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Seasonality of goat diet and plant acceptabilities in the coastal scrub of Baja California, Mexico

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ABSTRACT

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The feeding behavior of goats browsing in the coastal scrub of Baja California was studied for 2 years in order to characterize typical feeding periods in this highly variable climatic environment. As seasons may vary widely in dates, feeding periods were determined on the basis of the monthly variations in consumption of plants forming major components of the diet by means of a principal component analysis. Diet composition was determined using the bite-count method. Monthly observations of diet were distributed within three components, which explained 75.5% of the variation in the data. Three couples of positively correlated forages were found: (1) herbs and *Lotus scoparius* ($P<0.05$); (2) *Eriogonum fasciculatum* and *Viguiera laciniata* ($P<0.01$); and (3) *Artemisia californica* and *Eriogonum wrightii* ($P<0.01$), which characterized three distinct feeding periods: wet, transition and dry. Seasonal acceptability indices of principal feeds were then calculated to show the variations of dietary preferences of goats during these three feeding periods. Shrubs contributed 48.1, 67.5 and 75.5% to diet during wet, transition and dry period, respectively. During the wet period, goats exhibited strong feed selectivity with only a legume shrub and herbs representing more than 65% of the diet. During the transition and dry periods, the decrease in the availability of the most preferred feeds, and specific plant phenological responses, induced goats to diversify their diet.

Multivariate analyses of dietary data seem to be particularly useful on data collected from arid regions, where climate is highly unpredictable, in order give an overview of the variations of diet selection of range ruminants during climatically heterogeneous annual cycles.

Key words: Coastal shrub; Baja California; Feeding behavior; Diet selection; Resource variability; Goats

INTRODUCTION

Under the conditions of rangelands, heterogeneity of vegetation, as well as seasonal changes of potential feeds and nutritional restrictions, induce range ruminants to exhibit strong food selectivity (Holechek et al., 1982, Senft et

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al., 1987). Diets have characteristic compositions, in relation with the phenological status of plants (Westoby, 1978), and their temporal variations need to be considered in order to manage range livestock. The season is generally a useful step-time to characterize diets, but may be problematic to settle boundaries in regions where climatic conditions are highly variable. Baja California, like most of arid lands (McKell and Norton, 1981), shows a particularly variable climate because of influences of various types of climates (Daget and Reyess, 1989).

Preference or acceptability indices can evidence seasonal feed selectivity and rank different species, in a given environment, in terms of their relative acceptability by a category of animals (Loehle and Rittenhouse, 1982; Owen-Smith and Cooper, 1987). It is recognized that these indices must be used with caution because of the relative nature and limited geographical application (Nudds, 1980). They are, nevertheless, useful tools for different management decisions, such as determining carrying capacity (Nelson, 1978), studying plant–herbivore interactions (Duncan, 1983), and modelling range utilization (Ellis et al., 1976; Rice et al., 1984).

The coastal scrub of Baja California represents a diversified shrubland, exposed to severe and highly variable climate (Hasting and Turner, 1965). It is used extensively by livestock enterprises which, willingly or unwillingly, are modifying it very rapidly. Until now, information on species consumed by domestic herbivores and forage potentialities remain unknown in this habitat.

The purpose of this study was to define typical feeding periods of goats in the coastal scrub of Baja California, and characterize seasonal key-species as feed suppliers.

MATERIAL AND METHODS

Coastal scrub of Baja California is restricted to the Northwest of the peninsula, between 30°N and 33°N, within a 15 to 20 km strip along the Pacific coast. It is composed of a mixture of plant species with different growth-forms, such as drought-deciduous and evergreen shrubs, succulents, forbs and annual grasses. It has floristic similarities with the coastal scrub of the neighboring California region (Westman, 1981). Important genera include *Eriogonum, Viguiera, Encelia, Rhus, Cneoridium, Haplopappus, Artemisia, Agave, Bergerocactus, Ferrocactus, Bromus* and *Erodium* (Epling and Lewis, 1942; Minnich, 1983).

The study was conducted in a region located 80 km south of the Tijuana-San Diego border, called Mesa la Mision (32°N, 116°W) at an elevation of 200 m and a distance of 2 km from the Pacific coast. Soil is from the weathering of Miocen basalt. Climate is semiarid, with an average annual precipitation of 284 mm (σ=182 mm, n=38 years) which falls mainly during win-

ter and early spring. The study involved 70 local goats which foraged almost throughout the year in the study area, for 6 to 9 h/d.

Diet selection was determined for 2 years (July 1987 to June 1989) by direct observation of the animals, using the bite-count method (Reppert, 1960; Meuret et al., 1985). Five monthly observations of the feeding behavior are missing because the herd was not present at the time of the visit. Data were recorded monthly during an entire daily feeding time. Every 30 min, during a 10-min period, the bite count of eaten plant parts was recorded for a focal adult animal chosen randomly. A note on the species available to the animal was also made during this period. The focal animal was changed each 30 min. All herbaceous species were considered in a single group because of the difficulty in recognizing the species actually consumed, particularly among young plants.

Sampling of vegetation showed a broken mosaic of micropatches. In order to reduce sample bias in the determination of feeding behavior, the foraging area was differentiated into four homogeneous vegetation types on the basis of their main dominant species: (1) *Eriogonum fasciculatum* type; (2) *Rhus laurina* type; (3) combined *Artemisia californica* and *Rhus integrifolia* type; and (4) *Agave shawii* type. We then estimated the species contribution to diet (SCD_i) by the formula:

$$SCD_i = [(\Sigma_j N_{ij} \times T_j/B_j \times 10)/(\Sigma_i \Sigma_{ij} N_{ij} \times T_j/B_j \times 10)]$$

where SCD_i is contribution to diet of species i; N_{ij} is number of bites on species i observed in vegetation-type j; T_j is foraging time in vegetation-type j; B_j is number of 10-min observations in vegetation-type j.

Phenological information was recorded on plant parts consumed by goats. Phenological events included leaf initiation, vegetative growth, flowering, fruiting, summer dormancy for evergreen shrubs, and drying of leaves for herbs and drought-deciduous shrubs.

Plant acceptability was estimated using a modification of the site-based acceptance index (SA) proposed by Owen-Smith and Cooper (1987). It was calculated as the number of 10-min periods during which the species i was eaten, divided by the number of 10-min periods during which it was present in the array actually explored by the animal. A 10-min period was chosen instead of the 30-min period proposed by Owen-Smith and Cooper, because the structure of vegetation in the study area changed rapidly, allowing the possibility for the animals to pass from one vegetation type to another several times during a 30-min period.

A principal component analysis (PCA) (Green, 1978) was performed on the matrix of the nine species most frequently consumed by goats, and their contribution to diet for each month. This method allows a global study of the composition of the monthly diets by an analysis of similarities, or dissimilarities, in the contributions to diet of the different species forming it. Monthly

diet composition and species are put in geometric spaces in order to visualize and classify them into homogeneous groups.

Percent data were subjected to an arc sine transformation (Snedecor and Cochran, 1957). The principal components were computed from the correlation matrix of the contributions to diet of the plant species. Each original series was normalized to unit variance prior to the analysis (Davis, 1973).

RESULTS AND DISCUSSION

Although goats consumed a total of 21 shrubs, nearly 90% of the monthly diet was provided by only eight shrub species and the herb group. The main grazed herbs were *Erodium cicutarium, Bromus rubens* and *Bromus madritensis.* A detailed description of the monthly consumption levels of principal feeds has been published by Genin and Badan (1991).

A marked variation in the precipitation occurred during the study (Fig. 1). During the cycle July 1987 to June 1988 there was a total of 410 mm of rainfall, whereas only 110 mm was recorded from July 1988 to June 1989. Thus,

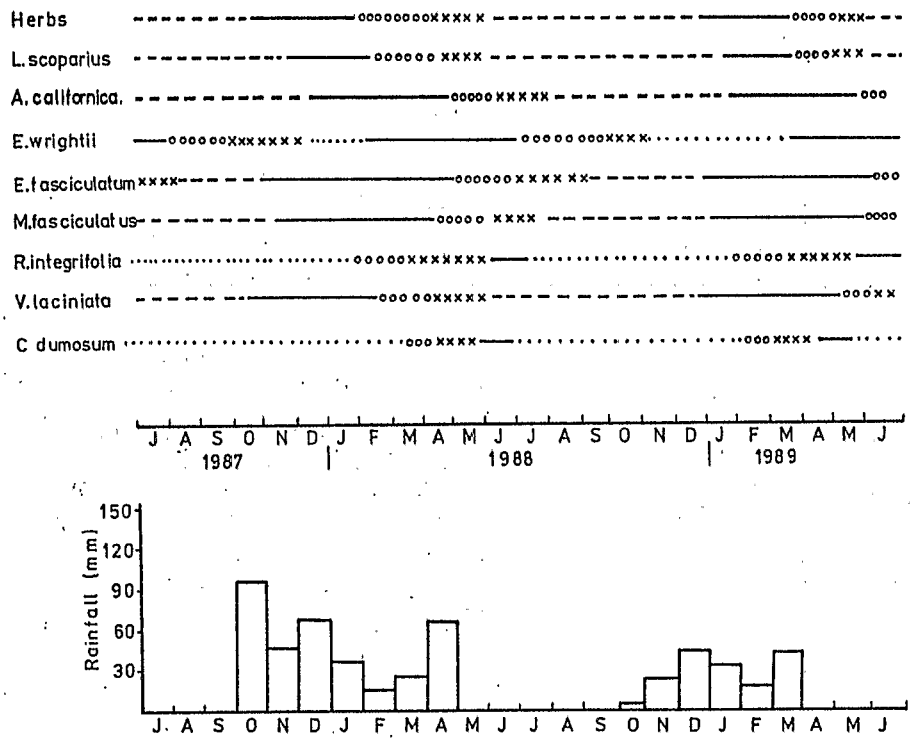

Fig. 1. Phenological stages of the principal forages of the coastal scrub of Baja California, and monthly precipitation during July 1987 to June 1989 (– – –, dried leaves; ——, vegetative growth; OOO, flowering; ×××, fruiting; ····, summer dormancy for evergreen shrubs).

plant growth followed this variation, starting in October and January, for the two cycles, respectively. A time-spread of the different phenological events during a large part of the year was observed (Fig. 1). It strongly influenced the composition of the diet (Genin and Badan, 1991).

Correlations among species show three pairs of positively correlated feeds. These are: (1) herbs and *Lotus scoparius* ($r=0.54$, $P<0.05$); (2) *A. californica* and *Eriogonum wrightii* ($r=0.64$, $P<0.01$); and (3) *Eriogonum fasciculatum* and *Viguiera laciniata* ($r=0.60$, $P<0.01$). Figs. 2 and 3 show the location of species and observations on the first three axes of the PCA. These axes explain 75.5% of the variation in the data. The first component, which explains 33.3% of the variance, represents the goat's choice for green herbs

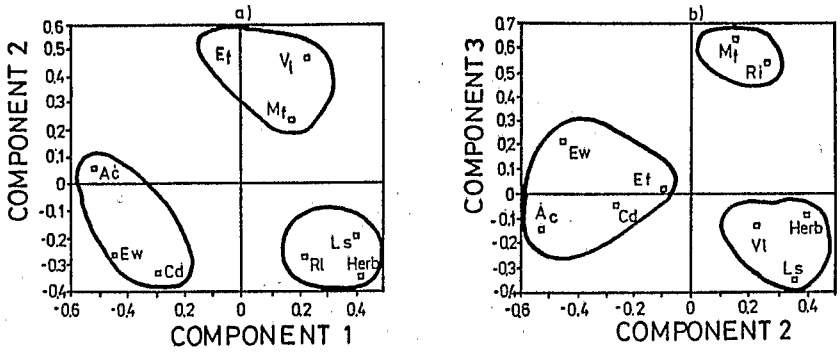

Fig. 2. Correlation scores of the principal feeds foraged by goats on the first three components of the PCA (code used for plant species: Herb, herbs; Ls, *Lotus scoparius*; Ac, *Artemisia californica*; Ef, *Eriogonum fasciculatum*; Ew, *Eriogonum wrightii*; Vl, *Viguiera laciniata*; Ri, *Rhus integrifolia*; Mf, *Malacothamnus fasciculatus*; Cd, *Cneoridium dumosum*).

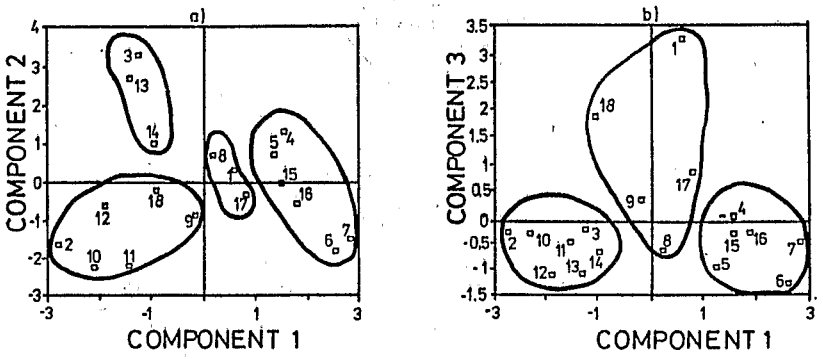

Fig. 3. Representation of the monthly observations of goat's diet in the first three components of PCA (1, July 1987; 2, August 1987; 3, October 1987; 4, December 1987; 5, January 1988; 6, February 1988; 7, March 1988; 8, May 1988; 9, June 1988; 10, September 1988; 11, October 1988; 12, November 1988; 13, January 1989; 14, February 1989; 15, March 1989; 16, April 1989; 17, May 1989; 18, June 1989).

and *L. scoparius* when available (winter and spring, Fig. 3a). *A. californica* and *E. wrightii* were negatively correlated with this component ($r=-0.52$ ($P<0.05$) and $r=-0.45$ ($P<0.05$), respectively). The first component can be interpreted as a gradient in green foliage availability. It allows the characteristic feeds and diets of summer and winter/early spring to be distinguished (Figs. 2 and 3).

E. fasciculatum and *V. laciniata* were positively correlated with the second component ($r=0.57$ ($P<0.05$) and $r=0.48$ ($P<0.05$), respectively), which explains 27.6% of the variance. Fall and early winter observations had positive scores on this axis. The second component indicates composition of the diet during the transition period between dry and wet seasons. Species that have positive score on this axis are all drought-deciduous shrubs, and are reported by Gray (1982) to have the capacity to respond very quickly to the first autumn rains.

Rhus integrifolia and *Malacothamnus fasciculatus* were positively correlated with the third component ($r=0.57$ ($P<0.05$) and $r=0.65$ ($P<0.01$), respectively), which explains 15.5% of the variance. This component segregated species which experienced consumption peak during the transition period between wet and dry seasons, i.e., late spring (Figs. 2b and 3b). *R. integrifolia* had mature fruits in this period, while *M. fasciculatus* had flowers. The two other species which have a positive score on this axis were flowering (*E. fasciculatum*) or initiating buds (*E. wrightii*) in late spring. These phenological stages are viewed to be attractive for goats (McCammon-Feldman et al., 1981).

To resume, PCA segregated clearly two typical feeding periods, corresponding to wet and dry seasons and following the interannual variability of precipitation. It also pointed out the goat's ability of adapting its diet to vegetation changes during the transition periods between these two seasons, following the variation of the phenological patterns of plants. In these phases (late spring and part of autumn), diet compositions presented some similarities and were more diversified. This supports the conclusions of Coblentz and others, that the goat exhibits opportunistic feeding behavior, rather than being a typical browser or grazer (Coblentz, 1977).

On this basis, we grouped the diet observations within three periods: wet, transition and dry. Fig. 4 shows the seasonal contributions and acceptabilities of the principal feeds. Herbs constituted important feeds throughout the year ($SCD_i > 25\%$), while shrubs experienced specific seasonal browsings. Mean proportions of shrubs in the diet were 48.1, 67.5 and 75.5% for the wet, transition and dry period, respectively.

During the wet period, the goat's diet had a low diversity, reflecting a relatively low constraint in the preferred feeds availability. Only three species contributed more than 5% to the diet (Fig. 4). During the transition period, diversified plant phenological responses induced a diversification of the goat's

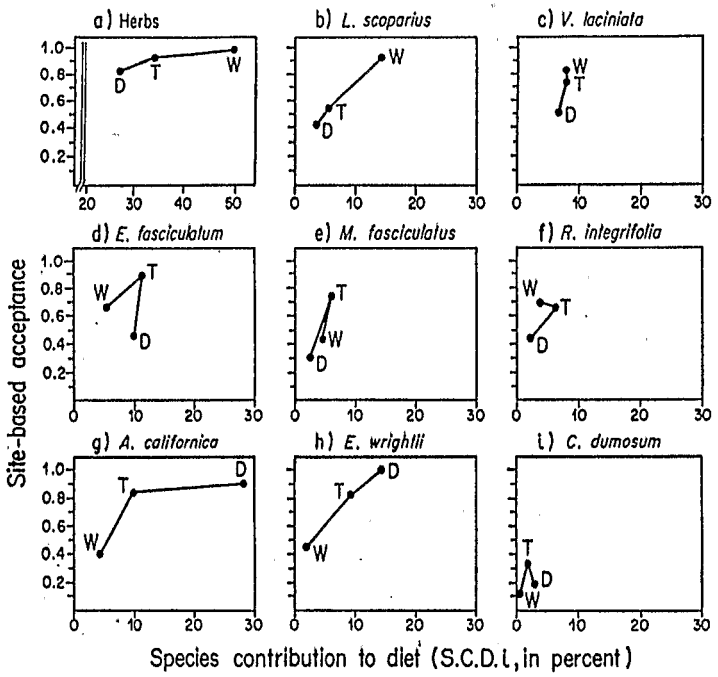

Fig. 4. Species contribution to diet and acceptability of the principal feeds during the wet (W), transition (T), and dry (D) periods in the coastal scrub of Baja California.

choice. Eight species showed a contribution to diet in excess of 5%, compared with five during the dry period. *A. californica* and *E. wrightii* contributed largely to diet, as presented in the PCA results, during the most drastic period. The former species is aromatic and contains high concentrations of secondary compounds (Nagy and Tengerdy, 1967). Nevertheless, it was consumed when dry, a phenological state in which its secondary compounds may be less extractable and, thus, less harmful to the animals (Robbins et al., 1987). The last species was flowering in summer, and could have had a relatively high nutritional value compared to the other potential foods, which were dry or in dormancy (Schwartz and Said, 1981). This expected favourable chemical composition should have determined its preference.

Acceptability indices (SA) varied widely depending on the season (SA range, 0.3–1.0), except for herb mixed class which was highly accepted throughout the year (SA >0.80), and for *Cneoridium dumosum* which was rejected almost all the time (SA <0.35). Based upon SA, three groups were found: (1) species which decreased in their acceptability as seasons advanced (Fig. 4a, b and c); (2) species presenting a peak of attraction during the transition period (Fig. 4d, e and f); and (3) species presenting an increase in their acceptability with drought (Fig. 4g and h). Species of low acceptability,

with the exception of *R. integrifolia* presented a reduced leaf abundance during the dry period.

It appears that physical structure of plants, and its interaction with nutritional value (Westoby, 1978), plays an important role in feed selectivity of goats. Plant parts can be classified along a decreasing gradient of preference in the following order: green leaves and flowers, fruits, dried leaves, and stems.

CONCLUSION

The multivariate analysis segregated typical feeding periods, based on variations in the consumption of plants forming major components of the diet, and not on arbitrarily established seasons. This analysis gave a general, descriptive overview in changes of diet during the annual cycle. Its use is particularly appropriate to regions where the climate is highly variable. In association with acceptability measurements, which supply detailed information on consumption of feed species, it can be a useful tool for analysing the feeding status of ruminants browsing on diversified rangelands.

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RESUME

Genin, D. et Pijoan, A.P., 1993. Régimes alimentaires saisonniers de caprins et acceptabilité des plantes dans le matorral côtier de Basse Californie, Mexique. *Small Rumin. Res.*, 10: 1–11.

Le comportement alimentaire de caprins dans le matorral côtier de Basse Californie à été étudié pendant deux années, de manière à mettre en évidence des périodes alimentaires caractéristiques dans ce milieu à grande variabilité climatique. Etant donné que la distribution temporelle des saisons peut varirer fortement d'une année à l'autre, les périodes alimentaires ont été caractérisées en fonction des variations mensuelles de la consommation des principales espèces fourragères constitutives du régime alimentaire, par une Analyse en Composantes Principales (ACP). La composition du régime alimentaire a été déterminée par la méthode des coups de dents. Les observations mensuelles du régime alimentaire se sont distribuées selon trois axes de l'ACP, qui expliquent 75,5% de la variation des données. Trois couples de fourrages positivement corrélés ont été mis en évidence: (1) les herbacées et *Lotus scoparius* ($P<0,05$); (2) *Eriogonum fasciculatum* et *Viguiera laciniata* ($P<0,01$); et (3) *Artemisia californica* et *Eriogonum wrightii* ($P<0,01$), qui caractérisent trois périodes alimentaires distinctes de la chèvre: humide, de transition et sèche. Les indices d'acceptabilité saisonniers des principaux fourrages ont ensuite été calculés pour ces trois périodes alimentaires. Les espèces arbustives ont répresenté respectivement 48,1, 65,5 et 75,5% du régime alimentaire durant les périodes humide, de transition et séche. Durant la période humide, les caprins ont montré une forte sélectivité alimentaire, un arbuste de la famille des légumineuses et les espèces herbacées représentant à eux-seuls plus de 65% du régime. Durant les périodes de transition et sèche, la baisse de disponibilité des fourrages préférés et des comportements phénologiques particuliers de certaines plantes, ont entrainé une diversification du régime alimentaire.

L'analyse multivariable des données de régime alimentaire apparait particulièrement intéressante à utiliser en milieux arides, afin de décrire les grands traits des variations de la sélection alimentaire de ruminants sur parcours durant des cycles annuels climatiquement contrastés.

RESUMEN

Genin, D. y Pijoan, A.P., 1993. Variaciones estacionales de la dieta de caprinos y aceptabilidad de plantas en el matorral costero de Baja California, México. *Small Rumin. Res.*, 10: 1–11.

Se estudió durante dos años el comportamiento alimenticio de caprinos en el matorral costero de Baja California, con el fin de caracterizar períodos alimenticios típicos en este medio climáticamente muy variable. Como las estaciones pueden variar en fecha entre años, se determinaron períodos alimenticios en función a las variaciones mensuales en el consumo de los principales forrajes constituyentes de la dieta, mediante un Análisis en Componentes Principales (ACP). Se determinó la composición de la dieta mediante el método de conteo de mordiscos. Las observaciones mensuales de la dieta de los caprinos se distribuyeron según tres ejes de la ACP que explicaron el 75.5% de la variación en los datos. Se encontraron tres pares de forrajes positivamente correlacionados: (1) las herbáceas y *Lotus scoparius* ($P<0.05$); (2) *Eriogonum fasciculatum* y *Viguiera laciniata* ($P<0.01$); y (3) *Artemisia californica* y *Eriogonum wrightii* ($P<0.01$), caracterizando tres períodos alimenticios distintos: húmedo, de transición y seco. Se calcularon inclices de aceptabilidad estacionales de los principales forrajes para estos tres períodos alimenticios. Los arbustos constituyeron el 48.1, 65.5 y 75.5% de la dieta durante los períodos húmedo, de transición y seco, respectivamente. Durante el período húmedo, los caprinos mostraron una fuerte selectividad alimenticia, con solamente un arbusto de la familia de las leguminosas y las herbáceas que representaron más del 65% de la dieta. Durante los períodos de transición y seco, la baja en la disponibilidad en los forrajes preferidos y comportamientos

fenológicos particulares de algunas plantas, produjeron una diversificación en el régimen alimenticio de los caprinos.

El análisis multivariado de datos referentes a regimen alimenticio parece ser de gran utilidad en zonas áridas para describir los grandes rasgos de las variaciones en la selectividad alimenticia de rumiantes en agostaderos, durante cíclos anuales climáticamente de gran contraste.