Hierarchical analysis of dietary preferences of sheep and goats during two seasons in California Chaparral[1].

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Introduction

The Chaparral plant community, one of the most fire-prone and fire-dependent plant communities in the world, covers more than 4.5 million ha of California's rangelands. This land is characterized by mountainous terrain with soils of low fertility and moisture-holding capacity (Sampson, 1944; Burcham, 1957), 14 to 25 inches of rainfall per year, temperature ranging from -2 to 35 degrees Celsius, and a broad-leaved sclerophyll vegetation type (Munz and Keck, 1968). The known written history of this land begins in the 1700s when cattle, horses, and Mediterranean grasses and forbs were introduced and natural burns occurred often (Burcham, 1957). Rapid urbanization of rural landscapes of California has led to a dramatic increase of exposure of property and human life to wildfires originating in chaparral. Although comprehensive landscape-level studies are lacking, it is believed that fire fuels have massively increased due to fire suppression, invasive weeds, and a strong reduction of grazing pressure by domestic species. Increasingly, land managers in California turn to the use of domestic herbivores, especially goats, in so-called prescribed grazing programs. In order to successfully apply a prescribed grazing regime, diet composition of herbivores must be determined. There are two reasons: First, prescribed grazing regimes targeting specific plants must be designed based on the time of the year where the target plant is likely to make up an important component of the diet of the animal species intended to be used. Second, several endangered plant species are members of chaparral communities, and timing and duration of grazing must be planned so as to minimize exposure of these species to defoliation.

The objective of the study reported here was to determine the diet composition of free grazing goats and sheep in a chaparral range site during two seasons. The data were collected in a larger project that is applying the alkane marker method to the estimation of diet composition of sheep and goats in California chaparral.

Material and Methods

Study area. The observation pasture is located on five acres of land at the University of California, Hopland Research Center (HREC), located at 39° 00’N latitude and 123° 4’W longitude with elevation from about 170 to 1,000 m. Four principal vegetation types (grass, woodland-grass, dense woodland, and chaparral) include more than 800 species and cover 95% of the Center's property. The pasture is fenced by a deer-proof fence, and is representative of a typical chaparral community. Due to extremely dense vegetation, a comprehensive plant inventory was not possible.

Animals. Six Western Whiteface sheep and six Kiko goats were observed in the morning and evening for six days during the months of May and August. Animals were dewormed prior to transfer to the pasture. They were accustomed to the observer, and did not avoid the contact necessary for recording behavior observations.

Observations and measurements. We used a non-invasive method of estimating the diet of herbivores by timing the amount of time each animal spent eating each plant species (Kababya et al., 1998). Sampling occurred in 20-minute intervals for each animal. Three times between 6:00 to 9:00 hr and 17:00 and 20:00 hr an animal was chosen at random for observation. The timing of observations was determined after initial full day lengths monitoring in order to identify the periods of the day when animals were most likely to graze.

An observer recorded the amount of time each plant was consumed, along with the plant's location and grazing behavior of the animal. When an animal went out of range, observations were moved to another animal. All behaviors (resting, walking, standing without grazing, and grazing) were recorded. At the beginning of each observation period, time, weather, animal number, and location (determined by G.P.S.) were noted. When the animals grazed on plants, the species of plant and the amount of time spent eating it were recorded. Plant samples from each location were hand-harvested, simulating animal browsing.

Statistical analysis. Statistical analyses of the data were performed on the response variable "Percent eaten of plant species x" by experimental unit "Individual Animal" observed during 20 minutes. The analysis must consider that observations made on one animal during a 20 minute period are not independent. The amount of time spent eating any plant species depends on the amount of time eaten the preceding species, and can therefore not be modeled as an independent observation with a simple least squares GLM model, as was the case in Kababya's et al (1998) analysis. It could be hypothesized that further dependencies exist among observations on the same animal taken in different observation periods. These correlations, if they exist, might depend on proximity in time of observation periods. However, the data material was not extensive enough to evaluate this hypothesis.

The response variable showed an extremely skewed distribution. Therefore, the data were transformed with the arcsine-square root transformation (Sokal and Rohlf, 1981)

Data were analyzed with a mixed model – maximum likelihood approach as follows:

$$y = \mu + \sigma_i + \pi_j + a_k + \alpha_l + \varphi_m + d(\sigma)_{in} + (\pi a)_{jl} + (\sigma \pi a)_{ijl} + \varepsilon_{ijklmn}$$

where σ denotes the effect of the i-th season, π the effect of the j-th period, *a* the (random) effect of the *k*-th animal, φ the effect of the *l*-th plant species, *d*(σ) the (random) effect of the n-th observation day within season, and ε denotes residual error. The remaining terms denote interaction terms between animal species and the three-way interaction season-plant species-animal species. The latter three-way interaction was not significant, and therefore dropped from the model. With this model, a covariance structure was fitted for the observations for the same animal in one time period. All analyses were carried out with SAS (SAS, 1999).

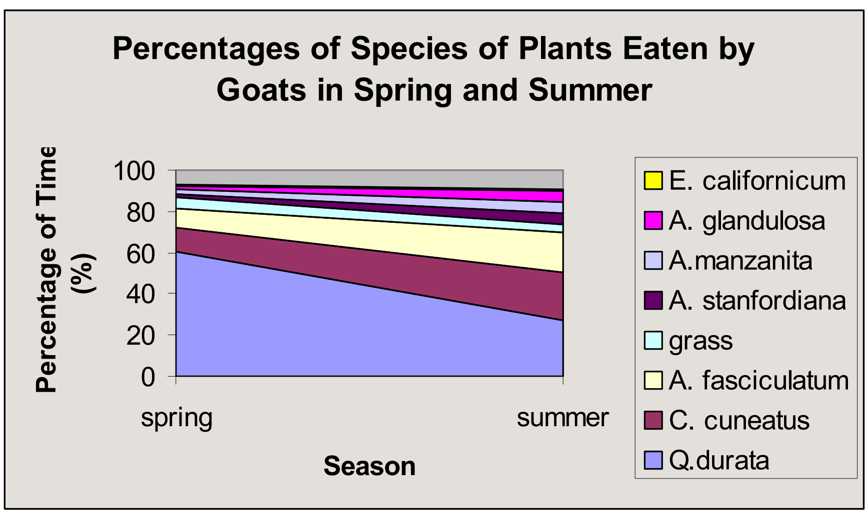
Results and Discussion

In spring goats consumed mostly *Quercus durata, Ceanothus cuneatus* and *Adenostoma fasciculatum*, while sheep consumed mostly *Adenostoma fasciculatum*, grass and *Quercus durata*. In the summer, goats consumed mainly *Quercus durata*, while sheep maintained preference for *Adenostoma fasciculatum*, grass and *Quercus durata*. Goats consumed more browse than sheep in both spring and summer. Goats are more selective than sheep in the summer when nutrient content of plants is decreased because goats are better adapted to selecting plants with higher nutritional quality. The analysis showed that the effects of season and plant species were highly significant. The interaction between animal species and plant species was also highly significant. However, although the data (Figures 1 &2) clearly demonstrated the differences in proportion of different plant species in the diets of sheep and goats, animal species was not determined to be significant in our analysis.

Because of the interaction between plant and animal species, the effect of animal species for each level of plant species was tested using a 'sliced' effects procedure (Westfall et al., 1999). It was found that significant differences existed between sheep and goats in consumption of *Adenostoma fasciculatum* (p=0.0038), *Quercus durata* (p=0.0497), and grass (p=0.0114). The difference in consumption of *Eriodyction californicum* was borderline significant (p=0.0692).

While observational data of diet composition are useful for the validation of marker-based approaches, considerable sampling effort is required to clearly differentiate animal species as an effect in diet composition and dietary preference. However, differences between sheep and goats are evident from our study. Based on the data collected in this study, and detailed chemical analysis of nutritional properties of these range plants, the dietary quality of a typical diet for both sheep and goats in spring and summer can be derived.

This information is used for the validation of a marker-based method for diet estimation and to develop a protocol for planned herbivory for fire-fuel reduction.



F igure 1. Diet composition of goats

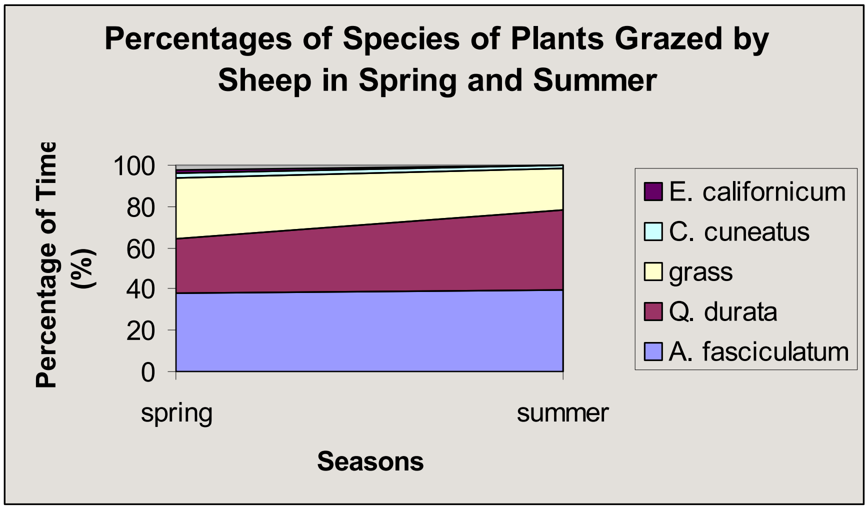


Figure 2. Diet composition of sheep

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