

Diets of California Spotted Owls in the Sierra National Forest¹

Thomas E. Munton,² Kenneth D. Johnson,² George N. Steger,² and Gary P. Eberlein²

Abstract

From May 1987 through October 1992 and from July through August 1998, we studied diets of California spotted owls (*Strix occidentalis occidentalis*). Regurgitated pellets were collected at roost and nest sites between 1,000 and 7,600 ft elevation in the Sierra National Forest and were examined for remnant bones, feathers, and insect exoskeletons. Remains of 2,038 individual prey were identified in 1,140 pellets. Woodrats (*Neotoma spp.*) were the predominant prey in low-elevation oak woodlands and riparian-deciduous forests, accounting for 74.3 percent of the biomass in diets during the breeding period and 81.9 percent during the nonbreeding period. In coniferous forests, northern flying squirrels (*Glaucomys sabrinus*) were the major prey, comprising 45.6 percent and 77.3 percent of prey biomass during the breeding and nonbreeding periods, respectively. Pocket gophers (*Thomomys spp.*) were the second largest component of owl diets, by biomass, in both vegetation types. In the breeding period, birds were a larger part of the owl's diet in coniferous forests (12.9 percent) than in the riparian-deciduous and oak habitats (1.8 percent). Other small mammals, insects, and lizards were also found in pellets. Diets differed among years.

Concern over the status of the California spotted owl (*Strix occidentalis occidentalis*) increased when the U. S. Fish and Wildlife Service listed the northern spotted owl (*S. o. caurina*) and then the Mexican spotted owl (*S. o. lucida*) as "threatened." Although not currently federally listed, the California spotted owl is classified as a "sensitive species" by the Pacific Southwest Region (Region 5) of the USDA Forest Service.

Several studies have examined diets of California spotted owls in the Sierra Nevada (Kadoch 1997, Laymon 1988, Marshall 1942, Thrailkill and Bias 1989, Verner and others 1992), but additional information on diets is needed to better understand the relations between owl occurrence and breeding and the availability of prey. An adequate understanding of diets can then guide studies of the ecological requirements of key prey species and help to guide forest management in ways that will favor conditions for the prey species and, in turn, for the owls.

We studied California spotted owl diets in the southern Sierra Nevada to describe prey composition and to examine annual and seasonal variations in the diets. We also compared diets between owls in coniferous forests and owls in oak woodlands and riparian-deciduous forests.

Study Area

We studied spotted owl diets in a 265-mi² study area in the Sierra National Forest, Fresno County, California, about 30 mi east of Fresno (Steger and others, in this volume). Twenty-three percent of the study area was below 4,000 ft in

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² Wildlife Biologist, Wildlife Biologist, Biological Technician, and Statistical Assistant, respectively, Pacific Southwest Research Station, USDA Forest Service, 2081 E. Sierra Ave., Fresno, CA 93710.

elevation, in oak-pine woodlands, blue oak (*Quercus douglasii*) savannas, and dense riparian-deciduous forests (Verner and Boss 1980). Coniferous forests covered the remainder of the study area, from about 4,000 to 9,600 ft in elevation. Ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*), and black oak (*Quercus kelloggii*) were the dominant tree species below 8,000 ft. Inclusions of Jeffrey pine (*Pinus jeffreyi*) and red fir (*Abies magnifica*) occurred near 8,000 ft. Above that, forests were dominated primarily by red fir, lodgepole pine (*Pinus contorta*), and western white pine (*Pinus monticola*).

Methods

Owls regurgitate the less-digestible parts of consumed prey (bones, feathers, exoskeletons, fur, and so on) in formed pellets. Prey remains in these pellets have long been used to study the diets of owls (Glading and others 1943, Marti 1987). From May 1987 through October 1992, and from July through August 1998, we studied diets of the owls by examining prey remains in regurgitated pellets collected below roost and nest sites. Pellets were classified as egested during either the breeding (March 1 through August 31) or nonbreeding (remainder of the year) period, and we analyzed only pellets that could be assigned unambiguously to either period. Identification to species was impossible for some specimens because remains were incomplete.

Sampling intensity varied considerably among sites, seasons, and years. From May 1987 through March 1990, we collected pellets opportunistically throughout each year while studying home ranges and habitat use of radio-tagged spotted owls. Thereafter, we collected pellets in conjunction with demographic studies, when most of the collected pellets were egested during the breeding period. Pellets collected at the same site on the same day, or within a brief period of a few days, were aggregated into one sample because remains of the same individual prey can be egested in more than one pellet (Forsman and others 1984).

As described by Munton and others (1997), pellets were dissected and skeletal remains, feathers, and pieces of exoskeleton were identified to species when possible, using a reference collection of specimens from the Carnegie Museum of Natural History, together with selected references and keys (Borror and DeLong 1964, Burt and Grossenheider 1976, Dunning 1984, Forsman and others 1984, Ingles 1990, Jameson and Peeters 1988, Robbins and others 1983, Swan and Papp 1972). These same sources were used to assign weights to prey items. Prey species with mean weight of at least 3.5 oz were considered to be "large prey." The number of individual prey items in a sample was tallied as the largest number of skulls or identical bone parts for each prey type per sample (the aggregate of pellets from a single site in one to a few days). The number of insects was estimated either from the largest number of heads, paired mandibles, or one-sixth the number of legs. The estimated mean weight of each prey type was multiplied by its observed frequency in each sample to convert counts to biomass.

Results

Coniferous Forests

In 620 pellets collected in coniferous forests, more than 94 percent from the breeding period, we identified remains of 1,344 individual prey, an average of 2.12 prey items per pellet. Excluding insects—highly variable in number in pellets and of little consequence to total biomass—pellets averaged 1.48 prey items each. At least 35 species (13 mammals, 11 birds, 10 insects, and 1 lizard) were present. Mammals comprised 57.8 percent of all prey and 87.2 percent of the biomass; the remainder consisted of birds, lizards, and insects (*table 1*). Large

Table 1—Percent frequency and percent biomass of prey in California spotted owl pellets from coniferous forests, Sierra National Forest

Wildlife	Breeding period ¹		Nonbreeding period ²		Mean annual percent of biomass
	Percent of individuals	Percent biomass	Percent of individuals	Percent biomass	
Bats	0.7	0.1	0	0	0.1
Birds	10.5	12.9	4.0	4.6	8.7
Diurnal squirrels	1.0	0.9	0	0	0.4
Flying squirrels	21.1	45.6	46.7	77.3	61.5
Gophers	11.0	18.4	9.3	11.5	15.0
Insects	32.3	0.6	24.0	0.3	0.5
Lizards	0.2	<0.1	0	0	<0.1
Mice	12.9	5.5	5.3	1.7	3.6
Moles	1.8	1.5	2.7	1.7	1.7
Shrews	1.7	0.2	6.7	0.6	0.4
Unidentified mammals	1.9	1.3	1.3	2.3	1.8
Voles	1.8	1.2	0	0	0.6
Woodrats	3.0	11.8	0	0	5.9

¹ $n = 1,269$ individual prey.

² $n = 75$ individual prey.

prey—flying squirrels (*Glaucomys sabrinus*), woodrats (*Neotoma* spp.), pocket gophers (*Thomomys* spp.), Steller's jays (*Cyanocitta stelleri*), northern flickers (*Colaptes auratus*), a western screech-owl (*Otus kennicottii*), an unidentified quail, and some unidentified mammals—accounted for 36.5 percent of the individual prey items and 78.3 percent of the biomass. Over the course of a year, flying squirrels contributed the most biomass to owl diets, followed by pocket gophers, birds, and woodrats (table 1). Owls were seldom found above 8,000 ft in elevation, and we found no pellets above 7,600 ft, probably because of low sampling intensity there.

We identified enough prey in five breeding periods to evaluate annual variations in biomass. The proportion of birds in diets was least variable (CV = 16.0 percent, table 2), followed by flying squirrels (CV = 22.8 percent). Interestingly, flying squirrels were most prevalent (54.1 percent of the biomass) in diets in 1992, when 87 percent of owl pairs produced young. No clear pattern emerged, however, when comparing percent biomass of flying squirrels in the diet and overall reproductive success of owls in the study. For example, flying squirrels were only slightly less prevalent (52.6 percent of the biomass) in 1988 diets, a year when pellets were collected from nonreproductive owls; and flying squirrels represented only 38.3 percent of the diet biomass in 1990, when 72 percent of pairs fledged young.

Table 2—Annual variation in percent biomass of prey in pellets of California spotted owls during the breeding period in conifer habitats of the southern Sierra Nevada; sample sizes (numbers of individual prey in parentheses beneath each year)

Wildlife	1988 (83)	1989 (295)	1990 (227)	1992 (362)	1998 (278)	Mean ± SD	Percent CV
Bats	0.1	0.1	0.2	0.1	0.1	0.1 ± 0.05	41.1
Birds	10.1	14.5	13.1	11.4	15.0	12.8 ± 2.05	16.0
Diurnal squirrels	1.7	0.3	1.0	0.2	2.1	1.1 ± 0.83	77.3
Flying squirrels	52.6	47.7	38.3	54.1	30.1	44.5 ± 10.16	22.8
Gophers	21.1	19.3	23.8	12.3	23.5	20.0 ± 4.70	23.5
Insects	0.6	0.8	0.5	0.4	0.8	0.6 ± 0.20	33.1
Lizards	0.0	0.0	0.1	0.0	0.0	<0.1 ± 0.03	223.6
Mice	1.7	3.1	3.5	6.0	11.7	5.2 ± 3.95	75.9
Moles	3.3	2.8	1.3	0.7	0.8	1.8 ± 1.18	66.4
Shrews	0.1	0.4	0.1	0.1	0.3	0.2 ± 0.13	66.6
Unidentified mammals	0.0	1.3	0.4	0.5	4.9	1.4 ± 2.02	141.8
Voles	0.7	0.8	0.3	0.6	3.2	1.1 ± 1.20	106.3
Woodrats	8.0	9.0	17.4	13.6	7.5	11.1 ± 4.28	38.6

Oak Woodlands and Riparian-Hardwood Forests

Data from low elevations in oak woodlands and riparian-deciduous forests are summarized from Munton and others (1997). In 520 pellets collected primarily during the nonbreeding period in 1988-1992, we identified remains of 664 individual prey, an average of 1.28 per pellet. Excluding insects, pellets averaged only 0.96 prey items each, 35 percent fewer than identified in pellets from the conifer forests. At least 20 species—nine mammals (70.0 percent of prey by frequency, 96.5 percent by biomass), six birds, and five insects—were identified (table 3). Large prey accounted for 48.5 percent of the total by frequency and 91.8 percent by biomass. Species included were woodrats, pocket gophers, western screech-owls, and unidentified mammals and owls. Woodrats were consistently the dietary staple—74.3 percent of prey biomass during the breeding period and 81.9 percent during the nonbreeding period. Pocket gophers comprised only 12.9 percent of the prey biomass over the full year; other mammal species, each contributing less than 5 percent of the total biomass, included mice (mainly *Peromyscus* spp.), voles (*Microtus* spp.), broad-footed moles (*Scapanus latimanus*), and shrews (*Sorex* spp.). Western scrub-jays (*Aphelocoma californica*) were the most numerous birds identified, followed by other species of owls.

Discussion

Diets of spotted owls at higher elevations (coniferous forests) and at lower elevations (oak woodlands and riparian-deciduous forests) were similar in dominance by a single prey species (flying squirrels at high elevations, woodrats

Table 3—Percent frequency and percent biomass of prey in California spotted owl pellets from low-elevation oak savannas, oak/foothill pine forests, and riparian-deciduous forests, Sierra National Forest (after Munton and others 1997)

Wildlife	Breeding period ¹		Nonbreeding period ²		Mean annual percent of biomass
	Percent of individuals	Percent biomass	Percent of individuals	Percent biomass	
Birds	2.2	1.8	6.7	4.2	3.0
Gophers	11.9	18.5	7.3	7.3	12.9
Insects	44.6	0.1	11.1	0.1	0.1
Mice	7.6	2.2	24.1	4.7	3.5
Moles	0.0	0.0	0.5	0.2	0.1
Shrews	0.4	<0.1	0.3	<0.1	<0.1
Unidentified mammals	1.1	0.2	1.6	0.7	0.5
Voles	5.0	2.7	2.6	0.9	1.8
Woodrats	27.3	74.3	45.9	81.9	78.1

¹ *n* = 278 prey items.

² *n* = 386 prey items.

at low elevations), increased reliance on the dominant prey species during the nonbreeding period, pocket gophers as the second greatest contributor to diet biomass and a higher proportion in diets during the breeding than the nonbreeding period, and higher frequency of insects during the breeding period. Main differences were the absence of flying squirrels from low-elevation diets (generally absent from those vegetation types); a greater reliance on the main prey species (woodrats) at low elevations; greater consumption of birds in coniferous forests, especially during the breeding period; greater consumption of birds and mice in coniferous forests in the breeding period than in the nonbreeding period, while the opposite trend occurred in oak woodlands and riparian-deciduous forests; and 1.55 times as many vertebrate prey per pellet in samples from the conifer forest than in samples from low-elevation sites.

The different numbers of prey items per pellet between high- and low-elevation sites most likely reflected the prevalence of woodrats in diets of owls in the low-elevation sites. Because woodrats outweigh flying squirrels by a factor of 1.82, one flying squirrel would provide only about 55 percent of the biomass available in one woodrat. Interestingly, note the close correspondence between the factor of 1.82 for the difference between weights of woodrats and flying squirrels and that of 1.70 for the difference between the numbers of prey items per pellet in the two areas.

Other studies (Kadoch 1997, Marshall 1942, Verner and others 1992) also found that flying squirrels dominate the diets of California spotted owls in coniferous forests of the southern Sierra Nevada during the breeding period. In addition, pocket gophers were found to be important prey in the Sequoia and Kings Canyon National Parks (Verner and others 1992) and in the Sierra National Forest by Kadoch (1997). Birds averaged 13.3 percent of the diet biomass during the breeding period on the Sierra National Forest in 1995 and 1996 (Kadoch 1997).

Diets of spotted owls in the Eldorado and Stanislaus National Forests from 1982 to 1984 were dominated by dusky-footed woodrats (*Neotoma fuscipes*) (31 percent) and flying squirrels (25 percent), followed by diurnal squirrels (14 percent) (Laymon 1988). Thraikill and Bias (1989) also found that woodrats (37.4 percent) and flying squirrels (31.2 percent) dominated spotted owl diets in the Eldorado National Forest, with birds making up another 12.4 percent of the biomass during studies in 1986 and 1987. The higher proportion of woodrats and lower proportion of flying squirrels found in their studies, in comparison with results of the present study in the southern Sierra Nevada, probably reflect the fact that the study areas in the central Sierra Nevada included considerable landbase at lower elevations, probably in the transition zone where flying squirrels are less abundant and woodrats more abundant than at the higher elevations corresponding to those in the coniferous forests of our study area.

The studies by Laymon (1988) and Thraikill and Bias (1989) both found a markedly higher percentage of diurnal squirrels (14.0 and 6.7 percent, respectively) than we found (0.9 percent) in the conifer zone of the Sierra National Forest. Pellets examined by Thraikill and Bias (1989) included golden-mantled ground squirrels (*Spermophilus lateralis*) and a western gray squirrel (*Sciurus griseus*). Laymon's (1988) pellets included chipmunks (*Eutamias* spp.), California ground squirrels (*Spermophilus beecheyi*), western gray squirrels, and Douglas' squirrels (*Tamiasciurus douglasii*). Kadoch (1997) found no diurnal squirrels in spotted owl diets in the Sierra National Forest in 1995 and 1996.

Other authors have observed annual (Kadoch 1997, Laymon 1988) and seasonal (Kadoch 1997, Munton and others 1997) variations in diets of the California spotted owl, although this study was the first to examine diets in the nonbreeding period in coniferous forests of the Sierra Nevada. Verner and others (1992) suggested that we need to manage for thriving populations of northern flying squirrel populations in Sierra coniferous forests and woodrats in other areas occupied by California spotted owls. The greater dominance of flying squirrels in coniferous forests and woodrats in riparian-deciduous and oak vegetation types in diets during the nonbreeding period emphasizes this need in the southern Sierra Nevada.

Differences in diets of this owl have been observed during the same season and year between pairs in sites in similar habitats (Kadoch 1997, Laymon 1988) and between breeding and nonbreeding pairs (Barrows 1987, Smith and others 1999, Thraikill and Bias 1989, White 1996). Although we found annual and seasonal shifts in spotted owl diets, sampling effort was not consistent from site to site, period to period, or year to year, so our results must be viewed with caution. We did not factor the breeding status of pairs into our analysis, primarily because pellets were collected only incidental to home-range and demographic studies. Nonetheless, we believe that results reported here are indicative of the overall trends of the owls' diets in our study area. Additional studies are needed that focus on diets in relation to prey populations to determine whether the relative importance of different prey species in their diets reflects changing owl preference, prey availability, or a mix of these factors.

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