

Numerical Response of Small Vertebrates to Prescribed Fire in a California Oak Woodland¹

Justin K. Vreeland² and William D. Tietje³

Abstract

Use of prescribed fire for management of livestock forage and fuel load is increasing in California oak woodlands, but its effects on vertebrate wildlife are unknown. We conducted a light-intensity prescribed fire in mixed blue oak-coast live-oak woodlands in coastal-central California and assessed vegetation change and numerical response of small, non-game vertebrates, to the fire. The prescribed fire significantly reduced four (grass, shrub cover, coarse woody debris, woodrat houses; $P < 0.05$) of the 13 vegetation and habitat components that we measured. We observed no change in relative abundance of small mammals, breeding birds, amphibians, or reptiles in response to the prescribed fire. Light- to moderate-intensity prescribed fire in California oak woodlands is probably beneficial by reducing resource competition from exotic annual grasses, stimulating shrub and tree vigor and, ultimately, overall habitat rejuvenation. A high-intensity prescribed fire is planned for the fall of 2002 to yield a better understanding of the response of terrestrial vertebrates to the range of prescribed fires that are conducted in California oak woodland.

Introduction

Oak (*Quercus* spp.) woodlands are the most extensive vegetation type in California, covering approximately 3 million ha (Griffin and Muick 1984, Rossi 1979). In varying compositions, 10 native shrub and nine native tree species comprise numerous woodland habitat types. More vertebrate wildlife species use oak woodlands than any other vegetation type in California (Airola 1988, Ohmann and Mayer 1987).

California oak woodlands are fire-adapted, having evolved with fire during the past one million years. The dominant use of oak woodlands is rangeland for livestock production. Prescribed fire is used in oak woodlands as a livestock forage and fuel management tool (Griffin and Muick 1984). The California Fire Plan (California Department of Forestry and Fire Protection 1996) suggests increased use of prescribed fire in California's oak woodlands to reduce the severity of wildfires by limiting fuel accumulation and to manage livestock forage.

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² Graduate Research Assistant, Pennsylvania Cooperative Fish and Wildlife Research Unit, Merkle Laboratory, The Pennsylvania State University, University Park, PA 16802

³ Natural Resources Specialist, Integrated Hardwood Range Management Program, Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720 (e-mail: wdtietje@ucdavis.edu)

In the central coast region of California (roughly the area between Santa Barbara and San Francisco extending to the coast mountain ranges approximately 80 km inland), the California Department of Forestry and Fire Protection (CDF) conducts prescribed burns on 1,000-4,000 ha annually (Parker, personal communication). The CDF presumes that prescribed fire benefits wildlife of oak woodland habitats, but no published research supports this assumption. Most research on effects of prescribed fire to wildlife and their habitats in California historically has been conducted in chaparral ecosystems (Lawrence 1966; Lillywhite North 1974; Longhurst 1978; Quinn 1979, 1983; Wirtz 1979, 1982). Except for a manuscript from this project (Vreeland and Tietje 1998), we are aware of no published research on effects of prescribed fire to California oak woodland habitats and associated wildlife species. Our objective was to quantify vegetation change and numerical response of small, non-game vertebrates to a prescribed fire conducted in mixed oak woodlands of the central coast region of California.

Materials and Methods

Study Area

We conducted this study at Camp Roberts (CR), California; a facility of the California Army National Guard located approximately 30 km from the Pacific Ocean in northern San Luis Obispo and southern Monterey counties. Topography at CR varies from flat to gently rolling hills and steep ($>45^\circ$ slope) hills. The climate of the study area is Mediterranean, characterized by cool, wet winters and hot, dry summers. Annual precipitation averages 38 cm (66-year range = 10.8-74.1 cm), falling almost exclusively as rain between November and March. Mean annual temperature averages 15.3°C . Summer high temperatures frequently approach 44°C ; winter lows rarely fall below -6°C (U.S. Weather Bureau, Sacramento, California). Sheep grazing and military training occur in our study area, but are limited in extent, duration, and intensity. Fire has been excluded from the study area for >15 years (Brian Duke, CR Environmental Office, Camp Roberts, California). Our study sites were on slopes $<20^\circ$, on north- to east-facing aspects, and 300-500 m elevation.

Camp Roberts comprises 17,000 ha, of which 41 percent is classified as oak woodland (Camp Roberts EMAP 1989). Three oak habitat types occur at CR: valley oak (*Quercus lobata*), coast live-oak (*Q. agrifolia*), and blue oak (*Q. douglasii*), with considerable overlap between coast live-oak and blue oak types. We used blue oak and mixed blue oak-coast live oak stands in the San Luis Obispo County portion of CR (Tietje and others 1997, Tietje and Vreeland 1997a). Blue oak sites were characterized by 40-60 percent canopy cover, <10 percent shrub cover, and >50 percent ground cover of exotic annual grasses. Blue oak was the dominant canopy species in the mixed blue oak-coast live-oak sites with a variable contribution (0-45 percent) of coast live oak. The mixed sites were characterized by 60-90 percent canopy cover, 10-30 percent shrub cover, and a well-developed, thick leaf litter layer with abundant herbs, forbs, and <30 percent grass cover.

Plants in the understory were primarily toyon (*Heteromeles arbutifolia*), redberry (*Rhamnus crocea*), poison oak (*Toxicodendron diversilobum*), and bigberry manzanita (*Arctostaphylos glauca*). Small (0.25 ha) patches of chaparral (*Adenostoma fasciculatum*, *Baccharis pilularis*, *Ceanothus* spp., *Lotus scoparius* and *Salvia mellifera*) occurred on three study plots. Common forbs included hummingbird sage (*Salvia spathacea*), filaree (*Erodium* spp.), and fiddleneck

(*Amsinckia* spp.). Wild oats (*Avena* spp.), bromes (*Bromus* spp.), and fescues (*Festuca* spp.) dominated grassy openings of the woodland floor. Tietje and others (1997) and Tietje and Vreeland (1997a) give detailed descriptions of vegetative and habitat characteristics of our study sites.

Prescribed Fire

We selected two areas to receive a prescribed fire treatment. One area (hereafter “Burn 1”) was 73 ha, the other area (hereafter “Burn 2”) was 130 ha. The California Department of Forestry and Fire Protection and the Camp Roberts Fire Department burned these areas on consecutive days in October 1997. The perimeter was burned first, then the interiors were ignited using drip torches, and accelerants delivered from a helicopter. Surrounding unburned areas hereafter are referred to as “Ctrl” or “unburned areas.”

Small Mammal Sampling

In winter 1996, we used a compass and meter tape to lay out an 8 by 8 grid with 15-m spacing (64 intersections) on each of 22 1.1-ha sampling plots. During May 1997-1999, we live-trapped small mammals on the plots by placing a single Sherman live trap at each of the 64 intersections. Plots were evenly divided between burned and unburned areas; six plots were in Burn 1 and five plots were in Burn 2. Four pairs of plots were approximately 40 m apart; the others were >100 m apart. Spatial separation between plots was adequate because <4 animals moved among plots during the study.⁴ We trapped for five consecutive nights during 1997 and three consecutive nights during 1998 and 1999. We baited traps with horse feed (“COB”: corn, oats, and barley laced with molasses), tagged animals with individually numbered ear tags, and released them at site of capture. We handled animals in accordance with University of California, Berkeley Animal Use Protocol No. R166-0199.

Breeding Bird Sampling

We conducted point-counts of breeding birds during March-April, 1997-1999. We used 86 50-m-radius point count stations located 150 m apart. Stations were evenly divided between burned (43 stations [13 stations were in Burn 1, 30 stations were in Burn 2]) and unburned areas (43 stations). We visited each station six times in each season. We rotated station visitations among start time, observer, and treatment. Two to four observers conducted counts in each year. We conducted counts for 10 minutes at each station between official sunrise and 1100 hours using standard breeding-bird survey protocols (Bibby and others 1992).

Amphibian and Reptile Sampling

We counted amphibians and reptiles under 136 61-cm by 61-cm by 1.27-cm plywood coverboards (DeGraaf and Yamasaki 1992, Grant and others 1992, Tietje and Vreeland 1997b) on each of nine 5.8-ha plots (8 by 17 grid, 30- by 15-m

⁴ Unpublished data supplied by W. D. Tietje.

spacing), established in 1993 for another study. Five plots were in the unburned area, two plots each were in Burn 1 and Burn 2. We checked each coverboard once every 7-10 days during late January-early May in 1995-1999. We used this size coverboard because we required thorough coverage throughout our plots and because larger coverboards warp and therefore may be less effective in the Mediterranean climate of our study area (Vreeland, personal observation). We first deployed coverboards in 1994 to allow them to weather for 6-9 months, dissipating chemicals used in their manufacture that might affect their use by amphibians and reptiles (Grant and others 1992). We had difficulty identifying slender salamanders (*Batrachoseps* spp.) (Scott, personal communication). California slender salamanders (*Batrachoseps attenuatus*) and black-bellied salamanders (*B. nigriventris*) potentially occur at CR, but cannot be distinguished in the field. Therefore we grouped them into one species category, hereafter “slender salamanders.”

Vegetation Sampling

Within 2 months before and within 2-3 months after the prescribed fire, we sampled vegetation on the 11 1.1-ha small mammal sampling plots in the burned areas. We randomly located five 10-m-radius sampling stations on each plot. At 10 m in the cardinal directions from the central point of each station, we measured canopy cover with a concave spherical densiometer (Lemmon 1956), understory obstruction (an index to shrub cover) with a vegetation pole (Griffith and Youtie 1988) graduated in five 0.5-m sections, and ocularly estimated ground cover within 1 m² frames. Litter depth (an index to litter volume) was taken with a ruler (nearest 0.5 cm) at the center of the square frame. Within 10 m of the central point of each station, we counted the number of pieces of coarse woody debris (CWD, ≥ 1 m long and maximum diameter ≥ 10 cm), number of snags (≥ 1.37 m tall and ≥ 10 cm diameter at breast height), and number of dwellings (hereafter “houses”) constructed by dusky-footed woodrats (*Neotoma fuscipes*).

Analyses

To assess fire intensity and coverage, we qualitatively described fire behavior according to CDF's fire intensity rating scale and we counted the number of grid intersections on small mammal trapping grids at which fire burned to within 1 m. In Vreeland and Tietje (1998), we conducted paired-sample *t*-tests to assess vegetation changes due to the fire. We considered differences significant at $\alpha=0.05$. We repeat an abbreviated version of those vegetation results here, but direct the reader to Vreeland and Tietje (1998) for details on vegetation results.

Because we were unable to randomly select burned areas and because treatment replication was low (true replication was at the burn level, i.e., two burn replicates), our animal data cannot meet some assumptions of analyses of variance (ANOVA). Therefore, rather than conduct inappropriate, low-power statistical tests, we used means and 95 percent confidence intervals (CI) to assess numerical response of vertebrates to the prescribed fire. We selected one species to represent each of the four vertebrate taxa that we monitored (amphibians, reptiles, birds, mammals). We selected the representative species based on two characteristics: large relative abundance and potential for demonstrating change as a result of prescribed fire.

Relative species abundance was calculated for each experimental unit (plot or point count station), and then averaged for a treatment area (Burn 1, Burn 2, Ctrl). Because we have pre- and post-fire data on burned and unburned areas, pre-fire differences in relative abundance between burned and unburned areas are unimportant. The meaningful test of an effect of the fire is a comparison between relative abundance of a species on burned areas compared to unburned areas (Ctrl) before and after the fire. This is analogous to the interaction term in a 2-way ANOVA. Differences between treatment means were considered not statistically different if any portion of their 95 percent CI overlapped.

Results

Prescribed Fire

The California Department of Forestry and Fire Protection rated the prescribed fire as light to moderate in intensity (3-4 on a 10-point scale). Flame height generally was <1 m except in a few areas of decadent grasses, chaparral, or dense accumulations of CWD. Few mature trees died. The fire was patchily distributed and carried better through blue oak stands with abundant grass cover than through mixed oak stands with thick leaf litter and dense canopy cover. Mineral soil was mostly unexposed except in small areas with high fuel load (dense CWD, chaparral). Area burned on 1-ha plots averaged 46 percent (range 30 to 66 percent).

Vegetation

Understory obstruction (shrub cover) and grass cover were reduced by 7 percent and 70 percent, respectively ($P < 0.05$). Much of the reduction in understory obstruction, however, resulted from our recording (as shrub cover) the obstruction by grass of the lower 0.5 m of the vegetation pole. Excluding this grass cover probably would result in no statistical reduction in understory (shrub) obstruction. Grass cover returned to pre-fire cover by one growing season after the fire. Canopy cover, number of snags, and litter depth did not change. Approximately 6 percent of the canopy was singed. Number of woodrat houses was reduced by 30 percent ($P < 0.05$) and number of pieces of CWD was reduced by 35 percent ($P < 0.05$). We recorded five new pieces of CWD in the 55 10-m vegetation plots. These pieces of CWD were created when roots of mature oaks were burned during the fire, causing the bole to fall to the ground. Vreeland and Tietje (1998) report detailed vegetation responses to the prescribed fire.

Small Mammals

We captured nine species of small mammals during 3 years of live trapping. Woodrats, piñon mice (*Peromyscus truei*), brush mice (*P. boylii*), and California mice (*P. californicus*) were the four most abundant species. Woodrats were the most frequently captured species (26.5 captures/100 trap-nights during 1997-1999). Relative abundance (captures/100 trap-nights) of woodrats on burned areas compared to the unburned areas did not change after the prescribed fire (*fig. 1*). Relative abundance of woodrats was approximately 60 percent lower in 1998 and 1999 than in 1997, but this reduction was proportional among burned and unburned areas.

Confidence intervals consistently overlapped treatment means and other CI within and among years.

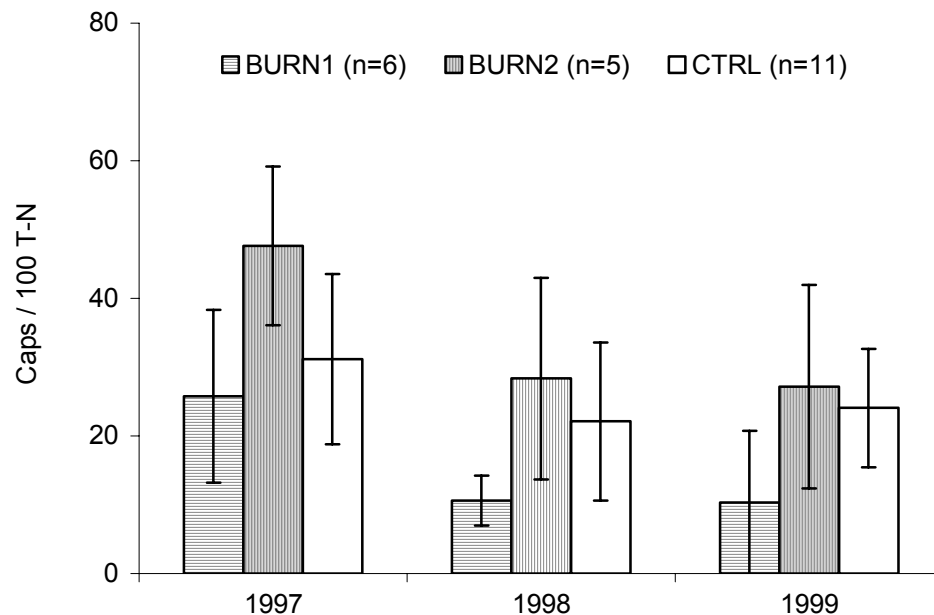


Figure 1—Dusky-footed woodrat abundance (captures per 100 trap-nights) in May 1997-1999 before and after an October 1997 prescribed fire in blue oak-coast live oak at Camp Roberts, California. Error bars are 95 percent confidence intervals.

Breeding Birds

We observed over 85 species of birds during the breeding season on the 86 point count stations. Dark-eyed juncos (*Junco hyemalis*) were one of the two most frequently observed species (1.7 observations/point/visit during 1997-1999, respectively). Relative abundance (mean number of observations/point) of juncos on burned areas compared to unburned areas did not change after the prescribed fire (*fig. 2*). We observed an approximately 80 percent increase in juncos 2 years post-fire, but this increase was proportional among burned and unburned areas. Juncos consistently were more abundant on Burn 1 than Ctrl, but the difference remained consistent before and after the fire. Other confidence intervals were narrow, but consistently overlapped treatment means and other CI within and among years.

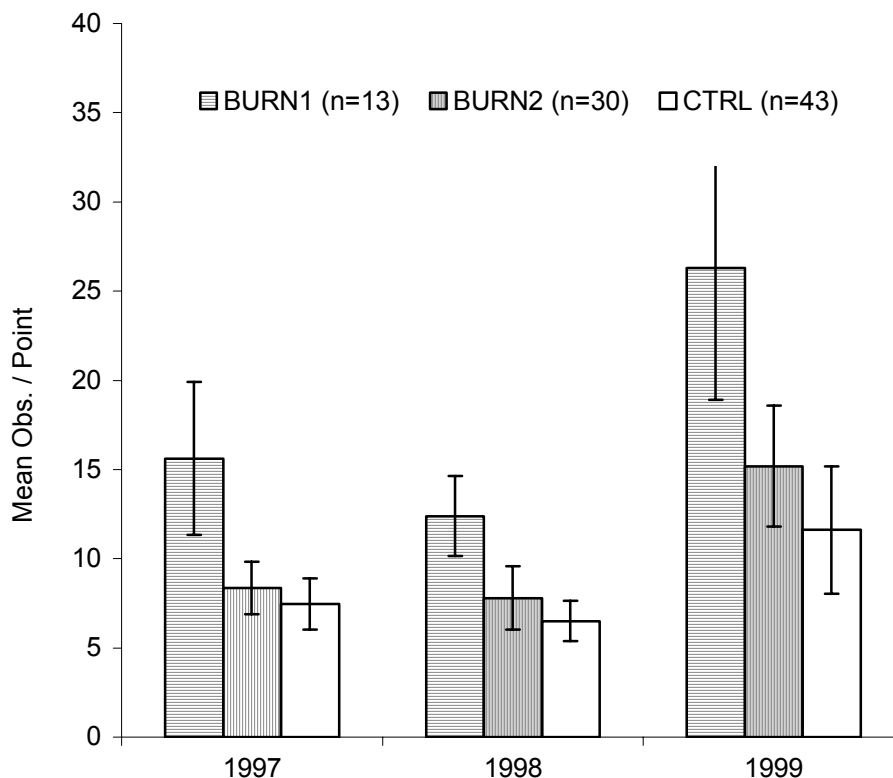


Figure 2—Dark-eyed junco abundance (mean number of observations per point) in March and April 1997-1999 before and after an October 1997 prescribed fire in blue oak-coast live oak woodlands at Camp Roberts, California. Error bars are 95 percent confidence intervals.

Amphibians and Reptiles

We observed four amphibian (two salamanders, one frog, one toad) and 11 reptile (five lizards, six snakes) species under plywood coverboards. Among amphibians, only slender salamanders were observed in appreciable numbers (1.74 observations/100 coverboard visits during 1995-1999). Relative abundance (number of observations/100 board-visits) of slender salamanders was similar on burned areas compared to unburned areas before and after the prescribed fire (*table 1*). Except during 1999, slender salamanders were more abundant on Burn 1 than Burn 2 or Ctrl, but this pattern of relative abundance remained consistent among years before and after the prescribed fire. Confidence intervals were broad, frequently included zero and other treatment means, and overlapped other CI within and among years.

Western skinks (*Eumeces skiltonianus*) were the most frequently observed reptile species (3.96 observations/100 coverboard visits during 1995-1999). Relative abundance (number of observations/100 board-visits) of western skinks varied among years and among treatment areas within and among years, but was similar on burned areas compared to unburned areas before and after the prescribed fire (*table 1*). Skink observation rate appeared to be increasing on Ctrl, decreasing on Burn 2, and irregular on Burn 1, but these trends began 2-3 years before the fire, and were not

caused by nor interrupted by the fire. Confidence intervals were broad, frequently included zero and other treatment means, and overlapped other CI within and among years.

Table 1—Relative abundance (mean, 95 percent CI) of slender salamanders and western skinks on burned and unburned areas before and after prescribed fire in blue oak–coast live oak woodlands at Camp Roberts, California, 1995–1999. The prescribed fire was conducted in October 1997. Pre-fire years are 1995–1997. See text for sample sizes.

Year	Treatment	Slender salamander	Western skink
1995	Burn 1	8.6 (0–89.0)	2.6 (0–13.3)
	Burn 2	0.8 (0–7.7)	4.0 (0– 8.3)
	Ctrl	0.6 (0–1.4)	3.3 (0– 6.7)
1996	Burn 1	2.0 (0–15.1)	2.0 (0–12.3)
	Burn 2	1.0 (0–11.3)	3.4 (0–10.4)
	Ctrl	0.3 (0–0.6)	3.5 (0–7.0)
1997	Burn 1	2.9 (0–19.2)	1.7 (0–7.7)
	Burn 2	2.4 (0–21.6)	2.7 (0–9.7)
	Ctrl	1.0 (0–2.2)	4.8 (0.2–9.3)
1998	Burn 1	6.6 (0–52.4)	3.3 (0–26.1)
	Burn 2	3.2 (0–32.1)	2.4 (0–4.7)
	Ctrl	1.0 (0–2.2)	6.7 (0.3–13.0)
1999	Burn 1	1.8 (0–15.4)	2.8 (0–18.9)
	Burn 2	2.8 (0–33.1)	2.4 (0–15.6)
	Ctrl	0.4 (0–0.9)	6.7 (0–12.7)

Discussion

We detected no change in relative abundance of small mammals, breeding birds, amphibians, or reptiles after a light- to moderate-intensity prescribed fire in a California blue oak-coast live oak woodland. The low intensity fire resulted in generally marginal or short-term changes to the 13 vegetation characteristics that we measured. Only four habitat elements: grass, shrub cover, coarse woody debris, and woodrat houses were reduced significantly ($P < 0.05$) by the fire, and these habitat alterations may not have been significant biologically. The significant removal of shrub cover was an artifact of our sampling method. Grass cover was 70 percent removed, but it grew back within a few months of the fire. Other habitat elements are also apparently more important than grass cover for habitat occupancy and the abundance of most of the small vertebrates that we monitored (Tietje and Vreeland 1997a). Although one of these habitat elements is coarse woody debris (Tietje and Vreeland 1997a), it is not surprising that the 35 percent reduction of coarse wood debris did not result in a detectable numeric change in relative abundance small vertebrates. Coarse woody debris was abundant throughout the study area and ample amounts likely remained to supply essential hiding, foraging, and breeding cover. Similarly, the availability of woodrat houses was likely not limiting after 30 percent were burned. Not all woodrat houses are occupied on the study area (Vreeland and

Tietje 1999) and the fire did not reach many of the houses in the densest habitats; therefore, few woodrats were forced to relocate to new areas or construct new houses after the fire. Responses to the fire were also minimal because small vertebrates have adapted to low intensity fire over the last millennia. Historically, fires were ignited by lightning or set intentionally by Early Americans to clear ground, aid in gathering acorns, and to drive game (as cited in Rossi 1980). They were frequent and rather low in intensity. Most small vertebrates have subterranean access or flee to avoid direct mortality.

The study has several shortcomings which compromise statistical inference. It was not practical or, in some cases possible, due to budget and feasibility constraints, to set up a true experiment. Fire control concerns rather than randomization dictated the location of our treatment areas (burn areas) and the treatment was not applied randomly to experimental units (small mammal and herpetofauna sampling plots or bird point count stations). The experimental units in our study, moreover, are pseudoreplicates within the burned ($n=2$) and unburned ($n=1$) areas), contributing to low statistical power (broad CI) for our data and rigorous statistical inference is compromised.

We believe our study, however, represents important, initial information on effects of prescribed fire to blue oak-coast live-oak woodland habitat and associated small, non-game vertebrates; and, our qualified conclusion of “no effect” is probably appropriate. We attempted to neutralize potential extraneous or nuisance variables not dealt with through proper control or randomization by adding time (before/after burning) as another control or reference. Therefore the natural changes in the abundance of the small vertebrates we monitored were less likely to be confused with a treatment effect. Annual fluctuations of monitored animals after the burn were within the range of abundances before the burn. “No effect” by species that we monitored was consistent within all four taxa (birds, small mammals, amphibians, reptiles) and across all pseudoreplicates of the treatment and control experimental units (22 small mammal plots, 86 bird point count stations, 9 herpetofaunal plots). Collectively, these support the supposition that, given similar blue-coast live oak woodland and fire intensity on the California central coast, one could expect little fire effect on the resident small vertebrates.

Management Implications

The CDF fire intensity scale (see table 1 in Tietje and others 2001) gives oak woodland managers and landowners an understanding of how to judge intensity based on the CDF criteria and where the intensity of our experimental fire at Camp Roberts lay. This fire was on the “light side” for prescribed burns conducted by CDF in oak woodland (Parker, personal communication). It provides strong subjective evidence that one could expect this result given this fire intensity in blue-coast live oak woodland similar in tree density and habitat structure to our study area at Camp Roberts. Prescribed fire that is light to moderate in intensity is also not detrimental to oak regeneration (Tietje and others 2001) but, overall, prescribed fire is probably beneficial by reducing resource competition from exotic annual grasses, stimulating shrub and tree health and vigor and, ultimately, mast production and overall habitat rejuvenation. Further study is needed to corroborate the results of this study and to evaluate the range of intensity of experimental burns and their effects on wildlife.

Acknowledgments

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