

Chapter 11

Role of Various Woody Species in Spanish Mediterranean Forest and Scrubland as Food Resources for Spanish Ibex (*Capra pyrenaica* Schinz) and Red Deer (*Cervus elaphus* L.)

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Abstract Spanish ibex (*Capra pyrenaica* Sinhinz) and red deer (*Cervus elaphus* L.) are highly abundant in Mediterranean habitats and are of major economic importance, primarily due to their value as game but also, in the case of red deer, for their meat. This study analyses the importance of nine woody species in the diet of two wild herbivores with browser and browser-grazer feeding habits: Spanish ibex in south-eastern and eastern Spain and red deer in south-eastern and central Spain. In south-eastern Spain, altitude (low and high zone), sex and age classes (males, females and animals younger than 2 years) and season were recorded for the whole Spanish ibex study area. Availability, selection index and specific nutritional parameters were recorded for the woody species (four) studied in south-eastern Spain. *Arbutus unedo* L., *Juniperus oxycedrus* L., *J. phoenicea* L., *Phillyrea angustifolia* L., *Ph. latifolia* L., *Pinus nigra* J.F. Arnold, *Quercus faginea* Lam., *Quercus ilex* L. and *Rosmarinus officinalis* L. were the species most eaten by Spanish ibex and red deer in the different areas studied.

Keywords Consumption, selection index, browsing, food quality, *Quercus ilex*

Introduction

Most wild herbivores diversify their diet in accordance with various types of ecological and physiological influences: unfavourable periods, limited highest quality resources, needs for specific nutrients and potential overlaps in habitats and trophic resources. Flexibility and plasticity in the feeding habits of both Spanish ibex and red deer allow them to easily adapt their consumption of the

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various plant categories based on changes in the availability of food resources in space and time (Martínez 1992, 1996; Garín et al. 2001). The energy and protein content of a wide range of plant species is also one of the most important restrictions for animal productivity (Holeček et al. 2004). In Mediterranean areas, caprine and cervid diet usually contains a high richness of plant species (Álvarez and Ramos 1991; Cuartas 1992; Martínez 1992, 1994b, 1996, 2001, 2002a; Heroldová 1997). However, only a small number of species plants form a substantial part of their diets. Both Spanish ibex (*Capra pyrenaica* Sinhinz) and red deer (*Cervus elaphus* L.) are grazers and browsers according to Hofmann's (1989) definition. Both types of feeding behaviour have been observed, with a varying tendency towards one type of behaviour or other (Maillard and Casanova 1994; Groot-Bruinderink and Hazebroek 1995; Heroldová 1997; Martínez 2000, 2001, 2002a). In Mediterranean forests, and particularly in the Iberian Peninsula, browsing tendencies become much more obvious than in other type of forests developed in other type of environments different from Mediterranean area and woody vegetation is an important food resource for both studied animal species as well as for other ruminants (Boza and Robles 1988; Palacios et al. 1989; Álvarez et al. 1991; García-González and Cuartas 1992; Martínez 1992, 1994a, 1996, 2002a; Aldezabal 2001). Consequently, knowledge about and evaluation of woody species in terms of their diet contribution, availability, chemical composition and degree of selection by consuming ruminants can provide accurate information towards sustainability of the natural environment and the silvopastoral systems that they use. Thus, within the mosaic of vegetation formations making up the woody vegetation in Mediterranean environments (*Quercus ilex* woodlands, pine forests, dehesas, open hills and scrubland), several species have been found to play a particularly important role in Spanish ibex and red deer feeding patterns. This paper analyses the importance or role played by nine woody species in the feeding habits of Spanish ibex and red deer in three large areas of Mediterranean forest in the Iberian Peninsula. The plant species studied were *Arbutus unedo* L. (strawberry tree), *Juniperus oxycedrus* L. (cade), *Juniperus phoenicea* L. (sabina negral), *Phillyrea angustifolia* L. (labiarnago blanco), *Phillyrea latifolia* L. (jasmine box), *Pinus nigra* J.F. Arnold subsp. *salzmannii* (Dunal) Franco (black pine), *Quercus faginea* Lam. (lusitanian oak), *Quercus ilex* subsp. *ballota* (Desf.) Samp. (holm oak) (from now named *Quercus ilex* L.) and *Rosmarinus officinalis* L. (rosemary). These species are native to Spanish Mediterranean forests and scrubland. This study quantifies and evaluates the consumption of the four most relevant woody species in the Spanish ibex and red deer total and woody diet in southeastern, eastern and central Spain. In addition to the consumption of these species, availability, the selection index of each species by the Spanish ibex and red deer, and specific nutritional parameters that explain energy and protein content were studied in south-eastern Spain.

Spanish ibex goat is an endemic species of high interest in the Iberian Peninsula due to its unique spatial distribution as it lives in meta-populations of the main Spanish mountain systems (Soriguer et al. 1992). In the two mountain massifs, Spanish ibex is well represented and it is a very important species from a hunting

and ecological point of view. The domestic goat *Capra hircus* aeagrus Erxleben has similar and higher browser behaviour than Spanish ibex in the studied areas.

Red deer is a Eurasian animal, with natural distribution from west Europe to central Asia, including islands of Córcega and Cerdeña and the MAGREB (Geist 1998). Nowadays, red deer occupies most of the Iberian Peninsular land, with the exception of the west of Galicia (NW Spain) and the Levante coast (SW Spain) (Carranza 2002).

The main distribution and ecology of the main plant species evaluated based on Polunin (1982) and López (2002) are now described.

Quercus ilex is a Mediterranean species which can be found as a tree or a perennial shrub. It is abundant in the Mediterranean part of the Iberian Peninsula and it grows in all types of soils, from the coast parts (where the subspecies *ilex* is more frequent) to the inner parts of the country with extreme and continental climate (where the sub species *ballota* is more frequent) from sea level up to 1,400m. Small shrub individuals can be found as high as 1,900–2,000m above sea level. *Quercus faginea* is a medium size marcescent (with leaves that wither but do not fall) tree, which lives in the most part of the Iberian Peninsula and in the NW of Africa. It can be found in areas with submediterranean or continental Mediterranean (not very extreme) climate, on all type of soils.

Arbutus unedo is a perennial shrub or small tree which grows in the Mediterranean West Europe and in Ireland. It is found in temperate climates associated with *Quercus ilex* and *Quercus suber* forests and in the degraded shrubland areas derived from both forest types, mainly in calcareous and siliceous soils, and it can be found in the South mountains up to 1,200m of altitude.

Juniperus oxycedrus is also a shrub or small tree of the Mediterranean region, found on most of the Iberian Peninsula as in the mountains and forest, dry and stony soils from the sea level over to 1,000m and it is associated with *Quercus ilex* and other sclerophilus Mediterranean forests. A similar species, *J. communis* L., is found in all types of soils from sea level up to 2,000m across Europe. *Juniperus phoenicea* is also a shrub or small tree of the Mediterranean region, found on all types of lands and conditions from sea level up to 1,400m.

The genus *Phillyrea* is represented by shrubs and small perennial trees in woodlands and stony areas of the Mediterranean countries. *Ph. angustifolia* can be found in the west part of the Mediterranean region. In the Iberian Peninsula it is not found in some parts of the north and northwestern area. It is found in the shrublands of the *Quercus ilex* and *Quercus suber*, being a thermophilus plant. *Ph. latifolia* is found in the Mediterranean region, located from the southern part of the Iberian Peninsula to the east part of Cataluña and in the northeast of Galicia. It can be found in *Quercus ilex* and other sclerophilus forests, and the shrubland which appear after the destruction of these forests. It can be found in siliceous and calcareous soils.

Pinus nigra is a tree species distributed and planted in many European countries. Its natural habitats in the Iberian Peninsula in central and eastern mountains reaching 800 and 1,500m of altitude.

Rosmarinus officinalis is a perennial aromatic shrub which is naturally distributed in the Mediterranean part of Europe. In the Iberian Peninsula, it is very frequent in

the lowlands where the climate is warm. It can be found in all types of soils, but prefers calcareous soil, from sea level up to 1,500m of altitude in the warmest mountains.

Study Area

The study area included three huge different zones (south eastern, eastern and central areas) of the Iberian Peninsula covered by Mediterranean forest and scrubland (Fig. 11.1).

The south-eastern area, the major source of information of this study, was in the in the Cazorla, Segura and Las Villas Nature Park (37°45' N and 2°40' W), where two zones with different altitudes were defined: low (800–1,500m) and high (1,500–2,000m). The local climate has extremely hot summers and frequent frosts in winter, with snow at the highest altitudes. Temperature and precipitation at an altitude of 1,360m is usually around 9.8°C and 1,129mm (10 years mean). There are two bi-climatic sub-regions: Supramediterranean, defined by the Betic Supramesomediterranean, basophyle-*Quercus faginea* and Betic Supramediterranean basophyle-*Q. rotundifolia* vegetation series, and the Oromediterranean defined by the Betic Oromediterranean basophyle-*Juniperus sabina* series (Rivas-Martínez 1987).



Fig. 11.1 Location of the studied areas

The eastern area is located in the Tortosa and Beceite Passes (40°45' N and 0°). The area is dominated by calcareous soils, warm and dry weather with a Mediterranean tendency and continental influence. It has been recorded a mean annual temperature around 11.6°C and a precipitation mean of around 580.8 mm (Morella weather station placed at 1,000 m asl) The altitude of this area ranges between 700 and 1,340 m asl and it is a typical Mediterranean hill landscape with a range of plant formations (holm oaks, pine forests and scrubland), this vegetation formations are described by Rivas Martínez (1987).

The central area is located in the Montes de Toledo range (39°25' N and 4°04' W). Two zones were defined: Zone I, Quintos de Mora (Toledo) and Zone II, Retuerta de Bullaque (Ciudad Real), with a characteristic dry Mediterranean climate, mild winters and a mesomediterranean bioclimate (Rivas Martínez 1987). Mean annual registered temperature of most closed weather station (Navahermosa) was around 14.8°C, being mean annual precipitation around 508 mm. The altitude of this area ranges between 800 and 1,200 m asl. The vegetation is characteristically a mixture of *Quercus ilex*, *Q. faginea* and shrub layer of *Phillyrea angustifolia*, *Arbutus unedo*, *Cistus ladanifer*, *Rosmarinus officinalis*, *Erica arborea*, *E. australis*, and also, several pine plantations (*Pinus pinea* and *P. pinaster*).

Methodology

This paper analyses and summarises the results from a number of studies, primarily by the author but also by other researchers in south-eastern, eastern and central Spain (Palacios et al. 1989; Álvarez et al. 1991; Martínez 1992, 1994a, b, 1996, 1997, 2002a). The Spanish ibex studies were conducted in south-eastern and eastern Spain, while those for red deer were conducted in south-eastern and central Spain.

Several methods and techniques used to determine a large number of parameters, are described in Martínez (1992, 1994a, 2000, 2001, 2002a). The method used to evaluate Spanish ibex diet in south-eastern Spain involved the botanical analyses of stomach contents (Martínez 1992, 2001; Klansek and Vavra 1992), while Spanish ibex diet in eastern Spain was studied using faecal analysis (Álvarez and Ramos 1991; Martínez 1988, 1994a, 2000; Heroldová 1997).

In south-eastern Spain, the study of the four most heavily consumed woody plant species by Spanish ibex was carried out for the whole studied area by altitude (low and high zone), sex and age classes (males, females and animals younger than 2 years) and season (number of samples rumen, see Table 11.2). The plant species studied were *Quercus ilex*, *Phillyrea latifolia*, *Juniperus oxycedrus* and *Rosmarinus officinalis*. In the eastern zone, consumption of the four woody plant species with highest consumption by Spanish ibex was evaluated for overall diet (225 faecal samples) and three seasons (spring (75 samples), summer (75 samples) and winter (75 samples)). The plant species studied were *Quercus ilex*, *Juniperus phoenicea*, *J. oxycedrus* and *Pinus nigra*.

Table 11.1 Availability (% biomass) and chemical composition of some plant species in south-eastern Spain

Woody species	Availability (%)			Components (%)			
	Total zone	Low zone	High zone	PROT	CC	LIG	DDM
<i>Quercus ilex</i>	23.7	31.0	11.0	7.5	53.2	38.5	33.8
<i>Phillyrea latifolia</i>	11.5	18.0	0.0	7.2	41.9	12.8	47.5
<i>Juniperus oxycedrus</i>	7.7	11.1	0.0	7.5	64.2	11.5	59.3
<i>Rosmarinus officinalis</i>	5.0	7.9	0.0	9.5	58.8	18.0	51.7
<i>Juniperus phoenicea</i>	–	–	–	6.4	75.5	18.6	64.1
<i>Pinus nigra</i>	–	–	–	5.0	60.2	13.6	55.8
<i>Arbutus unedo</i>	–	–	–	7.8	70.2	10.9	62.4
<i>Phillyrea angustifolia</i>	–	–	–	5.1	62.7	12.5	55.0
<i>Quercus faginea</i>	–	–	–	9.8	58.8	8.1	58.9

PROT = protein, CC = cellular content, LIG = lignin, DDM = apparent digestibility of dry matter

The method used to evaluate red deer diet involved the botanical analysis of stomach contents (Martínez 1992, 2001; Klansek and Vavra 1992). The study of overall red deer diet in south-eastern Spain used 16 rumen samples collected in spring, summer and winter. Red deer diet in central Spain (Montes de Toledo) was analysed using 42 samples collected in winter (December and January) in Quintos de Mora (zone I), and 16 samples from Retuerta de Bullaque (zone II) collected in autumn. The plant species studied were *Quercus ilex*, *Arbutus unedo* and *Phillyrea angustifolia* (zone I and II), *Rosmarinus officinalis* (zone I) and *Quercus faginea* (zone II).

The available vegetation in south-eastern Spain (Cazorla and Segura ranges), was sampled systematically using sampling plots set in different types of vegetation in accordance with altitudinal gradient and heterogeneity. The method described by Walker (1976) with certain modifications was used. The availability (biomass) of the woody species was evaluated on the basis of their volume and weight using regression equations (Martínez 1992).

In order to estimate availability (biomass) of shrubby and tree vegetation 11 transects were established in sampling plots of 240 m of length and 5 m width, where 4 sub-plots of 50 m² were established and all woody plants were measured. Transects were selected taking into account the distribution of the vegetation used in the diet analyses and the higher diversity-complexity of the vegetation. Following Walker (1976) the volume of each plant was estimated. Volume was estimated from the height and higher and smaller canopy diameter. Height was estimated as below or up to 2.5 m, because this height was standardised as the maximum ungulate shrub grazing height. In order to obtain dry biomass the volume/weight ratio was calculated from regression equations which predict plant biomass from volume. The regression equation was calculated by harvesting between 10 and 20 plants of the most relevant species in the diet and vegetation. These plants were measured, fresh weight determined; cut and stored in paper bags, air dried (they were periodically weighted for 60 days until constant

weight was obtained). Data were analysed with lineal regression ($y = a + b x$). Regression coefficients were high and significant. Confidence intervals were around 95% and the F test was used to adjust the regression. Samplings were made at the end of May.

Plant species selection was estimated by Ivlev's Selectivity Index, $ISI = (D - A) / (D + A)$, where D – diet (consumption) and A – Availability. The values of this index lay in the -1 and + 1 range. Values close to 1 indicated high selection of plant species by the animals, negative values indicated negative selection or avoidance of the species. Values close to 0 indicated a very close relationship between species consumption and availability

Food quality in the Cazorla and Segura ranges was evaluated using chemical analysis of the different organic parameters of plant species (Martínez 1992). The plant samples consisted of leaves and stem with less than 0.5 cm collected in May. Each plant sample was analysed for four organic parameters. Crude protein content (PROT) was estimated using the Kjeldahl method with a Bouat-Afora air-dragging device and the results being multiplied by 6.25. Other parameters: cellular content (CC), lignin (LIG) and apparent digestibility of dry matter (DDM) were determined by the method of Goering and Van Soest (1970) with modifications suggested by García-Criado (1974).

Availability, Consumption and Selection Index of the Four Most Relevant Woody Plant Species in the Spanish Ibx Diet in South-Eastern Spain

The availability of the four studied species can be seen in Table 11.1. It *Quercus ilex* was the most abundant species, representing around 23.7% of the woody vegetation evaluated (40 species) (Martínez 1992). Out of the four species studied *Rosmarinus officinalis* was the least abundant (5%) of the woody plants. The availability of the resources in the low area ranged from the 31% of *Quercus ilex* to 7.9% of *Rosmarinus officinalis*. *Phillyrea latifolia* and *Juniperus oxycedrus* were intermediate (Table 11.1). In the high land area, only *Quercus ilex* was found with lower availability than in the low area (around 11%). The other three species in the high zone were very scarce, being found close to the limit with the low zone, where goats eat them.

Most important woody species consumed by Spanish Ibx in south east Spain were *Quercus ilex*, *Phillyrea latifolia*, *Juniperus oxycedrus* and *Rosmarinus officinalis*. They explained around 32.2% of Spanish ibex annual diet and 52.7% of all consumed woody resources (Table 11.2). *Quercus ilex* was the most consumed, followed by *Phillyrea latifolia* and *Juniperus oxycedrus*. *Rosmarinus officinalis* was considerably less consumed than the former species. *Phillyrea latifolia* and *Juniperus oxycedrus* had a positive selection index (Table 11.3).

Quercus ilex represented 14.1% and 11.2% of the diet in the low and high zones respectively (Table 11.2). However, the selection index was considerably

Table 11.2 Proportion (%) in the biomass of the four most relevant woody plant species in the Spanish ibex diet and red deer diet in south-eastern Spain, 2(a) percentage of total diet, 2(b) percentages within the consumed woody vegetation or woody component of the diet (WV)

Woody species	Diet (biomass %)											Red deer	
	Spanish ibex											Annual	
	Annual	Low Z	High Z	♂	♀	Y	Spring	Summer	Autumn	Winter	Annual	Annual	
Samples (n)	105	57	38	52	34	19	22	28	20	35	16	16	
<i>Quercus ilex</i>	13.4	14.1	11.2	16.6	11.6	4.1	7.3	7.6	24.7	14.0	29.0	29.0	
<i>Phillyrea latifolia</i>	9.2	17.0	0.2	9.8	5.9	15.2	9.6	7.1	10.5	10.0	9.5	9.5	
<i>Juniperus oxycedrus</i>	6.8	8.2	5.4	5.5	10.0	5.2	1.2	0.5	4.6	16.8	3.0	3.0	
<i>Rosmarinus officinalis</i>	2.8	2.2	3.4	3.5	2.1	2.8	2.0	1.3	1.8	5.1	12.5	12.5	
Total (4 species)	32.2	41.5	20.2	35.4	29.6	27.3	20.1	16.5	41.6	45.9	54.0	54.0	
WV	61.3	64.0	51.2	63.0	58.3	58.1	41.6	59.0	66.6	77.6	73.7	73.7	
WV = Woody vegetation consumed, Z = Zone, Y = Young, Samples (n) = rumen samples													
Woody species	WV (biomass %)											Red deer	
	Spanish ibex											Annual	
	Annual	Low Z	High Z	♂	♀	Y	Spring	Summer	Autumn	Winter	Annual	Annual	
Samples (n)	22.0	26.6	0.4	15.6	10.1	26.2	23.1	12.0	15.8	12.9	13.0	13.0	
<i>Quercus ilex</i>	22.0	22.0	21.9	26.4	19.9	7.1	17.5	12.9	37.1	18.0	39.3	39.3	
<i>Phillyrea latifolia</i>	15.0	26.6	0.4	15.6	10.1	26.2	23.1	12.0	15.8	12.9	13.0	13.0	
<i>Juniperus oxycedrus</i>	11.1	12.8	10.5	8.7	17.2	9.0	2.9	0.8	6.9	21.7	4.0	4.0	
<i>Rosmarinus officinalis</i>	4.6	3.4	6.6	5.6	3.6	4.8	4.8	2.2	2.7	6.6	17.0	17.0	
Total (four species)	52.7	64.8	39.4	56.3	50.8	47.0	48.3	27.9	62.5	59.2	73.3	73.3	
TWV	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
TWV = Total woody vegetation													

Table 11.3 Selection index of 4 species of plants consumed by Spanish ibex and red deer in south-eastern Spain

Woody species	Spanish ibex							Red deer			
	Annual	Low Z	High Z	♂	♀	Y	Spring	Summer	Autumn	Winter	Annual
<i>Qi</i>	-0.04	-0.17	0.33	0.05	0.08	-0.54	-0.15	-0.29	0.22	-0.13	0.25
<i>Pl</i>	0.13	0.19	1.00	0.15	-0.06	0.40	0.34	0.02	0.16	0.06	0.03
<i>Jo</i>	0.21	0.07	1.00	0.09	0.41	0.10	-0.43	-0.80	-0.03	0.50	-0.30
<i>Ro</i>	-0.04	-0.40	1.00	0.06	-0.16	-0.02	-0.02	-0.39	-0.30	0.14	0.55

Z = zone, Y = young, Qi = *Quercus ilex*, Pl = *Phillyrea latifolia*, Jo = *Juniperus oxycedrus*, Ro = *Rosmarinus officinalis*

higher in the high zone than in the low zone. *Phillyrea latifolia* was the most heavily consumed and selected trophic resource in the low zone and made up 26.6%, of the woody plants. However, in the high zone this species was scarcely detected in the rumens analysed due to its absence in the high altitudinal areas (Table 11.1). *Juniperus oxycedrus* was the third most heavily consumed woody species by Spanish ibex, being intake also higher in low zones than in high zones (Table 11.2). This species was selected in both zones, but particularly at high altitudes where *Juniperus oxycedrus* is scarce. Finally, *Rosmarinus officinalis* was less eaten in the low zones than in high areas. Its selection by Spanish ibex was greater in the high zone where it is very scarce, and, as happened with *Juniperus oxycedrus* was also not found in the sampled plots. In the low zone, *Rosmarinus officinalis* was relatively abundant (Table 11.1) but was not positively selected by Ibex (Table 11.3).

In the male, female and young diets, the four studied species comprised amounts ranging from 27.3% in young to 35.4% in the case of males (Table 11.2). They comprised more than 50% of the consumed woody resources for both males and females and 47% for the young groups. Males consumed most *Quercus ilex* and showed a positive selection index. The other three species of plants also proved to be of interest in the male diet and showed a positive selection index. Female *Quercus ilex* consumption was lower than for males, but was also important as food resource for this group. Females showed an index selection close to zero, indicating that resource consumption and availability were similar (Tables 11.1 and 11.2). *Juniperus oxycedrus* was consumed by females in similar amounts to *Quercus ilex* and the selection index was positive (Tables 11.2 and 11.3). *Phillyrea latifolia* was also interesting in the female diet; meanwhile *Rosmarinus officinalis* is consumed in a lower degree (Table 11.2). The selection index for female of both plant species was negative. On the other hand, young age groups consumed much less *Quercus ilex* than male and female groups and showed a negative selection index. On the contrary, the young group primarily consumed *Phillyrea latifolia*, with a positive selection index (0.4). Finally, *Juniperus oxycedrus* was also selected by this group, and *Rosmarinus officinalis* was barely consumed (Table 11.3).

The group of four analysed species comprised from 45.9% to 16.5% of the seasonal diet, in winter and summer, respectively (Table 11.2a). This range was between 62.5% in autumn and 27.9% in summer when only woody vegetation is evaluated (Table 11.2b). In spring, the most eaten species was *Phillyrea latifolia*, followed by *Quercus ilex*. However, *Phillyrea latifolia* had a relatively high selection index, while *Quercus ilex* was rejected during this season. *Juniperus oxycedrus* and *Rosmarinus officinalis* were also rejected and their consumption was considerably lower than the previously mentioned species. The lower consumption for the four species happened during the summer, as their sum represented 16.5% of diet and 27.9% of the woody component. The most heavily consumed species were *Quercus ilex* and *Phillyrea latifolia*. As in spring, *Rosmarinus officinalis* and *Juniperus oxycedrus* were considerably less eaten. *Phillyrea latifolia* was the only species that had a positive selection index.

In autumn and winter the group of the four evaluated species represented an important component of the Spanish ibex diet (Table 11.2a). In autumn, they comprised 41.6% of total diet and 62.5% of the woody vegetation consumed. *Quercus ilex* and *Phillyrea latifolia* had a high level of consumption and positive selection index. *Juniperus oxycedrus* was consumed more in autumn than in spring and summer, and *Rosmarinus officinalis* was scarcely consumed in autumn, as occurred in spring and summer. *Juniperus oxycedrus* and *Rosmarinus officinalis* showed a negative selection index. Finally, in winter, the four analysed resources represented almost 60% of the woody vegetation consumed. In this period, *Juniperus oxycedrus* was the most heavily consumed species, surpassing its consumption in the rest of the seasons. *Quercus ilex* and *Phillyrea latifolia* were also appreciated (Table 11.2). *Rosmarinus officinalis* consumption was more than double in winter compared with the rest of the seasons. All species, with the exception of *Quercus ilex*, showed positive selection indexes, with a quite high index (0.50) for *Juniperus oxycedrus* (Table 11.3).

Consumption of the Four Most Important Woody Plant Species in the Spanish Ibex Diet in Eastern Spain

In the overall or general Spanish ibex diet, the four plant species formed 46.3% of the diet and 65.6% of all woody resources consumed. *Quercus ilex* was particularly important in the diet, followed by *Juniperus oxycedrus*, *J. phoenicea* and *Pinus nigra* (Table 11.4).

Quercus ilex was the most heavily consumed species over the three seasons studied, only being surpassed by *Pinus nigra* in the summer. Within a season, *Juniperus oxycedrus*, *J. phoenicea* and *Quercus ilex* showed a similar degree of intake. *Quercus ilex* consumption peaked in winter (25%), although it only represented around 28.4% of the woody component. This was a minor portion, considering that 88% of Spanish ibex consumption was woody vegetation in this

Table 11.4 Proportion (%) in the biomass of the four most relevant woody plant species in the total diet and in terms of the woody vegetation consumed by Spanish ibex in eastern Spain

Woody species	Annual	Spring	Summer	Winter	Annual	Spring	Summer	Winter
	Diet (Biomass %)				WV (Biomass %)			
Qi	17.3	17.0	10.0	25.0	24.5	29.5	15.1	28.4
Jp	9.7	10.3	8.5	10.0	13.7	17.9	12.8	11.4
Jo	12.2	9.9	8.5	18.0	17.3	17.2	12.8	20.5
Pn	7.1	4.0	13.8	3.5	10.1	6.9	20.9	4.0
Total	46.3	41.2	40.8	56.5	65.6	71.5	61.6	64.2
WV	70.6	57.7	66.2	88.0	100.0	100.0	100.0	100.0

WV = Woody vegetation consumed, Qi = *Quercus ilex*, Jp = *Juniperus phoenicea*, Jo = *Juniperus oxycedrus*, Pn = *Pinus nigra*, Total = Four species

period. In spring, on the other hand, this plant species constituted around the 17% of total Spanish ibex intake and 29.5% of woody matter, an indication of the importance of *Quercus ilex* in comparison to the rest of the woody species consumed in this season. Both, *Juniperus oxycedrus* and *J. phoenicea* consumption were also quite heavy in spring. In winter, the second ranking species after *Quercus ilex* was *Juniperus oxycedrus* (Table 11.4).

Consumption and Selection Index of the Four Most Relevant Woody Plant Species in Red Deer Diet in South-Eastern and Central Spain

In south-eastern Spain, overall red deer diet included 73.7% of woody plants (Table 11.2), with the four analysed species comprising 54% of the diet and 73.3% of woody resources consumed (Table 11.2) *Quercus ilex* was consumed most with 39.3% of the total woody vegetation. It was followed, to a lesser degree, by *Rosmarinus officinalis* (17%) and *Phillyrea latifolia* (13%). These three species were selected positively by red deer, with a particularly high index for *Rosmarinus officinalis* (Table 11.3). *Juniperus oxycedrus* was less consumed than the other species and showed a negative selection index by red deer.

In central Spain, red deer diet was studied in I and II zones. In zone I there was a high consumption of woody plants (95.7% of diet), with the four studied species comprising 71.5% of the total woody vegetation consumed. The most abundant species in the diet was *Quercus ilex*, followed by *Arbutus unedo*. Consumption of *Rosmarinus officinalis* and *Phillyrea angustifolia* was considerably lower (Table 11.5). In zone II, the four species comprised 61.1% of the diet and 87.3% of the woody vegetation consumed (Table 11.5). *Quercus ilex* consumption was

Table 11.5 Proportion (%) in the biomass of the four most relevant woody plant species in the total diet and in terms of the woody vegetation consumed by red deer in central Spain in winter and autumn

Woody species	Zone I		Zone II	
	Diet (%)	WV (%)	Diet (%)	WV (%)
<i>Quercus ilex</i>	35.4	37.0	23.1	33.0
<i>Arbutus unedo</i>	19.7	20.6	11.6	16.6
<i>Phyllirea latifolia</i>	–	–	–	–
<i>Juniperus oxycedrus</i>	–	–	–	–
<i>Rosmarinus officinalis</i>	9.4	9.8	–	–
<i>Phillyrea angustifolia</i>	7.0	7.3	19.4	27.7
<i>Quercus faginea</i>	–	–	7.0	10.0
Total (four species)	71.5	74.7	61.1	87.3
WV	95.7	100.0	70.0	100.0

WV = Woody vegetation consumed

slightly lower than in the two previous zones (23.1%), although constituted it the highest percentage of the species studied. *Phillyrea angustifolia* was consumed considerably more than in zone I (Table 11.5) but *Arbutus unedo* was consumed less in lower proportion, and *Rosmarinus officinalis* was not detected in the diet. The fourth most heavily consumed species in this zone was *Quercus faginea*.

Role or Importance of the Analysed Woody Species

Quercus ilex

In both south-eastern and eastern Spain, *Quercus ilex* has played an important role in the diet of Spanish ibex in the different periods and zones, and primarily for males and female in south-eastern area. The interest of this species has been widely reported in literature for *Capra* sp. (Schaller 1977; Cuartas and García-González 1992; Martínez 1992, 1994a, 2005; Soriguer et al. 1992).

In south-eastern Spain, *Quercus ilex* consisted of 22% of the woody vegetation consumed in the annual Spanish ibex diet (Table 11.2b), a large amount considering the high floristic richness (40) of the scrubland in this area (Martínez 1992). A close relationship was found between *Quercus ilex* consumption and availability, 22% and 23.7% respectively (Tables 11.1 and 11.2b respectively). The interest in *Quercus ilex* can also be seen in both study zones (low and high), where it was eaten a lot and had positive selection in the high zone. In the low zone, although consumption was substantial, the selection index was negative given the abundance of *Quercus ilex*. The male group consumed the largest amount of *Quercus ilex*, which also formed by far its most heavily consumed trophic resource in comparison with the rest of the ingested plant species. The male group showed positive selection for the species, indicating the interest of males in this resource, which it consumed

in larger amounts than its availability. Females consumed considerable amounts of *Quercus ilex* but less than males, possibly to optimize the energy level in the diet in relation to the use of the habitat (Nudds 1980; Mangel and Clark 1986). The peak consumption periods for females were autumn (46% of woody vegetation) and winter (14.5%) (Martínez 1992), the periods of greatest resource scarcity due to low availability of herbaceous plants and limitations of many woody deciduous species. *Quercus ilex* was less relevant for young ibex as it was consumed in third place and showed a negative selection index. The young group seemed to particularly prefer *Phillyrea latifolia* and also other species of plants with relatively high digestibility and protein content (Martínez 1992). They seemed to use the same feeding strategies as those of small ungulates, i.e., consumption of highly digestible food with a high nutrient concentration, thus facilitating ingestion of new food given their smaller rumen size (Hofmann 1989).

In south-eastern Spain, *Quercus ilex* played an important role in all seasons and was practically the most heavily consumed species amongst both woody and herbaceous species. In spring its consumption was only surpassed by *Phillyrea latifolia* and in winter by *Juniperus oxycedrus*. Spanish ibex showed a high consumption of *Quercus ilex* and a positive selection index in autumn, when variety and diversity of diet was the lowest in the year. In spring, *Quercus ilex* formed a large part of the woody component of the diet (17.5%), similar to winter when woody vegetation was consumed much more (77.6% in contrast to 41.6% in spring).

In the eastern zone, *Quercus ilex* comprised 17% of the spring diet but 29.5% of the consumed woody resources, suggesting that *Quercus ilex* was important in spring in comparison with the rest of the woody species eaten (Table 11.4) and (Martínez 1994b). The relative importance of *Quercus ilex* in spring in relation to other woody species is linked to the consumption of new shoots with a higher quality (higher protein content and digestibility) than in other periods (Soriguer et al. 1992; Baraza 2004). In the summer, *Quercus ilex* was consumed in similar amounts to spring, but this was the least relevant period in terms of consumed woody vegetation. Spanish ibex diet in summer had the highest species richness, a way of compensating for the lower efficiency of digestion of heavily lignified fodder.

Quercus ilex was the species most eaten by red deer in both study areas. In south-eastern Spain it amounted to almost 40% of consumed woody vegetation, a considerable amount given that woody resources make up practically three quarters of its diet. In addition, the species was positively selected. Red deer preference for *Quercus ilex* has also been noted by other authors (Álvarez and Ramos 1991; García-González and Cuartas 1992). It has been shown that *Quercus ilex* is also very important for high browser ruminants like the domestic goat (Cuartas 1992) or even for animal species with grazing habits such as mouflon, fallow deer (Cuartas and García-González 1992; Martínez 2002a) and even sheep (Cuartas 1992).

Heavy *Quercus ilex* consumption by ruminants is linked to its abundance in many Mediterranean zones, but is also related to its nutritional value which, in

comparison to other woody species, particularly with respect to its protein content, is medium quality (Martínez 1992; Baraza 2004). Its medium-low quality is primarily reflected in a high lignin content and low digestibility (Table 11.1). However, Milchunaset al. (1978) suggest that lignin-rich food facilitates gut passage, which helps to permit the ingestion of larger amounts of food and thus are of more nutritional value.

Phillyrea latifolia*, *Ph. angustifolia*, *Arbutus unedo* and *Quercus faginea

Phillyrea latifolia was positively selected by Spanish ibex in south-eastern Spain. In the low zone it was the most heavily consumed species and had the highest selection index of any of the four species studied in the southeast. However, in the high zone this species was scarcely detected in the analysed rumens because it does not grow or is extremely scarce in this zone. *Phillyrea latifolia* was the most heavily consumed species by the young age group, which had the highest selection index for this species. In spring, *Phillyrea latifolia* had also a positive selection by males, partially due to this group's browsing tendency. Our results show that *Phillyrea latifolia* can be regarded as a medium quality resource due to its low-medium lignin and protein content and its medium-low cellular content and digestibility (Table 11.1). The genus *Phillyrea* was a relevant diet resource for red deer. *Phillyrea latifolia* was selected positively in south-eastern Spain, while in the central zone, *Ph. angustifolia* made up a large part of the woody component of the diet (Table 11.5). *Arbutus unedo* was the second ranking species in consumption after *Quercus ilex* in Montes de Toledo (central zone). It was heavily selected by red deer, with consumption also seen in other zones (Martínez 1996). The quality of the species was relatively high given its high digestibility and medium-high protein content in data obtained for the species in the southeastern zone (Martínez 1992). Álvarez and Ramos (1991) also detected high *Phillyrea angustifolia* and *Arbutus unedo* consumption and preference amongst deer in winter in the Montes de Toledo area.

Quercus faginea showed high consumption in zone II of central Spain, forming 10% of the woody component. It was also found to be consumed by red deer and Spanish ibex in other areas, albeit in much smaller quantities (Martínez 2002a). It is a high quality resource with a high protein content and high digestibility according to data published in southeast Spain (Martínez 1992), although its tannin content is also high (Garín et al. 1996). Tannins can precipitate proteins and reduce the amount available (Robbins 1993; González-Hernández et al. 1999; González-Hernández 2005). However, herbivores adapted to the consumption of tannin-rich foods may produce salivary proteins that surround them in a highly specific way as a defence mechanism (Hagerman et al. 1992). Browsing herbivores may thus be better adapted to these tannins, as the parotid saliva gland is larger in browsers than in grazers (Hofmann 1989; Austin et al. 1989).

Rosmarinus officinalis

Rosmarinus officinalis is found in the Mediterranean region, being very frequent in the lowlands with warm climate in the Iberian Peninsula (López 2002). It should be regarded as an interesting food resource in forest and shrub environments, decreasing in accordance to the season, the geographic area and the herbivore in question. In southeast Spain, *Rosmarinus officinalis* was the least consumed resource by Spanish ibex of the four analysed, having a negative selection index, albeit close to zero. In high zones where the species was scarce, it was considerably more desirable than in low zones where it was relatively abundant, and showed a negative selection index. Its heaviest consumption was in winter, when the animals are distributed across lower areas and other herbaceous and woody resources are more limited (species that have lost their leaves and part or all of their fruits). *Rosmarinus officinalis* was avoided by females and young, while males had a higher consumption and showed positive selection (Table 11.3).

Rosmarinus officinalis was important in the diet of red deer diet, both in south-eastern and central Spain (zone I). In south-eastern zone it was the second most heavily consumed species after *Quercus ilex* and it had a particularly high selection index, suggesting a considerable preference for this resource. This is surprising considering its moderate availability in comparison with the rest of the woody resources. Its consumption could be linked to its availability, which in some areas is abundant, and to its nutritional value. Within the group of woody resources, it may be regarded as medium quality due to its relatively high cellular content and its protein content, which was higher than the other species analysed (Table 11.1).

Juniperus oxycedrus

In eastern Spain *Juniperus oxycedrus* was the second most consumed species by Spanish ibex after *Quercus ilex*. It was important in all seasons but most specially in winter. In south-eastern Spain, in both zones, Spanish ibex consumed a lot of *Juniperus oxycedrus* (with positive selection index), more so in the low zones than in the high zones, where it is scarce. *Juniperus oxycedrus* was selected in south-eastern Spain by females, who consumed similar quantities of this species to *Quercus ilex*. The three animal groups (males, females and young) showed positive selection for *Juniperus oxycedrus*. In winter, *Juniperus oxycedrus* was consumed more than at any other time. In this season, *Juniperus* spp. has a lower concentration of volatile oils and is more palatable (Riddle et al. 1996). *Juniperus oxycedrus* was less eaten in summer, probably because wider food resource diversity (flowers and fruits of rosacea and other species) was available, and because *Juniperus oxycedrus* is scarce (has low availability) in the high zone where Spanish ibex is more abundant in this season. *Juniperus*

oxycedrus may be bromatologically regarded as medium quality (Table 11.1), given that its cellular content and digestibility are relatively high for a woody plant. This may be because its consumption was high and the species was selected positively, particularly in winter when there is more qualitative and quantitative limitation of food resources. Both protein content and digestibility passed the minimum nutritional threshold required for ruminants (ARC 1968). Several *Juniperus* spp. species are more palatable in autumn and winter than in the other seasons, due to their lower content of volatile oils (Riddle et al. 1996), and probably also due to lower tannin content. In general, plants containing tannin tend to reach their peak levels in the growth season, after which they decline until the end of winter (González-Hernández et al. 2003). *Juniperus* spp. was selected by Spanish ibex in Mediterranean areas and also in alpine zones (Sierra Nevada) where, although it ate mainly pasture, *Juniperus communis* was one of the three most heavily consumed woody species and produced high selection indices (Martínez 2002b). Domestic goats in Texas also have abundant consumption of several *Juniperus* ssp., species which in fact are used in their control in several areas (Riddle et al. 1996).

Juniperus oxycedrus consumption by red deer is a controversial issue and varies between populations (Garín et al. 2001). *J. communis* is a significant part of red deer diet in some areas of the Aragon Pyrenees (Garín et al. 2001). In our Mediterranean study areas, however, *Juniperus oxycedrus* consumption was practically non-existent in central Spain, while in the southeast zone it was considerably less important for red deer than for Spanish ibex (Tables 11.2 and 11.5). This might be due to the patchy distribution of *Juniperus oxycedrus* in the study area, which does not always coincide with the distribution of the red deer population, or to its greater preference for more abundant and similar or better quality resources in its grazing area. Red deer thus seems to only use *Juniperus oxycedrus* in periods or situations of limited food supply, as shown by its lowest percentage in the red deer diet and its negative selection index.

Juniperus phoenicea

Juniperus phoenicea was the third most important plant species consumed in the Spanish ibex diet in eastern Spain, with uniform consumption throughout the three study seasons. It tended to be slightly less eaten in summer when species richness in the diet was greater (Martínez 1994b). In the high zones of Sierra Nevada, *Juniperus sabina* was also eaten and selected with a relatively high selection index (Martínez 2001). *Juniperus phoenicea* had low protein content, high lignin and cellular content (Table 11.1), and high digestibility (64.1%) compared with other woody species. The latter factor had a positive effect on consumption, with *Juniperus phoenicea* helping to meet the animal's energy requirements. High *Juniperus phoenicea* consumption by Spanish ibex in eastern Spain may be linked to its availability and food stress suffered by herbivores in

various Mediterranean zones as a consequence of high stocking rates (wild and domestic) and shortage or limitation of trophic resources in unfavourable periods or years triggered by climate conditions. In eastern Spain, all species that played a major dietary role (*Quercus ilex*, *Juniperus oxycedrus*, *J. phoenicea* and *Pinus nigra*) were of medium or medium-low quality, a reflection of the Ibex's efficiency in processing trophic resources. Some species are ranked as low quality as they contain terpenoids that may reduce the digestion of other feed through an inhibition effect on the microbial activity of the rumen (Schwartz et al. 1980; Maizeret and Tran Manh 1984).

Pinus nigra

Pinus spp. is a resource which, according to literature (Cuartas 1992; Martínez 1994b, 1996, 2002a; Heroldová 1997; Garín et al. 2001) is usually found to some degree in wild ungulate diets. However, *Pinus* spp. consumption fluctuates greatly between species, seasons and the availability of resources that are more preferred. In eastern Spain it was consumed most in summer (20.9% of woody vegetation) and in largest amounts by males (Martínez 1994a). In the south-eastern zone, Cuartas(1992) also observed large amounts of *Pinus nigra* in red deer and fallow deer diets, as well as in domestic goat and sheep. *Pinus nigra* showed a very low protein content with medium values for the rest of the analysed parameters (Table 11.1). These results were similar to the results found by Garín et al. (1996) for the same species in the Pyrenees. At medium-high altitudes in Sierra Nevada, *Pinus sylvestris* was consumed by Spanish ibex in July, forming 5.7% of its diet in a zone where grazing was the primary feeding habit, and woody plants were less than 19% of the diet (Martínez 2000). Spanish ibex used *Pinus nigra* shoots in spring, when the protein content is highest (Garín et al. 1996), but particularly in summer, the least favourable season for quality of other resources, and less used in winter, when *Quercus ilex* was most frequently eaten and consumed more by males. All of these results show that *Pinus* spp. can meet certain food requirements and is a recurrent resource for Spanish Ibex and other large herbivores, particularly in unfavourable zones and seasons.

Conclusions

Arbutus unedo, *Juniperus oxycedrus*, *J. phoenicea*, *Phillyrea angustifolia*, *Ph. latifolia*, *Pinus nigra*, *Quercus faginea*, *Quercus ilex* and *Rosmarinus officinalis* were the species most eaten by Spanish ibex and red deer in the different Spanish areas studied. *Quercus ilex* was specially eaten by both ungulates and particularly by red deer. *Phillyrea latifolia*, *Juniperus oxycedrus* and *J. phoenicea* were the most eaten

species by Spanish ibex after *Quercus ilex*. In contrast, red deer ate *Arbutus unedo*, *Phillyrea angustifolia*, *Ph. latifolia* and *Rosmarinus officinalis*.

The selection index of the fourth most important species eaten by Spanish ibex in south-east Spain was a different and depended on the area (lowlands and highlands), on seasons, and type of animals (males, females and young). Red deer positively selected the three most consumed species, but the fourth (*Juniperus oxycedrus*) had a negative selection index.

The importance of the analysed plant species for Spanish ibex and red deer diets depended largely on their availability and nutritive quality. Many of these species do not have an optimum nutritive quality, given that they are heavily lignified plants with medium-low digestibility and medium-low protein content. Consequently, Spanish ibex and red deer seem to maximise the capacity for obtaining energy from these plants species, given that they are an important part of their diet.

The exploitation of these species studied would be mainly by cervids and caprines (especially red deer and goats) as they consume those most, primarily in critical periods when herbaceous vegetation is in very limited supply and deciduous woody species have lost their leaves.

Potential pressure of herbivores on certain plant species, together with a tendency towards lower rainfall and higher temperatures in the semiarid Mediterranean zone may lead to a degradation of plant cover with less biomass production in the natural ecosystems. In this context, forest and grassland management trends should focus on re-defining the optimum densities of both wild and domestic ungulates to a sustainable level in the environment.

Given the crucial role of *Quercus ilex* as a food species for Spanish ibex and red deer in the Mediterranean habitats, its importance for domestic goats and, albeit on a smaller scale, other wild and domestic herbivores, optimum control of stocking rates of the various ruminants is a recommendable management strategy with a view to protecting *Quercus ilex* from heavy browsing impact and taking into account possible negative effects on tree regeneration. This policy will benefit the silvopastoral systems through appropriate management of herbivore populations, encourage regrowth and prevent exhaustion and stripping of plants that are accessible to large herbivores.

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