THE INFLUENCE OF CATTLE GRAZING ON POCKET GOPHERS IN THE CENTRAL SIERRA NEVADA MOUNTAINS, CALIFORNIA: POTENTIAL IMPLICATIONS FOR GREAT GRAY OWLS

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ABSTRACT—Great Gray Owls (*Strix nebulosa*) in the Sierra Nevada Mountains feed primarily on rodents, especially voles and pocket gophers. Voles have been shown to be negatively affected by cattle grazing, but effects of grazing on gophers in the Sierra Nevada Mountains are unknown. We investigated the effects of grazing on pocket gophers (*Thomomys monticola* and *T. bottae*) in 21 grazed and 21 ungrazed montane meadow sites in the central Sierra Nevada Mountains of California. Pocket gopher densities were significantly higher in grazed meadows than ungrazed meadows. Vegetation cover and height, thatch depth, and the frequency of sedge occurrence were higher in ungrazed meadows and there were negative correlations between pocket gopher densities and these vegetation variables. We suggest that potential negative effects of grazing on Great Gray Owls could be minimized by managing meadow vegetation commensurate with the habitat needs of their prey.

Key words: Botta's Pocket Gopher, cattle grazing, Great Gray Owl, meadows, Mountain Pocket Gopher, Sierra Nevada Mountains, *Strix nebulosa*, *Thomomys bottae*, *Thomomys monticola*

There is a long history of cattle grazing on public lands in the Sierra Nevada Mountains of California (Menke and others 1996). On national forests, ranchers annually use designated grazing allotments under 10-y renewable grazing permits. In most cases these grazing allotments have existed for many decades, and they are not expected to end or be periodic unless non-sustainable resource impacts occur that cannot be managed. There is relatively little monitoring, however, of rangeland condition or resource impacts of grazing (Menke and others 1996). In some cases appropriately managed cattle grazing can improve range conditions and be a useful tool for management of wildlife species reliant on short-grass habitats (Holecheck and others 1982; Severson 1990). In other cases there may be unmanageable negative impacts of grazing on native biota (Fleischner 1994).

At middle to high elevations in the central Sierra Nevada Mountains (>1300 m), cattle grazing occurs in summer months, especially in wet meadows and riparian areas. Meadow and riparian habitats are widely recognized as harboring a high species diversity of native plants and animals (Ratliff 1985), and it is important to gain a better understanding of the potential effects of grazing in these systems.

The Great Gray Owl (*Strix nebulosa*) is of particular conservation concern in the central Sierra Nevada Mountains. Here, Great Gray Owls are at the southernmost extent of their range (Winter 1986; Reid 1989; van Riper and Wagtendonk 2006), use meadows as critical foraging habitat (van Riper and Wagtendonk 2006), are a distinct lineage with respect to the larger species range in North America (Hull and others 2010), and have a small population size estimated at 100 to 200 individuals (Winter 1986). As such, they were listed as an endangered species under the California Endangered Species Act in 1980.

Evidence indicates that Great Gray Owls do not breed successfully when microtine populations are low (Winter 1986; Bull and Henjum 1990; Greene 1995). Great Gray Owls in the central Sierra Nevada Mountains, however, may use pocket gophers (*Thomomys* spp.) as an alternate prey species in years when vole (*Microtus* spp.) numbers are low (Winter 1986).

No studies have rigorously examined the influence of cattle grazing on rodent populations and habitats in these high elevation meadows (Winter 1986). Studies in other areas, however, suggest that cattle grazing sharply reduces the abundance of voles (Jones and others 2003; Evans and others 2006; Johnson and Horn 2008), and, given the expected effect of grazing on meadow vegetation height and thatch density, it is also reasonable to expect that cattle grazing may reduce vole abundance in the Sierra Nevada Mountains as well.

The influence of cattle grazing on pocket gophers is less predictable. In San Diego, California, Cox and Hunt (1992) found that Botta's Pocket Gopher (*Thomomys bottae*) preferred short grasses and dry soils, and Greene (1995) suggested that Mountain Pocket Gopher (*Thomomys monticola*) favored moderate to high-intensity cattle grazing in the Sierra Nevada Mountains. In contrast, species accounts suggest that, overall, Botta's Pocket Gopher (Jones and Baxter 2004) and the Mountain Pocket Gopher (Brylski 1990) respond negatively to cattle grazing. Working in the Central Valley grasslands of California, Hunter (1991) found that there were fewer Botta's Pocket Gophers in grazed areas. To date, there has been only 1 study of pocket gopher habitat selection in the Sierra Nevada Mountains (Ingles 1952), and it did not examine relationships with cattle grazing.

In this study we examined effects of cattle grazing on pocket gopher densities in high elevation meadows of the Sierra Nevada Mountains. Specifically, we hypothesized that cattle grazing reduces vegetation height which, in turn, is associated with higher pocket gopher densities. Here, we examine this hypothesis by testing 2 predictions: (1) vegetation will be significantly shorter and sparser in grazed meadows; and (2) estimated pocket gopher density will be significantly higher in grazed meadows.

Methods

Study site

This study was carried out in Stanislaus National Forest and Yosemite National Park in the central Sierra Nevada Mountains, California. All meadows were between 1400 and 2613 m in elevation to correspond with Great Gray Owl distribution and to minimize differences in plant community composition (Beck and Winter 2000; Fetz and others 2003). At these elevations, Mountain Pocket Gophers are far more common than Botta's Pocket Gopher (Ingles 1952; Jones and Baxter 2004), but gopher mounds and tunnels could not be distinguished to species level. The sample size consisted of 21 ungrazed and 21 grazed sites (4 to 60 ha). Each meadow constituted 1 site, unless it was >10 ha in size, in which case 2 sites were established in the same meadow (10 such cases); to maintain independence, the minimum separation distance used (>300 m) exceeded known home range size for pocket gophers (Ingles 1952; Jones and Baxter 2004).

The meadows consisted of forbs (for example, Triteleia ixioides, *Lewisia nevadensis*, *Rumex salicifolius*, *Achillea lanulos*, *Veratrum californicum,* Mimulus primuloides), grasses (*Achnatherum lettermanii*, *Poa pratensis*, *Deschampsia cespitosa, Holcus lanata*), sedges (*Carex rostrata, C. nebrascensis*), rushes (for example, *Juncus orthophylus, Heleocharis pauciflora*), and willow (*Salix* spp.). The surrounding forest was composed of conifers including Red Fir (*Abies magnifica*), Ponderosa Pine (*Pinus ponderosa*), Jefferey Pine (*Pinus jefferyi*), Sugar Pine (*Pinus lambertiana*), White Fir (*Abies concolor*), Lodgepole Pine (*Pinus contorta*), and Incense-cedar (*Calocedrus decurrens*). Grazing by domestic livestock has occurred in the study area for >100 y. Prior to the establishment of the national forests, grazing intensity was known to be severe in many areas, but specifics were poorly documented. Today, meadows are typically grazed from July through September with utilization levels set at 40 to 60% (A Rich, pers. obs.).

The study took place from June to July 2009, corresponding to the Great Gray Owl breeding and fledging season (Bull and others 1989; Bull and Henjum 1990) and pocket gopher summer foraging activity (Ingles 1952; Jones and Baxter 2004). There is pronounced seasonality in montane meadows that varies according to date and elevation; we minimized these effects on comparisons of grazed and ungrazed meadows by sampling a grazed meadow at the same elevation and within the same time frame as an ungrazed meadow. We also generally worked from lower to higher elevations over the field season.

Pocket gopher and vegetation sampling

Pocket gopher densities were estimated by counting evidence of pocket gopher presence (mounds or tunnels) within 10- × 100-m belt transects (0.1 ha). Three belt transects were randomly positioned and oriented at each study site subject to the constraint that all transects remained within 50 m of the forest edge. This constraint was used because we were interested in examining the density of pocket gophers potentially available to Great Gray Owls, and Winter (1986) observed that the maximum distance a Great Gray Owl will go from perch to stoop on prey is 61 m. When a 100-m transect could not fit in the meadow due to an obstruction, it was broken into a new segment that extended from the 1st transect but with a different bearing. Multiple segments (2 to 3) could be used for 1 transect (forming the shape of an ''L'' or ''Z'') as long as they totaled 100 m and each segment's direction was randomized.

In general, 1 observer slowly walked along a transect and tallied pocket gopher mounds and tunnels. Presence of pocket gophers was recognized by mounds of pushed up soil or earthen tunnels that were easily visible. In the few cases where tall vegetation obscured visibility of a transect's width from the central axis ($n = 6$ sites), we used 2 observers or walked in a serpentine fashion to ensure complete coverage. We assumed that all mounds and tunnels were detected within the transect (Reid 1989). Ingles (1952) reported that the mean territory size of a female Mountain Pocket Gopher was equivalent to a circle with a diameter of 11 m (male home ranges were smaller), and that the pocket gopher was solitary except for mating (Ingles 1952). Therefore, in order to avoid over estimating pocket gopher densities based on multiple mounds or tunnels, we only counted 1 mound or tunnel within each 11-m segment of the transect. Therefore, a maximum of 9 mounds or tunnels could be tallied per transect (3 transects/site); thus our estimates of pocket gopher density were conservative. Among the 42 sites, tallies ranged from 4 to 27 (13 to 90 gophers/ha), with only 1 site attaining the maximum value.

Vegetation sampling was done every 10 m along the axis of the transect. A 56- × 25-cm cover frame with 16 grid points (string intersections) was used to estimate ground vegetation cover. Thatch and maximum vegetation height (mm) was measured using a meter stick to record the height of accumulated dead matted vegetation (thatch) and maximum vegetation height within 5 cm of the meter stick. Vegetation density was sampled by using a sward stick (Winter 1986), which weighed 30 g and was dropped from a standardized height of 80 cm and measuring the height of vegetation at which it rested. The frequency of forbs, grasses, and *Carex* spp. were obtained by tallying presence or absence of each within a 10- × 10-cm metal frame placed at each 10-m interval.

Analyses

We used an Analysis of Covariance (ANCOVA) model to examine differences between: grazed and ungrazed meadows in pocket gopher density; vegetation cover; thatch height; maximum vegetation height; vegetation density; and frequency of occurrence of forbs, grasses, and *Carex* spp. In these analyses, elevation and sampling date were used as covariates (to control for differences in plant phenology), with meadow type (grazed, ungrazed) as the main factor. All data were normally distributed except thatch height, which we normalized with a log transformation. Scatter plots were used to examine correlations between pocket gopher densities and vegetation variables; plots that showed apparent correlations were further examined with Pearson's correlation analyses. An alpha value of 0.05 was used for all analyses. Means are reported ± 1 SE.

RESULTS

Pocket gopher density was significantly different between grazed and ungrazed sites. Mean pocket gopher density for grazed sites was 14.3 gophers/ha higher than for ungrazed sites (Table 1). Neither coefficient for elevation or date was significant.

TABLE 1. Mean (± $s_{\overline{X}}$) pocket gopher density estimates and vegetation measurements from 21 grazed and 21 ungrazed meadows sites in the Stanislaus National Forest and Yosemite National Park, California, June–July 2009, and test statistics from an Analysis of Covariance (ANCOVA) model of main treatment effects (grazed vs. ungrazed) and 2 covariates (elevation and sampling date).

	Ungrazed meadows	Grazed meadows	Main treatment effects (grazed vs. ungrazed)		Covariate 1 (elevation)		Covariate 2 (sampling date)	
	Mean ± $s\bar{x}$	Mean ± $s\bar{x}$	*F*	*P*	*F*	*P*	*F*	*P*
Gopher density	54.4 ± 4.9	68.7 ± 3.9	5.31	0.03	1.03	0.32	<0.01	0.94
Veg. cover[a]	10.7 ± 0.8	7.8 ± 0.69	15.75	<0.01	21.30	<0.01	5.02	0.03
Thatch height (mm)	10.9 ± 2.3	3.6 ± 0. 9	9.93	<0.01	2.66	0.11	1.39	0.25
Max. veg. (mm)	85.3 ± 10.7	53.5 ± 9.0	11.48	<0.01	24.05	<0.01	4.66	0.04
Veg. density[b]	134.0 ± 11.2	93.1 ± 10.9	11.95	<0.01	13.30	<0.01	7.19	0.01
NC[c]	0.21 ± 0.04	0.06 ± 0.02	12.59	<0.01	0.19	0.67	0.42	0.52
BC[c]	0.15 ± 0.04	0.03 ± 0.01	6.34	0.02	0.36	0.55	0.63	0.43
Forbs[c]	0.83 ± 0.02	0.76 ± 0.04	3.71	0.06	0.59	0.45	5.34	0.03
Grasses[c]	0.41 ± 0.05	0.43 ± 0.04	0.83	0.37	5.67	0.02	3.24	0.08

[a] Mean number of occurrences on 16 point grid cover frame
[b] Resting height (mm) of sward stick
[c] Frequency of vegetation in a 10 × 10 cm square; NC and BC refer to narrow- and broad-leaved *Carex* spp., respectively

Grazing influenced vegetation characteristics in the meadows. On average, ungrazed sites had significantly more cover, thicker thatch, taller maximum vegetation, and greater vegetation density (sward stick) than grazed sites (Table 1). The frequency of sedges was significantly higher in ungrazed than grazed sites for both narrow-leaved and broad-leaved *Carex* spp. There were no significant differences between grazed and ungrazed sites in the occurrence of forbs or grasses (Table 1). Vegetation cover, maximum vegetation height, vegetation density, and grass occurrence were significantly negatively correlated with elevation. Vegetation cover and maximum vegetation height were negatively associated with sampling date, whereas vegetation density and the occurrence of forbs were positively correlated (Table 1).

There were significant correlations between vegetation variables and pocket gopher density within grazed and ungrazed meadows. In particular, we found negative correlations between pocket gopher density and vegetation cover ($r = -0.45$, $P = 0.04$), thatch height ($r = -0.66$, $P < 0.01$; Fig. 1), and the frequency of

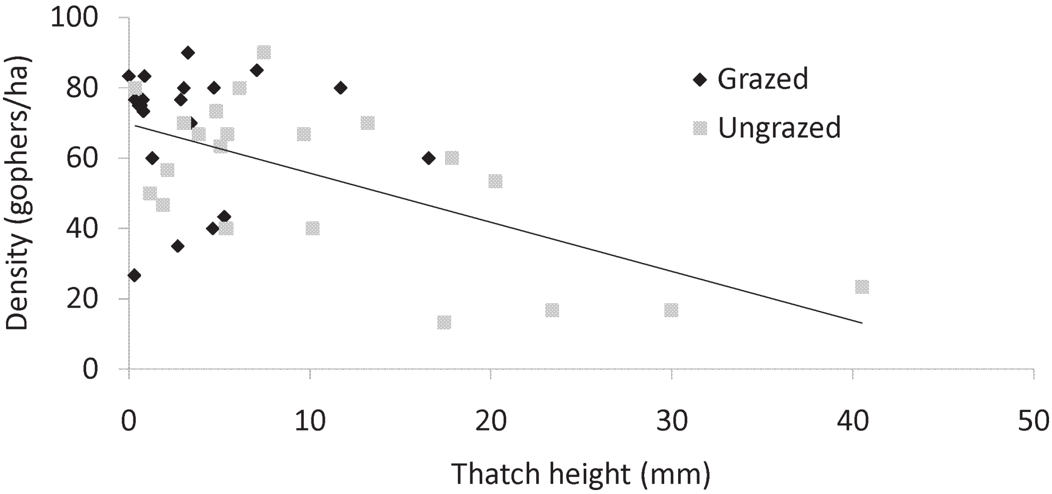

FIGURE 1. Estimated pocket gopher density and thatch height on 21 grazed and 21 ungrazed meadow sites in the Stanislaus National Forest and Yosemite National Park, June–July 2009. Solid line is the slope of the correlation for ungrazed sites.

narrow-leafed *Carex* spp. ($r = -0.56$, $P < 0.01$) in ungrazed sites. These 3 vegetation variables also were significantly negatively correlated with pocket gopher density across all sites (grazed and ungrazed combined), but those relationships were largely driven by the ungrazed sites. There were no significant correlations between pocket gopher density and quantified vegetation variables among the grazed sites alone (all $|r| < 0.32$, and $P > 0.15$).

DISCUSSION

Our results are consistent with the hypothesis that grazing and vegetation characteristics influence pocket gopher densities in high-elevation meadows of the Sierra Nevada Mountains. In our study, grazed meadows had higher pocket gopher density and lower vegetation cover, density, height, and thatch thickness. With our correlative results, it is not possible to determine causal relationships, but within ungrazed sites there was a negative correlation between several vegetation measurements and pocket gopher density. This suggests that grazing itself may not increase pocket gopher density, but certain vegetation characteristics, such as shorter vegetation and more bare soil, are associated with pocket gophers, and these characteristics are sometimes influenced by cattle grazing. Therefore, different grazing regimes may yield different vegetation characteristics and result in different effects on pocket gophers. For example, in grasslands of the Central Valley in California, Hunter (1991) found lower density of Botta's Pocket Gophers on grazed sites, which he attributed to compacted soils or lower quality forage resulting from overgrazing. We found significant negative correlations in ungrazed meadows between pocket gopher density and thatch height, narrow-leafed sedge occurrence, and vegetation cover. Cattle grazing can directly reduce thatch depth and cover by the removal of vegetation (Johnson and Horn 2008). Sedges are typically associated with wet areas, and it is difficult to distinguish whether cattle grazing and pocket gopher activity reduced the amount of sedge or whether pocket gophers settle into meadows that are drier and thus have less *Carex* spp. already established.

The conditions created by moderate grazing may provide suitable habitat for pocket gophers, but pocket gopher presence may also influence meadows in subtle yet significant ways. For example, Botta's Pocket Gophers change the soil by herbivory and create bare patches of ground affecting the establishment of tree seedlings (Jones and Baxter 2004). Tree growth can lead to succession and the conversion of meadow to forest habitat over time (Ratliff 1985). Ingles (1952) observed that Mountain Pocket Gophers increase the amount of grasses and inhibit the amount of sedges growing in meadows due to the burrow systems that the pocket gophers establish, which facilitates soil drying earlier in the season and surface runoff shifting deeper underground. Ratliff (1985) noted, however, that overgrazing emphasizes the negative effects of rodents, but that rodents inflict little harm to meadows in good condition.

Pocket gophers may serve as an alternate prey species for Great Gray Owls when vole densities are low (Winter 1986). Although grazing reduces vole abundance (Johnson and Horn 2008), our study indicates that pocket gopher densities are higher in grazed meadows than in ungrazed meadows. It may be possible to optimize the role of grazing by managing the spatial arrangement of grazed sites. Great Gray Owls typically have high site fidelity and remain in their home ranges over several years (Winter 1986; Van Riper and Wagtendonk 2006). An ungrazed meadow in close proximity to a grazed meadow could supply a pair of Great Gray Owls with foraging opportunities for both primary (voles) and alternate (pocket gopher) prey species, depending on their respective availability in a given year. This management strategy assumes that grazing on the national forest lands can be sufficiently monitored so that ungrazed meadows remain undisturbed.

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