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Interactions between grazing behaviour and plant community structure in shrubland and their consequences on desertification

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Abstract. Changes in grazing behaviour can be used as an early indicator for detecting plant community composition and structure modification. The purpose of this study was to evaluate the interrelationships between plants on offer at pasture and animal behaviour, so as to forestall desertification by applying management measures. The experimental area was a shrubland, dominated by *Cistus monspeliensis, Olea europea, Phillyrea latifolia, Pistacia lentiscus* and *Quercus coccifera*, in which a flock of 300 local goats grazed freely. The total area was divided into lightly, moderately and heavily grazed unfenced plots. Grazing behaviour data were recorded separately in each plot, in early spring, early summer, late summer and early winter. The preferred species during early spring, early summer and early winter was *Phillyrea latifolia*, while during late summer it was *Pistacia lentiscus.* The goats' average bite size, intake rate and total intake gradually decreased as the growing season progressed. The frequency of visits to a site, and thus the stocking rate on the heavily grazed paddocks gradually increased from spring to late summer, whereas the stocking rate of the moderately and lightly grazed paddocks was similar throughout the grazing seasons. If there is no modification of the present management over a number of years, signs of desertification will inevitably appear in the heavily grazed sites. Management guidelines could be introduced so that, once behavioral changes are detected, grazing pressure is reduced on the heavily grazed areas by better distribution of stock over the entire area.

Keywords. Desertification – Grazing behaviour – Overgrazing – Plant forage factors – Shrubland.

Les interactions entre le comportement sur parcours et la structure des communautés de plantes dans les zones arbustives, et leurs conséquences sur la désertification

Résumé. *La variation du comportement de l'animal sur parcours peut être utilisée comme un indicateur permettant de renseigner sur la composition de la végétation et la modification de sa structure. Si on arrive à détecter les changements du comportement avant tout changement significatif de la végétation, il serait possible d'éviter la désertification des sites menacés par un ajustement de la stratégie de pacage des animaux. L'objectif de cette étude est d'évaluer les relations entre les facteurs liés à la plante fourragère, afin d'empêcher la désertification en appliquant des mesures de gestion. Le site expérimental est un parcours arbustif dominé par* Cistus monspeliensis*,* Olea europea*,* Phillyrea latifolia*,* Pistacia lentiscus *et* Quercus coccifera*, et qui est pâturé par un troupeau de 300 chèvres locales. La superficie totale de ce parcours a été divisée en parcelles légèrement, moyennement et trop exploitées par les animaux. Les données relatives au comportement sur parcours ont été enregistrées séparément au niveau de chaque parcelle, en début de printems, début d'été, fin d'été et début d'hiver. L'espèce préférée en début de printemps, début d'été et début d'hiver est* Phillyrea latifolia*, alors qu'en fin d'été le* Pistacia lentiscus *est l'espèce la plus appétée. Le poids moyen du coup de dent des chèvres, la vitesse d'ingestion et la quantité ingérée par jour chutent progressivement avec l'avancement de la saison. La fréquence de visite du site, et par conséquent la charge animale sur les parcelles moyennement et légèrement pâturées est la même tout au long de la saison de pâturage. En l'absence de modification de ce mode de gestion pendant de nombreuses années, les signes de désertification apparaîtront certainement au niveau des parcelles surexploitées. Il est proposé d'introduire les indices de gestion pour que sitôt les changements comportementaux soient détectés, la pression de pâturage soit réduite par une répartition homogène des animaux sur tout le parcours. Par conséquent, la couverture végétale et la production deviennent normales.*

Mots-clés. *Désertification – Comportement sur parcours – Surexploitation – Facteurs liés à la plante-ressources fourragères – Parcours ligneux.*

I – Introduction

Ungulate grazing behaviour depends on environmental, animal as well as on plant-related factors. Environmental and animal-related factors can be considered as constant, in a broad sense, and thus cannot be modified by human intervention. The factors which can be manipulated over a short span of time are those related to plants. Forage resource availability and quality depends on the phenological stage of plants as modified by defoliation. Animal voluntary spatial movement leads to the revisiting of high-reward sites so as to optimize nutrient uptake (Nastis, 1997), resulting in the homogenization of resource availability over space. Thus, areas dominated by highly palatable species are expected to be preferred up to the point when grazing effort becomes less rewarded than in adjacent sites.

It is well documented that moderate stocking intensity leads to increased plant, and consequently forage, diversity (Willoughby, 1995), resulting in the formation of variable growth niches. However, intensive short-duration grazing forces animals to sample greater proportions of less palatable species in order to satisfy their requirements, because they are unable to select only the most palatable and potentially nutritious plants. However, when grazing pressure exceeds the proper use threshold, both plant species diversity and available forage gradually decrease (Nastis and Tsiouvaras, 1989), because the proportion of highly and moderately palatable species is reduced. Furthermore, overgrazing is the major cause of desertification, especially where the soil is poor and liable to erosion (Arianoutsou-Faraggitaki, 1985). During this process, it is believed that animal grazing behaviour changes anticipate the emergence of measurable changes of plant-related variables. Thus, any change in grazing behaviour can be considered as an early indicator for detecting modification in the composition, quality or structure of vegetation. As a consequence, by evaluating behavioural signals and modifying grazing strategy it may be possible to avoid desertification of intensively grazed, erosion-susceptible sites.

The objective of this study was to evaluate the interrelationships between plant-related variables and animal behaviour, so as to forestall desertification caused by overgrazing.

II – Materials and methods

The study area is located in the village community of Sykia at the south part of the Sithonia peninsula in Chalkidiki, northern Greece (longitude: 23°54', latitude: 40°00'), at an altitude of 100-300 m above sea-level. The climate is semi-arid to sub-humid Mediterranean with an average annual rainfall of 590 mm. The bedrock consists of mainly metamorphic rock of the Mesozoic era, and there are also sites covered by sedimentary rock.

The natural vegetation is a maquis-type shrubland dominated by the shrub species *Calicotome villosa, Cistus monspeliensis, Olea europaea, Phillyrea latifolia*, *Pistacia lentiscus* and *Quercus coccifera.* The dominant herbaceous species are *Anthoxanthum odoratum*, *Lagurus ovatus, Plantago bellardii, Plantago lagopus, Trifolium arvense, Trifolium dalmaticum* and *Vulpia muralis*.

The area is grazed mainly by goats which are housed over night in permanent sheds distributed throughout the village community territory. Goats graze freely around their sheds during the whole year, up to a distance of 1-2 km from them. Areas closer to the sheds are more frequently visited and therefore more heavily grazed than those located at a greater distance.

A representative flock of 300 goats housed in a shed belonging to a farmer resident in Sykia was studied. The area around the shed was divided into lightly, moderately and heavily grazed unfenced plots, based on the grazing intensity, closely related to the distance from the shed. Plant cover decreased as grazing pressure increased (Tables 1 and 2) (DRASME, 2000).

Grazing behaviour data were recorded in: (i) early spring (April), when average plant growth rate and forage abundance were the highest; (ii) early summer (June), when plant growth had ceased; (iii) late summer (August), when herbaceous plants were dry and most of them had been already

consumed, whereas shrub twigs were lignified; and (iv) early winter (December), when new fall regrowth was abundant. Goats grazed freely in the unfenced plots for three hours and thereafter were moved to a grassland beside the experimental area from 14:00 to 17:30. On this grassland they were watered and could graze herbaceous species and foliage from *Vitex agnus castus*, a nutritious shrub growing on the boundaries of the grassland. Afterwards, the goats were again transferred to the experimental area, for two more hours, before being housed again in the shed.

Table 1. Stocking rate (goats/ha) of the three plots in the shrubland during the grazing period

Paddock	April	June	August	December
Heavily grazed shrubland	7.3	7.9	9.2	8.5
Moderately grazed shrubland	2.4	2.5	2.5	3.1
Lightly grazed shrubland	0.3	0.3	0.2	0.3

Table 2. Plant cover (%) in the three shrubland paddocks with varying grazing pressure during 2000

	Lightly grazed	Moderately grazed	Heavily grazed
Vegetation cover	91.3	76.3	70.4
Litter	1.2	2.4	4.0
Bare ground	7.5	21.3	25.6
Total	100.0	100.0	100.0

In each plot, behavioural data from five adult goats, randomly selected every time, were recorded for two consecutive days during each test period. Each animal was monitored for five minutes, in the morning and afternoon. Measurements included: (i) number of bites per plant species; and (ii) bite size as the average of hand-plugged samples similar to those consumed by the animals (Cook, 1964). A total of 200 feed samples were collected both morning and afternoon on each sampling day. Grazing time was estimated by monitoring three goats with vibracorders (Stobbs, 1970; Scarnecchia, 1979) for seven consecutive days during each test period. In addition, the crude protein (CP) content of most preferred species was determined by the micro-Kjeldahl technique (AOAC, 1990).

Stocking rate (number of goats/ha) was evaluated by monitoring the number of goats and the duration of grazing in each plot. Grazing in the grassland was considered as complementary and thus it was not taken into account when estimating the intake. The intake rate and the voluntary intake of shrubland were estimated from the above data.

The experimental design was a factorial with two factors: (i) grazing pressure (high, moderate and low) and season (spring, early and late summer and winter); and (ii) two replications (Snedecor and Cochran, 1967). All data were subjected to analysis of variance. The Least Square Difference test was used for separating means at $P \leq 0.05$.

III – Results and discussion

Only the data collected in the heavily and moderately grazed paddocks are reported in this paper, because those collected in the lightly grazed area were inadequate for statistical analysis and sound conclusions, with the exception of stocking rate and grazing time. The animals visited the lightly stocked paddock only sporadically and only for a short time span during the day, which was usually inadequate for collection of all the necessary data.

Shrubs were the preferred class of plants during all seasons (Table 3), owing to their relatively high abundance in comparison with the herbaceous species, as well as to the fact that goats usually select shrubby rather than herbaceous species (Wilson *et al.*, 1975; Sidahmed *et al.*, 1981). The percentage of bites in spring (78%) and early summer (70%) showed that the goats' basic dietary component was *Phillyrea latifolia*, probably due to its abundance and the low fiberness and high CP content of its twigs (Fig. 1). During spring the percentage of bites for the herbaceous species (9%) was proportionally high despite their low abundance in comparison with shrubs, because most of them had early spring growth. In early summer the number of bites for the herbaceous species was very low (2%), because they mature very early in the growing season and CP concentration had diminished significantly (Fig. 1). In addition, most herbaceous species had already been heavily grazed in the spring and the possibility of selecting them was limited. Thus, their contribution to the goats' diet was insignificant. These findings are in agreement with data reported by other researchers (e.g. Fedele *et al.*, 1993; Papachristou and Nastis, 1993; Dumont *et al.*, 1995), who found that goats select a relatively higher proportion of grasses and forbs in spring, when their availability and nutritive value are high.

Table 3. Number of bites per 100 minutes for each plant or group of species in four different seasons

Species	April	June	August	December
Cistus monspeliensis	22 ab	11 b	0 b	40 a
Olea europea	34 b	199 a	62 b	204 a
Phillyrea latifolia	959 a	842 a	168 b	427 ab
Pistacia lentiscus	45 b	107 b	286 a	222 a
Calicotome villosa	37 a	11 b	0 b	19 b
Quercus coccifera	19 b	2 b	93 a	5 b
Vitex agnus castus	0 a	8 a	25 a	0 a
Trifolium spp.	42 a	0 b	0 b	6 b
Grasses	31 a	19 b	5 b	6 b
Other herbaceous species	37 a	3 b	0 b	11 b
Total	1226	1202	639	940

a, b: Means in the same row followed by the same letter are not significantly different ($P \leq 0.05$).

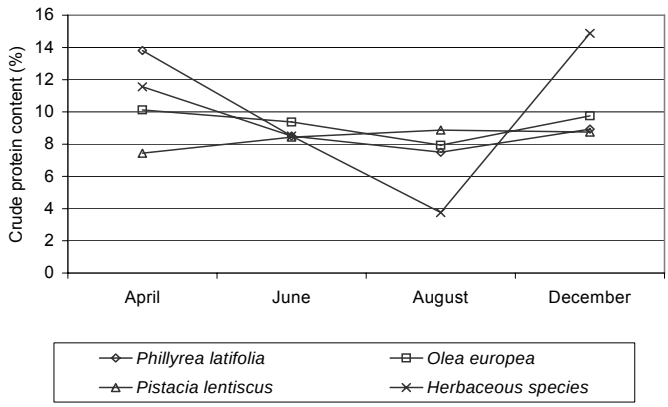

Fig. 1. Crude protein content (%) of the main shrubs and herbaceous species during the growing season.

In early summer, although *Phillyrea latifolia* was still the preferred species (Table 3), the proportion of bites from other shrubs, such as *Olea europea* and *Pistacia lentiscus*, presenting sufficient growth in early summer, increased in comparison with early spring and reached 17% and 9% respectively.

In late summer, diet composition changed and *Pistacia lentiscus* contributed more (45% of bites), because it was more abundant and maintained a relatively high CP content similar to that of other dominant shrubby species (Fig. 1), followed by *Phillyrea latifolia* (26%) and *Quercus coccifera* (15%). During this period the proportion of *Olea europea,* and especially of the herbaceous species, was drastically reduced in comparison with spring and early summer, because they had been heavily grazed by this time.

The average number of bites per 100 minutes (Table 3) decreased as forage availability decreased. The number of bites in August was 50% lower than in spring, because the shrubby species were mature, forage availability was low and the proportion of herbage was less than 1%. In contrast, Chacon and Stobbs (1976), Scarnecchia (1979), Scarnecchia *et al.* (1985) and Nastis and Malechek (1988) reported that the number of bites of cattle grazing herbaceous species increased as forage availability decreased. This behavioural difference between cattle and goats must be attributed to the time-lag between bites. Searching for the next bite in grassland, where the next bite is usually located near the previous one, does not take long time, while with shrubby species it takes much longer (Papachristou, 1997), because locating new twigs requires horizontal, vertical and also directional localization around the shrub.

According to the number of bites, in early winter the preferred species was *Phillyrea latifolia* (45.4%) followed by *Pistacia lentiscus* (23.6%) and *Olea europea* (21.7%). During winter, the proportion of herbaceous species in the goats' diet was very low because grasses had just initiated growth and were practically unavailable for grazing.

Phillyrea latifolia, the most selected species (Table 3), was heavily grazed early in the growing season, in early autumn, and even in winter, because it was the most abundant of the preferred species in the experimental area. Its popularity fell only in late summer owing to the fact that it had already been heavily grazed. Grazing had no apparent impact on its contribution to shrubland composition, even in the heavily grazed part of the pasture. This means that there was no over-utilization of this species. *Pistacia lentiscus*, a moderately palatable species (Ben Salem *et al*., 2000), was also grazed throughout the year, but mainly during summer and winter. *Olea europea* was less selected in August, when its availability was reduced, especially in the heavily grazed paddock. *Quercus coccifera* was not grazed during December, probably because its new autumn regrowth had already been utilized. It seems that *Olea europea* and *Quercus coccifera*, the two most selected species under conditions of equal abundance, were drastically reduced in the diet especially in the heavily grazed paddock.

Average bite size (Table 4) decreased only as the growing season progressed, presumably because the available shoots and stems were shorter. In addition, the shift of grazing, from *Phillyrea* sp. early in the growing season to *Pistacia* sp. later, had the partial effect of maintaining bite size at a relatively high level, because the newly introduced plant species in the goats' diet had long shoots by that time.

Table 4. Average bite size (g/bite) for goats grazing in the shrubland

April	June	August	December
0.13 a	0.12 a	0.13 a	0.09 b

a, b: Means followed by the same letter are not significantly different ($P \leq 0.05$).

The distribution of time spent grazing in the heavily, moderately and lightly grazed shrubland (Table

5) is an indication of the grazing pressure imposed. Total grazing time increased from April to June (Table 5), as forage availability and shoot length decreased. In August, with the shift to *Pistacia lentiscus*, grazing time was further reduced. Several other researchers (e.g. Arnold, 1964; Chacon and Stobbs, 1976; Scarnecchia, 1979; Nastis and Malechek, 1988) have reported similar results. Total grazing time was six hours in spring and early summer. Thereafter in August and December it decreased as forage quality and availability decreased.

Table 5. Grazing time (minutes) of goats to in a shrubland at four discrete phenological stages

Paddock	April	June	August	December
Heavily grazed shrubland	95	105	90	80
Moderately grazed shrubland	65	70	50	60
Lightly grazed shrubland	20	20	10	15
Total	180	195	150	155
Grassland paddock	180	170	120	105
General total	360	365	270	260

The rate of intake gradually decreased when plants matured and forage resources became scarce (Table 6). The slight increase in the intake rate in December compared to August must be attributed to the succulent and nutritious autumn regrowth of more shrubby species. Intake followed the same trend (Table 6). The goats' daily intake decreased from 290.7 g in spring, to 123.2 g in late summer, with a slight increase when the new growth occurred.

Table 6. Intake rate (g DM/min) and daily consumption (g DM) by goats browsing a shrubland†

	April	June	August	December
Intake rate	1.615 a	1.452 a	0.821 b	0.860 b
Total intake of browse	290.7 a	283.1 a	123.2 b	133.3 b

†Measurements in the grassland are not included.
a, b: Means followed by the same letter are not significantly different ($P \leq 0.05$).

IV – Conclusions

It is well documented that erosion increases as plant cover decreases (Baily and Copland, 1961). The plant cover (Table 2) was lower in the heavily grazed paddock (70.4%) than in the lightly grazed paddock (91.3%). If this continues over a number of years, signs of desertification will appear. Thus, wherever the rate of bites by goats grazing on shrubland decreases, the pasture can be classified as overgrazed. The proposed management in this case is to reduce grazing pressure by better distribution of grazing animals over the entire area. If this can be accomplished, the overall plant cover and production will return to normal and the proportion of the most palatable shrubby species, such as *Olea europea* and *Quercus coccifera,* will increase.

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