STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME
WILDLIFE MANAGEMENT DIVISION
NONGAME BIRD AND MAMMAL SECTION

BIOLOGY, MOVEMENTS, AND HABITAT RELATIONSHIPS OF THE SWAINSON'S HAWK IN THE CENTRAL VALLEY OF CALIFORNIA, 1986-87

by

James A. Estep

1989

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ABSTRACT

Four 93.6 sq km (36 sq mi) study plots were used to examine Swainson's Hawk biology, movements and habitat-use during the 1986 and 1987 breeding seasons. Thirty different land-uses or crop-types were identified for the total area studied. Croplands made up 45.4% of the area, and pasturelands made up 26.8%. The remaining lands (27.8%) were in various other uses. Sixty active Swainson's Hawk nests were located on all areas studied during the two years of field work. Breeding density ranged from 0.796 pairs/sq km (0.306/sq mi) to 1.446 pairs/sq km (0.556/sq mi). Nearest neighbor distances averaged 1.14 km (0.71 mi). Territory reoccupancy was 97%. Reproductive effort was low both years; 1.14 young/occupied nest and 1.33 young/successful nest (1986), 1.17 young/occupied nest and 1.44 young/successful nest (1987). Diet, in terms of biomass, consisted of 23.1% microtine rodents, 69.2% of the total mammalian prey. Birds were an important dietary component, comprising 49.8% of the total prey biomass.

The mean home range size of 12 radio-tagged Swainson's Hawks was 2760.4 ha (6818.2 ac). Males averaged 46.1% larger home ranges than females. Cropping patterns, changes in prey availability, and various farming practices were largely responsible for differences in home range size and seasonal and daily fluctuation of foraging ranges. Daily foraging ranges were from 12.2 ha (30.1 ac) to 6407.9 ha (15,763.4 ac). Swainson's Hawks preferred foraging cover-types, such as alfalfa and dryland pasture, that supported continually available prey. However, certain row crops were selected during harvest due to the sudden increase in prey availability and higher prey densities. Communal foraging occurred in areas where nesting habitat was limited but suitable foraging habitat remained. Hunting in response to various farming activities (e.g. mowing, harvesting, discing, and irrigation) accounted for 52.8% of the observed foraging time. Late in the season, large groups of Swainson's Hawks congregated in response to harvesting operations and the abundance of available prey that resulted. Nonbreeding groups of Swainson's Hawks were observed throughout much of the breeding season.

Most nests (78.1%) were located within riparian systems. Swainson's Hawks also nested successfully along busy roads and near human habitation. Use of alternate nest-sites was common. All nests were located on or adjacent to suitable Swainson's Hawk foraging habitat.

Given current trends, expansion of the type of agricultural and other land-use practices known to be incompatible with the habitat needs of the Swainson's Hawk is likely to continue in the Central Valley in the future. Loss of both nesting and foraging habitat to various kinds of development poses the greatest threat to the Central Valley population of Swainson's Hawk.

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RECOMMENDATIONS

1. Periodically survey Swainson's Hawk breeding habitat throughout the Central Valley to estimate the distribution and size of populations, monitor land-use trends, habitat changes, and known territories.

2. Develop management strategies to ensure protection of Swainson's Hawk habitat.

3. Preserve and protect riparian habitats essential to breeding Swainson's Hawks through legislation, acquisition, and private landowner cooperation.

4. Create nesting habitat throughout the breeding range of the Swainson's Hawk where the lack of nesting habitat is a limiting factor.

5. Encourage compatible agricultural practices for Swainson's Hawks through a program of incentives for the private landowner.

6. At the local government level, ensure that the habitat needs of the Swainson's Hawk are recognized and included in city and county development plans.

7. Determine the status of populations and habitat of Swainson's Hawks on their migration routes and wintering grounds.

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INTRODUCTION

Once common throughout most of lowland California (Grinnell and Miller 1944), the Swainson's Hawk (*Buteo swainsoni*) currently occupies only a small portion of its former breeding range (Fig. 1). Knowledge that an estimated 91% decline in the breeding population had occurred (Bloom 1980) moved the Fish and Game Commission to designate the Swainson's Hawk as a Threatened species in 1983. Causes contributing to the population decline are the same as those that have impacted much of California's wildlife, primarily loss of habitat as a result of the conversion of native vegetative communities to agricultural and urban land-uses. Conditions on the wintering grounds in South America may also contribute to the decline; however, little is known concerning this aspect of the Swainson's Hawk's life cycle. Apparently pesticide contamination of the food chain is not interfering with annual reproduction (Risebrough et al. in press).

Two populations comprise the current Swainson's Hawk range in California. In northeastern California, primarily Modoc, Siskiyou, and Lassen Counties, Swainson's Hawks occupy the upland Juniper-sage/steppe community and the agricultural valleys typical to this region. This area is the southwestern-most corner of the Great Basin population of Swainson's Hawk. The more isolated Central Valley population is within the confines of the Sierra Nevada and Coast ranges, in the fertile and intensively farmed agricultural regions of the Sacramento and San Joaquin Valleys. Bloom (1980) estimated that 375 pairs of Swainson's Hawks continue to nest in California, 280 of these in the Central Valley.

As with other North American raptor populations (Garrett and Mitchell 1973, Colvin 1985), the decline of the Swainson's Hawk in California may be primarily a result of agricultural conversion of native habitats. Since the latter part of the 19th century, the Central Valley has undergone a dramatic conversion of native communities to agricultural lands. For example, agricultural conversion has been the main force contributing to the removal of approximately 98% of the riparian forest that once existed in the Central Valley (Katibah 1983). Perennial grassland (primarily *Scirpus sp.* and *Typha sp.*) and Valley Oak (*Quercus lobata*) woodlands were once the dominant upland communities in the northern Central Valley while saltbush (*Atriplex sp.*) desert was common in the southern Central Valley. In addition to riparian systems, other wetland communities were found extensively throughout the Central Valley, existing primarily as a result of the seasonal flooding of the major drainages, the Sacramento and San Joaquin Rivers (Katibah 1983).

The Swainson's Hawk is generally regarded as a western plains species, closely associated with open grassland communities. The species was apparently common historically throughout the Central Valley (Grinnel and Miller 1944). Today, however, the Swainson's Hawk is found primarily in the mid-section of the Central Valley in the vicinity of Sacramento.

Few pairs nest in the northern and southern extremes of the Central Valley. Detrich (1986) considered the lack of a suitable forage base, particularly microtine rodents, as the reason for the few numbers of nesting Swainson's Hawks in Shasta and Tehama Counties, in the northernmost part of the Central Valley. The primary factors responsible for reducing prey populations were thought to be the conversion of perennial grassland to exotic annuals, coinciding with the introduction of livestock.

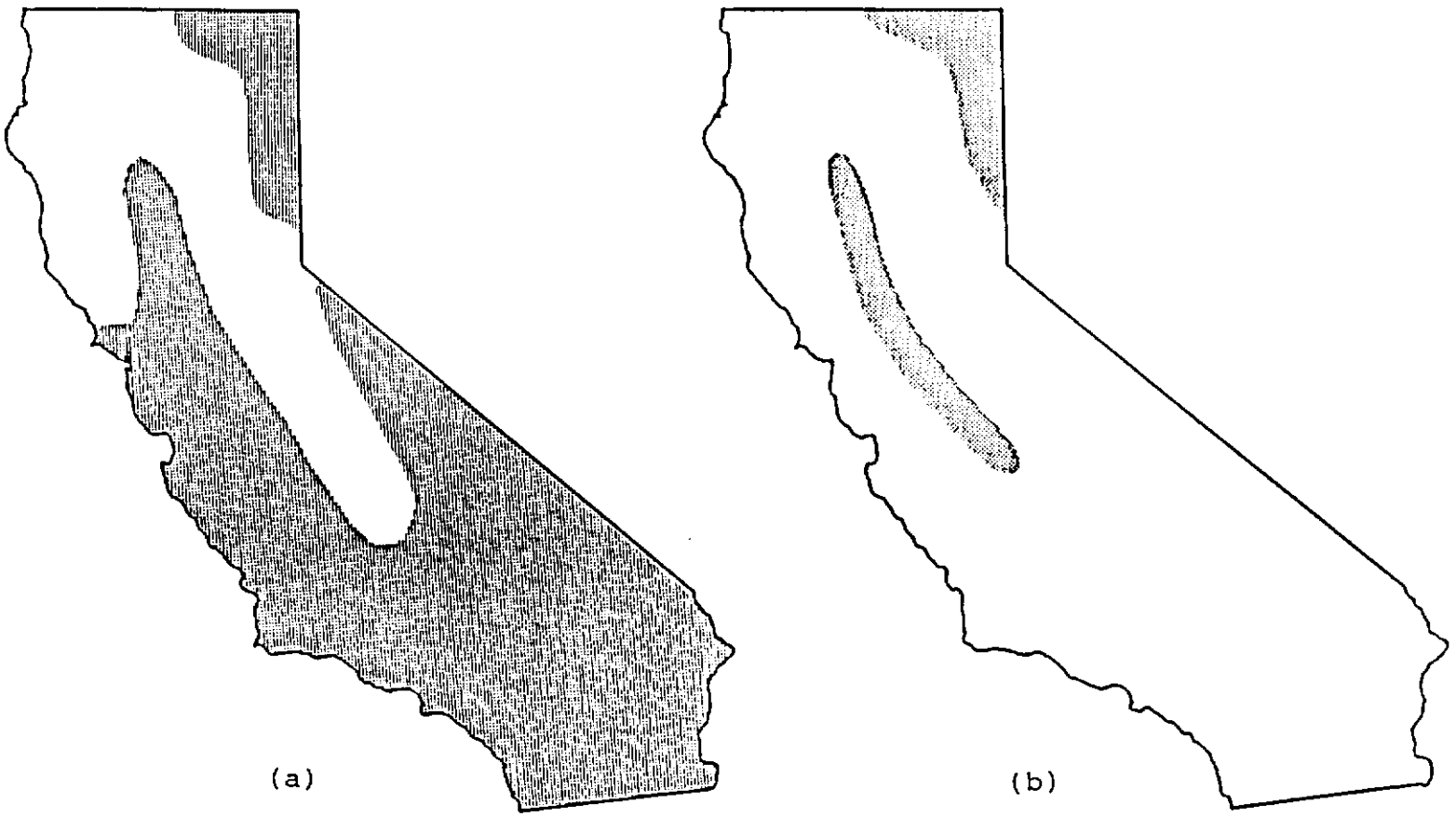

Figure 1. Historic (a) and current (b) (shaded area) range of Swainson's Hawk in California. (After Bloom 1980.)

The southern part of the Central Valley, the southern San Joaquin Valley, is largely devoid of suitable nest trees, due to agricultural conversion of the native vegetation. Bloom (1980) located only one nesting pair south of Fresno County. In addition, the present-day agriculture in this region, primarily cotton and vineyards, is incompatible with Swainson's Hawk's hunting style.

The Swainson's Hawk has, however, shown a certain ability to adapt to particular kinds of agricultural conversions that continue to replace native grassland habitat range-wide (Olendorff 1973, Munro and Reid 1982, Bechard 1982, Schmutz 1984, Woodbridge 1985). Virtually no native foraging habitat remains in the mid-section of the Central Valley. This is a region of intensively farmed croplands, pasturelands, and both large and small urban areas. Conversion to agricultural land-uses incompatible with Swainson's Hawk foraging needs and continued reduction of available foraging habitat from urban development could further impact the Central Valley population. Maintaining a viable population of Swainson's Hawks in the Central Valley while faced with incompatible land-use trends, requires information beyond that of basline population data. To help in fulfilling this need, this study was proposed.

The purpose of this study was to investigate the habits, movements, and habitat-use and relationships of the Swainson's Hawk in the Central Valley. The objectives were to: 1) determine home ranges of Swainson's Hawks in the Central Valley through radio-telemetry; 2) examine Swainson's Hawk foraging behavior and use of agricultural habitats; 3) determine the effect of cropping patterns on movement and habitat-use; 4) determine nesting habitat use and availability; 5) examine prey populations and Swainson's Hawk diet; 6) determine reproductive success, and, 7) examine Central Valley land-use trends.

STUDY AREA

Overview

The study area consisted of four, separate 93.6 sq km (36 sq mi) square sites located between Sacramento and a point 32 km (20 miles) south of Stockton (Fig. 2). This is the region of highest Swainson's Hawk breeding density in the Central Valley (Estep unpubl. data.) Similar in topography (mean elevational difference = 14.5 m (47.6 ft)) and diversity of land-use/cover-types, the study areas differed in the percentages and distribution of those cover-types. The result was that the four study areas combined to represent the range of nesting and foraging conditions typical for the species in the Central Valley.

Historically, the Central Valley consisted of a variety of vegetative communities, including marsh, riparian systems, oak woodland, and grassland. Today, these communities are virtually lost or radically altered, replaced by one of the most intensive and diverse agricultural industries in the world (Fig. 3). In general, the study area was a combination of intensively farmed croplands, pasturelands, and expanding urban development. The climate is generally mild, with cool, wet winters, and hot, dry summers. The mean annual precipitation in the study area ranges from 33.0 cm (13.0 in) in the south to 43.2 cm (17.0 in) in the north.

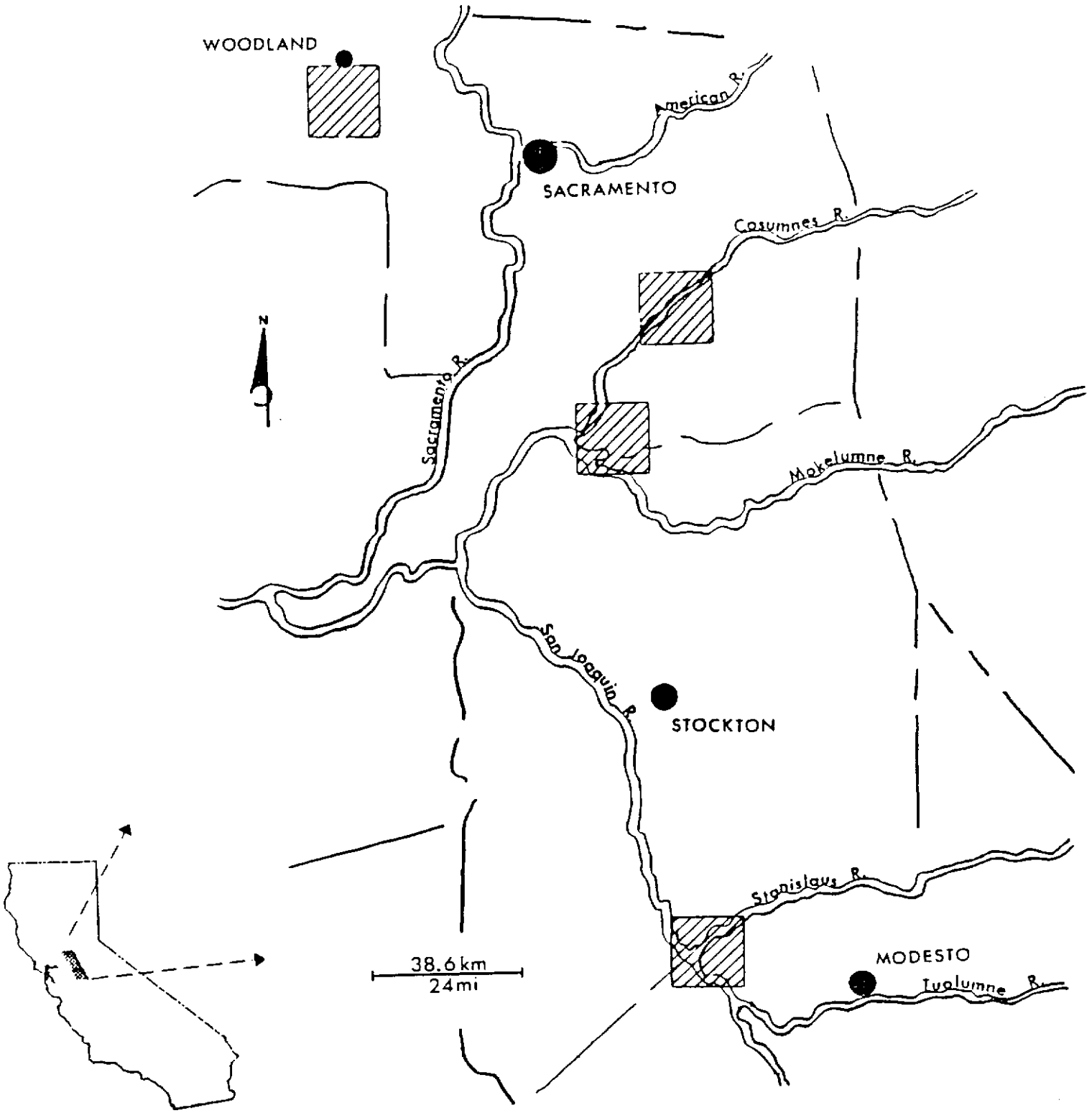

Figure 2. Location of four Swainson's Hawk study areas (cross-hatched squares) in the Central Valley of California, 1986-87.

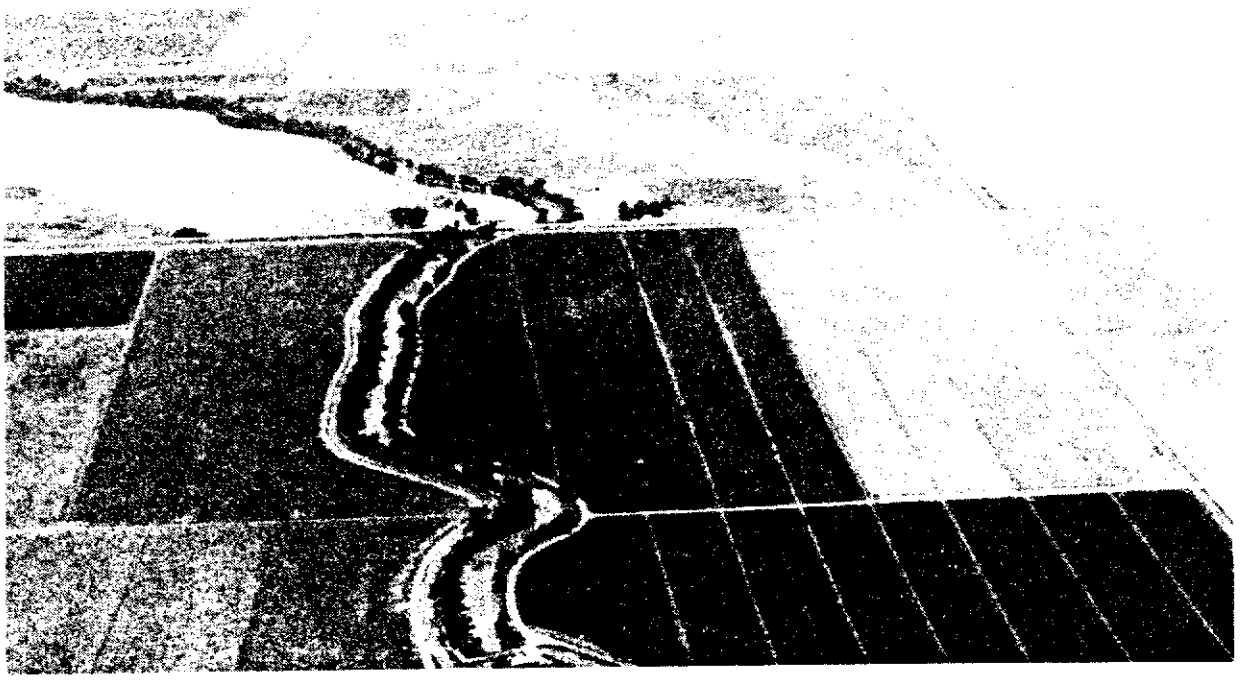

Photo by Ronald W. Schlorff

Figure 3. Aerial view of the Woodland study area showing typical land-use throughout much of the Central Valley. The narrow riparian system and the surrounding farmland provide important nesting and foraging habitat for Central Valley Swainson's Hawks.

Woodland Study Area

Woodland is the northernmost of the four study areas (Fig. 2), located between the cities of Davis and Woodland, approximately 29 km (11 mi) west of Sacramento. The area is characterized by flat, relatively treeless terrain and a criss-crossing network of roads (Fig. 3). Intensive row and grain crop farming is the primary land-use. Willow Slough and Dry Slough are the only natural waterways through the study area, each supporting a relatively small amount of suitable riparian nesting habitat. One freeway dissects the area and a small amount of high density residential development from the city of Davis is located along the southern boundary.

Wilton Study Area

The Wilton study area is approximately 39 km (15 mi) south of Sacramento (Fig. 2). Urbanization has accelerated in this area recently as residential growth expands southward from Sacramento. Low density residential development (1 to 5 acre parcels) is the primary land-use in the northwest and eastern portions of the study area. Much of the south is either irrigated or dryland pasture. Irrigated farmland is the primary land-use between the two main waterways, the Cosumnes River and Deer Creek, which run parallel with each other from the northeast corner to the southwest corner of the study area. Both support a narrow, but dense, riparian system throughout their length. The terrain is generally flat in the west and south, while much of the east is gently rolling hills.

Galt-Thornton Study Area

The Galt-Thornton study area is located between the cities of Galt and Thornton, approximately 57 km (22 mi) south of Sacramento (Fig. 2). A mixture of croplands, pasturelands, and low density residential development characterize this study area. Much of the eastern portion of the site is residential with associated small irrigated pastures and small tracts of farmland. The northwest is mainly cropland and much of the south and central is irrigated pasture. Cosumnes River, Mokelumne River, Dry Creek, Grizzly Slough and Bear Slough traverse the study area, each supporting a relatively large riparian system.

Vernalis Study Area

The Vernalis study area is the southernmost site, located near the town of Vernalis, approximately 52 km (20 mi) south of Stockton (Fig. 2). Two major rivers separate the extensive pasturelands in the east and central region from the main agricultural areas in the north and west. The southwest corner is a nearly treeless intensively farmed area. Both rivers, the Stanislaus and the San Joaquin, support relatively large riparian forests. Of all the study areas, Vernalis has the least amount of residential development. One highway traverses the southern half of the study area.

METHODS

Nest and Land-use Surveys

I surveyed known nest sites in March 1986 and 1987 to determine arrival dates of Swainson's Hawks into the Central Valley. In April survey effort increased

to locate all breeding pairs of Swainson's Hawks and other stick-nest building raptors in each study area. Breeding densities were calculated for all raptor species in each study area. Periodic visits were made to nest-sites throughout the season to collect productivity data, take nest and tree measurements, and to collect prey remains. Land-use was determined by surveying each study area by car, airplane, and on foot. All cover-types were recorded on USGS 1:24,000 topographic maps. Area measurements were calculated for all cover-types within each study area and home range using a planimeter with three-axis digitizer.

Radio-telemetry and Home Ranges

Swainson's Hawks were trapped using the Dho-Gaza capture technique (i.e. mist net with a live Great-horned Owl (*Bubo virginianus*) as a lure)). Birds were banded with numbered, colored plastic leg bands and standard USFWS aluminum bands. In 1986, two adult Swainson's Hawks (1 male and 1 female) from the Woodland study area were fitted with backpack-mounted AVM SB2 radio-transmitters. In 1987, 10 adult Swainson's Hawks (7 males and 3 females) were fitted with longer-lived AVM P-2 radio-transmitters. Receiving devices included Telonics TR1 and TR2 receivers, with 2 element H-antennas and 3 element Yagi antennas.

I constructed individual range maps for each radioed bird. All of the cover types on each map were delineated and given unit numbers. Exact location (unit number), activity, condition of unit (mature growth, harvested field, etc.), and farming activity in each recorded unit (irrigating, mowing, harvesting, discing) were recorded. Types of activity recorded included perching, incubating, foraging flight, nonforaging flight, prey capture attempt, feeding, and foraging in response to farming activities.

Movements of radioed birds were recorded from May to September, 1986 and 1987. All birds were from different breeding pairs. Swainson's Hawks in the Central Valley are very active foragers, covering large areas in a short amount of time. Therefore, to more effectively analyze habitat-use and foraging behavior, data were recorded in 5 minute intervals over 4 hour observation periods. Observation periods for each bird alternated between morning and afternoon hours for complete day-long periods.

I estimated home range and foraging range areas using a modified minimum polygon method (Harvey and Barbour 1965). This method excluded much of the unused area between nests and distant foraging habitats from home range and foraging range calculations.

Autocorrelation of locational data usually results when a short time interval between recorded locations is used. However, a reasonably accurate estimate of home range size was expected due to the large number of locations recorded, over a long time frame, thus reducing the effect of autocorrelation (Swihart and Slade 1985).

Habitat-use

Habitat preference data were analyzed using the FORTRAN program PREFER, a habitat-use/availability ranking technique (Johnson, 1980). The percentage of each available cover-type in each home range and the percent use of each cover-type was determined. Next, preference, through ranking of each cover-

type, for each individual and averaging across all birds was determined. Finally, it was determined which cover-types were preferred in relation to each other.

Prey populations and Food Habits

I estimated the relative abundance of rodent prey populations in various cover-types using a mark-recapture technique. From May to September, 1986-87, small mammals were captured in Sherman live-traps and individuals marked by toe-clipping. Traps were set 15 m (49.2 ft) apart in a seven by five rectangular grid of 35 traps. Traps were opened for three consecutive days, once a month.

Swainson's Hawk diet was examined through the direct observation of foraging hawks, recording of prey remains at the nest site, and the analysis of recovered regurgitated pellets. These data were collected on a regular basis from April to September, 1986 and 1987.

Nesting Habitat

I estimated nest tree availability in each study area by counting all suitable lone trees and groups of trees, and by measuring the extent of suitable riparian nesting habitat. Measurements were taken of individual nests and nest trees, including nest height and nest-tree height, diameter at breast height (DBH), diameter of supporting limbs, and nest diameter. Heights were measured using an abne level. Nearest neighbor distances were calculated for nest sites in each study area.

Nest-site and Mate Fidelity

As part of a continuing project to study nest-site and mate fidelity among Central Valley Swainson's Hawks, adult Swainson's Hawks were trapped and banded with colored, numbered plastic leg bands. For purposes of this study, I attempted to reestablish contact with birds in 1987 and early 1988 that were color-banded the previous year. There are plans to continue this study over several years in order to obtain additional data.

Statistical Methods

The FORTRAN program PREFER (Johnson 1980) was used to analyze habitat-use data. Habitat components were ranked by preference such that differences among habitats could be tested for significance. Two null hypotheses were tested: 1) all habitats were equally preferred; 2) selection of habitat component "i" equals that of habitat component "j". The first null hypothesis was tested using Hotelling's T statistic (Anderson 1958). The second null hypothesis was tested using the Waller-Duncan multiple comparisons procedure (Waller and Duncan 1969).

Correlations of some paired data were determined from calculations of Pearson Product-Moment Correlation Coeffecients. The t-test was used to determine differences between means.

The confidence level for statistical tests was 0.95.

RESULTS

Land-use and Habitat Characteristics

The land-use in the mid-section of the Central Valley is primarily agricultural; however, urban development is rapidly expanding. The total study area encompassed 37,957 ha (93,754 ac). Intensively farmed cropland made up 45.4% of this area, and 26.8% was irrigated or dryland pasture. Thirty cover-types were identified for the total area (Table 1). Nearly ten percent of the study area was residential development.

The study areas differed mainly in the percentages and distribution of the various cover-types. The Woodland study area was a mosiac of similarly sized (mean = 51.6 ha (127.5 ac)) individual fields. The variety of cover-types and the percentage of croplands was the highest of the four study areas (Table 1). Twelve crop-types made up 79.4% of the area. Only 1% of the area was pastureland. The two waterways (Willow Slough and Dry Slough) in the study area supported very narrow riparian systems (0.9%). Much of the sloughbanks had been denuded as a result of local farming practices. However, some of what remained was excellent Swainson's Hawk nesting habitat. Trees not associated with riparian systems (referred to here as upland trees or upland nesting habitat) were few, (potential upland nest-sites = 5.04/sq km (1.97/sq mi)) mostly roadside Walnut (*Juglans sp.*) and isolated Valley Oaks (*Quercus lobata*).

By contrast, the Wilton study area was divided into distinct areas of residential (26.9%), pasture (24.3%), and cropland (25.5%). The remaining 23.3% was in other cover types (Table 1). The mean cropland field size was 58.6 ha (144.7 ac). Pasturelands included both large and small irrigated pastures and large unbroken areas of dryland pasture. Mature riparian forest (3.4%) existed throughout the lengths of Deer Creek and the Cosumnes River. Upland trees included a small amount of remnant oak woodland (2.5%) and isolated Valley Oaks (Potential upland nest-sites = 5.41/sq km (2.11/sq mi)).

The Galt-Thornton study area was a mixture of croplands (mean field size = 51.6 ha (127.5 ac)) and large and small pastures (mean = 198.9 ha (491.3 ac)). Irrigated pasture was the dominant cover-type (33.7%). Corn was the dominant crop-type comprising 8.9% of the total area. Potential nesting habitat was more evenly distributed throughout this study area. All of the waterways (Cosumnes River, Mokelumne River, Dry Creek, Grizzly Slough and Bear Slough) supported dense, mature riparian systems (7.3%). In addition, upland trees (primarily Valley Oak) were more abundant here (potential upland nest sites = 9.46/sq km (3.69/sq mi)) resulting in less open, treeless terrain.

The Vernalis study area consisted of a 2631.8 ha (6500.5 ac) tract of irrigated pasture surrounded by cropland (mean field size = 53.5 ha (132.1 ac)). Irrigated pasture was the dominant cover-type (45.4%) and was the highest of the four study areas (Table 1). The Vernalis study area also had the highest percentage of riparian systems (14.6%). Both the San Joaquin and Stanislaus Rivers supported mature riparian forests on a relatively wide flood plain. Upland trees were also relatively abundant here (potential upland nest sites = 8.89/sq km (3.47/sq mi)).

Most fields were cultivated to the edge of riparian systems, restricting the outward expansion of riparian vegetation and resulting in little remaining

Table 1. Percentages of land-uses and crop-types on the four Swainson's Hawk study areas in the Central Valley, 1986.

Land-use	Woodland	Wilton	Galt/ Thornton	Vernalis	Total
Irrigated-pasture	1.0	24.3	33.7	32.9	23.0
Wheat	30.2	2.7	4.3	10.8	12.0
Corn	8.5	12.1	8.9	7.0	9.1
Low density residential	0.0	26.9	8.2	0.0	8.8
Roads, edges, channels, etc	8.4	7.2	8.7	6.1	7.7
Riparian	0.9	3.4	7.3	14.6	6.6
Alfalfa	7.9	0.0	2.3	9.2	4.8
Dry-land pasture	0.0	10.7	4.4	0.0	3.8
Tomatoes	12.2	0.4	0.0	1.9	3.6
Vineyard	0.1	2.5	7.6	3.2	3.4
Disced field	8.3	0.4	0.2	0.0	2.2
Beets	3.1	0.0	0.0	1.9	2.0
Rice	0.4	1.2	4.3	0.6	1.6
Oak woodland	0.0	2.5	3.0	0.0	1.4
Unidentified cropland	0.0	0.8	3.3	1.7	1.4
Oats	1.1	2.1	0.0	0.0	1.3
Fallow	2.8	2.5	0.5	0.0	1.3
Orchard	0.9	0.0	0.0	3.2	1.0
High density residential	3.2	0.0	0.7	0.0	1.0
Beans	0.0	0.0	0.0	3.0	0.8
Grass	6.3	0.0	0.0	0.0	0.7
Barley	0.0	0.0	0.0	2.3	0.6
Safflower	1.0	0.0	0.7	0.0	0.4
Peppers	0.0	0.1	1.0	0.0	0.3
Sunflower	2.2	0.0	0.0	0.0	0.2
Asparagus	0.7	0.0	0.0	0.0	0.2
Clover	0.0	0.2	0.7	0.0	0.2
Onions	0.0	0.0	0.0	0.7	0.2
County park	0.0	0.0	0.0	0.9	0.2
Golf course	0.8	0.0	0.0	0.0	0.2
	100%	100%	100%	100%	100%

oak woodland (5.5%). Sections of some streams were completely denuded of riparian vegetation. Riparian vegetation was dominated by Valley Oak in all study areas. Less common overstory species included Fremont Cottonwood (*Populus fremontii*), Walnut sp., Willow (*Salix sp.*), Box Elder (*Acer negundo*), Sycamore (*Platanus racemosa*), and Oregon Ash (*Fraxinus latifolia*). The more common midstory species included Wild Rose (*Rosa californica*), Poison Oak (*Rhus diversiloba*), California Blackberry (*Rubus vitifolius*), and Blue Elderberry (*Sambucus caerulea*).

Potential upland nest trees were of three types: roadside trees, usually Walnut or Eucalyptus (*Eucalyptus sp.*); lone trees, usually non-regenerating Valley Oaks isolated in the middle of an agricultural field or pasture; and rural farmhouse trees, usually Walnut or Eucalyptus surrounding a farmhouse.

Edge habitat was generally associated with croplands. Edges consisted of a variety of plants typically associated with disturbed areas (Appendix 1). Edges usually bordered irrigation ditches which divided individual fields. Some of these narrow strips, usually three to four meters wide, were permanent irrigation canals; however, most were temporary ditches, filled in after each harvest.

Fallow fields generally consisted of many of the same plants as edge habitat (Appendix 1). Some fallow fields were disced periodically to keep the weedy vegetation from maturing. In some fields, regeneration of the weed flora was extremely rapid.

Disced fields were those without any vegetation. Some were disced periodically to prohibit weed growth, others were prepared for planting, but never planted. The use of herbicides, both selective and broad spectrum, was very common, both to control weeds in maturing crops and to prohibit the growth of weeds in harvested or disced fields.

Most row crops were planted in the spring and matured while Swainson's Hawks were nesting. Harvest began in late July and continued through September. Many crops, particularly corn, sunflowers, beans, and safflower, were still largely unharvested by the time Swainson's Hawks began migration to their wintering grounds.

Wheat, a major grain crop in the Central Valley and particularly in the Sacramento Valley, was planted in early winter. By the time Swainson's Hawks began arriving in March, wheat fields were nearing mature growth. Most wheat was harvested in early June. After harvest, most wheat fields were left as wheat stubble for several weeks to several months, and eventually disced in preparation for the following years crop.

Alfalfa was the primary hay crop in all study areas. Mowed and bailed once a month, its vegetative cover was less than that of maturing row and grain crops. Unlike row and grain crops that are harvested and replanted each year, a single alfalfa planting may remain and continue to produce hay in a particular field for up to six years in the Central Valley.

Row and grain crops were rotated annually. The proportions of the major crop-types were similar from 1986 to 1987 in the study area, however, the distribution of the various crop-types was different between the years.

I divided residential development into high density (suburban housing) and low density (rural or ranchette development, 1 to 5 acre parcels) (Table 1). High and/or low density residential developments were in construction or planned in all study areas except Vernalis.

Breeding Season Chronology

Swainson's Hawks began arriving in the Central Valley in early to mid-March. The earliest observed arrival date in the study area was 11 March in 1986, and 12 March in 1987. Courtship and nest construction and repair activities began immediately upon arrival. The latest arrival date was 3 April 1986 and 4 April 1987. Most clutches were laid by mid-April, and the first nestlings appeared from mid to late-May. The first fledgling was observed on 4 July 1986, and 1 July 1987. Most birds left their breeding territories in late-August to early-September. The earliest departure date was 28 July 1987. The latest was 24 September 1987.

Breeding Density and Spatial Characteristics

In 1986 I located 39 pairs of nesting Swainson's Hawks in the four study areas. In 1987 I located 60 pairs (Fig. 4). The increase was probably due to an increase in survey intensity in areas where birds were not located the previous year, and the difficulty of locating nests in more inaccessible areas, rather than a population increase. Territory reoccupancy from 1986 to 1987 was 97%, with only one of 39 territories unoccupied in 1987. Nesting pairs of Red-tailed Hawks (*Buteo jamaicensis*), Red-shouldered Hawks (*Buteo lineatus*), and Black-shouldered Kites (*Elanus caeruleus*) were also located in each study area. Breeding densities were calculated for all species (Table 2). Swainson's Hawk breeding densities ranged from 0.796/sq km (0.306/sq mi) (Wilton) to 1.446/sq km (0.556/sq mi) (Woodland) and averaged 1.084/sq km (0.417/sq mi) for the four study areas combined. The highest density of all nesting raptors was found in the Galt-Thornton study area (3.539/sq km (1.36/sq mi)). Swainson's Hawks were the most abundant of the four surveyed raptor species overall, particularly in the Woodland study area, where they accounted for 56% of the nesting raptors surveyed.

There was no statistical relationship between breeding density and nest-site availability ($P > 0.05$). However, nesting habitat alone did not appear to be a breeding density limiting factor, since there were unoccupied potential nest-sites in all four study areas. Breeding density was highest in the Woodland study area (Table 2), which supported the least amount of available nesting habitat, while the Galt-Thornton study area supported the second highest amount of available nesting habitat and the second highest breeding density.

I calculated nearest neighbor distances (Clark and Evans 1954) for the nest-site distribution of Swainson's Hawks in each study area. In general, the distribution of Swainson's Hawk nest-sites followed the distribution of riparian systems (Fig. 4), the primary nesting habitat of Swainson's Hawks in the Central Valley (Estep 1984). The mean distance between nest sites was 1.14 km (0.71 mi) and ranged between 1.08 km (0.67 mi) (Wilton) to 1.18 km (0.73 mi) (Galt-Thornton) for the four study areas. The nearest distance between nests was 0.14 km (0.09 mi). Four nests in the Woodland study area were located along a 0.66 km (0.41 mi) stretch of Willow Slough (Fig. 4).

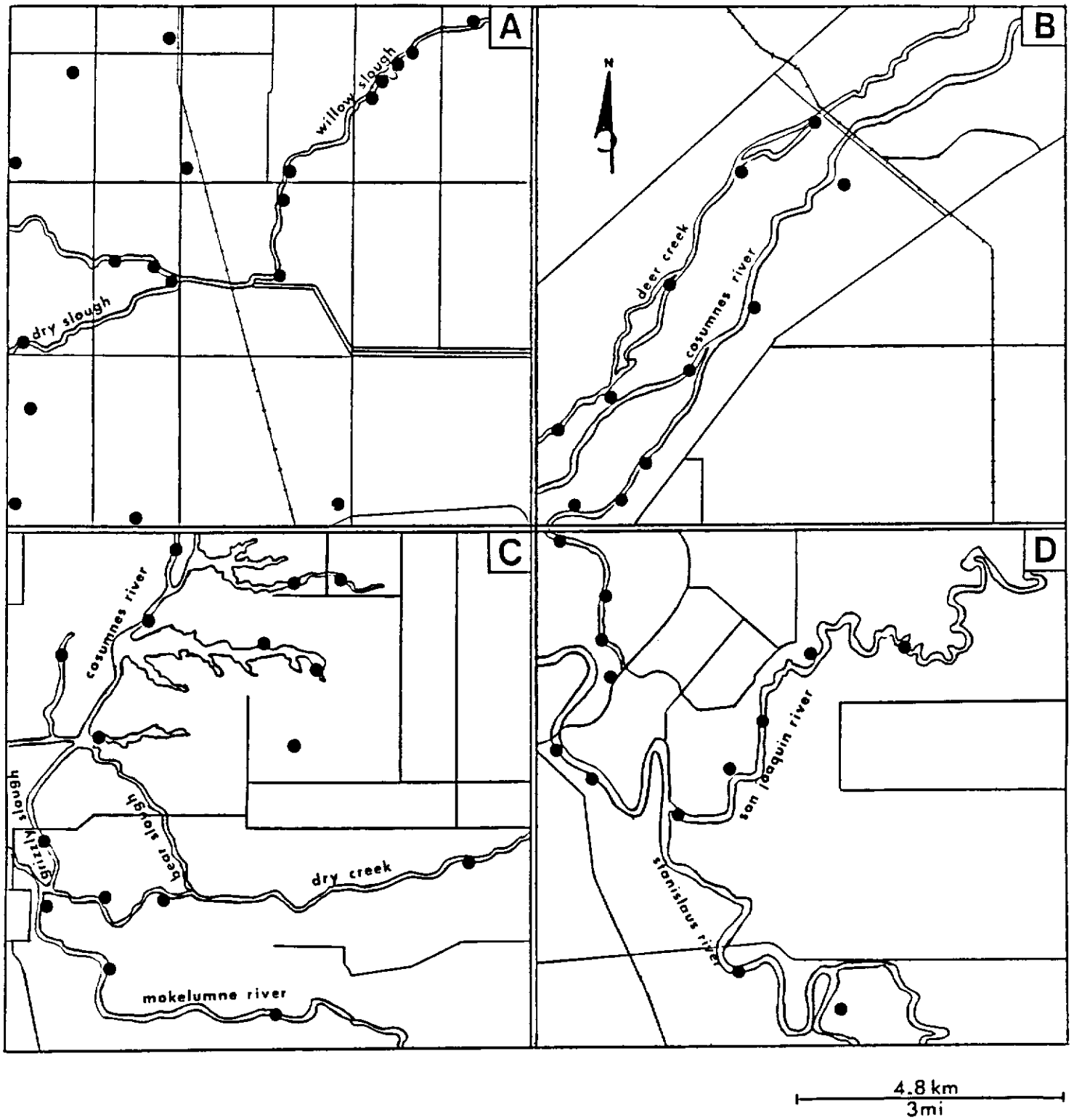

Figure 4. Swainson's Hawk nest locations (black dot) for each Central Valley study area (A-Woodland; B-Wilton; C-Galt-Thornton; D-Vernalis), 1987.

Table 2. Number of pairs and breeding densities of four raptor species in the Central Valley Swainson's Hawk study areas, 1987.

	Woodland	Wilton	Galt Thornton	Vernalis	Total
	#(#/sq km) (#/sq mi)	#(#/sq km) (#/sq mi)	#(#/sq km) (#/sq mi)	#(#/sq km) (#/sq mi)	#($\bar{x}$#/sq km) ($\bar{x}$#/sq mi)
Swainson's Hawk	20(0.21) (0.56)	11(0.12) (0.31)	16(0.17) (0.44)	13(0.14) (0.36)	60(0.16) (0.42)
Red-tailed Hawk	4(0.04) (0.11)	14(0.15) (0.39)	15(0.16) (0.42)	13(0.14) (0.36)	46(0.12) (0.32)
Red-shouldered Hawk	0(0.00) (0.00)	7(0.07) (0.19)	9(0.10) (0.25)	5(0.02) (0.14)	21(0.08) (0.15)
Black-shouldered Kite	12(0.13) (0.33)	6(0.06) (0.17)	9(0.10) (0.25)	2(0.02) (0.06)	29(0.08) (0.20)
Total #($\bar{x}$#/sq km) ($\bar{x}$#/sq mi)	36(0.38) (1.00)	38(0.41) (1.06)	49(0.52) (1.36)	33(0.35) (0.91)	156(0.42) (1.08)

Note: The corrections in Table 2 contained in this Errata are not reflected in the original text of the document.

Reproduction

Reproductive data were collected both years (Table 3). Due to the inaccessibility of many nests and the potential risk of causing nest abandonment during the incubation period (Fyfe and Olendorff 1976), data on clutch size and hatching success were not collected. A successful nest was defined as having fully fledged young. In 1986 I checked twenty-one nests in the Woodland and Wilton study areas. Eighteen were successful (85.7%) with 24 young fledged (Fig. 5). In 1987 I checked forty-eight nests (80%) from all four study areas. Thirty-nine (81.3%) were successful with 56 young fledged. The percentage of successful nests was high in the Central Valley, however, the number of young per occupied nest and successful nest was low (Table 3). Combining both years, 12 (17.4%) nests failed, 38 (55.1%) had 1 young, 15 (21.7%) had 2 young, 4 (5.8%) had 3 young, and none had 4 or more young. Eleven of the 12 radio-tagged birds successfully reproduced. There appeared to be no relationship between reproductive success and agricultural land-use. I found no statistical correlation ($P > 0.05$) between fledgling success and the amount of cultivated land or amount of pasture within Swainson's Hawk home ranges. Rather, the fledgling success of Swainson's Hawk pairs utilizing only cultivated land for foraging was similar to that of those utilizing pasturelands. There were no pairs, however, that foraged in pasturelands exclusively.

Prey Populations

I examined the differences in prey populations in twelve different cover-types. As a result of very low prey populations in several cover-types, I used a relative abundance index (the number of captures per 100 trap nights) to make comparisons between all cover-types (Table 4). Species trapped included California Vole (*Microtus californicus*), Deer Mouse (*Peromyscus maniculatus*), House Mouse (*Mus musculus*), Western Harvest Mouse (*Reithrodontomys megalotis*), and Black Rat (*Rattus rattus*). The House Mouse was the most commonly trapped rodent (52.8%). California voles, although important prey for the Swainson's Hawk in the Central Valley, were trapped in very low densities and in only four cover-types. This was partially due to their irregular distribution in agricultural areas (T. Marsh pers. comm.) and the difficulty of locating vole runways in agricultural fields. However, intensively farmed croplands are generally not conducive to high vole populations (T. Marsh pers. comm.).

Tomato and beet fields, each with dense, low-lying vegetation, supported relatively high rodent populations, compared with other row and grain crops (Table 4). Edges and fallow fields also supported relatively high populations. During the summer, croplands supported significantly higher rodent populations than pasturelands ($P < 0.01$, $t = 3.25$, d.f. = 9). In general, rodent populations increased as agricultural fields matured, then dropped to near zero after harvest and discing operations, while pasturelands maintained relatively constant, but low, populations.

Diet

During 1986 and 1987, I collected 451 Swainson's Hawk pellets from 21 nest sites. Twenty percent were then randomly chosen from each study area for a total of 90 pellets. These were analyzed to determine dietary composition (Table 5). The pellets contained 543 total prey items. Excluding four

Table 3. Swainson's Hawk reproductive data by study area, 1986-87.

	Woodland		Wilton		Galt Thornton		Vernalis		Total	
	86	87	86	87	86	87	86	87	86	87
#nests checked	16	19	5	10	-	10	-	9	21	48
#young fledged	19	18	5	12	-	12	-	14	25	56
% successful	81.3	68.4	100.0	90.9	-	80.0	-	88.9	85.7	81.3
% failed	18.7	31.6	0.0	9.1	-	20.0	-	11.1	14.3	18.7
#young/ occupied nest	1.19	0.95	1.00	1.20	-	1.20	-	1.56	1.19	1.17
#young/ successful nest	1.46	1.39	1.00	1.20	-	1.50	-	1.75	1.46	1.44

Photo by Philip J. Detrich

Figure 5. Typical successful Swainson's Hawk nest in the Central Valley with one young.

Table 4. Comparison of prey population indices (number of captures/ 100 trap nights) in 12 cover-types in the Central Valley, 1986-87.

	Prey						
Cover-type	M.m.[1/]	P.m.[2/]	R.m.[3/]	M.c.[4/]	R.r.[5/]	Total	%
Tomatoes	300.0	14.3	157.1	28.6	0.0	500.0	22.1
Beets	325.0	0.0	100.0	25.0	0.0	450.0	19.9
Edge	385.7	0.0	57.1	0.0	0.0	442.8	19.6
Fallow	16.7	200.0	8.3	8.3	0.0	233.3	10.3
Dryland pasture	16.7	183.3	0.0	0.0	0.0	200.0	10.3
Alfalfa	100.0	12.5	37.5	12.5	0.0	162.5	7.2
Riparian	0.0	0.0	0.0	0.0	83.3	83.3	3.7
Corn	0.0	66.7	0.0	0.0	0.0	66.7	2.9
Sunflowers	0.0	66.7	0.0	0.0	0.0	66.7	2.9
Irrigated pasture	33.3	0.0	0.0	0.0	0.0	33.3	1.5
Wheat	16.7	8.3	0.0	0.0	0.0	25.0	1.1
Disced field	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1194.1	551.8	360.0	74.4	83.3	2262.6	
% of total	52.7	24.4	15.9	3.3	3.7		100.0

1/ *Mus musculus*
2/ *Peromyscus maniculatus*
3/ *Reithrodontomys megalotis*
4/ *Microtus californicus*
5/ *Rattus rattus*

Table 5. Dietary composition as determined from regurgitated pellet analysis, prey remains, and observed prey captures by Swainson's Hawks in the Central Valley, 1986-87.

Species[1]	Number of Individuals	Percent Total Prey	Percent[2] Biomass
Meadow vole	92	15.0	23.1
Valley pocket gopher	11	1.8	5.8
Deer mouse	9	1.5	1.1
Western harvest mouse	3	0.5	0.3
Black rat	3	0.5	1.2
California ground squirrel	3	0.5	8.5
House mouse	2	0.3	0.2
Blacktail jackrabbit	1	0.2	0.5
Unidentified rodent	8	1.3	2.0
Unidentified mammal	1	0.2	0.6
(Total mammals)	(133)	(21.7)	(43.5)
Mourning Dove	7	1.1	4.9
Ring-necked Pheasant	6	1.0	15.1
Meadow Lark	4	0.7	2.6
Scrub Jay	2	0.3	0.8
Western Kingbird	2	0.3	0.6
Brewers Blackbird	1	0.1	0.4
European Starling	2	0.3	0.9
Black-headed Grosbeak	1	0.1	0.3
Cinnamon Teal	1	0.1	2.2
American Crow	1	0.1	2.2
Yellow-headed Blackbird	1	0.1	0.4
Wood Duck	1	0.1	3.7
Northern Flicker	1	0.1	0.9
Unidentified Sparrow	5	0.8	0.8
Unidentified raptor nestling	1	0.1	0.3
Unidentified passerine	16	2.6	5.2
Unidentified bird	14	2.3	8.8
(Total birds)	(66)	(10.8)	(49.8)
Gopher snake	2	0.3	0.6
Western toad	2	0.3	0.6
(Total reptiles and amphibians)	(4)	(0.6)	(1.3)
Crayfish	8	1.3	1.0
(Total crustaceans)	(8)	(1.3)	(1.0)
Grasshopper	244	39.9	3.1
Cricket	134	21.9	1.3
Silphadid	21	3.4	0.1
Dragonfly	1	0.2	3/
Pentatomidid	1	0.2	3/
(Total insects)	(401)	(65.5)	(4.4)

1/ Scientific names of animals listed in appendix 2.
2/ Weights of animals taken from Esten (1931), Evans and Emlen (1947), Wildlife and Fisheries Biology Museum, University California, Davis, and field weights from this study.
3/ < 0.1

pellets that were composed of only insect remains (in which as many as 100 individual prey items could be identified from a single pellet) the pellets averaged 3.4 items per pellet. In addition, 69 prey items were identified from prey remains found in or below nests, or from observed prey captures.

California voles were the most common mammalian prey item from all study areas (Table 5) and comprised 69.2% of the total mammalian prey. The California vole was the single-most important prey species in the Swainson's Hawk diet in the Central Valley, comprising 23.1% of the total prey biomass. Mammalian prey taken less frequently included Valley pocket gopher (*Thomomys bottae*), Deer mouse, Western harvest mouse, Black rat, California ground squirrel (*Spermophilus beecheyi*), House mouse, and Blacktail jackrabbit (*Lepus californicus*).

Birds were an important dietary component in terms of variety, percent of total prey items, and percent biomass (Table 5). Bird remains were found in 41.1% of all pellets, and overall, made up a greater portion of the percent biomass (49.8%) than did mammals (43.5%). This is somewhat misleading, however, due to the weight of the Ring-necked Pheasant (*Phasianus colchicus*) (juvenile weight used). Although the Ring-necked Pheasant and the Mourning Dove (*Zenaida macroura*), were the most common avian prey items, together they comprised only 2.1% of the total prey (Table 5). Insects, snakes, toads, and crayfish were also taken.

Fitzner, et al. (1981) reported snakes as the primary food of the Swainson's Hawk on the Hanford Site in Southeastern Washington State. Snakes and toads may be proportionately higher in the diet of the Central Valley Swainson's Hawk than indicated here, since pellet formation of undigestible remains of these groups is less likely. Swainson's Hawks were observed taking Gopher Snakes (*Pituophis melanoleucus*) and Western Toad (*Bufo boreas*) remains were found at several nest-sites; however, no remains of these species were identified from pellet analysis.

The insectivorous diet of the Central Valley Swainson's Hawk was similar to that reported elsewhere (Cameron 1913, Bent 1937, Johnson, et al 1987). Insects were frequently taken prey items (Table 5); however, in terms of biomass, made up only 4.3% of the Swainson's Hawk diet. Grasshoppers (*Melanoplus sp.*) and crickets (*Gryllus sp.*) were usually taken on the ground; however, grasshoppers were also taken on the wing as described by Woffinden (1986).

Foraging Behavior

Foraging activity made up 63.7% of the combined observation time for the 12 radio-tagged Swainson's Hawks (Table 6). The results do not indicate a significant difference between the percent foraging activity between the sexes; however, this is mainly a result of the different times of year individuals were tracked (Table 7). Care was taken not to trap birds during the incubation phase of the breeding cycle to avoid nest abandonment (Fyfe and Olendorff 1976). Just after young hatched, however, adult males proved easier to trap than females, hence the observation period for radio-tagged males was earlier in the year than for females (Table 7). In general, females rarely hunted during the incubation phase of the breeding cycle. While no attempt was made to collect quantitative data concerning the more detailed aspects of

Table 6. Percent of locations according to activity type of 12 radio-tagged Swainson's Hawks in the Central Valley, 1986-87.

Bird Code	Flying	Perching	On the Ground	Total
WO1M	69.7	26.3	4.0	100.0
WO2F	42.3	57.0	0.8	100.0
WO3M	46.4	42.5	11.2	100.0
WO4F	55.0	28.0	17.0	100.0
WO5F	30.0	57.5	12.6	100.0
WO6M	67.0	20.1	12.9	100.0
WI1M	91.0	5.9	3.0	100.0
WI2F	97.5	2.5	0.0	100.0
GT1M	61.0	24.9	14.1	100.0
GT2M	88.7	4.7	6.6	100.0
VE1M	79.0	9.8	11.2	100.0
VE2M	79.1	12.8	8.0	100.0

	Foraging	Not Foraging	Unknown	Total
WO1M	55.8	34.4	9.8	100.0
WO2F	35.2	64.8	0.0	100.0
WO3M	44.4	46.5	9.1	100.0
WO4F	60.8	34.2	5.0	100.0
WO5F	37.2	60.8	2.0	100.0
WO6M	63.6	29.6	6.8	100.0
WI1M	96.7	2.6	0.7	100.0
WI2F	91.4	8.6	0.0	100.0
GT1M	53.2	38.7	4.1	100.0
GT2M	86.5	13.1	0.4	100.0
VE1M	62.9	27.2	9.9	100.0
VE2M	72.7	21.9	5.4	100.0

Table 7. Telemetry information and total home range areas of 12 adult Swainson's Hawks in the Central Valley of California, 1986-87.

Bird Code	# Hours Tracked	# Locations	Tracking Period	Home Range Area(ha)
WO1M	108	1296	5-6 to 8-22-86	7839.0
WO2F	48	576	6-19 to 8-17-86	336.0
WO3M	112	1344	5-13 to 9-03-87	1258.7
WO4F	52	624	7-12 to 8-25-87	2193.6
WO5F	92	1104	6-16 to 9-12-87	1508.1
WO6M	60	720	7-28 to 9-02-87	8717.7
WI1M	44	528	7-3 to 8-06-87	2088.6
WI2F	42	504	7-3 to 8-07-87	2169.2
GT1M	40	480	7-4 to 8-21-87	2845.6
GT2M	40	480	5-16 to 7-30-87	1132.7
VE1M	42	502	5-15 to 7-29-87	1939.0
VE2M	44	528	5-15 to 6-19-87	1102.1
total =	724	8688	mean =	2760.4

Swainson's Hawk nesting ecology, I observed that females were almost totally provisioned by the males during the incubation period. During the nestling phase of the breeding cycle the hunting activity of females gradually increased. Male provisioning was no longer observed by the time young were near fledgling age.

Dividing hunting method into search technique and attack technique as outlined by Dunstan, et al. (1978), Central Valley Swainson's Hawks almost exclusively (unless responding to certain farming activities) searched for prey from a low altitude soaring flight, 30 to 90 m (98.4 to 295.2 ft) above the ground, and attacked by stooping toward the ground. In some portions of the Swainson's Hawk range, though only rarely observed among the Central Valley population, hunting from a perch (fencepost, utility pole) is also common (Woodbridge pers. comm.).

Unless farming activities attracted hunting Swainson's Hawks, birds would usually did not spend more than a few minutes searching a field for prey before moving on. This highly active foraging behavior often resulted in birds traveling as far as 29.0 km (18.0 mi) from the nest in search of prey. This occurred primarily during periods of increasing vegetative cover, and was presumably in response to decreasing prey availability. This, in turn, led to the formation of communal foraging groups of Swainson's Hawks in areas distant from suitable nesting habitat but where suitable foraging habitat remained.

Swainson's Hawks in the Central Valley appear to exploit an abundance of prey made available due to the effects of certain farming activities (e.g. harvesting, discing, mowing, flood irrigating, and agricultural burning). All of these activities made prey vulnerable to predation by reducing cover or otherwise increasing their exposure to foraging Swainson's Hawks. Overall, radio-tagged birds spent 52.8% of the observed foraging time hunting in apparent response to one of these farming activities. In addition, observations were made of 143 prey captures, of which 105 (73.4%) were made in fields being harvested, disced, mowed or irrigated.

In fields being harvested or disced, birds would hunt in front of or behind a harvester or tractor, capturing rodents that became exposed due to disturbance the farm machinery caused. Bent (1937) first reported the apparent association between foraging Swainson's Hawks and farm machinery. Hovering from a few meters to 30 meters (98.4 feet) from the ground, capture attempts were sometimes made within inches of a moving harvester blade or disc. The capture success of this hunting technique appeared to be very high. Caldwell (1986) found that certain species of raptors increase their hunting success (number of successful attempts per number of total attempts to capture prey) by hunting in association with farm machinery.

The increase in rodent populations in maturing crops was directly associated with a decrease in Swainson's Hawk use, presumably caused by a reduction in available prey as a result of increasing vegetative cover. Swainson's Hawks responded, however, to the abundance of prey that became available during harvest. During this time of year (late July through September), daily foraging ranges were as small as 12.2 ha (30.1 ac), as Swainson's Hawks restricted their hunting activities to a single field being harvested. Tomato and beet fields were of particular importance in this respect (particularly in the Woodland study area) because of their high rodent populations and cover-type availability. The high percentage of tomato field use by birds WO1M

(63.5%), WO3M (51.6%), WO4F (66.9%), and WO6M (31.6%) was primarily due to harvesting activities.

Mowing and irrigation activities applied primarily to alfalfa and occurred regularly throughout the Swainson's Hawk breeding season. Alfalfa supported only moderate prey densities (Table 4); however, the sequence of monthly mowing and weekly flood irrigating made it a crop-type of high prey availability. Flood irrigation forced prey to take refuge along exposed borders in alfalfa fields, where hunting Swainson's Hawks captured them easily. The home range of bird WO2F included 53.5% alfalfa divided into 12 separate fields (Fig. 6). The sequence of mowing and irrigation of these fields resulted in one of these farming activities occurring 18 days (64.3%) of each 28 day period. Hunting activity in response to these activities by WO2F accounted for 61.5% of observed foraging time. The observed foraging behavior of birds GT2M, VE1M, and VE2M was similar.

Swainson's Hawks became more gregarious after young had fledged and commonly joined into feeding groups in response to farming activities (harvesting, discing, agricultural burning, etc.). The increased rodent prey availability, and the abundance of insects disturbed or made available by these farming activities attracted feeding groups of up to 180 individuals. These did not appear to be permanently aggregated premigratory groups. Individuals joined and left groups regularly. Groups of immature and nonbreeding Swainson's Hawks, observed as early as 7 June, may have been more cohesive. In some cases, when large fields of beets or tomatoes were being harvested, feeding groups would remain for the length of the harvest, up to several days. Cameron (1913), Nickerson, et al (1985), Woffinden (1986), and Johnson, et al (1987) reported similar group feeding behavior among Swainson's Hawks.

Home Range Characteristics

Radio-tagged Swainson's Hawks were tracked for a total of 724 hours. Home ranges were calculated from 8,688 recorded locations (Table 7). The majority of tracking time (67.2%) occurred while birds were in flight (Table 6).

Some home ranges were extremely large (Table 7) when compared with those reported in other studies of Swainson's Hawk and other North American buteos (Craighead and Craighead 1956, Wakeley 1978, Bechard 1982). The mean home range was 2760.4 ha (6818.2 ac). Males averaged 46.1% larger home ranges than females. During periods of low prey availability, many birds flew to distant foraging habitats. Consequently, foraging ranges tended to expand linearly, often resulting in a generally elongated home range configuration (Fig. 7 and 8).

The foraging ranges (the modified mimimum polygon area within the home range that was used for foraging) of some radio-tagged birds, primarily those in the Woodland study area, had an elastic nature that fluctuated with the pattern of crop maturity and harvest. Bechard (1982) showed that increasing vegetative cover will reduce prey availability and result in a reduction of Swainson's Hawk use. Wakeley (1978) also measured vegetative cover and found a correlation between foraging use and prey availability among Ferruginous Hawks. While I did not measure vegetative cover directly, the pattern of crop maturity and Swainson's Hawk use was apparent. The foraging range of bird WO-01 illustrates this best (Fig. 9 and 10). The foraging range of bird WO1M varied daily, however, there were three major fluctuations within the 127 day

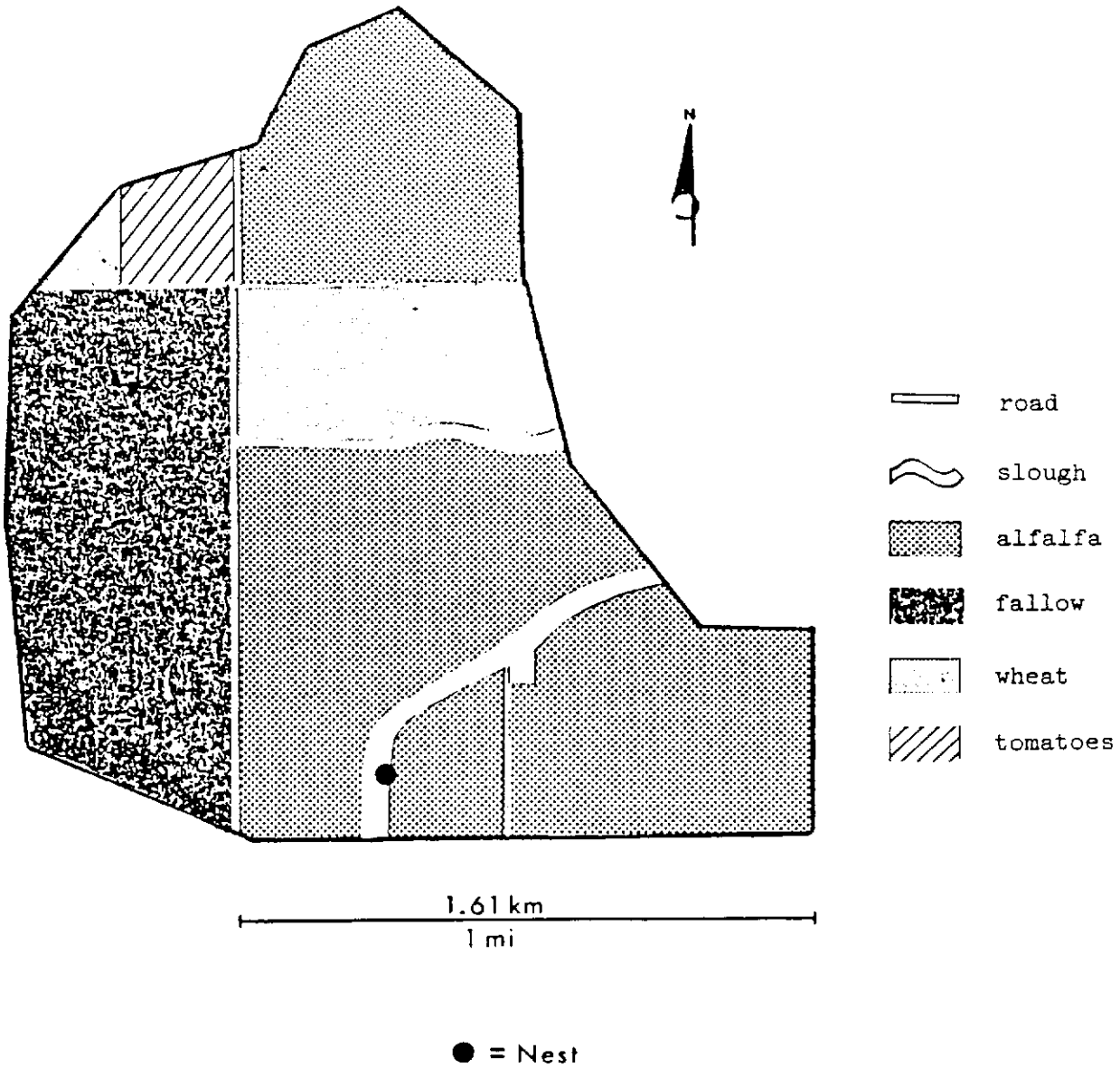

Figure 6. Land-use within the home range of bird WO2F, Central Valley, 1986.

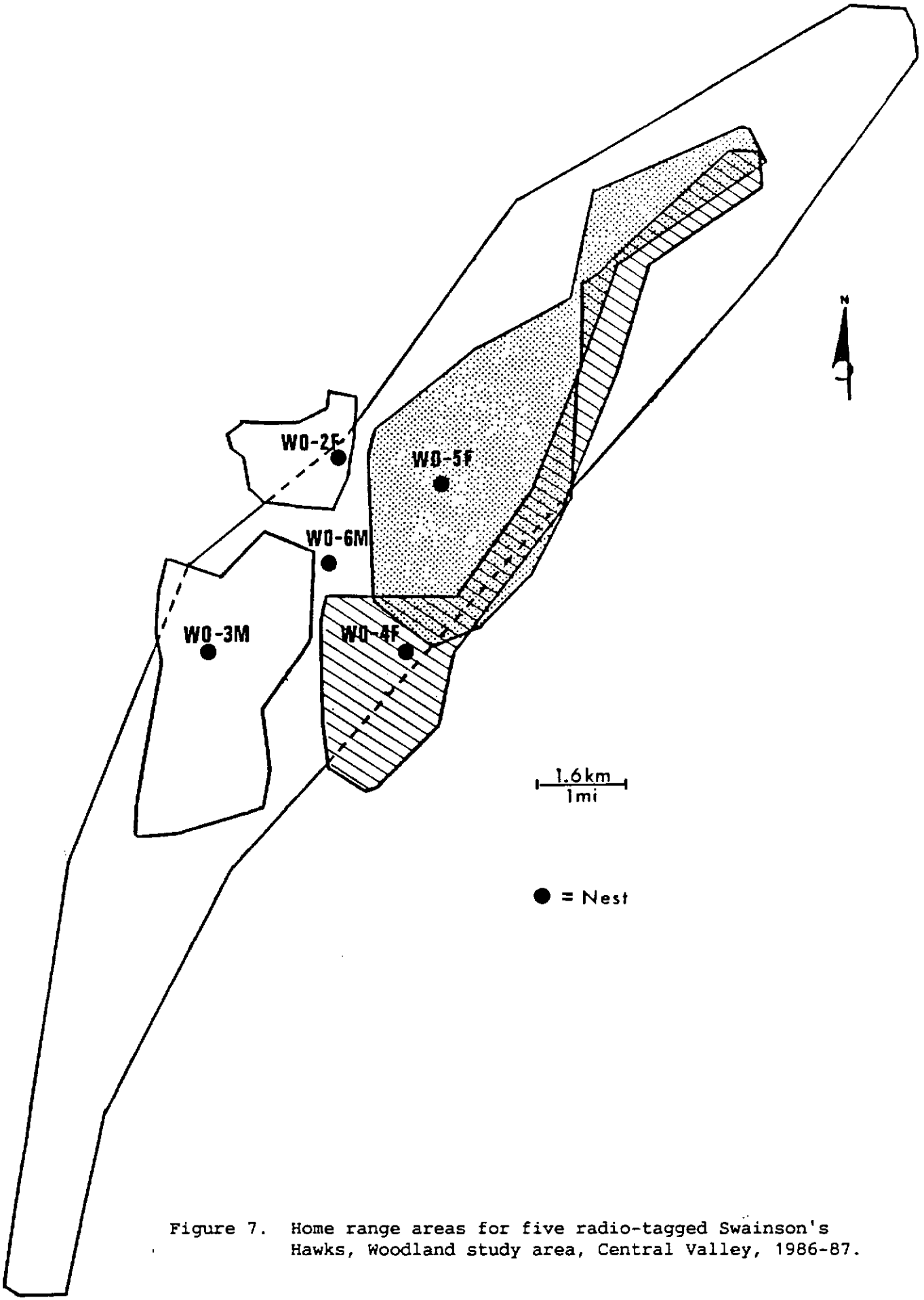

Figure 7. Home range areas for five radio-tagged Swainson's Hawks, Woodland study area, Central Valley, 1986-87.

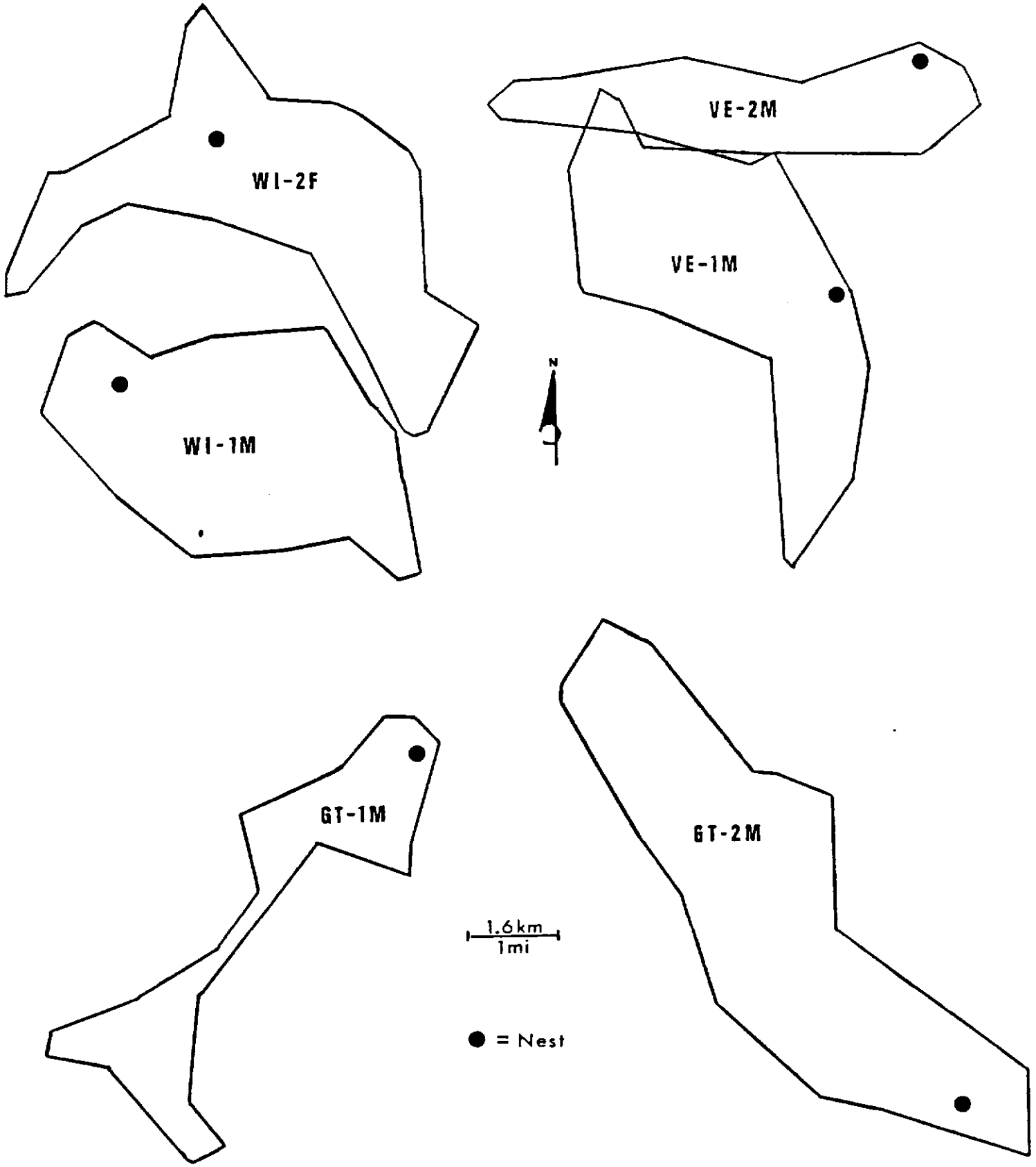

Figure 8. Home range areas for six radio-tagged Swainson's Hawks from the Wilton (WI-), Galt-Thornton (GT-), and Vernalis (VE-) study areas, Central Valley, 1987.

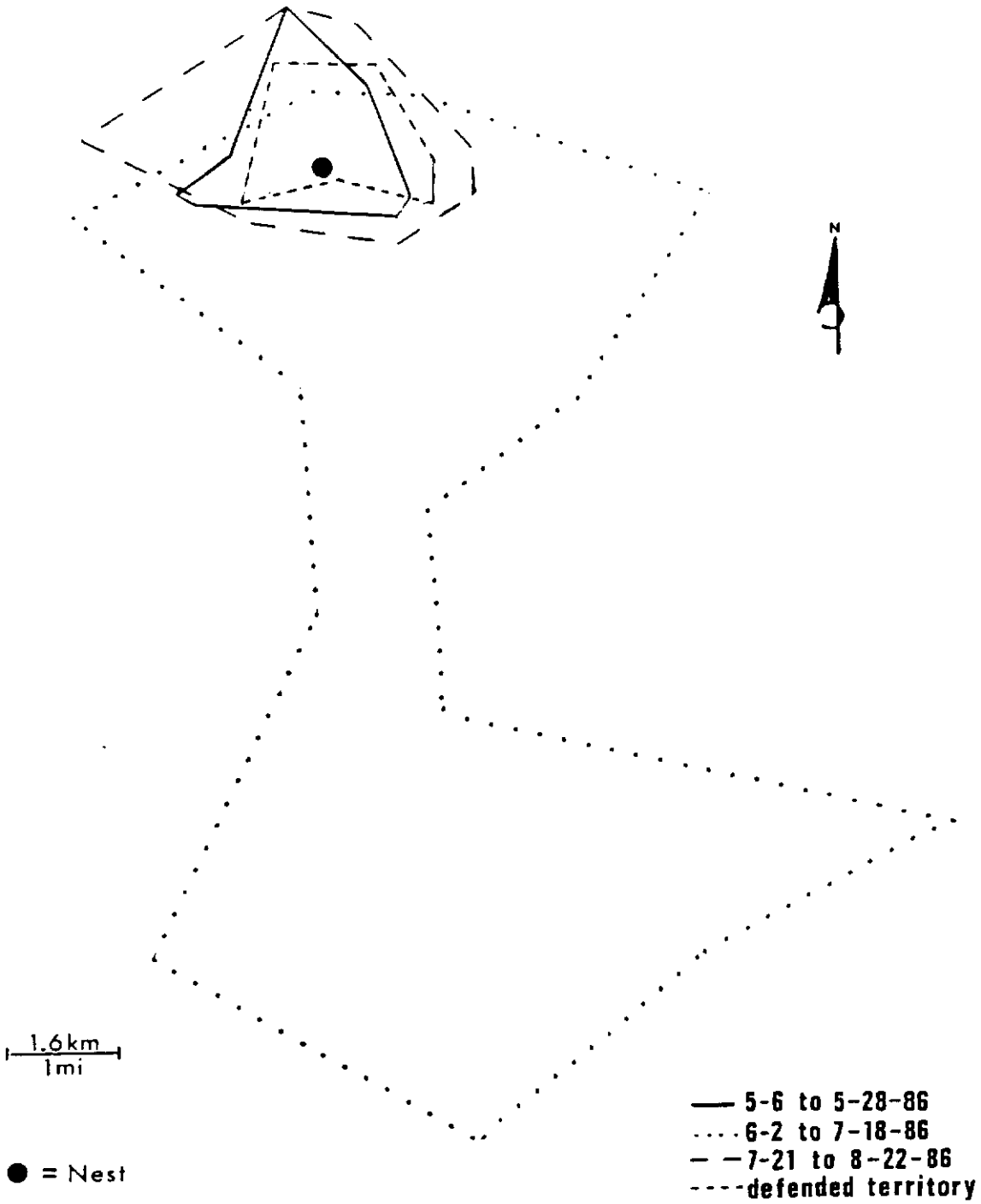

Figure 9. Foraging range areas and defended territory of bird WO-1M from 6 May to 22 August, 1986.

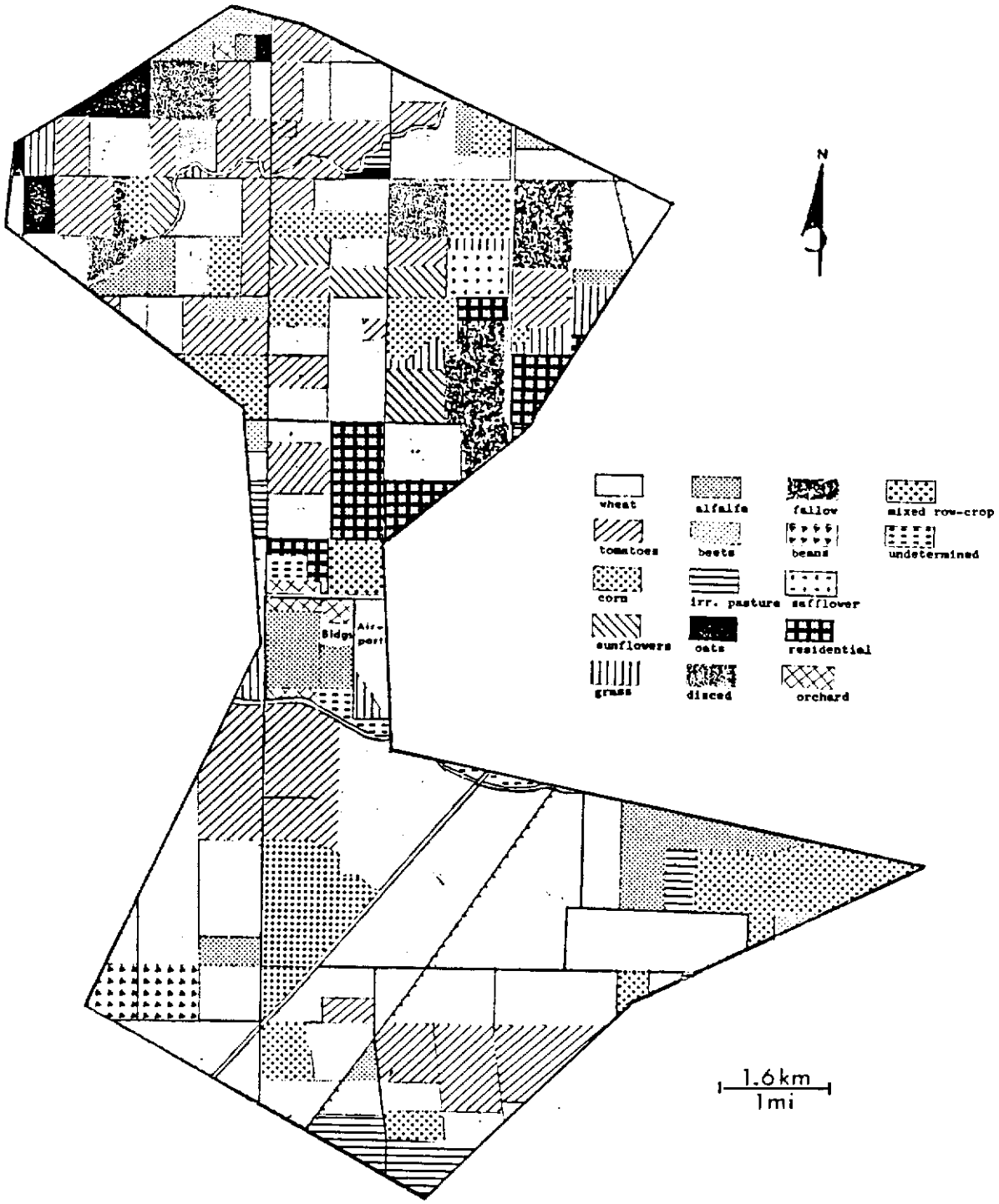

Figure 10. Land-use within the home range of bird WO-1M, Central Valley, 1986.

observation period. During the period from 5 May to 28 May 1986, most crops were immature or newly planted and vegetative cover was at a minimum. From 2 June to 18 July vegetative cover increased as crops matured, reducing prey availability and forcing Swainson's Hawk WO1M to expand its foraging range. On 21 July, harvest of the major row crops began, increasing prey availability while rodent populations were at their peak. This had the effect of reducing Swainson's Hawk WO1M's foraging range.

At the other extreme, 78.4% of bird WO2F's home range was in alfalfa production or fallow (Fig. 6), neither of which had a vegetative cover that would preclude foraging at any time of the breeding season. The result was a stable foraging range, roughly equal to the home range, which was small (336.0 ha (829.9 ac)), and aggressively defended. While not radio-tracked, incidental observations of bird WO2M indicated that it's home range was similar to that of it's mate, WO2F.

Home ranges in the other three study areas included higher percentages of pastureland and alfalfa (Fig. 11), both available for hunting season-long. Foraging ranges did not fluctuate seasonally as in the Woodland study area and were more aggressively defended. Home ranges were generally smaller and similar in size (Table 7). As Bechard (1982) found among Swainson's Hawks in Washington State, a significant positive relationship existed between home range size and the amount of cultivated land available ($P < 0.01$), $r = 0.97$, $df = 10$).

The size of daily ranges (the modified minimum polygon area calculated for each four-hour observation period) varied widely (12.2 ha (30.1 ac) to 6,407 ha (15,763.4 ac)), due mainly to the amount of available foraging habitat within each home range. Daily foraging ranges were smallest when fields were being harvested near the nest. It was common for Swainson's Hawks to forage in a single field being harvested for the duration of the harvest, up to several days. At the other extreme, when vegetative cover limited available foraging habitat, daily foraging ranges were largest.

Nest-sites were often eccentric within home ranges (Fig. 8). Factors causing nest-site eccentricity may have included the heterogeneous nature of available foraging habitat and the distribution of available nest-sites.

Defended territories were relatively small in relation to total home range area (Fig. 9). This was particularly true in the Woodland study area, where available foraging habitat around the nest was limited much of the season. Territories located near more preferred foraging habitat (Fig. 12) were more aggressively defended over a larger area in relation to home range size.

Foraging Habitat Use

Swainson's Hawks were observed foraging in 17 of the 30 identified cover-types. Some of these had very infrequent use and were therefore combined into "grains", "other row crops", and "other" categories. The result was that 10 cover-type categories (components) were used in the habitat preference analysis.

Results of habitat preference analysis revealed a statistically significant rejection of the null hypothesis that all components were equally preferred ($P < .01$, $F = 8.62$, $d.f. = 9,3$). The ranking of these components (Table 8) shows

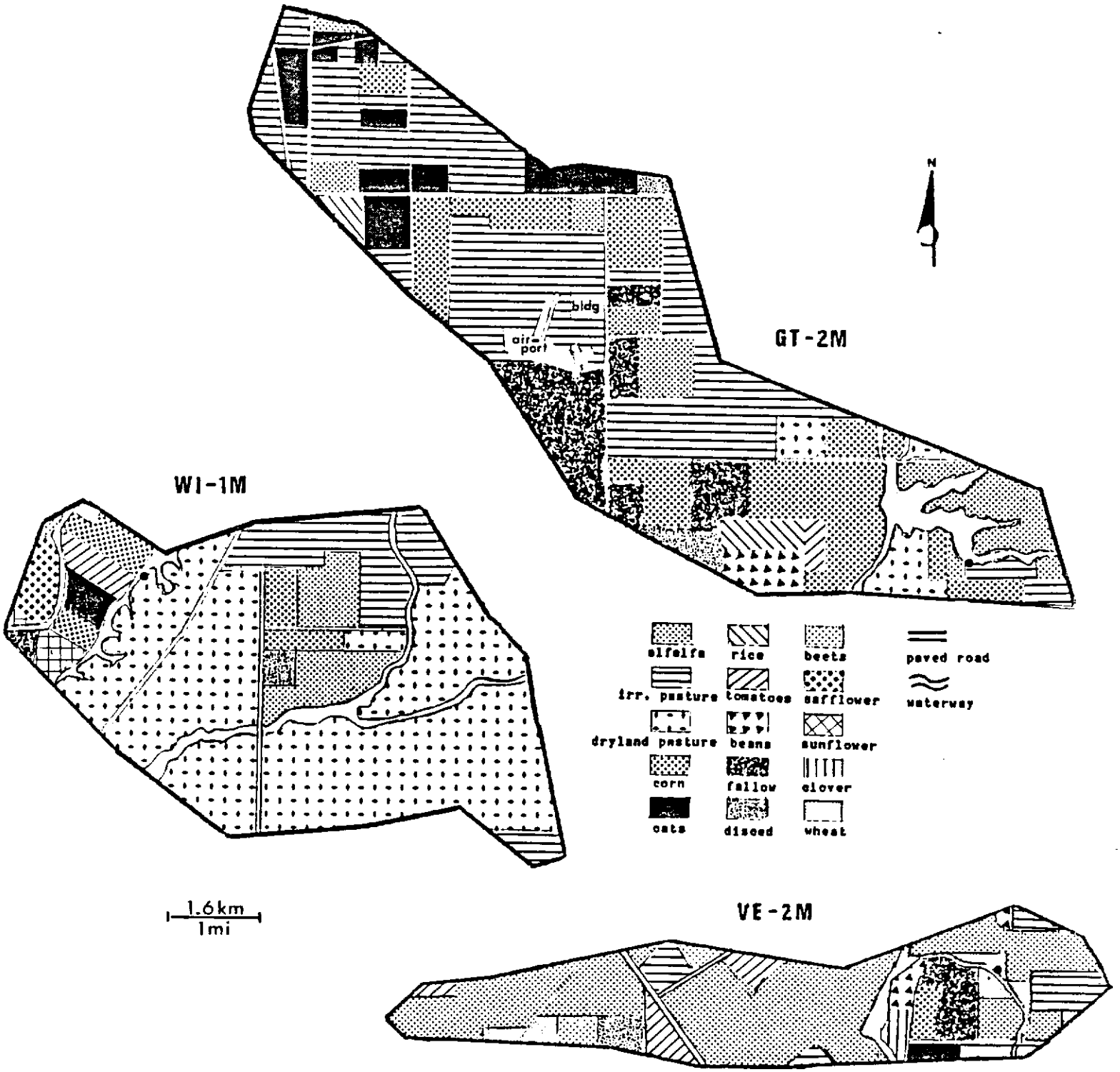

Figure 11. Land-use within the home ranges of three Swainson's Hawks in the Wilton (WI-1M), Galt-Thornton (GT2M), and Vernalis (VE-2M) study areas, Central Valley, 1987.

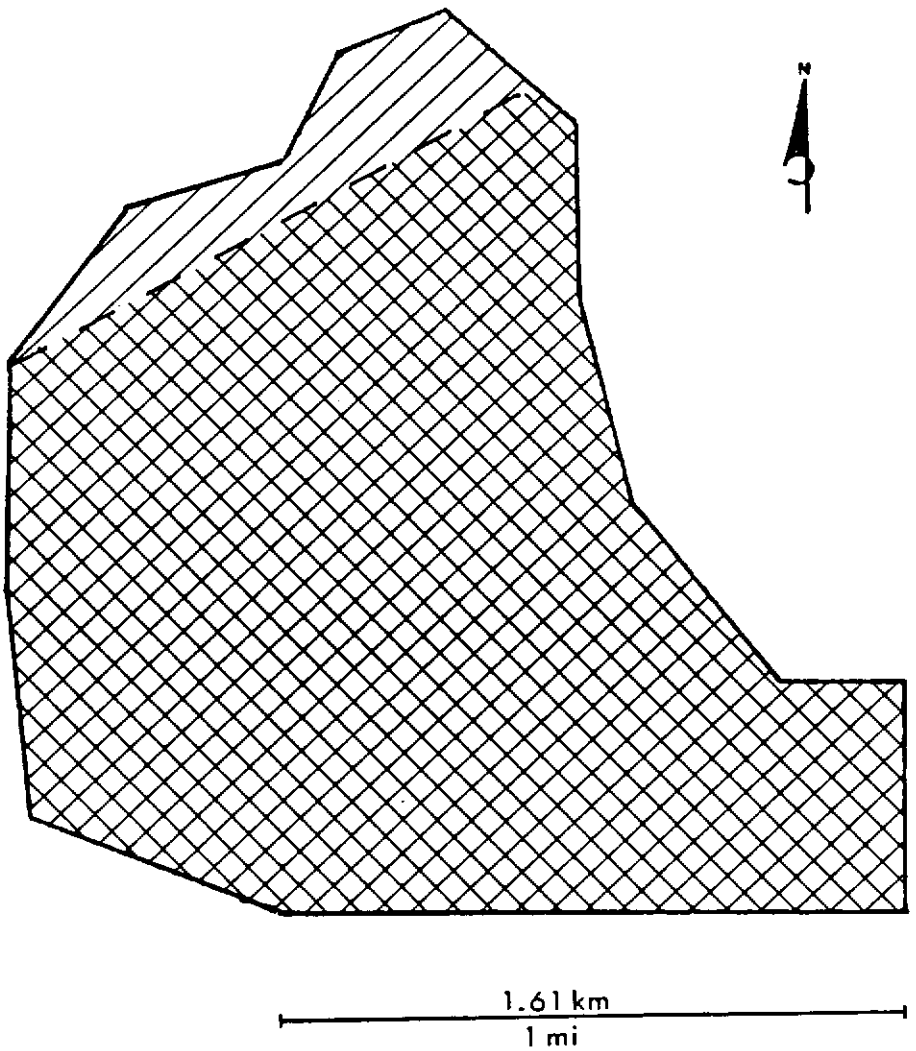

Figure 12. Home range (cross-hatched) and defended territory (double cross-hatched) of bird WO-2F in the Woodland study area, 1986.

Table 8. Relative importance of 10 agricultural habitats based on preference data gathered on 12 radio-tagged Swainson's Hawks in the Central Valley, 1986-87.

Component	Rank
Alfalfa	1
Disced field	2
Fallow	3
Dry-land pasture	4
Beets	5
Tomatoes	6
Irrigated pasture	7
Grains	8
Other row crops	9
Other	10

the relative importance of each to Swainson's Hawk foraging in the Central Valley; however, many of the multiple comparison results (Appendix 3) fell short of statistical significance (K = 100, W = 3.11), probably due to the relatively small sample size of radio-tagged birds (Johnson pers. comm.).

Cover-types that had less overall vegetative cover and greater prey availability ranked highest (alfalfa, disced field, fallow, and dryland pasture)(Table 8). Alfalfa was preferred across all 12 individuals and over all other components (Table 8 and Appendix 3). While supporting only moderate rodent prey populations (Table 4), the foraging use of alfalfa occurred continuously from March to September. Minimum vegetative cover and regular periods of increase in available prey due to frequent flood irrigating and mowing made alfalfa a highly compatible crop-type for foraging Swainson's Hawks.

Disced fields, while ranked second, were used primarily for feeding on grasshoppers and crickets. This was a daily activity for some Swainson's Hawks during the summer. Disced fields had little or no vegetative cover to reduce prey availability; however, they supported only very low rodent populations (Table 4). On a prey biomass basis, the relative importance of this foraging component is much less than its rank, which is based on use and availability.

Rodent populations were relatively high in fallow fields (Table 4) and vegetative cover relatively low. Swainson's Hawks successfully foraged in these fields unless the presence of certain plants, such as Bull Thistle (*Cirsium vulgare*) precluded access.

Dryland pasture most resembles the physical characteristics of historic grassland foraging habitat in the Central Valley. Much of the Wilton study area was open dryland pasture. Both WI-1M and WI-2F used this foraging habitat as their primary source of food, hunting in other cover-types opportunistically, usually in response to farming activities.

Irrigated pasture was rarely used by hunting Swainson's Hawks, except during periods of flood irrigating. Relatively low rodent populations were found in irrigated pasture (Table 4).

While beet and tomato fields supported the largest prey populations (Table 4), dense vegetative cover appeared to preclude Swainson's Hawk foraging during much of the year. However, during harvest they were hunted regularly. The Woodland study area had the greatest area planted to tomatoes and beets. Here, the radio-tagged Swainson's Hawks foraged almost exclusively in these crop-types from late-July to early-September.

The "other row crop" category included corn, sunflowers, safflower, beans, and peppers. Relatively small prey populations (Table 4) and low prey availability made these crop-types less preferred. As corn, sunflowers and safflower matured, growing to heights above 0.6 m (2 ft) they created an impenetrable barrier for hunting Swainson's Hawks. These crops often were not harvested until after Swainson's Hawks left the Central Valley for their wintering grounds.

The 'grains' component included wheat, oats, and rice. These crop-types were used only infrequently by hunting Swainson's Hawks, except for rice which was

never used. Wheat was one of the more common Central Valley crops, particularly in and around the Woodland study area (Table 1). Wheat is planted in early winter in the Central Valley and reaches a mature height soon after the arrival of most Swainson's Hawks in mid-March, reducing available prey in this crop-type. Swainson's Hawks were observed hunting in wheat fields while harvesting operations were in progress; however, only rarely in harvested wheat fields. Rodent populations were found to be relatively low in harvested wheat fields (Table 4).

The 'other' component included grass, clover, edges, riparian systems, vineyards, orchards, residential areas, oak woodland, asparagus, onions, a county park, and a golf course. These cover-types were used either very infrequently or not at all, due to low prey populations, inaccessibility, or low cover-type availability.

Nesting Habitat Use

I located sixty-one nest sites during the study. This includes the nest of one pair that did not renest in 1987, and does not include alternate nests that were used in 1987. Fifty nests (78.1%) were within riparian systems. Nine (14.1%) were in roadside trees (usually rows of trees bordering a paved county road or highway), and 5 (7.8%) were in lone, isolated trees in the middle of an agricultural field or pasture (Fig. 13). This close association with riparian nesting, which appears to be unique to the Central Valley of California and perhaps certain areas of Nevada (Herron 1985), is probably due to nest-site availability and reduced disturbance. Sharp (1902) noted a similar riparian association with nesting Swainson's Hawks in Southern California. Throughout the Central Valley, 87% of all known nests are within riparian systems (Estep 1984). Schlorff and Bloom (1983) evaluated the importance of Central Valley riparian habitat to nesting Swainson's Hawks and considered it critical to the survival of the population.

Valley Oak was the most commonly used nest tree species in all study areas (71.9%), followed by Walnut (12.5%) (primarily in the Woodland study area) Fremont Cottonwood (9.4%), Willow (3.1%), and Locust (*Robinia pseudoacacia*) (3.1%) (primarily in the Woodland study area). Valley Oak was the dominant tree species in all study areas, however, where oak and cottonwood trees were both present, cottonwood trees appeared preferred. Sharp (1902) noted that Swainson's Hawks in Southern California preferred cottonwood trees and rarely nested in oak trees. Gilmer and Stewart (1984) reported cottonwood as the preferred nest tree species in their North Dakota study area. During a survey of a 232 km (144 mi) stretch of the Sacramento River, all Swainson's Hawk nests located (30) were in Cottonwood trees (Estep 1987). Cottonwood trees were primarily associated with riparian systems, while oak trees were found both within and remote from riparian systems. Walnut trees were generally found along roadsides or near farmhouses as well as in riparian systems. However, only roadside Walnut trees were used as nest-sites.

Swainson's Hawks generally nested in trees that afforded a panoramic view of their territory. Trees were typically tall (mean = 17.6 m (57.7 ft), SD = 3.0 m (9.8 ft)) and located on the perimeter of riparian systems, or in isolated trees. Nests were often inaccessible, built high (mean = 14.4 m (47.2 ft), SD = 3.3 m (10.8 ft)) on the far reaches of small limbs. The mean tree and nest height (Table 9) were higher than any reported in the literature (Dunkle 1977, Munro and Reid 1982, Green and Morrison 1983, Thurow and White 1983, Gilmer

Table 9. Nest and nest tree characteristics of Swainson's Hawks in the Central Valley, 1986-87.

	N	Mean	S.D.	Range
Nest-tree Height	40	17.6m (57.7ft)	3.0m (9.8ft)	12.6-25.0m (41.3-82.0ft)
Nest Height	40	14.4m (47.2ft)	3.3m (10.8ft)	8.5-21.4m (27.9-70.2ft)
Distance From Top of Canopy	40	3.2m (10.5ft)	0.3m (1.0ft)	0.6-11.1m (2.0-36.4ft)
Nest Height as % of Tree Height	40	81.8		
DBH	36	84.8cm (33.1in)	26.9cm (10.5in)	34.3-145.5cm (13.4-56.7in)
Nest Diameter	6	44.5cm (17.1in)	12.2cm (4.8in)	30.5-55.0cm (11.9-21.8in)
Diameter of Nest-Supporting Limbs	15	11.0cm (4.3in)	3.8cm (1.5in)	5.1-15.2cm (2.0-5.9in)

and Stewart 1984). The diameter of nest trees was highly variable (Table 9). Nest construction was generally flimsy compared to the nests of other buteos and typically suffered wind damage during winter.

Use of alternate nests was common. Of the 25 pairs that had nests identified both years, 84% used an alternate nest in 1987. Nineteen (76%) used a different nest tree. Two (8%) pairs constructed a new nest in the same tree. Only 4 (16%) used the same nest both years. The mean distance between alternate nest trees was 176.5 m (578.9 ft) (range = 6.1 m (20.0 ft) - 756.9 m (2482.6 ft)).

Swainson's Hawks have been known to successfully nest near human activity (Gilmer and Stewart 1984, Schmutz 1984). In 1987 35% of the nests within the study area were within 0.4 km (0.2 mi) of a farmhouse or residential area, and 32% were within 0.4 km (0.2 mi) of a county road or highway. Three of the nests in the Woodland study area were along the edge of a busy state highway. There was no significant difference ($P > 0.05$) between the nesting success or productivity (number of young fledged) of any of these nesting conditions and other nests.

Nest-site and Mate Fidelity

During the 1986 and 1987 breeding seasons 34 adult Swainson's Hawks were banded with colored, numbered plastic leg bands. Included were 16 individuals without color-banded mates and nine pairs of color-banded birds. The purpose of this effort was to determine nest-site and mate fidelity among Central Valley Swainson's Hawks.

All color-banded birds returned to the same territory in the 1987 and 1988 breeding seasons. All pairs of color-banded birds returned and nested with the same mate in the 1987 and 1988 breeding seasons. There was no mortality among the color-banded birds and no known adult Swainson's hawk mortality within the study area. In contrast, Woodbridge (pers. comm.) has reported several instances of interchanging territories and mates among Swainson's Hawks in the Northeastern California population.

Dispersal and Longevity

Very little is known about the dispersal of young Swainson's Hawks (Fig. 14). Nestlings have been banded in both California populations since 1978 with few birds relocated. In 1986, two adult Swainson's Hawks were trapped in the Woodland study area that were originally banded as nestlings in 1978. It was discovered that both of these birds were nested within two miles from where they were banded as nestlings. Both birds returned to nest in 1987 and 1988, marking their ninth year in the wild.

Plumage Characteristics

Woodbridge (1985) gives a fairly complete description of the many plumage variations among Swainson's Hawks. There are several intermediates between the three main color morphs (light, intermediate, and dark). In the Central Valley there seems to be a tendency of lighter morph males mating with darker morph females. This was true for 83% of the study pairs. Most of the rest had plumage morphs considered equal. Also, all 'pure' light morph (white wing linings and white body) birds were male, and all but one of the completely

Photo by Kevin Guse'

Figure 14. Juvenile Swainson's Hawk, Central Valley, 1987.

melanistic (dark wing linings and dark body) birds was female. The significance of these data and whether or not this pattern of sexual dimorphism occurs in other areas is undetermined, except for the Northeastern California population where similar results have been reported (Woodbridge pers. comm.).

DISCUSSION

The vegetative communities of the Central Valley show little resemblance to that of historic times. Agricultural conversion and urban expansion have resulted in extensive loss of native communities and the decline of many associated species of plants and animals (Warner and Hendrix 1984). Agricultural conversion has been the primary force in reducing the native habitats of the Swainson's Hawk throughout much of California. In the Central Valley, nearly all foraging habitat available to Swainson's Hawks is privately owned agricultural land. Still, a relatively large population of Swainson's Hawks continue to inhabit the mid-section of the Central Valley. Schmutz (1987) found that Swainson's Hawk breeding density increased with moderate cultivation, and even in areas of intensive cultivation breeding density remained relatively high. Certain agricultural land-uses appear to be compatible with Swainson's Hawk foraging needs. If properly managed, these agricultural habitats can continue to support a viable Swainson's Hawk population in the Central Valley. Other agricultural land-uses, however, are incompatible, and their expansion, and the continued expansion of urban development, will result in further loss of Swainson's Hawk nesting and foraging habitat, and ultimately, further reduction of the breeding population.

Over 95% of the known Swainson's Hawk nesting territories in the Central Valley are within the region south of Butte County and north of Fresno County, where irrigated farmland, primarily hay, row and grain crops, is the primary land-use. While urban development is rapidly increasing throughout the Central Valley, some relatively large urban-free areas still exist. Trees are generally sparsely distributed; however, many of the drainages in this region still support relatively large, mature riparian systems. In certain areas the combination of mature trees and agricultural land-use are compatible to Swainson's Hawk nesting and foraging needs. It is in these areas of suitable and relatively abundant nest trees in association with an abundant and available prey base that Swainson's Hawks continue to nest.

The Swainson's Hawk breeding densities here exceed those reported elsewhere for the species (Lokemoen and Duebbert 1976, Dunkle 1977, Gilmer and Stewart 1984, Schmutz 1984). However, this is not characteristic of the entire mid-section of the Central Valley, nor is it indicative of a large and healthy population. The distribution of nesting Swainson's Hawks follows the same irregular distribution of suitable nesting and foraging habitat throughout this region. Large areas exist, even in the mid-section of the Central Valley, which are devoid of suitable nest trees. Other areas support less preferred foraging habitats. High Swainson's Hawk breeding densities exist only in those areas where habitat conditions are most suitable.

A combination of several factors determine the number of breeding pairs of Swainson's Hawks an area can support. The breeding density in the Woodland study area indicates that the number of trees alone is not neccessarily a factor above a certain density of suitable trees. Indeed, above a certain

density of trees, habitat suitability will decline. While tolerant of certain changing foraging conditions, the Swainson's Hawk remains a plains raptor, requiring wide-open space. The availability of suitable nest trees, their association with suitable foraging areas, historical Swainson's Hawk use, traditionality, presence of competitors, and human disturbance are all factors which will determine the density of breeding Swainson's Hawks.

Reproductive success (# fledglings/nest) of Swainson's Hawks in the Central Valley is low compared to other areas (Dunkle 1977, Gilmer and Stewart 1984, Bednarz 1985, Herron 1985, Woodbridge 1985) and is probably related to the overall sub-optimal habitat conditions in the region. It should be noted that since virtually no native foraging habitat remains in the Central Valley, none can be considered optimal. We can determine suitable and preferred habitats among the existing resources, but optimal Swainson's Hawk habitat no longer exists in the Central Valley. It follows that differences in available foraging habitat, particularly between those that support continually available prey and those that do not, might result in differential reproductive success. The farther a Swainson's Hawk must travel to successfully hunt, the less food it will bring back to the nest, and presumably the fewer young the pair can support. Evidence for this is revealed by Bechard (1983) who reported a lower Swainson's Hawk fledgling success with increasing cultivation. In contrast, however, Schmutz (1987) found that reproductive success of Swainson's Hawk pairs nesting near cultivated fields was higher than those nesting in extensive grassland areas. During this study I found no correlation between reproductive success and percentages of croplands or pasturelands within the home ranges of the radio-tagged birds. This was probably because there was not an extreme difference in foraging behavior or habitat availability. All pairs nested on or near cultivated fields. Only the Wilton study area pairs foraged primarily, but not exclusively, in pasture. It is likely, however, that Central Valley Swainson's Hawks today are overall less reproductively successful due to the nearly complete alteration of their former habitat.

Swainson's Hawks in the Central Valley are foraging opportunists, due mainly to the fluctuating prey density and availability in agricultural foraging habitats. They are very active foragers, hunting primarily from the wing and almost never from a perch. They also appear to be very selective foragers, sometimes traveling many miles, repeatedly, to a single field being harvested, until harvesting operations are complete. The foraging behavior of the Swainson's Hawk in the Central Valley has developed as a result of, and in response to, the very dynamic agricultural system. Prey density and availability change with the cycles of crop planting, maturity, and harvesting in each of the many crop-types in the Central Valley. The foraging behavior of Swainson's Hawks in the Central Valley is in response to these cycles, which likely increases their foraging effectivness.

Swainson's Hawk diet is quite variable throughout the breeding range. Fitzner et al. (1981), for instance, reported that snakes are the primary prey item on their study site in Washington State. Also in Washington State, Bechard (1984) reported Northern Pocket Gopher (*Thomomys talpoides*) and deer mice as as the most common prey species and found reptiles to be of little dietary importance. Gilmer and Stewart (1984), found that Northern Pocket Gohper and Richardson's Ground Squirrel (*Spermophilus richardsonii*) were the most common prey species on their North Dakota study area.

The diet of the Swainson's Hawk in the Central Valley consists of a relatively wide variety of prey species. The California Vole, while not found in large numbers in cultivated habitats, is the staple of the Swainson's Hawk in the Central Valley. The large percentage of California Voles in the diet of Swainson's Hawks and their apparent low densities and/or irregular distribution in agricultural habitats indicates a strong preference for this species by foraging Swainson's Hawks. The distribution and abundance of the California Vole may be an important factor in the distribution of the Swainson's Hawk in the Central Valley.

Birds made up a large percentage of the Swainson's Hawk diet in the Central Valley, and may be important during times of low rodent prey density and availability. Insects, particularly grasshoppers, are taken in great abundance by Swainson's Hawks in the Central Valley and elsewhere (Cameron 1913, Bent 1937, Johnson, et al. 1987).

Prey availability is an important controlling factor in the regulation of foraging activity, foraging ranges, and total home range area. Several other studies (Southern and Lowe 1968, Wakeley 1978, Baker and Brooks 1981, Bechard 1982, Janes 1985) have reported similar conclusions. During times of decreased prey availability Swainson's Hawks will enlarge their foraging ranges to secure adequate prey. Later, when prey availability increases near the nest, the foraging range is reduced. Where vegetative cover remains relatively constant and has less effect on the availability of prey, Swainson's Hawk foraging ranges fluctuate less and home ranges are generally smaller. In areas where prey are never available, Swainson's Hawks do not nest. Therefore, prey availability, as well as abundance, will affect the distribution and abundance of Swainson's Hawks, and it is certain crop-types and cropping patterns that largely determine the availability and abundance of prey.

The cover-types most compatible with Swainson's Hawk foraging are those shown to be most preferred by foraging birds. Alfalfa, particularly, because of its stable, continually available, and regularly enhanced (due to farming activities) prey base, is a highly compatible crop-type and the most preferred cover-type of foraging Swainson's Hawks in the Central Valley.

The preference for disced fields is somewhat misleading, and does not reflect their true value to overall Swainson's Hawk foraging. Disced fields were used by foraging Swainson's Hawks solely for feeding on insects, which contributed only a very small percentage of the overall dietary biomass. Still, disced fields supplied a readily available and easily obtainable source of food. Frequently, male Swainson's Hawks would hunt for insects in disced fields first thing in the morning, before hunting larger prey that would be brought back to the nest as provision for the female or as food for the young. In this instance, disced fields seemed to provide a quick and easy source of energy for foraging male Swainson's Hawks during the incubation and nestling periods.

Lightly grazed dryland pasture is also a compatible cover-type. While rodent prey populations are low here, particularly microtine rodents, prey availability is high. Swainson's Hawks successfully foraged here by covering large areas of unbroken pasture. However, even where dry-land pasture was abundant, Swainson's Hawks were attracted to fields being harvested, hunting opportunistically as harvesting operations occurred.

The greatest adjustments in Swainson's Hawk foraging behavior were made where row-crops are the dominant cover-type. The foraging use of row crops depends on the timing of planting and harvesting. Unlike tomato and beet fields, which were harvested earlier and supported large prey populations, most corn, sunflower, safflower, and bean fields were still unharvested by the time Swainson's Hawks departed for their wintering grounds, making those areas unavailable for foraging after vegetative cover reduced available prey.

The foraging use of beets, tomatoes, and other row crops occurred mainly while harvesting operations were in progress. The foraging ranges of some of the radio-tagged birds included so many individual tomato and beet fields that they hunted in these crop-types almost continuously from late-July to mid-September. Row and grain crops are rotated in the Central Valley annually; however, the basic cropping pattern remains similar. In general, certain row crops, while not the most preferred cover-types, can be an important part of overall Swainson's Hawk foraging, providing an abundance of prey during the last two months of the breeding season.

Swainson's Hawk foraging habitat-suitability in the Central Valley can be expressed in terms of land-use and cropping patterns based on the availability and abundance of prey. In general, land-use that includes a predominance of alfalfa, lightly grazed dryland pasture, or other cover-types with a continually available prey base and adequate prey populations, are highly compatible with Swainson's Hawk foraging needs. Cropping patterns that include combinations of hay crops, grains, and summer-harvested row-crops, and that support an adequate prey base, are also suitable. Foraging range adjustments will be made by Swainson's Hawks to secure food as prey availability fluctuates. Cropping patterns that include a predominance of grain crops are less suitable due to lower prey availability and prey populations. Cropping patterns with a predominance of late-harvested row-crops, particularly those that support low rodent populations, are even less suitable. Finally, cropping patterns that include an abundance of orchards, rice, vineyards, or cotton are unsuitable due to reduced prey abundance and availability. Orchards and vineyards remain indefinitely, effectively removing that land from potential Swainson's Hawk use.

The relative abundance of native trees that still exist in certain areas of the Central Valley provide the bulk of Swainson's Hawk nest trees. However, Swainson's Hawks have nested in exotic trees (such as Eucalyptus and ornamental fir trees) in the Central Valley, (Estep unpubl. data). Fitzner et al. (1981) reported that trees planted for shade or fruit were the primary source of Swainson's Hawk nest trees on their Hanford Site study area in Southeastern Washington State. They additionally mentioned that few Swainson's Hawk pairs would be present on the site if not for man's past activities. This is an indication of the potential for successfully expanding the current breeding range in the Central Valley by planting trees in areas where they are scarce but suitable foraging habitat remains, such as much of the southwest corner of the Central Valley.

It should also be noted that suitable Swainson's Hawk nesting habitat must be directly associated with suitable foraging habitat. While Swainson's Hawks in the Central Valley may travel long distances to secure food, they do not nest in regions of unsuitable foraging habitat. Every nest tree in the study area was on or adjacent to suitable foraging habitat.

The distribution of nesting Swainson's Hawks in the Central Valley closely follows the distribution of riparian forest. While Swainson's Hawks also nest in lone trees, roadside trees, and on the perimeter of groves, they are found most commonly nesting on the edges of riparian systems in the Central Valley.

Only a small fraction of the riparian forest that once existed in the Central Valley remains (Katibah, 1981). Loss continues primarily from bank protection projects, farm-related activities, and the expansion of urban development. Potential upland nest trees are also being reduced over time. Many remnant Valley Oaks are isolated in cultivated fields where their continued existence is threatened and regeneration is prohibited. Expanding urban areas also deplete potential upland nesting habitat.

While Swainson's Hawks are very traditional to their nesting territories, they commonly use alternate nest-sites. A pair whose territory includes many potential nest-sites, such as in a riparian system or grove, may construct a new nest in a different tree each year. Permanent nest-sites cannot be identified in these situations. For management purposes, all of the potential nest trees near an active Swainson's Hawk nest should be considered the nesting habitat for that pair, not just the currently active nest tree.

Some Swainson's Hawk pairs are apparently tolerant of a certain amount of human activity. In areas where nesting habitat is limited, such as in the Woodland study area, nest-sites are sometimes located near roads and houses. However, this is not to suggest that construction activity or the presence of houses or other structures will not cause nest abandonment. While some pairs do exhibit a certain degree of tolerance, others have abandoned their nests due to this type of human disturbance and some territories appear to have been permanently abandoned even though the surrounding nesting and foraging habitats appear unaltered (Estep pers obs.). Nesting Swainson's Hawks are particularly sensitive and prone to nest abandonment during the pre-nesting and incubation phases of the nesting cycle.

Land-use trends in the Central Valley continue to move toward increases in residential development and continued expansion of irrigated lands (DWR, 1983). Associated with the rapidly growing human population is the subdivision of farmland around cities into high-denisty suburban development and low-density rural residential development. Remaining natural areas and dry-land pastures may be impacted by the expected increase of over 202,347 ha (500,000 acres) of irrigated land by 2010 (DWR, 1983). Increases in the incompatible crops of rice, orchards, and vineyards are expected, further reducing the amount of available foraging habitat. Also, further tree loss may result due to agricultural and urban expansion.

If suitable foraging and nesting habitat is maintained, Central Valley agricultural habitats can support a viable Swainson's Hawk population. If current trends continue, however, the Swainson's Hawk breeding population in the Central Valley will face continued decline and eventual extirpation.

THREATS TO THE POPULATION

Continued loss of nesting and foraging habitat is the most significant threat to the remaining Swainson's Hawk breeding population in the Central Valley. Swainson's Hawks currently occupy only a small part of the historic Central Valley breeding range. In the mid-section of the Central Valley, habitat

conditions remain compatible to Swainson's Hawk needs. In some areas the breeding density is very high. At least two-thirds of the California population of Swainson's Hawk is found in this relatively small area. The disturbance of this area, resulting in habitat loss and territory abandonment, can affect a large percentage of the California breeding population.

Since the majority of Swainson's Hawk pairs nest within riparian systems in the Central Valley, continued loss of mature riparian forest will result in a reduction of breeding pairs. Loss of riparian forest occurs primarily from agricultural practices, state and federal bank stabilization and flood control projects, and urban development. Similarly, continued loss of upland trees will reduce available nesting habitat and reduce the number of breeding pairs.

There is a limited amount of nesting habitat in the Central Valley which exists in association with suitable Swainson's Hawk foraging habitat. Due to their long migration, Swainson's Hawks arrive on their breeding territories later than other stick-nest building raptors in the Central Valley. As habitat-loss occurs and available nest-sites are reduced, earlier nesting raptors, including Red-tailed Hawks, Red-shouldered Hawks, Black-shouldered Kites, and Great-horned Owls will utilize an increasingly greater percentage of the available nesting space, further reducing the Swainson's Hawk breeding population.

The current pace of urban growth in the Central Valley is such that each year several known Swainson's Hawk territories are abandoned or negatively impacted by loss of both nesting and foraging habitat. The conversion of agricultural land to urban development generally occurs without consideration of the foraging habitat needs of Swainson's Hawks or other raptors. The result is territory abandonment by the affected breeding pairs.

Incompatible crop-types reduce the availability of prey, and/or support reduced prey populations. While this type of habitat loss may be temporary, it can have a similar effect, that of causing territory abandonment and a reduction of breeding pairs of Swainson's Hawks. Orchards and vineyards, which are relatively permanent, can have long-term effects.

The status of the Swainson's Hawk on its South American wintering grounds is largely unknown. The shooting and pesticide poisoning of Swainson's Hawks in some South and Central American regions has been suggested as a possible threat to the species. However, until further research concerning the status, distribution and habitat relationships of the wintering population is conducted the validity of these concerns remain unknown.

MANAGEMENT RECOMMENDATIONS

Over 95% of the known Swainson's Hawk nest-sites in the Central Valley are on private land. This fact, coupled with less-than-effective protections afforded by Threatened and Endangered species legislation, make effective management difficult, at best. Ultimately, it will be private landowners who will determine the fate of the Swainson's Hawk in the Central Valley. The need for effective communication and cooperation cannot be over-stressed. Over the past several years I have found some Central Valley farmers and ranchers concerned over the loss of wildlife resources. Several, in fact, have made efforts toward preserving riparian systems and enhancing the wildlife value of their land.

Swainson's Hawk breeding habitat should be surveyed periodically throughout the Central Valley to keep current on the status of the population. Changes in land-use through urban development and incompatible agricultural practices and crop-types can have an immediate and deleterious effect on the remaining population. These trends should be monitored regularly.

Year-round protection of Swainson's Hawk habitat must be ensured. Often, nest trees are destroyed during the winter without regard to the returning pair of Swainson's Hawks. Nest-sites and nesting habitat should be identified throughout the Central Valley and efforts made toward protecting these sites year-round.

The preservation of riparian systems is critical. Recently, attention has been focused on the purchasing and preservation of some of the larger tracts of remaining riparian forest in the Central Valley. This is encouraging, however, even the most degradated riparian habitat will support nesting Swainson's Hawks. The smallest remnant riparian section along a river can support a Swainson's Hawk pair. Many pairs, particularly along the Sacramento River, nest in these 'islands' of riparian habitat. In addition, every effort must be made to preserve riparian systems along smaller drainages, such as Willow Slough in the Woodland study area, and Red Bridge Slough in the Vernalis study area. Any suitable tree, riparian associated or not, when found with suitable foraging habitat, should be considered a potential Swainson's Hawk nest tree.

Many areas of the Central Valley are devoid of suitable nest-trees while having suitable foraging habitat. These can be important areas for expansion of the Swainson's Hawk population in the future. A program of riparian revegetation and roadside tree planting can provide nesting habitat for this purpose.

Economics will determine what crop-types are available for foraging Swainson's Hawks. There are incentives provided by the Federal Government for farmers to leave land fallow for soil conservation purposes, or to provide habitat for wintering waterfowl. Perhaps similar incentives can be provided by the State of California for farmers to produce certain types of crops which are beneficial to the Swainson's Hawk and other California native wildlife.

Land development pressures exist throughout the Central Valley. Local governments and planning commissions need to be aware of dwindling natural resources in the Central Valley. An effort must be made to protect the habitats of the Swainson's Hawk and other Threatened and Endangered species on a local level where development pressures are greatest. Local development plans should recognize and consider the habitat needs of the Swainson's Hawk and be directed toward the preservation of those habitats.

In general, management of the Swainson's Hawk in the Central Valley includes providing for suitable nesting habitat through preservation of existing nest trees and potential nesting habitat, and efforts toward maintaining compatible agriculture. Both can only be accomplished through the cooperation of landowners and public officials, and the support of effective legislation.

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Appendix 1. Common plants found in edge and fallow field habitats in the Swainson's Hawk study areas of the Central Valley, 1986-87.

Common Name	Scientific Name
Cheeseweed	*Malva parviflora*
Field Mustard	*Brassica campestris*
Shortpod Mustard	*Brassica geniculata*
Black Mustard	*Brassica nigra*
Curly Dock	*Rumex crispus*
Common Knotweed	*Polygonum aviculare*
Pale Smartweed	*Polygonum lapathifolum*
Lambsquarters	*Chenopodium album*
Redroot Pigweed	*Amaranthus retroflexus*
Tumble Pigweed	*Amaranthus ablus*
Lanced-leaved Groundcherry	*Physalis lancifolia*
American Black Nightshade	*Solanum nodiflorum*
Devilsclaw	*Proboscidea louisianica*
White Horsehound	*Marrubium vulgare*
Spiney Clotbur	*Xanthium spinosum*
Cocklebur	*Xanthium strumarium*
California Goldenrod	*Solidago californica*
Mare's Tail	*Conyza canadensis*
Flax-leaved Fleabane	*Conyza bonariensis*
Milk Thistle	*Silybum marianum*
Yellow Starthistle	*Centaurea solstitialis*
Annual Sowthistle	*Sonchus oleraceus*
Spiney Sowthistle	*Sonchus asper*
Prickley Lettuce	*Lactuca scariola*
Yellow Nutsedge	*Cyperus esculentus*
Small Flower Umbrella Plant	*Cyperus difformis*
Ripgut Brome	*Bromus rigidus*
Wild Oat	*Avena fatua*
Littleseed Canarygrass	*Phalaris minor*
Bearded Sprangletop	*Leptochloa fascicularis*
Dallisgrass	*Paspalum dilatatum*
Witchgrass	*Panicum capillare*
Barnyardgrass	*Echinochloa crusgalli*
Yellow foxtail	*Setaria glauca*

Appendix 2. Scientific names of Swainson's Hawk prey from the Central Valley identified from dietary analysis, 1986-87.

Mammals	
California vole	*Microtus californicus*
Valley pocket gopher	*Thomomys bottae*
Deer mouse	*Peromyscus maniculatus*
Western harvest mouse	*Reithrodontomys megalotis*
Black rat	*Rattus rattus*
California ground squirrel	*Spermophilus beecheyi*
House mouse	*Mus musculus*
Blacktail jackrabbit	*Lepus californicus*
Birds	
Mourning dove	*Zenaida macroura*
Ring-necked Pheasant	*Phasianus colchicus*
Meadow Lark	*Sternella neglecta*
Scrub Jay	*Aphelocoma coerulescens*
Western Kingbird	*Tyrannus verticalis*
Brewers Blackbird	*Euphagus cyanocephalus*
European Starling	*Sturnus vulgaris*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Cinnamon Teal	*Anas cyanoptera*
American Crow	*Corvus brachyrhynchos*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Wood Duck	*Aix sponsa*
Northern Flicker	*Colaptes auratus*
Reptiles and Amphibians	
Gopher Snake	*Pituophis melanoleucus*
Western Toad	*Bufo boreas*
Crustaceans	
Crayfish	*Pasifastacus sp.*
Insects	
Grasshopper	*Melanoplus sp.*
Cricket	*Gryllus sp.*
Silphidid	*Silpha sp.*
Dragonfly	*Anisoptera*
Pentatomidid	*Pentatomidae*

Appendix 3. Results of Waller-Duncan multiple comparisons between ten habitat components. I is preferred over K if the difference in mean rank is negative and vice-versa. Statistically significant if absolute standard difference > W (3.11).

I	K	Difference in mean rank	Absolute Standard Difference
tomato	grain	-.20833	.27325
beets	grain	-1.45833	1.77374
beets	tomato	-1.25000	2.19649
alfalfa	grain	-1.91667	1.85175
alfalfa	tomato	-1.70833	1.72990
alfalfa	beets	-.45833	.59921
irr past	grain	-.04167	.05465
irr past	tomato	.16667	.26386
irr past	beets	1.41667	2.33915
irr past	alfalfa	1.87500	2.49476
dryland past	grain	-1.54167	2.01552
dryland past	tomato	-1.33333	2.27938
dryland past	beets	-.08333	.15060
dryland past	alfalfa	.37500	.49729
dryland past	irr past	-1.50000	3.63318
fallow	grain	-1.70833	2.32558
fallow	tomato	-1.50000	1.99664
fallow	beets	-.25000	.34768
fallow	alfalfa	.20833	.22444
fallow	irr past	-1.66667	2.88130
fallow	dryland past	-.16667	.38555
disced field	grain	-1.91667	2.23109
disced field	tomato	-1.70833	1.99563
disced field	beets	-.45833	.71180
disced field	alfalfa	.00000	.00000
disced field	irr past	-1.87500	2.68101
disced field	dryland past	-.37500	.72761
disced field	fallow	-.20833	.30342
row crop	grain	.58333	.62383
row crop	tomato	.79167	.99401
row crop	beets	2.04167	2.54084
row crop	alfalfa	2.50000	2.06218
row crop	irr past	.62500	.72886
row crop	dryland past	2.12500	2.55845
row crop	fallow	2.29167	2.65655
row crop	disced field	2.50000	2.21932
other	grain	3.62500	4.08270
other	tomato	3.83333	4.22489
other	beets	5.08333	5.81372
other	alfalfa	5.54167	5.99666
other	irr past	3.66667	4.84291
other	dryland past	5.16667	7.99207
other	fallow	5.33333	6.54438
other	disced	5.54167	5.71236
other	row crop	3.04167	4.42998