al. 1996). Nest searches and monitoring were conducted opportunistically during road surveys and intensive nest searches were conducted on 49 additional days by vehicle and foot (Estep 2008). During the course of intensive nest searches an attempt was made to cover 100 percent of the study area and virtually all trees were searched for nests with binoculars. Most of the area is accessible to vehicle by road, however, areas that are not, were covered by foot. The entire length of the creek, excluding a small portion west of the Capay Bridge and below Capay Dam was covered on foot or by access road. All accessible, non-private roads were driven and permission was obtained before accessing private property. Searches began 18 March 2010before the "leafing out" of trees when previous nests were still visible and when preliminary nesting behavior could be readily observed. All large stick nests were documented on a corresponding aerial map of the study area. Active nests were revisited periodically during the study period to determine if they were still active. Attributes including tree species, habitat, land use, and pertinent notes on occupancy, behavior, and number of birds at the nest were recorded in a field notebook and then transferred to a Microsoft Excel table corresponding with nest number.

Monitoring continued until 20 August 2010. Methodology developed by the Swainson's hawk Technical Advisory Committee (2002) was the basis for the timing of nest searches. No nest trees were climbed and nests were observed from a distance with Dakota elite 10 x 42 binoculars and a Nikon 15-45 x 20-60 spotting scope to avoid disturbing nesting birds.

Tree Morphometrics

Measurements were taken from nest trees in January and February, 2013 and random trees were measured in November and December, 2013 and January, 2014. I measured diameter at breast height (DBH), average crown diameter, tree height, recorded the species, and marked the tree's geographical positioning system (GPS) location. Additional measurements were taken from trees in which nests were still present (Appendix A). These included nest height, bearing, and the distance from the nest to the main trunk. Land owners were contacted before accessing private property. United States Department of Agriculture, Forest Service protocol for measuring big trees was followed (Powell 2005).

Trees were measured for DBH in centimeters (cm) with Forestry Suppliers, Inc. 10 m DBH tape. Breast height was considered 1.37 meters (m) from the ground. A Sunto Co. Type: PM-5/66 clinometer and Bushnell Scout 1000 Arc range finder were used to determine tree and nest height. Crown measurements were taken with a Keson model OTR-10M-165 meter tape.

Tree height was calculate by adding the A+ and B- angles, which were taken with the clinometer 66 feet (ft) (20.12 m) from the tree trunk, and then multiplying by a correction factor of 0.66.

$$[(A+) + (B-)] \cdot 0.66 = \text{Tree Height}$$

Nest height and nest distance from the trunk were determined by standing directly under the nest and aiming the range finder at the nest and then trunk respectively.

Nest tree location, taken from the base of the tree, was entered into a Garmin e-trex 20 Global Positioning System (GPS) unit using NAD 1983 UTM Zone 10N.

Average Crown Spread was taken by first measuring the crown at the widest diameter from tip to tip of the widest branches. Next the diameter at a 90° angle to the widest diameter was measured from tip to tip. To get an average, the total was divided by 2.

$$(\text{Widest diameter}) \cdot (90° \text{ diameter})/2 = \text{Average Crown Diameter}$$

Where trees shared a crown with neighboring trees, the perimeter of the nest tree was determined by the most discernable point where branches ended in a neighboring tree's canopy.

ArcGIS

Initially, a land-use map .kmz file of the study area was created using Google Earth (Google Earth 2013). The perimeter of this map extended beyond the CCARMP boundary in order to accommodate the buffer distances of the nests that were located near the edge of the boundary. Land-use polygons were created with the add polygon tool using 2010 Yolo County crop data, acquired from the California CalAgPermits Program, and 2010 Google Earth satellite imagery, accessed through the time slider tool (CalAgPermits 2013, Google Earth 2013). Each polygon was given two designations, a general California Wildlife Habitat Relationships (CWHR) designation, and a specific land-use category using the CalAgPermits data, Terrestrial Vegetation of California, Third Edition, survey notes, and Google Earth imagery (Barbour et al. 2007, CalAgPermits 2013, Google Earth 2013, Mayer and Laudenslayer Jr. 1988) (Appendix B). Due to small sample sizes for many of the specific land-use categories, several similar categories were combined for statistical analysis (Appendix B). Separate .kmz files were created in Google Earth using the Add Path tool for survey routes and the Add Placemark tool for Swainson's hawk nest locations, random tree locations, and red-tailed hawk nest locations (Google Earth 2013).

Random points were generated throughout the study area using ArcGIS 10.1 (ArcGIS) ArcToolbox Data Management Tools to determine the location of random trees. The random points were projected onto an aerial imagery base map in ArcMap and the Measure tool was used to locate the closest tree to each random point (ESRI 2012). Sixty random points were generated in case access to random trees was denied by land owners or DBH was below the minimum as determined by the smallest DBH recorded for a nest tree (Tietje et al. 1996). Once random trees were measured in the field, the .kmz file was created in Google Earth (Google Earth 2013).

Kmz files were then converted to ArcGIS shapefiles using ArcToolbox Conversion Tools (ESRI 2012). 400 m buffers were established around survey routes using the survey path as the center line so that the distance from one edge of the buffer to the other, when measured at a perpendicular angle to the survey path, would equal 800 m. Buffers were created with the buffer function in the Geoprocessing menu in ArcMap. 500 m and 1600 m buffers were established around Swainson's hawk nest trees and random trees. The 500 m radius was determined by the median, 56.3 hectares (ha), between 25.9 ha and 82.2 ha, the core area of intensive use determined by Babcock (1995) which is roughly 0.5 square km. From the center of the 0.5 square km to one corner is roughly 500 m. The 1600 m buffer reflects one of the goals, retaining high quality habitat within one mile (1.6 km) of Swainson's hawk nests, set forth by the Independent Science Advisors to Yolo County (Spencer et al. 2006).

Shapefiles were then created for each buffer using the Export Data function. After creating the new buffer shapefiles, land use data from the study area land-use shapefile needed to be projected onto each buffer. This was done using the intersect function in the Geoprocessing menu in ArcMap. Having intersected the buffers with the land use data, the occurrence of each land-use within the buffers could be analyzed (ESRI 2012, M. Roberts personal communication October 21, 2014).

Measurements of distance from nest trees and random trees to water, red-tailed hawk nests, paved roads, and human dwellings were done with the ArcMap Measure tool (ESRI 2012).

Data Analysis

Multinomial chi-square tests for goodness-of-fit followed by calculation of 95% and 90% confidence intervals were used to test for foraging habitat selection (Neu et al. 1974, Beyers et al. 1984, Haney and Solow 1992, Townend 2002). Averaged habitat proportions of the buffered strip transect survey routes were determined and considered available habitat for forage (Swolgaard et al. 2008). The area of each land use category was first determined for each route separately in order to account for the differences in transect lengths and to meet the assumption of equal availability and opportunity to forage (Neu et al. 1974, Byers et al. 1984, Swolgaard et al. 2008). The areas were calculated for two time intervals to represent shifts in use (e.g., idle to tomato) during the survey period. Time intervals were given equal values representing half of the survey period. Area measurements were then converted to proportions of the total area for the associated transect. The proportions for each time period were added and divided by two to produce a weighted average proportion. A combined weighted average for all transects was then determined for the chi-square analysis by multiplying the proportion of each land use category by its route length and then dividing the sum of the products by the sum of all route lengths (Table 1) (D. Wright personal communication, March 27, 2014).

Expected values for the chi-square test were then calculated by multiplying the average proportion of each habitat type by the total number of Swainson's hawk foraging observations (Byers et al. 1984, Haney and Solow 1992, Townend 2002). Chi-square values were produced from expected (Ei) and observed (Oi) values, where i represents

Table 1. Combined proportions of crop types per survey route.

Crop type		PropRt1	PropRt2	PropRt3	PropRt4	PropRt5	PropRt6	avg prop available (*Pio*)
Alfalfa (ALF)		0.036	0.057	0.074	0.301	0.222	0.034	0.141
Almond (ALM)		0.000	0.026	0.089	0.032	0.093	0.108	0.055
Corn (CRN)		0.039	0.000	0.094	0.034	0.037	0.007	0.032
Orchard-Vineyard (OR-VIN)		0.031	0.014	0.007	0.000	0.034	0.047	0.019
Grain Crop (GR)		0.095	0.228	0.025	0.101	0.101	0.117	0.123
Grazing-Annual Grass (GRZ-AGS)		0.033	0.222	0.051	0.116	0.097	0.359	0.147
Hay field (HAY)		0.000	0.036	0.005	0.028	0.023	0.012	0.021
Idle farmland (IDL)		0.292	0.140	0.177	0.136	0.157	0.110	0.159
Natural (NAT)		0.025	0.091	0.030	0.008	0.004	0.105	0.043
Residential (RES)		0.033	0.011	0.248	0.069	0.025	0.059	0.067
Sunflower-Safflower (SF-SAF)		0.056	0.024	0.059	0.018	0.030	0.001	0.029
Tomato-Row Crop (TOM-RC)		0.183	0.092	0.072	0.059	0.095	0.025	0.084
Walnut (WLN)		0.090	0.028	0.057	0.040	0.040	0.007	0.041
OTHER		0.087	0.029	0.014	0.058	0.042	0.009	0.039
Route length (km)	Total = 78.29 km	7.500	19.510	11.030	17.580	14.670	8.000	

the ith variable 1,2,3….n, using the formula: $\chi^2 = \sum(Oi\text{-}Ei)^2/Ei$. The sum of the chi-square values were then compared to the corresponding table value to determine if there was a significant difference from the null hypothesis that resources will be utilized relative to their abundance ($P < 0.001$, $\chi^2 = 103.512$, df = 13) (Byers et al. 1984, Townend 2002).

Ninety and ninety-five percent simultaneous confidence intervals representing the true proportion (P_i) of utilization for each category were calculated using Bonferroni's inequality approach for utilization (Neu et al. 1974, Byers et al. 1984). The formula is as follows:

$$\bar{p}_i - Z_{\alpha/2k}\sqrt{\bar{p}_i(1-\bar{p}_i)/n} \leq P_i \leq \bar{p}_i + Z_{\alpha/2k}\sqrt{\bar{p}_i(1-\bar{p}_i)/n}$$

where "$\bar{p}_i$" is the observed proportion of the i_{th} resource, "Z" is the upper standard normal table value corresponding to a probability tail area of α/2k, "k" represents the number of habitat categories (i), and "n" is the total number of birds observed. Two sets of intervals were calculated with $\alpha = 0.05$ and $\alpha = 0.10$ respectively to investigate if a higher α would cause categories that were close to the confidence interval boundaries to become significant. If the expected values, as calculated for the chi-square test, fell outside of the confidence interval, then a significant difference was concluded. Falling below the interval suggested that the resource was utilized more than expected and falling above the interval suggested that the resource was being utilized less than expected (Neu et al. 1974, Byers et al. 1984, Haney and Solow 1992).

Each habitat was then ranked in terms of foraging preference using Ivlev's electivity index (1961):

$$E_i = (U_i - A_i)/(U_i + A_i)$$

Where E_i is the index value, U_i is the proportion of use by foraging Swainson's hawks for each land use category, and A_i is the proportion of each land use category that is available for use by foraging Swainson's hawks. The index ranges from – 1 (completely avoided) to + 1 (maximum positive selection) with zero representing use that was proportional to the availability (Jenkins and Benn 1998, Phipps et al. 2013).

To analyze nest tree habitat association, I compared land use within Swainson's hawk nest tree buffers to land use within random nest tree buffers. I was interested in whether certain land use characteristics reliably predict hawk nest tree selection (Bloom et al. 2013, Wilson and Martin 2008, Compton et al. 2002). I analyzed data using logistic regression, with the presence or absence of nesting Swainson's hawk as my outcome variable (0 = absent, 1 = present). To limit the number of explanatory variables in the model, I used backward selection procedure (Hosmer et al. 2013). Backward selection works as follows. Initially, the model is fit to all explanatory variables to determine which variable is "least significant" (i.e., weakest predictor). That variable is then removed and the model is re-estimated. This continues in a stepwise manor until the only variables that are left are those that best explain the difference between the presence of Swainson's hawk and their absence when $p < 0.10$. Positive coefficients indicate that the variable is associated with the nest site while negative coefficients indicate a negative association (Wilson and Martin 2008). All logistic regression tests were conducted using Stata IC software (version 12.2) (StataCorp 2011).

Morphometric measurements of trees were compared using explanatory statistics only because the smaller sample size excluded them from the logistic regression model. Wilcoxon rank sum tests were used for DBH, height, and average canopy spread to determine if there was statistical difference between nest trees and random trees. Distance to red-tailed hawk nest, water, paved road, and human dwelling were also compared with the Wilcoxon rank sum test (Zar 1999, Triola 1986).

RESULTS

Foraging

The five most dominant crop categories in the area covered by road surveys were idle farmland (16%), grazing-annual grass (15%), alfalfa (14%), grain crops (12%), and tomato-row crops (8%). Other categories included walnut, almond, orchard-vineyard (fruit trees and grapes), corn, sunflower-safflower, hay, residential (urban and agricultural-urban), natural habitat (restoration sites, valley-foothill riparian, blue oak woodland, willow scrub), and other (agricultural-industry, aggregate mining, cemetery, industrial, rice). A total of 1040 raptors were observed on six survey routes from March through August in 2010. Of these, 464 were Swainson's hawk (44.6% of total raptor observations) including 229 foraging observations (49.4% of Swainson's hawk observations). Alfalfa had the highest percentage of Swainson's hawk observations (23.6%) followed by tomato-row crop (15.7%), idle farmland (14.4%), and grazing-annual grass (10.9%). Swainson's hawks were often observed foraging in large groups in flooded, and recently cut alfalfa fields, which included red-tailed hawk, great blue heron (*Ardea herodias*), great egret (*Adrea alba*), black-crowned night-heron (*Nycticorax nycticorax*), American crow (*Corvus brachyrhynchos*), common raven (*Corvus corax*), and turkey vultures (*Cathartes aura*). Swainson's hawks were also frequently observed foraging in groups in freshly disked fields and harvested tomato fields typically following tractors if they were still working the field.

Chi-square analysis showed that there was a significant difference between expected and observed foraging use by Swainson's hawk at the Crop level of land use categories (df = 13, $P < 0.001$, CV = 34.528, $\chi 2 = 103.512$) (Table 2). Therefore the null hypothesis that crop types are utilized for foraging in proportion with their availability was rejected. Hay contributed the most to the overall chi-square (35%), while alfalfa and tomato-row crop were second (14.8%) and third (14.4%) highest contributors. Ninety-five percent simultaneous confidence intervals showed that alfalfa, hay, and tomato-row crop were used for foraging significantly more than expected. Foraging use of grain crops was significantly less than expected ($\alpha = 0.05$, $k = 14$, $Z\alpha/2k = 2.92$) (Table 3). When the confidence interval was lowered to 90%, almond, walnut, residential, and other were also utilized significantly less than expected ($\alpha = 0.10$, $k = 14$, $Z\alpha/2k = 2.6$) (Table 4).

Nest Sites

I compared 39 buffered nest trees with 39 buffered random trees. The distance to red-tailed hawk was the only variable that was significant across all models with a negative coefficient indicating a negative effect on nest presence (Tables 5-8). The marginal effects of the CWHR classification indicate a roughly 2.5 percentage point decrease in the presence of nests for every 100 m increase in distance. The effect was slightly greater when models used specific crop classifications resulting in a 3 percent marginal effect for every 100 m increase. Additional model results are displayed in Tables 5-8.

The results of the 500 m buffer model with CWHR classification showed that agricultural-urban, aggregate mining, irrigated field crops, and distance to human dwelling all had negative influence on the presence of Swainson’s hawk, while

Table 2. Chi-square analysis of Swainson's hawk foraging use in averaged available habitats.

Crop type	avg prop available (*Pio*)	Expected usage (*nPio*)	Observed usage	(Obs-Exp)^2/Exp
Alfalfa (ALF)	0.141	32.203	54	14.753
Almond (ALM)	0.055	12.542	6	3.413
Corn (CRN)	0.032	7.370	5	0.762
Orchard-Vineyard (OR-VIN)	0.019	4.249	6	0.721
Grain Crop (GR)	0.123	28.199	11	10.490
Grazing-Annual Grass (GRZ-AGS)	0.147	33.572	25	2.189
Hay field (HAY)	0.021	4.898	18	35.049
Idle farmland (IDL)	0.159	36.479	33	0.332
Natural (NAT)	0.043	9.755	15	2.820
Residential (RES)	0.067	15.347	6	5.693
Sunflower-Safflower (SF-SAF)	0.029	6.697	10	1.629
Tomato-Row Crop (TOM-RC)	0.084	19.314	36	14.415
Walnut (WLN)	0.041	9.331	2	5.759
OTHER	0.039	9.044	2	5.486
Total:	1	229	229	103.512

df = 13, $\alpha = 0.001$, CV = 34.528, $\chi 2 = 103.512$

Table 3. Results of 95% confidence intervals for Swainson's hawk foraging habitat selection and Ivlelv's electivity index for foraging habitat.

Crop type	Expected *Pi*	*Pi*-Zα/2*k*√*Pi*(1-*Pi*)/*n*		95% CI Observed *Pi*		*Pi*+Zα/2*k*√*Pi* (1-*Pi*)/*n*	>/< than expected
Alfalfa (ALF)	0.141	0.156	≤	0.236	≤	0.325	More than expected
Almond (ALM)	0.055	0.004	≤	0.026	≤	0.072	
Corn (CRN)	0.032	0.002	≤	0.022	≤	0.065	
Orchard-Vineyard (OR-VIN)	0.019	0.004	≤	0.026	≤	0.072	
Grain Crop (GR)	0.123	0.015	≤	0.048	≤	0.103	Less than expected
Grazing-Annual Grass (GRZ-AGS)	0.147	0.055	≤	0.109	≤	0.180	
Hay field (HAY)	0.021	0.033	≤	0.079	≤	0.143	More than expected
Idle farmland (IDL)	0.159	0.081	≤	0.144	≤	0.222	
Natural (NAT)	0.043	0.025	≤	0.066	≤	0.126	
Residential (RES)	0.067	0.004	≤	0.026	≤	0.072	
Sunflower-Safflower (SF-SAF)	0.029	0.012	≤	0.044	≤	0.097	
Tomato-Row Crop (TOM-RC)	0.084	0.091	≤	0.157	≤	0.237	More than expected
Walnut (WLN)	0.041	0.000	≤	0.009	≤	0.043	
OTHER	0.039	0.000	≤	0.009	≤	0.043	

$k = 14$, $\alpha = 0.05$, $Z\alpha/2k = 2.92$

Table 3 continued. Results of 95% confidence intervals for Swainson's hawk foraging habitat selection and Ivlelv's electivity index for foraging habitat.

Crop type	Expected *Pi*	Observed *Pi*	(obs*Pi*-exp*Pi*)/(obs*Pi*+exp*Pi*)	Rank
Alfalfa (ALF)	0.141	0.236	0.253	3
Almond (ALM)	0.055	0.026	-0.353	10
Corn (CRN)	0.032	0.022	-0.192	9
Orchard-Vineyard (OR-VIN)	0.019	0.026	0.171	6
Grain Crop (GR)	0.123	0.048	-0.439	12
Grazing-Annual Grass (GRZ-AGS)	0.147	0.109	-0.146	8
Hay field (HAY)	0.021	0.079	0.572	1
Idle farmland (IDL)	0.159	0.144	-0.050	7
Natural (NAT)	0.043	0.066	0.212	4
Residential (RES)	0.067	0.026	-0.438	11
Sunflower-Safflower (SF-SAF)	0.029	0.044	0.198	5
Tomato-Row Crop (TOM-RC)	0.084	0.157	0.302	2
Walnut (WLN)	0.041	0.009	-0.647	14
OTHER	0.039	0.009	-0.638	13

Table 4. Results of 90% confidence intervals for Swainson's hawk foraging habitat selection.

Crop type	Expected *Pi*	$Pi - Z\alpha/2k\sqrt{Pi(1-Pi)/n}$		90% CI Observed *Pi*		$Pi + Z\alpha/2k\sqrt{Pi(1-Pi)/n}$	>/< than expected
Alfalfa (ALF)	0.141	0.163	≤	0.236	≤	0.309	More than expected
Almond (ALM)	0.055	0.000	≤	0.026	≤	0.054	Less than expected
Corn (CRN)	0.032	0.000	≤	0.022	≤	0.047	
Orchard-Vineyard (OR-VIN)	0.019	0.000	≤	0.026	≤	0.054	
Grain Crop (GR)	0.123	0.011	≤	0.048	≤	0.085	Less than expected
Grazing-Annual Grass (GRZ-AGS)	0.147	0.056	≤	0.109	≤	0.163	
Hay field (HAY)	0.021	0.032	≤	0.079	≤	0.125	More than expected
Idle farmland (IDL)	0.159	0.084	≤	0.144	≤	0.204	
Natural (NAT)	0.043	0.023	≤	0.066	≤	0.108	
Residential (RES)	0.067	0.000	≤	0.026	≤	0.054	Less than expected
Sunflower-Safflower (SF-SAF)	0.029	0.009	≤	0.044	≤	0.079	
Tomato-Row Crop (TOM-RC)	0.084	0.095	≤	0.157	≤	0.220	More than expected
Walnut (WLN)	0.041	0.000	≤	0.009	≤	0.025	Less than expected
OTHER	0.039	0.000	≤	0.009	≤	0.025	Less than expected

$k = 14$, $\alpha = 0.10$, $Z\alpha/2k = 2.6$

Table 5. Model results of the logistic regression comparing nest trees to random trees with a 500 meter buffer with the California Wildlife Habitat Relationships classification of variables (n=78).

Variable	Coefficient	95% Confidence Interval		p-value	Marginal effect	95% Confidence Interval		p-value
Agricultural-urban	-0.104	-0.178	-0.030	0.006	-0.017	-0.028	-0.006	0.002
Eucalyptus-Conifer	5.197	1.606	8.791	0.005	0.845	0.337	1.352	0.001
Aggregate Mining	-0.084	-0.151	-0.018	0.013	-0.014	-0.024	-0.004	0.007
Irrigated Row-Field Crop	-0.062	-0.108	-0.016	0.008	-0.010	-0.017	-0.003	0.004
Distance to Red-tailed hawk	-0.398	-0.263	-0.059	0.002	-0.026	-0.039	-0.013	<.001
Distance to Human Dwelling	-1.070	-0.799	-0.067	0.020	-0.070	-0.120	-0.020	0.006

Pseudo R2 = 0.289

Table 6. Model results of the logistic regression comparing nest trees to random trees with a 500 meter buffer with the Crop classification of variables (n=78).

Variable	Coefficient	95% Confidence Interval		p-value	Marginal effect	95% Confidence Interval		p-value
Agricultural-industry	0.237	0.005	0.471	0.046	0.043	0.004	0.082	0.031
Annual Grass	0.101	-0.002	0.205	0.056	0.018	0.000	0.036	0.049
Natural	0.076	0.020	0.131	0.008	0.014	0.004	0.023	0.004
Row Crop	-0.622	-1.059	-0.184	0.005	-0.113	-0.184	-0.041	0.002
Dist. to Road	-0.417	-0.682	-0.152	0.002	-0.076	-0.120	-0.032	0.031
Dist. to Red-tailed hawks	-0.109	-0.201	-0.016	0.021	-0.020	-0.034	-0.006	0.006

Pseudo R2 = 0.227

Table 7. Model results of the logistic regression comparing nest trees to random trees with a 1600 meter buffer with the California Wildlife Habitat Relationships classification of variables (n=78).

Variable	Coefficient	95% Confidence Interval		p-value	Marginal effect	95% Confidence Interval		p-value
Dist. to Red-tailed hawks	-0.127	-0.218	-0.037	0.006	-0.026	-0.040	-0.011	0.001
Dist. to Human Dwelling	-0.248	-0.489	-0.007	0.044	-0.050	-0.094	-0.007	0.024

Pseudo R^2 = 0.147

Table 8. Model results of the logistic regression comparing nest trees to random trees with a 1600 meter buffer with the Crop classification of variables (n=78).

Variable	Coefficient	95% Confidence Interval		p-value	Marginal effect	95% Confidence Interval		p-value
Aggregate Mining	-0.010	-0.022	0.002	0.089	-0.002	-0.003	0.001	0.071
Row Crop	-0.054	-0.099	-0.008	0.012	-0.009	-0.012	-0.002	0.006
Idle Farmland	0.008	0.001	0.014	0.018	0.001	0.000	0.002	0.005
Hay	0.045	0.012	0.079	0.010	0.007	0.003	0.012	0.003
Corn	-0.030	-0.055	-0.005	0.017	-0.005	-0.009	0.001	0.009
Grain Crops	-0.014	-0.027	0.001	0.073	-0.002	-0.005	0.000	0.054
Dist. to Red-tailed hawks	-0.200	-0.306	-0.093	0.033	-0.032	-0.428	-0.021	<.001

Pseudo R2 = 0.300

eucalyptus-conifer had a positive influence (Table 5). Eucalyptus-conifer also had the largest marginal effect indicating 85% rate of increase in nest presence with every added hectare of eucalyptus-conifer. Marginal effects for agricultural-urban, aggregate mining, and irrigated field crops showed a rate of decrease in nest presence of about 1% for every additional hectare while distance to human dwelling showed a 7% decrease for every 100 m increase in distance.

Results of the 500 m buffer model with the Crop classification showed that agricultural-industry, annual grass, and natural habitats all had a positive influence on nest presence while row crops and distance to paved roads had a negative influence (Table 6). Marginal effects for paved roads and row crops showed a 7.6% decrease in likelihood of nest presence for every additional 100 m and 11% rate of decrease for every additional hectare. Agricultural-industry, annual grass, and natural habitats showed a respective 4.3%, 1.8% and 1.4% rate of increase in the likelihood of nest presence for every additional hectare.

The only two variables that had a significant influence on nest presence for the 1600 m buffer with CWHR variables were the distance to red-tailed hawk nests and distance to human dwelling which also had a negative influence on nest presence (Table 7). The marginal effect showed a 5% decrease in the likelihood of a nest for every additional 100 m from a human dwelling. Results of the 1600 m model with Crop variables showed a negative influence on nest presence by aggregate mining, row crops, grain crops, and corn, and a positive influence by idle farmland and hay crops (Table 8). Marginal effects for aggregate mining, row crops, grain crops, and corn showed a respective 0.2%, .9%, 0.2%, and 0.5% rate of decrease in nest likelihood for every additional hectare. Idle farmland and hay crops had marginal effects that showed a rate of increase of 0.12% and 0.7% with every additional hectare.

Twenty-seven of thirty-nine nest trees were located in Valley oak (*Quercus lobata*) (69%). Seven nests were located in black walnut (*Juglans spp.*), two in willow (*Salix spp.*), one each in California sycamore (*Platanus racemosa*) and Eucalyptus (*Eucalyptus spp.*), and one nest tree was unidentified but suspected to be an extremely old citrus tree. Twelve nest trees (30.8%) were in trees associated with human development (agricultural-industry lots, residences, farmyards), ten (25.6%) were roadside trees, nine (23%) were in riparian habitat along Cache Creek, streams, and man-made canals, 3 (7.7%) trees were in tree lines associated with ditches or unpaved agricultural roads, three (7.7%) were lone standing trees, and two (5%) were at the edge of orchards which bordered Cache Creek.

Tree Morphometrics

Thirty-three nest trees and thirty-nine random trees were measured for DBH, average canopy spread, and height (Table 9). One nest tree had been removed and access was not granted for five others. Of the nest trees measured, twenty-seven nests remained and were measured for height, aspect, and distance from the trunk. Fourteen nests were in the northern aspect (N-7, NE-5, NW-2), six were in the southern aspect (SE-4, SW-2), five faced west, and two faced east. Mean nest height was 12.09 m (Std. error, 0.715) and mean distance from the trunk was 4.37 m (Std. error, 0.802).

Table 9. Recorded mean measurements of Swainson's hawk nest trees and random trees.

	DBH (cm)	Height (m)	Crown Average (m)	to RTHA (m)	To Riparian (m)	to H2O (m)	to Road (m)	to Human Dwelling (m)
Nest Trees	102.37 (SE, 6.57)	13.96 (SE, 0.72)	19.22 (SE, 1.00)	980.90 (SE, 94.4)	846 (SE, 137)	574.7 (SE, 85.1)	125.4 (SE, 30.4)	201.1 (SE, 31.4)
Random Trees	80.51 (SE, 4.54)	12.01 (SE, 0.62)	16.10 (SE, 0.75)	1431.9 (SE, 99.9)	1233 (SE, 306)	378.7 (SE, 80.5)	245.1 (SE, 56.5)	339.2 (SE, 48.5)

Random Trees - n = 39, Nest Trees - n = 33 for DBH, Height, and Crown Average, n = 39 for toRTHA, To Riparian, toH2O, to Road, to Human Dwelling.

The results of the Wilcoxon rank sum tests showed that for all three morphometric variables, nest trees were significantly greater than random trees and that nest trees were significantly closer to red-tailed hawk nests, paved roads, and human dwellings than random trees ($p \leq 0.05$) (Table 10) (Figures 3-5). There was no significance in the distance to water or riparian habitat between nest and random trees. The results of the distance comparisons reflect the predictions of the logistic regression models which showed an increase in nest likelihood with proximity to red-tailed hawk nests, human dwellings, and roads.

Table 10. Results of Wilcoxon rank sum tests for nest vs. random trees.

	DBH	Height (m)	Crown Average (m)	to RTHA (m)	To Riparian (m)	to H2O (m)	to Road (m)	to Human Dwelling (m)
Wilcoxon W	433	458.5	413	203	299	263	251	224
Z	-2.379	-2.091	-2.605	-2.601	-0.2621	-1.772	-1.94	-2.317
P value	0.017	0.036	0.009	0.009	0.795	0.077	0.0524	0.02

Ho = There is no difference between nest trees and random trees, $p \leq 0.05$. Random Trees - n = 39, Nest Trees - n = 33 for DBH, Height, and Crown Average, n = 39 for toRTHA, To Riparian, toH2O, to Road, to Human Dwelling.

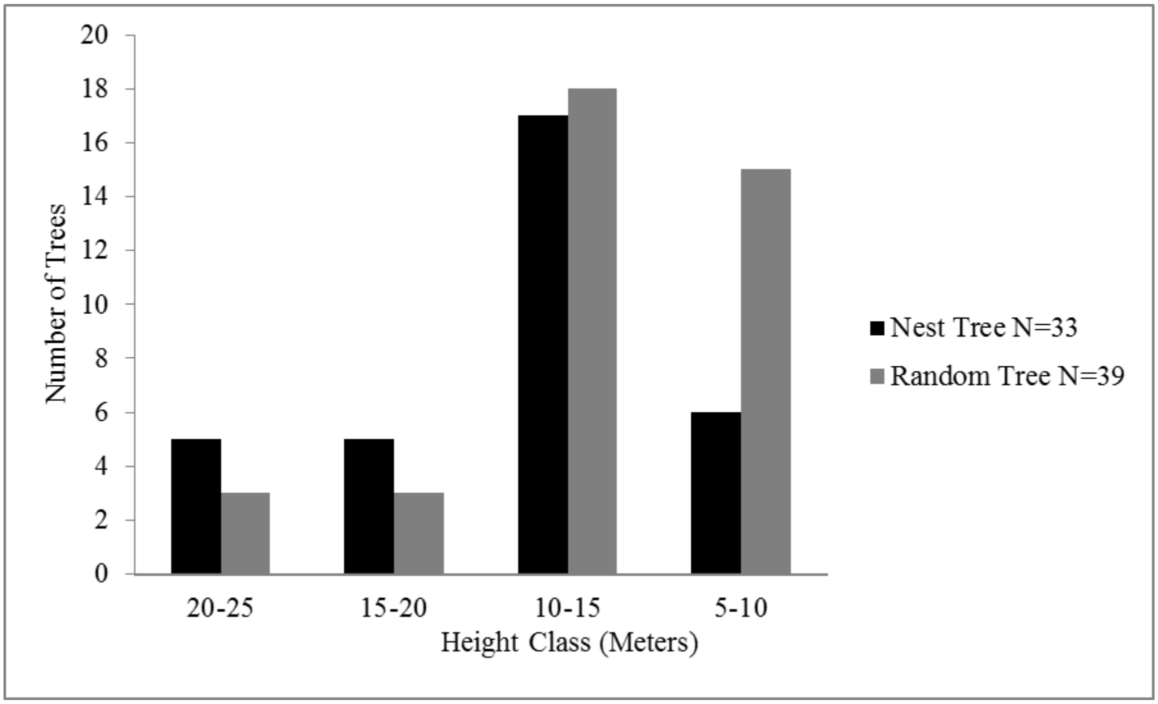

Figure 3. Nest versus random tree height in the Cache Creek study area grouped into four 10 meter range classes.

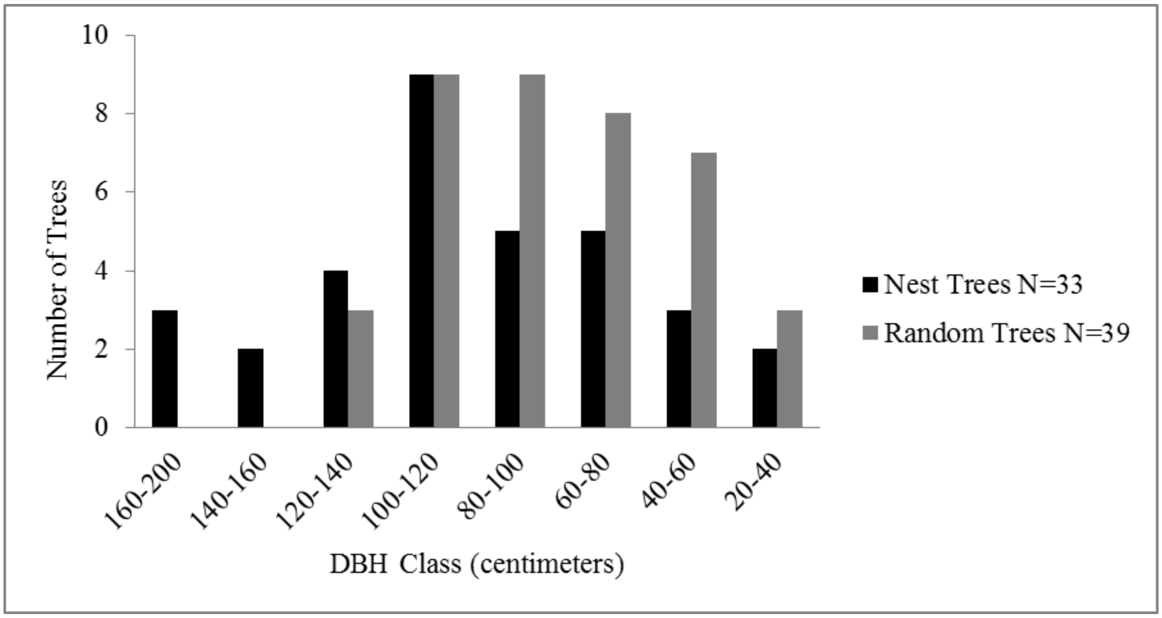

Figure 4. Nest versus random tree diameter at breast height (DBH) in the Cache Creek study area grouped into eight range classes.

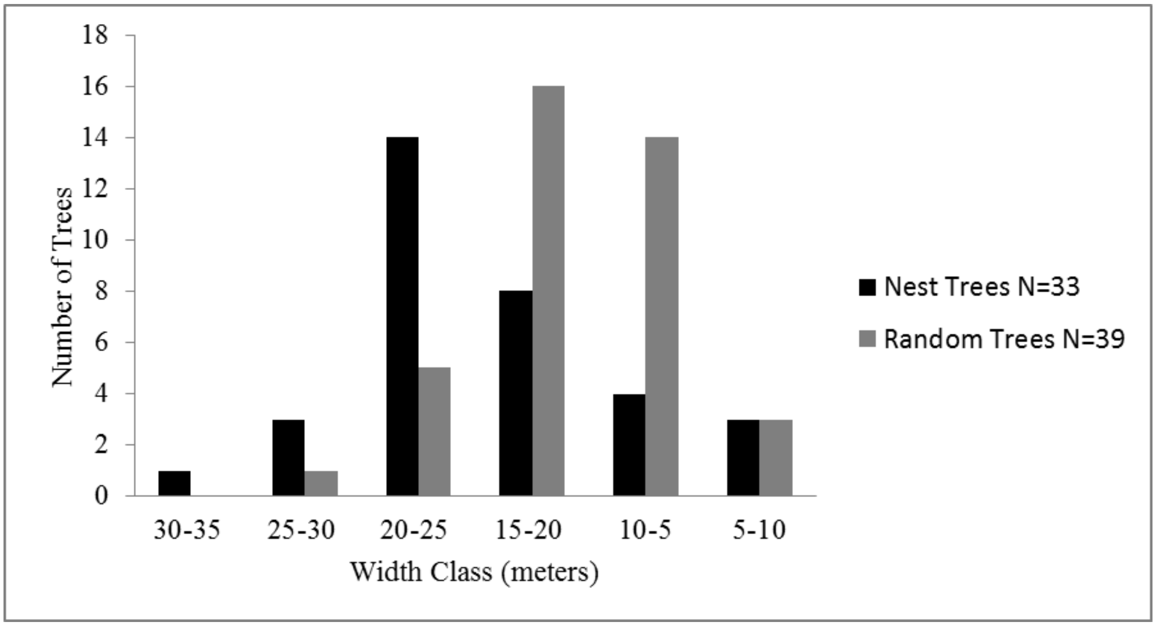

Figure 5. Nest versus random tree average crown width in the Cache Creek study area grouped into six 5 meter range classes.

DISCUSSION

Within the lower Cache Creek Management Area there is a wide array of land uses ranging from complete urban development to restored natural habitat with agriculture playing a major role. The results of this study show that despite this variety, certain of these land uses are more valuable than others to the Swainson's hawk which is selective in its foraging and nesting preferences.

Foraging

Swainson's hawk in the Cache Creek study area showed preference for certain crop types disproportionately to their availability within the survey route buffers. Preferred crop types in order of preference were hay fields, tomato-row crops, alfalfa, natural habitat, sunflower-safflower, and orchard-vineyard. Crop types that were not preferred, listed from least avoided to most avoided, were idle farmland, grazing-annual grass, corn, almond orchards, areas surrounding residences, grain crops, other, and walnut orchards. Swainson's hawk selection of hay fields, tomato-row crops, and alfalfa was significant. These habitats were utilized in a greater proportion to their availability. Almond orchards, grain crops, residential areas, walnut orchards, and other were used significantly less than their availability.

These findings support what other research in the Central Valley has found, namely, that Swainson's hawk prefers alfalfa, hay and tomatoes for foraging (Estep 1989, Babcock 1995, Swolgaard et al. 2008). Idle farmland, as defined by fields that have been disked or plowed but were not planted, was the dominant cover type (16%) within the transect boundaries and had the third highest frequency of foraging (33) but was not significantly different than what was expected. Grazing-annual grass had the second highest availability (14.7%) and fourth highest frequency of foraging observations (25) but still scored low in terms of preference because it was utilized less than expected based on availability. Much of the grazing and annual grassland associated with the transects occurred in the foothills of Capay Valley on the western border of the study area and in the Dunnigan hills along the northern boundary as well as irrigated grazing land to the west of the Dunnigan hills. Swainson's hawk prefers to forage in the lowlands of the valley so the location in the hilly regions of the study area may play a role in the lower than expected foraging observations (Estep 2008). These two foraging habitats are considered to be important to Swainson's hawk but are not high valued foraging habitat due to low prey densities, although prey species become more available during irrigation in pastureland (Estep 1989).

Swainson's hawks have elastic home ranges that expand and contract with the crop rotation patterns (Estep and Dinsdale 2012). Certain crops such as tomatoes and grain crops provide foraging opportunities during different times of the breeding season (Estep 2009). Tomatoes are a high value crop early in the growing season when foliage is low but become less ideal during the mid-season due to lowered visibility of prey for foraging hawks. However, during harvest they become highly valuable again and Swainson's hawks will gather in large groups while harvesting is occurring (Estep 1989, Estep 2009, personal observation). The second highest frequency of foraging was observed in tomato fields (36) which were ranked second as a preferred crop for foraging hawks and fourth (8.4%) in availability.

On many occasions, groups of Swainson's hawks were observed foraging in large mixed groups with other opportunistic avian predators during flood irrigation of alfalfa fields, during and after mowing. Alfalfa fluctuates in height throughout the season due to frequent mowing and can be irrigated every week which provides high quality foraging opportunities for Swainson's hawk (Babcock 1995, Swolgaard et al. 2008, Estep 2009). The highest occurrence of foraging was observed in alfalfa during the study period (56) and it ranked third in availability (14.1%).

Estep (1989) and others identified grain crops as important foraging habitat for Swainson's hawk in the Central Valley (Babcock 1995, Swolgaard et al. 2008). During the course of this study, grain was utilized significantly less than expected. Barley, sorghum and oats were categorized under grain in this study, however wheat made up the majority of the category. Estep (2009) found that growth patterns of wheat make it a low quality foraging habitat for much of the time my road surveys were conducted. Planted in late fall or early winter, it can reach between 89 and 101 cm (35 and 40 inches) in height forming a dense cover that is inconducive to foraging (Estep 2009). Foraging value increases rapidly from late June to mid-July and peaks in early August. Surveys were completed mid-August so it is possible that Swainson's hawk had not yet completely shifted foraging patterns to take advantage of the newly available resource.

Walnut and Almond orchards combine to make up 9% of the survey area and were utilized significantly less than expected at the 90% confidence level. This is no surprise as they tend to block all visibility for aerial foragers. All six of the foraging observations in almond orchards were made in young orchards that had not yet established a canopy. The two foraging observations associated with walnut orchards were of aerial feeding during large outbreaks of dragonflies which Swainson's hawk will readily eat on the wing (England et al. 1997). Swolgaard et al. (2008) found that vineyards were used less than expected in San Joaquin County. In the Cache Creek study area they did not occur in a high enough proportion to meet the chi-square requirements and were combined with fruit orchards which also occurred sparsely. These categories were combined because the fruit orchards in the study area were planted with wide rows that were more similar to vineyard habitat than the dense canopy of almond or walnut. Together they made up only 1.9% of the total area. The vineyards that did occur were planted in wide trellised rows with annual grass that was mowed multiple times during the survey period. The combination of the frequent mowing and proximity to a nest territory likely accounted for the 6 foraging observations that were documented.

Swainson's hawks are opportunistic foragers which likely accounts for the observations in residential and "other" categories (England et al. 1997). Many of the residences along the survey routes have large yards which were adjacent to suitable foraging habitat. The two foraging observations in the "other" habitat were observed over the western portion of the SYAR gravel mine which is disconnected from the main operations and is adjacent to alfalfa fields that were frequently used as group foraging locations. There were also three nesting sites occurring within 1 km of the mine.

Nest Sites

Swainson's hawk nest buffers were distinguishable from random tree buffers at both the 1600 meter radius and the 500 meter radius. A total of 36 variables were included in the models and of those, 15 different predictor variables appeared in at least one of the four models. Twelve of the predictor variables were land use categories. Six had a positive predictive influence (agricultural-industry, annual grass, natural habitat, eucalyptus-conifer, idle farmland, and hay), and six had a negative predictive influence (agricultural-urban, aggregate mining, corn, irrigated field crops, row crops, and grain) with an increase in area. Three additional predictor variables (distance to red-tailed hawk, human dwelling, and paved road) were measurements of distance and all had a negative predictive influence when distance from the nest increased. Distance to red-tailed hawk was the only variable that appeared in all models, however, row crop appeared in both of the Crop models, and its equivalent, irrigated field crop, appeared in the 500 m CWHR model. Distance to human dwelling appeared in both CWHR models. None of the other predictors occurred more than once. None of the models showed that alfalfa was an indicator of nest presence however other hay crops which are harvested similarly to alfalfa were a positive predictor for the 1600 m Crop buffer. Also, while it was not significantly different than random trees, alfalfa was incorporated into 26 of 39 (67%) 500 m nest tree buffers and 100% of the 1600 m buffers.

It is not surprising that distance to red-tailed hawk factored into all of the models. Swainson's hawk is known to compete for nesting territories with red-tailed hawks and engage in impressive aerial combat which can last for an entire day (Janes 1984). Nest site features such as distance to roads and human dwelling as well and tree size and species selection are similar for both Swainson's and red-tailed hawks and they will often nest within 0.5 km of each other (Bechard et al. 1990, Bosakowski et al. 1996). Janes (1994) found that red-tailed hawks often lost peripheral territory to Swainson's hawk particularly in sites with high prey availability and high density of quality perches. Swainson's hawk was the aggressor 82% of the time. However, aggression and territory acquisition by Swainson's hawk did not lead to lower reproductive output or territory abandonment by red-tailed hawk (Janes 1994). Swainson's hawk will also attempt to dislodge sometimes successfully incubating red-tailed hawks from nests (England et al. 1997). In contrast to Janes (1994), Schmutz et al. (1980) found that reproduction was significantly reduced when Swainson's and red-tailed hawks nested in close proximity although Bosakowski et al. (1996) found that red-tails will tolerate nesting closer to Swainson's hawk than to other red-tailed hawks. In the Cache Creek study area, aggressive behavior toward red-tailed hawks and other raptors was observed on several occasions near nesting sites however the two species were observed foraging in flooded alfalfa fields, that were not directly associated with nest sites, without conflict.

Association with eucalyptus-conifer may also be explained by the need for suitable perches. However, eucalyptus-conifer as an indicator for nest presence in this study should be approached with caution. It was found to have a positive effect on the 500 m CWHR model, but only 4 nest buffers (10%) contained eucalyptus-conifer as opposed to 2 random buffers which may account for its presence in the model. While only a small portion of buffers contained eucalyptus-conifer twice the amount of nest tree buffers contained it which may explain the high marginal effect. Eucalyptus is widely used throughout the study area as an industrial crop, for windbreaks in urban and agricultural-urban settings, as well as around farmyards and roads associated with farming. At the 1600 m scale eucalyptus-conifer was spread relatively evenly, 8 nest buffers contained (20%) eucalyptus-conifer while 7 random buffers (18%) contained eucalyptus-conifer.

The other predictor variables (idle farmland, hay, agricultural-industry, natural habitat, and annual grass) fall better in line with what others have found. Alslup (2012) found that the amount of uncultivated areas within nesting areas was a significant predictor of nesting success. Fallow land was the third most represented habitat type associated with nests in Utah (Bosakowski et al. 1996). Estep (1989) found that hay was the primary land use in Central Valley Swainson's hawk territories. Gilmer and Stewart (1984) also found that nest territories contained more hay than what was available in the overall area. In both of these studies hay included alfalfa and grass hay. Alfalfa and hay were separate categories in this study. Row and grain crops are also typically associated with nests (Estep 1989). In this study the likelihood of nest presence decreased with an increase of both grain and row crops. Tomatoes represented a separate category of their own but were not a significant predictor of nest presence or absence although they are considered to have high foraging value to Swainson's hawk (Bloom 2009).

Several studies have found that Swainson's hawk nest successfully in areas of high human activity including in urban settings and tree rows surrounding farmyard (Schmutz 1984, England et al. 1995, Alslup 2012). Agricultural-industry was a positive predictor of nest presence in this study and the highest percentage of nest trees (30.8%) were associated with residences, farmyards, or agricultural-industry lots for storing equipment. Another 25.6% were roadside trees which is slightly higher than the 18.6% observed by Estep (2008) throughout all of Yolo County. In Washington, Swainson's hawk nests were closer to human structures, particularly ranches and farms, and paved roads than both red-tailed hawks and ferruginous hawks, although all these species were associated with roads and human structures (Bechard et al. 1990). Along Cache Creek, Swainson's hawk nest presence was negatively affected as distance from human dwelling and distance to paved roads increased. Many of the remaining trees available to Swainson's hawk occur around human structures and roads as farming practices over the years have cleared trees to make room for crops. Surprisingly, agricultural-urban habitat was a negative predictor in the 500 m CWHR model. The agricultural-urban category was much broader than the agricultural-industry category, however, and included agricultural-industry, farmyards, residential land-use, as well as fields used for grazing that were associated with agricultural-urban development. When the Crop model was run, these categories were eliminated from the model as not significant during the stepwise process.

Natural habitat, which included restoration sites, valley riparian, and blue oak woodland was also a positive predictor of nest presence in the Cache Creek study area. The association of Swainson's hawk nest trees with riparian habitat and its high value for breeding Swainson's hawk is well documented (Bloom 1980, Schlorff and Bloom 1984, Estep 1989, Schlorff and Estep 1993, Estep 2008, Estep and Dinsdale 2012). Forty-nine percent of Yolo County Swainson's hawk nests documented by Estep (2008) were associated with riparian woodland habitat including along natural streams and man-made channels. Twenty-three percent of nest trees in this study were associated with riparian habitat on Cache Creek, streams, and man-made canals. Two other trees were on the edge of orchards that bordered the creek riparian zone. If these are added then 28% of nest trees were associated with riparian habitat.

Janes (1985) suggested that annual grass had replaced much of the natural perennials due to a long history of grazing in other portion of Swainson's hawk range in Utah, Idaho, and Oregon which is likely the case in the California with its long history of livestock operations (Alagona 2011). In Utah, Idaho, and Oregon, Swainson's hawk selected grasslands over other habitats for nesting (Janes 1985). Bosakowski et al. (1996) found that pastureland was the second highest representative in area around Swainson's hawk nests in Utah. Along Cache Creek, The annual grass category, which included pastureland and grazing was also found to be a positive predictor of nest presence.

Logistic regression models are useful as a tool for identifying predictors that may have important influence over nest presence but are relatively small and easily hidden by more obvious predictors (Hosmer et al. 2013). However, the models cannot predict all of the factors associated with nest presence. The R-square (R2) values for the models in this study are relatively low and only explain about 15 to 30 percent of the difference between nest buffers and random buffers (1600 CWHR R2 = 0.15, 1600 Crop R2 = 0.30, 500 CWHR R2 = 0.29, 500 Crop R2 = 0.23). Other studies have shown that factors such as perch density, prey species availability, nest tree characteristics, and distribution of potential trees have significant influence on nest presence (Janes 1984, Janes 1985, Estep 1989, Schmutz 2006 Estep and Dinsdale 2012). Swainson's hawk exhibits nest site fidelity so it may be that the more permanent features of the nest site are as important, if not more important, to the decision to nest than the specific land use, especially in the Central Valley where crops are frequently rotated and fields can lie idle during any given breeding season (England et al. 1997).

Tree Morphometrics

Results of this study show that nest tree height, DBH, and average crown were significantly greater than random trees. Mean tree height was 13.96 m and was similar to what Anderson et al. (2007) found throughout the range of the species for one of their study years (14.81 m) but less than in the other year (16.18 m). Bloom (1989) also had on average taller nest trees in his range wide survey measuring 17.6 m as did Swolgaard (2004) (18.8 m). Mean DBH for nest trees (102.37cm) was larger than Bloom's (1989) measurements (84.8 cm) but similar to the 108.2 cm found by Swolgaard (2004) in the San Joaquin Valley. Average crown diameter (mean = 19.22 m) was slightly larger than what Swolgaard (2004) found (mean = 17.3 m). As in this study, Swolgaard (2004) found that nest trees were significantly taller, broader, and wider than random trees measured. These results suggest that tree size factors into the decision to nest. It is possible that taller trees allow for a better vantage point from the nest enabling better defense of the nest territory from intruders and allow the nest to be built high above the ground limiting access from terrestrial predators. Crown width may contribute to better concealment of the nest from below. The large DBH mean suggest that the trees being selected are older trees.

The selection for older trees may be a function of their height and width. However, this presents a problem if large older trees fail to be replaced by younger trees or are damaged due to reduced agricultural water usage during drought years (Bosakowski 1996). This may become an issue in California as farmers reduce water usage and are allocated less during the current historical drought conditions. Bloom (1980) and Swolgaard (2004) found that Swainson's hawks utilized large cottonwoods for nesting trees as well as valley oaks which were the preferred trees for nesting in this study (69%). Faster growing than oaks, cottonwoods may be a viable species for restoration efforts, however, protection and retention of young oaks and oak groves to replace older trees reaching the end of their lifespan should be a priority for land managers (Swolgaard 2004). No cottonwoods were used by Swainson's hawk in this study however red-tailed hawks were found in four. Valley oak was also the preferred tree for red-tailed hawks (46%), as has been shown in other studies, however red-tailed hawks use a variety of nesting substrates and are more versatile than Swainson's hawk (Tietje 1996, Estep 2008).

The continued decline of suitable trees will likely cause more interspecific conflict over available nesting territories. In this study, conflict was directly observed between red-tailed and Swainson's hawks as well as aggression by Swainson's hawk toward nesting great horned owls, both species that nest prior to Swainson's hawk and will use historical Swainson's hawk nests. In some cases Swainson's hawks will abandon traditional nesting sites due to red-tailed hawk occupancy or move nests to less desirable locations once great horned owls no longer occupy the nest (Estep 2008). In this study, a Swainson's hawk pair repeatedly mobbed a great horned owl nesting in a valley oak. Once the owls fledged, the Swainson's hawk pair dismantled the nest and moved it to a new nest tree (which was subsequently removed the next year). This nest was never confirmed as being productive. Conflicts such as these could potentially be detrimental to reproduction for both species involved.

Conclusion

The retention of high quality foraging and nesting habitat is essential to the sustainability of Swainson's hawk in California. With urban development expanding in the Central Valley and changes occurring in farming practices, a heightened effort to identify potential areas for protection should be undertaken. Cooperation between agricultural enterprises, lead agencies, and conservation groups should be fostered, to promote an atmosphere of good will and facilitate efficient negotiations and decision making processes. This dialogue is critical not only in California but throughout the breeding and wintering range of the species where changes in land use practices may affect Swainson's hawk access to prey, foraging, roosting, and nesting habitat.

Documenting Swainson's hawk nesting locations should continue so that critical nesting habitat can be protected and incorporated into habitat conservation plans and mitigation banks. A concerted effort should be made to protect remaining oak groves and riparian habitat in the Valley and establish new groves in areas with high foraging potential but low nest tree availability. Reconnecting riparian corridors such as the Lower Cache Creek that have been fragmented by recent or historical anthropogenic activity should also be a priority. New plantings should be initiated as soon as possible to allow trees time to grow as large as possible before older trees die. When areas near existing riparian corridors are slated to be developed, plans should include green belts and buffers to maintain habitat connectivity and ecological value.

Getting creative about the approach to tree conservation can go a long way in re-establishing suitable nesting substrate for Swainson's hawk. For example, planting trees along roadways in agricultural settings has the potential to provide suitable nest trees at a potentially low cost. The affinity of nesting Swainson's hawk for trees associated with human structures and farmyards is an interesting result of this study. Outreach efforts should be undertaken by local governments to encourage residents to preserve large trees around their properties and plant new trees around the perimeter. Tree give-a-ways and plant-a-tree programs can be a way to excite the community about contributing to natural resource conservation and establish a sense of ownership and connection to the recovery of Swainson's hawk.

Conservation efforts in Swainson's hawk breeding range can only go so far to prevent further decline of the species and facilitate an increase in population numbers. Identification and management for land use and prey species abundance in critical migration stopover points remains an important area for new research and necessary to maintaining healthy birds transitioning back and forth between wintering grounds and breeding grounds. In Argentina, an effort has been made to curtail the use of organophosphate pesticides which can be lethal to foraging Swainson's hawks and have the potential to cause mass die-off events in a single application (Woodbridge et al. 1995, Canavelli et al. 2001). Continued effort to work with South American governments to remove harmful pesticides from the market along with educating farmers about timing the application so that pesticides are applied when Swainson's hawk are at least risk of exposure is imperative (Canavelli et al. 2001). The need also exists to investigate how wintering Swainson's hawks react to changes in land use on their wintering grounds and determine if there is a need to identify and conserve certain lands or agricultural practices that benefit the species.

Finally, outreach should be undertaken to educate and excite young people about the value of wildlife and the many other natural resources that California has to offer so that future generations remain active in the outdoors and are given the tools to contribute new ideas for a sustainable future.

APPENDIX A

SWAINSON'S HAWK NEST TREES IN THE LOWER CACHE CREEK RESOURCES MANAGEMENT AREA

Table 11. Swainson's Hawk Nests in the Lower Cache Creek Resources Management Area.

Nest ID	Latitude	Longitude	Tree Spp.	Height (m)	DBH (cm)	Crown Diameter (m)	Nest Height (m)	Nest Aspect	Nest Distance From Trunk (m)	Status
SWHA5	N 38 44.209	W 121 49.014	VO	12.07	162.30	20.65	-	-	-	active
SWHA9	N 38 43.917	W 121 49.493	VO	17.70	124.40	25.64	16.46	N000	0.00	active
SWHA11	N 38 43.731	W 121 49.612	WLN	12.87	99.20	19.34	12.80	W260	7.32	fledgling
SWHA18	N 38 42.865	W 121 50.941	VO	18.11	135.40	24.70	16.46	SW232	5.59	confirmed
SWHA32	N 38 42.795	W 121 49.644	VO	-	-	-	-	-	-	active
SWHA32_1	N 38 43.210	W 121 48.816	WLN	7.85	30.80	7.00	4.57	N340	0.92	confirmed
SWHA35	N 38 42.441	W 121 49.553	VO	20.52	109.00	22.54	19.20	N346	6.40	confirmed
SWHA40	N 38 42.133	W 121 50.081	WN	9.66	143.20	20.90	-	-	-	confirmed
SWHA42_1	N 38 41.738	W 121 50.377	VO	14.28	113.50	25.54	10.67	NE37	5.59	confirmed
SWHA44	N 38 41.595	W 121 50.120	WLN	17.10	152.00	21.39	15.55	N007	4.57	fledgling
SWHA46	N 38 41.665	W 121 49.821	VO	14.28	106.20	22.54	-	-	-	confirmed
SWHA48	N 38 41.965	W 121 49.808	VO	13.88	115.50	22.50	10.97	W270	0.00	confirmed
SWHA49	N 38 41.581	W 121 49.538	WLN	10.66	79.90	16.49	13.72	E092	3.96	active
SWHA50_1	N 38 41.775	W 121 49.353	VO	-	-	-	-	-	-	active
SWHA54	N 38 42.362	W 121 48.896	SYC	17.90	95.80	19.71	16.46	NE015	0.00	active
SWHA62_1	N 38 41.332	W 121 50.424	VO	12.67	96.00	20.41	-	-	-	fledgling
SWHA67	N 38 41.407	W 121 49.299	VO	11.67	128.30	24.51	10.97	NW330	7.32	confirmed
SWHA84	N 38 40.638	W 121 50.713	VO	11.27	52.30	9.20	10.06	NW306	1.22	fledgling
SWHA90	N 38 40.681	W 121 49.543	VO	15.89	79.90	15.89	-	-	-	confirmed
SWHA96	N 38 40.705	W 121 48.984	VO	-	-	-	-	-	-	confirmed
SWHA105_1	N 38 39.577	W 121 50.116	WLN	21.93	191.90	28.87	20.12	SW224	7.32	confirmed
SWHA110	N 38 42.287	W 121 51.828	VO	21.12	173.50	31.82	10.97	SE145	16.46	active
SWHA114	N 38 41.871	W 121 53.798	VO	13.68	70.00	14.85	12.80	NE021	0.92	active
SWHA130	N 38 41.523	W 121 54.371	VO	-	-	-	-	-	-	territorial/fledgling
SWHA131	N 38 41.379	W 121 57.178	VO	11.47	70.30	14.02	10.06	SE159	0.92	confirmed

Table 11 continued. Swainson's Hawk Nests in the Lower Cache Creek Resources Management Area.

Nest ID	Latitude	Longitude	Tree Spp.	Height (m)	DBH (cm)	Crown Diameter (m)	Nest Height (m)	Nest Aspect	Nest Distance From Trunk (m)	Status
SWHA135_1	N 38 40.549	W 121 55.499	WLN	14.48	120.30	21.03	10.97	EN56	1.83	active
SWHA144_1	N 38 30.006	W 121 53.717	EUC	21.93	83.20	16.85	14.63	SE150	4.57	fledgling
SWHA146_1	N 38 40.315	W 121 53.040	VO	-	-	-	-	-	-	active
SWHA156	N 38 41.783	W 121 57.841	VO	9.86	111.30	15.09	11.89	N0	0.00	active
SWHA158	N 38 42.413	W 121 57.827	VO	20.52	111.50	20.18	18.29	WS233	3.66	territorial
SWHA161	N 38 42.932	W 121 55.589	WILL	12.87	59.00	8.15	7.62	W266	5.59	confirmed
SWHA175	N 38 41.550	W 121 58.558	VO	-	-	-	-	-	-	territorial/fledgling
SWHA182_1	N 38 40.790	W 121 58.030	WILL	9.86	51.20	15.59	9.15	N340	1.22	active
SWHA188_1	N 38 41.076	W 121 59.234	UNK	6.64	70.00	14.57	4.57	NE022	2.80	active
SWHA189	N 38 40.269	W 122 01.215	VO	11.27	113.00	20.78	11.89	SW240	2.74	confirmed
SWHA190	N 38 40.835	W 122 00.950	VO	9.86	36.30	10.70	4.57	SE174	4.63	active
SWHA204	N 38 42.536	W 122 02.743	VO	13.88	106.00	21.39	10.97	ES120	5.76	confirmed
SWHA206	N 38 42.295	W 122 05.765	VO	11.06	106.00	25.10	-	-	-	confirmed
SWHA209	N 38 42.508	W 122 01.678	VO	11.67	81.00	16.54	10.06	N4	4.57	confirmed

Nest Status Codes:

Territorial: Pair or individual observed defending the nest territory (escorting intruders out of territory, diving at intruders, grappling, perched near nest calling).

Active: Pair observed exhibiting breeding behavior on or in the vicinity of nest (leg dangling, sky-dancing, paired flight, nest building, food sharing, copulating).

Confirmed: Female observed in nest incubating. Chicks observed in nest.

Fledgling: Fledglings observed "branching" in nest tree or perched near nest tree with or without adult.

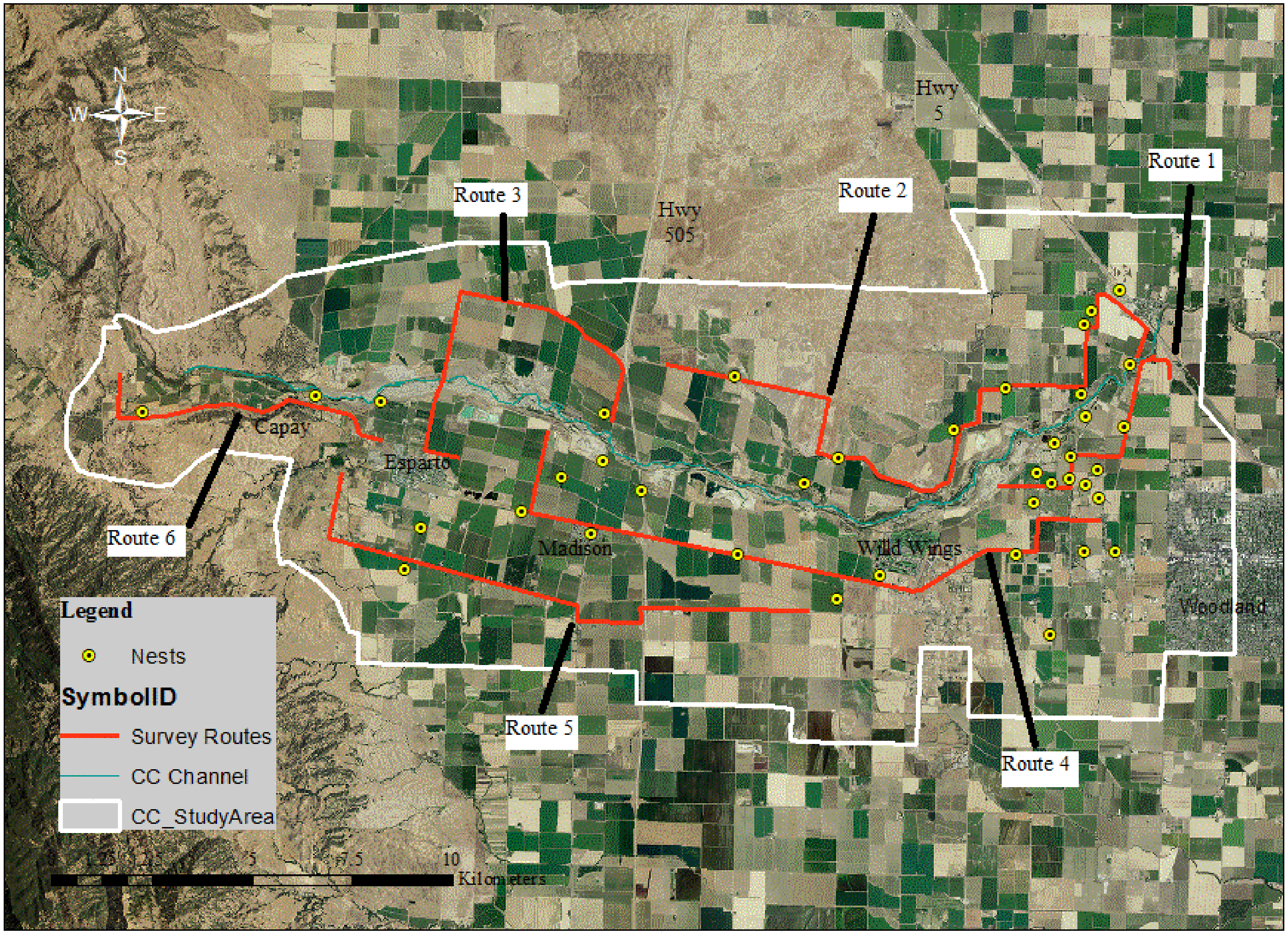

Figure 6. Map of Swainson's hawk nest locations and survey routes along Lower Cache Creek, Yolo County, California.

Table 12. Cache Creek road survey route lengths and descriptions.

Route	Distance (km)	Description
1	7.5	Begins at the end of County Road (Co. Rd.) 20 at Tiechart Aggregates and runs east (E) to Co. Rd. 96B. Travels north (N) on Co. Rd. 96B to Co. Rd. 19B. Travels E on Co. Rd. 19B to Co. Rd. 97A. Travels N on Co. Rd. 97A. Ends at Co. Rd. 18.
2	19.51	Starts where Co. Rd. 97 B runs into Cache Creek Levee. Travels N/N West (W) to Co. Rd. 17. Travels W on Co. Rd. 17 to 96B. Travels South (S) on 96B to Co. Rd. 18A. Travels W on Co. Rd. 18A to Co. Rd. 95.Travels S on Co. Rd. 95 to Co. Rd. 94B. Travels S on Co. Rd. 94B to Co. Rd. 20. Travels W on Co. Rd. 20 to Co. Rd. 92C. Travels N on Co. Rd. 92C to Co. Rd. 19. Travels W on Co. Rd. 19. Ends at canal 1 km E of Highway (Hwy) 505.
3	11.03	Starts on Co. Rd. 20X 0.95 km E. of Co. Rd. 87. Travels W to Co. Rd. 87. Travels N on Co. Rd. 87 to Co. Rd. 19. Travels E on Co. Rd. 19 to Co. Rd. 89 just W of Hwy 505. Travels S on Co. Rd. 89 to the terminus.
4	17.58	Begins at the corner of Co. Rd. 97 and Co. Rd. 21. Travels W on Co. Rd. 21 to Co. Rd 96. Turns S. on Co. Rd 96. Turns W on Hwy 16. Travels W on Hwy 16 to Co. Rd. 88B. Travels N on 88 B ending at the terminus.
5	14.67	Begins at the bridge 0.85 km W of Co. Rd. 23. Travels W on Co. Rd 24 across Hwy 505 to Co. Rd. 24A. Turns S on Co. Rd. 24A then W. on Co. Rd. 24A until it hits Co. Rd. 89 and goes N. Travels W on Co. Rd. 23 to Co. Rd. 85B. Travels N on Co. Rd. 85B. Ends at Co. Rd. 21A.
6	8	Begins 0.30 km W of Parker Place on Hwy 16 in Esparto. Follows Hwy 16 W through Capay to Co. Rd. 82. Follows Co. Rd. 82 north to the gate at the terminus.

APPENDIX B

HABITAT CLASSIFICATIONS IN THE LOWER CACHE CREEK RESOURCES MANAGEMENT AREA

Table 13. Classification system of habitats as defined by the California Wildlife Habitat Relationships System (CWHR). Continued on the next page.

Name	Code	Description
Annual Grassland	AGS	Natural or human altered open areas dominated by annual herbaceous plants – mainly grasses.
Barren	BAR	Any habitat with <2% total vegetation cover by herbaceous, desert, or non-wildland species and < 10% cover by tree or shrub species.
Aggregate Mining†	AGM	A non-CWHR category: Area dominated by aggregate mining operations
Agricultural-urban††	AGU	A non-CWHR category: rural residences and adjacent ruderal lots and pastures, farm operations, roads, and corridors between agricultural fields
Blue Oak Woodland	BOW	Areas dominated by 10% or > cover in blue oak (*Quercus douglasii*)
Conifers‡	CON	Mixed industrial conifer groves
Dryland Grain	DGR	Agricultural areas planted in annual, unirrigated grain or hay crops
Deciduous Orchard	DOR	Areas dominated by deciduous orchard crops
Evergreen Orchard	EOR	Areas dominated by evergreen orchard crops
Freshwater Emergent Wetland	FEW	Freshwater wetland areas dominated by erect, rooted herbaceous hydrophytes
Idle Farmland††	IDL	A non-CWHR category: all agricultural fields underused during a growing season
Irrigated Row-Field Crops	IRF	All irrigated row crops field crops

Table 13 continued. Classification system of habitats as defined by the California Wildlife Habitat Relationships System (CWHR).

Name	Code	Description
Irrigated Hay	IRH	Irrigated, perennial hayfields that are successively harvested during the season
Lacustrine	LAC	Open still freshwater habitats
Irrigated pasture	PAS	Irrigated, perennial forage fields that are consistently grazed during the season
Irrigated Grain	IRG	Agricultural areas planted in annual, irrigated grain or hay crops.
Rice	RIC	Flooded, leveed rice fields
Urban	URB	Human altered habitat in areas of dense human population, including commercial or industrial areas
Vineyard	VIN	Areas dominated by vineyards
Valley Oak Woodland	VOW	Areas dominated by 10% or > cover in valley oak (*Quercus lobata*)
Valley-Foothill Riparian	VRI	Areas along waterways that are dominated by tree & shrub cover
Willow Scrub‡	WSC	Open to dense broadleaf thicket dominated by willow <10m in height and tolerant to frequent flooding and sustained inundation. Occurs in sparse clumps in scour prone areas with little ground cover. May include cottonwood saplings shrubs and forbes.
Eucalyptus	EUC	Industrial Eucalyptus groves and windbreaks.

†Designation determined by author. ††Swolgaard et al. 2008. ‡Barbour et al. 2007. Table adapted from Swolgaard 2004.

Table 14. Crop categories, their codes, and descriptions. Continued on next page

Name	Code	Description
Annual Grassland	AGS	Natural or human altered open areas dominated by annual herbaceous plants – mainly grasses
Agricultural-industry	AGI	All farming operations, buildings and adjacent lots (EUC and CON were included in this category‡)
Aggregate Mining	AGM	All aggregate mining operations
Alfalfa	ALF	Alfalfa field
Almond	ALM	Any Almond orchard
Apple	APL	Any Apple orchard
Plum	PLM	Any Plum orchard
Barley	BAR	Fields planted in barley
Canal	CNL	Agricultural canal
Canola	CAN	Fields planted in canola
Carrot	CAR	Fields planted in carrots
Cemetery	CEM	Any cemetery

Table 14 continued. Crop categories, their codes, and descriptions. Continued on next page.

Name	Code	Description
Citrus	CTR	Any Citrus orchard
Corn	CRN	Field corn
Freeway median	FM	Center or side median strips along major freeways
Garlic	GAR	Field planted in garlic
Grain	GR	Any grain field
Grazing	GRZ	Open areas used for grazing
Hay	HAY	Any hay field other than alfalfa
Idle	IDL	Barren or fallow farmland
Industrial	IND	Urban industrial area
Melon	MLN	Field planted in melon
Natural	NAT	any natural habitat (BOW, VOW, VRI, RST, WSC)
Olive orchard	OLV	Any olive orchard
Orchard	OR	Any orchard
Onion	ONION	Field planted in onion

Table 14 continued. Crop categories, their codes, and descriptions. Continued on next page.

Name	Code	Description
Pepper	PEP	Field planted in peppers
Park	PRK	Public Park
Stonefruit	STF	Any stonefruit orchard
Pomegranate	POM	Any pomegranate orchard
Telephone Pole/ Power Pole	PP/TP	Any pole connecting telephone or power wires
Power Tower	PT	Large metal towers connecting power lines
Pistachio	PTC	Any pistachio orchard
Pumpkin	PKN	Fields planted in pumpkin
Railroad	RR	Any railroad
Road	RD	Over or on a paved road
Road median	RM	Side median strip along a paved road
Row crops	RC	Any row crop
Residence	RES	Agricultural-urban residence, incorporated urban communities

Table 14 continued. Crop categories, their codes, and descriptions.

Name	Code	Description
Restored	RST	Areas that have been restored to natural conditions (e.g., gravel pits)
Ruderal area	RUD	Open, vacant lot
Ryegrass	RYE	Field planted in ryegrass
Safflower	SAF	Safflower field
Sunflower	SF	Sunflower field
Sorghum	SRG	Field planted in sorghum
Tomatoes	TOM	Field planted in tomatoes
Triticale	TRI	Fields planted in Triticale
Walnut	WAL	Any walnut orchard
Wheat	WHT	Fields planted in wheat

Table 15. Crop combined classifications for Chi-square foraging analysis. Continued on next page.

Name	Code	Crop Categories Included
Alfalfa	ALF	Alfalfa
Almond	ALM	Almond
Corn	CRN	Corn, Sorghum
Orchard-Vineyard	OR-VIN	Stonefruit, Apple, Cherry, Plum, Pomegranate, Vineyard
Grain Crop	GR	Barley, Oats, Wheat, Ryegrass, Triticale
Grazing-Annual Grass	GRZ-AGS	Annual Grass, Fresh Emergent Wetland, Grazing, Lacustrine, Pastureland
Hay field	HAY	All hayfields other than Alfalfa
Idle farmland	IDL	Idle farmland
Natural	NAT	Blue Oak Woodland, Valley Riparian, Willow Scrub, Valley Oak Woodland, Restoration
Residential	RES	Agricultural-urban and Urban residences
Sunflower-Safflower	SF-SAF	Sunflower, Safflower
Tomato-Row Crop	TOM-RC	Tomato, All row crops

Table 15 continued. Crop combined classifications for Chi-square foraging analysis.

Name	Code	Crop Categories Included
Walnut	WLN	Walnut
Other	OTHER	Aggregate mining, Agricultural-industry, Cemetery, Industrial, Rice

Table 16. Crop combined classifications for logistic regression analysis. Continued on next page.

Name	Code	Crop Categories Included
Aggregate Mine	AGM	Aggregate Mining Operation
Agricultural-industry	AGI	Aggregate mining, Agricultural-industry, Cemetery, Conifer, Eucalyptus, Industrial, Rice
Annual Grass	AGS	Annual Grass, Freeway medians, Road medians
Alfalfa	ALF	Field planted in alfalfa
Almond	ALM	Almond orchard
Corn	CRN	Corn, Sorghum
Deciduous Orchard	DOR	All orchards other than Almond and Walnut, Vineyards
Grain Crop	GR	Barley, Oats, Ryegrass, Triticale
Grazing	GRZ	Fresh Emergent Wetland, Grazing, Lacustrine, Pastureland
Hay field	HAY	All hayfields other than Alfalfa
Idle farmland	IDL	Idle farmland
Natural	NAT	Blue Oak Woodland, Valley, Riparian, Willow Scrub, Valley Oak Woodland

Table 16 continued. Crop combined classifications for logistic regression analysis.

Name	Code	Crop Categories Included
Residential	RES	Agricultural-urban residences and Urban
Restoration	RST	Any restoration site
Row Crop	RC	All row crops other than Tomato
Sunflower-Safflower	SF-SAF	Sunflower, Safflower
Tomato	TOM	Field planted in Tomato
Walnut	WLN	Walnut orchard
Wheat	WHT	Field planted in wheat

Table 17. California Wildlife Habitat Relationships (CWHR) combined classifications for logistic regression analysis.

Name	Code	Crop Categories Included
Annual Grassland	AGS	Annual Grass, Freshwater Emergent Wetland, Lacustrine, Irrigated Pasture,
Aggregate Mining	AGM	Aggregate Mining
Agricultural-urban	AGU	Agricultural-urban
Eucalyptus-Conifers	EUC-CON	Industrial Eucalyptus and Conifer groves
Dryland Grain	DGR	Dryland Grain
Orchard	OR	Deciduous Orchards, Evergreen Orchards, Vineyards
Idle Farmland	IDL	Idle Farmland
Irrigated Row- Field Crops	IRF	All irrigated row crops field crops
Irrigated Hay	IRH	Irrigated Hay
Irrigated Grain	IRG	Irrigated Grain
Rice	RIC	Rice
Urban	URB	Urban
Valley Foothill Riparian	VFR	Barren, Blue Oak Woodland, Valley Oak Woodland, Valley-Foothill Riparian, Willow Scrub

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