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Short Note

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Does livestock influence the diet of Iberian ibex *Capra pyrenaica* in the Peneda-Gerês National Park (Portugal)?

Abstract: We carried out a pilot study about the influence of the domestic goat *Capra hircus* on the feeding ecology of the Iberian ibex *Capra pyrenaica* in the Peneda-Gerês National Park (PGNP, Portugal). We mapped the grazing areas of domestic goat flocks and determined their stocking rates in two mountains of PGNP, Gerês and Amarela, and we investigated the diets of both ungulates using fecal microhistology in an area where they partially overlapped during spring and summer. Diet composition, ligneous diversity, and ligneous trophic niche were compared seasonally. Although differences in ligneous components were observed, results revealed a considerable diet overlap mainly due to graminoids consumption, especially during autumn and spring. This suggests that direct or indirect foraging competition between the goat species should not be discarded if they spatially concur. Results also emphasized distinct summer feeding strategies of *C. pyrenaica* in the area, and the influence of cattle (*Bos taurus*) and horses (*Equus caballus*) were hypothesized. We recommend removing feral goats from the mountain environment and monitoring grazing areas of domestic flocks. Estimates of ecological carrying capacity and future diet studies should include cattle, horses, and improvement of herb identification.

Keywords: *Capra hircus*; domestic goat; feeding ecology; feral goat; potential competition.

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Knowledge of the feeding habits and trophic relations of wild and domestic ungulate populations are fundamental for their management and for the sustainability of natural ecosystems (Martínez 2002b, 2007). The Iberian ibex *Capra pyrenaica* Schinz, 1838 (ibex, hereafter; see Sarasa et al. 2012) has recently recolonized two mountain ranges (Gerês and Amarela) in the Peneda-Gerês National Park (PGNP; Figure 1A) originating the unique population of the species in Portugal (Moço et al. 2006). Ibex is classified as Critically Endangered in Portugal (Cabral et al. 2005), and the range of the population is included in the Transboundary Park Gerês-Xurés (TPGX; includes the Portuguese PGNP and the Spanish Baixa Límia-Serra do Xurés Natural Park), recently declared as a Transboundary Biosphere Reserve by UNESCO (Figure 1A). In this region, extensive breeding of domestic goat (*Capra hircus* L., 1758), cattle (*Bos taurus* L., 1758), and horses (*Equus caballus* L., 1758) represents an important human activity since ancient times (ICNB 2010). Domestic goats and cattle are herded collectively, i.e., each herder is successively assigned a number of days of guarding proportional to the number of animals he/she owns. Flocks of domestic goats are conducted through circular or linear grazing paths, usually in shrubland areas, that extend to higher altitudes during spring and summer. They are guarded with the aid of dogs and return to the villages by the end of the day. Nevertheless, the settlement of individuals in the mountain range, deliberately or inadvertently left by herders (feral goats, hereafter), is not uncommon

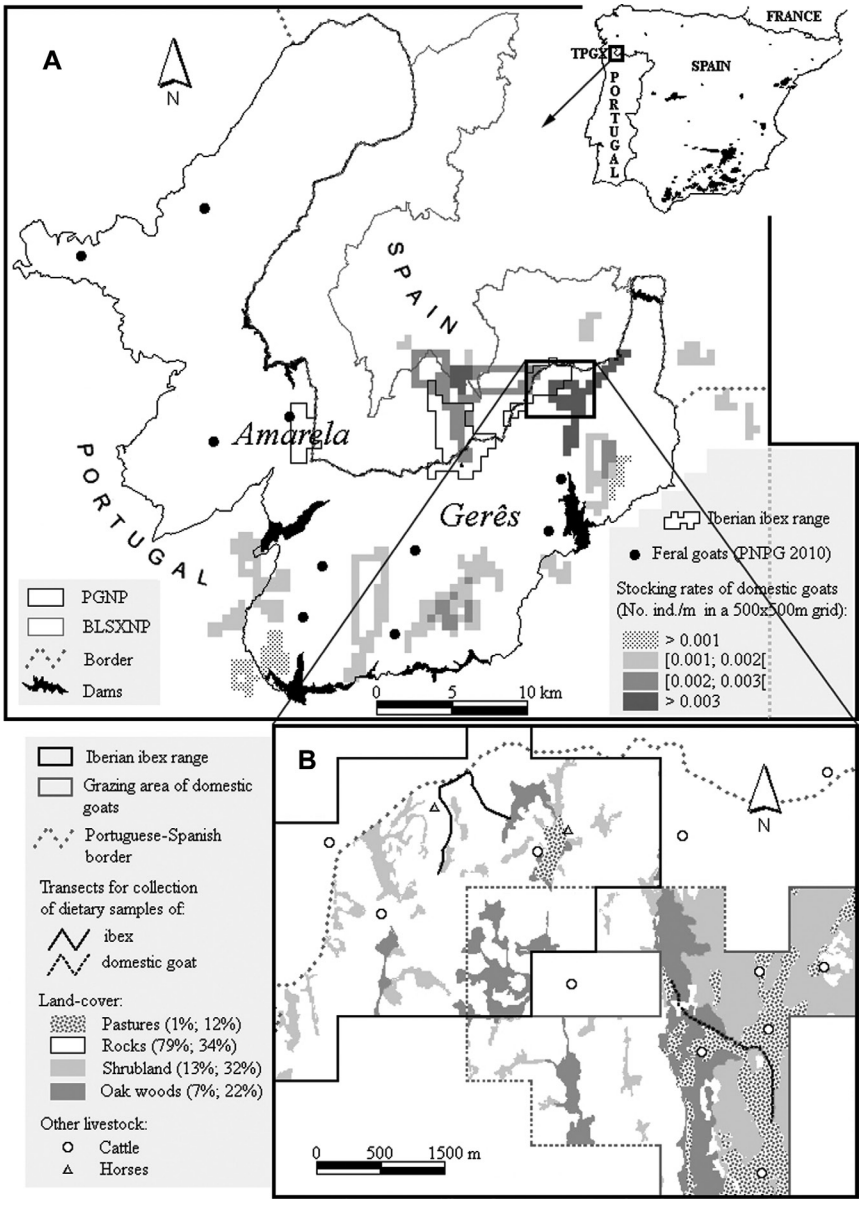

Figure 1 (A) Grazing areas and stocking rates of flocks of domestic goat (*Capra hircus*) and ibex (*Capra pyrenaica*) range in the Transboundary Park Gerês-Xurés (TPGX). Data are presented in a 500×500 m grid. (B) Sampling area for diet assessment with land-use percentages in ibex range and flock grazing area, respectively. Dotted lines indicate the occasional grazing area of domestic goats in spring and summer. "Pastures" in the ibex range are turbary and hygrophilous vegetation units, while in the domestic goat grazing area are grassland-rich units (CIBIO 2007).

(PGNP 2010). Cattle graze in agroforestry grassland-rich mosaics near the villages during autumn and winter and are conducted to high-altitude pastures (mainly turbary and hygrophilous vegetation; CIBIO 2007) from May to September, following transhumant paths. Horses are frequently encountered in the mountain environment in a free-ranging regime throughout the year. To date, stocking rates of livestock species grazing in the mountain environment have not been estimated. In view of previous studies showing that domestic small ruminants potentially displace ibex from pastures to steeper environments (Martínez 1990) and less suitable habitats (Acevedo et al. 2007), and considering that interactions between ibex and human activities in PGNP may generate conflicts of interests (see Bagchi et al. 2004, La Morgia and Bassano 2009), we carried out a pilot study on the effects of domestic goat on the ibex diet in PGNP.

During 2001, we investigated spatial concurrence between domestic goat flocks and ibex range (Moço et al. 2006) in the Portuguese and Spanish sides of Gerês and

Amarela mountains. For that purpose, grazing areas of flocks were mapped *in situ* with a GPS Garmin 12XL [GARMIN (Europe) Ltd 2001, Romsey, UK] and their stocking rates were estimated by direct counts from January to August. The results obtained are presented in Figure 1A. The daily grazing paths of flocks were considerably variable as they depended on the meteorological conditions and herder and, consequently, so were the boundaries of their seasonal grazing areas. However, results evidenced that Gerês presented higher stocking rates of domestic goats and that two flocks' grazing areas occasionally overlapped with the ibex range in this mountain during spring and summer. It is important to note that although the domestic goat grazing area shown in Figure 1B includes grassland-rich units, these are exclusively used for agriculture and cattle grazing during unfavorable seasons.

Subsequently, during 2003 and 2004, diets of both *Capra* species were assessed in PGNP (see Figure 1B) through fecal microhistology. Field sampling was carried out in winter (February), spring (May), summer (August), and autumn (November). Data consisted in 10 fecal samples per ungulate and season (except in spring for domestic goats; n=5). Ibex samples were picked from the ground after detecting and observing animals defecating. Domestic goat samples were collected in a grazing path used by the flock to return to the village at the end of each day, thus avoiding misidentification with ibex droppings. Ibex and domestic goat samples were preserved at -10°C. Subsequently, 10 pellets were randomly chosen from each sample and processed individually following the technique by Baumgarter and Martin (1939) and modified by Maia et al. (2003). One hundred non-digested vegetal epidermises were identified per sample using a plant reference collection elaborated throughout this study and from material available from previous research (Maia et al. 2003). The percentage of dietary elements was obtained per sample as the ratio between the number of vegetal fragments of each and the total number of fragments (Chapuis 1980), and averaged seasonally per ungulate. Dietary data were pooled into vegetal categories as shrubs, graminoids, forbs, and mosses. Ligneous components were analyzed separately as a percentage of taxa with respect to total shrubs. The diversity of dietary ligneous components was calculated with the Shannon-Weaver diversity index (SW) (Martínez 2001, 2002b) as $SW=-\Sigma\, p_i \log_{10} p_i$, where p_i is the seasonal average percentage of shrub *i*. SW excluded non-identified shrubs. Trophic niche was estimated as the number of shrub taxa (ligneous richness), and diet overlap was estimated with the Kulczynski similarity index (KSI; Martínez 2001, 2002b). Being *a* and *b* two data sets to be compared and *i* the mean relative percentage of one resource, $KSI=[\Sigma 2W/\Sigma(a_i+b_i)]$, where *W* is the lesser percentage of the resource in *a* and *b*. Seasonal changes in diets were inspected with a multivariate analysis of variance (MANOVA) based on robust Pillai's trace tests. This was done separately for vegetal categories and ligneous components. The MANOVA approach was first performed on the means to help protect against inflating the type 1 error rate in the follow-up ANOVAs (see Table 1) and *post hoc* comparisons from correlated response variables (Hair et al. 1999). The response variables (ungulates, seasons, and their interaction) were defined as canonical derived dependent variables from percentages of vegetal

Table 1 Individual ANOVAs for vegetal categories and ligneous taxa and main-effects ANOVA for ligneous diversity (Shannon-Weaver index) and trophic niche of the Iberian ibex *Capra pyrenaica* and the domestic goat *Capra hircus* diets in the Peneda-Gerês National Park (Portugal).

	Season		Ungulate		Season*ungulate	
	F	p-Value	*F*	p-Value	*F*	p-Value
Vegetal category						
Shrubs	33.53	<0.000	59.48	<0.000	8.89	<0.000
Graminoids	48.43	<0.000	58.88	<0.000	18.72	<0.000
Forbs	6.30	0.001	6.97	0.010	3.70	0.016
Ligneous component						
Pterospartum tridentatum (L.) Willk.	15.61	<0.000	0.54	0.467	2.88	0.042
Ulex spp.	0.76	0.523	101.95	<0.000	3.37	0.023
Halimium spp.	4.44	0.007	32.18	<0.000	4.98	0.004
Cytisus spp.	10.65	<0.000	5.75	0.019	6.92	0.000
Calluna vulgaris (L.) Hull	5.57	0.002	10.18	0.002	2.86	0.043
Erica spp.	8.76	<0.000	38.16	<0.000	4.99	0.003
Non-identified shrubs	9.12	<0.000	9.09	0.004	1.62	0.192
Shannon-Weaver index	29.40	0.010	110.15	0.002	–	–
Trophic niche	6.05	0.087	26.68	0.014	–	–

categories and shrub taxa with an average percentage ≥1%. Basic MANOVA assumptions (lack of residual pattern and normality) were previously checked. Seasonal changes on ligneous diet diversity and trophic niches were investigated with main-effects ANOVA. Statistical analyses were performed with STATISTICA 6.0 (Version 6, StatSoft Inc. 2001, Tulsa, USA).

As presented in Figure 2A, the consumption of vegetal categories depended on ungulate species and season (Pillai statistic=0.58, df=9, $p<0.000$; R^2=89%; see Table 1). Mosses consumption was <1%. Ibex fed mainly on graminoids while domestic goat fed on shrubs (Figure 2A). Yet, graminoids were particularly consumed by both ungulates in spring and were also important for domestic goat in autumn. As a result, the degree of diet overlap between both species was considerable in terms of vegetal categories and particularly in these seasons (Table 2). We detected 16 taxa on the ligneous component of the ibex diet from which nine were exclusive but occurred in minor proportions (<1% of total shrubs) specifically *Quercus* spp., *Amelanchier ovalis* Medicus, *Arbutus unedo* L., *Rubus* spp., *Thymelaea broteriana* Coutinho, *Vaccinium myrtillus* L., *Lithodora prostrata* (Loisel.) Griseb., *Armeria* spp., and *Sedum* spp. In domestic goat ligneous diet, we detected nine shrub taxa with only *Ilex aquifolium* L. (<1%) as exclusive. Most relevant shrubs for both ungulates diets (>1% of total shrubs) are presented in Figure 2B. As illustrated, their percentages varied considerably between *Capra* species and seasons (Pillai statistic=0.76, df=21, $p<0.000$; R^2=60%; Table 1). Ibex consumed higher quantities of *Erica* spp. and practically no *Ulex* spp. Conversely, this shrub was the most abundant in the domestic goat diet, especially in spring. Domestic goat also consumed more *Halimium* spp. and *Calluna vulgaris* (L.) Hull. *Cytisus* spp. highlighted in the diet of both *Capra* species particularly in spring. The consumption of *Pterospartum tridentatum* (L.) Willk. was comparable between ungulates. Figure 3 shows that the ligneous component of ibex diet was characterized by lower diversity and higher richness than that of the domestic goat; however, given the substantial amount of non-identified shrubs (Figure 2B) and our small sample size, these results need to be considered with caution. However, they show that plant diversity in the diet of both ungulates markedly decreased in spring and that their ligneous trophic niches, although not significantly, expanded in summer (Figure 3 and Table 1). Ligneous component similarity was higher in unfavorable seasons (Table 2) mainly due to *P. tridentatum*, *Cytisus* spp., *C. vulgaris*, and *Halimium* spp. percentages.

Our results highlighted the importance of graminoids for ibex and domestic goat, in agreement with Malechek and Leinweber (1972) and Martínez (2007). Consumption of these resources by both ungulates in spring was certainly related to their vegetative growth, protein content, and digestibility (Martínez 2001). At the same time, both species reduced the intake of ligneous resources (both in percentage and diversity) in spring, thus maximizing the benefit obtained from the season with the highest quality of forage (Martínez 2000, 2001, 2002a). In autumn, graminoids percentage in the domestic goat diet was probably associated with flocks' access to recently fire-burned patches in which herbs easily sprout after first autumn rainfalls; this is a practice traditionally used by local people in the end of the summer to augment grazing areas for livestock (ICNB 2010). Consequently, diet overlap was considerable between these species, particularly in spring and autumn, but this does not demonstrate competition by itself (Colwell and Futuyma 1971, Martínez 2002a). Actually, differences encountered on ligneous components supported our personal observations of *Capra* species feeding in distinct vegetation units. Still, direct or indirect foraging competition between these species should not be discarded in case of (even if not simultaneously) spatial concurrence (La Morgia and Bassano 2009) and most especially during seasons with limitation of resources (Wingard et al. 2011). In view of the higher stocking rates and broad distribution of domestic goat flocks in Gerês, the potential for competition with ibex is therefore greater in this area.

This study also supported previous evidence of opposite summer dietary strategies of ibex in Gerês and Amarela (Moço et al. 2013). In this season, ibex in Amarela increased its graminoids consumption and did not expand its ligneous trophic niche. According to Martínez (2001) a wider ligneous trophic niche in summer could be a response to the decrease in graminoids nutritive quality. However, altitudinal ranges of Gerês and Amarela contradict this hypothesis, as we would expect graminoids vegetative growth to be delayed (and accordingly their nutritive quality to be somewhat higher) in summer in Gerês. One more plausible reason to explain these different strategies in summer could be the arrival of more consumers to higher-altitude pastures in Gerês. The spatial concurrence of consumers with similar feeding habits may deplete resources and promote spatial segregation of species (Bagchi et al. 2004). As a result, their trophic niches are expected to expand (Martínez 2002b, 2007) and their dietary overlap to decline (Martínez 2002a,b). Considering these authors, we could presume mutual spatial segregation between ibex and domestic goat in summer in Gerês or, as domestics are guided by herders, the displacement of ibex to steeper areas, as supported by the

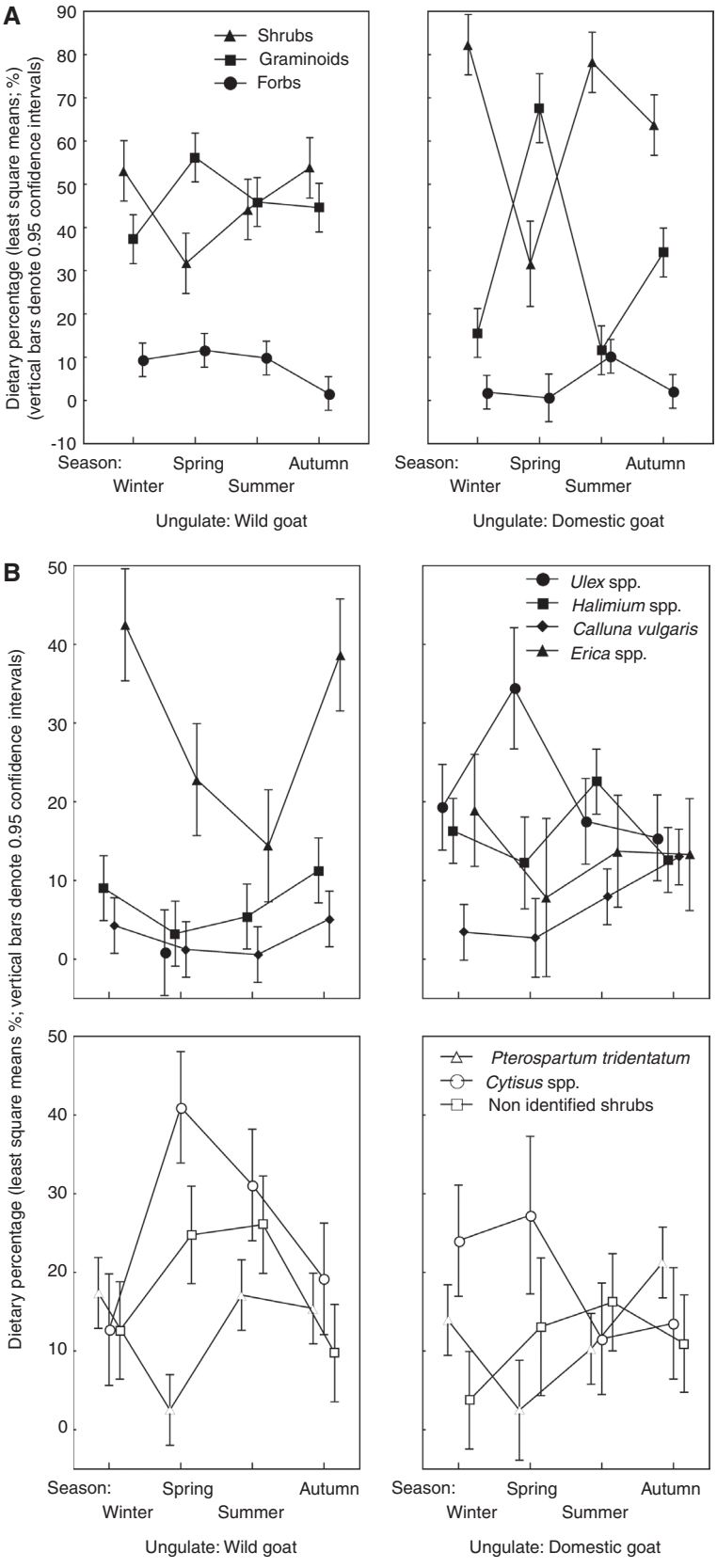

Figure 2 Seasonal changes in diets of the Iberian ibex *Capra pyrenaica* and the domestic goat *Capra hircus* in the Peneda-Gerês National Park (Portugal) detected with a multivariate analysis of variance based on robust Pillai's trace tests for vegetal categories (A) and ligneous components (B).

Table 2 Seasonal diet overlap between the Iberian ibex *Capra pyrenaica* and the domestic goat *Capra hircus* in the Peneda-Gerês National Park (Portugal).

	Kulczynski similarity index (%)			
	Winter	**Spring**	**Summer**	**Autumn**
Vegetal categories	70.7	88.6	65.6	89.6
Ligneous component	63.3	52.9	52.8	65.3

appearance of rupicolous vegetal taxa in diet (e.g., *Vaccinium myrtillus* and *Amelanchier ovalis*). Nevertheless, in accordance with our field observations and dietary evidence, domestic goat flocks rarely moved onto pastures of the ibex range. In summer, pastures in the mountain environment are mainly occupied by cattle and horses. To our knowledge, cattle and horses stocking rates have never been estimated in the mountain environment; however, our personal observations (see also ICNB 2010) point to considerably higher densities in Gerês than Amarela. Also, summer diets of cattle and horses are characterized by high quantities of graminoids (Martínez 2007) and foraging competition between Bovinae and Equidae species, and Himalayan ibex (*Capra sibirica* Pallas, 1776) has already been suggested (Bagchi et al. 2004). Hence, we hypothesize these livestock species may influence the ibex summer dietary behavior in Gerês. Therefore, we recommend further research on the ecology of the interaction between livestock and ibex in the TPGX, including estimates of ecological carrying capacity and future diet studies that include cattle, horses, and improvement of herb identification. We also advise the immediate removal

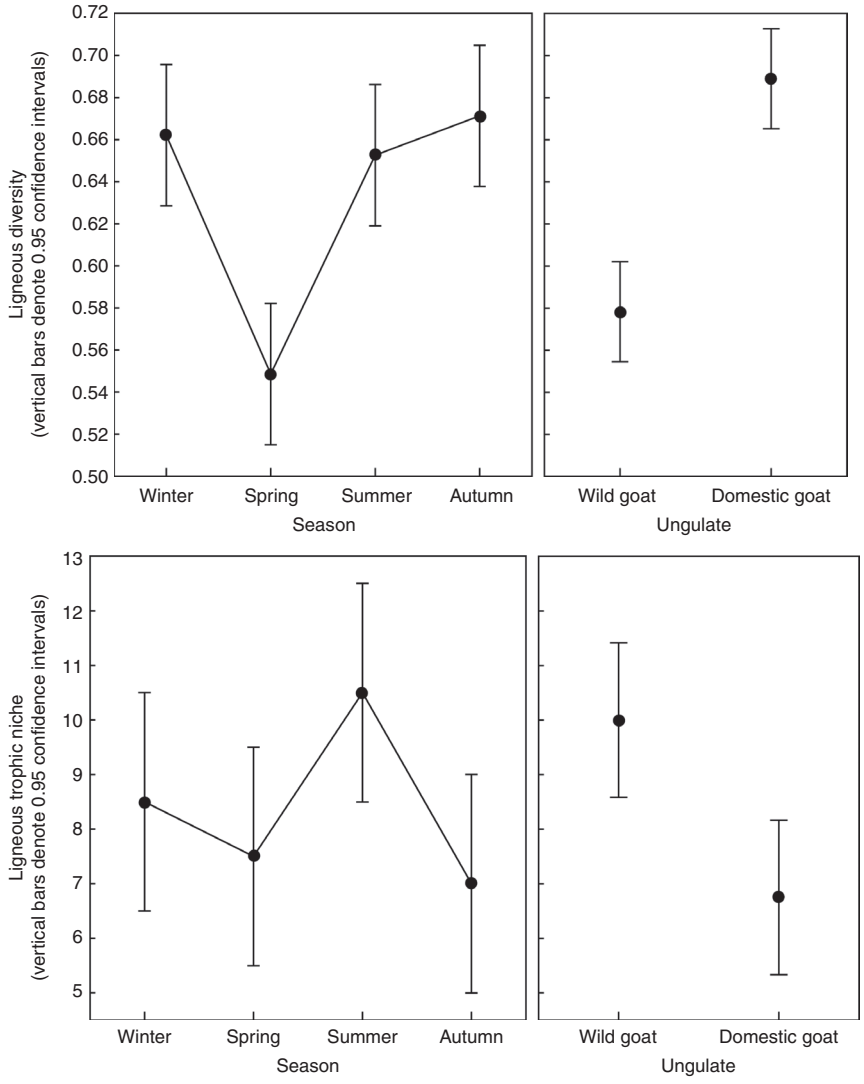

Figure 3 Seasonal changes on ligneous diet diversity and trophic niche of the Iberian ibex *Capra pyrenaica* and the domestic goat *Capra hircus* in the Peneda-Gerês National Park (Portugal) obtained with main-effects ANOVA (see Table 1).

of feral goats from these environments and monitoring grazing areas of domestic flocks.

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References

Acevedo, P., J. Cassinello and C. Gortazar. 2007. The Iberian ibex is under an expansion trend but displaced to suboptimal habitats by the presence of extensive goat livestock in central Spain. Biodiv. Conserv. 16: 3361–3376.

Bagchi, S., C. Mishra and Y.V. Bhatnagar. 2004. Conflicts between traditional pastoralism and conservation of Himalayan ibex (*Capra sibirica*) in the Trans-Himalayan mountains. Anim. Conserv. 7: 121–128.

Baumgarter, L. and A. Martin. 1939. Plant histology as an aid in squirrel food studies. J. Wildl. Manage. 3: 266–268.

Cabral, M.J. (coord.), J. Almeida, P.R. Almeida, T. Dellinger, N. Ferrand de Almeida, M.E. Oliveira, J.M. Palmeirim, A.I. Queiroz, L. Rogado and M. Santos-Reis. 2005. Livro Vermelho dos Vertebrados de Portugal. Instituto da Conservação da Natureza, Lisboa, Portugal. pp. 660.

Chapuis, J. 1980. Méthodes d'études du régime alimentaire du lapin de garenne *Oryctolagus cuniculus* (L.) par l'analyse micrographique des fèces. Rev. Ecol. (Terre Vie) 34: 159–198.

CIBIO. 2007. Biotopes of the Peneda-Gerês National Park. Map of Natural Habitats. Centro de Investigação em Biodiversidade e Recursos Genéticos (digital resource).

Colwell, R.K. and D.J. Futuyma. 1971. On the measurements of niche breadth and overlap. Ecology 52: 567–576.

Hair, J.F., R.E. Anderson, W.C. Tatham and W.C. Black. 1999. Multivariate data analysis. Prentice Hall International, London, UK. pp. 816.

ICNB. 2010. Revisão do Plano de Ordenamento do Parque Nacional da Peneda-Gerês. Instituto da Conservação da Natureza e da Biodiversidade I.P. Ministério do Ambiente, Ordenamento do Território e Desenvolvimento Regional, Lisboa, Portugal. pp. 66.

La Morgia, V. and B. Bassano. 2009. Feeding habits, forage selection, and diet overlap in Alpine chamois (*Rupicapra rupicapra* L.) and domestic sheep. Ecol. Res. 24: 1043–1050.

Maia, M.J., F. Rego and M. Sousa. 2003. Determining optimal sampling schemes to study red deer diets by fecal analysis. Silva Lusitana 11: 91–99.

Malechek, J.C. and C.L. Leinweber. 1972. Forage selectivity by goats on lightly and heavily grazed ranges. J. Range Manage. 25: 105–111.

Martínez, T.M. 1990. Régimen alimentario de la cabra montés (*Capra pyrenaica*) en la zona alpine de Sierra Nevada durante los meses de julio y agosto. Ecología 4: 177–183.

Martínez, T.M. 2000. Diet selection by Spanish ibex in early summer in Sierra Nevada. Acta Theriol. 45: 335–346.

Martínez, T.M. 2001. The feeding strategy of Spanish ibex (*Capra pyrenaica*) in the northern Sierra de Gredos (central Spain). Folia Zool. 50: 19–33.

Martínez, T.M. 2002a. Summer feeding strategy of Spanish ibex *Capra pyrenaica* and domestic sheep *Ovis aries* in south-eastern Spain. Acta Theriol. 47: 479–490.

Martínez, T.M. 2002b. Comparison and overlap of sympatric wild ungulate diet in Cazorla, Segura and Las Villas Natural Park. Pirineos 157: 103–115.

Martínez, T.M. 2007. Estrategia alimentaria de la cabra montés y de los herbívoros domésticos simpátricos en el centro de España. In: (J.E. Granados et al., eds.) Tendencias actuales en el Estudio y Conservación de los Caprinos Europeos. II Congreso Internacional del género *Capra* en Europa. Junta de Andalucía, Consejería de Medio Ambiente, Granada, Spain. pp. 71–83.

Moço, G., M. Guerreiro, A.F. Ferreira, A. Rebelo, A. Loureiro, F. Petrucci-Fonseca and J.M. Pérez. 2006. The ibex *Capra pyrenaica* returns to its former Portuguese range. Oryx 40: 351–354.

Moço, G., E. Serrano, M. Guerreiro, A.F. Ferreira, F. Petrucci-Fonseca, M.J. Maia, R.C. Soriguer and J.M. Pérez. 2013. Seasonal dietary shifts and selection of Iberian ibex *Capra pyrenaica* Schinz, 1838 in Peneda-Gerês National Park (Portugal). Galemys 25. doi: 10.7325/Galemys.2013.A2.

PGNP. 2010. Inventário dos rebanhos de cabras assilvestradas no Parque Nacional da Peneda-Gerês. Parque Nacional da Peneda-Gerês, Braga, Portugal. pp. 9.

Sarasa, M., S. Alasaad and J.M. Pérez. 2012. Common names of species, the curious case of *Capra pyrenaica* and the concomitant steps toward the "wild-to-domestic" transformation of a flagship species and its vernacular names. Biodiv. Conserv. 21: 1–12.

Wingard, G.J., R.B. Harris, D.H. Pletscher, D.J. Bedunah, B. Mandakh, S. Amgalanbaatar and R.P. Reading. 2011. Argali food habits and dietary overlap with domestic livestock in Ikh Nart Nature Reserve, Mongolia. J. Arid Environ. 75: 138–145.