A Post-Hoc Assessment of the Impacts to Wildlife Habitat from Wood Cutting in Blue Oak Woodlands in the Northern Sacramento Valley[1]

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***Abstract**: Impacts to wildlife habitat from wood cutting in woodlands dominated by blue oak (*Quercus douglasii*) were assessed with vegetation data gathered from 103 0.1-acre circular plots sampled in August-September 1993 in Shasta and Tehama counties, California. Plots were located at 19 cattle ranches in areas where wood had been cut. Using growth model projections for a 50-year period for all ranches combined, average tree diameter at breast height was 9.0-12.5 inches and 9.0-11.6 inches, while average tree canopy cover was 16-34 percent and 53-70 percent for cut and uncut conditions, respectively. Models of habitat relationships for 21 wildlife species were used to evaluate impacts, and one species was negatively affected, seven species were positively affected, and 13 species were unaffected by tree cutting.*

Wood cutting in California's hardwood rangelands has been a persistent land use probably since the late 1700's when domestic livestock were introduced to California (Mayer and others 1986). Wood is cut to modify rangeland and provide wood products. Bolsinger (1988) estimated that, between 1945 and 1985, almost 1.2 million acres of California's estimated 7.4 million acres of hardwood woodlands had been converted to other habitats through wood cutting and clearing. Through the mid-1900's, forage improvement through tree removal was the primary reason for cutting. Firewood was a source of additional income from the harvested wood.

Wood cutting for rangeland modification and firewood products continues throughout the state, particularly in the northern Sacramento Valley where more than 50 percent of California's firewood is harvested in hardwood rangelands dominated by blue oak (*Quercus douglasii*). Between 1988 and 1992, wood was cut on almost 25,000 acres of California hardwood rangelands (Standiford and others 1996).

California's hardwood rangelands are very important wildlife habitat. At least 313 of the 650 species of amphibians, reptiles, birds, and mammals in the California Wildlife Habitat Relationships (CWHR) System were predicted to occur in the state's five hardwood rangeland habitat types (Blue Oak, Blue Oak-Foothill Pine, Valley Oak, Coastal Oak, and Montane Hardwood) (Garrison 1996).

The large number of wildlife species occurring in hardwood rangelands, combined with the estimated 2,000 species of vascular plants and 5,000 species of invertebrates (Pavlik and others 1991), results in hardwood rangelands having some of the highest levels of species richness of any equivalent broad habitat group in California. Wildlife species include several important game animals, such as mule deer (*Odocoileus hemionus*), California quail (*Callipepla californica*), and wild turkey (*Meleagris gallopavo*), which contribute millions of dollars annually to California's economy through revenues from recreational hunting. Furthermore, hardwood rangelands are important environments for large numbers of neotropical migratory birds such as flycatchers, vireos, and warblers, which are a wildlife group receiving considerable conservation emphasis because of large-scale population declines (U.S. Department of Agriculture, Forest Service 1994).

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Despite the value to wildlife and long-term, extensive, and continuing losses and modifications of hardwood rangelands, little information exists on impacts to wildlife from habitat loss or modification. Gathering meaningful data on wildlife impacts is hindered by several factors. First, cutting of trees such as blue oak and other hardwoods on private rangelands is not regulated by the State of California as is harvesting of softwoods such as coast redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*), and other conifers. Therefore, basic information on the harvest is not available, nor is environmental review by agencies such as the California Department of Fish and Game (CDFG).

Second, most hardwood rangelands are privately owned, and access for evaluation is restricted. Furthermore, many landowners do not generally empathize with the need for wildlife impact studies, particularly when their lands might be evaluated and government agencies such as CDFG are involved. Third, CDFG and other agencies have limited budgets and manpower, thereby restricting their ability to conduct impact assessments. Lastly, studies on the impact of wood cutting have focused primarily on wildlife on public lands, such as National Forests, because of the multiple-use mandates and environmental regulations of state and federal agencies.

With this foundation, this study used data from a larger study of blue oak sprouting (Standiford and others 1996) to assess the impacts to wildlife from wood cutting in blue oak woodlands. This is a post-hoc analysis because we used lands where wood cutting had already occurred, and we could not gather pre- and post-harvest wildlife information from field inventories. Our objectives were to: (1) quantify baseline wildlife habitat characteristics of lands where wood had been cut; (2) determine wildlife species that might be most indicative of impacts from wood cutting; and (3) estimate habitat impacts for these species using existing models of habitat relationships.

Study Area

This study was conducted on 19 individual private ranches in Shasta and Tehama counties, California. The ranches were randomly selected from a larger pool of ranches where wood had been cut over the past 10 years. Twelve ranches were located in Tehama County, and seven ranches were located in Shasta County. These ranches were representative of the conditions on privately owned blue oak-dominated hardwood rangelands in the northern Sacramento Valley.

Dominant trees on these ranches are blue oak, foothill pine (*Pinus sabiniana*), and interior live oak (*Q. wislizenii*). Shrub layer vegetation includes poison-oak (*Toxicodendron diversilobum*), manzanita (*Arctostaphylos* spp.), and *Ceanothus* spp. Herbaceous layer plants are dominated by exotic annual grasses. Elevations were 500-2,000 feet above sea level, and topography was generally flat with steeper areas along watercourses. Ranches were equally distributed on the west and east sides of the northern Sacramento Valley.

Methods

Vegetation Measurements

On each ranch, 5-7 0.1-acre circular plots were randomly located within harvested areas. Only plots with one or more stumps from harvested trees were sampled. Within each plot, diameter, height, and species of all stumps were recorded. Height of the tallest stump sprout, if any, was measured. Diameter at breast height (DBH), height, canopy diameter, and species were recorded from all residual trees in the plot. The number and diameter of all snags >4 inches DBH and acorn storage (granary) trees used by acorn woodpecker (*Melanerpes*

formicivorus) were also recorded. A 0.01-acre belt transect (4.4 feet x 100 feet) was randomly located through the plot center to measure woody debris (downed logs ≥3 inches diameter at large end) and brushpiles. Management information on herbicide use, prescribed burning, and acreage harvested was collected from interviews with ranch owners and/or managers.

Vegetation Growth Projections

From these data, pre-cut tree DBH and height conditions of uncut stands were estimated from relationships derived from uncut trees. Pre- and post-cut stand structures were applied to a statewide growth and yield model of individual blue oaks (Standiford 1995) to estimate stand growth with and without wood cutting over a 50-year period. Average stem diameter (quadratic mean) of all woody stems ≥5 inches DBH and canopy cover were estimated using the same growth model for cut and uncut conditions. Growth for cut and uncut conditions were individually projected for the 19 ranches.

With these projections for cut and uncut conditions, wildlife impacts were assessed for (1) all 19 ranches combined (see below) and (2) four individual ranches selected to represent a range of harvest conditions and 50-year growth projections. The 19 ranches combined had a total of 13,200 acres of harvested habitat for the wildlife impact assessment, while the harvest size on the four ranches selected for impact analysis ranged from 40 to 1,400 acres (*table 1*).

Table 1—Baseline vegetation characteristics (mean ± std) from blue oak woodlands where wood cutting occurred on four selected ranches and 19 ranches combined in blue oak woodlands of Shasta and Tehama counties, California.

Vegetation variables	Ranches				
	1 (*n*=6)	2 (*n*=6)	3 (*n*=5)	4 (*n*=6)	All (*n*=19)
Woody debris *(ft³/acre)*	83±180	247±503	444±722	34±64	120±115
Pct brushpile	9.0±5.9	2.7±4.4	12.4±17.6	1.3±3.0	5.1±5.6
Snag basal area *(ft²/acre)*	0.0±0.0	0.4±0.8	6.7±13.3	0.0±0.0	1.6±2.5
Snag density *(number/acre)*	0.0±0.0	1.7±3.7	2.0±4.0	0.0±0.0	3.0±4.4
Acorn woodpecker granary density *(no./acre)*	0.0±0.0	0.0±0.0	20.0±26.7	2.1±4.6	1.5±4.5
Pct shrub cover	0.0±0.0	3.5±5.0	0.0±0.0	0.0±0.0	1.9±3.3
Pct oak sprout cover	6.0±3.7	4.7±6.6	0.0±0.0	0.0±0.0	2.5±2.5
Oak sprout age *(years)*	8	9	7	7	4.6±2.5

For comparative purposes, individual ranch averages were used to determine average values for the entire study area. However, for the wildlife impact analysis (see below), weighted average stem diameter and canopy cover for the 50-year period were calculated for the 19 combined ranches using the size of the individual ranch harvest unit as the weighting factor. For each ranch, harvest unit size was multiplied by the average stem diameter and average canopy cover. These values were summed across all 19 ranches, and the total was divided by 13,200 acres to calculate the weighted average. A weighted average was preferable to an unweighted average because of the wide range of harvest sizes (40-7,000 acres). Weighted averages were similarly calculated for downed

woody debris, snag and granary densities and basal areas, and percent brushpiles, oak sprout cover, and shrub cover. Simple arithmetic averages of the plot data were calculated for the four individual ranches.

Average stem diameter and canopy cover for cut and uncut conditions for the 50-year period were combined with baseline vegetation species composition to determine the appropriate habitat type and tree size/canopy cover class from the CWHR habitat classification system (Mayer and Laudenslayer 1988) (*table* 2). These CWHR habitat types and classes were used to generate a list of wildlife species predicted to occur in the study area (see below).

Table 2—Mean tree diameter at breast height (DBH), percent canopy cover, and California Wildlife Habitat Relationships (CWHR) habitat type and stage for cut and uncut conditions from blue oak woodlands over a 50-year period where wood cutting occurred on four selected ranches and 19 combined ranches in Shasta and Tehama counties, California.

	Ranch 1		Ranch 2		Ranch 3		Ranch 4		All Ranches	
	Cut	Uncut	Cut	Uncut	Cut	Uncut	Cut	Uncut	Cut	Uncut
Year 0										
DBH [1]	<5.0	8.7	<5.0	9.6	10.8	10.0	7.9	10.5	9.0	9.0
Pct canopy cover	0	51	0	41	22	65	7	26	16	53
CWHR habitat type and stage	[2]AG2D	BO3M	AG2M	BO3M	BO3S	BO3D	AG1P	BO3P	BO3S	BO3M
Year 10										
DBH	<5.0	9.2	5.4	10.1	11.3	10.4	8.4	11.0	9.5	9.5
Pct canopy cover	11	55	2	45	30	70	11	29	22	57
CWHR habitat type and stage	BO2S	BO3M	AG2M	BO3M	BO4P	BO3D	BO3S	BO4P	BO3S	BO3M
Year 20										
DBH	<5.0	9.7	6.7	10.6	11.9	10.9	9.1	11.5	10.3	10.1
Pct canopy cover	13	58	3	47	32	74	12	31	25	61
CWHR habitat type and stage	BO2S	BO3M	AG2M	BO3M	BO4P	BO3D	BO3S	BO4P	BO3P	BO3D
Year 30										
DBH	<5.0	10.2	7.7	11.1	12.4	11.4	9.6	12.1	11.0	10.6
Pct canopy cover	15	61	4	50	35	78	13	33	28	64
CWHR habitat type and stage	BO2S	BO3D	AG2M	BO4M	BO4P	BO4D	BO3S	BO4P	BO4P	BO3D
Year 40										
DBH	<5.0	10.7	8.7	11.6	13.0	11.9	10.2	12.6	11.8	11.1
Pct canopy cover	18	64	6	52	38	82	15	36	31	67
CWHR habitat type and stage	BO2S	BO3D	AG2M	BO4M	BO4P	BO4D	BO3S	BO4P	BO4P	BO4D
Year 50										
DBH	<5.0	11.2	9.6	12.1	13.6	12.4	10.7	13.1	12.5	11.6
Pct canopy cover	20	66	6	54	38	84	15	38	34	70
CWHR habitat type and stage	BO2S	BO4D	AG2M	BO4M	BO4P	BO4D	BO3S	BO4P	BO4P	BO4D

[1]Average stem diameter (quadratic average) of all woody stems ≥5.0 inches diameter at breast height (DBH).

[2]Habitat types from the California Wildlife Habitat Relationships (CWHR) System are: AG = Annual Grassland; and BO = Blue Oak Woodland. CWHR habitat stages for AG are: 1 = height ≤12.0 inches; 2 = height >12.0 inches; P = 10.0-39.9 percent vegetation cover; M = 40.0-59.9 percent cover; and D = 60.0-100.0 percent cover. CWHR habitat stages for BO are: 2 = DBH 1.0-5.9 inches; 3 = DBH 6.0-10.9 inches; 4 = DBH 11.0-23.9 inches; S = 10.0-23.9 percent vegetation cover; P = 24.0-39.9 percent cover; M = 40.0-59.9 percent cover; and D = 60.0-100.0 percent cover.

Wildlife Impact Assessment

Selecting Evaluation Species

Impacts from wood cutting were assessed by selecting wildlife species to represent a range of habitat needs and use patterns so that a variety of impacts (i.e., positive, negative, unaffected) could be determined. The CWHR habitat types and classes determined with the vegetation modeling were used with CWHR Version 5.2 (Timossi and others 1994) to generate a list of wildlife species predicted to occur in all 17 possible size/cover classes of blue oak woodland habitat in Shasta and Tehama counties. The CWHR query included species occurring any time of the year. Twenty-nine habitat elements were determined to be absent from the study areas, and these elements included those primarily associated with marine and developed agricultural and human habitats. Absent elements excluded wildlife species for which the elements were predicted by CWHR to be essential for their occurrence. From this query, 213 species of amphibians, reptiles, birds, and mammals were initially predicted for the study area.

Our purpose was to estimate impacts to wildlife species primarily associated with the hardwood tree component of blue oak woodlands in the northern Sacramento Valley. Therefore, the initial CWHR list of 213 species was further reduced by eliminating species meeting one or more of the following five criteria: (1) species primarily associated with aquatic habitats; (2) species primarily associated with conifer-dominated habitats; (3) species whose geographic distribution did not include the study area; (4) non-native species primarily associated with human habitation; or (5) species *without* arithmetic average habitat suitabilities ≥0.66 (Medium habitat suitability) for at least one of the 17 tree size/cover class combinations for blue oak woodland habitat. A total of 143 species remained after eliminating 70 species on the basis of the five criteria.

A scoring system using five additional criteria was used to rank the 143 species for their applicability in evaluating impacts of wood cutting. The criteria included: (1) CWHR-predicted sensitivity to differences in canopy cover (see below); (2) overlap of geographic distribution with the range of blue oak woodlands in California (1 = no or low overlap; 2 = moderate overlap; 3 = high overlap); (3) a subjective confidence rating for CWHR model accuracy (1 = no or low confidence; 2 = moderate; 3 = high); (4) whether or not the species breed in oak woodlands (0 = no; 1 = yes); and (5) whether or not the species has a special legal status, such as harvest, threatened, endangered, or special concern (0 = none; 1 = yes). A maximum score of 11 was possible, but scores ranged from 4 to 10. The wild pig (*Sus scrofa*) was the only species with the highest score of 10.

Sensitivity for Criterion 1 was determined using the difference in CWHR-predicted, arithmetic-average habitat suitability values between blue oak woodland habitat stages with <40 percent canopy cover (open canopies) and stages with ≥40 percent canopy cover (closed canopies). Species received a score of 3 (high sensitivity) with habitat suitability differences of ≥2 CWHR suitability index classes (e.g., High for open canopies and Low for closed canopies). Species with differences of one suitability index class were given a score of 2 (moderate sensitivity), while species with differences of less than one class were given a score of 1. Species with scores of 2 or 3 were categorized as preferring open or closed canopy conditions depending on which cover condition had the greatest average suitability value. Species with a score of 1 were categorized as having no preference (*table 3*).

From this ranking, a preliminary score threshold of ≥7 was used to further reduce the list and select evaluation species. Fifty-six species met this threshold as potential evaluation species. A score of 7 was selected as a threshold because approximately one-third of the ranked species met or exceeded that score.

Guilds based on primary breeding substrates and primary food habits were developed, and the 56 species were placed in appropriate guild cells. The absence or low number of species for several important guild cells necessitated adding species with scores of 5 to 6 to those cells. In most cases, the species with the highest score within a cell was selected as an evaluation species. However, five species with lower scores were chosen because we were more confident that the species actually occurred in the study area. Finally, 21 species were selected for evaluation which we felt were the most appropriate for assessing impacts from wood cutting because of the wide range of habitat conditions represented and possible predicted impacts (*table 3*).

Table 3—Rating scores, canopy cover preferences, and resource use patterns for 21 wildlife species used for a post-hoc assessment of habitat impacts from wood cutting in blue oak woodlands in Shasta and Tehama counties, California.

Common name	Scientific name	Rating score[1]	Cover sensitivity score[2]	Preferred canopy cover	Primary breeding substrates	Primary feeding habits
Ensatina	*Ensatina eschscholtzii*	7	2	Closed	Subsurface	Invertebrates
Cooper's hawk	*Accipiter cooperii*	8	2	Closed	Trees	Vertebrates
Red-tailed hawk	*Buteo jamaicensis*	7	1	None	Trees, cliffs	Vertebrates
Wild turkey	*Meleagris gallopavo*	9	1	None	Surface	Invertebrates, seeds, acorns, plants
Mourning dove	*Zenaida macroura*	9	2	Open	Trees	Seeds
Western screech-owl	*Otus kennicottii*	6	1	None	Tree cavities	Invertebrates, vertebrates
Acorn woodpecker	*Melanerpes formicivorus*	9	2	Open	Tree cavities	Acorns, fruits, invertebrates
Pacific-slope flycatcher	*Empidonax difficilis*	7	2	Closed	Trees	Invertebrates
Ash-throated flycatcher	*Myiarchus cinerascens*	7	2	Open	Tree cavities	Invertebrates
Western scrub-jay	*Aphelocoma californica*	7	1	None	Trees, shrubs	Acorns, fruits, invertebrates
Bushtit	*Psaltriparus minimus*	6	1	None	Trees, shrubs	Invertebrates, seeds, fruits
White-breasted nuthatch	*Sitta carolinensis*	7	1	None	Tree cavities	Invertebrates, seeds, fruits
Western bluebird	*Sialia mexicana*	7	2	Open	Tree cavities	Invertebrates, fruits
Western meadowlark	*Sturnella neglecta*	7	3	Open	Surface	Invertebrates, seeds
California ground squirrel	*Spermophilus beecheyi*	6	2	Open	Subsurface	Invertebrates, seeds
Western gray squirrel	*Sciurus griseus*	7	1	None	Trees	Acorns, nuts, seeds, fruits
Dusky-footed woodrat	*Neotoma fuscipes*	7	1	None	Surface	Plants, acorns, fruits
Gray fox	*Urocyon cinereoargenteus*	7	2	Open	Tree cavities, cliffs, rocks	Invertebrates, vertebrates, fruits
Mule deer	*Odocoileus heminous*	8	2	Open	Surface	Plants, acorns, fruits
Western fence lizard	*Sceloporus occidentalis*	5	1	None	Surface	Invertebrates
Gopher snake	*Pituophis melanoleucus*	6	2	Open	Subsurface	Vertebrates

[1]Results of numeric ratings for five criteria, including cover sensitivity score.

[2]Numeric rating for CWHR-predicted sensitivity to differences in blue oak tree canopy cover (1 = no difference, 2 = difference of 1 CWHR rating class, 3 = difference of ≥2 rating classes).

Evaluating Impacts

Habitat suitability index values (HSI) from the CWHR system for the 21 species were used in a Habitat Evaluation Procedures (HEP) analysis (U.S. Department of Interior, Fish and Wildlife Service, 1980) to quantify impacts from wood cutting. HEP is a standardized impact assessment method used to quantify impacts to wildlife habitat from land use activities (Doering and Armijo 1986, Williams 1988). HSI values were the arithmetic averages of suitability values for reproduction, cover, and feeding calculated by CWHR for the appropriate habitat type and stage. Six target years (0, 10, 20, 30, 40, and 50) were used for the 50-year impact assessment period (*table 2*), and HSI values were generated for each ranch scenario/target year combination. A Lotus 123® spreadsheet was used to calculate changes in HSI values and habitat units (HU) (HU = HSI value × study area acreage) over the 50-year period according to HEP guidelines. Species-specific CWHR-predicted HSI values = 0.0 were raised to 0.01 to minimize unreasonably large HU changes for the 50-year period, and recognize the likelihood of some habitat value existing in CWHR-predicted unsuitable habitats.

Impacts were determined by averaging changes in HUs for the 6 target years. These averages are known as Average Annual Habitat Units (AAHU), and AAHUs were calculated for the future-with-project (cut condition) and future-without-project (uncut condition) scenarios according to HEP guidelines. Garrison (1992) found it appropriate to quantify CWHR-predicted habitat changes between two conditions using future-with-project versus future-without-project scenarios.

Impacts were compared between evaluation species and among ranch scenarios by calculating percent change in AAHUs from the cut condition to uncut condition (*table 4*). Percent change was calculated using the following equation:

$$\left(\frac{F_{wo} - F_{w}}{F_{wo}}\right) \times 100 = \text{Percent Change}$$

where F_{wo} = future-without-project AAHUs and F_{w} = future-with-project AAHUs.

Using percent change standardized impacts among ranch scenarios because AAHUs are greatly influenced by project area size, which varied greatly among the five ranch scenarios (40-13,200 acres) (*table 4*). Determining biological significance of CWHR predictions is tenuous for many reasons (Garrison 1994); therefore, we selected an AAHU percent change of +50 percent as the significant impact threshold. This level represents a relatively conservative threshold because a 50 percent change means that average habitat suitabilities differed by one or more rating classes between the cut and uncut conditions.

Results

Vegetation

Substantial variation existed among the individual ranches in baseline vegetation characteristics on the harvested areas (*table 1*). This variation was masked when vegetation characteristics were averaged for the entire study area. For example, snags were lacking for two of the four (50 percent) individual ranches in *table 1*, and eight of the 19 (42 percent) ranches in the study. Furthermore, average snag density and average snag basal area for the entire study area exceeded that of 14 (74 percent) and 15 (79 percent), respectively, of the 19 ranches. Percent cover by oak sprouts, an index to oak recruitment in harvested areas, averaged 2.5 percent for all ranches combined, but only eight of the 19 (42 percent) ranches had sprout cover exceeding the combined ranch average. Similar relationships were found

Table 4—Percent change in Average Annual Habitat Units (AAHU) for 21 wildlife species from blue oak woodlands over a 50-year period where wood cutting occurred on four selected ranches and 19 combined ranches in Shasta and Tehama counties, California.

Wildlife species	Ranches and harvest size				
	1 1,400 ac	2 300 ac	3 40 ac	4 500 ac	All 13,200 ac
Ensatina	-17.9	-97.7	-33.3	-10.0	-23.1
Cooper's hawk	-58.2	-78.0	-34.2	-17.5	-41.4
Red-tailed hawk	-12.4	-24.6	46.9	-19.7	28.7
Wild turkey	-26.6	0.0	12.4	-4.5	8.3
Mourning dove	-17.3	-45.0	196.1	-19.7	59.3
Western screech-owl	-54.6	-67.0	12.4	-6.7	8.3
Acorn woodpecker	-51.1	-98.6	77.6	-25.5	44.4
Pacific-slope flycatcher	-80.1	-99.0	-47.2	-42.4	-56.0
Ash-throated flycatcher	28.8	-98.5	199.7	-17.1	113.7
Western scrub-jay	-60.3	-99.0	-2.3	-25.5	-15.4
Bushtit	-50.4	-99.0	-2.3	-25.5	-15.4
White-breasted nuthatch	-52.5	-98.7	4.5	-27.5	-11.9
Western bluebird	-30.0	-29.0	189.4	-43.3	135.5
Western meadowlark	9,900.0	9,900.0	5,850.0	77.6	6,750.0
California ground squirrel	113.0	203.0	110.3	5.2	103.0
Western gray squirrel	-85.8	-98.5	-16.4	-54.8	-26.1
Dusky-footed woodrat	80.3	-97.0	-9.7	80.3	30.9
Gray fox	5.6	-44.2	122.8	-28.5	59.4
Mule deer	27.1	-43.4	40.0	-12.7	33.1
Western fence lizard	11.7	-67.0	51.5	-6.7	30.0
Gopher snake	4.4	0.0	203.0	0.0	88.3
No. significant differences[1]					
Positive	3	2	9	2	7
Negative	8	12	0	1	1
Unaffected	10	7	12	18	13

[1]Significant differences defined as percent change ± 50 percent between the cut and uncut conditions.

between the study area average and individual ranch averages for other vegetation variables (*table 1*).

Considerable differences existed between average stem diameter and average tree canopy cover between the cut and uncut conditions over the 50-year period (*table 2*). As expected, uncut conditions had the greatest amount of canopy cover, averaging 2-3 times more tree canopy than cut conditions. Average stem diameters, however, were almost identical for the cut and uncut condition for the entire study area.

Ranch 3 and All Ranches had the most similar stem diameters and canopy cover among the five scenarios. Similar stem diameters may indicate that harvesting was proportionately directed at all tree sizes. The most substantial differences in stem diameters were with Ranches 1 and 2, indicating a harvest directed at the larger trees. Because of the similarities in stem diameters and canopy covers, CWHR habitat types and stages were relatively similar to those of Ranch 3 and All Ranches.

Ranches 1, 2, and 4 had been harvested such that post-cut habitat conditions did not meet the criterion of 10 percent tree canopy cover for a tree-dominated CWHR habitat type (Mayer and Laudenslayer 1988) (*table 2*). These three ranches were typed as Annual Grassland habitats for Target Year 0, and Ranch 2 remained Annual Grassland habitat over the entire 50-year period because initial harvesting was so substantial that tree canopy cover never was ≥10 percent. Ranches 1 and 4 grew into blue oak woodland habitat by Target Year 10. For Ranches 3 and 4 and All Ranches, cut and uncut canopy cover classes differed by 1-2 classes (i.e., S [Sparse 10.0-23.9 percent] for cut and P [Open 24.0-39.9 percent] for uncut).

Wildlife

The 21 evaluation species included one amphibian, two reptiles, 13 birds, and five mammals (*table 3*). The western fence lizard (see *table 3* for scientific names) had the lowest score (5), while the wild turkey, mourning dove, and acorn woodpecker had the highest scores (9). The wild pig had the greatest score of all potential evaluation species, but it was not chosen because of controversy over its desirability as an occupant of California's oak woodlands. These evaluation species are representative of wildlife communities found in similar oak woodlands in California (Block and others 1991, Wilson and others 1991). A wide variety of breeding substrates and feeding habits are used by the evaluation species. In particular, trees and/or tree cavity breeding substrates were used by 13 species. At least six species used acorns as a primary food source.

Three species (ensatina, Cooper's hawk, Pacific-slope flycatcher) were predicted by CWHR to prefer blue oak woodlands with ≥40.0 percent tree canopy (closed canopies). CWHR predicted that nine species (mourning dove, acorn woodpecker, ash-throated flycatcher, western bluebird, western meadowlark, California ground squirrel, gray fox, mule deer, gopher snake) preferred open canopied (10-39.9 percent) blue oak woodlands. The remaining nine species had similar CWHR-predicted suitability values and were categorized as having no preference.

Patterns of AAHU percent change was relatively consistent among the five ranch scenarios (*table 4*). Using the 50 percent change significance threshold, the Cooper's hawk, western screech-owl, acorn woodpecker, Pacific-slope flycatcher, western scrub-jay, bushtit, white-breasted nuthatch, and western gray squirrel appeared to be the most negatively affected by wood cutting because they exceeded the negative threshold for two or more scenarios. Conversely, the mourning dove, ash-throated flycatcher, western bluebird, western meadowlark, California ground squirrel, dusky-footed woodrat, gray fox, and gopher snake were the most positively affected because they exceeded the positive threshold for two or more scenarios. The acorn woodpecker, ash-throated flycatcher, dusky-footed woodrat, and western fence lizard had negative changes for one or more ranches (Ranches 1 and/or 2) and positive changes for another ranch (Ranches 1 or 3 and/or All Ranches) (*table 4*).

Of the five scenarios, Ranch 4 had the least significant impacts. Ranches 1 and 2 had the greatest number of species negatively affected, while Ranch 3 and All Ranches had the greatest number of species positively affected. Ranches 1 and 2 had the greatest numbers of species positively and negatively affected.

Discussion

Differences in habitat conditions between cut and uncut conditions were plainly evident. Wood cutting resulted in substantially lower amounts of canopy cover. Stem densities were variously affected depending on the tree diameters selected during the harvest.

Wildlife were variously affected depending on the CWHR-predicted habitat suitabilities for each species. Generally, species favoring closed-canopy conditions with larger diameter trees, such as the Cooper's hawk and Pacific-slope flycatcher, were negatively affected when cutting resulted in grasslands or oak woodlands with small diameter trees and open canopies. Conversely, species favoring grasslands or very open woodlands, such as the western meadowlark, California ground squirrel, and gopher snake, were positively affected.

Some species favoring tree habitats with open canopies, such as the mourning dove, ash-throated flycatcher, western bluebird, gray fox, and mule deer, were

predicted to be positively affected or unaffected on the basis of the magnitude of the tree cutting. The western screech owl, acorn woodpecker, western scrub-jay, bushtit, white-breasted nuthatch, and western gray squirrel were significantly negatively affected only when substantial differences occurred between the cut and uncut conditions. The ensatina, red-tailed hawk, wild turkey, mule deer, and western fence lizard were relatively unaffected by the cutting, despite varying degrees of canopy cover preference.

Substantial positive changes in AAHUs were calculated for the western meadowlark and California ground squirrel because CWHR predicted blue oak woodland habitats with even moderate amounts of tree canopy cover as unsuitable (HSI = 0.0). It is likely that CWHR underestimated the habitat value to these species, and some habitat value exists. AAHU changes would have been less if suitability values had existed for those habitat conditions.

Clearly, the magnitude of tree cutting influenced wildlife impacts. Ranch 3 and All Ranches had relatively minor amounts of tree cutting, and impacts were either positive (Ranch 3: nine species; All Ranches: seven species) or not significant (Ranch 3: 12 species; All Ranches: 13 species). The harvesting at Ranch 3 and All Ranches actually resulted in woodlands with larger diameter trees and more open canopy conditions than the uncut condition. Ranches 1 and 2 had relatively large amounts of tree cutting, and their impacts were mostly negative (Ranch 1: eight species; Ranch 2: 12 species). Ranch 4 had relatively similar canopy cover levels for the cut and uncut woodland conditions, and relatively few species were affected (one and two species negatively and positively affected, respectively).

It was difficult to assess the importance of habitat elements, such as snags, woody debris, and shrubs, in causing or minimizing wildlife habitat impacts. Differences in elements among ranches could be due to variable harvesting activities and/or natural resources. Either way, these habitat elements play major roles in supporting wildlife communities. Absence of key elements may mean absence of dependent wildlife species. Land use activities that maintain and recruit important elements, such as snags, granaries, woody debris, shrubs, and brushpiles, likely will minimize adverse impacts to wildlife. For example, the dusky-footed woodrat requires shrubs for habitat occupancy according to CWHR habitat models.

Hardwood habitat management guidelines employed by CDFG (California Department of Fish and Game 1989) establish *minimum* retention standards for several of these elements as well as canopy cover. Ranches 1 and 4 did not meet CDFG's blue oak habitat snag retention standard of 1 blue oak snag/5 acres (0.20 snags/acre), and eight of the 19 (42 percent) ranches did not meet the snag guideline. CDFG standards of 40 percent for tree canopy cover retention were not met by four of the five (80 percent) ranch scenarios in *table 2*, nor by 14 of the 15 (93 percent) ranches with baseline uncut canopy covers ≥40 percent.

Our results using CWHR and blue oak growth models indicate that over a relatively long time period (50 years in this case), the magnitude of wildlife impacts from tree cutting in blue oak woodlands varies by species. Effects of tree canopy cover are important when average tree diameters are similar between cut and uncut conditions. To minimize negative impacts and have some positive impacts, cutting should be proportionately directed at trees of all sizes or disproportionately more large trees should be left such that average tree diameter changes relatively little or slightly increases, respectively. Immediate post-harvest retention of tree canopy cover should be between 25 and 40 percent. Land management practices should allow for tree recruitment through stump sprouting, acorn germination, and retention of smaller, presumably younger, trees. Furthermore, snags, shrubs, downed woody debris, acorn-producing trees, brushpiles, and other habitat elements should remain or be enhanced.

CWHR models have inaccuracies as Block and others (1994) demonstrated for predictions from California oak woodlands. Therefore, our results should be cautiously interpreted and applied only to the 21 evaluation species. Furthermore, any management decisions or generalizations about impacts of wood cutting to wildlife communities in blue oak woodlands throughout California should be tempered. This post-hoc impact assessment used models of habitat relationships based on varying amounts of scientific information; on-site wildlife inventories were not done, and models were not tested. Also, impacts were evaluated over a 50-year period, and immediate impacts from tree cutting were not explicitly discussed, although they were accounted for with the HEP analysis.

We think that some inaccuracies have been minimized to the largest extent possible through the process of selecting evaluation species. This process resulted in use of 21 evaluation species that, we are relatively confident, occur in the study area and indicate blue oak woodland conditions. Nevertheless, the biological significance of CWHR-predicted impacts must be cautiously interpreted as Block and others (1994) and Garrison (1994) suggest.

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