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Quercus ilex browse utilization by Caprini in Sierra de Cazorla and Segura (Spain)

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Abstract

The impact of domestic and wild Caprini browsing on *Quercus ilex* has been examined in an area of the Sierra de Cazorla. Vegetation as a herbivore food supply, herbivore feeding regime and density in the study area during six sampling periods throughout two years, has been quantified. Wild Caprini show diets similar to the available vegetation, whereas domestic Caprini tend more towards the trophic specialities (browsing or grazing) of their genus. Nevertheless, this tendency was more pronounced in domestic goats than in sheep. A hypothetical estimate of *Q. ilex* intake by each species under the study conditions was carried out. It was found that domestic Caprini have a greater impact on the holm oak than wild Caprini, density and feeding-niche deviations being the main factors responsible for this situation.

Abbreviations: DM = dry matter.

Nomenclature: Quercus ilex in this paper refers to *Q. ilex* ssp. *rotundifolia* (according with Greuter *et al.* 1986. Med-Checklist. 3. Dicotyledones. Ed. Jardin bot Ville de Genève). Plant species names follow Tutin *et al.* (1964–1980), Flora Europeae.

Introduction

A long history of fire and grazing characterizes *Quercus ilex* (holm oak) ecosystems on the circum-mediterranean fringe. Many authors support the idea that the expansion of *Q. ilex* has been favoured by anthropogenic action during the last 5000 years (Bran *et al.* 1990) this being exacerbated by the appearence of domestic herbivores. In fact, the area in which domestic Caprini have evolved coincides partly with the distribution area of the *Q. ilex* (Clutton-Brock 1987). The wide capacity for sprouting after cutting and fire is a well-known feature of the holm oak. However, in spite of its great incidence, the effects of browsing by large herbivores are less well-known.

The Natural Park of the Sierras de Cazorla, Segura and Las Villas, in the south-east of Spain, belongs to the supra- and meso-mediterranean bioclimatic belts. As in other Parks and protected areas, wild ungulate numbers have notably increased in the last 30 years (Escos 1988). In the same way, domestic Caprini, which traditionally utilize summer pastures in the area, have recently increased in number. All this has caused problems to wild animal populations (due to lack of space and feeding) and to the vegetation, the plant canopy having deteriorated.

The aim of this study was to determine the feeding regime of 4 sympatric Caprini species in an area of Cazorla's Park. These 4 species have a marked influence on Mediterranean grazed ecosystems. Given the wide range of available plants, the variety of diets and their seasonal variations, we have concentrated on the heavily grazed species, such as holm oak, in order to investigate the possible effect of herbivores on the vegetation and to provide an ecological basis for management of ungulates in this area. The 4 herbivores chosen have the peculiarity that the two wild species (*Capra pyrenaica* and *Ovis musimon*) can be considered as wild ancestors (or very close to them) of the two domestic species (*Capra hircus* and *Ovis aries*) (Ryder 1984; Mason 1984). This provides an opportunity to observe the effects of domestication on the feeding strategies of these herbivores.

Study area and methods

Study area

This study was carried out in the Sierras de Cazorla, Segura and Las Villas Natural Park, whose total area is 2140 km^2. It is situated in the far east of the Jaen province, between latitudes 37° 45′–38° 10′ and longitudes 2° 40′–3° 00′. The geological substratum mainly consists of dolomized limestones. The average rainfall in the 10 years prior to the study at Vadillo was 1060 mm.

We have selected a representative study area of 2 km^2 between 1300 and 1500 m close to the 'Nava S. Pedro' site. Vegetation belongs to supramediterranean betican basophylous series of the holm oak forest (Rivas Martinez 1987), with a predominance in the shrub stratum of *Quercus ilex*, *Berberis hispanica*, *Crataegus monogyna*, *Rosa canina*, *Juniperus oxycedrus*, *Daphne gnidium*, *Cytisus reverchonii*, *Echinospartum boisierii* and *Thymus zygis*. Past forest management practices have favoured the predominance of *Pinus nigra*.

Besides the already mentioned ungulates, the study area is also used by fallow deer (*Dama dama*) and red deer (*Cervus elaphus*) with high and low densities respectively. Wild boar are occasionally seen, but their actual density is unknown.

Vegetation sampling

Vegetation sampling carried out from 1988 to 1990 tried to asses the food supply available to large herbivores, adapting likewise to the mediterranean climatic regime with a high level of equinoctial rains. Three periods were chosen for study. First a period of resource abundance (spring), second, a period of scarce resources (end of winter) and third (end of summer), a period in which resources would normally be scarce due to the summer drought, but could be of relative abundance in years of high summer rainfall.

As there is no one ideal method for assessing herbaceous and ligneous vegetation together, two kinds of technique were used. The herbaceous and lower shrub stratum was determined by means of four fixed transects covered on foot. Every three steps the plant species touching the observer's toe was recorded (Dunbar 1978). In the first two samples the number of steps was 5. A total number of 400, 400, 678, 737, 641 and 637 contact points were obtained in each of the following sampling periods respectively: May and September 1988, February, May and September 1989 and February 1990.

Ligneous vegetation abundance (30 to 200 cm) was estimated using two sampling techniques. In 1988, plant species cover was determined in 80 plots of 5 m radius at regular intervals on the previous transects. Cover was checked in two strata: 50–100 cm and 100–200 cm. From February 1989 the line intercept method was used with the following features: on the fixed transects themselves and at regular intervals, 1 × 10 m strips perpendicular to the transect were established. On each strip the length of ligneous species patches parallel to the longest strip side was measured at two levels: 60 and 120 cm. In February and May 1989 40 and 50 strips respectively were evaluated and in September 1989 and February 1990 80 strips for each sampling were evaluated.

With the aim of comparing diets to available vegetation species frequencies obtained in the different strata, were weighted by the relative importance of the total vegetation at the corresponding level and were summed (Kasworm *et al.* 1984). Two basic hypotheses have been assumed: a) that food-search happens only on the plant material and b) that the probability of a species being eaten is proportional to its abundance in the herbivorous space (0–200 cm), whatever the height at which it occurs. Thus the occurrence probability of each plant species (p_i) in the space available to the herbivores is as follows:

$$p_i = p_{i1} \times f_1 + p_{i2} \times f_2 + p_{i3} \times f_3$$

p_{in} being the occurrence probability of species i in the plant fraction of stratum n and f_n plant abundance in the stratum n with regard to all other strata.

Diet analysis

In this study the diets of 269 animals, 69 domestic goats, 30 wild goats, 105 sheep and 65 moufflon were determined as follows. Homogeneous mixtures of each species' fresh faeces, collected in each of the previous sampling periods were made. A part of each mixture was analysed using the micrographic technique (Garcia-Gonzalez 1984), which is based on microscopic recognition of indigestible plant fragments (mainly epidermis) in the droppings. A reference collection of the most abundant or most used plant species epidermis in the study area has been made previously (Garcia-Gonzalez & Cuartas 1989). Between 400 and 500 microscopic identifications were made for each animal species and period. This number has proved sufficient in determining the feeding regime of herbivores using this method (Chapuis 1980). To display the results, both of diets and available vegetation, plant species have been grouped into three categories: ligneous, forbs (which include herbaceous dicotyledons and non-graminoid monocotyledons: mainly Liliiflorae) and graminoids (i.e. the Gramineae, Ciperaceae and Juncaceae).

Preference or rejection shown by herbivores for a particular species or plant category was established by means of the modified Ivlev selection index:

$$\text{I.S.} = \frac{\text{I} - \text{A}}{\text{I} + \text{A}} \times 10$$

I being the proportion of a plant in the diet and A the proportion in available vegetation. This index varies between + 10 and −10. A zero value represents no selection: i.e. a food item is eaten in proportion to its availability.

Kulzynski's similarity index (Gauch 1973) has been employed to compare herbivorous diets:

$$\text{K.S.I.} = \frac{\Sigma\, 2c}{\Sigma\,(a + b)} \times 100$$

where c is the lesser percentage of a common plant species or taxon in the diets and $\Sigma(a+b)$ is the sum of the percentages of all the species in the two diets.

Animal abundance

Animal abundance was determined by a combination of the fixed point observation method and the systematic survey method (Escos & Alados 1988). A census of the study area was taken on two consecutive days during each study period. The estimated values were calculated by applying the equation:

$$N_e = 2 \times N_{max} - N_{max-1}$$

following Seber (1982)

where N_e is the estimated census, N_{max} is the máximum number of individuals of a species counted in a sampling period and N_{max-1} is the number of individuals counted before the maximum in the same sampling period.

Results

Available vegetation

At the species or genus level a 94 taxa was recorded, 26 of which were classified as ligneous, 52 as herbaceous and 16 as graminoids (see Appendix). The proportions of plant type categories experiencing variations according to the sampling period is shown in Table 1. The differences, taking all periods jointly, are statistically significant ($\chi^2 = 46.1$; d.f. = 10; p = 0.0001). The same happens in the same sampling period taken in different years: $\chi^2 = 5.6$ (p = 0.06); $\chi^2 = 13.2$ (p = 0.001); $\chi^2 = 7.4$ (p = 0.02); d.f. = 2 for May, September and February respectively. However annual plant supply, comparing the two sampling years, did not show significant differences ($\chi^2 = 0.23$; d.f. = 2; p = 0.89), the total average proportion being 48.6% (s.d. = 9.8), 22.8% (s.d. = 7.8) and 28.6% (s.d. = 11.4) for ligneous, herbaceous and graminoid plant types respectively.

Table 1 shows a high percentage of graminoids in February 1989 and in September 1989. This may be because the graminoid category includes a high proportion of terophyte species, which give a quick response to short periods of rainfall when temperature is high. The two winters corresponding to the two years under consideration were particularly mild and wet (in the February 1989 sample, a notable amount of sprouting forbs were observed). Furthermore, the proportions of vegetation available correspond to the sampling of a hypothetical space able to be used by herbivores and the abundance of ligneous species is greatly influenced by sampling variations in their vertical structure and not only by current annual growth. The percentages of cover in the herbaceous and lower shrub stratum, however, show a greater correspondence with the normal growth period, peaking in May (Fig. 1).

Table 1. Variation in the relative abundance (%) of the main vegetation types in the study area throughout the study period. Relative frequencies of species were established by weighting frequencies obtained at three levels: 0–30, 30–100 and 100–200 cm (for explanations see text).

Plant type	May 88	Sep 88	Feb 89	May 89	Sep 89	Feb 90
Ligneous	55.6	59.0	34.1	39.0	52.4	51.4
Forbs	25.0	25.8	19.1	35.3	12.3	19.1
Graminoids	19.4	15.1	46.7	25.7	35.2	29.5

Herbivore diets

Figure 2 shows the results from different animal species' diets for each sampling period. The frequency of each plant category was obtained by summing the species or taxon frequencies belonging to that category.

a) Capra hircus
The domestic goat consumes on average a very high percentage of ligneous plants ($\bar{x} = 97.7\%$;

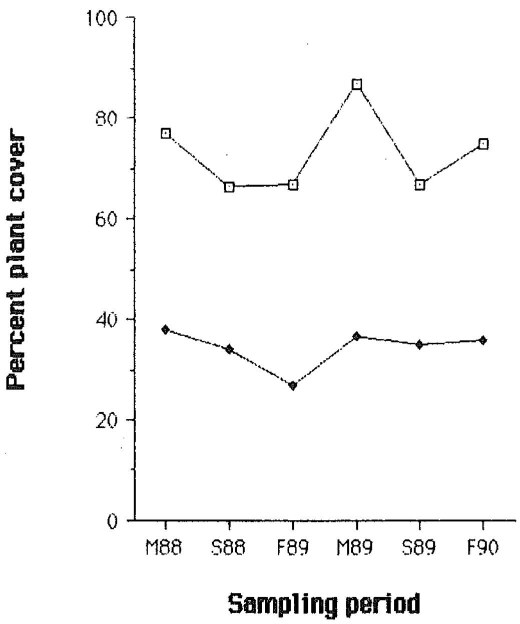

Fig. 1. Variation in vegetation cover (percentage of plants in relation to total cover). Open symbols: herbaceous level (< 30 cm) only. Filled symbols: all herbaceous and shrub levels (< 200 cm).

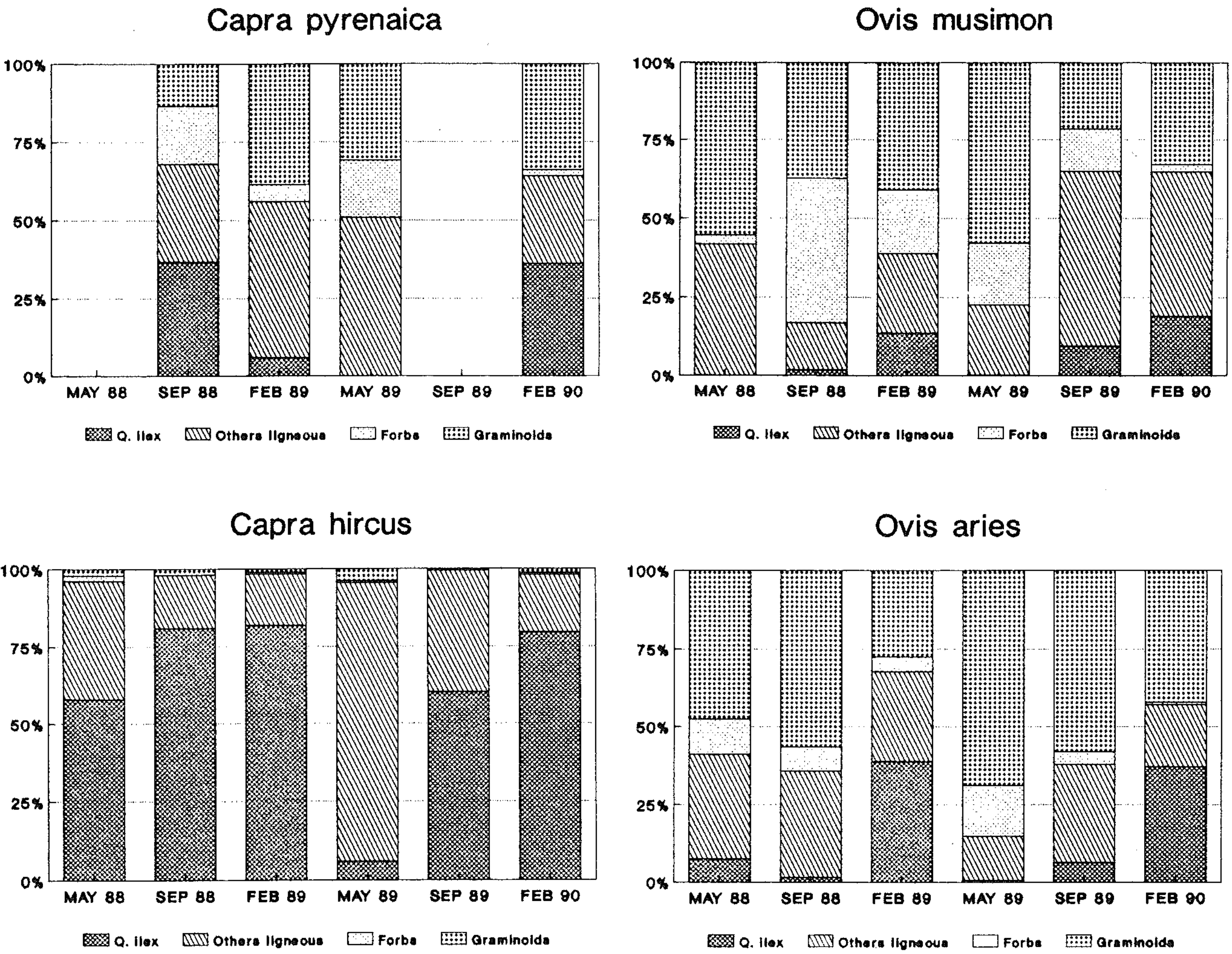

Fig. 2. Cumulative frequencies of main vegetation types in herbivorous diets and in available vegetation in each sampling period.

s.d. = 1.5) and a very low percentage of forbs ($\bar{x} = 0.6\%$; s.d. = 0.6) and graminoids ($\bar{x} = 1.7\%$; s.d. = 1.22) (Fig. 3). The distribution of its feeding regime among the three plant categories was very homogeneous throughout the study period. It was the only herbivore not to show significant differences among the diets at different periods ($\chi^2 = 7.7$; d.f. = 10; p = 0.66). The most eaten species was *Q. ilex* ($\bar{x} = 61.1\%$; s.d. = 29.1; Fig. 3) on which a strong selection was shown at all times (Table 2). Nevertheless the low percentage of this species consumed in May 1989 (6%) should be noted, *Pinus nigra* (34%) and *Crataegus monogyna* (40%) being the preferred species.

Table 2. Estimated preference for *Q. ilex* shown by herbivores in each sampling period. Applied selection index was S.I. = (I − A/I + A) × 10, I being the proportion in the diet and A the abundance in the vegetation.

Period	Dom. goat	Wild goat	Sheep	Moufflon
May 88	8.6	•	2.5	− 10.0
Sep 88	7.9	5.9	− 7.3	− 6.5
Feb 89	9.3	3.3	8.6	6.4
May 89	2.2	− 10.0	− 7.0	− 8.9
Sep 89	7.6	•	− 1.3	0.7
Feb 90	8.6	7.2	7.3	5.3
Sum	44.2	6.5	2.7	− 13.1
Mean	7.4	1.6	0.5	− 2.2

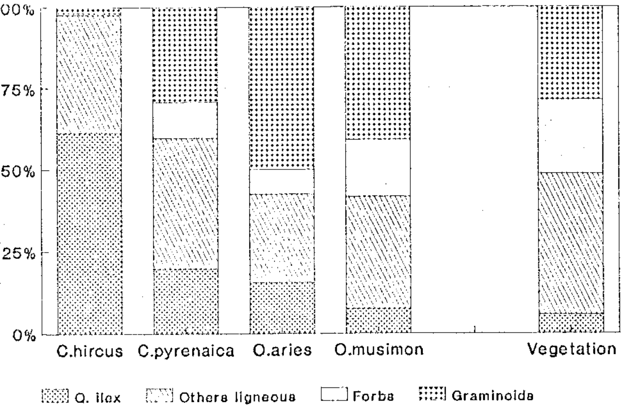

Fig. 3. Mean cumulative frequencies of main plant categories in herbivorous diets and in available vegetation over the whole study period.

b) Capra pyrenaica

Fecal analysis show the wild goat's diet to average 59.7% (s.d. = 7.6) ligneous species, 11.1% (s.d. = 8.6) herbaceous and 29.2% (s.d. = 11) graminoid (Fig. 3), with significant differences at different times of the year ($\chi^2 = 35.4$; d.f. = 6; p = 0.0001).

Diet results for May 1988 period were not considered because microscopic analysis showed pellets belonging to fallow deer (hair presence). In September 1989 a decrease in species numbers, due to a serious mange epidemic, prevented the localization of any individuals.

The average consumption of *Q. ilex* was 19.7% the maximum occurring in September 1988 and February 1990 (37% and 36% respectively; Fig. 2). However in February 1989 the consumption of browse was shared among several species, *Helianthemum* spp. (10%) and *Thymus zygis* (15%) being the most important. In May 1989 a high consumption of *Erinacea anthyllis* was observed (28%). The preference for *Q. ilex* over the whole study period could be considered as moderate (Table 2).

In general, herbaceous dicotyledons were poorly grazed by wild goat, with the exception of the September 1988 and May 1989 diet's. The maximum value for herbaceous species in September 1988 was a consequence of a notable non-graminoid monocotyledons (*Liliiflorae*) being eaten (13%). Among the monocotyledons the consumption of *Helictotrichon filifolium* in winter should be noted (15% and 17% in February 1988 and 1989 respectively).

c) Ovis musimon

Moufflon consumed an average of 41.7% ligneous species (s.d. = 20.3), 17.3% herbaceous (s.d. = 16) and 41% graminoids (s.d. = 13.8). There were significant differences between periods ($\chi^2 = 146.4$; d.f. = 10; p = 0.0001). The highest values for *Q. ilex* (19% and 13%) were found in February (Fig. 2). Just as with the sheep, the moufflon only chose holm oak in winter (Table 2), showing on average less preference for it ($\bar{x} = -2.2$). In the remaining sampled periods the consumption of ligneous species is shared between other browse species, of which one should mention *Erinacea anthyllis* in May 1988 (11%), *Helianthemum* spp. in September 1989 (20%) and *Cytisus reverchonii* in September 1989 and February 1990 (15% and 19% respectively). Consumption of dicotyledoneous forbs was at its maximum in May 1989 (19%) and among graminoids there was a great consumption of *Brachypodium phoenicoides* and *Festuca rubra*. The high consumption of geophytic monocotyledons (*Liliiflorae*) in September 1989 (40%) should be noted.

d) Ovis aries

Sheep consumed an average of 42.5% (s.d. = 18.4) ligneous species, 7.4% (s.d. = 5.6) forbs and 50% (s.d. = 14.4) graminoids, showing significant seasonal variations ($\chi^2 = 81.6$; d.f. = 10; p = 0.0001). Consumption of holm oak was greatest in February (39% and 37%; Fig. 2). In other sampled periods the consumption of browse was shared out among several species: *Pinus nigra*, *Cytisus reverchonii*, *Helianthemum* spp. and *Thymus zygis* being the most consumed species. Herbaceous dicotyledons were consumed in low proportions, except in May 1988 when it reached 16%. Graminoids were strongly selected throughout the year, especially *Brachypodium phoenicoides* and *Festuca rubra*. The sheep did not show preference for holm oak, except during the winter period (Table 2).

Table 3. Absolute abundance (no. of individuals) of Caprini species in the study area (2 km²). Censuses were obtained by a combination of observation points and transect methods (Escos & Alados 1988).

Animal species	May 88	Sept 88	Febr 89	May 89	Sept 89	Febr 90	Mean
Domestic goat	71	71	23	21	21	11	36.3
Wild goat	18	25	2	1	0	4	8.3
Sheep	633	633	140	260	260	130	342.7
Moufflon	24	22	2	8	4	20	13.3

Animal numbers

The area in which censuses were taken corresponds to the 2 km^2 of the study area. It was assumed that variations due to animal displacements would not be important. Radiotelemetry studies have established a home range of 0.6 km^2 for female wild goats in Cazorla's Park (Escos, pers. comm.). Oscillations both in numbers and use of space by domestic animals were easily controlled.

Average density values for Caprini obtained for the study area (Table 3) were at a maximum during 1988 (370 indiv./km^2). The lowest densities were found in February (80 indiv./km^2). Medium values were obtained in May and September 1989 (140 indiv./km^2 on average). These oscillations in total Caprini density are mainly due to variations in domestic species numbers. In the May and September sampling periods the sheep contingent increased because of the arrival of migratory flocks. The decrease in domestic goat numbers was due to management needs and in wild goat to the high mortality rate produced by a virulent mange epidemic which started in 1988.

To these numbers can be added a large number of fallow deer (9.4 indiv./km^2) and a smaller number of red deer (1.2 indiv./km^2). This gives a total wild herbivore density of 21.4 indiv./km^2, which in hunting terms would be considered high. If we add domestic herbivores the density rises to 222 indiv./km^2, although in zootechnical terms this would be considered moderate (2.2 indiv./Ha) (Perevolotsky 1989).

Hypothetical estimation of holm oak intake

Feed intake is a homeostatic mechanism regulated by physical functions (i.e. gastrointestinal capacity, passage rate) or physiological functions (i.e. blood level in certain metabolites) (Robbins 1983). It also shows wide inter- and intra-species variations, with regard to forage use (i.e. cellular wall component concentrations or calorific content) (Van Soest 1982). Even so, some experimental values, assuming wide variation ranges, could allow us to carry out a hypothetical estimation of the annual intake of holm oak leaves under the conditions of this study (Table 4).

In this study, the greatest consumer of holm oak is the domestic goat (annual mean $\bar{x} = 61.1\%$), followed by, to a similar degree, wild goat and sheep (19.7% and 15.4% respectively). Moufflon shows the least incidence at 7.5%. Whatever the rate, the overall impact of each species on *Q. ilex* obviously depends on their relative

Table 4. Idealized estimation of holm oak (*Q. ilex*) intake by herbivores in the study area in Tm DM/km^2/year. Calculations assume an intake of 100 gr DM/kg$^{0.75}$/day by a Caprini of 35 Kg live weight. A: animal density (indiv./km^2). B: holm oak utilization (average % in faeces). C: holm oak utilization relative to density (A × B/100). D: estimated dry matter holm oak intake in Tm/km^2/year (C × 1.44 kg DM/day × 365 days/year × 1 Tm/1000 kg). E: percentage (%) by animal species.

Caprini species	A	B	C	D	E
Domestic goat	18.2	61.1	11.11	5.837	28.7
Wild goat	4.2	19.7	0.82	0.432	2.1
Sheep	171.3	15.4	26.31	13.829	67.9
Moufflon	6.7	7.5	0.50	0.261	1.3

Fig. 4. Prostrated, cushioned and sandglass-shaped forms of *Q. ilex* characterize intensily browsing zones in Cazorla Sierra.

densities in a particular area. Under our conditions it can be deduced that, in spite of low sheep preference for *Q. ilex*, the high density of this animal in the area makes a greater impact than other species.

The revision of a high number of controlled experiments established that daily sheep feed intake ranges between 50–100 gr DM by kilogram of metabolic weight ($kg^{0.75}$) (Van Soest 1982). Other experiments using metabolic cages and chrome oxide markers on domestic goats browsing in a *Q. ilex* and *Q. pubescens* community (Meuret 1989) show that holm oak intake for this species could reach 100 gr $DM/kg^{0.75}$ a day. If we assume a similar degree of ingestion for the two other wild Caprini and take into account their density (Table 3), we could arrive at a probable maximum holm oak intake of 20.4 Tm DM/km^2/year (Table 4), considering a high ingestion level (100 gr $DM/kg^{0.75}$/day) and an average weight per Caprini of 35 kg. These figures could range between 9.1–26.5 Tm DM/km^2/year taking into consideration a live weight variation per individual of 30–50 Kg. Three per cent of this intake corresponds to moufflon and wild goat and the rest to sheep (68%) and domestic goat (29%).

Discussion

Effect of domestication on herbivore diets

Caprini were chosen from among the existing ungulates in the area because, within each genus, *Capra* and *Ovis*, one species is the result of artificial selection (domestication) imposed on another. This is of great importance for the trophic strategy developed by each species (Schwartz & Ellis 1981). It is possible that, because they belong to the same genus, there would be a similarity between trophic niches of domestic goats and wild goats, or between sheep and mouflons. The results of this study show that *Capra* species do have browsing food habits, whereas *Ovis* are grazers, (in agreement with Hoffman's (1989) classification), but domestic herbivores showed a more pronounced niche tendency. Moreover, the differences between *C. hircus* and *C. pyrenaica*

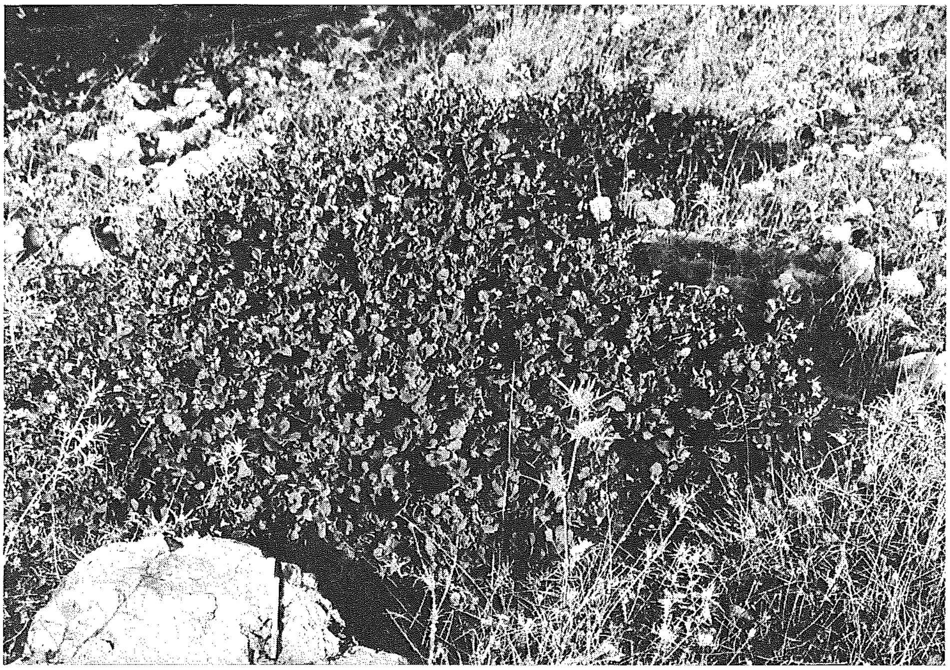

Fig. 5. A cushion-shaped holm oak example caused by large herbivore browsing in study area.

were shown to be higher than those between *O. aries* and *O. musimon*. The Kulzynski similarity index had a value of 39% when comparing mean diets of *Capra* species and 71% for *Ovis* species.

Some authors have noted that one effect of domestication is to produce a more generalist (less discriminating) feeding behaviour (Mukhachev 1984). Results, at least those for the domestic goat, show the contrary, as it clearly chose ligneous vegetation, particularly *Q. ilex*. The sheep showed a high level of herbaceous consumption, similar to that of the moufflon, although grass consumption was on the whole higher in the former species. It has been said that sheep probably have a higher reticular-ruminal volume than that which corresponds to their body size, enabling them to increase fibrous forage intake (Schoonveld *et al.* 1974; Hanley & Hanley 1982). It has been shown that ruminal volume in sheep is greater than in moufflons of the same size (Garcia-Gonzalez 1987). If domestication had produced a similar effect among *Capra*, and if domestic goats had a relatively high ruminal volume, this would cause, among other effects, an increase in daily intake. Together with the browsing tendency of the genus this could explain the high consumption of *Q. ilex* observed, which is one of the most abundant ligneous food resources in the area possessing an acceptable nutritive value (Rodriguez-Berrocal *et al.* 1973).

Caprini impact on holm oak

Data on the primary production of such an important species in the mediterranean landscape as *Q. ilex* are rare. Ferres *et al.* (1984), in a detailed study of the production of a holm oak forest in Montseny (NE Spain), found a leaf production of 3.1 Tm/Ha/year. However, the authors themselves consider this production to be abnormally high due to the favourable edaphic and climatic conditions in the study area. One of the authors (Ferres 1985) considers that the most usual production values for the Iberian Peninsula would be 0.7 to 1.5 Tm/Ha/year. Rapp (1971) points out a shoot production of 0.9 Tm/Ha/year for an holm

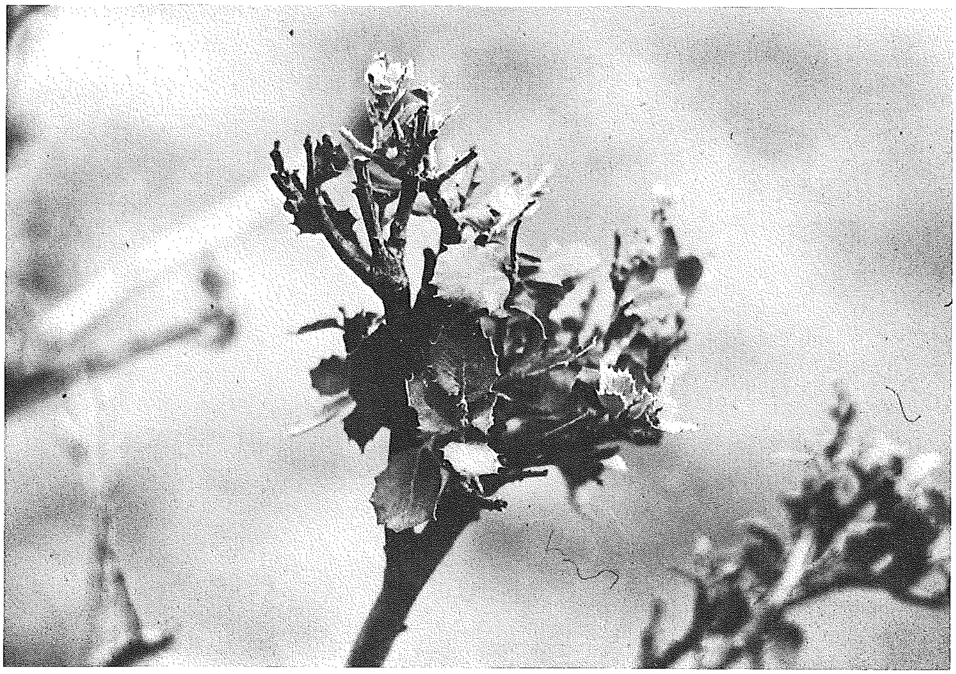

Fig. 6. Detail of a extremely browsed twig of *Q. ilex* with compacted and thorn leaves.

oak woodland of 1400 stems/Ha near Montpellier.

If we accept a holm oak aerial net production of 0.7–1.5 Tm/Ha/year, the holm oak production in the study area could be as high as 4.1–8.7 Tm/km^2/year assuming a relative abundance of 5.8% (Appendix). Wild Caprini have an estimated intake of 0.7 Tm/km^2/year (Table 4). The effect of wild ungulate browsing on *Q. ilex* in the study area is, therefore, acceptable in terms of leaf production. The effect of the species' regenerative dynamic could be very different, given the high toll of young individuals taken by browsing. The absence of new *Q. ilex* shoots in recent years could seriously be affecting its population dynamics (Herrera, pers. comm.). Nevertheless, *Q. ilex* intake by domestic herbivores could be 2.5 to 5 times its primary net production (Table 4), seriously affecting its biomass. This heavy impact on holm oak produces a large quantity of prostrate, cushion, or cone shaped forms to be found in the study area (Fig. 4 and 5). These shrubby forms are usually associated with a high leaf/secondary tiller ratio, small-sized leaves and an increase in thorniness (Fig. 6).

The domestic goat would seem to show different preferences for the various *Quercus* species. Leouffre *et al.* (1989) points to a marked preference for *Q. pubescens* instead of *Q. ilex* in an area of south-east France. Soriguer (1988) also shows a bias among browsers towards *Q. faginea* instead of *Q. ilex* in the Cazorla Sierra. These differences can probably be attributed to the lower content of indigestible substances (cutin, lignin) and the higher content of protein in the deciduous and semi-evergreen *Quercus* compared with evergreens. The tanin content could also be an important factor in this differential preference (Nastis & Malechek 1981).

Therefore, in this study, the browsing effect of herbivores could be even more damaging both for the more attractive species of *Quercus*, such as *Q. faginea*, which has almost completely disappeared from the study area (Garcia-Gonzalez & Cuartas 1989), and also, for other scarce species of high genetic value, which are preyed on in the most critical moment of their reproductive period (Herrera 1987). It should not be forgotten however, that some studies indicate a favourable effect of goat grazing on herbaceous production (Perevolotsky 1989).

In conclusion, normal wild ungulate densities in the study area (21.4 indiv./km^2), although high in hunting terms, suggest that the browsing impact on holm oaks could be withstood by this species, given its great sprouting capacity. The introduction of domestic ungulates seriously alters the situation, particularly when the proportion of browsers or/and animal densities is high. Under these circumstances great attention should be paid to the compatible stocking rate, not only with the tolerance of abundant species by high sprouting rates (i.e. *Q. ilex*), but also with the persistence of other rarer species, whose essential reproductive strategy is sexual.

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Appendix

Available vegetation in each sampling period. Plant species percentage abundance (%) for total plant cover below 2 m.

Plant types	May 88	Sept 88	Febr 89	May 89	Sept 89	Febr 90	Mean
Shrubs and trees							
Pinus nigra	10.13	8.92	4.39	3.37	3.71	6.89	6.24
Rosa spp.	7.37	6.75	1.43	5.01	5.24	4.20	5
Acer spp.	0.46	0	0	0	0	0	0.08
Juniperus phoenicea	6.04	1.60	1.87	0.69	0.72	1.31	2.04
Berberis hispanica	4.82	9.03	3.84	3.72	7.77	6.12	5.88
Quercus ilex	4.49	9.35	3	3.78	8.41	5.88	5.82
Amelanchier rotundifolia	0.96	0.61	0	0.47	0.70	0.96	0.62
Crataegus monogyna	3.48	4.73	6.59	5.81	5.53	5.50	5.27
Rhamnus spp.	0.08	0.64	0	0	0.26	0.05	0.17
Quercus faginea	0	0	0	0	0.04	0.12	0.03
Rubus sp.	0	0.12	0	0	0.96	1.28	0.39
Juniperus communis	0.18	1.17	1.63	0.37	0.62	0.87	0.81
Juniperus oxycedrus	1.52	1.43	0.83	0.62	0.98	1.07	1.08
Teucrium poleum	0.44	1.46	1.10	0.99	0.60	0.88	0.91
Satureja montana	1.09	1.95	0.55	0.49	0.90	0.73	0.95
Lavandula latifolia	0.65	0	0.55	0.12	0.60	0.44	0.39
Helianthemun spp.	1.52	1.46	0.37	2.72	2.99	1.91	1.83
Echinospartum boissierii	3.48	3.66	2.21	1.11	3.74	4.09	3.05
Thymus zygis	7.61	4.15	3.50	4.81	3.14	4.82	4.67
Erinacea anthyllis	1.09	0.73	0.92	0.74	1.80	1.61	1.15
Cytisus reverchonii	0.22	0.24	0.37	2.95	3.24	2.05	1.51
Daphne gnidium	0	0.73	0.55	1.23	0	0	0.42
Santolina rosmarinifolia	0	0	0	0	0	0.15	0.03
Thymus mastichina	0	0	0	0	0.15	0.15	0.05
Fumana ericoides	0	0	0.37	0	0.30	0	0.11
Daphne laureola	0	0	0	0	0	0.29	0.05

Appendix. Continued.

Plant types	May 88	Sept 88	Febr 89	May 89	Sept 89	Febr 90	Mean
Unidentified	0	0.24	0	0	0	0	0.04
Total	55.63	58.97	34.07	39	52.40	51.37	48.57
Forbs							
Trifolium campestre	4.35	2.20	3.86	2.84	0	0	2.21
Catananche caerulea	0.22	0.49	0	2.22	0	0.15	0.51
Leontodon taraxacoides	4.13	1.46	0	1.98	0	4.53	2.02
Hieracium pilosella	1.09	0.49	0	1.98	0.30	.29	0.69
Geranium spp.	0	0	2.02	1.73	0	2.19	0.99
Trifolium stellatum	1.31	0	0	1.48	0	0	0.47
Scabiosa turolensis	1.31	2.20	0.75	1.23	0.45	0	0.99
Plantago lanceolata	0	0	0.37	1.23	0	0	0.27
Arenaria sp.	0	0	0	1.11	0	0	0.19
Rumex spp.	0	0	0	0.99	0	0	0.17
Centaurea sp.	0	0	0	0.49	0	0	0.08
Marrubium sp.	0	0	0	0.37	0	0	0.06
Geum sylvaticum	0	0	0.18	0.37	0	1.17	0.29
Bellis perennis	0	0	0	0.25	0	0	0.04
Ionopsidium abulense	0	0	0	0.25	0	0	0.04
Santolina rosmarinifolia	0	0	0	0.12	0	0	0.02
Cerastium boissierii	0	0	0	0.12	0	0.29	0.07
Helleborus phoetidus	0	0	0	0.12	0	0	0.02
Ranunculus paludosus	0	0	0	0.12	0	0	0.02
Sanguisorba minor	0	0	0	0.12	0	0.15	0.05
Mantisalca salmantica	0	0	0	0.12	0	0	0.02
Carlina corymbosa	0	0.98	0	0.12	0	0	0.18
Sherardia arvensis	0	0	0	0.37	0	0	0.06
Paeonia broteroi	0	0	0	0.12	0	0	0.02
Armeria sp.	0	0	0	0.12	0	0	0.02
Bellis silvestris	0	0	0	0.12	0	0	0.02
Silene sp.	0	0	0	0.12	0	0	0.02
Capsela bursa-pastoris	0	0	0	0.12	0	0	0.02
Plumbago europaea	0	0	0	0	0.15	0	0.03
Lotus angustissimus	0	0.49	0	0	0	0	0.08
Eryngium campestre	3.48	8.29	0	3.70	1.65	0	2.85
Trifolium tomentosum	0.44	0	0	0	0	0	0.07
Echium vulgare	0	0.24	0	0.37	0.15	0.15	0.15
Ragadiolus stellatus	0.22	0	0	0	0	0	0.04
Cirsium sp.	0	4.15	0	0	0	0	0.69
Chondrilla juncea	0	2.20	0	0	0	0	0.37
Convolvulus sp.	0	0.73	0	0	0	0	0.12
Astragalus incanus	0	0.24	0	0	0.30	0	0.09
Crucianella angustifolia	0	0.24	0	0	0	0	0.04
Phlomis lychnitis	0	0.73	0	0.25	0	0	0.16
Filipendula vulgaris	0	0	0	0	0	0	0
Pethrorargia nanteuilii	0	0.24	0	0.12	0	0	0.06
Torilis leptophilla	0	0.24	0	0	0	0	0.04
Ranunculus gramineus	0	0	0.55	0	0	0	0.09
Briophyte	0	0	0.55	0	0	0.29	0.14
Trifolium sp./*Medicago* sp.	0	0	9.38	0	7.78	4.97	3.69

Appendix. Continued.

Plant types	May 88	Sept 88	Febr 89	May 89	Sept 89	Febr 90	Mean
Liliiflorae	1.09	0	0	2.10	0.45	0.44	0.68
Unidentified	7.40	0.24	1.47	8.39	1.05	4.53	3.85
Total	25.04	25.85	19.13	35.26	12.28	19.15	22.79
Graminoids							
Grasses	17.22	14.87	45.82	25.68	35.32	29.51	28.07
Carex hallerana	1.74	0.24	0.92	0	0	0	0.48
Juncus spp.	0.44	0	0	0	0	0	0.07
Gran total	100.07	99.93	99.94	99.94	100	100.03	99.99