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Seasonal dietary shifts and selection of Iberian wild goat *Capra pyrenaica* Schinz, 1838 in Peneda-Gerês National Park (Portugal)

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Abstract

This study intended to know Iberian wild goat *Capra pyrenaica* Schinz, 1838 feeding strategy in two proximate mountains it recently recolonized, Gerês and Amarela (Peneda-Gerês National Park, PGNP, Portugal). For that purpose we studied species dietary composition using faecal diet microhistological determinations and also its diet selection. Albeit wild goat exhibited an intermediate browse - graze behaviour in the two areas, grazing was more pronounced in Gerês while browsing in Amarela. Both areas presented a dietary shift in spring consisting in an increase on the consumption and preference for graminoids. This feeding strategy extended through summer only in Amarela. Results obtained are congruent with wild goat generalist feeding behaviour in other regions of the Iberian Peninsula and suggest that species feeding strategy in PGNP respond to spatial patterns of resources, specifically of graminoids, and to livestock stocking rates and management.
Keywords: feeding strategy, livestock, non-invasive sampling, pastures, recolonization.

Resumen

En este estudio describimos la estrategia alimentaria de la cabra montesa ibérica *Capra pyrenaica* Schinz, 1838 en dos sierras adyacentes recientemente recolonizadas por la especie, Gerês y Amarela, en el Parque Nacional da Peneda-Gerês (PNPG, Portugal). Para ello estudiamos la composición y selección de la dieta de la cabra montesa utilizando el análisis microhistológico de heces. La cabra montesa presentó un comportamiento intermedio ramoneador - pastador en ambas áreas, aunque con una mayor tendencia al ramoneo en Amarela y al pastoreo en Geres. También se observó un cambio importante en la dieta de primavera en ambas sierras caracterizado por el aumento en el consumo y preferencia por gramíneas. Esta estrategia se mantuvo en verano apenas en Amarela. Los resultados obtenidos son congruentes con el comportamiento generalista ampliamente descrito para la cabra montesa en otras regiones de la Península Ibérica y sugieren que su estrategia alimentaria en el PNPG depende de la distribución espacial de los recursos, en particular de las herbáceas graminoides, y de la carga y gestión ganaderas en la región.
Palabras clave: estrategia alimentaria, ganado, muestreo no invasivo, pastos, recolonización.

Introduction

After more than a century of absence, the Iberian wild goat (*Capra pyrenaica* Schinz, 1838) returned recently to Portugal by accidental escapes and natural expansion from the Spanish region of Galicia (Moço *et al.* 2006). The species reoccupied two adjacent mountains in Portugal, Gerês and Amarela, located in Peneda-Gerês National Park (PGNP; Fig. 1).

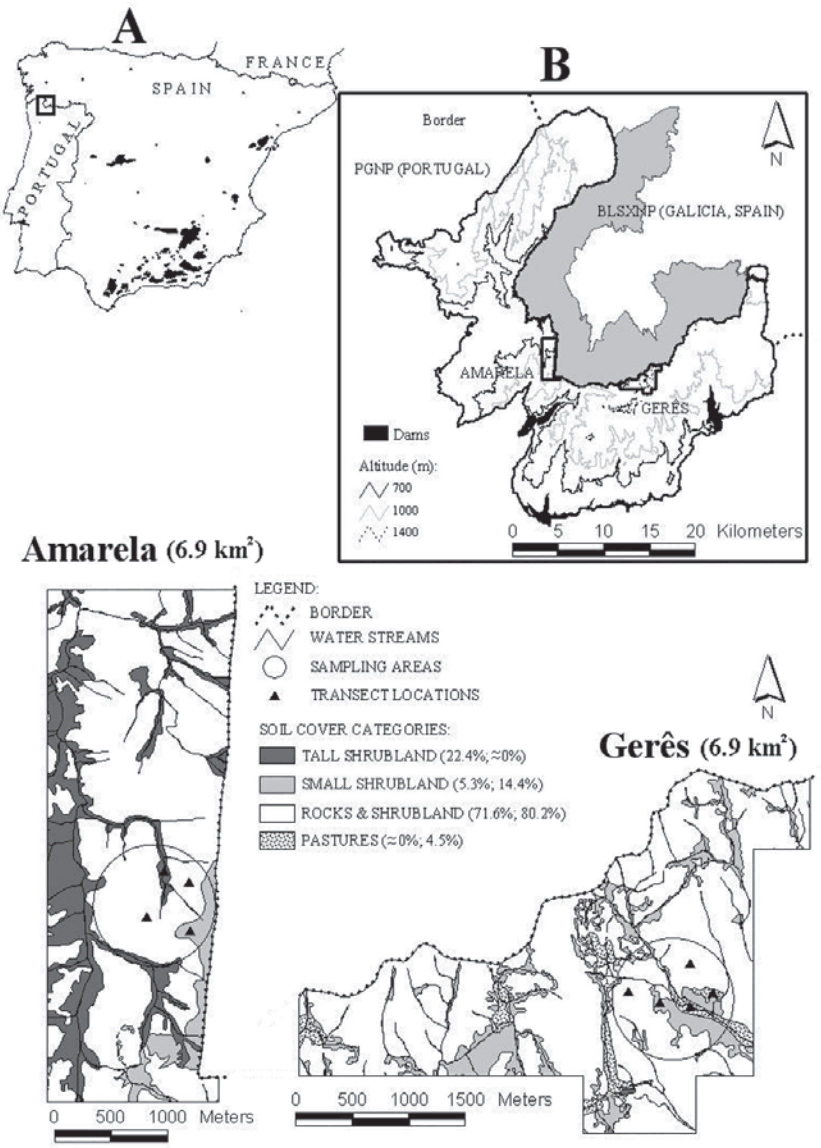

Figure 1. A) Iberian wild goat distribution (adapted from Pérez *et al.* 2002 and Acevedo & Cassinello 2009) and location of PGNP in Iberian Peninsula; B) PGNP and wild goat ranges studied (adapted from Moço *et al.* 2006); ranges and sampling areas (approx. 1 km^2 each) for availability and diet are highlighted. Relative contribution (% respect to 6.9 km^2) of vegetation units (adapted from CIBIO 2007) are presented for Amarela and Gerês, respectively.

PGNP had been the last redoubt of Iberian wild goat in Portugal. Hunting pressure, agricultural development and habitat deterioration are pointed as potential causes of its extinction during the last decade of the 19th century (Pérez *et al.* 2002). Hunting is presently forbidden in species range in PGNP and agriculture has lost much of its substantial importance in the region during the last decades (ICNB 2010), but habitats continued to be degraded. To our knowledge, massive cuts of shrubland to obtain energy from vegetal coal after II World War, wolfram exploitation during the 1950's and increasing of touristic affluence constituted latest disturbances in the region, particularly in Gerês. But the most important agent of habitat destruction in the region is probably a deep-rooted human tradition related to livestock extensive breeding (ICNB 2010): due to the scarcity of high-altitude pastures, locals use fire to augment grazing areas and this practice frequently affects large extensions of mountain rangeland. Its recurrent use is referred as promoting soil erosion, compromising the recovery of natural communities in the study area (Proença 2009) and favouring the substitution of vegetal communities with higher quality by others of lower productivity and cover (Honrado 2003). Habitat deterioration diminishes wild goat odds in PGNP (Fischer & Lindenmayer 2000) and it may have entailed a current reduction on habitats suitability respect to the moment of species extinction, dissenting with essential points of IUCN guidelines for the biological feasibility of translocations (IUCN 2012). Although the population is apparently increasing without limitation of resources (Moço *et al.* 2006), it is not ill-advised to consider that ecological carrying capacity may jeopardize ecosystem functioning and wild goat long-term maintenance in PGNP. Because herbivores nutrition is closely determined by vegetal communities (Fritz & Duncan 1994, Langvatn *et al.* 1996, Hochman & Kotler 2006), knowledge on their diet composition and resources availability are essential for decision-making on species and ecosystems conservation and management, e.g., for the design of effective grazing systems (Malechek & Leinweber 1972).

In view of the usually low nutritive content of plants, food selection by herbivores has been referred as a strategy to maximize nutrients ingestion (Belovsky 1984). According to Robbins (1993), this is primarily determined by animals' digestive system and efficiency. Extrinsically, it is mostly influenced by plants' nutritive quality (Martínez 2001, 2009*,* Hochman & Kotler 2006), which is usually highly variable (Westoby 1974*,* Belovsky 1984). As an example, changes on plants protein content have been related to seasonal shifts on dietary regimes of goats (Genin & Pijoan 1993), including Iberian wild goat (Martínez 2001), which may thus indicate periods of particular importance for herbivores nutrition. Moreover, information on dietary selection is valuable to predict herbivores effects on plant communities (Sfougaris *et al.* 1996).

This work intended to be a first approach toward understanding Iberian wild goat relation with its recolonized Atlantic environment. We intended to describe species dietary regime in both mountains it presently occupies in PGNP primarily focusing on wide vegetal categories and, given species browsing tendency (García-González & Cuartas 1992, Martínez 2002b, 2009), also on its ligneous dietary component. For this purpose we used faecal diet microhistological determinations (FDMD), particularly useful when working with endangered species (Holechek *et al*. 1982). Diet selection was also assessed, which required the quantification of food availability. The study was conducted seasonally in order to perceive dietary shifts and be able to relate them with changes in availability.

Material and methods

Study area

Peneda-Gerês National Park (41º41'N-42º05'N, 8º25'W-7º53'W; 695.96 km^2) is included in the Atlantic European province of the Eurosiberian region, with influence of temperate oceanic to Submediterranean climate (Rivas-Martínez *et al.* 2002). Valleys are naturally occupied by oak forests of *Quercion robori-pyrenaicae* alliance (Honrado *et al*. 2001). Shrubland constitutes the most common landscape (approximately 74%) (ICNB 2010) and is mainly constituted by Ericaceæ (*Erica arborea* L., *Erica australis* L., *Erica umbellata* L., *Erica cinerea* L., from 700 m to 1000 m) and Leguminosæ (*Ulex* spp., *Cytisus* spp., *Pterospartum tridentatum* (L.) Willk., mostly above 1300 m) (see Serra & Carvalho 1989).

Domestic small ruminants (mainly goats, but also sheep), cattle and horses are frequently encountered in the mountain environment. According to our personal observations, their stocking rates are higher in Gerês. Flocks of small ruminants are pastured during the day supervised by shepherds and dogs and conducted to higher altitudes from spring to late summer. Cattle and horses ascend in altitude from May to late July and reach higher pastures in summer, there remaining at least until September. Nevertheless, many stay in the mountain environment all year around.

We selected two sampling areas of approx. 1 km^2 in Iberian wild goat range located above 700 m a.s.l. in Amarela and 1000 m a.s.l. in Gerês (Fig. 1). Food availability and diet assessment were sampled simultaneously and by the same observers. The study coursed from February 2003 to November 2004 and data were seasonally pooled for winter (February), spring (May), summer (August) and autumn (November).

Availability determination

Vegetation cover was used as a quantitative measure of food availability (Puig *et al.* 2011). Nine sampling transects of 2 m each (n=5 in Gerês and n=4 in Amarela) were distributed through most important vegetation units in accordance to their relative contribution (Fig. 1). These were separated from each other by more than 100 m and permanently marked in the terrain for seasonal replications. Line-intercept method was used to measure shrubs and forbs (non-graminoid herbs) cover, identifying ligneous specimens to species level whenever possible. Lengths (cm) occupied by forbs/specimens of the same ligneous taxa were measured and summed (Hanley 1978, Floyd & Anderson 1987*,* Bullock 1996). Quadrats 1 x 1 m (20 quadrats successively positioned on the ground per transect) were used to quantify graminoids and mosses cover using a Braun-Blanquet scale (Mueller-Dombois & Ellemberg 1974) and respective total percent covers estimated as the mean cover of all quadrats. Resource percentages were obtained per transect respect to total covers obtained and averaged seasonally per area.

Diet assessment

In each area, a total of 40 samples, i.e., well differentiated wild goat faecal depositions (n= 10 per season) were entirely picked from the ground, preferably after detecting and observing animals defecating. Samples were preserved at –10ºC for posterior FDMD. Ten pellets were then randomly chosen from each sample and processed individually following the technique by Baumgarter & Martin (1939) and modified by Maia *et al.* (2003). One hundred non-digested vegetal epidermis were identified per sample using a plant reference collection elaborated throughout this study and from material available from previous research (Maia *et al*. 2003), comprising a total of 51 taxa (36 shrubs and 15 herbs). Whenever possible, ligneous fragments were identified to species level. Percentage of dietary elements was obtained per sample from the ratio between the No. of vegetal fragments of each and the total No. of fragments (Chapuis 1980) and averaged seasonally per area.

Data analysis

Availability and dietary data were pooled into vegetal categories as shrubs (ligneous plants), graminoids, forbs and mosses. Ligneous components were analysed separately and for these we used percentages of distinguished shrubs taxa respect to total shrubs. Kulczynski similarity index (KSI; Martínez 2002a, 2002b) was used to compare seasonal dietary and availability profiles of areas. Diversity of ligneous component excluded non-identified shrubs and was calculated with the Shannon-Weaver diversity index (SW) (Martínez 2002b) as SW= $-\sum p_i \log_{10} p_i$, where p_i is the seasonal average percentage of shrub *i*.

To explore area and seasonal dietary and availability profiles we used a multivariate analysis of variance (MANOVA) based on robust Pillai's trace tests. Dietary and available resources with average percentage ≥ 1% were considered for analysis. The MANOVA approach was first performed on the means to help protect against inflating the Type 1 error rate in the follow-up ANOVAs and post-hoc comparisons from correlated response variables (Hair *et al.* 1999). The response variable was defined as a canonical derived dependent variable from percentages of vegetal categories and shrub taxa. Basic MANOVA assumptions (lack of residual pattern and normality) were previously checked. In our ANOVA analysis the area (Gerês and Amarela), seasons (as previously defined) and their interaction were the response variables. Main effects ANOVA was used to explore area and seasonal effects of ligneous component diversity of diet and availability (response variables).

Dietary selection of vegetal categories and ligneous components was investigated using chi-square goodness-of-fit tests followed by Bonferroni confidence intervals (Byers & Steinhorst 1984). In our case, when the expected dietary relative percentage of one resource lied within the interval for α= 0.05 we concluded it was consumed in accordance with its availability (indifference). Otherwise, it was avoided (lied above the confidence interval) or preferred (lied below).

Statistical analyses were performed with STATISTICA 6.0 © (StatSoft Inc. 2001).

Results

Availabilities

Areas availability presented high similarity for vegetal categories and ligneous components (Appendix 1). Nevertheless, differences were detected on vegetal categories (Pillai statistic= 0.47, df= 9, P= 0.000; R^2= 0.92; Table 1) evidencing higher abundance of forbs in Amarela in spring (Fig. 2.A). Vegetative growth of shrubs was most noticed from spring to summer in both areas. Conversely, graminoids decreased in these seasons, especially in spring in Amarela and in summer in Gerês. Differences on ligneous components between areas were observed independently of season (Pillai statistic= 0.43, df= 42, P= 0.960; R^2= 0.41; Table 1). *Quercus* spp. and *Cytisus* spp. were more abundant in Amarela (Fig. 2.B) which showed higher ligneous diversity (Fig. 2.C) due to, e.g., low abundant taxa as *Arbutus unedo* L., *Lithodora prostrata* (Loisel.) Griseb., *Pyrus* spp. and *Rubus* spp. Gerês registered higher abundance of *Thymus* spp. and presence of endemic *Thymelaea broteriana* Coutinho.

Table 1. Individual ANOVAs for dietary and available percentages of vegetal categories and ligneous components and Main effects ANOVA for diversity of ligneous components. [1] – less than 1% or absent in diet; [2] – less than 1% or absent in availability.

	Availability						Diet					
	Season		Area		Season*Area		Season		Area		Season*Area	
	F	P	F	P	F	P	F	P	F	P	F	P
Vegetal category												
Shrubs	6.07	0.001	0.90	0.346	0.84	0.480	16.30	< 0.000	34.88	< 0.000	6.74	0.000
Graminoids	2.73	0.051	2.48	0.120	1.28	0.288	20.78	< 0.000	43.45	< 0.000	7.97	< 0.000
Forbs	19.59	< 0.000	8.84	0.004	14.18	< 0.000	1.72	0.169	0.21	0.647	3.08	0.033
Mosses [1]	1.71	0.174	5.51	0.022	0.57	0.639	-	-	-	-	-	-
Shrubs taxon												
Pterospartum tridentatum	0.05	0.986	3.72	0.058	0.01	0.999	19.79	< 0.000	5.03	0.028	3.50	0.020
Halimium spp.	0.03	0.993	4.96	0.029	0.02	0.996	11.39	< 0.000	60.96	< 0.000	10.73	< 0.000
Cytisus spp.	0.02	0.997	10.44	0.002	0.04	0.990	38.44	< 0.000	1.77	0.187	0.36	0.782
Calluna vulgaris	0.16	0.923	0.01	0.912	0.04	0.990	2.98	0.037	6.84	0.011	1.48	0.228
Erica spp.	0.03	0.994	1.45	0.233	0.01	0.998	6.99	0.000	52.96	< 0.000	3.09	0.032
Arbutus unedo	0.07	0.978	10.62	0.002	0.08	0.969	19.94	< 0.000	93.36	< 0.000	17.23	< 0.000
Quercus spp. [1]	0.00	0.999	15.55	0.000	0.00	0.999	-	-	-	-	-	-
Ulex spp. [1]	0.01	0.999	3.20	0.078	0.01	0.998	-	-	-	-	-	-
Pyrus spp. [1]	1.15	0.336	7.45	0.008	1.44	0.240	-	-	-	-	-	-
Rubus spp. [1]	0.30	0.826	8.66	0.004	0.37	0.772	-	-	-	-	-	-
Thymelaea broteriana [1]	0.76	0.521	7.77	0.007	0.61	0.612	-	-	-	-	-	-
Thymus spp. [1]	0.10	0.958	17.13	< 0.000	0.02	0.995	-	-	-	-	-	-
Lithodora prostrata [1]	0.46	0.708	9.07	0.003	0.59	0.621	-	-	-	-	-	-
Sedum spp. [1]	0.27	0.846	1.05	0.308	0.15	0.930						
Hedera spp. [2]	-	-	-	-	-	-	9.96	< 0.000	26.44	< 0.000	5.16	0.003
Ilex aquifolium [2]	-	-	-	-	-	-	5.50	0.002	14.19	< 0.000	2.60	0.058
Non-identified shrubs [2]	-	-	-	-	-	-	3.60	0.018	3.36	0.071	1.04	0.380
Diversity	2.05	0.285	327.26	0.000	-	-	28.74	0.010	1.74	0.279	-	-

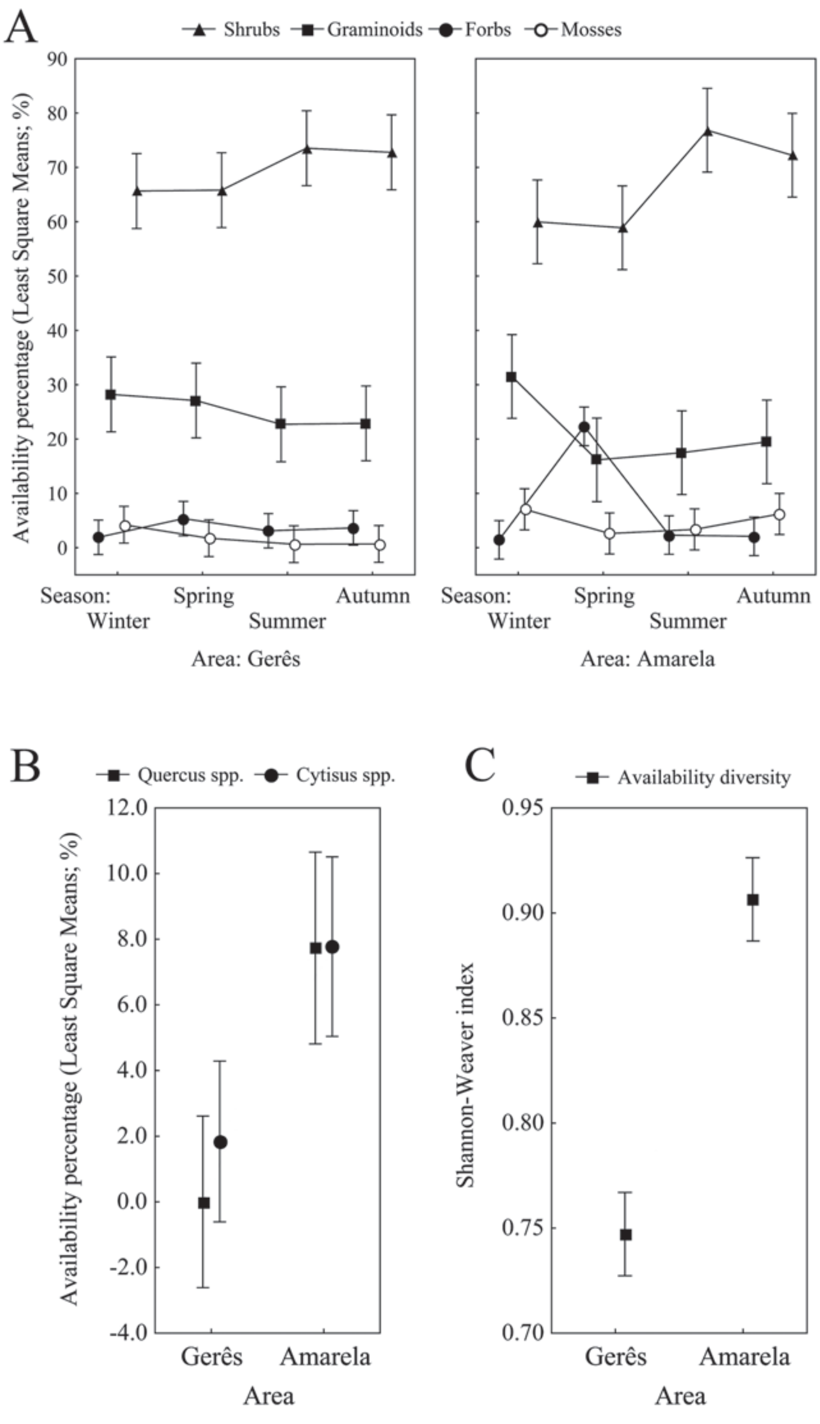

Figure 2. Seasonal changes in availability of Gerês and Amarela (Peneda-Gerês National Park, Portugal) for vegetal categories (A), and differences in areas ligneous components and diversity (C). Vertical bars denote 0.95 confidence intervals.

Diets

Wild goat diet in both areas was characterized by a strong browse behaviour, important consumptions of graminoids and hence high similarity in terms of vegetal categories (Appendix 2). Yet, differences encountered (Pillai statistic= 0.47, df= 9, $P< 0.000$; $R^2= 0.88$; Table 1) showed that shrubs were more consumed in Amarela and graminoids in Gerês (Fig. 3.A). These vegetal categories occurred in diets with converse importance and two dietary shifts were detected, i.e. from less browse to more grazing in spring in both areas and the reverse in summer and autumn for, respectively, Gerês and Amarela. Dietary ligneous components also varied with area and season (Pillai statistic= 1.14, df= 27, $P< 0.000$; $R^2= 0.64$; Table 1). Local diets most distinguished during unfavorable seasons by dietary importance of *Halimium* spp. in Gerês and of *A. unedo* in Amarela (Fig. 3.B). In this last, diet was also characterized by considerable percentages of *Hedera* spp., especially in summer. Independently

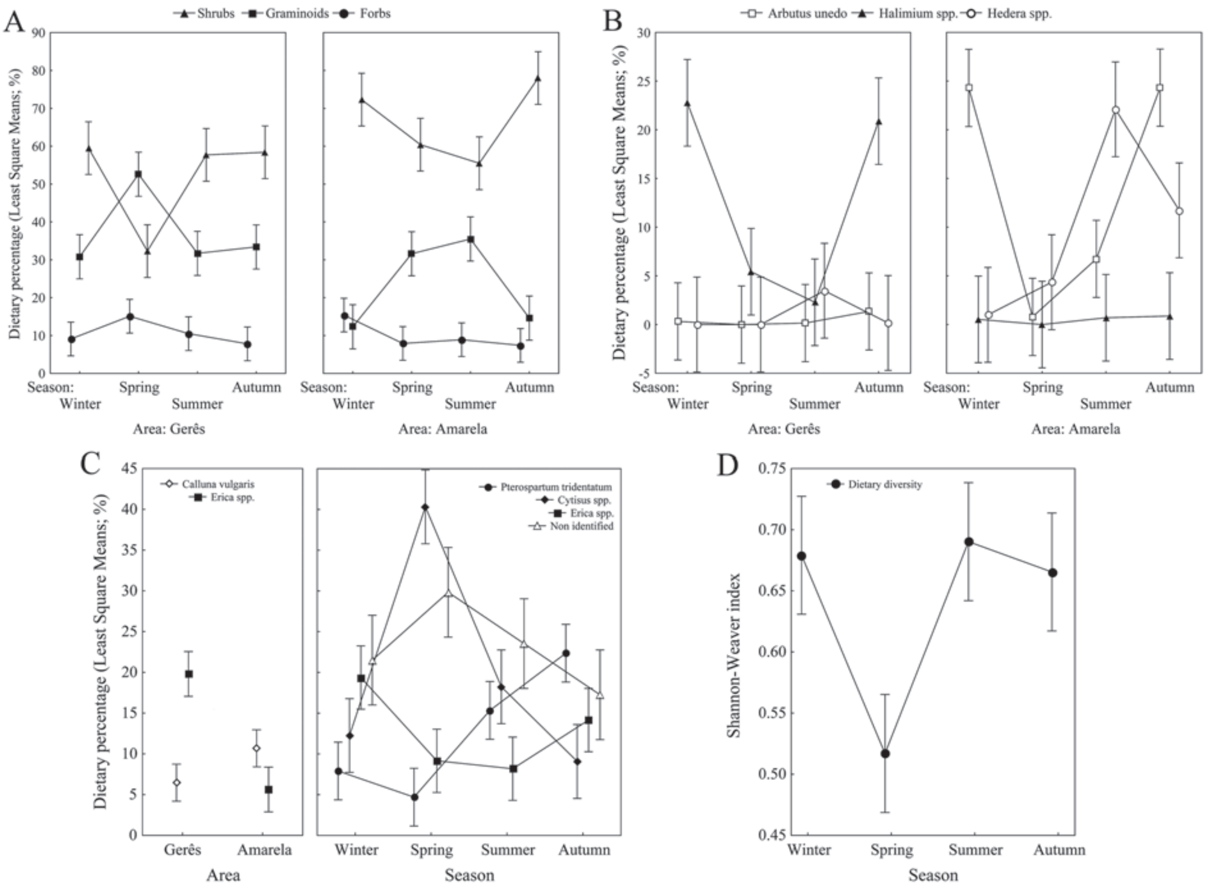

Figure 3. Seasonal changes in diets of Gerês and Amarela (Peneda-Gerês National Park, Portugal) for vegetal categories (A) and ligneous components (B), area and seasonal differences in dietary ligneous components (C) and seasonal variation in ligneous diversity (D). Vertical bars denote 0.95 confidence intervals.

of seasons, *Erica* spp. was more consumed in Gerês and *Calluna vulgaris* (L.) Hull in Amarela (Fig. 3.C). In both areas, *P. tridentatum* was most important in autumn, *Erica* spp. in winter and *Cytisus* spp. in spring. In this season diets had the lowest diversity (Fig. 3D) and most similar ligneous components (Appendix 2).

Dietary selection was detected in both areas and varied across seasons (Table 2). Shrubs were usually avoided in Gerês while consumed with indifference or even preferred in Amarela in winter. Results for distinguish shrubs taxa showed preference for *Cytisus* spp. in both areas and coincidently during spring and summer. In Amarela, preference was also detected for *C. vulgaris* from winter to summer and for *A. unedo* during unfavorable seasons. As for herbaceous categories, wild goat preferred forbs in winter and graminoids in spring in both areas. The firsts were also preferred in Gerês in spring and the lasts in Amarela in summer.

Discussion

This study evidenced intermediate browse - graze behaviour of wild goat in both areas. However, browsing and preference for shrubs were more evident in Amarela, where relative contribution of dietary vegetal categories was most comparable to the described for Mediterranean areas (García-González & Cuartas 1992, Martínez 2002b, 2009). Wild goat grazed more intensively in Gerês approaching dietary strategy of Gredos (Martínez 2001) and Sierra Nevada (Martínez 2000, 2002a). These differences may be related with the spatial distribution of resources. Herbivores are likely to perceive spatial patterns of vegetation assemblages (Senft *et al.* 1987) and physical landscape elements (Senft *et al.* 1987, Hochman & Kotler 2006), and to exhibit a plastic feeding behaviour in accordance with spatial distribution of resources (Abbas *et al.* 2011). According to Coughenour (1991), unities with adequate quantities of food are often

Table 2. Food selection by Iberian wild goat: P= preferred; I= indifferent; A= avoided.

	Gerês				Amarela			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
χ^2 Goodness-of-fit								
Vegetal categories[1]	32.3	60.6	25.2	13.2	156.0	26.7	46.6	21.4
Ligneous component[2]	125.5	1265.2	352.5	55.2	326.5	296.4	122.6	416.6
Selection outputs[3]								
Vegetal category:								
Shrubs	I	A	A	A	P	I	A	I
Graminoids	I	P	I	I	A	P	P	I
Forbs	P	P	I	I	P	A	I	I
Mosses	A	A	A	A	A	A	A	A
Ligneous component:								
Pterospartum tridentatum	A	A	I	I	A	I	I	I
Ulex spp.	A	A	A	A	A	A	A	A
Halimium spp.	I	I	A	I	A	A	I	A
Cytisus spp	P	P	P	I	I	P	P	I
Calluna vulgaris	I	I	I	I	P	P	P	I
Erica spp.	I	I	A	I	I	A	A	A
Sedum spp.	A	I	A	A	A	A	A	A
Thymelaea broteriana	I	A	A	A	-	-	-	-
Thymus spp.	I	A	A	I	-	-	-	-
Quercus spp.	-	-	-	-	A	A	A	A
Arbutus unedo	-	-	-	-	P	I	I	P
Pyrus spp.	-	-	-	-	A	A	A	A
Rubus spp.	-	-	-	-	I	A	I	I
Lithodora prostrata	-	-	-	-	A	A	A	A

[1] $\chi^2_{<0.00,\,3}$ [2] Gerês: $\chi^2_{<0.00,\,8}$ Amarela: $\chi^2_{<0.00,\,11}$ [3] Bonferroni approach

preferentially used and previous studies suggest that a clumped distribution of preferred plants favors their consumption by grazing herbivores (Edwards *et al.* 1994, Dumont *et al.* 2002). Thus, grazing by wild goat in Gerês may have been favored by the presence of graminoid-rich patches (pastures), which are practically inexistent in Amarela (Fig. 1).

Wild goat feeding strategies in summer appeared to contradict the previous idea, suggesting the influence of another factor with direct impact on vegetal availability. That is, a differential livestock effect between the two areas, as previously described. This suggestion was supported by depletion on graminoids during summer in Gerês (while recovering on Amarela; see Fig 2.A), particularly on pasture-type patches and surrounding shrubland (Fig. 1). Thus, potential dietary competition for graminoids and/or wild goat displacement from pastures (Martínez 2002a, 2002b, Acevedo *et al.* 2007) may be occurring in this area, influencing wild goat feeding strategy. Considering also the previously described on habitats management in PGNP, we consider as investigation priorities studies on livestock stocking rates, grazing areas and seasonal dietary regimes and estimation of carrying capacity of PGNP rangelands.

As reported in other regions (Martínez 2000, 2001, 2002a, 2002b, 2009), wild goat exhibited a generalist behaviour, i.e., it adapted to shrubs offer, as perceived by its higher dietary diversity in Amarela. At the same time, it presented common selective traits independently of availability, e.g., toward *Cytisus* spp. in spring. Because this genus is not frequent in the study area and is restricted to streams vicinities (Honrado 2003) we recommend monitoring of its distribution, abundance and herbivory by wild goat. As for *C. vulgaris*, plant or patch association appear to have influenced its selection since it was consumed with indifference when occurring in pasture-type patches but preferred when concurring with *Cytisus* spp. in rocky areas.

The spring dietary shift observed in both areas was probably due to seasonal changes on plants phenology, in agreement with studies that relate higher consumptions of herbs with plants showing higher protein content and digestibility in this season (Martínez 2000, 2001, 2002a). As stressed by this author, such strategy maximizes the benefit obtained from the season with the highest quality on forage. Phenology could also have favoured consumption of flowering and fructificating *Cytisus* spp. in spring. The importance of non-preferred shrubs in wild goat diet out of this season matched to the necessity of maintaining total intake regardless of quality (Westoby 1974). This appeared to be compensated by diversifying ligneous diet and preferring forbs (during winter in both areas), generally characterized by high cellular and protein and low fibre and lignin contents, in accordance with Martínez (2001, 2002a). Preference for *A. unedo*, with a wide fructification period, may exemplify the importance of supplementary protein sources in less favourable seasons for wild goat.

The major disadvantage of the non-invasive approach used was related to accuracy (Holechek *et al.* 1982, García-González & Cuartas 1992, Martínez 2000, 2002a). Considering the high percentage of non-identified shrubs, dietary diversities were probably underestimated. To cope with this uncertainty and improve insight on the selection of herbaceous resources, future studies will require improvement of epidermis collection. Also, a broader availability sampling (e.g., in cliffs crevices) would allow to quantify dietary selection of resources like *Hedera* spp.

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Appendix 1. Seasonal availability in Gerês and Amarela (mean % ± standard deviation; SW = Shannon-Weaver diversity index for ligneous component) and similarity (KSI = Kulczynski similarity index) between areas.

	Winter		Spring		Summer		Autumn	
Vegetal categories	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela
Shrubs	65.6 ± 13.6	60.0 ± 10.9	65.8 ± 11.0	58.9 ± 10.6	73.5 ± 11.6	76.8 ± 5.9	72.8 ± 11.0	72.2 ± 10.1
Forbs	1.9 ± 3.2	1.4 ± 1.4	5.3 ± 5.2	22.3 ± 12.2	3.1 ± 3.5	2.3 ± 1.5	3.6 ± 3.3	2.1 ± 1.2
Graminoids	28.2 ± 15.2	31.5 ± 11.1	27.1 ± 12.4	16.2 ± 6.2	22.7 ± 12.2	17.5 ± 4.8	22.9 ± 12.0	19.5 ± 5.6
Mosses	4.2 ± 8.7	7.1 ± 7.6	1.8 ± 3.7	2.6 ± 3.3	0.6 ± 1.4	3.4 ± 4.4	0.7 ± 2.0	6.2 ± 7.1
Non-identified	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
KSI (%)	93.9		82.1		94.0		94.5	
Ligneous component								
Phanaerophytes								
Quercus spp.	0.0 ± 0.0	4.4 ± 7.7	0.0 ± 0.0	3.6 ± 5.2	0.0 ± 0.0	5.8 ± 9.1	0.0 ± 0.0	5.1 ± 7.5
Taxus baccata	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Amelanchier ovalis	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Arbutus unedo	0.0 ± 0.0	2.0 ± 4.1	0.0 ± 0.0	1.4 ± 2.7	0.0 ± 0.0	1.8 ± 3.4	0.0 ± 0.0	1.9 ± 3.5
Pyrus spp.	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0	0.7 ± 1.4	0.0 ± 0.0	1.1 ± 2.0	0.0 ± 0.0	0.1 ± 0.2
Rubus spp.	0.0 ± 0.0	0.4 ± 0.8	0.0 ± 0.0	0.5 ± 0.9	0.0 ± 0.0	1.0 ± 2.2	0.0 ± 0.0	0.5 ± 1.0
Ilex aquifolium	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Pterospartum tridentatum	22.6 ± 19.6	11.6 ± 10.9	21.6 ± 19.2	11.8 ± 12.1	23.5 ± 22.2	14.0 ± 12.2	23.1 ± 19.9	13.7 ± 13.0
Ulex spp.	5.3 ± 8.6	12.2 ± 14.2	5.7 ± 8.7	12.7 ± 14.6	6.4 ± 9.3	14.1 ± 15.2	6.4 ± 9.3	13.7 ± 15.5
Halimium spp.	10.2 ± 13.3	4.5 ± 7.2	9.1 ± 11.9	3.2 ± 4.8	10.4 ± 13.5	4.9 ± 7.2	10.2 ± 13.0	5.7 ± 8.4
Cytisus spp.	1.1 ± 2.4	4.7 ± 7.0	1.4 ± 3.0	3.5 ± 4.5	1.4 ± 2.8	5.9 ± 6.8	1.4 ± 2.9	5.1 ± 6.9
Calluna vulgaris	2.5 ± 5.4	2.4 ± 6.3	2.2 ± 4.7	1.9 ± 4.2	3.1 ± 6.6	5.1 ± 9.4	3.4 ± 7.2	4.2 ± 7.9
Erica spp.	20.9 ± 16.5	14.5 ± 18.0	20.8 ± 15.2	14.4 ± 16.9	24.3 ± 18.4	18.7 ± 21.1	22.4 ± 16.0	17.6 ± 18.9

Appendix 1 (continuation). Seasonal availability in Gerês and Amarela (mean % ± standard deviation; SW = Shannon-Weaver diversity index for ligneous component) and similarity (KSI = Kulczynski similarity index) between areas.

	Winter		Spring		Summer		Autumn	
	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela
Chamaephytes								
Thymelaea broteriana	0.3 ± 0.7	0.0 ± 0.0	1.1 ± 2.1	0.0 ± 0.0	0.4 ± 0.6	0.0 ± 0.0	0.7 ± 1.0	0.0 ± 0.0
Vaccinium myrtillus	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Thymus spp.	1.5 ± 1.8	0.2 ± 0.3	1.3 ± 1.5	0.0 ± 0.0	1.7 ± 2.5	0.1 ± 0.2	1.9 ± 2.6	0.1 ± 0.4
Lithodora prostrata	0.1 ± 0.2	1.1 ± 2.0	0.3 ± 0.5	2.1 ± 3.0	0.7 ± 1.3	1.5 ± 2.3	0.5 ± 0.9	1.3 ± 2.3
Armeria spp.	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.8 ± 2.4
Sedum spp.	1.1 ± 2.3	1.9 ± 3.7	2.3 ± 4.8	2.9 ± 5.5	1.7 ± 3.5	2.8 ± 5.3	2.7 ± 6.1	2.2 ± 4.1
Epiphyte								
Hedera spp.	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Non-identified	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
KSI (%)	69.4		69.5		69.7		74.2	
SW	0.73	0.89	0.76	0.90	0.74	0.92	0.77	0.91

Appendix 2. Seasonal dietary profiles in Gerês and Amarela (mean % ± standard deviation; SW= Shannon-Weaver diversity index for ligneous component) and similarity (KSI= Kulczynski similarity index) between areas.

	Winter		Spring		Summer		Autumn	
vegetal categories	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela
Shrubs	59.5 ± 8.4	72.3 ± 12.1	32.3 ± 11.7	60.4 ± 11.5	57.7 ± 10.9	55.5 ± 13.1	58.4 ± 8.2	78.0 ± 11.5
Forbs	9.1 ± 5.8	15.4 ± 12.1	15.1 ± 8.7	7.9 ± 5.0	10.5 ± 6.6	8.9 ± 6.5	7.8 ± 3.0	7.4 ± 4.8
Graminoids	30.8 ± 9.5	12.3 ± 5.6	52.6 ± 6.1	31.6 ± 9.2	31.7 ± 6.8	35.5 ± 9.9	33.4 ± 7.1	14.6 ± 15.6
Mosses	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Non-identified	0.6 ± 0.8	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.3	0.4 ± 0.7	0.0 ± 0.0
KSI (%)	81.1		71.8		96.2		80.6	
Ligneous component								
Phanaerophytes								
Quercus spp.	0.1 ± 0.3	0.3 ± 0.7	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Taxus baccata	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Amelanchier ovalis	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	1.4 ± 2.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Arbutus unedo	0.2 ± 0.4	18.6 ± 10.8	0.0 ± 0.0	0.6 ± 1.1	0.1 ± 0.3	4.2 ± 3.5	0.8 ± 1.0	17.9 ± 6.8
Pyrus spp.	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Rubus spp.	0.0 ± 0.0	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.4	0.2 ± 0.6	0.0 ± 0.0	0.2 ± 0.4
Ilex aquifolium	0.7 ± 1.3	5.3 ± 5.7	0.0 ± 0.0	0.1 ± 0.3	0.5 ± 0.8	2.3 ± 1.8	0.3 ± 0.7	1.5 ± 1.5
Pterospartum tridentatum	6.1 ± 3.6	4.2 ± 4.7	1.1 ± 1.8	4.1 ± 2.9	12.6 ± 5.4	5.7 ± 5.3	13.2 ± 8.1	17.2 ± 8.8
Ulex spp.	0.4 ± 0.7	0.0 ± 0.0	0.0 ± 0.0	1.9 ± 1.4	0.3 ± 0.7	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Halimium spp.	13.9 ± 9.5	0.4 ± 0.5	1.4 ± 1.3	0.0 ± 0.0	1.5 ± 1.8	0.3 ± 0.9	12.2 ± 7.2	0.8 ± 1.5
Cytisus spp.	7.7 ± 4.5	8.3 ± 5.7	14.6 ± 9.5	22.1 ± 6.6	11.7 ± 5.9	9.3 ± 5.8	5.2 ± 3.0	7.7 ± 6.4
Calluna vulgaris	3.0 ± 3.0	9.4 ± 7.3	1.5 ± 2.1	7.1 ± 6.3	6.5 ± 5.1	7.9 ± 5.0	3.7 ± 4.2	3.5 ± 3.6
Erica spp.	16.0 ± 6.1	7.6 ± 7.4	4.9 ± 5.0	3.0 ± 2.1	7.6 ± 6.7	2.0 ± 2.0	15.4 ± 7.0	1.6 ± 2.1

Appendix 2 (continuation). Seasonal dietary profiles in Gerês and Amarela (mean % ± standard deviation; SW= Shannon-Weaver diversity index for ligneous component) and similarity (KSI= Kulczynski similarity index) between areas.

	Winter		Spring		Summer		Autumn	
	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela	Gerês	Amarela
Chamaephytes								
Thymelaea broteriana	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Vaccinium myrtillus	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Thymus spp.	0.7 ± 1.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.5 ± 0.8	0.0 ± 0.0
Lithodora prostrata	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Armeria spp.	0.1 ± 0.3	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Sedum spp.	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Epiphyte								
Hedera spp.	0.0 ± 0.0	0.8 ± 1.5	0.0 ± 0.0	2.7 ± 3.7	2.0 ± 3.4	11.8 ± 5.3	0.1 ± 0.3	9.5 ± 14.2
Non-identified	10.3 ± 6.4	17.1 ± 11.4	8.4 ± 4.2	18.6 ± 9.2	13.2 ± 6.2	11.8 ± 4.1	7.0 ± 3.1	18.1 ± 6.3
KSI (%)	45.8		70.2		58.5		49.2	
SW	0.68	0.68	0.49	0.55	0.68	0.70	0.67	0.66