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Intermediate Periodicities in Juniper Consumption and Sampling Strategies to Estimate the Diet of Free-Grazing Goats

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Abstract

We conducted this study to describe the intermediate-term periodicities in percentage juniper (*Juniperus* spp.) in goat diets and to develop optimal sampling schemes to estimate individual animal variation in juniper consumption. Fecal samples were collected from 12 multiparous female Angora goats on Monday and Thursday for a 24-mo period. Percentage juniper in the diet was determined using fecal near-infrared reflectance spectroscopy. Spectral analysis was used to determine the presence and length of cyclic variation in juniper consumption during growing and dormant season periods. Significant periodicities were found for 37% and 68% of the goats in the dormant and growing seasons, respectively. Cycle lengths varied from 9 d in the dormant season to 7 or 8 d in the growing season. The simple coefficient of determination between a two-sample moving average and the mean of all observations on individual goats was highest during a 3-mo period in the spring, which indicates that samples collected in the spring provided the best estimate of the yearlong percentage juniper in the diet. Monte Carlo simulations for 7-d cycles showed the root mean squared difference between estimated and population mean for two samples with 2 or 3 d between samples was only 1% greater than the root mean square difference for three or four samples collected every other day. The optimal sampling strategy for determining the dietary percentage of a species is to collect two samples separated by one-half of the cycle length.

Key Words: biological rhythms, diet selection, goat, juniper, periodogram, spectral analysis

INTRODUCTION

Animals demonstrate periodic variation in many behaviors (Sollberger 1965). The frequency of these cycles varies from short (seconds or less) to long (annual). Understanding these rhythms is of inherent interest for understanding foraging behavior as well as important for developing sampling schemes that ensure the behavior of interest is measured in a manner that provides an unbiased estimate of the parameter measured. Botanical composition of the diet of free-grazing herbivores has long been recognized to exhibit annual cycles (Fraps and Cory 1940), and more recently the existence of intermediate (Pfister et al. 1997) and short term (Parsons et al. 1994; Dziba and Provenza 2008) cycles in diet composition have been demonstrated. The ability to inexpensively measure the botanical composition of free-grazing herbivores using fecal near-infrared reflectance spectroscopy (F.NIRS; Walker et al. 2007) provides the opportunity to collect an adequate number of samples to investigate periodicities of diet selection in free-ranging herbivores.

Our immediate interest in the cyclic variation of diet selection is related to developing sampling protocols to accurately estimate the true propensity of goats to consume juniper (*Juniperus* spp.). Juniper contains monoterpenes (Owens et al. 1998; Campbell and Taylor 2007), and monoterpenes can regulate diet intake (Riddle et al. 1996; Dziba and Provenza 2008). A study using F.NIRS to estimate the heritability of percentage juniper in goat diets found that repeatability of juniper consumption was low (Waldron et al. 2009). Low repeatability could be caused by cyclic variation in the diet composition that was not adequately accounted for by the sampling scheme. If goats rhythmically vary the amount of juniper in their diets and this effect is not taken into account, it is possible to sample a goat at the apex of a cycle one time and the nadir the next. Such variation can greatly affect the outcome of studies where individual variation is the topic of interest such as in genetic studies.

The objectives of this study were to: 1) look for intermediate length periodicities; 2) determine the best season to collect samples to estimate an animal's true propensity for juniper consumption; and 3) use these results to determine an optimal sampling strategy for estimating the true percentage of juniper in a goat's diet.

METHODS

Study Site, Animals, and Sampling

The study was conducted at the Texas A&M AgriLife Research Station at Sonora (lat 30°15′N, long 100°33′W), located in the western Edwards Plateau region of Texas. Long-term annual precipitation from 1918 through 2006 was 600 mm with a bimodal distribution consisting of spring and fall peaks. Soils are primarily the Tarrant series, which are in the thermic family

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of the Lithic Haplustolls (Thurow et al. 1988). Dominant are Tarrant stony clay soils, which are generally 15 to 30 cm deep. These soils contain 5% to 70% limestone fragments or limestone outcrops. The topography has gentle slopes of 3% to 4%.

Taylor (2008) described the study site as characterized by scattered live oak (*Quercus virginiana* Mill.) mottes dominated by mature trees with encroaching Ashe (blueberry) juniper (*Juniperus ashei* Buchholz) and redberry (*J. pinchotii* Sudw.) juniper, both in the oak mottes and in the interspaces. The study pasture had about 45% woody plant cover, of which about 30% was *Juniperus* spp. There is little herbaceous vegetation under the woody plant canopy. Intercanopy vegetation is a mix of short and midgrasses, summer perennial forbs, and low palatability shrubs. Important midgrasses include sideoats grama (*Bouteloua curtipendula* [Michx] Toirr), Wright's threeawn (*Aristida wrightii* Nash), fall witchgrass (*Digitaria cognata* [Schult.] Pilg.), Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.), and cane bluestem (*Bothriochloa barbinodis* var. barbinodis Lag. Herter). Common short grasses are curly-mesquite (*Hilaria belangeri* [Steud.] Nash) and hairy grama (*B. hirsute* Lag.). Important forbs include Texas bluebonnet (*Lupinus texensis* Hook.), Upright prairie coneflower (*Ratibida columnaris* [Nutt.] Woot. & Standl.), Texas croton (*Croton texensis* [Klotzsch] Müll. Arg.), Spreading sida (*Sida abutifolia* Mill.), Texas snoutbean (*Rhynchosia texana* Gillies ex Hook. var. texana [Torr. & A. Gray] M.C. Johnst.), Plantago (*Plantago* spp.), Bushsunflower (*Simsia* spp.), Orange zexmenia (*Wedelia texana* [A. Gray] B.L. Turner), Oxalis (*Oxalis* spp.), Knotweed leafflower (*Phyllanthus polygonoides* Nutt. ex Spreng.), and Velvetleaf bundleflower (*Desmanthus velutinus* Scheele).

The same 16 ha pasture was used throughout this study. The stocking rate of 9.5 ha per animal unit equivalent is light moderate. Juniper availability far exceeded animal demand, and juniper intake was considered a function of availability and quality of alternative dietary choices.

Animals. Twelve multiparous female Angora goats, average age 3.7 yr (range=2 to 7 yr) that weighed 31.5 kg (SD=4.2 kg) at the beginning of the study were used. The goats were selected from a flock of 279 does that had previously been measured to estimate juniper consumption. Based on three previous determinations of percentage juniper in their diets that were made between December 2003 and March 2004, half (six) of the goats were selected from the first quartile (goats with highest percentage juniper in their diet) and half were selected from the fourth quartile (goats with the lowest percentage juniper in their diet). Once selected, these does grazed the same 16-ha pasture for the next 24 mo beginning in September 2004, except for periods when they were moved to the drylot for a 21-d period in February 2005 and March 2006 for shearing and a subsequent period to allow regrowth of mohair in a protected environment prior to returning to pasture. Does were supplemented with approximately 0.11 $kg \cdot d^{-1}$ of whole cottonseed for 90 d both winters. Does were unbred throughout the study. All procedures involving animals were approved by the Texas A&M University Institutional Agricultural Animal Care and Use Committee under protocol 2004-215.

Sampling Procedures. Fecal samples were collected to determine percentage juniper in the diet using near-infrared spectroscopy. When goats were on pasture, they were sampled twice weekly on Monday and Thursday except in February 2006 when they were sampled every other day for a total of 14 collections. To collect fecal samples does were penned in individual 46×91 cm pens with expanded metal floors for about 1 h beginning at 0800 hours. Fecal samples, about 10 g, were collected from screen bottomed trays located beneath the floor. A potential maximum of 196 samples were collected from each goat during the 24-mo study.

Sample Preparation and Analysis. Fecal samples were dried, ground in a cyclone mill to pass through a 1-mm screen, dried in a forced-air oven (50°C for 12 h), and conditioned for 24 h in an environment with constant temperature and humidity (21°C, 65% relative humidity). Approximately 4 g of ground and conditioned sample were packed into a quarter-cup sample cell with a near-infrared, transparent, quartz cover glass. Cells were scanned 32 times using a scanning reflectance monochromator (model 6500, NIR Systems Inc, Silver Spring, MD). Reflected energy (log [1/R], where R=reflectance) was measured and averaged over the 32 scans and recorded at 2 nm intervals from 1 100 to 2 500 nm. Percentages of juniper in the diets were determined using previously established calibration equations (Walker et al. 2007, 2010). These calibrations have been successfully used and validated to accurately predict juniper consumption in environments that differed from the calibration environment (Utsumi et al. 2010).

Statistical Analysis

Analytical Periods. The data were divided into four sets of contiguous time series that represented two paired sets of time series that were paired for the same season and duration in different years (Fig. 1). A dormant season time series consisted of observations from October 2004 to January 2005 and a similar set for the 2005 to 2006 season; the two data sets are

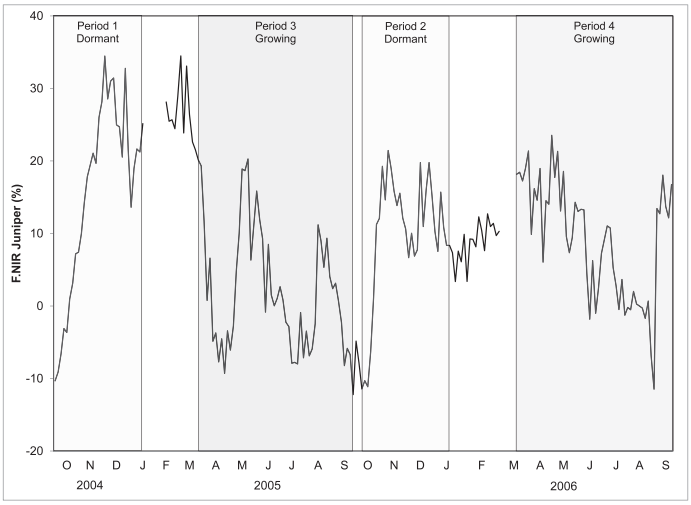

Figure 1. Average fecal near-infrared reflectance spectroscopy (F.NIRS) determined percentage juniper in the diet of 12 free-grazing female goats on a juniper woodland during a 2-yr period. Sample periods used for spectral analysis are shown.

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