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ECOLOGÍA Y CONSERVACIÓN DE LA CABRA MONTESA IBÉRICA *Capra pyrenaica* SCHINZ, 1838) EN EL PARQUE NACIONAL DA PENEDA-GERÊS, PORTUGAL

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Ecology and Conservation of the Iberian Ibex (*Capra pyrenaica* Schinz, 1838) in the Peneda-Gerês National Park (Portugal)

Gisela Maria Teixeira Moço

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PhD Thesis

STATEMENT

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A António Rebelo, Miguel Dantas da Gama e Jean-Paul Crampe

"Porque os outros se mascaram mas tu não
Porque os outros usam a virtude
Para comprar o que não tem perdão.
Porque os outros têm medo mas tu não.

Porque os outros são os túmulos caiados
Onde germina calada a podridão.
Porque os outros se calam mas tu não.

Porque os outros se compram e se vendem
E os seus gestos dão sempre dividendo.
Porque os outros são hábeis mas tu não.

Porque os outros vão à sombra dos abrigos
E tu vais de mãos dadas com os perigos.
Porque os outros calculam mas tu não."

Sophia de Mello Breyner

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"Na realização da política de ensino incumbe ao Estado garantir a todos os cidadãos, segundo as suas capacidades, o acesso aos graus mais elevados do ensino, da investigação científica e da criação artística".

Artigo 74.º, nº 1, alínea d) da Constituição da República Portuguesa

ABSTRACT

This PhD Thesis focused on basic aspects of the ecology of a recent population of Iberian ibex *Capra pyrenaica* inhabiting the Peneda-Gerês National Park (Portugal) since 1998, namely on its distribution range, diet and abundance. The species had formerly existed in the study area until the end of the 19th century and research was conducted on the causes that draw the former population to extinction. The inclusion of ibex in Portuguese fauna justified a debate on the vernacular name of the species. Research was exclusively based on non-invasive methodologies. Outputs contributed to define the current conservation status of ibex in Portugal and initiate procedures for population monitoring, namely of abundance estimation through Distance Sampling. Conclusions obtained are valuable to design further research and monitoring on species' abundance, e.g., using molecular markers and faecal samples, and expansion possibilities, e.g., through landscape ecology analysis. Conservation of this population is highly human-dependent.

Keywords: *Capra pyrenaica;* conservation; diet; Distance Sampling; extinction; landscape heterogeneity; livestock; monitoring; non-invasive sampling; return; vernacular name

RESUMEN

Esta Tesis Doctoral se ha enfocado hacia aspectos básicos de la ecología de una población de Cabra montesa ibérica (*Capra pyrenaica*) recientemente establecida en el Parque Nacional de Peneda-Gerês, Portugal (1998). Concretamente se ha estudiado su rango de distribución, su dieta y su abundancia. La especie ya existía en la zona hasta finales del siglo XIX, por lo que se han revisado las causas que originaron dicha extinction. Se llevó a cabo un debate sobre el nombre común de la especie. Esta investigación se ha realizado exclusivamente con metodologías no invasivas. Los resultados han contribuido a definir el estatus de conservación actual de la especie en Portugal y a iniciar protocolos de monitorización. Las conclusiones obtenidas permiten el diseño de planes futuros de investigación sobre esta especie. La conservación de esta población depende en gran medida de las limitaciones de las actividades humanas en el área de estudio.

Palabras-clave: *Capra pyrenaica;* conservación; dieta; extinción; heterogeneidad del paisaje; monitorización; muestreo por distancias; muestreos no invasivos; nombre común; regreso; ungulados domésticos

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CHAPTER 1. GENERAL INTRODUCTION

"The children asked him if to kill was not a sin
'Not when he looked so fierce', his mummy butted in
'If looks could kill it would have been us instead of him'."

The Beatles

GENERAL INTRODUCTION

1.1. Humans, extinctions and translocations

Modern humans are top predators and have been a threat to biodiversity since early times. The spread of *H. sapiens* all over the planet during the Pleistocene coincided with a mass extinction of large mammals in all continents, namely of several artiodactyls in North America and Africa (Agustí & Antón 2002; Gaston & Spicer 2004). According to these authors (pp 111), during the last 400 years, and the 19th century in particular, there was a considerable increase in the number of known extinctions.

In Portugal, the list of human-caused extinctions by exploitation or persecution is important. As historical examples, the Brown bear (*Ursus arctos* Linnaeus) became extinct in the 16th century (Costa 1706) and the ibex (*Capra pyrenaica lusitanica*) by the end of the 19th century. At the present, the list of Critically Endangered species for which overexploitation prevails or is expected is noteworthy (see Cabral *et al.* 2005). It includes fishes (*Salmo salar* and *S. trutta*), many birds (namely, *Milvus milvus*, *Aegypius monachus*, *Circus cyaneus*, *Aquila adalberti*, *Pandion haliaetus*, *Fulica cristata*, *Gallinago gallinago*, *Pterocles alchata*) and mammals (*Lynx pardinus* and *Capra pyrenaica victoriae*).

Translocations, i.e., the moving of individuals to new environments (introductions) or to ranges the species formerly inhabited (reintroductions; see IUCN/SSC 2012) have been performed by humans since at least the beginning of domestication processes (Agustí & Antón 2002). Until recently, translocations of animals served human interests for the most part, providing meat, fur or hunting trophies (Nielsen & Brown 1989). Nowadays, these actions are primarily carried out for conservation or ecological reasons and encouraged to respond to ethic guidelines (Nielsen & Brown 1989; Price 1989; IUCN/SSC 2002). Thus, the capture and moving of free-ranging animals should only be considered when a wild population is threatened or has been localy extinct due to a known factor, and the following conditions are assured: i) the cause of extinction no longer exists; ii) habitat suitability for a new

population is assured and; iii) animals of the same species are available and may be translocated safely to the reintroduction area. Moreover, monitoring the post-release process is not only recommended but also a responsibility issue and a unique opportunity to improve knowledge and experience in future translocations.

Overexploitation for meat and trophies and habitat alteration and disruption continue to be serious risks to many Bovidae, including *Capra* spp. populations (Weinberg 2008a, 2008b; Weinberg *et al.* 2008; Michel 2010). Several species of this family have been subject to translocations in the last decades (Nielsen & Brown 1989; Price 1989; Maudet *et al.* 2002). Unfortunatelly, and despite theoretical guidelines previously mentioned, the threats that caused former extinctions in this mammal family are frequently the same that hamper the survival of reintroduced populations. These are chronically related with humans, directly and/or indirectly, and include poaching, habitat degradation or destruction, displacement to suboptimal habitats by wild (usually introduced) and domestic competitors, and diseases transmited by these lasts (Nielsen & Brown 1989; Shackleton 1997; Dupré *et al.* 2001; Acevedo *et al.* 2007). The higher vulnerability of reintroduced populations founded by a small number of individuals with low genetic diversity is crescently recognized (Maudet *et al.* 2002).

1.2. Ibexes across the world

Goats (*Capra* spp.) belong to the family Bovidae, the most diverse of extant large mammals (Hernandez-Fernandez & Vrba 2005; Figure 1). Bovidae diversification occurred in pulses during periods of rapid climatic and vegetation changes, probably in the coolest episode of the Miocene (Schaffer & Reed 1972; Grubb 2001; Hernandez-Fernandez & Vrba 2005).

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Cetartiodactyla
Suborder: Rumantia
Infraorder: Pecora
Family: Bovidae
Subfamily: Caprinae
Tribe: Caprini
Genus: *Capra* (Linnaeus, 1758)

Figure 1. Taxonomy of *Capra* spp

.

The rapid diversification of Bovidae may explain important gaps on the knowledge of this family phylogeny, like the basal relationships of Caprinae. The tribe Caprini appeared about 15 million years ago (Ma) during a global climate cooling (Hernandez-

Fernandez & Vrba 2005; Price *et al.* 2005). The rapid radiation of *Capra* spp. (Hartl *et al.* 1990; Manceau *et al.* 1999b; Ropiquet & Hassanin 2006) and their association to mountainous environments (Schaffer & Reed 1972), unfavourable to fossilization, may explain the scarcity on fossil records for this group. Hence, the evolutionary history and phylogenetic relationships within *Capra* spp. are still incomplete.

Fossil record place the origin of *Capra* spp. in Central Asia in the Plio-Pleistocene (Pilgrim 1947) and their arrival to Europe by the end of the Median Pleistocene, i.e. c. 300,000 years ago (ka, hereafter) (Couturier 1962; Crégut-Bonnoure 1992). The most ancient form in the old continent has been named *C. camburgensis* by some authors and considered as the probable ancestor of the actual European species, *C. ibex* and *C. pyrenaica* (Toepfer 1934). Allozyme (Hartl *et al.* 1990), mtDNA and Y-chromossome studies (Manceau *et al.* 1999b; Pidancier *et al.* 2006; Kazanskaya *et al.* 2007) support this hypothesis. On the other hand, Crégut-Bonnoure (1992, 2005) suggests that the first immigrants of *Capra* spp. to Europe belonged to an ancient form of the Alpine ibex (*C. ibex ibex*). This author also considers a second independent immigration of an akin of the actual *C. caucasica* and/or *C. cylindricornis* to Europe (*C. caucasica praepyrenaica*), during the Late Pleistocene (c. 80 ka). García-González (2011) suggests former immigration events based on fossiles found in the Iberian Peninsula, namely of *C. baetica* (Arribas & Garrido 2008; Superior Pliocene, 2.0 Ma), and *C. alba* (Moyà-Solà 1987; Made *et al.* 2008; Early Pleistocene, 1.0 to 1.3 Ma). These species or their ancestors may have reached the Iberian Peninsula from the Pyrenees or the Strait of Gibraltar, there remaining during the Quaternary.

The systematics of extant *Capra* spp. has been based on morphological characters and is also controversial (Couturier 1962; Schaller 1977; Shackleton 1997). Such classification is not supported by molecular studies (Hartl *et al.* 1990, 1992; Manceau *et al.* 1999b), except for the horn morphology, generally concordant with the Y-chromosome phylogeny (Pidancier *et al.* 2006). According to Grubb (2005) there are nine wild *Capra* spp. distributed through Eurasia, the Middle East and the North of Africa (Figure 2) and one cosmopolitan domestic form (*Capra hircus*, domestic goat hereafter).

As many representants of the Bovidae family, *Capra* spp. are a valuable source of global economic incoming for humans, through meat and other products' of the domesticated form and from hunting trophies of wild animals (UNDP 2002; Price *et al.* 2005; FAOSTAT 2013). All species are gregarious (Schaffer & Reed 1972) and may interbreed in captivity and produce fertile offspring (Couturier 1962; Manceau *et al.* 1999a) in accordance with a recent phylogeny. Hybridization between wild taxa and the domestic goat has been documented

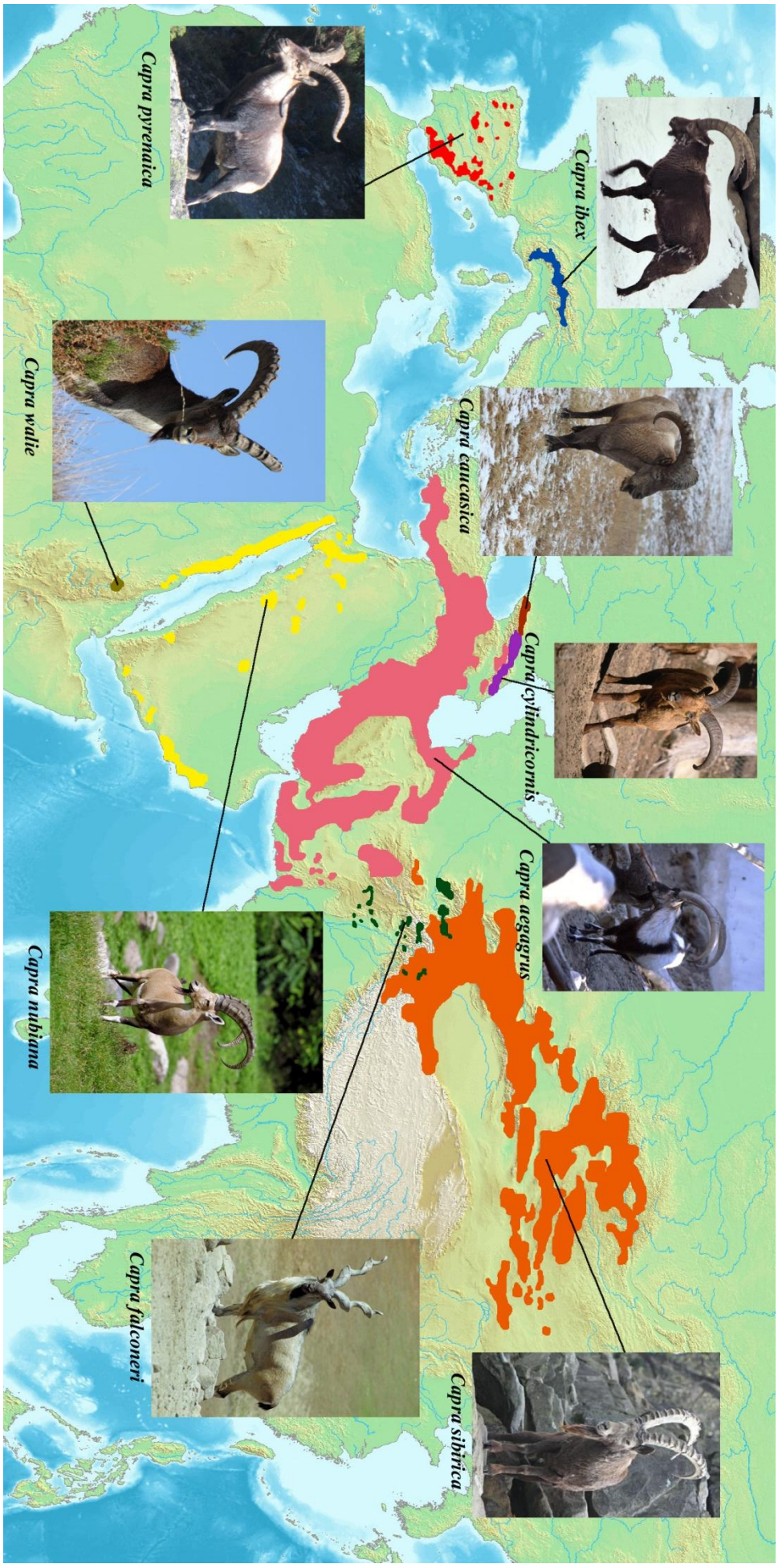

Figure 2. Geographic distribution of wild *Capra* spp. (Grubb 2005). Species ranges adapted from IUCN (2015). All photographs except *Capra pyrenaica* (author's photograph) courtesy of ©Brent Huffman, www.ultimateungulate.com.

in the wild (Giacometti *et al.* 2004). It was hypothesized that hybridization may also occur between sympatric populations of wild *Capra* spp. (Gray 1954; Couturier 1962; Corbet 1978), although there is no reliable evidence of its occurrence.

Wild *Capra* spp. have highly dimorphic horns of continued growth. These are larger and massive in males, adapted for fighting during mating and may also be a defense against predators. Main threats to these species are overexploitation, habitat destruction, competition with livestock, risk of diseases transmission and population fragmentation (IUCN 2015). Four species are globally threatened, namely *C. aegagrus, C. caucasica, C. nubiana* and *C. walie*. Despite a non-endangered global status, other species are regionally threatened (e.g., *Capra pyrenaica* in Portugal) or unknown due to insufficient data (e.g. *Capra aegagrus* in Afghanistan and Iran due to wars).

1.2.1. The Iberian ibex or Iberian wild goat

The Iberian ibex or Iberian wild goat (ibex hereafter) is a medium-size wild goat, endemic to the Iberian Peninsula (Pérez et al 2002; Acevedo & Cassinello 2009) in the western edge of wild *Capra* spp. range (Fig. 2). The species has been subject to a good number of reviews concerning its biology, distribution range and conservation status, among others (Granados *et al.* 2001; Pérez *et al.* 2002; Acevedo & Cassinello 2009) and may be considered well-known. It inhabits a variety of rocky substrats, wide altitudinal range and climatic conditions from Atlantic to Mediterranean. Males exhibit horns "curved like a lyre and triangular in cross-section without flat clashing surface and transverse knobs" (Pidancier *et al.* 2006, pp 740). Ibex is legally hunted for sport and many populations are highly managed.

The fossil record suggests that the colonization of the Iberian Peninsula by the ibex likely occurred between the Riss-Würm glaciations (Engländer 1986). Nevertheless, hypotheses for its origin diverge in its ancestors and period of differentiation, as previously introduced. On the one hand, it may have differentiated around 200 to 120 ka (Toepfer 1934; García-González 2011) from: i) *C. camburgensis*; ii) an ancient type of *C. ibex* or; iii) from the intermixing of *C. baetica* and/or *C. alba* with *C. camburgensis*. This hypothesis is supported by molecular studies (Hartl *et al.* 1992; Manceau *et al.* 1999b; Pidancier *et al.* 2006; Kazanskaya *et al.* 2007). Other authors propose a later differentiation of *C. pyrenaica*, between the Medium and the second half of the Late Pleistocene, from *C. caucasica praepyrenaica* (Engländer 1986; Crégut-Bounnoure 1992, 2005). Generally, all authors agree that the species originated in the Pyrenees. From here, *C. pyrenaica* expanded through the Iberian Peninsula, reaching the Portuguese massifs (Cabrera 1911; García-González 2011).

The oldest fossil remains of ibex (considering the previous, *C. pyrenaica* or *C. caucasica pyrenaica*) identified in Portugal date from the Middle and Upper Palaeolithic (Harlé 1910-11; Cardoso 1996, 2006). The species is well represented in human rock-art of the Upper Palaeolithic (Aubry *et al.* 2012; Baptista 2009). The altitudinal range between these locations is wide and frequently associated with rocky environments, suggesting that ibex would inhabit the most important Portuguese mountain ranges.

Four subspecies of *C. pyrenaica* were described by Cabrera (1911, 1914) and are currently accepted although with controversy (Shackleton 1997; Acevedo & Cassinello 2009): *C. p. pyrenaica, C. p. victoriae, C. p. hispanica* and *C. p. lusitanica*. A small number of individuals were used in their description (Barboza du Bocage 1857; Cabrera 1911, 1914; França 1917) and there is great variability of the characteristics used to differentiate them (Cabrera 1911), basically horns shape and coat colour. In addition, molecular studies only differentiate *C. p. pyrenaica* from the two extant subspecies *C. p. victoriae* and *C. p. hispanica* (Manceau *et al.* 1999a). In the opinion of Almaça (1980), the small number of differences between the subspecies of *C. pyrenaica* and the fact that the geographically intermediate forms presented intermediate characteristics between extremes of variability (Cabrera 1911) support the hypothesis of a sufficient genetic flow between populations and thus low genetic divergence. This would explain the considerable adaptive capacity of the ibex to Iberian environments and the high success of ibex translocations during the last century (Acevedo & Cassinello 2009).

Excessive hunting is usually referred as the main cause of the general decline of ibex in the Iberian Peninsula (Cabrera 1914, Pérez *et al.* 2002, Manceau *et al.* 1999b). In the beginning of the 20th century, the eminence of the extinction of most populations of ibex was recognized and two populations that formerly occupied the NW and NE of ibex distribution range had already vanished. These were the last known population of *C. p. lusitanica* (in Portugal) and the French population of *C. p. pyrenaica*. The protection of the remnant populations (c. 10, with few individuals) was initiated between 1900 and 1960 (Manceau *et al.* 1999b). *Capra pyrenaica pyrenaica* became extinct to Spain in 2000 (Pérez *et al.* 2002).

Presently, ibex is expanding its range throughout the Iberian Peninsula, partially reflecting an increase on the sampling effort of many populations in the last decades (Pérez *et al.* 2002; Acevedo & Cassinello 2009). At the same time, recent expansions to historical redoubts of the ibex included natural expansions to Peneda-Gerês National Park (PGNP) in Portugal in 1998, the southern range of the Pyrenees (Herrero *et al.* 2007; Herrero *et al.* 2013) and the reintroduction in the French side of this mountain range. (Crampe *et al.* 2015). Regardless the

increasing trend of ibex distribution and numbers (Herrero & Pérez 2008), poaching and direct human disturbance, habitat loss and degradation, umproper management of translocations and hunting, isolation from neighbor populations, genetic background, competition with domestic and wild ungulates and diseases still constitute serious menaces to ibex and may lead to local- or regional-level extinctions (Fandos 1991; Granados *et al.* 2001; Pérez *et al.* 2002; Acevedo *et al.* 2007; Acevedo & Cassinello 2009).

Presently, the ibex global status is non-threatened (Least Concern; Herrero & Pérez 2008) while Critically Endangered in Portugal (Cabral *et al.* 2005) due to the small size of its founder population. The species is protected under the Appendix III of the Bern Convention and the Annex V of the EU Habitats and Species Directive.

1.3. Thesis goals and outline

This thesis focused on the return of the Iberian ibex (or Iberian wild goat; *Capra pyrenaica* Schinz, 1838) to Portugal after more than 100 years of species' absence. As further detailed, ibex return started with a reintroduction beyond Portugal's border with Galicia (Spain) but close enough to allow the arrival of naturally expanding visitors to the Peneda-Gerês National Park (PGNP, Portugal). This protected has a singular importance on wildlife conservation in the country. It was created in 1971 (Decreto nº 187/71 de 8 de maio) and the first Portuguese protected area. It is the unique National Park of Portugal. It comprises an area of 695,92 km^2 and together with the Baixa Límia – Serra do Xurés Natural Park (BLSXNP, Spain) contitutes the Gerês-Xurés International Park (GXIP) since 1997. GXIP is also considered a PanPark since 2008 and Gerês-Xurés Biosphere Reserve since 2009. Presently, PGNP is the ibex gateway to the rest of the country.

Portugal rapidly re-registered the species in its fauna inventory (Cabral *et al.* 2005). One may call this return a collateral effect or a lucky strike. Anyway, as soon as the first ibex crossed our human-invented border Portugal recovered an old responsibility.

This work intended to describe and understand the underlying ecological processes of the first years of recolonization of PGNP by the ibex. After considering priorities and possibilities, the goals of this thesis were delineated in five principal issues, as follows:

a) First of all, to confirm ibex presence in PGNP, assess numbers of the initial population and range in order to determine its conservation status in Portugal (*Chapter 2.1*).

b) Because learning from the past is essential in preparing ibex future, analyse the historical distribution range of *C. p. lusitanica*, human-ibex interactions and habitat trends evolution through time in

Portugal. This was primarily done through bibliographical research (*Chapter 2.2*).

c) To open a debate about the factors associated and the convenience of consensus to ibex vernacular name. (*Chapter 3.1*).

d) To test the feasibility of the Distance Sampling (*Chapter 4.1*) in estimating ibex abundance in the PGNP and;

e) the possibility of using non-invasive (faecal) samples to conduct molecular studies of the population, namely abundance estimation (*Chapter 4.2*).

f) To investigate: i) ibex feeding strategy in the two mountain ranges the species recolonized in PGNP, Gerês and Amarela (*Chapter 5.1*), and; ii) the influence of the domestic goat (*Chapter 5.2*) and iii) landscape heterogeneity (*Chapter 5.3*) on ibex feeding ecology; these studies were based on non-invasive (faecal) samples.

1.4. References

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CHAPTER 2. IBEX RETURNS

"Sem aviso, a realidade superou a ficção. Os eternamente sonhados contornos materializaram-se sobre fragas recônditas do Parque Nacional..."

Miguel Dantas da Gama

2.1. THE IBEX *Capra pyrenaica* RETURNS TO ITS FORMER PORTUGUESE RANGE

MOÇO G, GUERREIRO M, FERREIRA AF, REBELO A, LOUREIRO A, PETRUCCI-FONSECA F & PÉREZ JM

ORYX, 2006, Vol. 40, 351-354

2.2. REVISITING EXTINCTIONS TO SUPPORT REINTRODUCTIONS: INSIGHTS FROM HISTORIC RESEARCH ON THE IBERIAN IBEX *Capra pyrenaica*

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In prep

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Short Communication

The ibex *Capra pyrenaica* returns to its former Portuguese range

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Abstract The ibex *Capra pyrenaica* has recently recolonized its former Portuguese range from a contiguous Spanish protected area. The first observations of ibex in Portugal were in Peneda-Gerês National Park in 1998. In 2001 we began a survey to confirm ibex presence in Portuguese territory, and to determine the current status of the species there. There are three ibex nuclei in the general area of the international border, and they are expanding their geographical range with two of the nuclei almost restricted to Portuguese territory. In 2003 the ibex population consisted of a minimum of 75 individuals. Different founder histories have led to distinct age structures in each nucleus, but in general they exhibit the population dynamics typical of a recently reintroduced population with high reproductive potential. Priority conservation actions for this newly established population need to include increased monitoring, and reinforcement of the population with individuals from elsewhere. Effective conservation will require collaboration between staff of both Portuguese and Spanish protected areas and an integrated Spanish-Portuguese conservation plan.

Keywords *Capra pyrenaica*, ibex, Portugal, Red List, reintroduction, Spain.

The ibex *Capra pyrenaica* was once widely distributed throughout the Iberian Peninsula and the French Pyrenees but over the last 2 centuries its populations decreased greatly as a result of excessive hunting and habitat loss (Alados, 1985; Crampe, 1990; Pérez *et al*., 2002). This mountain ungulate became extinct in Portugal and France in the 19th century but persisted in Spain. The ibex population that inhabited north-west Portugal and the Galicia region of Spain until the last decade of the 19th century belonged to the subspecies *C. p. lusitanica* (Cabrera, 1914) and the Gerês-Xurés massif of Portugal and Galicia was its last redoubt. The last known individuals were a female captured alive and another found dead, both in the Portuguese part of Gerês-Xurés in 1890 (Tude de Sousa, 1927).

The subspecies *C. p. pyrenaica* inhabited the Pyrenees and continued to occupy Spanish territory after its extinction in the French Pyrenees, but it became extinct in Spain in 2000 (Pérez *et al*., 2002). There are now only two extant subspecies: *C. p. hispanica* in central and Mediterranean Spanish mountain ranges, categorized as Lower Risk: conservation dependent on the IUCN Red List (IUCN, 2004), and *C. p. victoriae* in the north-west Iberian Peninsula, categorized as Vulnerable. Both subspecies are important hunting trophies in Spain. At the species level *C. pyrenaica* is categorized as Lower Risk: near threatened (IUCN, 2004). Generally, ibex populations in Spain have increased in both total numbers and range in the last 3 decades, and the total Spanish population was estimated at the end of the 1990s to be *c*. 50,000 in more than 50 nuclei (Pérez *et al*., 2002; Fig. 1a).

In 1998 ibex were unexpectedly reported in Portugal. Here we describe the circumstances that led to this and present the first data on the founder population that recolonized the species' former Portuguese range.

The return of ibex to Portugal was the result of the translocation of the subspecies *C. p. victoriae* to Galicia (Fig. 1a). In 1992 four males and eight females were moved from Gredos Nacional Reserve in Salamanca, Spain, to Invernadeiro Natural Park in Galicia. By 1997 this population had increased to 71 animals, and 18 were translocated to Baixa Limia-Serra do Xurés Natural Park. This protected area is adjacent to Portugal's Peneda-Gerês National Park. The two Parks were together named as Gerês-Xurés International Park in 1997.

In Baixa Limia-Serra do Xurés Natural Park five males and 11 females were kept in an enclosure at Salgueiros and one male and one female in an enclosure at Santa Eufémia (PNBLSX, 2001; Fig. 1b). By the end of 1998 the

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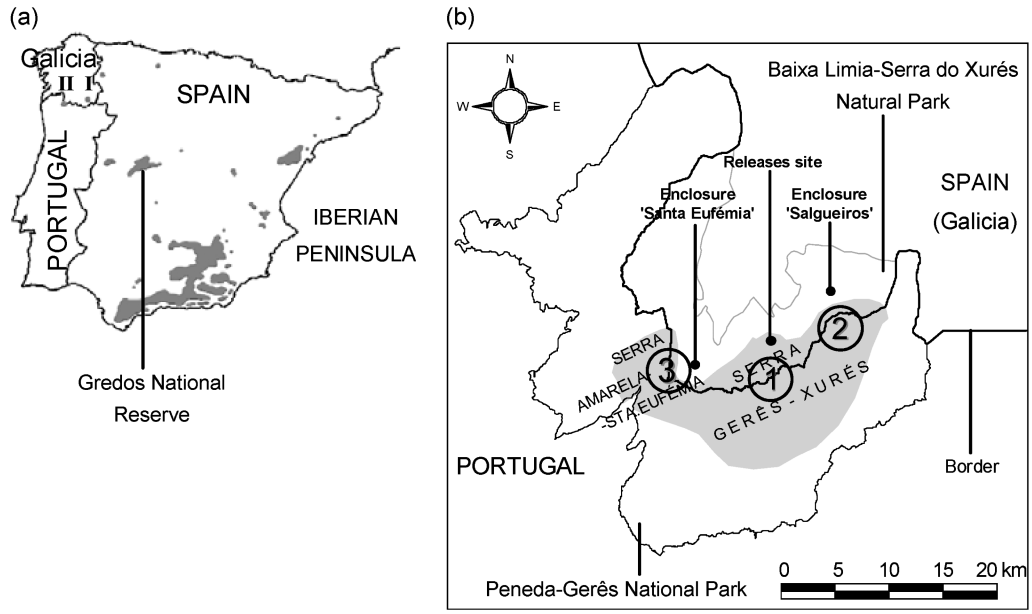

Fig. 1 (a) Ibex translocations to the north-western Iberian peninsula in 1992 (I, Invernadeiro Natural Park) and 1997 (II, Geres-Xures International Park); grey areas indicate the current distribution of ibex (from Pérez *et al.*, 2002). (b) The area surveyed (shaded grey) in Gerês-Xurés International Park on the Portuguese-Spanish border, with the locations of the two enclosures and the release site, and of ibex nuclei 1–3 (see text for details).

first ibex escapes from both enclosures were reported and these events led to the first observations of ibex in Portuguese territory: three ibex in Serra Amarela (3.4 km from the Santa Eufémia enclosure) and three in Serra do Gerês (3.0 km from Salgueiros). During 2000 and 2001 the Natural Park officially released a total of 25 ibex in Serra do Xurés.

In 2001 we started monitoring ibex presence and movements in Gerês-Xurés International Park. Our goals were to (1) investigate ibex presence in Portuguese territory, (2) determine the species' status, and (3) on the basis of such information, develop guidelines for population monitoring and management.

Monthly between September 2001 and December 2003 we surveyed the two massifs (with Portuguese and Spanish ranges) where ibex had been documented since 1998: Serra do Gerês-Xurés and Serra Amarela-de Santa Eufémia (Fig. 1b). We systematically searched on foot (n = 150 transects) and from fixed observation points (n = 54). The number of km walked per day was 1.9–25.8 km (mean ± SD 6.8 ± 5.9 km, total = 1,020.7 km) with 5–13 survey hours (mean ± SD 6.8 ± 3.2 hours, total = 1,185.3 hours) per day. In each encounter we recorded number, sex and age class, and location for inclusion in the geographical information system *ArcView 3.1* (ESRI, 1996). Ibex nuclei were defined as localities where the same individuals were observed in consecutive surveys. Although we were only able to distinguish a few individuals, the social behaviour of the species, the low number of ibex per nucleus and the distance between localities allowed us to identify these units. The geographical ranges of nuclei and the overall area of ibex occurrence were determined as the 100% Minimum Convex Polygon (MCP) of ibex locations (Dunham, 2001) using the Animal Movement extension to *ArcView* (Hooge *et al.*, 1999). The MCPs were calculated for 2001–2002 combined (because only a few locations were obtained for 2001) and for 2003. Once we were familiar with the study area the number of ibex in each nucleus was determined by direct total counts (Staines, 1978; Tellería, 1986; Alados & Escós, 1996) because ibex range was limited and numbers were low. If animals showed sedentary behaviour we assumed that we were able to detect all individuals. When this assumption was not possible the total number of individuals observed was considered to be the minimum number (Dunham, 2001). Age classes were defined as adult (≥2 years), yearling (1–2 years) and kid (<1 year). The term juveniles was used when referring to both yearlings and kids. Sex ratio was calculated as number of adult females/adult males and a reproductive index as number of kids/number of adult females (Pereladova *et al.*, 1998). Causes of death and missing individuals were investigated by inquiries with local shepherds and staff from Peneda-Gerês National Park and Baixa Limia-Serra do Xurés Natural Park.

The presence of three ibex nuclei in the study area was confirmed (Fig. 1b). Nucleus 1 occupies the central part

of the Gerês-Xurés mountain range, nucleus 2 the eastern limit of the same range and nucleus 3 the Amarela-Santa Eufémia range. Nuclei 2 and 3 correspond to the localities of the first ibex observations in 1998, and it therefore appears that they were the result of escapes from Salgueiros and Santa Eufémia enclosures, respectively. Nucleus 3 did not receive any immigrants during our study. There were immigrants to nucleus 2 during the survey period (Table 1) that could have come from nucleus 1 (we frequently observed ibex signs between the two locations) or were new escapees from Salgueiros enclosure. Nucleus 1 has formed of individuals from the official releases of Baixa Limia-Serra do Xurés Natural Park but it is possible it also receives escapees from Salgueiros. Nucleus 1 occupies the largest area (Table 1), with 75% of it located on the Spanish side of the border. The MCPs of nuclei 2 and 3 are smaller and predominantly located in Portugal (<1% of the MCP of nucleus 2 is in Baixa Limia-Serra do Xurés Natural Park in Spain and nucleus 3 is restricted to Peneda-Gerês National Park in Portugal). MCP areas of all nuclei, and in particular that of nucleus 3, increased from 2001–2002 to 2003.

In 2003 there was a minimum of 75 individuals (Table 1). Because most of the released and escaped ibex were adults there is a high proportion of adults in the population. As a result of the small population size and restricted range of the ibex in Peneda-Gerês National Park, it has been proposed that the species' Red List status in Portugal is changed from Extinct to Critically Endangered (Cabral *et al.*, in press). Sex ratios and reproductive indices of each nucleus (Table 1) were influenced in particular by the initial composition of the founders. Information from local people suggested that there has been poaching of individuals from both nuclei 2 and 3.

Our results describe a population that is apparently increasing without resource limitation, and the geographical ranges of the nuclei are expanding, probably as a consequence of population growth. There are, however, some conservation concerns for individual nuclei. Nuclei 2 and 3, with lower numbers, are relatively near human habitation and their ranges are easily accessible to livestock, shepherds and tourists, and to poachers from both Portugal and Spain. Despite its higher reproductive potential, nucleus 3 may be affected by inbreeding, given its demographic history and geographic isolation. The range of nucleus 1 includes a hunting zone in Baixa Limia-Serra do Xurés Natural Park, and this nucleus could therefore become affected by hunting.

Priority conservation actions for this newly established population of *Capra pyrenaica* needs to include increased monitoring, and reinforcement of the population with individuals from elsewhere. Any hunting plans for ibex need to be considered cautiously, and there needs to be control of feral goats and dogs, domestic sheep and goats, and tourism in current and potential ibex range. Effective conservation will require collaboration between staff of both Portuguese and Spanish protected areas and an integrated Spanish-Portuguese conservation plan for the species.

Following our recommendations Peneda-Gerês National Park put into practice a surveillance plan for ibex and has continued to support studies of ibex diet and the monitoring of abundance, range and habitat use, and habitat modelling.

Table 1 The number of ibex in three nuclei in Gerês-Xurés International Park during 2001–2003, with the sex ratio, reproductive index and home range areas calculated as the minimum convex polygon (MCP; see text for details).

		Number of ibex								
Nucleus	Year	Males	Females	Yearlings	Kids	Undetermined	Total	Sex ratio	Reproductive index	MCP(km^2)
1[1]	2001	6[2]	14	0	4	5	29	2.3	0.3	5.29
	2002	10	13[2]	3	7	1	34	1.3	0.5	–
	2003	12	14	3	9	5	43	1.2	0.6	7.04
2[1]	2001	1	1	1	1	0	4	1.0	1.0	0.39
	2002	3[3]	3[3]	1	1	0	8	1.0	0.3	–
	2003	6[4]	4[4]	1	4[4]	0	15	0.7	1.0	1.81
3	2001	2	2	1	3	0	8	1.0	1.5	0.09
	2002	2	3	3	4	0	12	1.5	1.3	–
	2003	2	5	3	6	1	17[5]	2.5	1.2	0.92
Total	2003	20	23	7	19	6	75	1.2	0.8	9.77

[1]Minimum number of individuals (see text for details)
[2]One male died due to bad winter conditions (Parque Natural Baixa Límia – Serra do Xurés, pers. comm.) and one female due to unknown causes
[3]One male missing; 3 males and 1 female immigrated
[4]One female with kid, and two males immigrated
[5]One undetermined individual missing during summer

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Biographical sketches

Gisela Moço is carrying out research on ibex population dynamics in Peneda-Gerês National Park. Jesús Mª Pérez focuses his research on populations of mountain ungulates. Ana Filipa Ferreira and Margarida Guerreiro carry out research on ibex habitat suitability and diet. Francisco Petrucci-Fonseca is interested in the conservation of wolves and their prey. Armando Loureiro is a biologist in Peneda-Gerês National Park, where he is responsible for game management. António Rebelo is a collector at Peneda-Gerês National Park, collaborating in several mammal monitoring and distribution studies.

Revisiting extinctions to support reintroductions: insights from historic research on the Iberian Ibex *Capra pyrenaica* in Portugal

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ABSTRACT

After becoming extinct in Portugal in the 19th century, the Iberian Ibex *Capra pyrenaica* recolonized the Portuguese Peneda-Gerês National Park in 1999. Since then, the population has been increasing in numbers and range and it will likely expand beyond the limits of the National Park. Based on these evidences, the ibex return to Portugal appears as a successful case of natural expansion and species' recovery. We accomplished an extensive analysis of the causes that likely leaded to ibex decline in Portugal in the past through the revision of ancient to present bibliography. Our goals were to objectively analyse the former shrinking in the distribution range of the ibex and the evolution of human-related factors through time. The results obtained showed that in Portugal, ibex was restricted to a very limited range, and probably isolated from neighbouring populations, since at least the end of the Middle Ages. Our research also points to important changes on ibex former habitat and the possibility that its former ecological niche has been occupied by livestock during its absence. Finally, several factors involved in species' former extinction are potentially prevailing. Our conclusion is that the conservation of ibex in Portugal is far from being ensured. Priority should be devoted to measure the ecological carrying capacity of PGNP to sustain ungulates' community and launch an education/development program including the local human population.

Keywords: *Capra pyrenaica*, conservation, humans, Peneda-Gerês National Park

INTRODUCTION

Reintroductions are human actions that consist on delivering animal or plant populations to areas within their historical distribution from which they became extinct in the past (IUCN 1998). These actions reflect our increasing awareness of human's responsibility in extinctions and concern to maintain the biological diversity in natural ecosystems. Reintroductions require the previous identification of the causes that leaded populations to extinction, the evaluation of the persistence of those causes and viability studies that determine the areas' capacity to sustain new populations without

permanent complementary measures (Price 1989; SNPRCN 1991; IUCN 1998).

Understanding the cause(s) that leaded one population to extinction may be a difficult task when the information about its historical distribution and status is insufficient. As expressed by França (1917) when writing about the extinct Iberian Ibex (*Capra pyrenaica* Schinz, 1838) in Portugal: "It is certainly difficult to know the habits of a species that, living in the most wild places of the highest peaks, was almost extinct when we published the first zoological work about it". How to ascertain the impact of the factor(s) that reduced the numbers of one population below the threshold of extinction risk if its historical numbers and distribution are unknown? Moreover, an insufficient knowledge about the historical evolution of potential causes of extinction leads to inaccurate assumptions of past scenarios. One consequence of these limitations could be the design of too-optimistic models of habitat suitability and persistence for a reintroduced population.

The Iberian ibex (ibex, hereafter) is an endemic species of the Iberian Peninsula and Pyrenees and the unique wild Caprinae in the Iberian Peninsula. Its current distribution range is shown in Figure 1.A. It has been hypothesized that ibex was widely spread and abundant in this vast region until the Middle Ages. By the middle of the 19th century, ibex was extinct from the French side of the Pyrenees and its distribution range consisted on few isolated areas in the Iberian Peninsula. The subspecies *Capra pyrenaica lusitanica* Schlegel, 1872 supposedly inhabited the northwestern mountain ranges of this region, i.e., Galicia (Spain) and the North of Portugal (Seoane 1861, 1866; Cabrera 1911, 1914; Miller 1912; Almaça 1992; García-González 2011). In the middle of the 19th century, *C. p. lusitanica* was restricted to the Courel mountain range in Galicia (Seoane 1861, 1866) and the Gerês mountain range in Portugal, this last presently included in the Portuguese Peneda-Gerês National Park (PGNP; Fig. 1.B - C). Ibex decline in Portugal was then recognized and its extinction dated between 1890 and 1892 (França 1917) due to excessive hunting and habitat loss. In the following decades and along the 20th century, Spain protected its remnant ibex isolates and entailed several restocking actions to former or depleted realms of the species (Pérez et al. 2002). By their part, the Portuguese authorities made some unfruitful claims to obtain animals from Spain in order to reintroduce them in the Gerês range (Bravo 1970; SNPRCN 1991; Mendes 1968; Gama 1992, 2008). The most used arguments to justify ibex reintroduction in Portugal were its main cause of extinction – hunting - was no longer a menace; Portugal's responsibility for biodiversity restoration and; the ecological benefit that ibex would represent as a prey of endangered predators as the golden eagle (*Aquila chrysaetos* Linnaeus, 1758) and the wolf (*Canis lupus* Linnaeus, 1758).

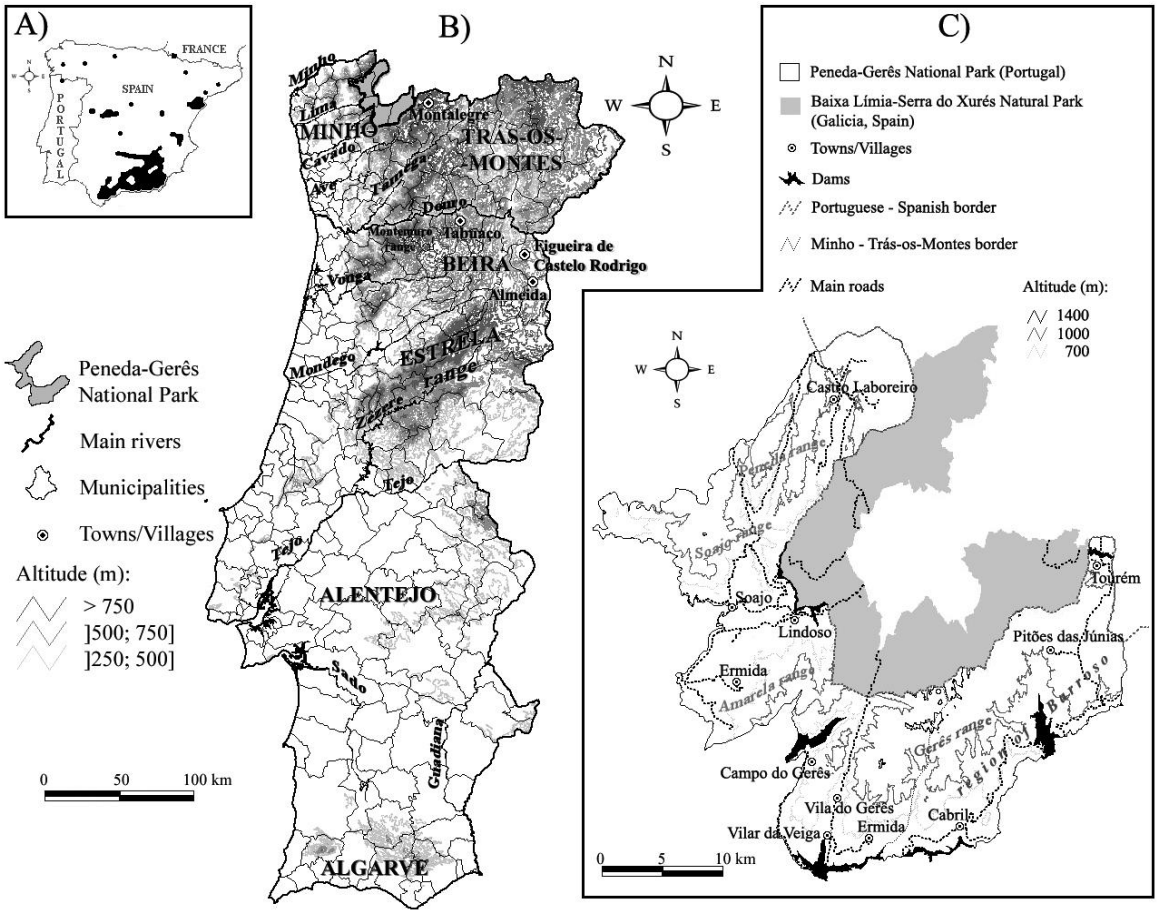

Figure 1. A) Distribution range of ibex (*Capra pyrenaica* Schinz, 1838) in the Iberian Peninsula (adapted from Pérez et al. 2002; Acevedo and Cassinello 2009; Crampe et al. 2015); **B)** geographical features, municipalities and villages/towns mentioned in the text, and Peneda-Gerês Nat National Park location; C) Peneda-Gerês National Park.

In conformity, pilot reintroduction proposals (SNPRCN 1991; Gama 1992) and habitat suitability studies (Moço 1998; Santana 2001) were conducted. These authors underlined the need of a livestock-free space and habitat restoration measures to guaranty the success of a future reintroduction of ibex in the PGNP.

Ibex populations are usually intensively-managed, with humans and diseases as their main regulation factors (Acevedo and Cassinello 2009). The return of ibex to its last Portuguese redoubt occurred in 1999 of animals from the Baixa Límia-Serra do Xurés Natural Park (BLSXNP, Spain; Fig. 1.C) near the border with PGNP (Moço et al. 2006; Gama 2008). This bordering population presents an increasing trend (Moço et al. 2006; Figueiredo 2011; Fonseca et al. 2013) but its Portuguese range is restricted to the PGNP and it is classified as Critically Endangered in Portugal (Cabral et al. 2005). Globally, the species is classified as Least Concern in the Iberian Peninsula (Herrero and Pérez 2008). During the first years of ibex return, Portugal invested on the research, monitoring and vigilance of the founder population. The increase of the population

size and prohibition to hunt it have been often reported in the media, reflecting an optimistic perspective about the future of ibex in Portugal. Nevertheless, these evidences do not guarantee the species' maintenance by themselves. Actually, poaching has been threatening this ibex population since the beginning (Moço et al. 2006; Geraldes 2012) and it is expected to increase as ibex expands to non-protected zones. Illegal hunting is difficult to quantify, but considering cases registered on, e.g., the wolf in Portugal (Álvares 2011) it is not alarmist to say it potentially causes a severe impact on Portuguese wildlife (Manel et al. 2002). Besides poaching, to our knowledge none of the measures of habitat management concerning ibex and livestock proposed by researchers were undertaken in the PGNP. Moreover, the vigilance and monitoring programs, recognized as fundamental by the SNPRCN (1991) and set forward in the first years of ibex return, greatly depend on research funding and the goodwill of underpaid and ill-equiped rangers.

In this paper we address the question: "Is Portugal suitable to sustain viable populations of ibex?" Our goals are: i) to depict a long-term and national-scale picture of the former presence of ibex and the causes that leaded to its extinction in Portugal and; ii) to discuss human- and habitat-related factors presently operating and aspects related with the founder population of ibex that potentially affect its future viability.

MATERIALS AND METHODS

Data on the historical distribution of ibex, humans and human activities in Portugal (Fig. 1.B) were obtained in bibliographic sources dated from the 16th century to the present.

Information on the last redoubt of ibex in Portugal was complemented with field research in the Peneda-Gerês National Park (41º41'N-42º05'N, 8º25'W-7º53'W; 695.96 km^2) (Fig. 1.C) from 1998 to 2007. This consisted in direct contact with locals, especially those that still depend on livestock breeding as their main sustenance activity in the mountain ranges of Gerês and Amarela. Human activities considered as potentially affecting ibex were human density and settlements, hunting, extensive breeding of livestock, habitat destruction by clearings, induced fires and charcoal production (especially in mountain ranges), and war conflicts.

Data were organized in eight periods of time, namely: i) Prehistory; ii) Pre-Roman and Roman periods (1st century BC – 5th century AD); iii) Middle Ages (5th-15th centuries); iv) 16th century; v) 17th century; vi) 18th century; vii) 19th century and; viii) 20th-21st centuries. Whenever possible, data were spatially referenced with ArcView 3.1 (ESRI 1996). Since the administrative and regional divisions of Portugal (for governmental statistics, like human population censuses) have changed considerably through time, the spatial

referencing of some historical data must be interpreted as the best approximation possible at the level of the municipality.

RESULTS

Ibex in Portugal

Origin and Prehistory. The most ancient forms of the genus *Capra* spp. in the Iberian Peninsula are *C. baetica* (Arribas and Garrido 2008), dated from the Superior Pliocene (2.0 Million years ago, Ma hereafter), and *C. alba* (Moyà-Solà 1987; Made et al. 2008), from the Early Pleistocene (1.0 to 1.3 Ma). These species or their ancestors may have reached the Iberian Peninsula from the Pyrenees or the Strait of Gibraltar, there remaining during the Quaternary (García-González 2011). Hypotheses for the origin of *C. pyrenaica* diverge in its ancestors and period of differentiation but all agree that it occurred in the Pyrenees. On the one hand it may have differentiated somewhere between 200 to 120 thousands years ago (ka hereafter) (Toepfer 1934; García-González 2011) from: i) *C. camburgensis* (Toepfer 1934); ii) an ancient type of *C. ibex* or; iii) from the intermixing of *C. baetica* and/or *C. alba* with *C. camburgensis* (Hypothesis A; Fig. 2). This hypothesis is supported by molecular studies (Hartl et al. 1992; Manceau et al. 1999; Pidancier et al. 2006; Kazanskaya et al. 2007). Other authors propose that *C. pyrenaica* differentiation occurred later (Hypothesis B; Fig. 2), between the Medium and the second half of the Late Pleistocene, from *C. caucasica praepyrenaica* (Engländer 1986; Crégut-Bounnoure 1992, 2005; Rivals and Testu 2006). From the Pyrenees, *C. pyrenaica* expanded through the Iberian Peninsula, reaching the Portuguese massifs (Cabrera 1911; García-González 2011) (Fig. 1).

Remains of ibex (considering the previous, *C. pyrenaica* or *C. caucasica pyrenaica*) have been identified in natural deposits and in carnivores' and human's refugees dated from the Middle and Upper Palaeolithic (Harlé 1910-11; Cardoso 1996, 2006). The species is also well represented in human rock-art of the Upper Palaeolithic (Aubry et al. 2006, 2012; Baptista 2009). The altitudinal range between these locations is wide (Fig. 3) and frequently associated with rocky environments (Cardoso 2006). This author suggested that ibex presence could be conditioned to climate changes from colder to warmer periods, e.g., decreasing in favour of other ungulates like the wild boar (*Sus scrofa* Linnaeus, 1758) and the roe deer (*Capreolus capreolus* Linnaeus, 1758) before the Würm glaciation. Ibex was better represented in the Portuguese fauna before and during the Last Glacial Maximum that after respect to other ungulates, as the wild boar and the red deer (*Cervus elaphus* Linnaeus, 1758) (Aubry et al. 2012). Unlike the red deer and the horse (*Equus caballus* Linnaeus, 1758), there are no references to ibex in rock-engraving and paintings of the

Neolithic (Jorge and Jorge 1991). Gomes et al. (1983) relate the representations of bovids (*bucrania*) of the Escoural sanctuary (Fig. 3) to a society of transhumant shepherds of domestic goats (*Capra hircus* Linnaeus, 1758) from the Neolithic and the Chalcolithic (approximately, between 4500 to 3800 years before present (BP hereafter). More recently, Otte and Silva (1996) dated rock-engraving and paintings of Escoural cave from the Solutrean (Upper Palaeolithic).

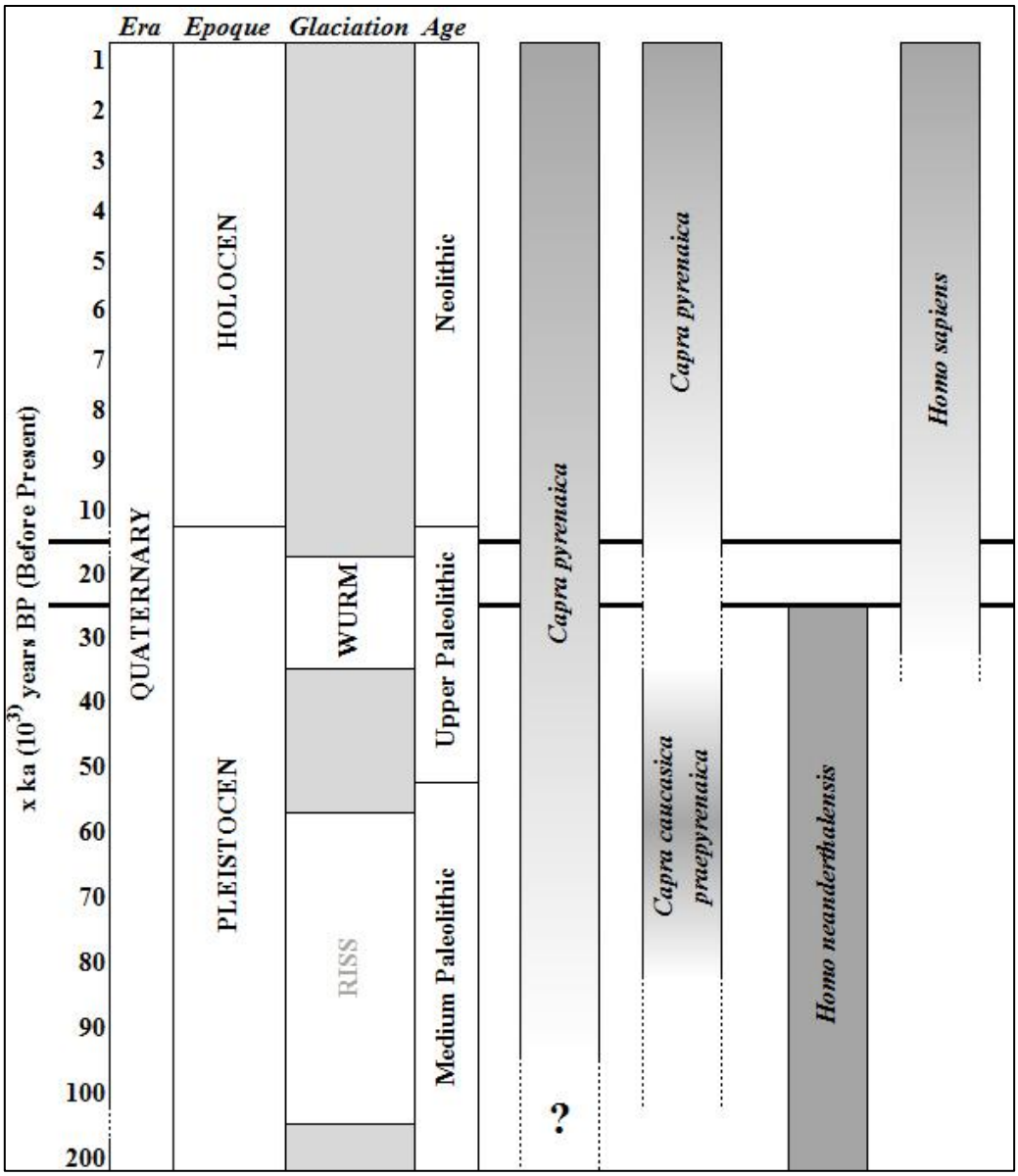

Figure 2. Historical coexistence of *Homo neanderthalensis*, *H. sapiens* and *Capra* spp. in Portugal. Grey areas in the column "Glaciation" are inter-glacial periods. The Last Glacial Maximum interval is signaled with two black horizontal lines (Antunes et al. 1989; Cardoso 2006; Hughes and Woodward 2008). Two hypotheses (**A** and **B**) for ibex origin are indicated (see text for further explanation).

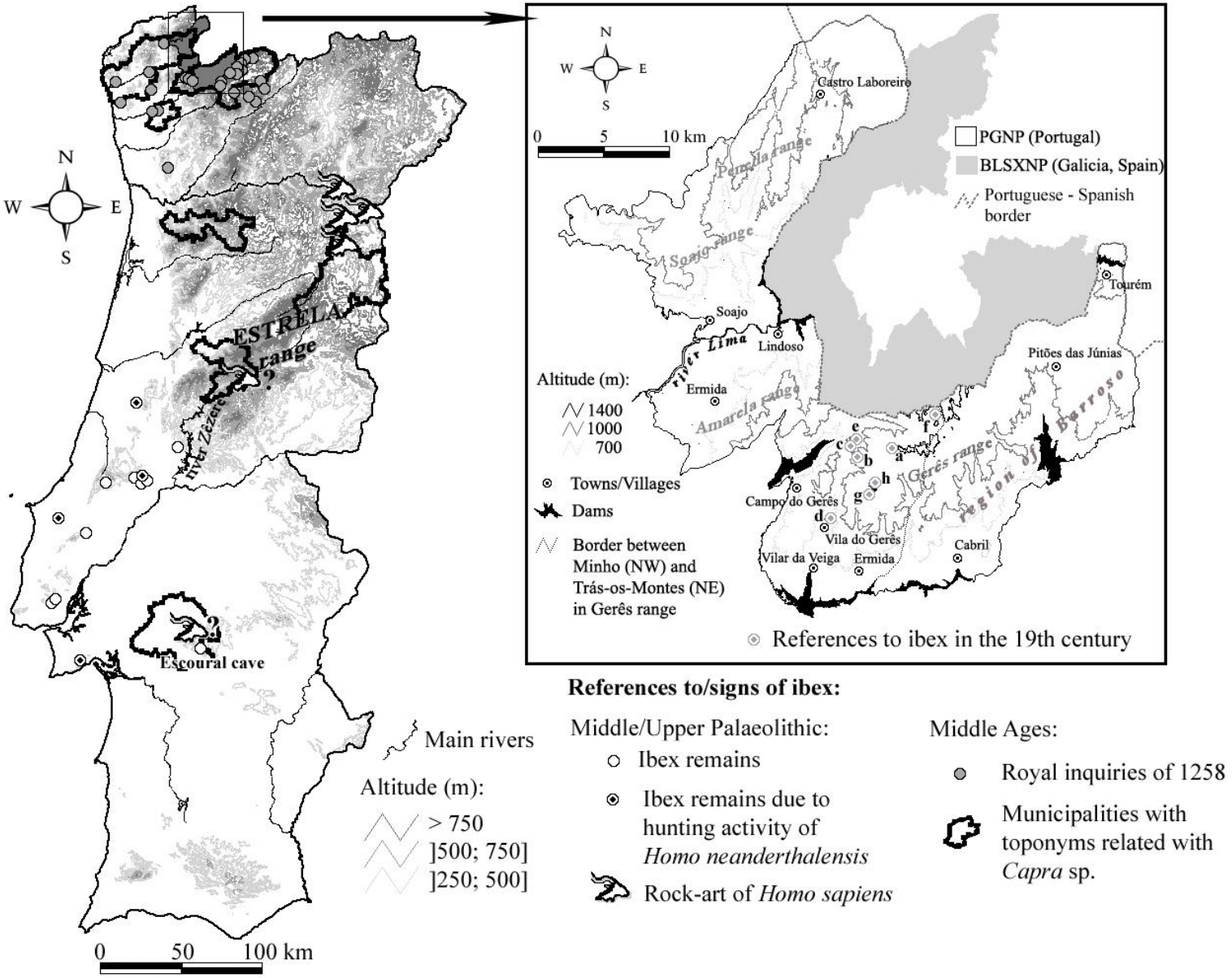

Figure 3. Historical distribution of ibex (*Capra pyrenaica* Schinz, 1838) in Portugal and in the Peneda-Gerês National Park (PGNP, Portugal); BLSXNP – Baixa Límia-Serra do Xurés Natural Park; references to ibex in the 19th century in the PGNP (a, b, c, d, e, f, g, h) are detailed in Table 1.

Pre-Roman and Roman periods. Ibex hunting was probably one of the main activities and an important food supply for the pre-Roman human populations of actual Portugal (Mendes 1968). During the Roman occupation, Strabo (1st century BC-1st century AD; 1903) described that "goat", i.e., ibex or domestic goat, was the principal nourishment of Iberian mountaineers and that the Iberian Peninsula had great abundance of "antelopes (could be ibex, red deer, roe deer and/or *Rupicapra* spp.) and wild horses".

The Middle Ages. The richness of Portugal in toponyms related to the name "cabra" (Portuguese for "goat") such as "Cabril" and "Cabreira" may have originated in the Middle Ages (Vasconcellos 1933) and it is not possible to ascertain if they were associated with ibex, domestic goat or family names (Vasconcellos 1933). These toponyms are mostly located to the North of the river Douro and the proximity of Estrela mountain range (Costa 1706, 1708; Bautista de Castro 1762; Vasconcellos 1884, 1933; França 1917) (Fig. 3). After the foundation of the kingdom of Portugal (1143) the kings made a considerable effort to institute their administrative power over the country and ordered several inquiries during the 13th-14th centuries to enumerate Portugal's patrimony (natural values included), people's obligations, feudal tributes, privileges and product or money taxes (Oliveira 1970; Gonçalves 1998, 2006). The systematic and general inquiries of 1258 show several references to ibex in the northwest (NW) of Portugal, including the northeast (NE) hillsides of Gerês range in the region of Trás-os-Montes (Gonçalves 1998) (Fig. 3). Pereira (1918) and Vasconcellos (1933) argue that some of these references belong to roe deer. Conversely, the descriptions of Peixoto de Azevedo (1692) and Costa (1706) show that natives of the Gerês range clearly distinguished those species. Ibex was a valued game animal since its capture was taxed with the payment of one leg (Gonçalves 1998) or part of the animal (Sousa 1909) to the nobility. However, ibex is not mentioned, as were the wild boar, the roe deer, the red deer and the brown bear (*Ursus arctos* Linnaeus, 1758) in documents from the 13th and 14th centuries devoted to big game hunting and the establishment of penalties to those who practiced it without royal permission (see Pereira 1918). Still, hunting an ibex illegally would be certainly sanctioned with penalties imposed to any big game species.

16th century. There is only one unambiguous reference to ibex by the end of this century and it appears in the description of the Gerês mountain range of Brito (1597). Another possible trace of the species in this century is found in a miniature of the book of Resende (1593) (Fig. 4).

Ibex was neither mentioned in the laws that

Figure 4. Miniature from Resende (1593). A faun with ibex (*Capra pyrenaica* Schinz, 1838) horns?

ruled hunting in Portugal in this century (Portugal 1561, 1565, 1570) nor in descriptions from the Estrela mountain range (Brito 1597).

17th century. Ibex was restricted to Gerês and Amarela ranges (Fig. 3) by the end of the 17th century (Peixoto de Azevedo 1692; Stevens 1705; Costa 1706). According to Peixoto de Azevedo (1692) and Costa (1706), ibex was difficult to capture and tame, vigilant and dangerous to humans during the rut[1]. Locals shot them "from the top of the trees" (Peixoto de Azevedo 1692) and captured them with a rudimentary technique (Fig. 5): a piece of wood, covered with fresh herbs was suspended on the rocky eminences, thus allowing the crash of the ibex when it tried to consume the herb (Contador de Argote 1738; Costa 1980). Ibex meat and leather (e.g., for shoes) were much appreciated (Peixoto de Azevedo 1692).

Ibex is virtually absent in Portuguese wall tiles of this century and the following, in contrast with profusions and detailed illustrations of other wild ungulates. Figure 6 shows the one dog harassing one goat. This most ressembles a domestic goat but we include it here because the scene reminds the frequent use of dogs for hunting in the range of Amarela mentioned by Costa (1706).

18th century. The constraint of ibex to the Gerês range and foothills of the region of Barroso (Fig. 3) is reported since the end of this century (Contador de Argote 1738; Cardoso 1751; Reis 1779; Link 1801; Silveira 1804; Araújo 1949). Ibex was observed "in herds" (Reis 1799), found "not uncommonly" and shot with "high frequency" by the Gerês people (Link 1801). Despite this apparent abundance, only one dead animal was observed by Link and Hoffmannsegg in 1798 (Link 1801) (Table 1). Reis (1779) detailed several medicinal uses of the horns, bladder and bezoars of the ibex of Gerês and referred a personal payment to local hunters for getting ibex bezoars. According to Link (1801), ibex meat was so much appreciated by natives that hunters would sell their skin but not their carcasses (Contador de Argote 1738 and Araújo 1949). Link (1801) observed that ibex skins and horns were used as covers for mules and ornaments in houses, respectively.

19th century. In 1856, Portuguese specimens of ibex were scientifically described for the first time (Barboza du Bocage 1857).

[1] Similar descriptions about the fierceness of ibex males during the rut in the Pyrenees are found in Cabrera (1914) and França (1917).

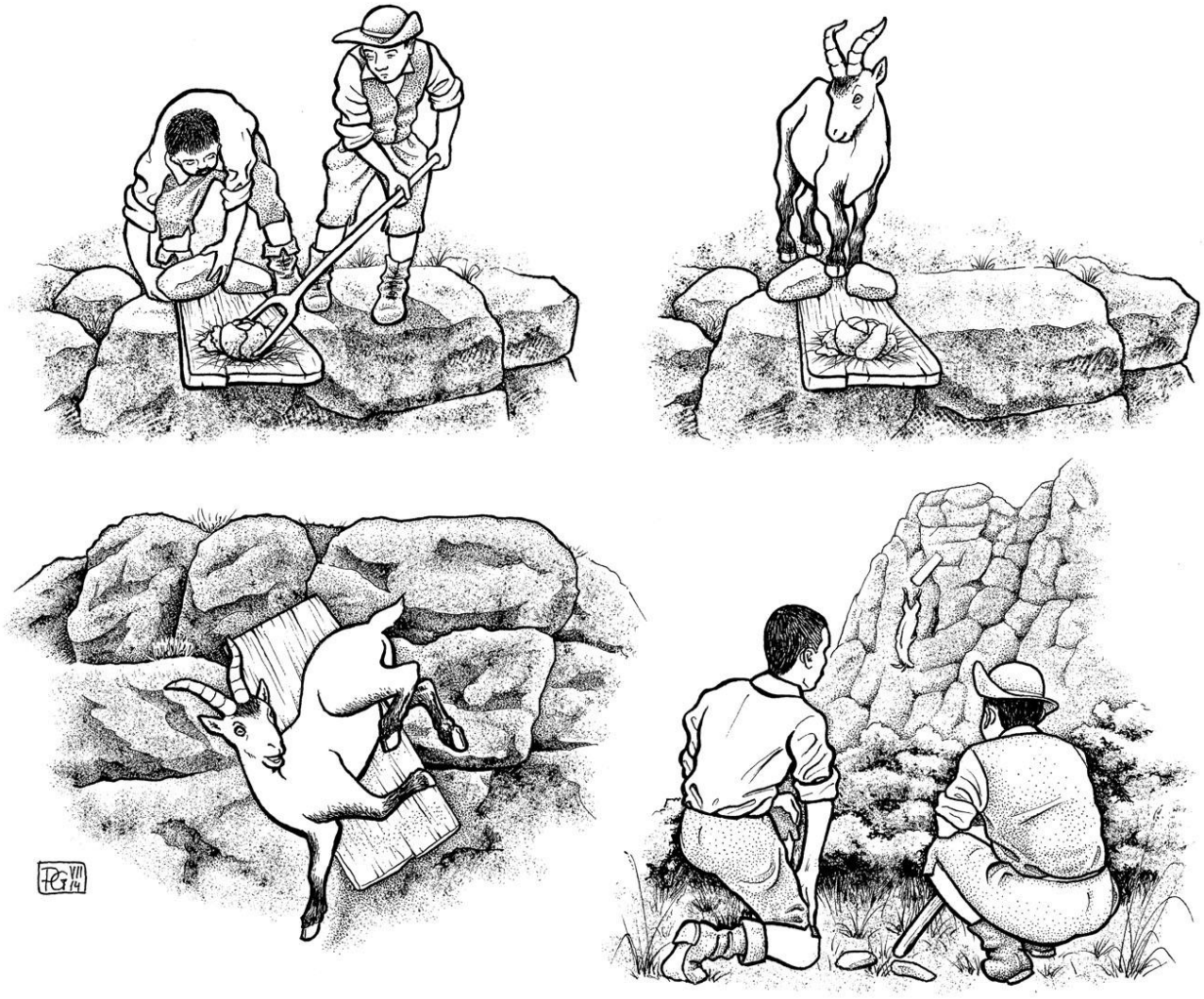

Figure 5. Traps used to capture ibex (*Capra pyrenaica lusitanica* Schlegel, 1872) pictured by Pablo Guerrero from descriptions of Peixoto de Azevedo (1692), Argote (1738) and Costa (1980).

This author considered it restricted and rare in the Gerês range (Barboza du Bocage 1857; Barbosa du Bocage 1863). Others continued suggesting that the species was frequently observed and captured in that range: Perestrello (1850a) wrote that ibex were grouped in herds and its meat was much appreciated by natives, and Leal (1875a, 1886) reported the high frequency with which ibex was shot by locals. These authors were probably reiterating 17th and 18th centuries' sources. In 1890, locals of Soajo enquired by Moller (1894) reported the sporadic presence of the species in Amarela range (Fig. 3). These hunters also stated that ibex did not cross the Lima valley.

Figure 6. Wall tile of 1680 in the "Hunting room" of the Museu Nacional do Azulejo, (Lisboa, Portugal): a dog hunting one goat. Photograph by Natividade Teixeira.

Table 1. Records of ibex (sightings, hunted specimens and other remains) in the 18th and 19th centuries.

Date	Ibex data		Last location known:	Present location:	Reference(s)
	No. of ind (M=male; F=female; ?=probably ibex; Und.=undetermined No.)	Type of data (details)			
? ("ancient")	1M	Specimen remains (horns with bone axis)	In 1917, at Museu Bocage (Lisbon)[2]	Destroyed in museum's fire in 1978?	França (1917)
?	1F	Specimen remains (horns)	In 1917, at Repartição Florestal do Gerês (Gerês)	Unknown	França (1917)
?	1M	Specimen remains (one horn, used as a trumpet, obtained near Lindoso)	In 1917, with Mr. Barroso	Unknown	França (1917)
1798	1M	Specimen (shot)	In 1801, in the private collection of the Count of Hoffmannsegg (Germany)	Museum für Naturkunde (Berlin, Germany)?	Link (1801)
c. 1850	1F	Specimen (hunted in October)	At least since 1857 at Museu de Coimbra (Coimbra)	Museu da Ciência da Universidade de Coimbra	Barboza du Bocage (1857) França (1917) Mendes (1974) Mobil (1974)
c. 1850	1M	Specimen (hunted in November)	At least since 1857 at Museu de Coimbra (Coimbra)	Museu da Ciência da Universidade de Coimbra	Barboza du Bocage (1857) França (1917) Mendes (1974) Mobil (1974)
1852[3]	1	Shot? Alive? (captured in May)	Unknown	Unknown	Parques e Vida Selvagem (2011)
1852[3]	7?	Alive (captured in May)	Unknown	Unknown	Parques e Vida Selvagem (2011)

(continues)

Table 1 (cont.). Records of ibex (sightings, hunted specimens and other remains) in the 18th and 19th centuries. Georreferenced data (a,b,c,d,e,f,g,h) are shown in Figure 3.

Date	Ibex data		Last location known:	Present location:	Reference(s)
	No. of ind (M=male; F=female; ?=probably ibex; Und.=undetermined No.)	Type of data (details)			
1870	7	Observation? Enquiry?	-	-	Barreiros (1900)
1874	1M	Shot (by hunter of Cabril)	Unknown	Unknown	França (1917)
1876	1M	Shot[a]	Unknown	Unknown	França (1917)
1885	1M	Specimen remains[b] (horns; shot)	In 1917, one horn with Mr. Ivo Ribeiro (Terras de Bouro) or Mr. Tude de Sousa Pereira; the other supposedly at Covide	Unknown	França (1917)
1886	Around 12	Observation (in Rio Caldo valley, by Priest Sebastião de Freitas)	-	-	França (1917)
1888	Und.	Observation (by local hunters during battues organized for the royal family by the Priest Sebastião de Freitas)	-	-	Ilustração Portuguesa (1908a) França (1917)
1890	1F	Specimen, captured alive[c]	In 1917, at the Escola de Medicina Veterinária de Lisboa (Lisbon)	Unknown	Oliveira and Vieira (1896) Sousa (1909)
1890	1	Found dead[d]	Unknown	Unknown	Ilustração Portuguesa (1908a)
1891	1	Found dead[e]	Unknown	Unknown	Ilustração Portuguesa (1908a)
1892	Und.	Observation[f]	-	-	Pereira (1908)
1892	Und.	Signs[g]	-	-	Moller (1894)
1893	Und.	Signs[h]	-	-	Pereira (1908)

[2]"Museu Bocage" was the former name of the actual "Museu Nacional de História Natural e da Ciência da Universidade de Lisboa" (Lisbon)

[3]Reference to eight ibex captured by locals in Gerês as a gift to the royal family (Carvalho 1941)

There are several references to collective battues gathering from 20 to 300 men to hunt ibex during this century (Capêlo and Torres 1883; Barreiros 1900; Ilustração Portuguesa 1908a, e; França 1917; Mendes 1968). Table 1 resumes documented data on ibex specimens, hunting, observations and signs until 1893 (see also Fig. 3). Besides references to ibex on Table 1 it is worth to refer fruitless hunting expeditions to ibex reported in 1882 (Capêlo and Torres 1883; none ibex was observed) and in 1891 (Barreiros 1900). Costa (1980) mentioned the killing of "the last ibex" in an indefinite date of the end of this century supposedly published in a hunting-specialized journal which reference was not revealed and remains unconfirmed. The last ibex confirmedly captured in Gerês was an old female in September of 1890 (Table 1; Fig. 7.A). The animal presented signs of senility and illness probably by coenurosis, a parasitic infection caused by *Taenia* spp. (Oliveira and Vieira 1896; França 1917). The last author documented the use of males' horns as trumpets by locals of Gerês and Amarela ranges in Carnival festivities and for announcing and reunite communitarian herds of small ruminants. Predation by carnivores (Moraes 1897; França 1917), overhunting by humans, the low number of females, feeble reproduction, sexual segregation after the rut and the consequent lack of females' protection against carnivores by males, and habitat limitations and diseases (França 1917) were then pointed as the potential causes of ibex decline.

20th – 21st centuries. In the beginning of the 20th century, while ibex hunting was strictly restricted in Spain (Cabrera 1914; França 1917) Portugal was reluctant to assume species extinction (Ilustração Portuguesa 1907, 1908a; Pereira 1908; Oliveira 1931). Therefore, one hunting expedition was organized in a bizarre intent to deny or confirm it (Ilustração Portuguesa 1907, 1908a, b, c). No ibex were observed. In 1908, a false photograph of an ibex captured in the Gerês range between 1890 and 1900 was published in Ilustração Portuguesa (1908d; Mendes 1968) (Fig.7.B). Although Sousa (1909), Cabrera (1911) and França (1917) recognized ibex extinction in Portugal, unconfirmed rumours of individuals observed in Gerês continued to feed false expectations for a long time (see Mendes 1968 and SNPRCN 1991). Bravo (1970) mentions the unconfirmed killing of a male in a hunting expedition in 1921. The presence of the ibex in Portugal was thus reduced to museum specimens of *C. p. lusitanica* (Table 1; Fig. 7.C-E). Ibex reappeared in the Portuguese natural history in 1999 as the result of its reintroduction in Galicia, Spain (Moço et al. 2006; Gama 2008). Presently, a bordering population inhabits the mountain ranges of PGNP Gerês, Amarela (Moço et al. 2006) and Peneda (Figueiredo 2011) (Fig. 1.B). The population size is increasing rapidly

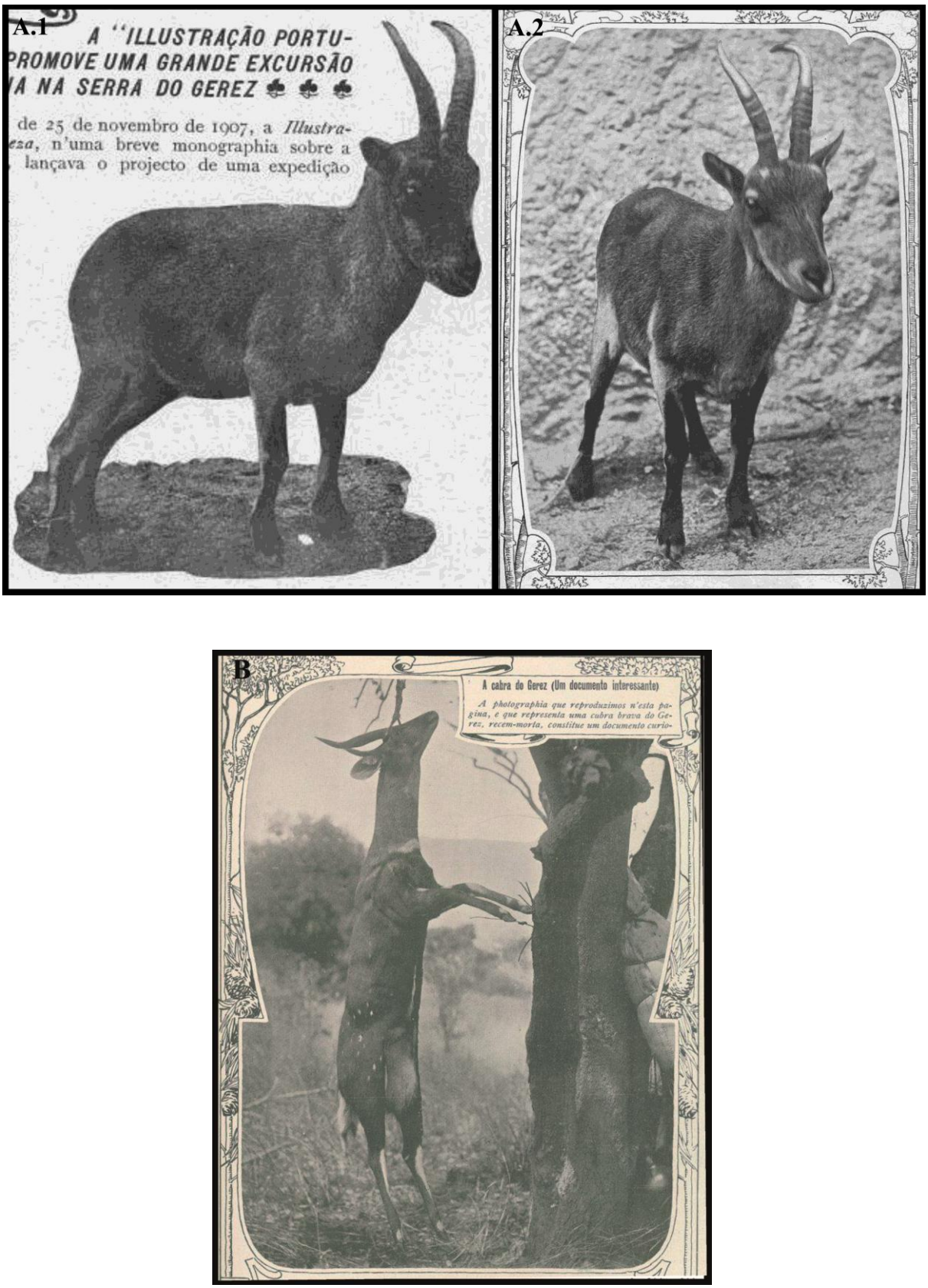

Figure 7. Illustrations and specimens attributed to ibex (*Capra pyrenaica lusitanica* Schlegel, 1872) in Portugal. **A.1-2)** Female hand-captured in Gerês in 1890, photographed by Emilio Biel (respectively, from Ilustração Portuguesa 1908a, b). **B)** A false ibex (likely, a *Tragelaphus* spp.), supposedly captured and photographed (unknown author) in the Gerês range between 1890 and 1900 (Ilustração Portuguesa 1908d); **(continues)**

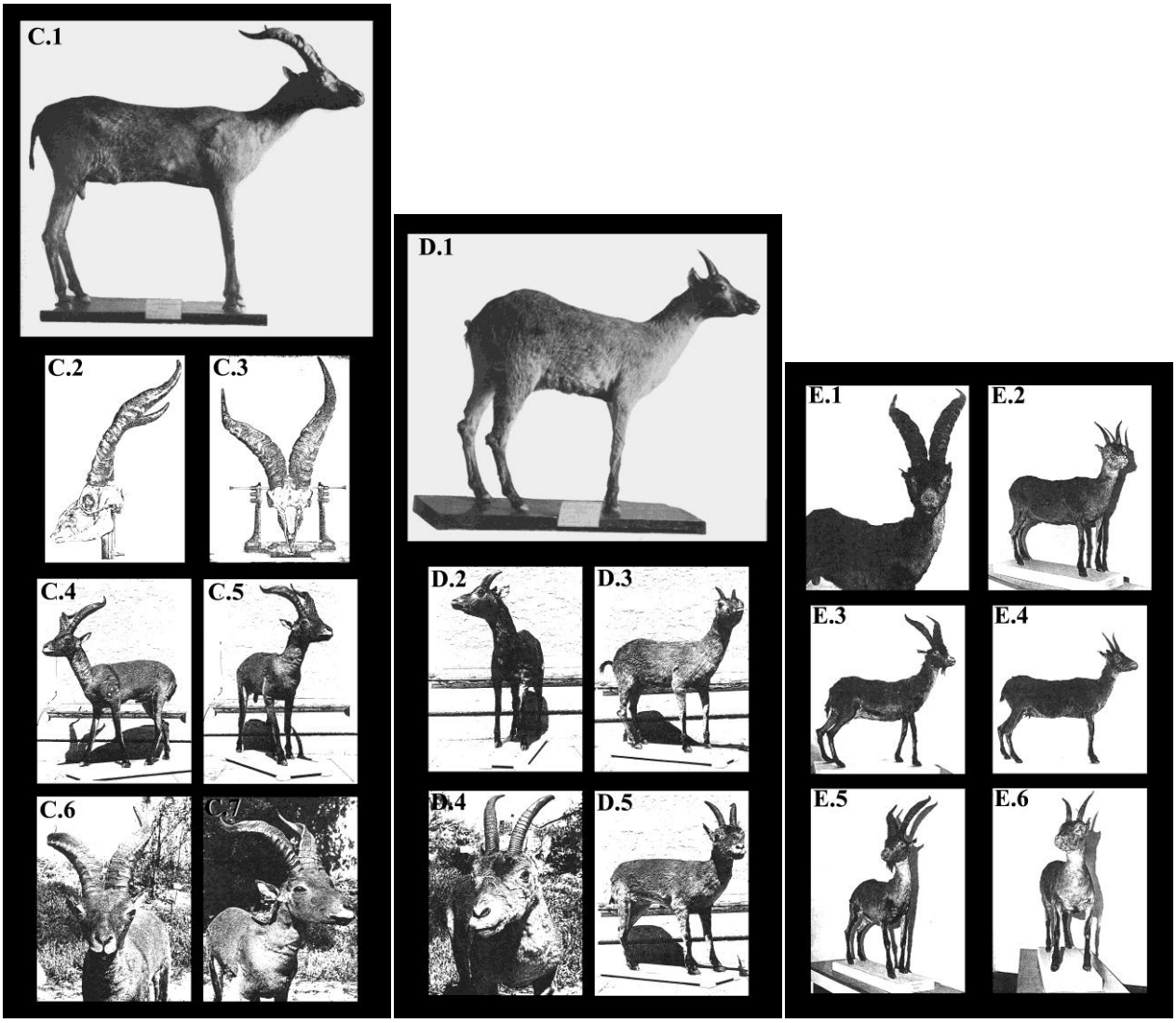

Figure 7. (cont.)
C.1-7) Male specimen of the Museu de Lisboa (Lisbon): **C. 1)** in 1907 (Ilustração Portuguesa 1907); C.2-3) in 1917 (França 1917); **C.4-7)** in 1974 (Mendes 1974; Mobil 1974); note that the specimen was disassembled by França (1917) and posteriorly reassembled. **D.1-5)** Two female specimens in Museu de Lisboa: **D.1)** "female 1" in 1907 (Ilustração Portuguesa 1907); **D.2-3)** "female 1" in 1974 (Mendes 1974; Mobil 1974); **D.4-5)** "female 2" in 1974 (Mendes 1974; Mobil 1974). **E.1-6)** Two specimens of the Museu de Coimbra: **E.1, 3, 5)** male in 1974 (Mendes 1974; Mobil 1974); **E.2, 4, 6)** female in 1974 (Mendes 1974; Mobil 1974).

(Moço et al. 2006; Fonseca et al. 2013) and ibex expansion to the outer limits of the National Park is soon expected (Moço et al. 2007). The proximity of ibex to domestic goats deliberately or inadvertently left by herders in the mountain ranges of the National Park ("feral domestic goats") is considerable (PGNP 2010). Recent research indicated that foraging competition between ibex and domestic goats is likely to occur in case of spatial concurrence (Moço et al. in press) and that changes on the feeding strategy of the ibex during summer in the Gerês range are potentially related with the presence of cattle (*Bos taurus* Linnaeus, 1758) and free-ranging horses (Moço et al. 2013a; Moço et al. 2013b). One case of poaching on ibex has been recently confirmed (Geraldes 2012). An ongoing molecular research detected a low heterozigosity of the founder population probably due to successive bottlenecks from the source population (Serra de Gredos, central Spain) to the BLSXNP (Moço et al. *in prep*).

Humans in Portugal

Prehistory. Many open-air sites and caves, both of residential and temporary character, document the presence of *H. neanderthalensis* in Central and South Portugal from the Middle to the Upper Palaeolithic (Cardoso 1996, 2006) (Fig. 8). According to this author, the exploitation of food and geological resources by these human communities was opportunistic, i.e., according to their availability. Aubry et al. (2012) describe hunter-gatherer societies of *H. sapiens* in the Upper Palaeolithic that made long-distance displacements, or occupied intermediate areas, between the valley of the river Côa and coast shelters in the south, i.e., surrounding the Estrela mountain range (Fig. 8).

There is prolific evidence of human presence in the Portuguese territory during the Neolithic (Jorge and Jorge 1991; Jorge 1992). As examples, the South of Portugal lodges early megalithic constructions dated from the 8th-7th millennium BP, as well as numerous menhirs and dolmens (particularly frequent in Alentejo). Profusions of megalithic constructions and rock-engraving and painting are also found between Mondego and Douro rivers (Jorge 1992; Silva 2012). In this

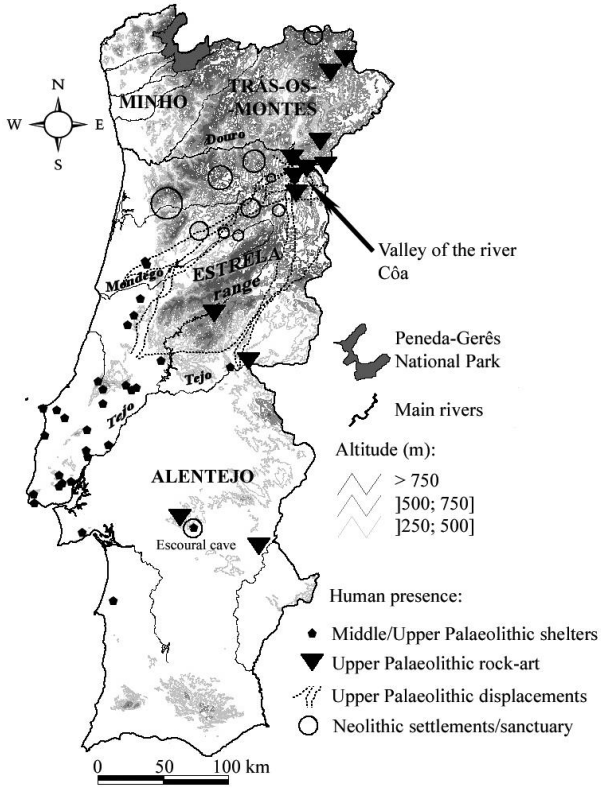

Figure 8. Humans in Portugal during Prehistory**.**

region, human communities were constituted by a small number of individuals sustaining on hunter-gathering and seasonal transhumance of small ruminants in the Estrela range and the platform of river Mondego since the 5th millennium BP (Silva 2012) (Fig. 8). In the North, funerary constructions are mainly concentrated in Minho and the Western part of Trás-os-Montes, including the PGNP region (Oliveira 1970; Baptista 1984; Jorge 1984). This last hypothesizes that Northern human communities from the 6th-5th millennium BP occupied ecologically diversified ranges (including low and high altitude zones), sustained on agro-pastoralism and hunting, used fire to free natural areas for agriculture and their settlements were subject to a certain rotation related to the exhaustion of the soil productivity. Ingenium (1990) and Andrade (1994) place the sedentarization of hunter-gatherer and pastoralism communities of Minho in altitudes above 700 m in the 5th-4th millennium BP.

Pre-Roman and Roman periods. In the beginning of the 3rd century BC the human population inhabiting the actual Minho increased, acquired higher complexity and occupied lower altitude, fertile and closer to the coast valleys, basing their sustenance on agro-pastoralism (Matos da Silva 2008). Urban development below 500 m a.s.l. continued to increase during the 1st and 2nd centuries BC and so did gold and tin exploitation (Andrade 1994). In the south, woodland exploitation was already important (Devy-Vareta 1985).

Romans arrival to “Iberia” or “Hispania” (the current Iberian Peninsula) supposed a warlike situation in many regions, especially in the North and the surroundings of Estrela range (Costa 1708; Leal 1874b). Northern lands delayed legions advances due to orography, worse accesses and tribes’ character. These are described by Strabo (1903) as geographically isolated mountaineers who possessed little and dedicated to warfare. Yet, under Roman occupancy (from the 1st century BC to the 2nd century AD) the cities in the actual Portuguese territory gained importance and promoted the centralization of human density in urban nuclei (Andrade 1994). Strabo (1903) described the emigration of many people from the NW of Iberia to the South side of the river Tagus. Also, the road network (Leal 1874b; Ingenium 1990; Pidal 1992; Andrade 1994) (Fig. 9), the exploitation of silver, tin and gold (Leal 1874b; Strabo 1903; Martins 2008; Silva and Félix 2008; Henriques et al. 2010) (Fig. 9) and the maritime and fluvial traffic trade (Strabo 1903) were improved. Along the roman road that crosses the Gerês range one can still find mileposts dated from the 79 to the 353 years AD (Guia de Portugal 1965). The lands to the North of the river Tagus were considered fertile, with abundance of livestock and cereal production, but inlands were for the most part

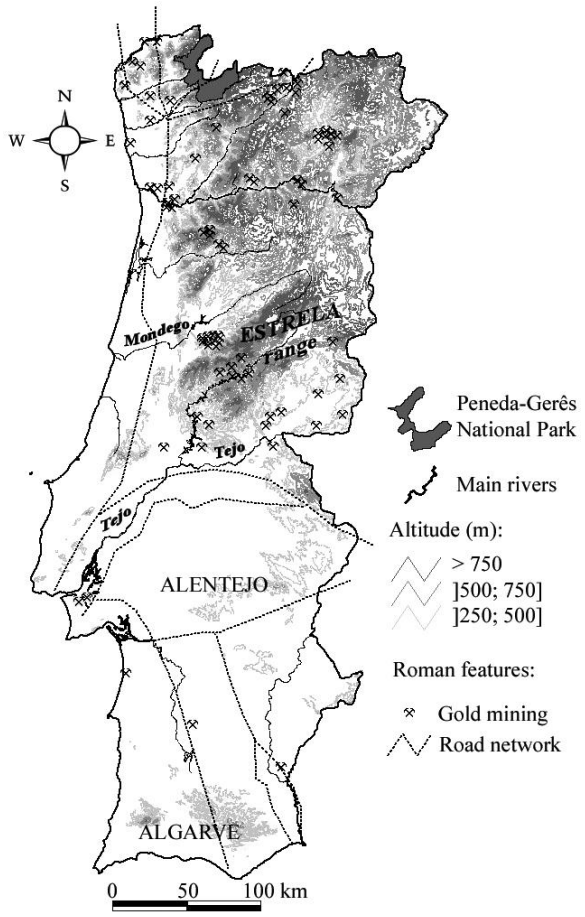

Figure 9. Road network (Pidal 1992; Andrade 1994) and gold exploitation (Martins 2008; Silva and Félix 2008; Henriques et al. 2010) in Portugal during the Roman Empire.

unfarmed (Strabo 1903). These lasts provided considerable quantities of wood to Alentejo and Algarve in (Devy-Vareta 1985). In the Tagus basin and to the South, Iberia produced much appreciated wine, corn, olive oil, honey and wax, pitch, dye (probably obtained from *Dactylopius coccus* Costa, 1835), salt and also timber for shipbuilding (Strabo 1903). Alentejo was considered the granary of Hispania (Perestrello 1850b) and Algarve had great quantity of livestock (Strabo 1903). Given the importance of wool and rams production in Turdetania (the administrative region that included Algarve in Iberia), we deduce that Algarve's livestock was mainly constituted by small ruminants.

The Middle Ages. After Romans departure from the Iberian Peninsula, many regions of actual Portugal were under an intermittent warlike situation for centuries, e.g., during the invasions of the Swabians (4th century) and the Visigoths (5th to 6th century). During the three centuries of Visigoths occupancy, the urban nuclei decayed in organization and Northern communities re-adapted to a self-management system mostly based on pastoralism, less demanding in hand labour than agriculture, and metallurgy. The void of central authority contributed to reinforce the cohesion of these people's autonomy and communitarian lifestyle (Andrade 1994). Vikings raids during the 8th century (Leal 1874b; Andrade 1994), Arabs' arrival in the 8th century and the Quest of Christian kingdoms against the Arabs (from the 8th to the 12th century) that wiped out the Iberian Peninsula from the North to the South (Cruz 1983), pushed Northern people further to higher inlands (Silveira 1804), debilitated their incipient agriculture even more and increased their dependence on livestock and natural resources (Oliveira 1970; Ramos 1991; Gonçalves 1998). As a critical example, palynological data revealed deforestations in the highest peaks of the Gerês range during the 9th-11th centuries, probably due to livestock extensively raised (Devy-Vareta 1985). According to Leal (1874a), people of

Tabuaço (see region of Beira in Fig. 1.B) sustained their economy on domestic goats since the 11th century. During their dominance in the Iberian Peninsula, the Arabs exploited woodlands (timber, charcoal and cork) and improved agriculture and extensive pastoral activities in Alentejo and Algarve (Devy-Vareta 1985).

In the 12th century, the Christians were not only fighting against the Arabs but also among each other for the foundation of the kingdom of Portugal (Cruz 1983) (Fig. 10).

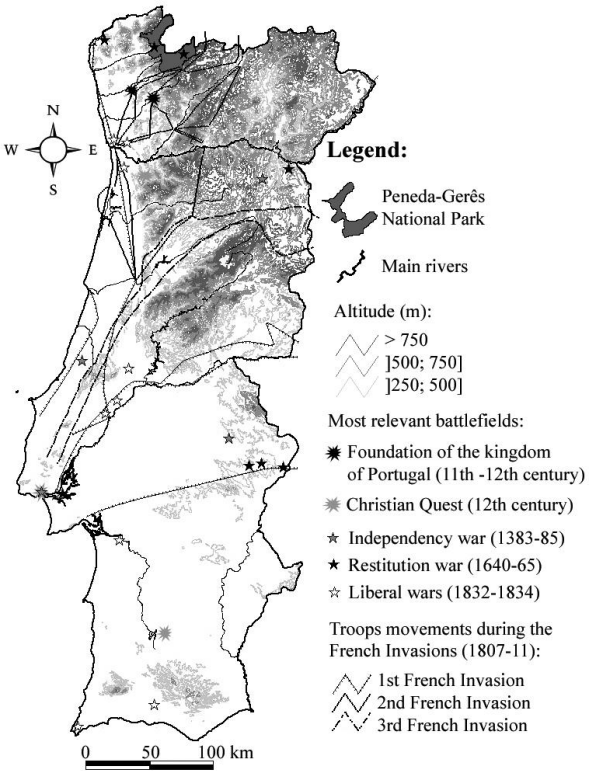

Figure 10. Wars in Portugal between the 11th and the 19th centuries (Leal 1876; Guia de Portugal 1965; Cruz 1983; Saraiva 1983a, b, c; Sertão 1983).

After Portugal's foundation, the human population increased, particularly in Minho (Devy-Vareta 1985; Andrade 1994). Important cities resurged and shipyards were established near the coast, favouring the contrast of human density between the littoral and inlands. This increment on humans' density and maritime external trade implied a crescent demand of firewood and timber for handicraft and shipyards (Devy-Vareta 1985). Also, many forests and shrubland were cleared (frequently burned) for agriculture. Consequently, in the 13th century the Portuguese forests were already much fragmented, particularly near urban nuclei of the littoral and areas of lower altitude. The king, the nobility and the high clergy practiced big game hunting frequently and created many exclusive reserves for that purpose (Pereira 1918; Mendes 1968; Oliveira 1970; Devy-Vareta 1985, 1986; Ramos 1991), e.g. in Soajo and Gerês ranges. The inhabitants of many villages of the actual PGNP were excused to participate in war conflicts but had the obligation to guard and maintain defensive structures of the border with Spain (Costa 1706; Leal 1874a, c; Oliveira 1970). This guarding, both in terms of structures and peoples' movements, was more intense in the NW (Minho) than in the NE (Trás-os-Montes) of the Gerês range (Leal 1886; Sousa 1909; Ingenium 1990; Gonçalves 2006) (Fig. 1.C).

Gradually, the settlement of the royal court in Lisbon displaced the kings' attention to the South and the Northern region fell in a state of "immobility, conservatism and poverty with the usual outcome of demographic deflation caused by continuous emigration" (Andrade 1994). According to this author,

progresses on the commercial trade accentuated the asymmetries between the littoral and the interior. Here, some valleys were also densely occupied while highlands were inhabited by low density, agro-pastoral transhumant communities, with an important communitarian hunting activity for subsistence (e.g., predators' control, obtainment of meat and skins). For some, hunting was a specialized task as important as, or even more than, agriculture (Oliveira 1970). Small ruminant flocks were apparently ubiquitous and more frequent than cattle (Andrade 1994). According to this last, this type of livestock was more expensive and unattainable to the majority of peasants and was frequently shared by several persons or belonged to all the community[4].

In the 14th century, the conflicts between Portugal and the kingdom of Castela (part of actual Spain) augmented people's poverty and dependence on natural resources (Saraiva 1983a) (Fig. 10). Pastoral activity intensified in Alentejo (Devy-Vareta 1985). Hereinafter, the increment on the Atlantic commercial trade and Portugal's maritime expeditions overseas, the demands of firewood for household and of ash and charcoal for industry (e.g., soap and glass industries, respectively), the intensification of woodland clearings for agriculture (frequently using fire) and the promotion of pastoral activities entailed the exploitation and destruction of more areas of woodland in several regions of Portugal, including massive deforestations in the Gerês range (Freire 1739; Perestrello 1850a; Sousa 1908; Devy-Vareta 1985, 1986; Reboredo and Pais 2014). The nobility exchanged big game hunting recreation by maritime expeditions and this diminished the incipient protection of woodlands so far existing for hunting reasons (Pereira 1918; Devy-Vareta 1985, 1986). According to this last, in periods of recrudescent crisis rural populations emigrated or turned to illegal hunting, cuts of woodland and charcoal production to guarantee their subsistence. By their part, landowners traded woodland products illegally to secure their profits. From the 15th century forward the Portuguese human population size registered a substantial increase (Fig. 11).

16th century. In the 16th century Portuguese woodlands were seriously depleted and great extensions of the mountain ranges were deforested and their soil degraded (Devy-Vareta 1986). This author reports reforestations that favoured *Pinus* spp. diffusion and vineyards expansion in Minho from this century on.

The few hunting reserves that remained in Portugal were mainly located to the South (Ramos 1991). The number of weapons per capita would be high, since the law obliged

[4] Before the use of artificial insemination of cows, the communal property of one cattle male for breeding was usual in many villages of the region of Barroso (see Fig. 1). Traditional bullfights (in Portuguese, "chega de bois") between cattle males of different villages were frequently organized by locals. Currently, some private owners continue to arranje these events.

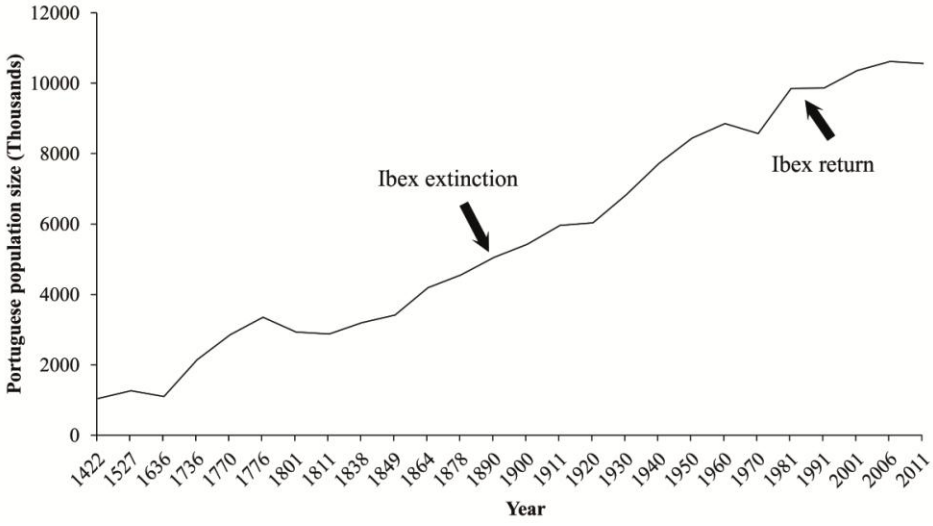

Figure 11. Trend on human population size in Portugal from the 15th century to 2011 (adapted from Valério 2001 and INE 2002, 2007, 2012).

nobles and servants to possess a certain number (spears, swords and also arquebuses), proportional to nobles' properties (Portugal 1570). In the region of Estrela, natives usually carried weapons (Brito 1597). With the annexation of Portugal by Spain in 1581, more hunting reserves were devoted to abandonment and it was possible to freely hunt in most the country (Ramos 1991). Big transhumant herds of sheep (*Ovis aries* Linnaeus, 1758) from Alentejo and Spain grazed in Estrela range (Brito 1597; Devy-Vareta 1986).

17th century. The restitution of Portugal as an independent kingdom in this century entailed battles especially in the South but also in the region of the actual PGNP (Leal 1876; Oliveira 1970; Sertão 1983; Ingenium 1990) (Fig. 10). The relevance of pastoralism and hunting to the sustenance of rural people was well reflected by Stevens (1705) and Costa (1706, 1708, 1712). Charcoal was produced in large quantities in Minho, Trás-os-Montes and Estrela range. Minho was the most populated province of the country (Leão 1610). This province was famous for its great quantity of livestock (400000 bovids and small ruminants according to Stevens 1705) and game species, guns, gunsmiths, dogs, birds of prey and hunters' aim (Leão 1610; Costa 1706; Mendes 1968). Its fertility and water abundance contrasted with the low human density, poorness and dryness of Trás-os-Montes (Leão 1610). The Gerês range was practically uninhabited, especially its NE foothills (Costa 1706). Population's poverty was documented in the Estrela range, where people subsisted mainly from livestock and chestnut (Leão 1610; Stevens 1705). Big herds of sheep from Alentejo and the basin of Guadiana continued to graze in Estrela's foothills during great part of the year (Leão 1610; Stevens 1705).

18th century. In this century Portugal produced wheat, corn, rice, olive oil, honey, silk and grazing ground for livestock. Cow milk was rarely found outside big cities and the most frequent in rural villages was goat's. Trás-os-Montes and Alentejo were the less prosperous provinces, their lands and livestock being majorly owned by nobility. Pastoralism was closely associated with terrains of poor quality for agriculture in Trás-os-Montes, Montemuro range and Alentejo (Freire 1739; Link 1801) and of favourable conditions for the maintenance of grazing grounds in Minho and in Estrela range (Freire 1739; Link 1801; Perestrello 1850a, b) (Fig. 1.B). The use of fire to promote the sprout of fodder for livestock extensively reared was frequent in the ranges of Gerês and Estrela (Contador de Argote 1738; Link 1801). Charcoal production was reported in Minho, Trás-os-Montes, Estrela range and Alentejo by Link (1801).

Hunting in Portugal was somewhat constrained by limitations to the access to private properties (Ramos 1991). In the Gerês range, people hunted big game freely, including ibex (Contador de Argote 1738; Cardoso 1751; Araújo 1949). This last describes the robustness, nimbleness and practice in the use of guns of youngsters of this mountain range.

Minho was the most populated region of Portugal and thus called "the continued city" by Freire (1739), but the contrast between its littoral and inlands was considerable (Homem 1794) (Fig. 12.A). There was also a large disparity on human density between Minho and Trás-os-Montes, notorious in the Gerês range (Freire 1739). The development of the thermal facilities of "Caldas do Gerês", located in Vila do Gerês (Fig. 1.C) in the beginning of the century propitiated the affluence of tourists and the opening of many accesses to the surrounding mountain ranges (Henriques 1726; Maia 1963). Yet, local communities of pastoralist continued living according to their ancient self-sustaining and communitarian lifestyle, e.g., in the alternating system of livestock guarding (Contador de Argote 1738; Link 1801; Sousa 1927). The quantity of cattle in the highlands of Gerês between spring and autumn was considerable. In accordance with the previous described for Minho and Trás-os-Montes, the NW hills of the Gerês range were intensively cultivated with terraces of fodder for livestock (Link 1801), presently known as "prados de lima", while its NE hills were mostly inhabited (Fig. 12.A) and uncultivated.

19th century. This century was marked by the French Invasions, which particularly affected the Northern region in 1809 (2nd invasion; Guia de Portugal 1965; Saraiva 1983b) (Fig. 10). The Gerês range was one important stage of quarrels between the civil guerrilla and the French troops (Kingston 1845a; Leal 1874c; Sousa 1908). By the end of these wars the national state of poverty was extreme. Agriculture and livestock had

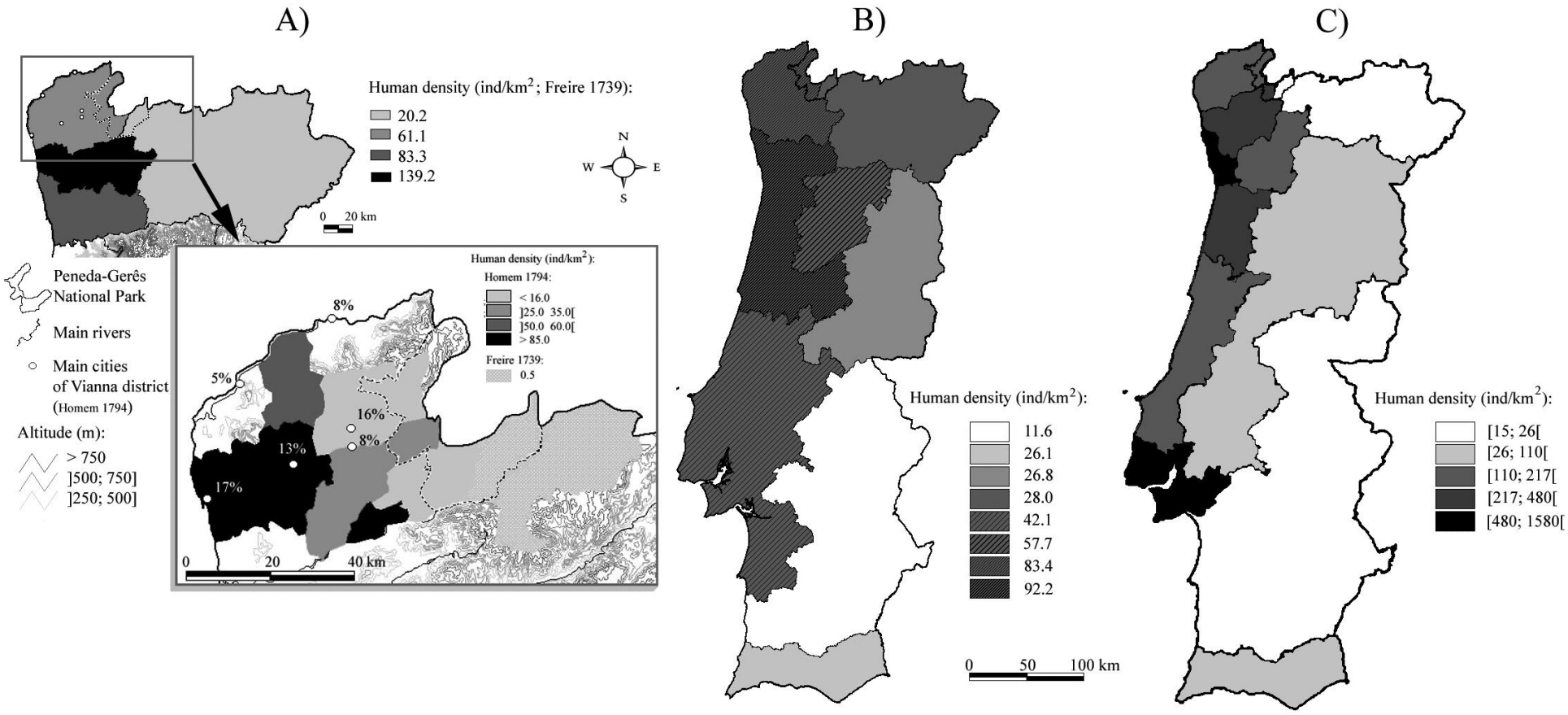

Figure 12. Geographic distribution of the human density in Portugal: **A)** demographic contrast between the littoral and inlands of the North in the 18th century (Freire 1739); the enlarged area presents the human density in the municipalities of Vianna (Homem 1794) respect to the total population of that district (Homem 1794); **B)** in the 19th century (Leal 1874b); **C)** presently (adapted from INE 2012).

been decimated (Leal 1880) and, for many, survival depended on the exploitation of natural resources (Leal 1874c). To the French Invasions followed the Liberal wars (Saraiva 1983c) (Fig. 10) and, after these, a popular revolution ("Revolução da Maria da Fonte") that burst out in the region of Minho and spread all over the country (The "Patuleia" civil war in 1846-1847; Leal 1874b).

Corn, rye, potatoes, legumes, fruit, linen, wine, olive oil, honey and marine salt were amongst the most important Portuguese products (Reichard 1820; Leal 1874b). As shown in Figure 13, the rearing of livestock was also considerable, particularly in the littoral North, Minho, Estrela range, Trás-os-Montes, the basin of Tejo and Alentejo. Cattle were mainly produced between the rivers Cávado and Vouga, where the quality of its meat and importance for work power and manure in agriculture were much valued (Link 1801; Perestrello 1850b). In Minho, Perestrello (1850a) accounted for 400000 bovids and horses and reported the furtive introduction of livestock from the Spanish region of Galicia (Fig. 1.C). The region of Barroso was famous for the quantity and quality of its cattle as well, having more than 12000 of these animals (700 to 800 in Pitões das Júnias, Fig. 1.C) (Leal 1875a, 1876). Horses, mules and donkeys were also used as work power in agriculture and for transportation in mountainous and rocky environments (Perestrello 1850b) like Trás-os-Montes that had but poor road accesses (Leal 1875b; Kingston 1845b). Swine were extensively raised in higher numbers in Alentejo and Trás-os-Montes (Perestrello 1850a, b; Leal 1874c, 1880). Small ruminants were most abundant in Minho (200,000 reported by Perestrello 1850a) and the mountain ranges of Beira and Alentejo (Kinsey 1829; Kingston 1845b; Perestrello 1850a, b; Leal 1874b). This livestock was frequently raised in areas of barren lands for agriculture, less peopled and economically depressed, like Trás-os-Montes and Beira (Kingston 1845b). In the Soajo range (PGNP), small ruminant herds summed more than 1000 domestic goats and many sheep, these lasts a source of meat, wool and "burel" for clothing (Oliveira 1970). The transhumant herds between Alentejo and Beira were mainly constituted by sheep. Domestic goats were usually produced for local consumption and predominated in the region of Barroso (Fig. 1.C).

The exportation of wine from the basin of the river Douro (Reichard 1820) and, from the middle of the century henceforth, of cattle, swine, sheep's wool and dairy products (Fig. 14) yielded important economic incomes (Leal 1874a; Leal 1875a; Perestrello 1850a, b). Vegetal charcoal was produced in Minho, Trás-os-Montes, Estrela range and Algarve (Kingston 1845b; Perestrello 1850a; Leal 1874b, 1880, 1886). Forests' burning was pointed as the cause of the decline of the wild boar in the region of Barroso by Leal (1875a). This ungulate and the roe deer

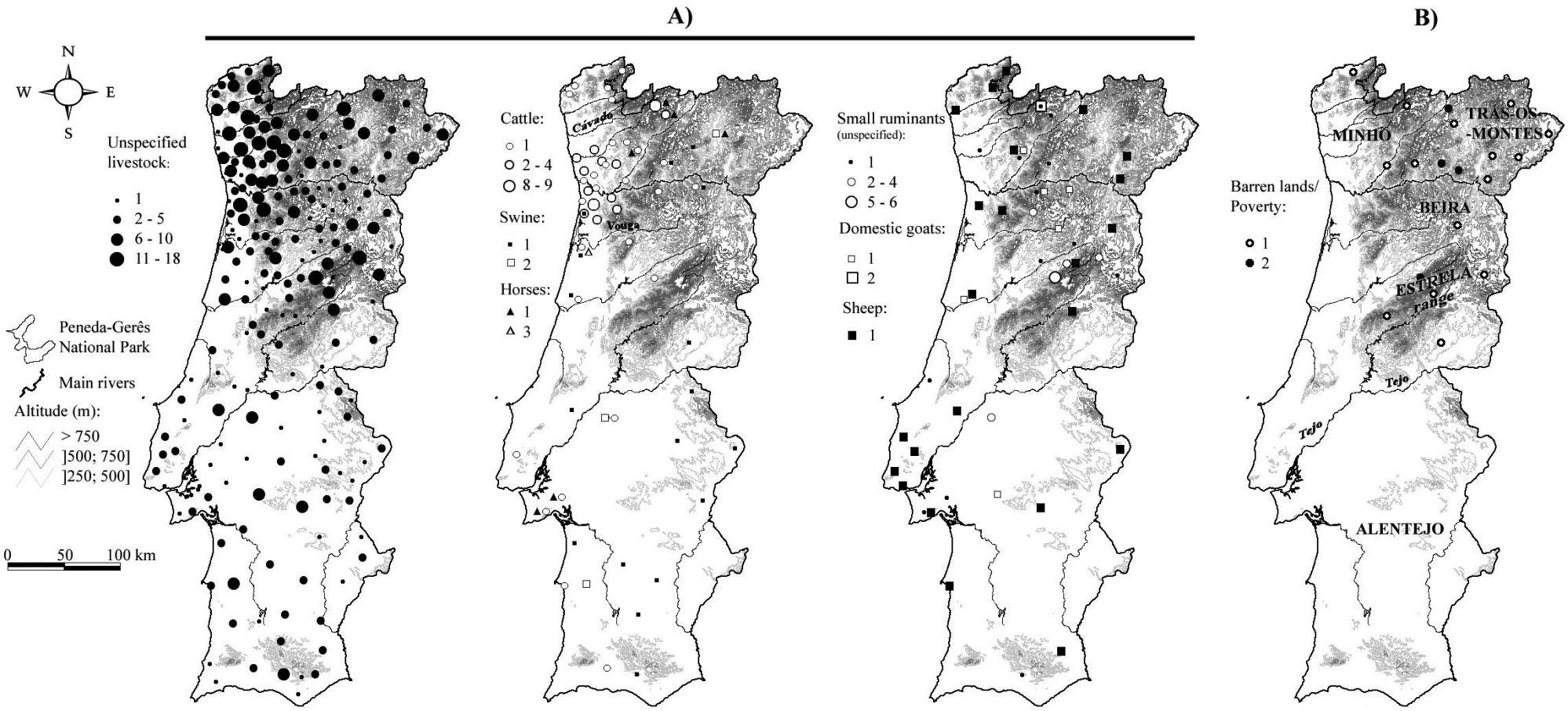

Figure 13. Livestock production and agricultural poverty in Portugal during the 19th century (from Leal 1874a, b, c; 1875 a, b; 1876; 1878; 1880; 1886): **A)** livestock production; **B)** areas with barren lands for agriculture/extreme poverty. Legend numbers represent "No. of references/municipality".

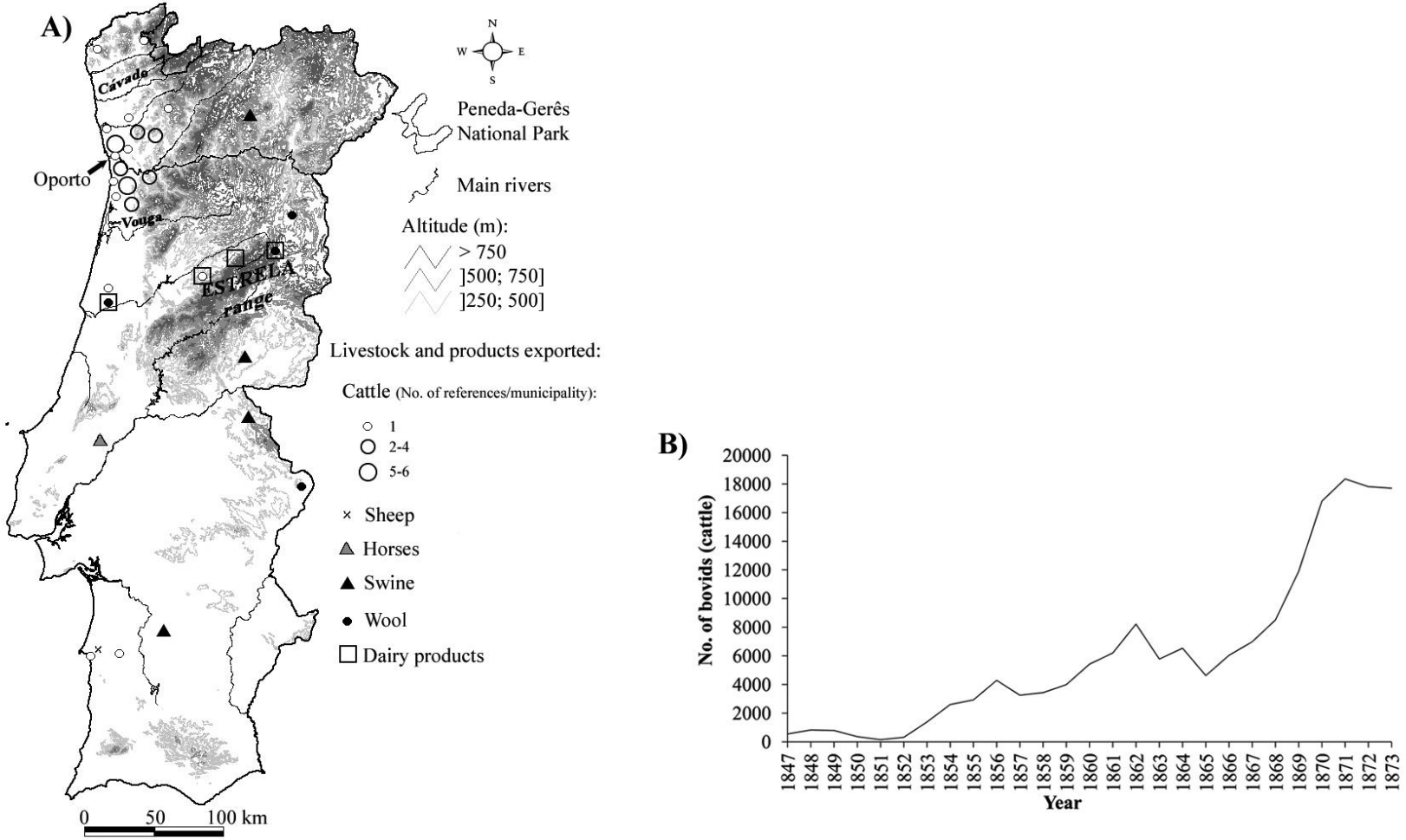

Figure 14. Exportation of livestock, dairy products and wool in Portugal in the 19th century. **A)** Origin of products (Leal 1874a,b,c; 1875a,b;1876;1878;1880;1886); **B)** evolution of cattle exportation from Oporto to England between 1847 and 1873 (Leal 1875a, pp 129).

were considered abundant in Alentejo and Beira and the red deer was restricted to private reserves (Perestrello 1850b). The hunting pressure was high in the the Estrela range and Algarve (Leal 1874a), Figueira de Castelo Rodrigo and Almeida (Kingston 1845 b) (Fig. 1.B). According to Kingston (1845a), Portuguese shepherds usually carried guns and were accompanied by dogs (Fig. 15).

Figure 15. "Goatherd of the Serra d'Estrella" (Kingston 1845a; pp 9).

In the Gerês range, the most skilled hunters of ibex were from Vilar da Veiga, Ermida, Cabril and Campo do Gerês (Barboza du Bocage 1857; França 1917) (Fig. 3). In terms of human occupancy, the contrast between the littoral and inlands of Portugal was evident (Fig. 12.B), and so did the disproportion in human density between the NW and NE ranges of Gerês (Leal 1874b). As examples, the number of inhabited houses in Pitões das Júnias decreased about 50% between 1757 and 1876 (Leal 1876) while in Vilar da Veiga the number of houses increased in 52% between 1768 and 1878 (Carnarvon 1848 and Perestrello 1850a) (Fig. 1.C). This disparity augmented during the summer, when the thermal springs of Caldas in Vila do Gerês received hundreds of visitors (Leal 1886). At the same time, the mountaineers of the actual PGNP maintained their self-ruling lifestyle based on livestock (Leal 1875a, b; 1878). In the words of Leal (1886), these communities were "small republics similar to those of our ancestors before the Roman domain" with popular "courts" or "joints" that ruled the management of livestock and hunting[5]. Like Araújo (1949), Leal (1886) underlined the aptitude of Gerês' youngsters to a rough life and their ability in the use of fire guns, of which each house was provided with a private arsenal. As today, livestock was conducted to the higher pastures of this range in summer and the partition of the grazing grounds was frequently controversial between concurrent herders of different villages (Leal 1878). In Leal (1874b) we find descriptions of the careless guarding of cattle, goat and sheep in this range, "almost as wild as the Gerês itself" (p275). By the end of the century the state of degradation of the pristine vegetation of

[5] Traces of this communitarian lifestyle persist today, e.g. the joint of the "vezeiros". This joint manages the collective herds of livestock (cattle or small ruminants) from different owners in which each (or a representative) guards the herd a number of days according to his/her number of animals. Traditionally, the "vezeiros" are also responsible for the maintenance of pedestrian trails and traditional stone shepherds' shelters (localy named "fornos") in the mountain range. Money or working fines are applied to the offenders of the joint's rules.

Gerês was severe due to overgrazing and human-induced fires used to promote the sprout of fodder for livestock (Pereira 1908; Sousa 1908; Neves 1952). The Portuguese Government initiated the protection and management of this range in 1888 with restrictions in the use of grazing grounds and systematic reforestations (Pereira 1908; Sousa 1908; Guia de Portugal 1965; Neves 1952; Mendes 1968). Two collateral effects were the introduction of exotics and the opening of new accesses to the mountain range (Pereira and Rodrigues 1907; Sousa 1908; Neves 1952).

20th – 21st centuries. In the beginning of the 20th century Vila do Gerês and its thermal springs were already amongst the most important national tourist destinations, especially from the end of the spring to the middle of the autumn (Maia 1963). Meanwhile, following their secular traditions and scarce possibilities the majority of inhabitants of the actual PGNP continued to subsist on livestock (Sousa 1908; Neves 1952; Oliveira 1970). During the 1950's some communities of the Gerês range were in such poverty that used higher altitude pastures to cultivate rye (António Rebelo and António Pires, personal communication). During the Second World War and many years after its end, fuel scarcity propelled charcoal production in Portugal. Traces of this activity are still visible in the highest areas of the Gerês range (António Rebelo and authors' personal observation). The exploitation of molybdenum and wolfram in Gerês was also important between the 1940's and the 1970's (Barbosa 2013).

Mineral exploitation, stone pits, dams construction for hydroelectric production (Fig. 1.C), the consequent opening of many car and pedestrian accesses and human-induced fires shaped and destroyed wide areas of high ecological and cultural value in the PGNP (Maia 1963; Mendes 1968; Oliveira 1970; Neves 1976; Pimenta 1983). One example was the flooding of the village Vilarinho da Furna in 1971 by the dam between the ranges of Gerês and Amarela (Fig. 1.C). Accesses opening favoured the increment of touristic pressure in sensible zones (Maia 1963; Ingenium 1990). According to Pimenta (1983), poaching, mainly by outsiders (see also Neves 1952) and the increase of feral dogs (Soares 1987) were other factors affecting PGNP's biodiversity in the 1980's. The great number of feral dogs in the PGNP was reported by Álvares (2011).

By the end of the 20th century, PGNP was considerably humanized, with about 10000 - 15000 inhabitants distributed by 114 population nuclei (Ingenium 1990). Nevertheless, some municipalities registered important population decreases and ageing. As a critical example, the human population of the municipality of Montalegre (Fig. 12.A) decreased nearly 50% between 1979 and 1999 (Pôças et al. 2011). Nowadays, the contrast

between the littoral and inlands of Portugal and PGNP is evident (Fig. 12. C).

Livestock production in Portugal has been changing in the last decades. Particularly since the 1970's, the production of small ruminants has been decreasing and that of cattle is increasing to some extent (FAOSTAT 2013). In the PGNP, livestock extensively raised is generally under a decreasing trend (Oliveira 1970; ICNB 2010a; Álvares 2011) but the density of small ruminants and cattle in this protected area and surrounding municipalities was yet considerable by the end of the 20th century (Fig. 16). In the municipality of Montalegre, the number of cattle increased from 11820 in 1979 to 12429 in 1989 and 14159 in 1999 (Pôças et al. 2011) due to agro-environmental

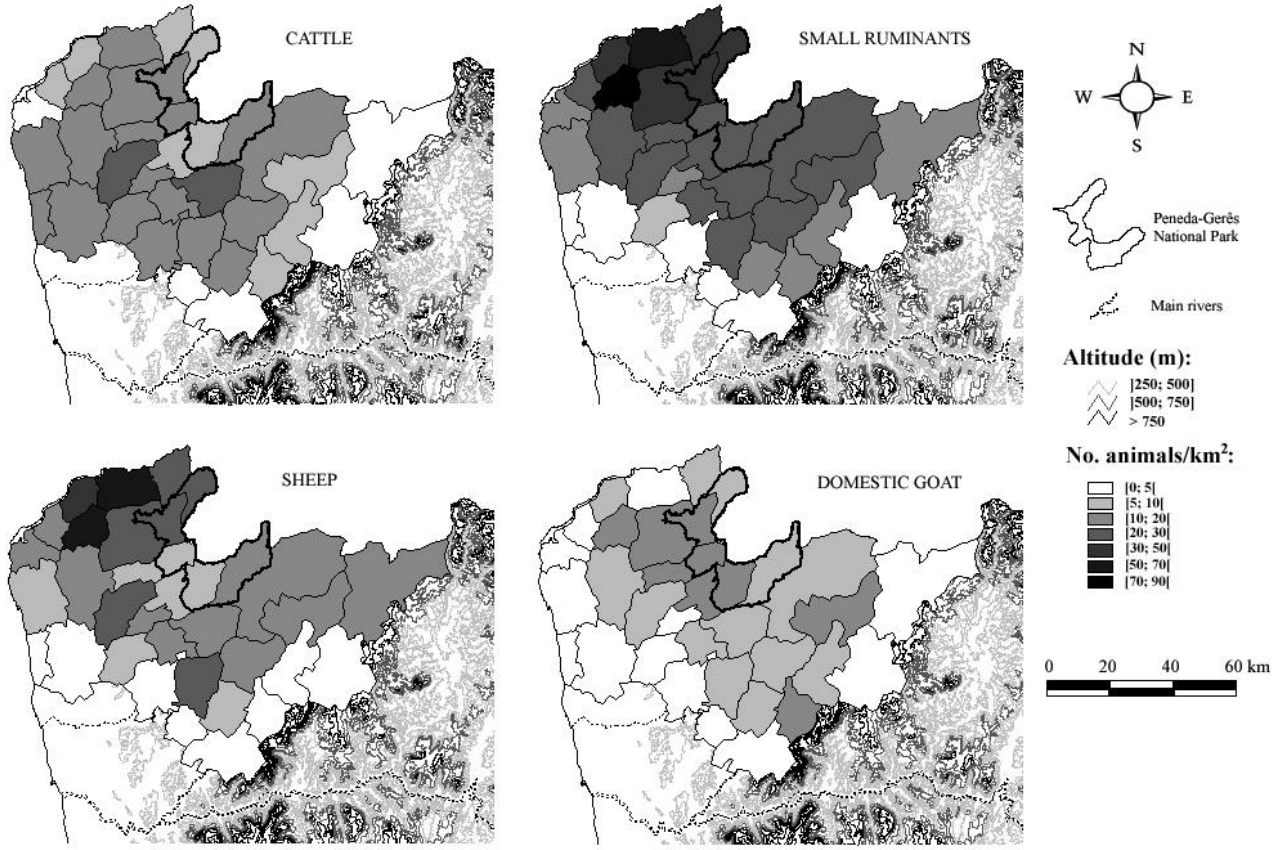

Figure 16. Livestock density (No. of animals/km2) in the Northwestern of Portugal by the end of the 20th century.

funding of the autochthon cattle "Barrosã". Transhumance of cattle is practiced in PGNP as in ancient times: herds gradually ascend to highest pastures from May to September and return to lowlands by the end of the summer. The herds of small ruminants use higher grazing grounds frequently during spring and summer and return to villages every day. Nevertheless, as previously explained, feral domestic goats are commonly observed in the mountain ranges of PGNP. The ineffective guarding of horses and cattle is frequent (PGNP 2010; ICNB 2010a; Moço et al. 2013b). Between 1997 and 2006

we detected punctual outbreaks of sarcoptic mange (*Sarcoptes scabiei* De Geer, 1778) and brucellosis (*Brucella abortus* Schnidt, 1901) in domestic small ruminants flocks (authors' personal observations).

The area (km^2) annually affected by fire in Portugal increased in the last decade respect to the previous (DGF 2002; AFN/DUDF 2012; Fig. 17). This trend includes Portuguese protected areas and PGNP is one of the most

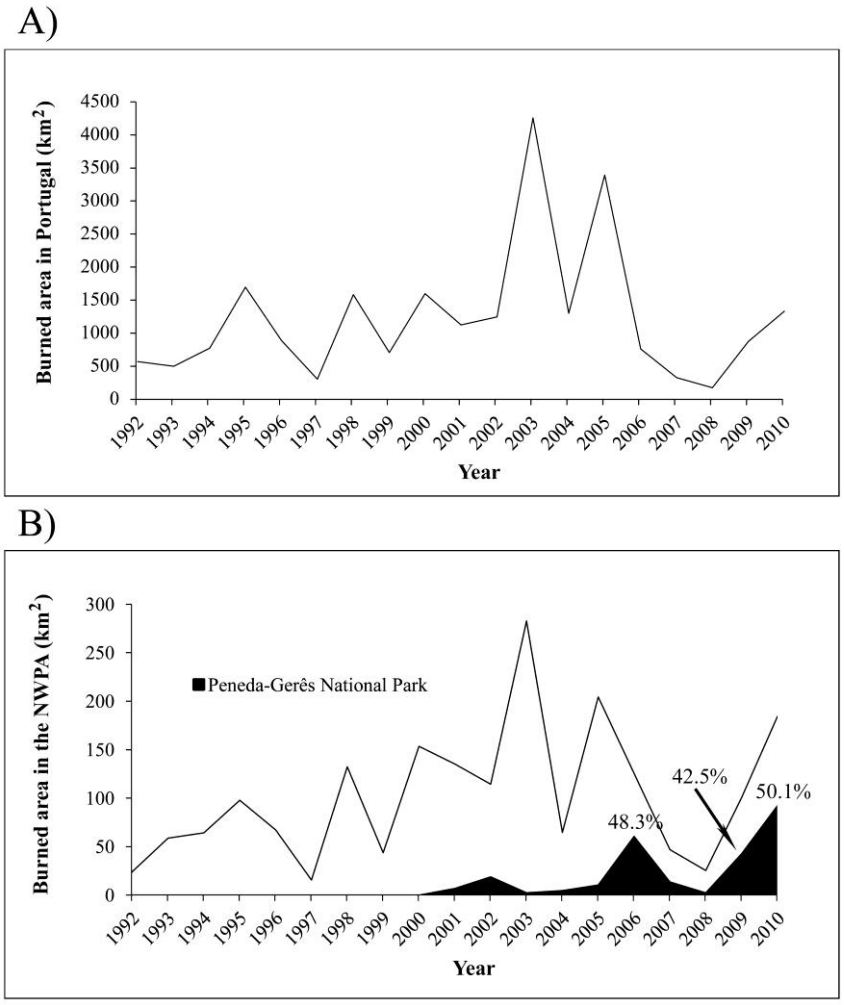

Figure 17. Evolution of the area (km2) burned in the last two decades: **A)** in Portugal and **B)** in the National Web of Protected Areas of Portugal (NWPA); the area burned in the Peneda-Gerês National Park in the last decade and the relative percentages (%) respect to the total area burned in NWPA in 2006, 2009 and 2010 are indicated.

affected (ICN 2002, 2003, 2004, 2005, 2006, 2007; ICNB 2008, 2009, 2010b, 2011; ICNF 2013). In 2001, the intentional use of fire to "clean" shrubland and fuel load in forests (e.g., debris from clearing cuts) was responsible for great part of the fires of known origin in the protected areas of Portugal (ICN 2002). According to this source, the purpose of 57% of these induced fires was the renewal of pastures for livestock and the regions most affected were the mountain ranges of Trás-os-Montes, Douro, Minho, Beira and the littoral of this last. In PGNP, fires usually occur from January to May and from August to November, depending on seasonal rainfalls of spring and

autumn (ICNB 2008, 2009, 2010b) and often affect large areas, including the ibex range (Moço et al. 2013a; Moço et al. 2013b). Fire has also been used in the National Park as a reprisal to the management and interdiction of the State to locals' activities (Neves 1952).

DISCUSSION

Quantity and quality of the references on ibex

Information on the historical presence of ibex was majorly related to three periods: i) the Prehistory, in areas favourable to fossilization and others used by the first communities of *H. sapiens* for art expression and/or communication; ii) the 13th century, thanks to the royal inquiries of 1258 and; iii) the 19th century, with a higher number and better conserved bibliographical sources. Data on ibex were attained by inquiries (e.g., the descriptions of Costa, Leal and Perestrello) but on few occasions. This way of obtaining information would explain the inexactness of Link's (1801) descriptions about the resemblance of *C. aegagrus* with the ibex of Gerês and the lack of horns of the female of this last (Barboza du Bocage 1857). Moreover, many references on ibex distribution and habits are veiled reiterations of preceding authors, namely: Brito (1597) is repeated by Contador de Argote (1738) and this last by Capêlo and Torres (1883) and probably Pereira and Rodrigues (1907); Peixoto de Azevedo (1692) by Costa (1706), Contador de Argote (1738), Perestrello (1850a) and Leal (1875a, 1886); Araújo (1949) by Leal (1886) and; Link (1801) by Kinsey (1829). The problem with consecutive reiteration without a scientific base is that it may bias our interpretation about the evolution of past events and hence of reality (Stringer and Gamble 2010; Cercas 2001). In the case of ibex in Portugal, reiteration may suggest that ibex was abundant in Gerês until the middle of the 19th century, though its population size was probably below a threshold for viability much earlier.

The historic evolution of ibex and human ranges in Portugal

In Portugal, *C. pyrenaica* or one of its ancestors was contemporaneous of *Homo neanderthalensis* and it coexisted with *H. sapiens* until the present (Antunes et al. 1989; Cardoso 1996, 2006; Bocquet-Appel and Demars 2000). Both human species included ibex in their diets, as reported by bone accumulation in human shelters and settlements dated from the Middle and the Upper Palaeolithic (Antunes et al. 1989; Cardoso 1996, 2006; Ready 2013). Assuming that the exploitation of resources by *H. neanderthalensis* was opportunistic (Cardoso 2006) and given that paleontological remains accumulated by their hunting activity depict the contemporary fauna, ibex ubiquity in the Portuguese territory during the Middle Palaeolithic is arguable. The species occupied both high and lowlands but it was most

associated with rocky areas (Cardoso 1996, 2006). The early interest of *H. sapiens* for ibex is evident in abundant rock-art representations in the valley of the river Côa (Aubry et al. 2006, 2012). It is uncertain if bovid representations in the river Zêzere (foothills of Estrela range, Fig. 3) and Escoural cave represented ibex (Gomes et al. 1983; Otte and Silva 1996; Baptista 2009). Respect to the last site, taking into account the presence of ibex in the Upper Palaeolithic (Cardoso 1996) we hypothetise that the description of *bucrania* "with semicircular structure, sometimes with extroverted extremities, with a lira shape" (Gomes et al. 1983) could represent the species. The hunting pressure of *H. sapiens* on ibex may have been directly proportional to an increase of human density from the Mousterian to the Magdalenian (Davis 2002; Aubry et al. 2012), reducing ibex numbers considerably after the Last Glacial Maximum (Aubry et al. 2012) (Fig. 2). Also, in view of the known distribution of humans and their movements, the range of ibex in Portugal between the rivers Douro and Tagus (i.e., including the mountain range of Estrela) may have been constrained since the Upper Palaeolithic. Later, the wide range of human occupation and the early livestock transhumance documented for the Estrela range (Silva 2012) and the South of Portugal (Gomes et al. 1983) potentially reduced the available habitat for ibex in the South of the river Douro.

Ibex presence in Portugal was difficult to trace during the pre-Roman and Roman periods. Humans' numbers, spatial occupancy (roads, lands occupation for agriculture and extensive pastoralism) and exploitation of resources (e.g., woodlands, minerals) in Portugal increased substantially. This certainly reduced the habitat availability for ibex, particularly in the South. To the North, the warlike character and lack of possessions of mountaineers described by Strabo (1903) suggest that their communities greatly depended on hunting, and hypothetically on ibex, for their subsistence.

The numerous wars that intermittently impelled human communities to self-sustaining lifestyles, the destruction of natural habitats (for the exploitation of timber and wood-derived products, agriculture and pastoralism) and the low altitudinal range of the Portuguese territory (Fig. 1.B) support the hypothesis of ibex being constrained to few isolates by the end of the Middle Ages. The toponyms and royal inquiries of 1258 suggest that, if not restricted to, ibex was more abundant to the North of the river Douro than to the South and particularly around the Gerês range. Although hunting pressure likely caused important reductions on ibex numbers in this region, the species may also have benefited from humans' migrations to the littoral of Minho.This perception may be biased by the lack of research on fauna references in the royal inquiries carried out in

other regions of Portugal[6] (note that the focus of the valuable work of Gonçalves 1998 was the NW of the country) and the poor preservation and destruction of Portuguese parchment and paper manuscripts from the Middle Ages to present (Peixoto de Azevedo 1692; Andrade 1994). The hypothesis of the species rareness or even absence to the South of Douro by the end of the Middle Ages is supported by the intense pastoralism, frequent human-induced fires an high hunting pressure in the Estrela range and surrounding foothills. In fact, Link (1801) and Leal (1874b) coincide in attributing the wildlife rareness and barren lands of that massif, with practically no trees, to secular fires and intense hunting. The absence of specific references to the ibex in hunting treaties and the virtual absence of illustrations of ibex in Portuguese art, in contraposition with other game animals, as previously exposed corroborate the idea that it was already rare in Portugal by the end of the 13th century. Moreover, the lack of precision of possible Iberian representations of ibex (Fig. 18) if compared with e.g. Phébus (1387-1389) suggests it would be rare in all the Peninsula and thus poorly known and roughly represented. One set-off to this hypothesis is ibex association to mountainous environments, far away from places of governance and thus hardly observed by court artists. Still, considering ibex importance for local communities and trophy hunters previously exposed, it is hard to believe that its presence would be unnoticed. Thus, most probably, by the end of the Middle Ages ibex was extinct from the Estrela range. The remnant populations to the North of the river Douro were probably isolated from each other and from other Iberian populations.

Data collected showed that ibex was probably restricted to the Gerês and Amarela ranges (Fig. 1.C) by the end of the 16th century. The abundance of weapons,the absence of a hunting regulation and habitats destruction likely increased ibex mortality and the geographic segregation between those mountain ranges. To the North of the Amarela range, the valley of the river Lima may have been a physical barrier to ibex since the early times of the Modern Age (Moller 1894).

The Restitution wars during the 17th century must have increased locals' poverty and sustenance on natural resources like ibex hunting, now facilitated by the use of fire guns, in the mountain ranges of Gerês and Amarela. In these, highland habitats still available for ibex continued to be destroyed by fire to serve extensive pastoralism and fuel (charcoal) requirements. The higher human density in the NW region of the Gerês range complicated ibex movements between this range and Amarela.

The deterioration of natural habitats by fire and extensive rearing of livestock persisted in the Gerês and Amarela ranges during the 18th century. We deduce that, until that century

[6] http://www.aatt.org/site/index.php?op=Nucleo&id=188

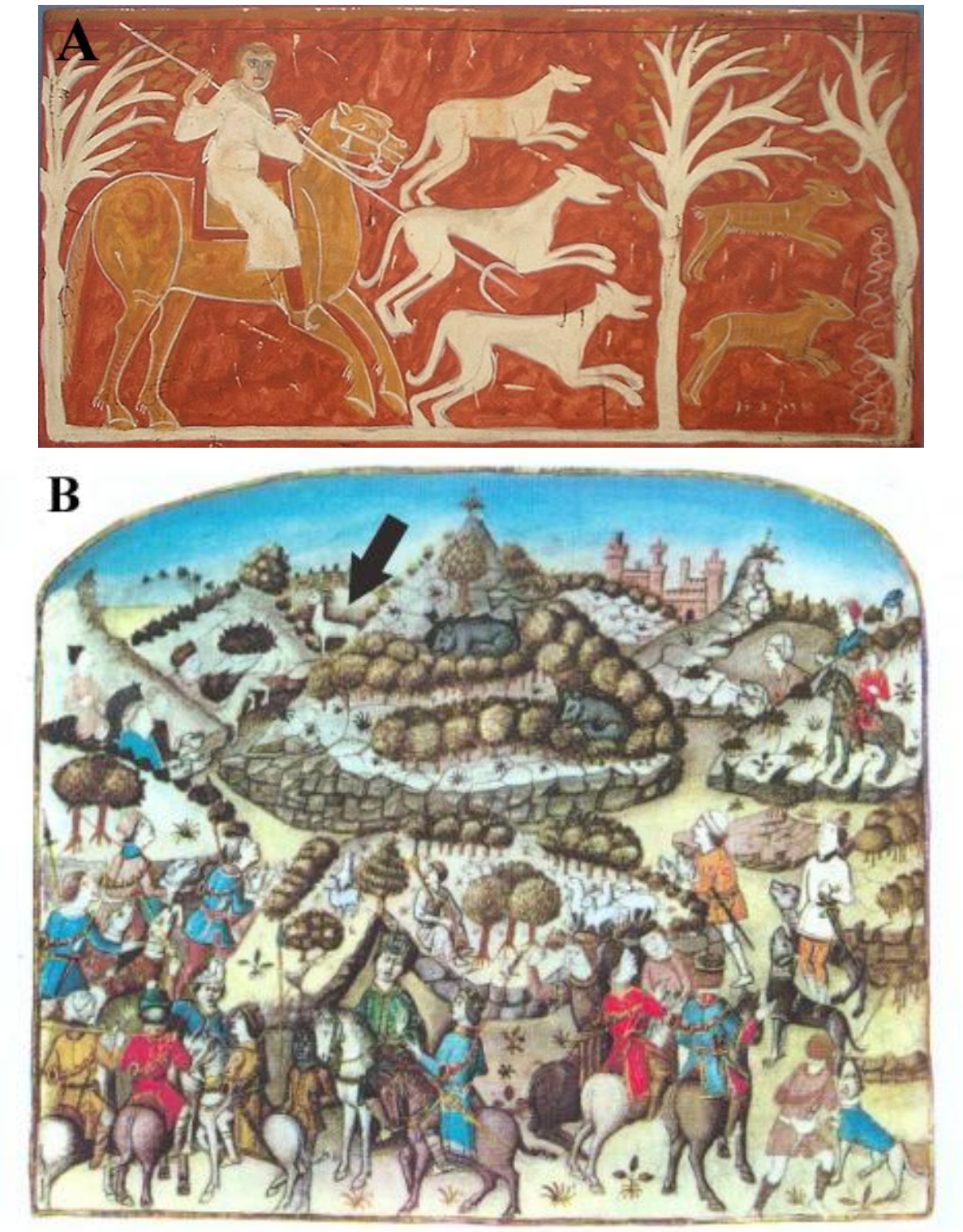

Figure 18. Possible Iberian representations of ibex (*Capra pyrenaica* Schinz, 1838): **A)** mural painting of the 12th century (Ermit of San Baudelio, Berlanga, Soria, Spain) representing a knight and dogs hunting ibexes? [7]; **B)** illumination of the 14th/15th centuries (from Montoya 2003) representing a hunting scene including an ibex? (signaled with a black arrow).

[7] from: https://www.museodelprado.es/coleccion/galeria-on-line/galeria-on-line/obra/caceria-de-liebres/

ibex hunting served self-sustenance purposes or, as described for the roe deer in the region (Sousa 1909), the payment of favours or the interests of loans. In view of the poverty conditions, the lack of hunting restrictions and the easy access to fire guns previously described, we suppose that this type of hunting caused important casualties on the ibex population. The higher occupation of the NW hills of the Gerês range by locals and tourists probably displaced ibex to the NE of this range. If the species was still present in Amarela this nucleus was likely isolated from Gerês.

Ibex mortality may have increased during the war conflicts that affected the actual region of PGNP in the first jubilee of the 19th century. About the effects of wars on other populations of wild *Capra* spp., see Fandos (1991) and UNDP (2002). The continuous destruction of the habitat available for ibex by fire and livestock worsened by the crescent careless guarding of livestock in the mountain ranges. If the remnant population ever had the chance to recover from a small number of individuals in an increasingly degraded habitat, this was truncated by frequent collective battues reuniting a great number of men. Because the collective hunting of ibex was not previously documented (Sousa 1909, 1927), we hypothesize that these battues responded to a greater demand of touristic entertainment in the region. The health state of the last ibex captured supports the idea that the remnant population was susceptible to diseases, nutritionally depressed and inbred. This suggestion meets the incapacity of the remnant Spanish population of *C. p. pyrenaica* to recover from a small number of individuals during the 20th century until its extinction in 2000: adverse climatic conditions, susceptibility to diseases, undernutrition due to competition with livestock and southern chamois (*Rupicapra pyrenaica pyrenaica* Bonaparte, 1845) and inbreeding (Granados et al. 2001; Pérez et al. 2002).

This review contradicts the idea that ibex habitat did not change since the moment of species extinction. Most importantly, fire continued and continues to degrade considerable extensions of the PGNP each year, livestock management is far from being regulated and road accesses and tourism pressure have increased. At the same time, ibex hunting has not been eradicated. In resume, the actual factors of concern regarding the ibex population are: i) low heterozigosity of the founder population; ii) risk of epizooties due to inappropriate sanitary management of domestic goats flocks; iii) potential hybridizing with feral domestic goats (Giacometti et al. 2004; Gama 2008; Moço et al. in press); iv) insufficient carrying capacity of PGNP's and surrounding mountain ranges to sustain ibex, livestock and sympatric wild ungulates (roe deer, wild boar and, in Amarela range, also the red deer); v) barriers to the expansion of the population; (vi) poaching and; (vii) at last but not the

least, lack of economical investment, international management and native's involvement in specific research and conservation programs for ibex.

Interactions between ibex and livestock

Unmanaged livestock constitutes a source of direct and indirect competition, and epizooties affecting native ungulates. If undetected in an early phase, epizooties in the natural environment may become difficult to solve, even catastrophic (Fandos 1991). Regarding domestic goats, the possibility of hybridization with ibex compromises the genetic integrity of the ibex population and promotes the interspecific transmission of infectious diseases like brucellosis and sarcoptic mange (Fandos 1991; Pérez et al. 1997; León-Vizcaíno et al. 1999; Giacometti et al. 2004). Despite previous considerations about data obtained by inquiries, if we consider the possibility that Link (1801) actually based his writings on personal observations, we may pose different hypothesis to justify his inexact descriptions of ibex. Thus, the author may have encountered feral domestic goats, in which females or both sexes may lack horns (Cabrera 1914), or ibex x domestic goat hybrids (Almaça 1980; Giacometti et al. 2004). In fact, Link (1801) wonder whether the ibex of Gerês was "a degenerate and wild variety of the tame-goat, or the wild parent stock of the latter". Whatever the hypothesis and in view of the actual presence of several nuclei of feral domestic goats in the PGNP (PGNP 2010; Moço et al. in press), a strict management plan for livestock and the removal of feral domestic goats from its mountain ranges are urgent.

Fire

Fire was probably the main cause of brown bear's extinction in Portugal (Contador de Argote 1738), wild boar's decline in the region of Barroso in the 19th century (Leal 1875a) and is still among the most threatening factors to the Portuguese and PGNP wildlife (Gama 1992; 2008). Presently, forest fires counteract the slight increase of forest areas due to agro-environmental measures and land abandonment (Pôças et al. 2011).

Poaching

Hunting was probably the cause of ibex restriction to the NW of Portugal and undoubtedly of ibex extinction from the Gerês range. This human activity has also been referred as the main cause of extinction of the Iberian ibex in the French Pyrenees and its reduction to few individuals in the Spanish range in the middle of the 19th century (Cabrera 1914; Crampe 1990). Nowadays, evidences of poaching on ibex in the PGNP cannot be discarded as an important menace to the species. Poaching must be counteracted with an effective vigilance program and public awareness on the ecological value of ibex for local communities. Other forms to

promote ibex positive reception by locals are considered below.

Ecological drawbacks of the present economical crisis

Changes on agropastoralism practices "creates problems of sustainability for the ancestral mountain landscapes over short to medium temporal scales" (Pôças et al. 2011). Portuguese tend to emigrate in periods of scarcity (Fig. 11) and the Northern communities of Portugal are no exception (Oliveira 1970; Ingenium 1990; ICNB 2010a). Therefore, considering the actual scenario of economic and social crisis, it is intuitive to foreshadow an increase of rural emigration to foreign countries, i.e., human and livestock density will continue decreasing in mountainous areas like the PGNP. In these regions, the abandonment of agropastoral practices and some agricultural policies (e.g., the allocation of subsidies for meadows conservation in detriment of annual crops) favoured landscape homogenization in the last decades (Pôças et al. 2011) and may promote fuel loads and fires numbers and extent (Moreira et al. 2001; Pôças et al. 2011; Tedim et al. 2013). On the other hand, while emigration to foreign countries may attract many unemployed, others may migrate from urban to rural areas in search of a self-sustenance lifestyle, especially in areas where agropastoralism is historical, like the PGNP. As well expressed by Andrade (1994) when describing the human communities of the NW of Portugal in the Middle Ages, herds allow a temporary and adaptable to circumstances lifestyle. In this case, the loss of communitarian traditions due to social disruption caused by population decrease and ageing may promote the unregulated management of livestock and fire.

Whatever the human and livestock balance (in terms of density) between these situations, fire appears as a serious menace to be taken into account in PGNP management plans. In a short-term future, Portugal may register more mega-fires due to climate change (Tedim et al. 2013). Apart from taking measures on counteract global warming, these authors recommend more investment on measures that reduce wildfire risk than on merely extinction measures and the engagement of societies in wildfire risk management according to their local environmental and cultural peculiarities.

To the previous we have to sum the cuts of the budget attributed to conservation issues that usually derives from a situation of national economic crisis. The effectiveness of monitoring, vigilance and compensation (e.g., for wolf's damages on livestock) plans depend on these funds and, consequently, so do the conservation of biodiversity. The implication of the civil society and particularly of PGNP's natives on nature's conservation, which is of vital importance in any scenario, would be now highly useful to counterbalance these economic difficulties.

Humans and environmental management in the PGNP

The traditional human lifestyle in the region of the PGNP constitutes a singular case in Portugal's culture (Sousa 1909, 1927; Mendes 1968; Oliveira 1970). Although the secondary and tertiary sectors have been increasing in detriment of the primary since the 1950's, traces of their cooperative nature persist today (Guia de Portugal 1965; Neves 1976; Ingenium 1990; ICNB 2010a). Current examples are the joint of the "vezeiros" and traditional bullfights between cattle males in Barroso, previously referred, and the management of the water for irrigation and of cereals culture. Other communitarian activities recently extinct or falling in disuse left us a rich architectonical patrimony of watermills, cereal granaries ("sequeiros") and bread ovens. From the point of view of biodiversity, the human presence in the PGNP and surroundings is associated with the cattle breed "Barrosã", the dog breed "Castro Laboreiro" and the pastures biotope "Prados de lima". Disregard for these traditions leads not only to culture impoverishment, it may also affect biodiversity. As an example, the imminent loss of the remnant joints of "vezeiros" favours the use of fire by the younger generations of shepherds (to clear shrubland from trails rapidly).

Ibex conservation and locals' lifestyle in PGNP may be compatible and even mutually beneficial. Besides its ecological value, the return of the species may promote social and economic improvements in a region where governmental and regional policies have failed to fix population and create jobs (Pôças et al. 2011). One way to approach such aspiration is to integrate conservation and social development in a community-based model, i.e., in which the human community is involved in the planning and execution phases. UNDP (2002) illustrates a well succeeded program of such kind devoted to the conservation of the Markhor (*Capra falconeri* Wagner, 1839) and the Afghan Urial (*Ovis orientalis* Gmelin 1774) in Balochistan (Pakistan). The first lesson to be taken into account from this example is that understanding and appreciation of the character, social organization, needs, constraints and psyche of local populations are crucial to conciliate human and ecological requirements (Neves 1976; UNDP 2002).

In the case of the human populations in the PGNP, their ability to subsist on agropastoralism and hunting, readiness to emigrate and frequent opposition to foreign influences in their native territory resulted for the most part from a secular history of exploitation by successive forms of feudalism and a self-sustenance way of life during large periods (Mendes 1968; Ingenium 1990). With such background, governmental restrictions *per se* hardly contribute to the desired balance between conservation principles and the exploitation of natural resources. In fact, more than forty years after the creation of the PGNP, many locals do not recognize this

governmental figure as its own. This was well expressed in Guerreiro (1980) when addressing the divergence about the opening of a border road in the 1980's between PGNP (detractors) and locals (supporters): "All this arises because the local populations and governments do not feel participants in the common labour that, for them, was supposed to be the Gerês Park". The present discontent of locals with the management of the PGNP is evident in open letters signed up by locals' associations to the Director of the PGNP[8] and the Ministry of Environment and Territorial Planning of Portugal[9]. It seems that the local populations perceive many restrictions and few benefits from the existence of the National Park. This has frequently resulted in locals retaliations with negative consequences to biodiversity (e.g., poaching, induced-fire).

The coexistence between wildlife and humans in the PGNP requires a consensual management. Assuming that humans are fundamental actors and the main shapers of the region, the cultural and social promotion (here we include economic aspects) of local communities will likely support the promotion of the PGNP aims (Guerreiro 1980; Soares 1987; UNDP 2002). Following these authors recommendations and experience we strongly encourage environmental managers of the PGNP to entail a broad-community and long-term conservation approach: i) patiently listen to native's expectations about the PGNP (e.g., the return of the ibex); ii) focus on creating acceptability and promoting a sense of responsibility and ownership toward natural resources by the local community, instead of adopting an authoritarian attitude when defending conservation aims; iii) involve locals and local governments directly, besides the scientific community and non-governmental institutions, in long-term educational, cultural and social promotion and decision making; this aspect in particular was recommended by the Governmental Institution of Portugal for Nature Conservation when planning an ibex reintroduction in 1991 (SNPRCN 1991); iv) directly or indirectly link conservation and economic incentives, in accordance to the expectations of the local communities; for example, seriously consider an ecotourism program focused on ibex and managed by locals with direct economic benefits for their communities.

Vanishing traces of Capra pyrenaica lusitanica Schlegel, 1872

As a final commentary to the loss of the Portuguese biodiversity, we want to express our disappointment respect to the scarce number of extant specimens of *C. p. lusitanica*. At least nine complete specimens (three males and six females) and the remains

[8] see https://docs.google.com/document/d/1MQmae3q9Qn-jU-uS8yEKbj8MnpwB8akplf20KREdU-U/edit?pli=1

[9] see https://docs.google.com/file/d/0B8QVShZeKdzZNjg3OWU0ZDYtZDdhZC00MDJiLTkyMTctNGM3YTZlOWFhOWE2/edit?pli=1

of other four (horns of three males and one female) were documented in private collections and Portuguese and German museums (Table 1). Nowadays, only the two specimens of the Museu de Coimbra are localizable.

The specimens of the Museu Natural de História Natural e da Ciência da Universidade de Lisboa have been vanishing since at least 1917, when França reported the missing of two females. In 1974, one of the missing specimens supposedly reappeared but this information was not accompanied by photographic evidences (Mobil 1974) (Fig. 7.D). Moreover, the photographs of the "female 2" in the Museu de Lisboa (Fig. 7.D.4-5) do not agree with the age of any of the specimens reported by Barboza du Bocage (1857): this author indicated that the four female specimens of the museum had one, two and three years old (without specifying the age of each specimen) and the "female 2" appears to be older. Another vanished specimen was the last female captured alive in Gerês in 1890, held by the museum of the Faculdade de Medicina Veterinária da Universidade de Lisboa until, at least, 1917 (França 1917) and whose location is presently unknown (Mobil 1974; Parques e Vida Selvagem 2011). Considering the ages of the specimens described by Barboza du Bocage (1857), could "female 2" be the last female hand-captured in 1890 (Fig. 7.A and 7.D.4-5)? The verification of this supposition would require a careful analysis of the original photographs of these specimens. These and, as far as we are acquainted, the remains of an old male (Table 1) held in Lisbon's museum were destroyed by fire in 1978. Nevertheless, the location of at least two of the females studied by Barboza du Bocage (1857) and of the last female captured alive in Gerês remains unknown. Finally, the ibex male held by the Museum für Naturkunde of Berlin (Germany) and the horns of two males (private collections) and one female (until 1917, in the Repartição Florestal do Gerês) were not possible to locate. The recovery of the lost traces of the *C. p. lusitanica* would have a priceless scientific value to the Portuguese natural history.

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CHAPTER 3. THE VERNACULAR NAME: A MATTER OF CONCERN?

"Eu não sei como te chamas
Oh Maria Faia!
Nem que nome te hei-de eu pôr"

Zeca Afonso (cariz popular)

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¿CUÁL ES EL NOMBRE COMÚN DE *Capra pyrenaica*?: UNA REVISIÓN Y UNA PROPUESTA

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RESUMEN

La sistemática del género *Capra* y la hipótesis de que todos sus representantes pertenecen a la misma especie siguen estando en debate. Ante la posibilidad de un cambio en los binomios científicos de este género, el uso de nombres comunes podría adquirir mayor importancia. En este trabajo proponemos a la comunidad científica la adopción de un nombre vernáculo exclusivo y en distintos idiomas para *Capra pyrenaica*, bajo criterios bien definidos. Realizamos una revisión de los nombres vernáculos atribuidos a la especie en publicaciones científicas desde el inicio del siglo XIX hasta la actualidad y evaluamos las circunstancias en las que aparecieron. Los resultados demuestran que la mayoría de los nombres comunes utilizados tienen asociado un gentilicio y que factores humanos (como el idioma de publicación y la nacionalidad de los autores) aparecen como determinantes en su elección. El período de publicación también parece influir en el tipo de nombre utilizado, pero no refleja los cambios sufridos por la especie en su área de distribución. A través de una encuesta realizada a especialistas en Caprinos hemos averiguado que la mayoría considera que el área de distribución actual y la morfología de la especie deberían ser los criterios a utilizar en la elección de su nombre vernáculo. Siguiendo estas directrices, proponemos los términos "cabra montesa ibérica" e "Iberian wild goat" como nombres comunes de *Capra pyrenaica* en castellano e inglés.

Palabras clave: cabra montesa, *Capra pyrenaica*, dimensiones humanas, distribución, literatura científica, morfología, nombre común.

ABSTRACT

Which name for Capra pyrenaica*? A review and a suggestion*

Systematics of genus *Capra* and the inclusion of all its forms under the same scientific binomial remain controversial. In such context, the adoption of unique common names for each presently recognized species can become a relevant issue. With this work we propose the use of one exclusive vernacular name for *Capra pyrenaica* by scientific community under well defined criteria and in different languages. We revised a variety of vernacular names attributed to *C. pyrenaica* in scientific literature since beginning of 19th century to present, analysed

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circumstances on which they arose and frequency of their use through time. Results show that common names of *C. pyrenaica* usually carry a geographic character. Human factors (language of publication and nationality of authors) seem to influence the choice toward most frequently used vernacular name for the species. Period of publication also appear to determine common name used, but it does not reflect changes on species distribution range through time. An enquiry to Caprinae specialists indicates current distribution range and morphology as selected criteria to define species common name. Following these, we suggest "cabra montesa ibérica" and "Iberian wild goat" as vernacular names for *C. pyrenaica* in spanish and english, respectively.

Key words: *Capra pyrenaica*, common name, distribution, human dimensions, Iberian wild goat, morphology, scientific literature.

Introducción

La necesidad de nombrar a las cosas es inherente al ser humano y de reconocida utilidad a la hora de identificar el sujeto de una conversación. Los organismos vivos no son una excepción a este hecho. A través del sistema de nomenclatura binaria formalizado por Linneo en el siglo XVIII, la comunidad científica multilingüe puede reconocer, con la mejor precisión posible, cualquier especie de entre todas las descritas. La relevancia de compatibilizar la universalidad y la continuidad de esta nomenclatura con las clasificaciones taxonómicas de los científicos llevó a la creación de códigos internacionales de nomenclatura zoológica y botánica.

Los nombres comunes o vernáculos de los animales y plantas pueden generar dudas, sea por el uso de más de un nombre para una especie en particular (sinonimia), o por el uso del mismo nombre para más de un taxón (polisemia). Pero a pesar de la ambigüedad a que pueden dar lugar, los nombres comunes siguen siendo utilizados frecuentemente en la literatura científica.

El hecho de que todas las especies del género *Capra* compartan el mismo número de cromosomas (2n= 60) (Nadler *et al.* 1974), de que todas puedan hibridar en cautividad (Gray 1954) así como la existencia de precedentes de hibridación en la naturaleza (Turĉek 1951) mantiene abierta la hipótesis de que las especies reconocidas actualmente sean, en realidad, una única especie. Las características morfológicas particulares de los individuos de distintas poblaciones de *Capra* son utilizadas con menos controversia a la hora de distinguir dichas poblaciones. Si en un futuro próximo se considera que todos los individuos pertenecen a la misma especie, la utilidad de los nombres vernáculos como forma de designar correctamente las distintas formas del género puede ganar importancia. En ese contexto, la uniformización de estos nombres será imprescindible.

Las revisiones existentes sobre distribución, estatus o taxonomía de animales incluyen normalmente una relación de los nombres vernáculos de las especies en diferentes idiomas (Mitchell-Jones *et al.* 1999), o en los idiomas oficiales del mismo país (Palomo *et al.* 2007). Esos nombres comunes suelen estar relacionados con el área de distribución o la localidad de origen de la especie y con sus características morfológicas. Como ejemplos en la terminología inglesa podemos citar el "African elephant" (elefante africano *Loxodonta africana*), "Alpine ibex" (íbice alpino *Capra ibex*), "East Caucasian tur" (tur del Cáucaso oriental *Capra cylindricornis*), "Dwarf Blue sheep" (oveja enana azul *Pseudois [nayaur] schaeferi*) y el "Red Wolf" (lobo rojo *Canis rufus*).

Capra pyrenaica Schinz, 1838 (Artiodactyla: Bovidae: Caprinae) es una de las cinco especies del género *Capra* reconocidas por la UICN (Unión Internacional para la Conservación de la Naturaleza)/Caprinae Specialist Group (Shackleton 1997). Es una especie de caza mayor incluida en la categoría de "Preocupación menor" (Herrero y Pérez 2008). Su distribución histórica (entre el Holoceno y el siglo XIX) incluía la Península Ibérica – actualmente Portugal, España y Andorra – y los Pirineos franceses, su probable localidad de origen (Engländer 1986, Crampe y Cregut-Bonnoure 1994, Alados y Escós 1996). La especie fue abundante en la península durante el Paleolítico y el Neolítico (González 1982, Alados 1985, Cardoso 1996) hasta la Edad Media, pero desapareció de Francia y Portugal a mediados y finales del siglo XIX, respectivamente (Cabrera 1914, Couturier 1962), probablemente por la sobreexplotación cinegética (Couturier 1962, Mendes 1980, Crampe 1990). La distribución de la especie quedó restringida a España hasta 1998, año durante el que recolonizó Portugal (Moço *et al.* 2006). Su estatus en este país fue oficialmente reconocido como "En peligro crítico" poco tiempo después (Cabral *et al.* 2005).

Los nombres comunes de las especies y subespecies del género *Capra* tienen generalmente asociado un gentilicio. En Shackleton y Lovari (1997) *C. pyrenaica* es denominada "Spanish ibex" (íbice español) y más recientemente la especie ha sido nombrada como "Iberian wild goat" (Cabra montesa ibérica) (Herrero *et al.* 2007). Cada subespecie del género (Cabrera 1911), tiene también un gentilicio en su nombre común: *C. p. hispanica* - "Spanish ibex", *C. p. lusitanica* (extinta) - "Portuguese ibex" (íbice portugués), *C. p. pyrenaica* (extinta) - "Pyrenean ibex" (íbice pirenaico) y *C. p. victoriae* – "Gredos ibex" (íbice de Gredos). En su redescripción de *C. p. hispanica* como *C. p. nowaki*, Wyrwoll (1999) también recurrió a un atributo geográfico para denominar comúnmente el nuevo trinomio - "Mediterranean (=southern Spanish) ibex" (íbice mediterráneo o del sur de España).

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En este contexto, comenzamos por ilustrar la variedad de nombres comunes utilizados para la especie en la literatura científica hasta el presente y las circunstancias asociadas a su uso. Para ello investigamos la frecuencia de uso de los distintos nombres y su asociación con factores humanos (idioma de publicación y nacionalidad de los autores), período de publicación y distribución de la especie en la fecha de publicación. Los resultados obtenidos fueron comparados con los de una encuesta dirigida a investigadores especialistas en el género *Capra*, en la que se solicitaba su opinión acerca de los nombres vernáculos. Basándonos en estos resultados, hemos elaborado una propuesta acerca de los criterios a tener en cuenta así como los nombres comunes a utilizar en castellano e inglés.

Material y métodos

Este trabajo se basó en una revisión de publicaciones científicas sobre la especie, desde 1838 hasta el presente (Tabla 1). Los datos recopilados a partir de revisiones de distribución y taxonómicas se describen en detalle por incluir varios nombres comunes para la especie. Las restantes se organizaron según:

1) el nombre común: (a) ausente (presentan sólo el nombre científico) o sin cualquier mención a una característica particular, como íbice, cabra montés o cabra salvaje en distintos idiomas (**Sin**); (b) con gentilicio español ("Spanish" en inglés) (**Es**); (c) con gentilicio ibérico ("Iberian" en inglés) (**Ib**); y (d) con gentilicio pirenaico ("Pyrenean" en inglés) (**P**)
2) el período de publicación, definido de acuerdo con el número de publicaciones existente por década: (a) de 1830 a 1910; (b) 1940 y 1970; (c) 1980; (d) 1990; y (e) 2000
3) la distribución de la especie en la fecha de publicación: (a) Portugal, España y por lo menos una de las vertientes de los Pirineos, o sea, hasta el año 1892 (**I**); (b) restringida a España, incluyendo la vertiente española de los Pirineos, de 1892 a 1997 (**II**); de nuevo presente en Portugal y España (incluyendo la vertiente española de los Pirineos), de 1998 hasta el año 2000, inclusive (**III**); y (d) Portugal y España (excluyendo los Pirineos) de 2000 (año de la extinción de *C. p. pyrenaica*) hasta la actualidad (**IV**)
4) el idioma de publicación: (a) inglés (**In**); (b) castellano (**Es**); (c) francés (**Fr**); (d) portugués (**Pt**); (e) italiano (**It**); y (f) holandés (**Ho**)
5) la nacionalidad del autor (o de la mayoría, en las publicaciones de varios autores): (a) Española (**Es**) y (b) otra (**Otra**).

TABLA 1
Referencias bibliográficas recopiladas sobre *Capra pyrenaica*. Se identifican las revisiones taxonómicas y de distribución (#). Libros, capítulos de libros y monografías se incluyen en el apartado "Referencias".

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La relación entre el nombre común (Nombre) y los factores (Período, Distribución, Idioma y Nacionalidad) fue investigada a través de un análisis de contingencia y un test de χ^2 de Pearson (Siegel y Castellan 1988). Para evitar sesgos y garantizar la independencia de los datos sólo se consideró una publicación por autor (o grupo), año y nombre común utilizado. Estos análisis fueron efectuados utilizando el software SPSS 15.0.1, empleando un α = 0,05. Con objeto de incrementar la exactitud del test de χ^2 (frecuencias esperadas superiores a 0,5) (Conover 1999), algunas clases tuvieron que ser agrupadas y, para el efecto, los siguientes factores fueron reclasificados: i) Nombre común: (a) **Sin**, (b) **Es;** y (c) **Otro** (=Ib+P); ii) Período: (a) hasta la década de 1970, inclusive (**1**); (b) década de 1980 (**2**); y (c) desde 1990 hasta la actualidad (**3**); iii) Distribución: (a) **(I)** (=**I**+**IV**); (b) (**II**) y (c) (**III**); y iv) Idioma: (a) **Es**, (b) **In;** y (c) **Otro** (=Fr+Pt+Al+Ho).

La opinión de investigadores especialistas en Caprinos se recabó mediante una encuesta que incluía las siguientes cuestiones:

1) ¿Considera importante el uso del nombre vernáculo de una especie?
2) ¿Considera que la elección de un nombre común debería estar reglamentada?
3) Si contestó afirmativamente a las dos cuestiones anteriores ¿qué característica debería reflejar el nombre común de una especie?: (**A**) su distribución actual; (**B**) su distribución ancestral; (**C**) sus características morfológicas (color, tamaño, forma de los cuernos, como ejemplos); (**D**) la localidad/región donde se originó como especie; y (**E)** Otra
4) ¿Qué nombre común atribuiría a *C. pyrenaica* en castellano/inglés?: (A) Cabra montés hispánica/Spanish ibex o Spanish wild goat (**Es**); (B) Cabra montés ibérica/Iberian ibex o Iberian wild goat (**Ib**); (C) Cabra montés pirenaica/Pyrenean ibex o Pyrenean wild goat (**P**); (D) Cabra montés/Ibex o Wild goat (**Sin**); (E) Otro (**Otro**).

Los investigadores fueron invitados a incluir cualquier comentario que les pareciera relevante acerca del tema. Finalmente, se compararon los resultados obtenidos a partir de la consulta bibliográfica y de las respuestas obtenidas en la encuesta.

Resultados

En las revisiones consultadas sobre distribución y taxonomía (n= 11; Tabla 1) observamos 2 tipos de nombres vernáculos:

1) sin ningún tipo de gentilicio (como por ejemplo “cabra montés” en castellano,

"wild goat" o "ibex" en inglés, "cabra-montês" o "cabra-brava" en portugués, "bouquetin" en francés, "stambecco" en italiano, "Steinbock" en alemán, además de otros nombres regionales en éstos y otros idiomas co-oficiales de algunos de estos países),

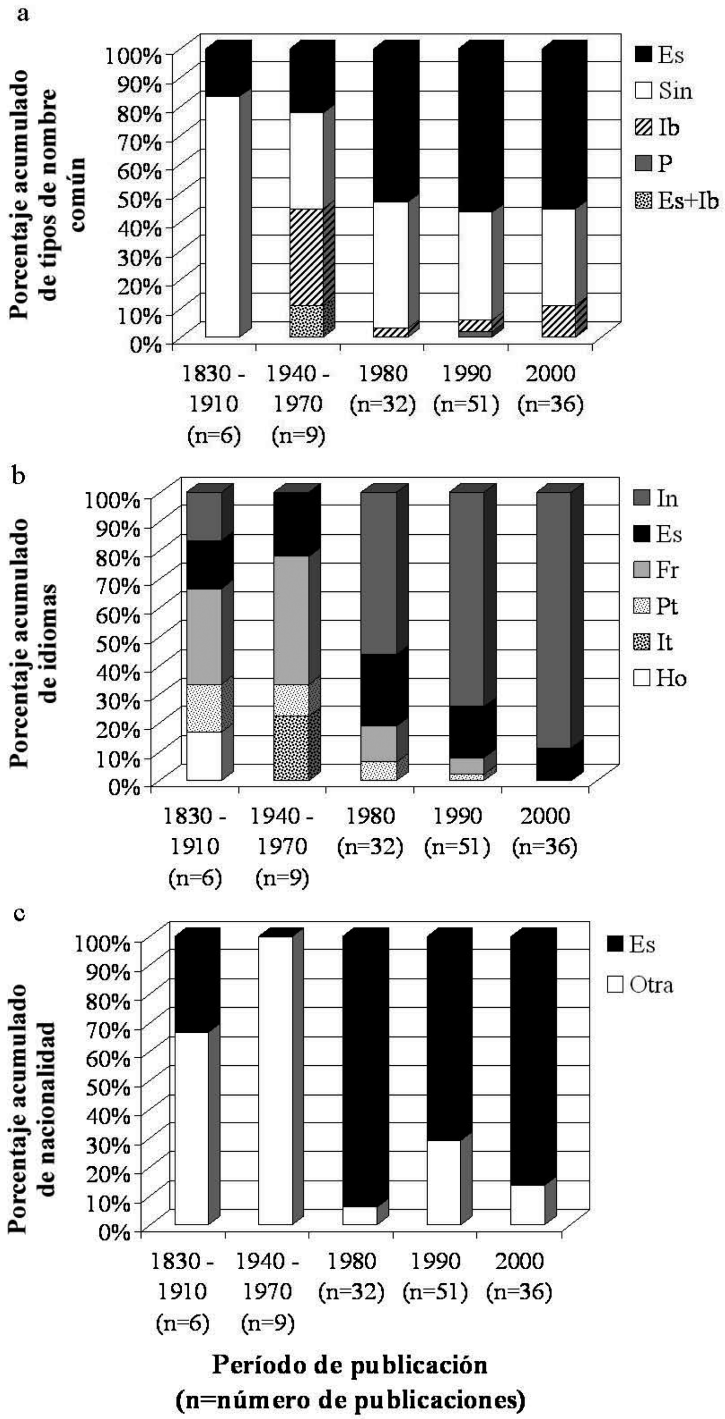
2) asociado a un gentilicio geográfico o político. Estos gentilicios están relacionados con los Pirineos ("Pyrenäen-Steinbock" en alemán, "bouquetin des Pyrénées" en francés), con la Península Ibérica ("Iberischer Steinbock" en alemán, "Iberian wild goat" en inglés, "stambecco Iberico" en italiano) y con España ("Spanish ibex" en inglés; "Bouquetin d'Espagne" en francés). Este último aparece sobre todo en nombres vernáculos de la terminología inglesa.

De las restantes publicaciones (n=134), el 40% no presenta ningún nombre vernáculo, o lo hace sin gentilicio. Entre los nombres con gentilicio, destaca el **Es** como el más frecuente (85%). El uso simultáneo de los gentilicios **Es+Ib** y el gentilicio **P** aparecen, cada uno, representados una única vez en el 15% restante.

La representatividad de los tipos de nombres vernáculos atribuidos a *C. pyrenaica*, de los idiomas más utilizados y de la nacionalidad de los autores que publicaron acerca de la especie, evolucionó a lo largo de los períodos de tiempo considerados (Figura 1 a-c). Podemos ver que en la mayoría de las primeras publicaciones no se mencionaban nombres vernáculos o se hacía sin usar gentilicios. Se utilizaban diversos idiomas, siendo el francés el más frecuente, y la nacionalidad de la mayoría de los autores era diferente a la española. Sin embargo, el primer gentilicio registrado ("Spanish") apareció ya en el primer período (Cabrera 1911). En las décadas siguientes la utilización de gentilicios ganó relevancia, apareciendo por primera vez el **Ib** en la década de 1940 (De Beaux 1949) y, en una ocasión, simultáneamente con **Es** (De Beaux 1955). El francés seguía siendo el idioma más utilizado. A partir de la década de 1980 se incrementó considerablemente el número de publicaciones sobre la especie.

Figura 1. Representatividad de a) tipos de gentilicios utilizados en el nombre vernáculo de *Capra pyrenaica* (Es – español; Sin – sin gentilicio; Ib – ibérico; P – pirenáico), b) idioma de publicación (In – inglés; Es – castellano; Fr – francés; Pt – portugués; It – italiano; Ho – holandés) y c) nacionalidad de los autores (Es – Española; Otra – otra) a lo largo del tiempo.

Proportion of a) vernacular names of Capra pyrenaica *(Es – Spanish; Sin – absent sobriquet or no reference to vernacular name; Ib – Iberian; P – Pyrenean), b) language of publication (In – English; Es – Spanish; Fr – French; Pt – Portuguese; It – Italian; Ho – Dutch) and c) authors' nationality (Es – Spanish; Otra - Other) through periods of time considered.*


a
Porcentaje acumulado de tipos de nombre común
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Es
Sin
Ib
P
Es+Ib
1830 - 1910 (n=6)
1940 - 1970 (n=9)
1980 (n=32)
1990 (n=51)
2000 (n=36)
b
Porcentaje acumulado de idiomas
In
Es
Fr
Pt
It
Ho
c
Porcentaje acumulado de nacionalidad
Es
Otra
Período de publicación
(n=número de publicaciones)

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Desde entonces, el inglés pasó a ser el idioma dominante superando el 90% de las citas recopiladas desde el año 2000. Muchas publicaciones siguieron refiriéndose a *C. pyrenaica* sin recurrir a gentilicios. Sin embargo los nombres con gentilicio **Es** aparecen en más de la mitad de los casos en las últimas tres décadas. El gentilicio **P** aparece en una publicación de la década de 1990 (Lauvergne *et al.* 1998). Al contrario de las décadas anteriores, la mayoría de los autores que publican sobre la especie desde los años ochenta son españoles.

La evolución de la representatividad de los nombres comunes en función de los cambios en el área de distribución de *C. pyrenaica* registrados desde el inicio del siglo XIX (Figura 2) ilustra una marcada diferencia entre el primer período considerado (en el cual predominaban los nombres **Sin**) y los siguientes. En el segundo período aparecen los gentilicios **Es** (poco después de la restricción de la especie a España) y el **Ib.** El uso del gentilicio **Es** fue aumentando relativamente a nombres **Sin** y a los nuevos gentilicios que fueron surgiendo. Entre éstos, la frecuencia del gentilicio **Ib** ha incrementado en la última década (después de su regreso a Portugal) y el gentilicio **P** dejó de utilizarse después de ser registrado una única vez en la década de los noventa.

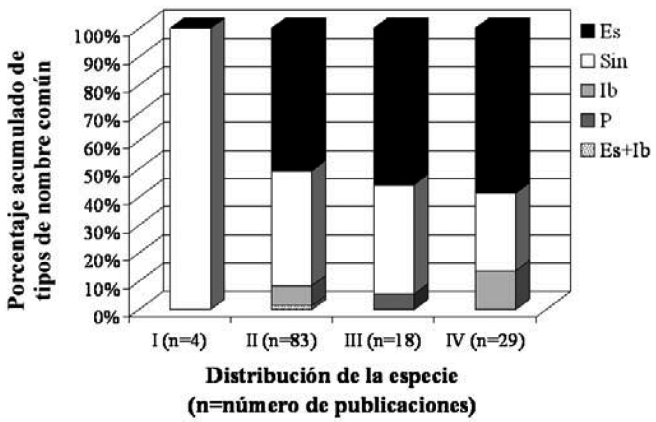

Figura 2. Representatividad de gentilicios utilizados en el nombre vernáculo de *C. pyrenaica* (Es – español; Sin – sin gentilicio; Ib – ibérico; P – pirenáico) en distintas épocas de distribución (I – hasta 1892; II – de 1892 a 1998; III – 1998 a 2000 y IV – de 2000 hasta la actualidad).

Proportion of vernacular names of Capra pyrenaica *(Es – Spanish; Sin – Absent sobriquet or no reference to vernacular name; Ib – Iberian; P – Pyrenean), in different distribution events of the species (I – until 1892; II – from 1892 to 1998; III – from 1998 to 2000 and IV – from 2000 to present).*

El análisis de contingencia demuestra que el nombre común elegido en las publicaciones consultadas (n=125) está influenciado, en orden decreciente, por el idioma, la nacionalidad y, en menor grado por el período (Tabla 2), mientras que la distribución parece no influir de forma significativa en el tipo de nombre utilizado. Específicamente, los nombres **Es** aparecen relacionados con el idioma **In** cuando la Nacionalidad es **Es** (Figura 3a y 3e) y principalmente en las últimas décadas (Figura 3b) aunque ya de forma notoria desde los ochenta (Figura 3c). En esta última década se observa también una asociación entre los nombres **Sin** y el idioma **Es** (Figura 3c), la cual parece mantenerse, aunque de forma menos significativa, desde la década de 1990 (Figura 3f). Ambos nombres **Es** y **Sin** aparecen relacionados con la Nacionalidad **Es** en la década de 1980 (Figura 3d).

TABLA 2

χ^2 de Pearson y respectivos coeficientes de contingencia e incertidumbre obtenidos en los análisis de contingencia entre pares de factores (Factor1 x Factor2) y entre éstos considerando un factor control (Factor1 x Factor2 x Factor Control).

Pearson χ^2 and correspondent contingency and uncertainty coefficients obtained through contingency analysis (between pairs of factors - Factor1 x Factor2 – and between these and a control factor - Factor1 x Factor2 x Factor Control).

Factores	χ2 de Pearson			Coef. contingencia[1]		Coef incertidumbre[2]	
Factor1 x Factor2 *x Factor Control*	**Valor**	**g.l**	**Sig asintótica (bilateral)**	**Valor**	**Sig. Aprox.**	**Valor**	**Sig. Aprox.**
Nombre x Idioma	59,19	4	0,000	0,29	0,000	0,57	0,000
x Nacionalidad=Es	50,91	4	0,000	0,40	0,000	0,59	0,000
x Periodo=3	34,09	4	0,000	0,27	0,000	0,54	0,000
x Periodo=2	26,04	4	0,000	0,63	0,000	0,70	0,000
Nombre x Nacionalidad	11,25	2	0,004	0,06	0,005	0,29	0,004
x Periodo=2	13,46	2	0,010	0,24	0,029	0,58	0,001
x Idioma=In	9,08	2	0,011	0,08	0,018	0,32	0,011
Nombre x Periodo	10,82	4	0,029	0,05	0,036	0,28	0,029
x Idioma=Es	6,97	2	0,031	0,17	0,110	0,48	0,031
Nombre x Distribución	3,37	4	0,498	-	-	-	-

[1]Coeficiente de contingencia. Valor comprendido entre 0 (no hay asociación) y 1 (gran relación entre las variables).

[2]Coeficiente de incertidumbre. Indica la reducción proporcional del error cuando los valores de una variable se emplean para pronosticar valores de la otra variable. Por ejemplo, un valor de 0.83 indica que el conocimiento de una variable reduce en un 83% el error al pronosticar los valores de la otra variable.

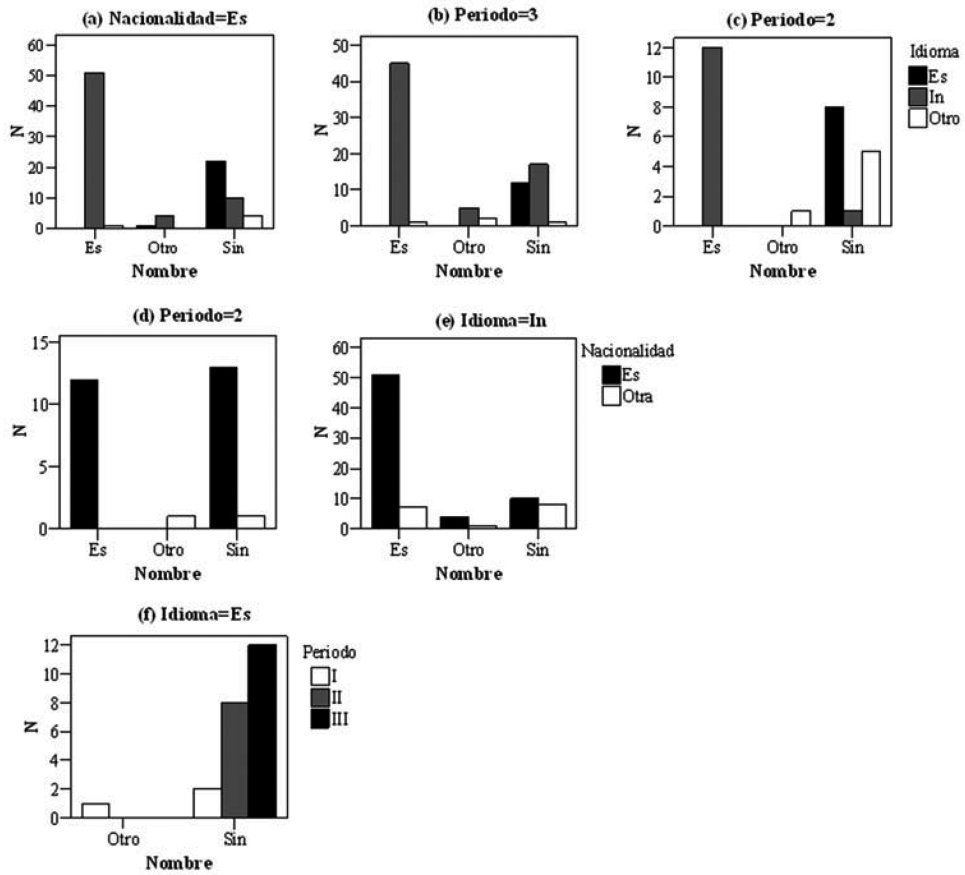

Figura 3. Gráficos de barras agrupadas del análisis de contingencia entre 3 factores: (a) Nombre x Idioma x Nacionalidad; (b y c) Nombre x Idioma x Periodo; (d) Nombre x Nacionalidad x Periodo; (e) Nombre x Nacionalidad x Idioma; (f) Nombre x Perido x Idioma.

Graphic results of contingency analysis between 3 factors: (a) Name x Language x Nationality; (b and c) Name x Language x Period; (d) Name x Nationality x Period; (e) Name x Nationality x Language; (f) Name x Period x Language.

De las 136 encuestas enviadas, 101 (74 %) llegaron a su destino y sólo se recibieron 24 respuestas (23 %). La gran mayoría de los encuestados considera que el nombre vernáculo es importante, pero algunos dudan sobre si debe ser reglamentado (respuestas ambiguas el 9%) e incluso consideran que no ha de serlo (17%) (Figura 4). Los investigadores que contestaron "Si" a las dos primeras cuestiones justificaron su opción argumentando que los nombres comunes

traducen los binomios científicos y deberían, por tanto, estar relacionados con ellos; permiten identificar especies a nivel coloquial y fuera del ámbito científico; facilitan la comunicación incluso en el seno de la comunidad científica, evitando múltiples nombres y la confusión consecuente y, además pueden aportar información sobre alguna característica de la especie. Los encuestados que discreparon de esta opinión consideran: que el nombre vernáculo es prescindible o no tiene importancia; que es irrelevante considerar un único nombre vernáculo y que al hacerlo se pierde diversidad lingüística; resaltan la dificultad en consensuar un único nombre vernáculo y refieren el esfuerzo invertido por algunos grupos de investigadores para proponer nombres comunes que no llegaron a superar el desacuerdo; sugieren que los investigadores no tienen derecho de describir criterios para los nombres vernáculos que fueron, en su mayoría, creados por gente local en tiempos ancestrales y que el sentido común y los nombres más antiguos ya existentes deberían ser alternativas a seguir.

Las respuestas a la cuestión nº 3 fueron diversas y muchos investigadores (39%) eligieron múltiples opciones (A/C; B/E; B/C/D; e incluso el 17 % eligió todas las posibilidades). Tan sólo tres investigadores (13%) no eligieron ningún criterio. La opción "Otro" fue seleccionada el 13% de las ocasiones y, tanto en estos casos como en las respuestas múltiples que incluían esta opción, se presentaron varias sugerencias: la tradición, la etimología de las palabras "cabra montés", el nombre que más se ha venido utilizando a lo largo de la historia en cada lugar, la naturaleza silvestre de la especie (que la diferencia claramente de las cabras domésticas asilvestradas), cualquier característica inherente a la especie y cualquier característica que la diferencie claramente de otras *Capra*. Las opciones A (distribución actual), B (distribución ancestral) y C (características morfológicas) fueron elegidas, respectivamente, por el 17%, el 9% y el 9% de los encuestados. La opción D (localidad de origen) no fue elegida por separado en ninguna ocasión. Al considerar las respuestas acumuladas por opción (Figura 4), la distribución actual aparece como el criterio más seleccionado (24%), seguido por (en orden decreciente) las características morfológicas de la especie (22%), su distribución ancestral y otras características (ambas 18%) y finalmente su localidad de origen (11%). Se acumuló un 7% de respuestas nulas en esta cuestión.

En cuanto a la elección de nombres con distintos gentilicios (Cuestión 4), también se recibieron respuestas múltiples, (**Es/Ib** y **Es/Sin**, sumaron el 13%), 1 respuesta nula (4%) y 1 **Otro** utilizando un criterio morfológico: "Spiralled wild goat", en inglés. Los nombres **Ib** fueron elegidos, por sí solos, en el 48% de los

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casos, seguidos por los nombres **Sin** (17%), los nombres **P** (4%) y por fin los **Es**. Considerando las respuestas acumuladas (Figura 4), el orden decreciente de elección hacia un nombre común para *C. pyrenaica* fue **Ib**, **Sin**, **Es**, **Otro**. Las respuestas nulas sumaron el 4%.

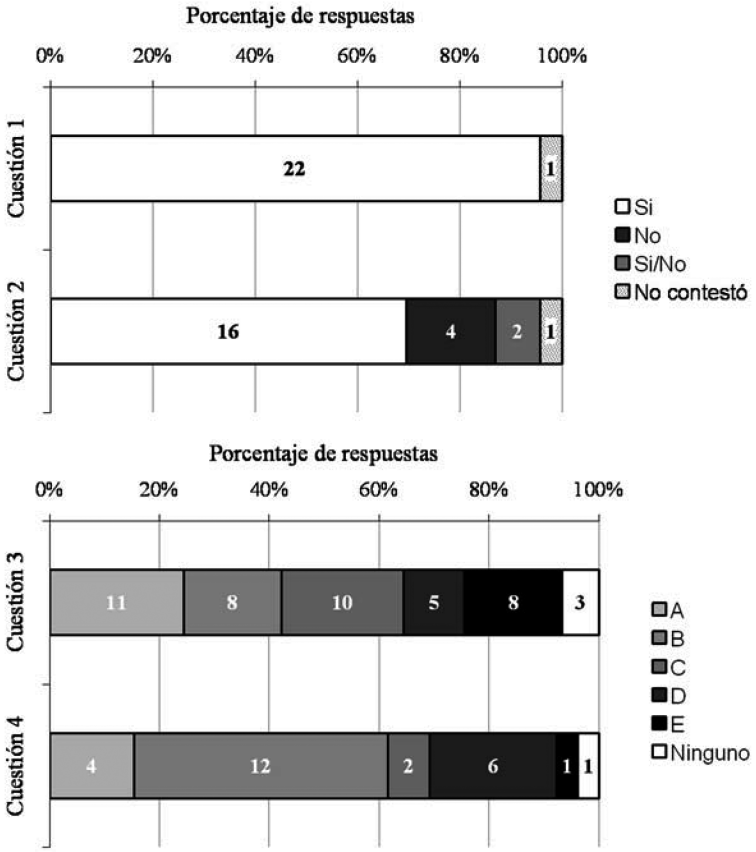

Figura 4. Resultados obtenidos de la encuesta. Los valores absolutos de las barras corresponden: i) al número de encuestados (cuestiones 1 y 2) y ii) a las respuestas acumuladas por opción (cuestiones 3 y 4). Leyenda "Cuestión 3": A=Distribución actual; B=Distribución ancestral; C=Morfología; D=Localidad de Origen; E=Otra. Leyenda "Cuestión 4": A=gentilicio Español; B=gentilicio Ibérico; C=gentilicio Pirenáico; D=sin gentilicio; E=Otro.

Results obtained through enquiry to researchers. Absolute values in graphic bars refer to: i) number of researchers answering to question 1 and 2 and ii) answers per option (questions 3 and 4). Legend Question 3: A=Actual distribution range; B=Former distribution range; C=Morphology; D=Local of origin; E=Other. Legend Question 4: A=Spanish sobriquet; B=Iberian sobriquet; C=Pyrenean sobriquet; D=Without sobriquet; E=Other.

Discusión

La literatura científica presenta una considerable variedad de nombres vernáculos para *C. pyrenaica* y muchos autores (más de la mitad de los consultados) los usan incluso con un gentilicio en sus publicaciones. El elemento común entre estos gentilicios es su carácter geográfico, o más bien político, a semejanza de lo que ocurre con otras especies de *Capra* (véase Shackleton 1997). En orden decreciente de frecuencia, el gentilicio elegido para designar a *C. pyrenaica* está relacionado con España, la Península Ibérica y los Pirineos.

La popularización de determinados gentilicios en la literatura científica aparece relacionada con factores de orden humano, específicamente a los idiomas inglés y castellano y a los autores españoles. Estos autores son responsables de la mayor parte de la producción científica sobre de la especie y su preferencia por un gentilicio español es evidente en publicaciones en inglés desde la década de los ochenta. Esta tendencia pudo haber sido influenciada por ser el primer tipo de gentilicio en ser utilizado en dicho idioma por un autor español (Cabrera 1911). A medida que el inglés ganó protagonismo en la divulgación científica, el uso del mismo gentilicio ganó expresión. Al usar el idioma nativo los autores españoles prefieren nombres vernáculos sin gentilicio.

No se encontró una relación significativa entre el nombre vernáculo y el único factor que podríamos considerar relacionado intrínsecamente con la especie: los cambios en su distribución a lo largo del tiempo. Asimismo, el hecho de que estuvo restringida a España durante cerca de 100 años - el rango de distribución temporal más amplio - pudo haber favorecido la aceptación de "Spanish ibex" como su nombre vernáculo en revisiones oficiales (Shackleton 1997) e incluso con su catalogación como endemismo español (Blanco y González 1992). El gentilicio ibérico parece estar incrementando su frecuencia de utilización quizás debido a la influencia del último cambio en el área de distribución de la especie. El gentilicio pirenáico fue aplicado a la especie una única vez y pocos años antes de su extinción de la vertiente española de los Pirineos.

La distribución actual de la especie fue elegida como el criterio que debería tenerse en cuenta en el reglamento del nombre común. En concordancia, el nombre más votado por los encuestados tiene un gentilicio ibérico. Su elección fue justificada por éstos considerándolo el más preciso y objetivo, ya que describe el área en la cual la especie evolucionó y se distribuyó ancestralmente y en la que está confinada actualmente. Algunos investigadores refirieron que otro gentilicio

podría ser considerado subjetivo, parcial o político y que sólamente cabría usarlo para referirse a una subespecie o población en particular. La inclusión de "ibérico" en el nombre vernáculo de *C. pyrenaica* se está incrementando, de hecho recientemente la UICN (Herrero y Pérez 2008) la denominó "Iberian wild goat".

A pesar de la estrecha relación filogenética entre *C. ibex* y *C. pyrenaica* (Pidancier *et al.* 2006, Kazanskaya *et al.* 2007), algunos especialistas, siguiendo la opinión de Schaller (1977), enfatizan que esta última no es un "íbice" y que, por lo tanto, debe denominarse "cabra montés". En cuanto a este nombre (particularmente en su variante "macho montés"), encontramos una falta de concordancia de género entre sustantivo y adjetivo y proponemos el uso estandarizado de "cabra montesa" cuando se use el castellano y también el portugués.

Respecto a la traducción de "cabra montesa" al inglés, "mountain goat" parece la más correcta. Sin embargo, este nombre ya se utiliza para designar a la cabra blanca de las Rocosas *Oreamnus americanus* en ese idioma (Shackleton 1997). Aunque "wild goat" se use actualmente para referirse a *C. aegagrus*, hemos optado por utilizar también este nombre en inglés para *C. pyrenaica*, precedido de un gentilicio que identifica la especie.

Aunque la morfología también se tuvo en cuenta en la definición del nombre común, apenas un encuestado presentó una propuesta en ese sentido ("Spiralled wild goat", o sea, "Cabra montés espiralada") y lo justificó por el hecho de que la distribución de la especie está sujeta a cambios que no permiten la adopción de un gentilicio apropiado a lo largo del tiempo. De hecho, según Schaller (1977), la morfología de los cuernos de *C. pyrenaica* es única entre los Caprinos, presentando 3 curvaturas que conforman una espiral: para fuera y hacia arriba, después hacia atrás y por fin hacia dentro y hacia arriba. El inconveniente de esta propuesta es que podría generar alguna confusión con el marjor (*C. falconeri*).

En conclusión, los resultados presentados en esta revisión sugieren que las razones que llevaron a la adopción del gentilicio español como el más frecuente en el nombre común de la especie fueron sobre todo de carácter humano, aunque en los últimos años el uso del mismo se ha podido deber a su inclusión en la última clasificación publicada por el grupo de expertos en Caprinos de la UICN (Shackleton y Lovari 1997). Es una denominación ampliamente utilizada en la divulgación científica pero este nombre sugiere que la especie se encuentra restringida a España, o incluso que se trata de un endemismo español, lo cual no se corresponde con la realidad actual. Elegimos el gentilicio ibérico como el más adecuado a la especie en términos de distribución tanto

ancestral como actual, y de zona de origen. Además, la utilización de este gentilicio puede promover una dimensión humana que consideramos importante: la responsabilidad compartida de conservación de la especie por parte de todos los estados que constituyen la Península Ibérica y que con ella comparten una importante continuidad geográfica.

En definitiva, proponemos el uso de los siguientes nombres comunes para *C. pyrenaica* en las publicaciones científicas: "Cabra montesa ibérica" en castellano y en portugués, "Cabra salvatge ibèrica" en catalán, "Cabra fera ibérica" en gallego, "Basahuntz iberiar" en vasco, "Iberian wild goat" en inglés, "Bouquetin ibérique" en francés, "Stambecco iberico" en italiano e "Iberischer Steinbock" en alemán.

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CHAPTER 4. IBEX ON NUMBERS

"Must we lose hope if observation and biological sampling are not possible?"

Michael H. Kohn and Robert K. Wayne

4.1. THE EFFECT OF DATA ANALYSIS STRATEGIES IN DENSITY ESTIMATION OF MOUNTAIN UNGULATES USING DISTANCE SAMPLING

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ITALIAN JOURNAL OF ZOOLOGY, 2015, Vol. 82, 262-270

4.2. A PRIMER OF THE NON-INVASIVE MONITORING OF THE IBERIAN IBEX *Capra pyrenaica* IN THE PENEDA- GERÊS NATIONAL PARK (PORTUGAL)

MOÇO G, SILVA T, PÉREZ JM, SORIGUER RC, SERRANO E & ALVES PC

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The effect of data analysis strategies in density estimation of mountain ungulates using distance sampling

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Abstract
Distance sampling is being extensively used to estimate the abundance of animal populations. Nevertheless, the great variety of ways in which data can be analyzed may limit comparisons due to the lack of standardization of such protocols. In this study, the influence of analytical procedures for distance sampling data on density estimates and their precision was assessed. We have used data from 21 surveys of mountain ungulates in the Iberian Peninsula, France and the Italian Alps. Data from such surveys were analyzed with the program Distance 6.0. Our analyses show that estimated density can be higher for higher levels of data truncation. We also confirm that the estimates tend to be more precise when data are analyzed without binning and without truncating. We found no evidence of size biased sampling as group size and distances were uncorrelated in most of our surveys. Despite distance sampling being a fairly robust methodology, it can be sensitive to some data analysis strategies.

Keywords: *Distance sampling, mountain ungulates, data analysis, population monitoring, precision*

Introduction

Estimating the abundance of wild animal populations is a basic management action. Unbiased and precise population estimates and related demographic parameters are often needed to monitor and manage wild populations. Caprids, like other big game species, are not an exception (Shackleton 1997). Currently, different methods are available for estimating animal abundance. They could be direct (based on the observation of individuals) or indirect (based on the record of calls, dung, tracks, etc.) methods; some of them are simple and others complex, e.g. taking into account the heterogeneity in detection probability, or combining simple and independent methods (Krebs 2001; Borchers et al. 2002; Williams et al. 2002). Among this variety of methodologies, distance sampling (DS hereafter) has become a popular and versatile technique. It can be applied as a direct or an indirect method, and does not necessarily involve the capture and handling of animals (Williams et al. 2002). If the methodological assumptions are met, it allows obtaining robust and precise estimates of population density with a good balance between cost and results (Southwell & Weaver 1993; Buckland et al. 2001, 2004; Fewster et al. 2005). During the last two decades, DS has been used for estimating numbers of ungulate populations in a wide variety of habitats (Trenkel et al. 1997; Marques et al. 2001; Focardi et al. 2002; Ward et al. 2004; Ellis & Bernard 2005; Olson et al. 2005; Franzetti & Focardi 2006; Ogutu et al. 2006; Acevedo et al. 2008), and its efficiency is often compared to that of other methods such as total counts, block counts, capture–recapture, and

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derived population estimates (Seddon et al. 2003; Herrero et al. 2011). This methodology has also been used for monitoring mountain ungulate populations (Escos & Alados 1988; Palomares & Ruiz-Martínez 1993; Pérez et al. 1994; Liu et al. 2008; Carranza 2010; Herrero et al. 2011; Wingard et al. 2011; Schmidt et al. 2012).

DS methodology uses a count of observations (i.e. animals or groups, dung, nests, songs, among others) and their distance from the observer (radial distance if observations are made from a point, or perpendicular, when using line transects). Importantly, DS relaxes the critical assumption that detection probability in a sampling unit is equal to 1. Statistical inference based on DS depends on the validity of different assumptions (Burnham et al. 1980; Barry & Welsh 2001; Buckland et al. 2001; Borchers et al. 2002): (1) objects (animals) located precisely on the point or on the transect line are always detected. This means that g(0) = 1, where g(x) is a decreasing function of distance and denotes the probability to detect an object, given that it is at distance x; (2) animals are detected at their initial location, prior to any movement or, in other words, the animals are detected by the observer before the observer has any influence on their position; (3) distances and angles, if applicable, are accurately measured, or objects are included in the appropriate distance bin (or distance range) if grouped data are used; and (4) observations are independent events.

Otto and Pollock (1990) emphasized the problem of size bias: bigger groups should have a higher probability of being detected than the smaller ones, especially at larger distances, which could contribute to overestimation of the mean cluster size of the population and, by consequence, the real abundance as well. Buckland et al. (2001, sections 3.5, 4.8) provide several recommendations to account for size-biased issues in DS. On the other hand, Southwell and Weaver (1993) remarked on the great number of arbitrary decisions we have to make when working with DS (e.g. which estimator to use, whether data must be binned in distance categories or not, truncated or not, or if we have to use observations as individuals or groups). Nevertheless, the way in which data are analyzed in each survey is rarely described with this level of detail in the published literature. A few exceptions might be found for other taxonomic groups; see for instance Stanbury and Gregory (2009) on breeding bird abundance.

In this work, we compare the most common strategies described in the specialized literature about truncating and binning data (Buckland et al. 2001). Our main objective is to assess the effects of different analytical procedures on the density estimates and their precision for several populations of Iberian ibex (*Capra pyrenaica*), Alpine ibex (*Capra ibex*), Pyrenean chamois (*Rupicapra pyrenaica*) and Alpine chamois (*Rupicapra rupicapra*) in order to improve data analysis protocols, and to make comparable estimations carried out in different years and locations, as indicated in Morellet et al. (2011).

Materials and methods

We used data from 21 field surveys carried out between 1995 and 2012 in the Parc National des Pyrénées (PNP), France, for Pyrenean chamois; Parque Nacional de Peneda-Gerês – Baixa Limia and Serra do Xurés Natural Park (PNPG), two adjacent and contiguous areas in northern Portugal and northwestern Spain, respectively, Sierra de Loja (SL), Sierra Sur de Antequera (SSA), Sierra de Tejeda y Almijara (STA), Sierra Mágina (SM) and Sierra Nevada Natural Space (SN), southern Spain, for Iberian ibex, and Parco Naturale Val Troncea (PNVT), western Italian Alps, for Alpine chamois and Alpine ibex (Figure 1, Table I). These surveys accounted for a total of 1919.7 km of walked transect. The surveys were designed to sample at least 10% of the study surface area and transects were placed using a stratified sampling design (regarding orientation, slope, height and type of vegetation). For details in survey design, see Palomares and Ruiz-Martínez (1993) and Pérez et al. (1994). In Table I, we indicate the date (month and year) in which each survey was performed. Transects were sampled from 07:00 to 10:00 and

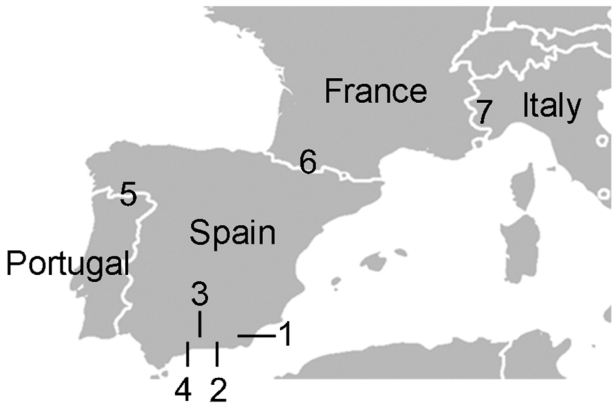

Figure 1. Distribution of the study sites. 1: Sierra Nevada Natural Space for *Capra pyrenaica hispanica*; 2: Sierra Mágina for *C. p. hispanica*; 3: Sierras de Tejeda y Almijara for *C. p. hispanica*; 4: Sierra de Loja for *C. p. hispanica*; 5: Sierra Sur de Antequera for *C. p. hispanica*; 6: Parque Nacional de Peneda-Gerês – Baixa Limia and Serra do Xurés Natural Park for *Capra pyrenaica victoriae*; 7: Parc National des Pyrénées for *Rupicapra pyrenaica*; 8: Parco Naturale Val Troncea for *Rupicapra rupicapra* and *Capra ibex*.

Table I. Data describing surveys used in this study: location and date (month and year) of each survey, species studied (Cp: *Capra pyrenaica*, Rp: *Rupicapra pyrenaica*, Rr: *Rupicapra rupicapra*, Ci: *Capra ibex*), K: number of transects, L: total length (in km), Md: maximum distance of observation, Td (5%): distance used for truncation of 5% of observations, Td (10%): distance used for truncation of 10% of observations (all above-mentioned distances in m). Superscript numbers 1: 20%, 2: 33.3%, 3: 15%, 4: 20% and 5: 30% of observations truncated. SN: Sierra Nevada Natural Space; STA: Sierra de Tejeda y Almijara; SL: Sierra de Loja; SSA: Sierra Sur de Antequera; SM: Sierra Mágina; PNPG: Parque Nacional de Peneda-Gerês–Baixa Limia and Serra do Xurés Natural Park.

Location	Date	Species	K	L	Md	Td (5%)	Td (10%)
SN	Jun 1995	Cp	19	269.5	800	550	300
SN	Nov 2001	Cp	47	283.7	500	500	475
SN	Jul 2002	Cp	40	319.5	800	500	400
SN	Jul 2003	Cp	40	374.7	800	500	420
SN	Oct 2009	Cp	26	155.5	420	237	197
STA	Oct 2009	Cp	20	139.5	623	471	375
SL	Jun 2005	Cp	8	33.4	850	550	440
SL	Jun 2007	Cp	8	33.9	480	450	400 [1]
SSA	Oct 2009	Cp	5	32.5	313	274	221
SM	Nov 2012	Cp	13	83.1	750	600	600
PNPG	Jul 2005	Cp	9	39.3	554	554	300
PNPG	Feb 2006	Cp	9	39.3	534	534	450 [2]
PNPG	Mar 2007	Cp	9	41.0	541	479	447 [3]
PNP	Oct 2002	Rp	1	2.8	150	147 [4]	140 [5]
PNP	Oct 2005	Rp	1	2.6	600	530	500
PNP	Oct 2007	Rp	1	4.5	265	252	247
VT	Oct 2006	Rr	8	29.2	593	527	390
VT	Oct 2007	Rr	8	18.4	600	370	300
VT	Oct 2008	Rr	5	17.3	633	490	413
VT	Jul 2009	Rr	15	51.4	811	574	455
VT	Jul 2009	Ci	10	31.7	418	391	300

from 17:00 to 21:00, coinciding with daily activity periods of animals.

Each transect was walked by two or three observers who recorded the observed number of groups, group sizes and their perpendicular distances to the transect line. We used a compass, laser telemeter and global positioning system (GPS) to navigate, measure distances and note locations of species occurrences.

We used Distance 6.0 release 2 (Thomas et al. 2010) to obtain density estimates and corresponding coefficient of variation. To model the detection functions we used half-normal with hermite polynomial expansion, uniform with cosine expansion and hazard-rate with cosine expansion (Buckland et al. 2001; Franzetti & Focardi 2006). A maximum of two adjustment terms was used in order to balance between bias and precision, and the lowest AIC (Akaike's Information Criterion) value was used for model selection. Encounter rate and mean group size were obtained for each survey. Variance of encounter rate was estimated empirically. The coefficient of variation (CV) of density estimates and their associated 95% confidence intervals were also obtained.

In the absence of group size bias, the following estimator of density can be used to account for the effect of group size:

$$\hat{D} = \frac{n.\hat{f}(0).\bar{s}}{2L} \quad (1)$$

where n is the number of observed groups, $\hat{f}(0)$ is an estimator of the probability density function of perpendicular distances evaluated at distance 0, $\bar{s}$ is the observed mean group size and L is the transect length. The estimation of f(0) plays a very important role. For a reliable estimate of D, it is recommended that the histogram of observed perpendicular distances presents a shoulder near the line or point (i.e. near distance zero). Also, it is recommended that detections at great distances from the transect, that are considered outliers, should be discarded to facilitate modelling of the data since they provide little information to estimate f(0) (Buckland et al. 2001).

The estimated variance is given by:

$$\hat{var}(\hat{D}) = \hat{D}^2\left\{[\mathrm{cv(n)}]^2 + \left[cv\left\{\hat{f}(0)\right\}\right]^2 + [cv(\bar{s})]^2\right\} \quad (2)$$

where cv denotes the coefficient of variation of each variance component (Buckland et al. 2001).

We used 21 different strategies of data analysis: three right truncation levels (0%, 5% and 10% of observations) and seven data binning categories

(using unbinned distances – no binning – and binning distance data into five to 10 equal intervals). After careful inspection of the distance histograms for the surveys, we did not find evidence of heaping, which might justify the analysis of binned data in distance categories. We performed analyses with the conventional distance sampling (CDS) engine. For each strategy, we calculated density estimates with the corresponding coefficient of variation. We used Friedman's χ^2 tests (Siegel & Castellan 1988) to compare the ranks of density estimates and their associated CVs, and to find possible significant differences among strategies, since the data from the same surveys are repeatedly used for each analysis. We used the post-hoc Dunn test to check for pairwise comparisons when significant differences were detected among strategies. Statistical analyses were performed using SPSS 18.0 (SPSS Inc. 2009). For each survey, we also calculated the correlation between group size and perpendicular distance.

Results

In Table II, we present a summary statistics of each survey: number of observations (individuals and groups), encounter rate for groups, mean group size and its associated coefficient of variation, and the observed correlation coefficients between group size and distance of observation, with the corresponding p-values. Evidence of correlation between group size and distance of observations was almost always absent. Only in the survey of PNP carried out in 2007 for *R. pyrenaica* were group size and perpendicular distance positively correlated: $r = 0.52$; df = 24, $p = 0.003$.

Overall, the 21 surveys detected 5852 individuals and 1274 groups. Nevertheless, only six of the surveys presented adequate sample sizes (> 60 groups), and nine surveys presented questionable sample sizes for analyses (from 29 to 58 groups). The remaining six had inadequate sample sizes (from three to 26 groups) to perform DS estimation.

Thus, only surveys with adequate and questionable sample sizes were used for comparing density estimates and associated CVs under the different analysis strategies to perform DS estimation. These surveys also have an adequate number of replicates ($K \geq 15$), as can be observed in Table I.

In Table III, we present a summary of the statistical tests resulting from the comparison of strategies for surveys with adequate sample sizes. We notice that for unbinned data, density estimates differed significantly with truncation ($p = 0.015$). The post-hoc Dunn test shows that densities obtained after

Table II. Data describing observations from each survey: location and year (in brackets) of each survey, n_i: number of individuals detected, n_c: number of clusters detected, ER_c: encounter rate (clusters), mcs: mean cluster size obtained for each sample and its respective coefficient of variation (CV, %), cor: correlation between cluster size and distance of observation (x_i), *p*: p-value associated to the correlation coefficient, a: Alpine chamois survey, b: Alpine ibex survey. SN: Sierra Nevada Natural Space; STA: Sierra de Tejeda y Almijara; SL: Sierra de Loja; SSA: Sierra Sur de Antequera; SM: Sierra Mágina; PNPG: Parque Nacional de Peneda-Gerês–Baixa Limia and Serra do Xurés Natural Park.

Survey	n_i	n_c	ER_c	mcs	CV (%)	cor	*p*
SN (1995)	521	138	0.51	3.78	11.47	−0.06	0.750
SN (2001)	966	119	0.42	8.12	8.88	0.14	0.073
SN (2002)	830	241	0.75	3.44	5.89	−0.04	0.726
SN (2003)	540	169	0.43	3.38	16.04	0.01	0.460
SN (2009)	489	79	0.51	6.19	10.16	−0.02	0.573
STA (2009)	196	58	0.42	3.38	13.06	−0.08	0.719
SL (2005)	298	46	1.38	6.46	16.89	0.12	0.206
SL (2007)	264	30	0.88	8.80	21.83	−0.19	0.848
SSA (2009)	87	29	0.89	3.00	13.54	−0.24	0.900
SM (2012)	240	43	0.52	5.63	11.36	−0.11	0.753
PNPG (2005)	74	6	0.20	12.33	49.66	−0.17	0.625
PNPG (2006)	109	3	0.08	36.33	36.73	−0.87	0.838
PNPG (2007)	137	13	0.32	10.46	31.08	−0.10	0.604
PNP (2002)	21	10	3.57	2.10	36.51	−0.39	0.868
PNP (2005)	63	21	8.08	3.00	21.82	−0.12	0.695
PNP (2007)	72	26	5.82	2.77	13.33	0.52	0.003
VT (2006)	189	43	1.47	4.40	15.07	0.09	0.280
VT (2007)	171	42	2.28	4.07	22.96	−0.11	0.760
VT (2008)	97	33	1.91	2.94	32.84	−1.47	0.920
VT (2009 a)	409	96	1.87	4.26	12.40	0.001	0.500
VT (2009 b)	79	29	0.91	2.72	15.77	0.19	0.840

Table III. Results from Friedman's test to compare densities and their coefficients of variation (CV) by strategies – Friedman's χ^2: observed value for the test statistics; df: degrees of freedom; p: p-value; *: significant at 0.05.

Strategies	Density Friedman's χ^2	df
No binning: without truncating; truncating 5%; truncating 10%	8.435	2
No binning: without truncating; binning 5–10 classes	16.316	6
No binning: without truncating; binning in 5–10 classes and truncating 5%	4.639	6
No binning: without truncating; binning in 5–10 classes and truncating 10%	3.521	6
No binning: truncating 5%; binning in 5–10 classes and truncating 5%	5.856	6
No binning: truncating 10%; binning in 5–10 classes and truncating 10%	1.153	6
Binning in 5–10 classes: truncating 5%; binning in 5–10 classes: truncating 10%	8.845	11

truncating 10% of data were significantly higher than those obtained when using all the information from the surveys (i.e. 0% right truncation) (p = 0.018). Similarly, binning untruncated data into distance intervals produced significantly different density estimates (p = 0.012). Nevertheless, truncation did not affect the precision of density estimates, i.e. associated CVs (p = 0.200), nor did binning untruncated data into distance intervals (p = 0.069). Also, we did not find significant differences when comparing densities or CVs using different binning strategies if data were truncated at 5% or 10%.

Density estimates did not differ when comparing untruncated–unbinned data and other data binning strategies for truncation at 5% or at 10% (p = 0.591 and p = 0.741, respectively). Associated CVs for density estimates did not significantly increase when data were binned and truncated at 5% (p = 0.079) nor when truncated at 10% (p = 0.331).

No significant differences in either estimated densities or their associated CVs were observed when

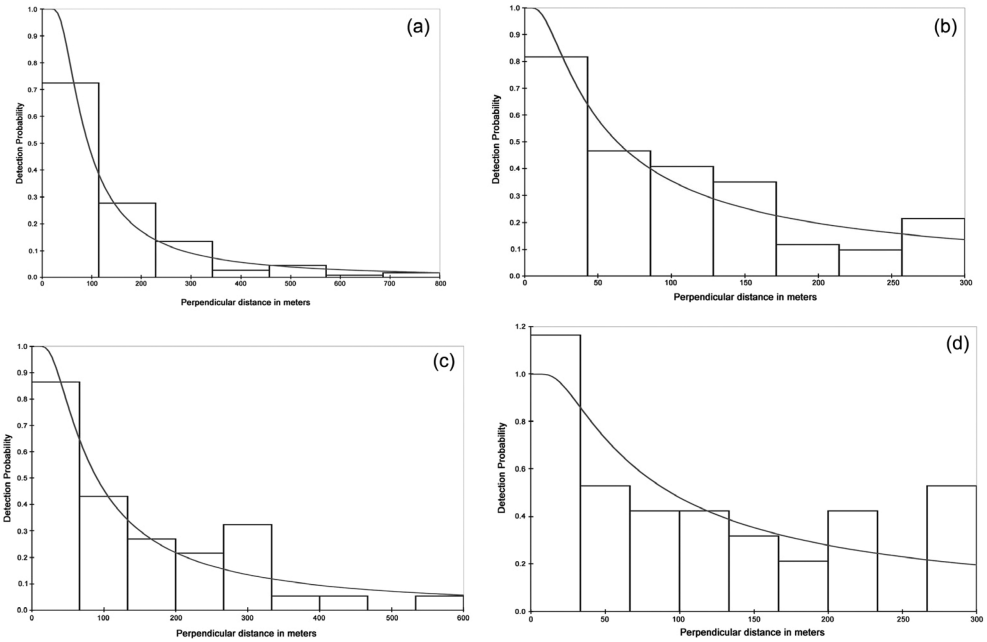

Figure 2. The effect of truncation of 10% of observations on the adjustment of the detection functions to distance data on the density estimate and its associated CV illustrated with surveys from two different locations; df = degrees of freedom; P = p value for GOF (goodness of fit) test; K = number of parameters of the detection function; D = estimated density; CV = estimated coefficient of variation associated to D; CI = confidence interval. (a) Sierra Nevada (1995), *Capra pyrenaica*; unbinned distance data; total Chi-square value = 5.7630; df = 4.00; P = 0.21756; hazard/cosine; K = 2.0; D = 6.85, CV = 46.88, 95% CI = 2.73–17.20; number of observed clusters = 138. (b) Sierra Nevada (1995), *Capra pyrenaica*; distance data truncated at 10%; total Chi-square value = 7.9731; df = 4.00; P = 0.09257; hazard/cosine; K = 2.0; D = 8.42, CV = 51.62, 95% CI = 3.12–22.72; number of observed clusters = 124. (c) Val Troncea (2007), *Rupicapra rupicapra*; unbinned distance data; total Chi-square value = 7.0644; df = 6.00; P = 0.31494; hazard/cosine; K = 2.0; D = 30.74, CV = 39.13, 95% CI = 14.51–65.13; number of observed clusters = 42. (d) Val Troncea (2007), *Rupicapra rupicapra*; without binning and truncating 10% of data; total Chi-square value = 2.6380; df = 5.00; P = 0.75559; hazard/cosine; K = 2.0; D = 32.44, CV = 46.46, 95% CI = 13.43–78.34; number of observed clusters = 38.

using binned data truncated at 5% and 10% (p = 0.636 and p = 0.609, respectively). For the sake of completeness, we also analyzed surveys with questionable sample size ($26 \leq n \leq 60$), and similar results were found (results not presented).

Figure 2 illustrates the effect of data truncation on model fitting, density estimates and their associated CV. In these two selected surveys, we can observe a slight tendency of increasing density and decreasing precision after truncating 10% of observations.

Discussion

Almost any analyst interested in the application of DS methodology is confronted with some technical and often arbitrary decisions that sometimes induce misleading results. Should data analyses involve truncation and, if so, how much should we truncate? Should distance categories be used to bin the data? How many bins should we use? The effect of truncating, binning the data into distance categories and choosing an "optimum" number of classes is rarely discussed when presenting results in the published literature. Buckland et al. (2001) advocate truncating about 5% or 10% of the data in order to eliminate extreme observations or outliers. There is a trade-off between the amount of data available for density estimation and data binning or truncation.

When data are truncated and/or binned there is a reduction in the amount of information available for estimation, which could lead to a decrease in precision. In the case of binned data, DS uses the count and the mid-point of each interval class for estimation purposes, rather than individual distance observations. Our results suggest some evidence that binning untruncated data has a significant effect on density estimates. However, there is no really good reason to bin distance data unless there is evidence of problems such as measurement error, heaping or movement. Although assumption violations in our studies were kept to a minimum, we argue that when sampling mountainous ungulate populations, these types of problems are more likely to occur due to the particular features of the land topography. The effect of binning might actually be different depending on what are the underlying problems that led to the need for binning.

One of the main findings of the current study is that density estimates may increase with increasing level of truncation. This might seem counterintuitive and in disagreement with previous work (see for instance, Southwell & Weaver 1993; Stanbury & Gregory 2009).

We could consider that the use of truncated data can severely underestimate the effective strip width and, consequently, overestimate density. However, for the species in consideration, DS data often are clustered, and truncation sometimes involves removing a significant amount of data at larger distances (either clusters or individuals) in mountainous terrain without necessarily impacting the probability of detection, but seriously affecting density estimates due to the trade-off between the number of detections ignored after truncation and the estimated effective strip width. This may be particular important in data collected from mountainous terrain, where the topography plays an important role in detectability, and the detectability function may not be strictly monotonically decreasing.

Our results, however, agree with those obtained by Southwell and Weaver (1993) regarding the loss of precision in estimates when working with truncated and/or binned data. This work also suggests that DS methodology likely is fairly sensitive to the choice of data analysis strategy. However, we cannot assess the accuracy of our estimates, as the real density remains unknown in the majority of cases. Therefore, further research involving simulations, artificial or marked populations and/or combined methodologies (e.g. DS and capture–recapture) would be necessary for assessing whether DS methodology is appropriate to monitor mountain ungulate populations (Pérez et al. 2002).

In order to increase the precision of density estimates, some users of DS methodology may use single animals as individual observation units, even in the presence of grouped populations. This approach is completely inadequate and has been widely discussed in the literature. Grouped animals are not independent observations; therefore, we recommend treating groups as the units of observation to avoid possible violation of the assumption that every observation must be an independent event (Burnham et al. 1980; Barry & Welsh 2001; Buckland et al. 2001; Borchers et al. 2002). The variance associated with mean group size is an added component of the overall variance of the estimated density, as shown by Equation 2 (Leatherwood et al. 1978; Southwell & Weaver 1993; Buckland et al. 2001).

Different authors have pointed out the possibility that group size and perpendicular distance of observation are dependent variables (Drummer & McDonald 1987; Drummer et al. 1990; Otto & Pollock 1990; Drummer 1991; Chen 1996; Chen & Cowling 2001), but, in general, this was not the case in our study. A possible explanation for the lack of dependency between group size and detection distance might be related to the topographic features of the terrain, the vegetation type or some other factors, but further research is needed to investigate this finding. Nevertheless, additional work using multiple

covariate distance sampling (MCDS) would help us to determine if group size or other covariates (e.g. habitat type, sex and age of animals) are needed to better model detectability.

Our study provides evidence that estimating the density of mountain ungulates with high precision and accuracy is difficult. A detailed description of the way in which data are analyzed is fundamental to better understand and make comparable results from different surveys.

There is often unaccounted variance in DS estimates, as these are conditional on some essentially ad hoc decisions. However, if there are no issues in the data, and for adequate sample sizes, the impact of these choices may be negligible. Often, differences observed among specific data strategies are the result of the joint effect of possible problems in the data sets, common to ungulate data, and an eventual effect of the strategy itself. Therefore, these strategies are mostly important and needed when dealing with data for which some assumptions are violated. Then the analysis chosen cannot be taken from a recipe; it must be carefully chosen to minimize the violation of the assumptions. For the surveys that we analyzed, assumption violations were kept to a minimum because strict sampling protocols were followed during data collection.

One may suspect that animals can react to the presence of the observers prior to their detection. Therefore, the assumption that $g(0) = 1$ could be violated. This assumption was assessed with the use of Bayesian statistics (Markov's chains; see Monteiro 2010). For this purpose, Monteiro used the observations of the surveys from PNP (*Rupicapra pyrenaica*) since most of the individuals of this population are marked (Alpízar-Jara & Pollock 1996). The results demonstrated that $g(0)$ did not significantly differ from 1.

The distance to the animal or to a group was measured to their initial location. For this purpose, if the animals moved, any referential object (e.g. a tree or a stone) can be very useful. When we work under optimal light conditions (this implies an adequate sampling design regarding the hours used to carry out the survey, and avoiding sampling under bad weather conditions) accurate measures of distances and angles can be obtained.

Finally, the use of the cluster (or group) as the observation unit guarantees that each observation is an independent event.

Even when the assumptions of the DS methodology are met, obviously the results must also be correctly interpreted and/or discussed. For instance, a high CV value can indicate a great variability of local density within the study area, even when a high number of observations have been recorded, or else it must be due to a great variability of cluster sizes (see surveys from the PNPG, Table II).

Estimating year-to-year changes in density is not a realistic goal for most species, and population density *per se* provides no information on the relationship between the population and its habitat (Morellet et al. 2007). For these reasons, these authors propose the use of a set of indicators of animal performance, population abundance, habitat quality and/or herbivore habitat impact within the context of management programs.

The reliability of density estimates by means of DS, particularly in those areas in which a small number of observations are recorded, might be reached after implementing repeated surveys over a year (see Loison et al. 2006).

Sampling free-ranging populations, like those in the wild, is a difficult task, despite the methodology used. In any case, our results highlight that DS works also in mountainous habitats.

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A primer of the non-invasive monitoring of the Iberian ibex *Capra pyrenaica* in the Peneda- Gerês National Park (Portugal)

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ABSTRACT

The population of Iberian ibex *Capra pyrenaica* in the Peneda-Gerês National Park (Portugal) originated from a small number of individuals with documented records of demographic bottlenecks. We used a set of 15 microsatellites in two PCR multiplex reactions to quantify the genetic variability of the founders and test the feasibility of a non-invasive approach for the future monitoring of free-ranging individuals in PGNP. Fourteen *loci* were amplified and scored both in invasive (blood from founders) and non-invasive (faeces from free-ranging individuals) samples. The genetic variability of the founders was low suggesting inbreeding: the average number of alleles per locus was 3.79 and the observed and expected heterozigosity over all *loci* were 0.30 and 0.45, respectively. The global quality index (QI) obtained in the non-invasive approach was 0.56. Using faecal samples with QI's above this value (57.8% of the samples) the rates of successful PCR, allelic dropout and false alleles were 89%, 0.05 and 0.12, in that order. Excluding *loci* with QI<0.56, evidences for null alleles (MCM527) and significant heterozygote deficit (INRA 63), eight *loci* (SPS115, TGLA122, BM4505, SR24, D5S2, BM1329, UCO5, MAF65) were recommended for future non-invasive molecular studies of the population. Considering these, the overall probability of identity (PI) and the PI for siblings using these lasts were respectively $2.45x10^{-5}$ and $1.35x10^{-2}$, i.e., close to the 0.01 threshold required for population size estimation. To increase the power of individual discrimination we recommend development of optimal conditions for other *loci* and the use of sex markers. Sticks instead of gloves in faeces collection may improve QI for samples.

Keywords: faeces; microsatellites; probability of identification; quality

The estimation of abundance is a critical issue for the monitoring and management of wild populations, especially if endangered (Kohn et al. 1999; Valière et al. 2007). Non-invasive sampling allows genetic studies without disturbing or observing the target individuals and is most appropriate when studying elusive and endangered species (Creel et al. 2003; Wilson et al. 2003; Goossens et al. 2005; Vercillo et al. 2005; Oliveira et al. 2010). Many studies focusing the abundance

estimation of wild populations of mammals rely on DNA fingerprints from non-invasive samples. At the same time, DNA fingerprints may provide a tool to identify poaching. Nevertheless, the use of non-invasive approaches must be critically analysed once pitfalls have been identified that can bias, e.g., population size estimates (Waits & Leberg 2000).

Pilot studies are recommended to assess technical difficulties and improve the efficacy of further research (Taberlet et al. 1999; Valière et al. 2007), e.g., test markers and samples adequacy for DNA amplification and variability, and assess errors associated with the genotyping process that may bias estimates of population size (Kohn et al. 1999; Waits & Leberg 2000).

The Iberian ibex *Capra pyrenaica* (ibex hereafter) is a mountain ungulate that formerly occupied a great extent of the Iberian Peninsula (Pérez et al. 2002). During the 19th century, the distribution range of this ungulate was severely reduced mainly due to hunting. As critical examples, ibex was extinct from Portugal (*C. p. lusitanica*) and France (*C. p. pyrenaica*) by the end of that century. Recently, *C. p. pyrenaica* was also extinct to Spain. The remnant populations of ibex in Central (*C. p. victoriae*) and South (*C. p. hispanica*) of this country have been the source of numerous translocations in the last century, usually with few individuals (Pérez et al. 2002; Acevedo & Cassinello 2009). Although it is widely recognized that founder effects should be considered in order to guaranty genetic diversity, to our knowledge the genetic variability of founders has never been taken into account in these translocations.

The Gredos (Central Spain) population of ibex was the source for translocations to the North and NW of the Iberian Peninsula, namely to Invernadeiro and Baixa Límia-Serra do Xurés (BLSXNP) Natural Parks (Galicia, Spain). These promoted ibex return to Peneda-Gerês National Park (PGNP, Portugal) by natural expansion in 1998 (Moço et al. 2006). PGNP includes ibex last redoubt in Portugal and, as it occurred in the past, is presently the edge of the species distribution. Although ibex is considered of Least Concern by the IUCN (Herrero & Pérez 2008) the species is Critically Endangered in Portugal (Cabral et al. 2005) due to its small size and restricted distribution. For the moment, PGNP is the only source for the potential expansion of the species in Portugal. One research priority for planning ibex conservation and management is the accurate estimation of the abundance of its populations (Pérez et al. 2002; Acevedo & Cassinello 2009) which is difficult to obtain accurately in mountain environments (Pérez et al. 2015). Two cases of poaching were already registered (author's personal observations).

In this paper we present data on the genetic variability of the founders of the Portuguese ibex population and a pilot study to evaluate the feasibility of a non-invasive approach to

assess and monitor the abundance of ibex population in the PGNP. Our goals were: i) to test the success of one set of microsatellites to amplify and be correctly scored on invasive and non-invasive (faecal) samples of free-ranging individuals; ii) to quantify the power of the multilocus genotyping to discriminate between individuals.

Samples analysed belonged to *Capra pyrenaica victoriae* Cabrera, 1911, one of the extant subspecies of ibex accepted by the IUCN (Grubb 2005). Blood samples (N=18) were collected from the founder individuals of the extant Portuguese-Galician population (Moço et al. 2006) in 1997 during veterinary monitoring, and stored in vials at -20 °C. Non-invasive samples consisted of faecal pellets (N=84) collected along line transects systematically distributed in PGNP during Distance Sampling tasks (see Pérez et al. 2015) in 2005 and 2006. Each sample consisted of a well-differentiated deposition of fresh droppings (0–12 h post defecation based on moisture or direct observation) collected with sterilized and disposable gloves to an individual plastic bag. At the end of each sampling day, one to four droppings from each sample were placed in a 25-mL leak-proof vial using flame-sterilized metal tweezers and totally covered with 96% ethanol. Crushing of droppings was carefully avoided and tubes were stored away from light at room temperature for posterior processing.

DNA extraction from blood samples was performed through salting-out procedure adapted from Sambrook et al. (1989). Faecal samples were prepared for DNA extraction in a UV-sterilised room. DNA was extracted from intestinal cells washed off from faecal droppings surface in 350 μL of a lysis washing buffer (0.1 M Tris–HCl, 0.1 M EDTA, 0.01 M NaCl, 1% *N*–lauroyl sarcosine, pH 7.5–8) during 15 min on a rotary agitator. The supernatant (~300 μL) was then used for DNA extraction using the DNeasy™ Blood Kit (Qiagen) following the manufacturer's procedures.

Most of the microsatellites used had been formerly designed for Bovidae and some already tested in ibex (Table 1). INRA23, MCM527, BM1329, D5S2 and PZ963 were tested for the first time in this study.

To reduce contamination lab rooms used for pre- and post-PCR experiments were physically separated (Taberlet & Luikart 1999). Amplification mixtures were prepared in a UV-sterilised area separated from the extraction zone and amplification was carried out in a separate room. We used filtered tips for pipetting and one control PCR blank was included for each set of amplifications. *Loci* were amplified in two PCR multiplex reactions using the QIAGEN Multiplex PCR kit following the manufacturer's protocol.

Forward primers sequences were modified to include an additional universal tail fluorescently labelled with two dyes

Table 1. Characteristics of the 15 microsatellite *loci* multiplexed in two fluorescent sets. Chr.=chromosome location; [Un]=Unasigned; [B]=Bovinae; [S]=Sheep; [C]=Cervidae; [G]=*Capra* spp.; [R]=*Rupicapra pyrenaica*. BOVMAP=Microsatellite name in BOVMAP database. Cpyr (bp)=allele length range documented for *Capra pyrenaica*; [1]=Maudet et al. 2004; [2]=Silva 2005.

Locus	Seq. 5'- 3'	Dye	Chr.	BOVMAP	Cpyr (bp)
INRA5	TTC AGG CAT ACC CTA CAC CAC ATG AAA TAT TAG CCA ACT GAA AAC TGG G	1	12 [B;S;G;R;C]	D12S4	Not clear to be scored[1] 139-141[2]
SR24	AGC AAG AAG TGT CCA CTG ACA G TCT AGG TCC ATC TGT GTT ATT GC	2	Un.	-	156-162[1] 159-165[2]
BM1258	GTA TGT ATT TTT CCC ACC CTG C GAG TCA GAC ATG ACT GAG CCT GM	2	23 [B;S;C]	D23S22	101-105[1]
BM4505	TTA TCT TGG CTT CTG GGT GC ATC TTC ACT TGG GAT GCA GG	2	26 [B;S;C]	D26S8	272-280[1]
OarCFB20	GGA AAA CCC CCA TAT ATA CCT ATA C AAA TGT GTT TAA GAT TCC ATA CAT GTG	1	2 [B]	D2S21	95-97[1]
TGLA122	CCC TCC TCC AGG TAA ATC AGC AAT CAC ATG GCA AAT AAG TAC ATA C	2	21 [B;S]	D21S6	145-157[1]
SPS115	AAA GTG ACA CAA CAG CTT CTC CAG AAC GAG TGT CCT AGT TTG GCT GTG	1	Un.	-	No PCR product[1]
INRA63	GAC CAC AAA GGG ATT TGC ACA AGC AAA CCA CAG AAA TGC TTG GAA G	1	18 [B;S;G;R]	D18S5	160-178[2]
MAF65	AAA GGC CAG AGT ATG CAA TTA GGA G CCA CTC CTC CTG AGA ATA TAA CAT G	1	15 [B;S]	D15S11	124-132[2]
UCO5	GCC TCA GGA AAG ACA AAG TCA C GCA CCT CCA CCC CTT CAT A	2	Un.	-	132-148[2]
INRA23	GAG TAG AGC TAC AAG ATA AAC TTC TAA CTA CAG GGT GTT AGA TGA ACT	1	3 [B;S;C]	D3S10	-
BM1329	TTG TTT AGG CAA GTC CAA AGT C AAC ACC GCA GCT TCA TCC	2	6 [B;S;C]	D6S14	-
D5S2	TAC TCG TAG GGC AGG CTG CCT G GAG ACC TCA GGG TTG GTG ATC AG	2	Un.	-	-
MCM527	GTC CAT TGC CTC AAA TCA ATT C AAA CCA CTT GAC TAC TCC CCA A	1	Un.	-	-
PZ963	CTT AAA GGT GCT GGG ATG G CCA CAA AAC CAA ACT GAC ACA T	2	22 [B;S]	D22S44	-

(Applied Biosystems, Foster City, CA, USA). A touch-down thermocycling protocol was performed as following: 95ºC for 15 min; 6 cycles of denaturation at 94ºC for 30s, primer annealing with temperatures between 62-57ºC, decreasing 1ºC every cycle for 60s, and sequence extension at 72ºC for 60s; followed by 25 cycles of the previous cycling protocol but with a permanent annealing temperature of 57ºC; eight additional cycles at 53ºC for labelled tails' incorporation and a final extension step at 60ºC for 30 min. Amplifications were performed in a total volume of 10µl using both an Applied Biosystems thermal cycler (GeneAmp® PCR System 9700) and Bio-Rad thermal cyclers (MyCycler and iCycler). Afterwards, PCR products were separated by size on an ABI3130xl Genetic Analyzer (Applied Biosystems Inc.) and genotypes were determined in GENEMAPPER 4.1 (Applied Biosystems Inc.) by comparison with size standard fragments of Genescan-500 LIZ, ABI. All genotyping steps included the negative controls for extraction and PCR. Additionally, a reference positive control was

always included to infer PCR success and to calibrate independent runs.

The following analyses were performed to blood samples. Deviations from Hardy-Weinberg equilibrium (HW), linkage disequilibrium (LD) and inbreeding coefficient (F_{IS}; Weir & Cockerham 1984) were checked with GENEPOP 4.2 (Raymond & Rousset 1995). The presence of null alleles was examined with Micro-Checker 2.2.3 (Van Oosterhout et al. 2004). Allele frequencies, observed and expected heterozygosities (H_O and H_E) were estimated with GIMLET 1.3.3 (Valière 2002). The power of the multilocus genotyping to discriminate between individuals was tested through the probability of identity for each locus (PI). The unbiased PI (PI_{UNB}) and the PI for siblings (PI_{SIB}) were obtained with GIMLET 1.3.3 (Valière 2002) considering that the observed probability in the population ranged from the first to the last (Waits et al. 2001; Valière et al. 2007).

The reliability of the non-invasive approach was evaluated with the Quality Index (QI) proposed by Miquel et al. (2006) and the quantification of genotyping errors using a multiple tube approach. In our case, amplification of multilocus genotypes was repeated three times and genotypes were deduced by analyzing the set of all experiments (see Taberlet et al. 1996). Consensus genotypes were obtained following the threshold rule "alleles had to appear at least twice out of three PCR repetitions". The PCR success and genotyping errors were calculated empirically (Pompanon et al. 2005; Luikart et al. 2008) as follows: (i) "PCR +" when a PCR product was obtained; it was presented as % of all amplification experiments; (ii) "allelic dropout" when one allele was not amplified for an heterozygous individual; (iii) "false allele" when one allele differed from consensus for an homozygous individual; and; (iv) "others" when no consensus genotype was achieved due to ambiguity.

From the 15 *loci* tested, locus BM1258 was only scored in five blood and one faecal sample being monomorphic in all cases (with 129 bp). This locus had been previously amplified in *Capra pyrenaica* (Maudet et al. 2002) with alleles' size being shorter than the obtained in this study (Table 1). Our failure to score it could be due to large amounts of primer dimers in the capillaries of the sequencer and a reduction in primer concentration could lessen that drawback (Valière et al. 2007). All other *loci* were polymorphic (Table 2). Locus MCM527 showed evidences for a null allele.

The average number of alleles per locus was 3.79. The size range of alleles was concordant with previous studies for INRA63, MAF65 and OarCFB20 (Table 1).

The average observed heterozigosity (H_O) over all *loci* was 0.30 and the mean expected heterozigosity (H_E) was 0.45. These values were lower than the obtained for seven bottlenecked populations of *Capra ibex* (Maudet et al. 2002), *Ammotragus lervia*.

Table 2. Microsatellite *loci* tested on 18 individuals of *Capra pyrenaica victoriae*. R=Allele length range. Na=Number of alleles. H_O and H_E=observed and expected heterozygosities, respectively. PI_{UNB}=unbiased PI. PI_{SIB}=PI for siblings. *Loci* ordered by decreasing H_E.

Locus	R (bp)	N	Na	H_O	H_E	F_{IS}	PI_{UNB}	PI_{SIB}
INRA23	198-220	15	8	0.33	0.79	0.521	3.50E-02	3.70E-01
TGLA122	160-180	13	5	0.56	0.66	-0.132	1.50E-01	4.67E-01
BM4505	246-298	13	5	0.50	0.64	-0.039	1.47E-01	4.75E-01
UCO5	153-169	18	3	0.56	0.55	0.026	2.38E-01	5.41E-01
PZ693	256-262	14	3	0.50	0.55	-0.125	2.67E-01	5.46E-01
MCM527	163-171	14	4	0.33	0.54	0.243	1.94E-01	5.42E-01
BM1329	182-196	15	6	0.28	0.49	0.349	2.14E-01	5.76E-01
SR24	174-178	14	2	0.22	0.46	0.409	3.76E-01	6.20E-01
INRA5	115-117	18	2	0.39	0.42	0.112	3.92E-01	6.43E-01
SPS115	243-247	14	3	0.17	0.30	0.328	4.61E-01	7.27E-01
INRA63	166-178	18	3	0.06	0.29	0.819	4.63E-01	7.34E-01
MAF65	121-133	17	3	0.17	0.26	0.351	5.07E-01	7.60E-01
D5S2	199-209	15	3	0.11	0.24	0.472	5.37E-01	7.78E-01
OarCFB20	92-98	16	3	0.06	0.12	0.500	7.46E-01	8.85E-01

(0.63 and 4.65, respectively) and *Gazella dorcas* (0.53 and 3.75, respectively) (Beja-Pereira et al. 2004).

Loci INRA63 and INRA23 presented a significant heterozygote deficit (P=0.0004 and P=0.0017, respectively) and the multi-locus test was also significant (P=0.000). Linkage disequilibrium (P<0.01) was detected between four pairs of *loci*, involving locus INRA63 in association with INRA5 and BM1329 and, locus MAF65 in association with D5S2 and BM4505. Physical linkage between MAF65 and D5S2 may not be excluded since this last has not been mapped. However, considering the population bottleneck history, significance for *loci* in linkage disequilibrium could occur by chance alone (Maudet et al. 2002).

The overall PI using all *loci* was $1.30x10^{-8}$ and the PI_{SIBS} was $8.44x10^{-4}$. We obtained a global QI of 0.56. Ten *loci* (MCM527, SPS115, TGLA122, BM4505, SR24, D5S2, BM1329, INRA63, UCO5 and MAF65) and 37 faecal samples (57.8% of the samples analysed) had QI's above that vale (Figure 1). Excluding *loci* with QI<0.56, INRA 63 (heterozygote deficit) and MCM527 (possibility of a null allele) the overall PI decreased to $5.30x10^{-5}$ and the PI_{SIBS} was $1.84x10^{-2}$, close to the 0.01 threshold required for studies aiming population size estimation (Mills et al. 2000). The genotyping errors were calculated from 64 faecal samples (Table 3).

This study demonstrated the feasibility of eight *loci* and a non-invasive approach with faecal samples to produce genotyping data useful for the estimation of the population abundance of ibex in PGNP. Yet, the development of optimal conditions for the

remaining *loci* and the use of sex markers would allow the identification of the gender of samples, thus increasing the power of individual discrimination by reducing the probability of identity.

Considering the QI obtained, effort in further non-invasive sampling should be incremented respect to this study. We recommend the use of sticks instead of gloves in further samples collection to minimize destruction of cellular and DNA material in the surface of pellets.

Our results suggest that the founder population of ibex in PGNP has a high level of inbreeding, probably due to successive bottlenecks from the source population (Serra de Gredos, central Spain) to the BLSXNP. Thus, although this population is increasing in numbers and range, stochastic events such as an outbreak of sarcoptic mange

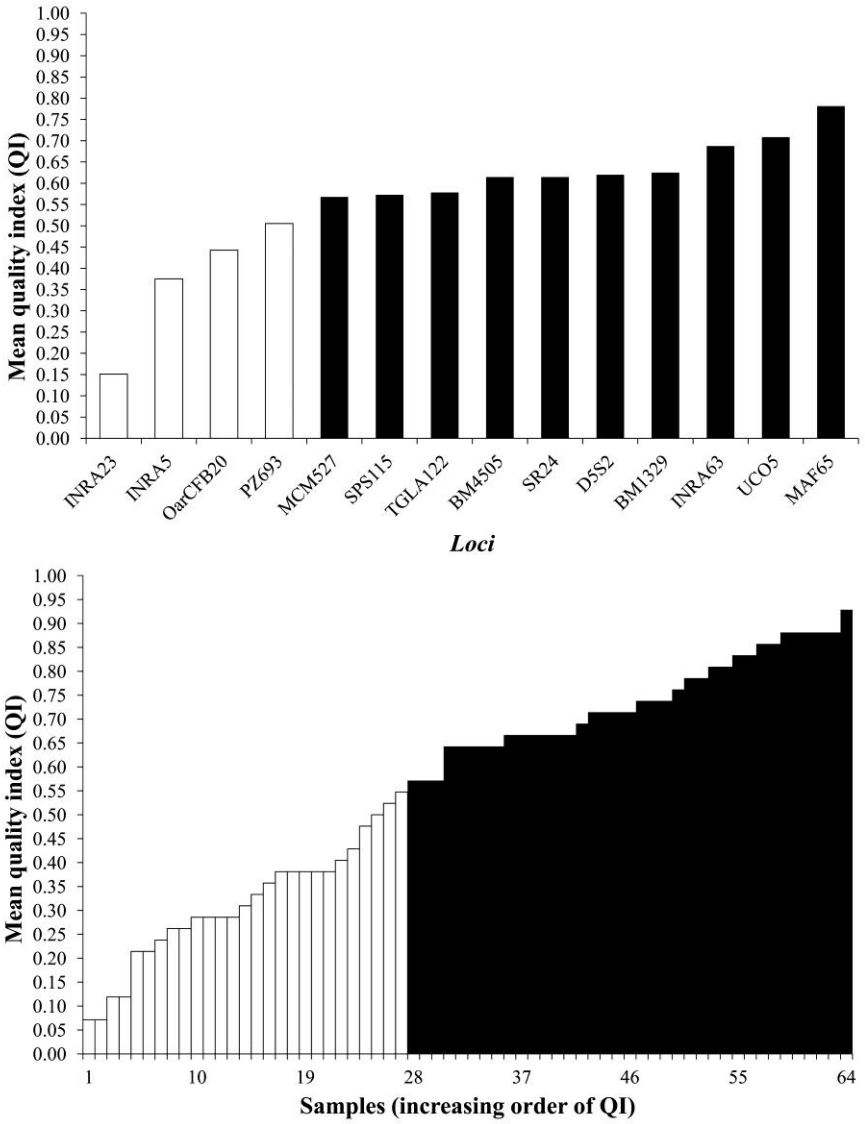

Figure 1. Quality of the non-invasive approach tested in PGNP (Portugal) for *Capra pyrenaica victoriae*. Dark bars indicate *loci* and samples with quality above global QI threshold (0.56).

Table 3. Genotyping errors from non-invasive samples of *Capra pyrenaica victoriae* in PGNP (Portugal). Rates of positive PCR (PCR+), allelic dropout (AD) and false alleles (FA) for each locus considering: a=all samples (N=64); b=samples with QI > 0.56 (N=37).

Locus	PCR +		AD		FA		Others	
	a	b	a	b	a	b	a	b
SPS115	0.68	0.93	0.10	0.12	0.00	0.00	0.08	0.09
OarCFB20	0.91	0.95	0.05	0.04	0.46	0.58	0.19	0.12
MCM527	0.76	0.93	0.13	0.14	0.05	0.07	0.03	0.04
MAF65	0.89	0.99	0.08	0.08	0.06	0.06	0.04	0.00
INRA63	0.93	0.99	0.12	0.03	0.10	0.14	0.08	0.09
INRA5	0.66	0.79	0.11	0.10	0.18	0.24	0.14	0.14
INRA23	0.31	0.41	0.00	0.00	0.00	0.00	0.10	0.13
D5S2	0.89	0.98	0.04	0.03	0.20	0.25	0.11	0.03
BM1329	0.78	0.86	0.02	0.03	0.07	0.07	0.12	0.07
BM4505	0.67	0.91	0.05	0.06	0.00	0.00	0.00	0.00
PZ693	0.56	0.83	0.03	0.03	0.00	0.00	0.03	0.03
SR24	0.79	0.98	0.07	0.03	0.07	0.06	0.05	0.03
TGLA122	0.67	0.91	0.00	0.00	0.00	0.10	0.08	0.09
UCO5	0.90	0.99	0.04	0.00	0.10	0.09	0.14	0.17
Mean	0.74	0.89	0.06	0.05	0.09	0.12	0.09	0.07

(*Sarcoptes scabiei*) may deplete it. Such a situation has been previously documented in ibex (Pérez et al. 2002). Outbreaks of mange occur sporadically in PGNP (authors' personal observations). Monitoring of the sanitary status of this population is necessary.

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CHAPTER 5. IBEX FEEDING REVISITED

"Uma cabra-montesa no pascigo;
Fiel ao seu balido,
Um fauno apaixonado;
Entre os dois, um açude adormecido,
Imagem do instinto represado.

Corcunda como a vida,
Uma ponte arqueada de suspiros
A ligar as arribas do desejo;
E um guarda ao passadiço, uma presença humana,
O pastor, a moral quotidiana."

Miguel Torga

5.1. SEASONAL DIETARY SHIFTS AND SELECTION OF IBERIAN WILD GOAT *Capra pyrenaica* SCHINZ, 1838 IN PENEDA-GERÊS NATIONAL PARK (PORTUGAL)

MOÇO G, SERRANO E, GUERREIRO M, FERREIRA AF, PETRUCCI-FONSECA F, MAIA MJ, SORIGUER RC & PÉREZ JM

GALEMYS, 2013, Vol. 25,13-27

5.2. DOES LIVESTOCK INFLUENCE THE DIET OF IBERIAN IBEX *Capra pyrenaica* IN THE PENEDA--GERÊS NATIONAL PARK (PORTUGAL)?

MOÇO G, SERRANO E, GUERREIRO M, FERREIRA AF, PETRUCCI-FONSECA F, SANTANA D, MAIA MJ, SORIGUER RC & PÉREZ JM

MAMMALIA, 2013, DOI 10.1515/MAMMALIA-2013-0139

5.3. DOES LANDSCAPE HETEROGENEITY INFLUENCES THE FORAGING GOALS OF MIXED-FEEDER UNGULATES?

MOÇO G, SERRANO E, FERREIRA AF, GUERREIRO M, PETRUCCI-FONSECA F, MAIA MJ, SORIGUER RC & PÉREZ JM

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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).

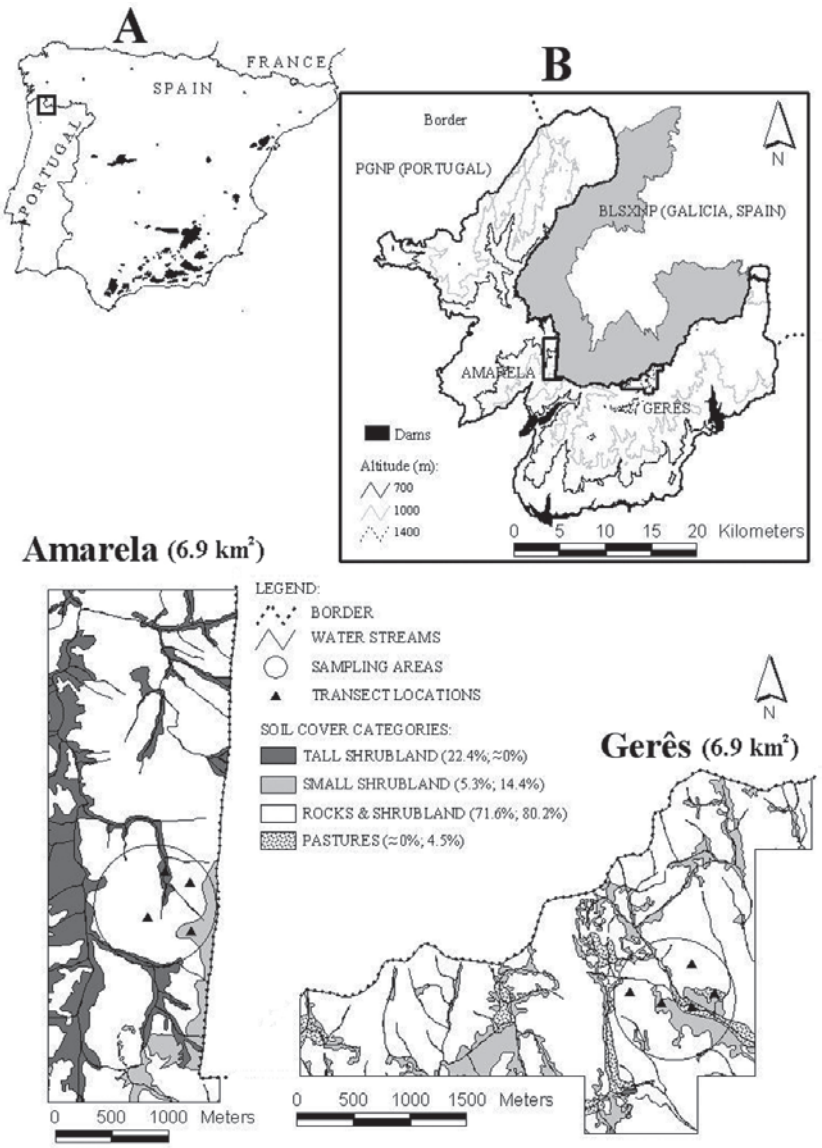

Figure 1. A) Iberian wild goat distribution (adapted from Pérez *et al.* 2002 and Acevedo & Cassinello 2009) and location of PGNP in Iberian Peninsula; B) PGNP and wild goat ranges studied (adapted from Moço *et al.* 2006); ranges and sampling areas (approx. 1 km² each) for availability and diet are highlighted. Relative contribution (% respect to 6.9 km²) 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 $\alpha = 0.05$ 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	-	-

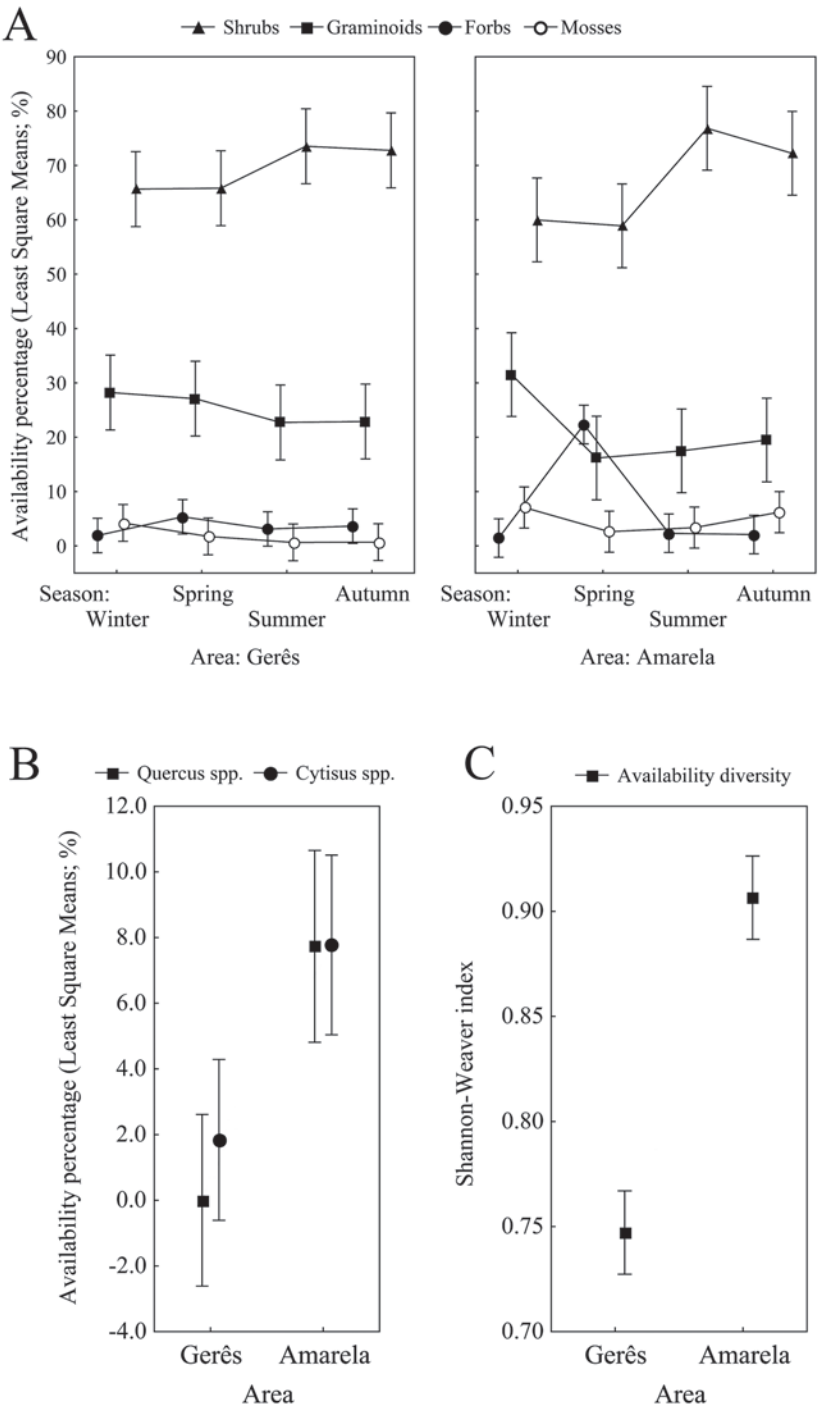

Figure 2. Seasonal changes in availability of Gerês and Amarela (Peneda-Gerês National Park, Portugal) for vegetal categories (A), and differences in areas ligneous components and diversity (C). Vertical bars denote 0.95 confidence intervals.

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

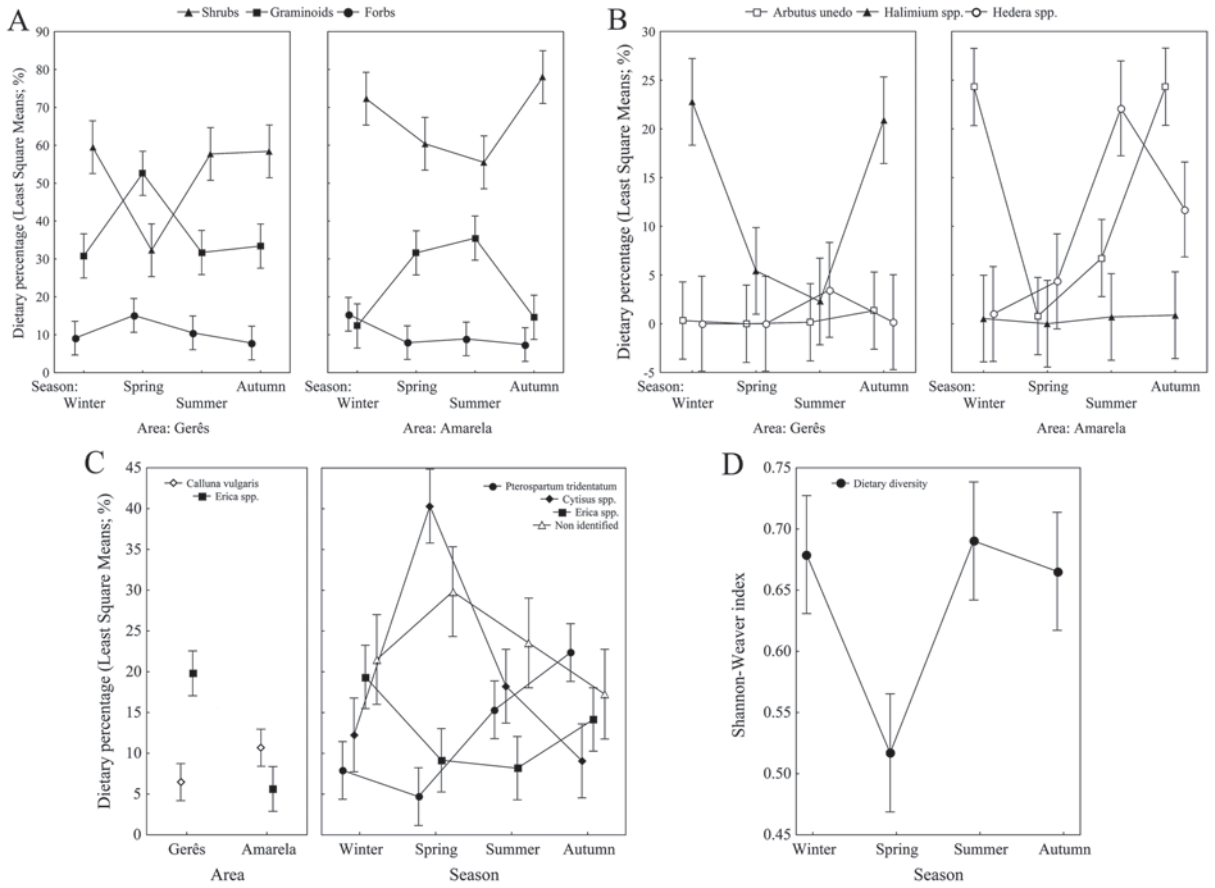

Figure 3. Seasonal changes in diets of Gerês and Amarela (Peneda-Gerês National Park, Portugal) for vegetal categories (A) and ligneous components (B), area and seasonal differences in dietary ligneous components (C) and seasonal variation in ligneous diversity (D). Vertical bars denote 0.95 confidence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

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

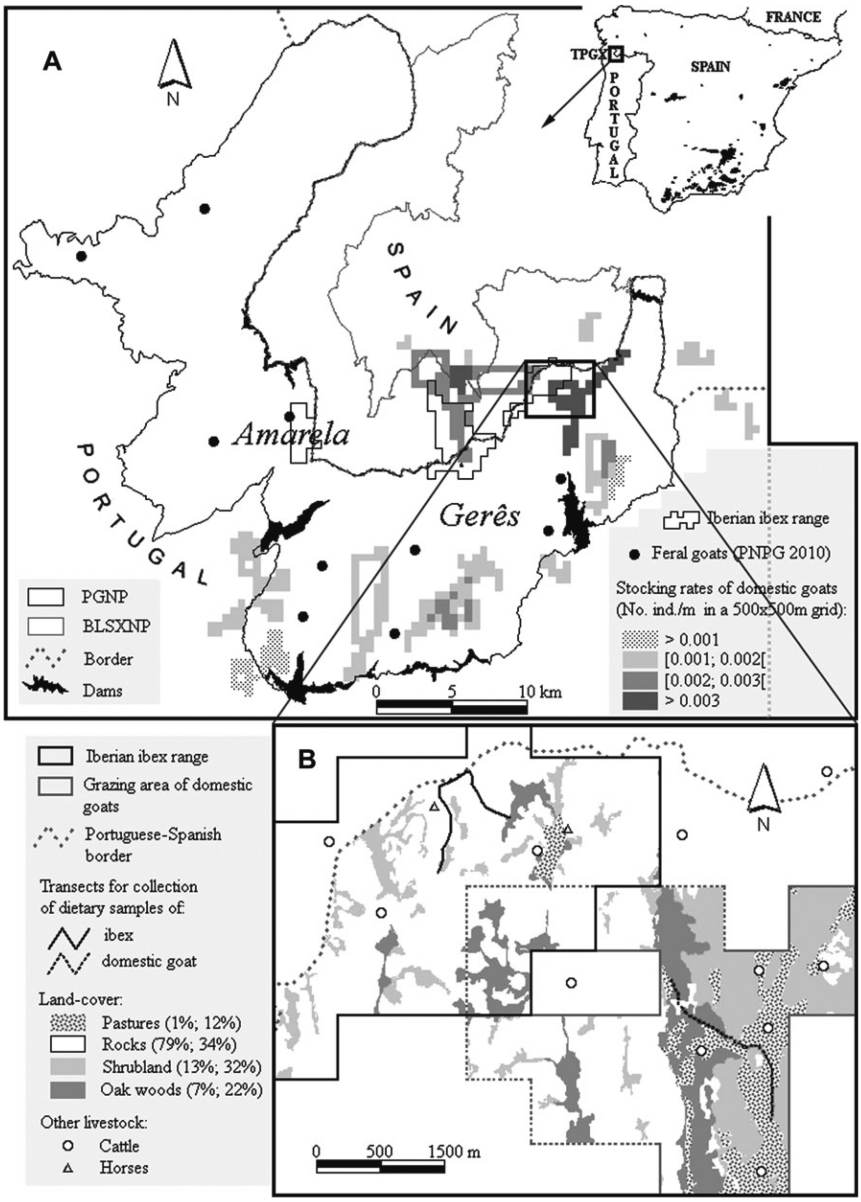

Figure 1 (A) Grazing areas and stocking rates of flocks of domestic goat (*Capra hircus*) and ibex (*Capra pyrenaica*) range in the Transboundary Park Gerês-Xurés (TPGX). Data are presented in a 500×500 m grid. (B) Sampling area for diet assessment with land-use percentages in ibex range and flock grazing 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

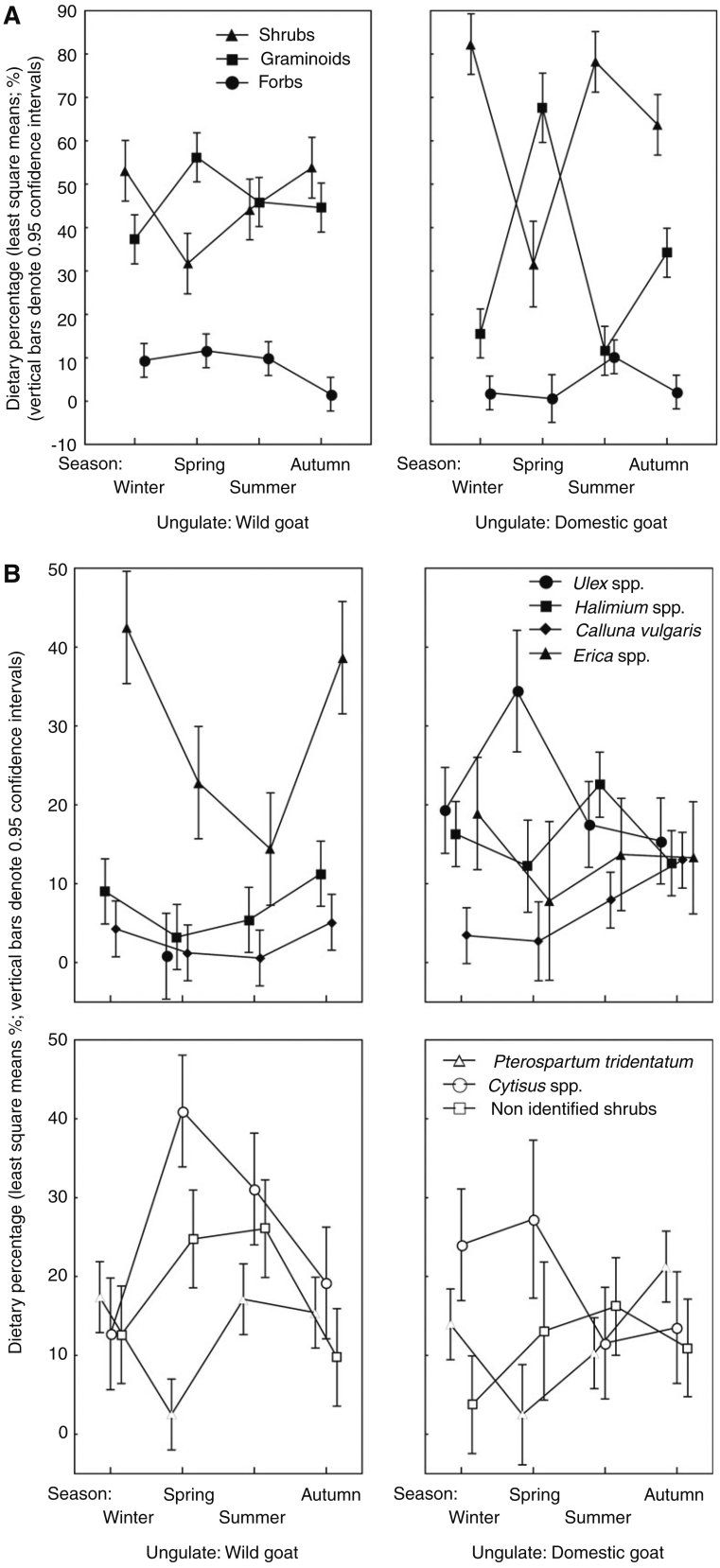

Figure 2 Seasonal changes in diets of the Iberian ibex *Capra pyrenaica* and the domestic goat *Capra hircus* in the Peneda-Gerês National Park (Portugal) detected with a multivariate analysis of variance based on robust Pillai's trace tests for vegetal categories (A) and ligneous components (B).

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

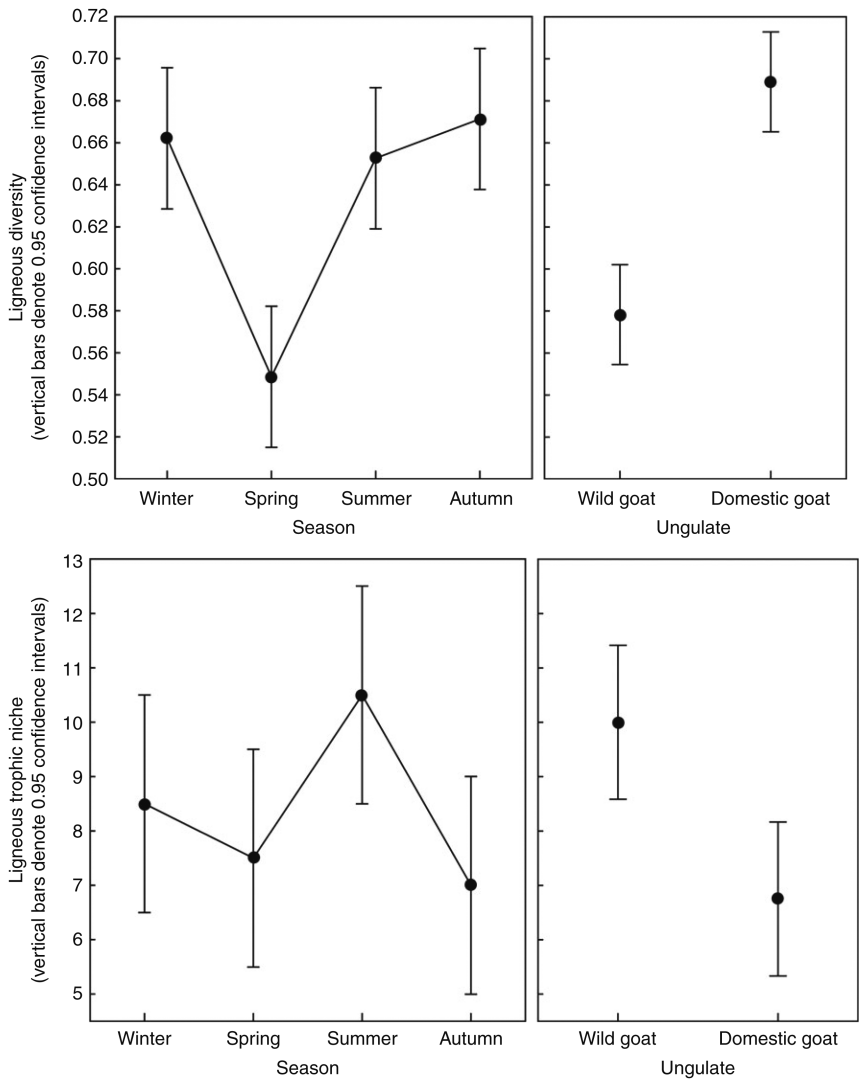

Figure 3 Seasonal changes on ligneous diet diversity and trophic niche of the Iberian ibex *Capra pyrenaica* and the domestic goat *Capra hircus* in the Peneda-Gerês National Park (Portugal) obtained with main-effects ANOVA (see Table 1).

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

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Does landscape heterogeneity influences the foraging goals of mixed-feeder ungulates?

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ABSTRACT

The functional effect of landscape heterogeneity on ecological processes involving ungulates still lacks empirical evidence. The recolonization of new environments provides valuable opportunities to improve understanding on mixed-feeders responses to landscape heterogeneity. Our attention focused on two Atlantic areas (Gerês and Amarela) recently recolonized by Iberian ibex (*Capra pyrenaica*) in which it adopted distinct feeding strategies: a higher consumption of graminoids versus a richer ligneous diet. We aimed to investigate the influence of landscape heterogeneity on the dietary goals of this mixed-feeder ungulate. We assessed the spatial distribution of food resources at two spatial scales. Food availability was quantified at the finer (patch) scale and provided information on graminoids abundance and structural features of main land-cover categories. At a broader scale (ibex range) we quantified the relative contribution, shape, dispersion, edge-contrast and intermixing of land-cover categories. Food resources were spatially structured in both areas. Graminoids were clearly associated with pastures in Gerês and yielded high contrast to this land-cover category. Also, pastures were rather uniformly distributed and intermixed in the landscape. In Amarela, graminoids-patch association was weaker although more abundant in shrubland, whose patches presented a contagious distribution. On the other hand, the forest/shrubland land-cover category, characterized by a higher richness on ligneous resources, presented a regular spatial distribution on the landscape. Our findings suggest that a mixed-feeder ungulate will take advantage from the "protein-source" more uniformly distributed, i.e., in our particular study, pastures in Gerês and forest/shrubland in Amarela.

Keywords: diet; patch; recolonization; ruminants; scale

INTRODUCTION

The relationship between the spatial distribution of resources and ungulates has long been recognized (Senft et al. 1987; O'Neill, Johnson & King 1989; Coughenour 1991; Turner et al. 2001) and may constitute a

critical issue for the efficacy of management and conservation planning of both resources and ungulates (Apps et al. 2001). These animals perceive variations in the spatial patterns of vegetation assemblages and physical elements (Pearson et al. 1995; Turner et al. 1997; Sánchez-Prieto et al. 2008) but understanding of their interaction and ungulates responses to the resources in their environment still require empirical evidence (Gordon 2003; Weisberg & Bugmann 2003).

Diet choices and foraging behaviour of mixed (browse-graze) ruminant herbivores are expected to differ in relation to the resources upon which they feed (Gordon 2003). That seems to be the case of Iberian ibex (*Capra pyrenaica* Schinz, 1838; ibex hereafter), a mountain ungulate that inhabits a variety of environments in the Iberian Peninsula (Pérez et al. 2002; Acevedo & Cassinello 2009; see Figure 1). Ibex exhibits a browse-graze feeding regime mainly determined by the availability (abundance) and phenology of ligneous and herbaceous strata (Martínez 2000, 2001, 2002, 2009). As it occurs with other generalist herbivores (e.g., roe deer, see Abbas et al. 2011), ibex is expected to adapt its feeding behaviour to landscape heterogeneity, as already suggested by Martínez (2001) but to date not directly addressed. The return of ibex to two mountainous areas (Gerês and Amarela) in Peneda-Gerês National Park (PGNP, Portugal) provided a valuable opportunity to get better understanding on mixed-feeders interaction with their environment. Moço et al. (2013) studied ibex dietary regime in these areas and showed that its graminoids consumption was significantly more important in Gerês while its dietary ligneous component was more diverse in Amarela. These authors also evidenced that differences on ibex ligneous diets were congruent to areas ligneous offer, but differences on ibex grazing behaviour could not be explained by availability, since Gerês and Amarela presented similar graminoids abundance.

Because ungulates interact with vegetal resources at several levels of ecological resolution, scale adequacy is crucial in understanding their responses to landscape heterogeneity (Senft et al. 1987; Li & Reynolds 1995; Turner et al. 1997; Apps et al. 2001). As highlighted by Turner et al. (2001), when addressing the importance of landscape heterogeneity for ecological processes the identification of scales that best characterize their relationship shall be emphasised. While fine-scale approaches are fundamental to assess components that influence herbivores feeding at the community level, e.g. structural aspects of vegetation (Moser et al. 2008; Etzenhouser et al. 1998), several authors refer the convenience to scale-up research on ungulate-vegetation interactions (see Wiens 1989; Weisberg & Bugmann 2003) in order to identify which of these patterns also emerge as relevant at broader scales (Coughenour 1991; Turner et al. 1997), i.e., are non-scale dependent.

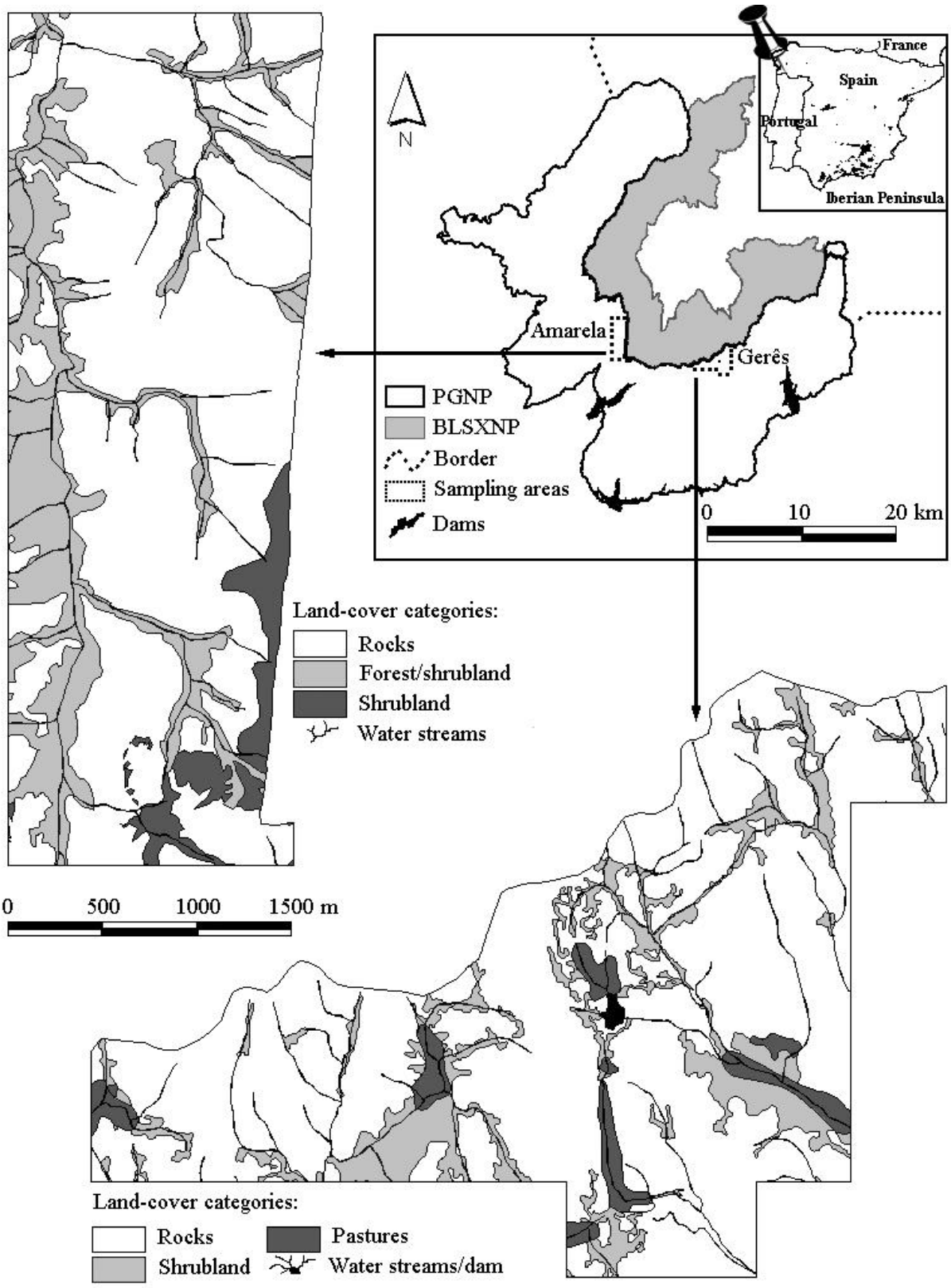

Figure 1. Location of Peneda-Gerês National Park (PGNP, Portugal) in Iberian Peninsula (dark spots illustrate distribution of *Capra pyrenaica* Shinz, 1838) and landscape mosaics in ibex ranges of Gerês and Amarela in PGNP. BLSXNP – Baixa-Límia Serra do Xurés Natural Park (Spain). Adapted from Moço et al. 2013.

Following priorities outputted by considerable research over the last two decades (see Turner et al. 1997), multiple scales studies relating landscape heterogeneity with space use and foraging selection by herbivores are currently increasing (Shrader et al. 2011; Massé & Côté 2012).

The aim of this study was to investigate the effect of landscape heterogeneity, specifically the spatial variability of food resources, on the dietary choices of ibex in Gerês and Amarela. The study was conducted at a fine (patch) and a broader (ibex range) scale. The use of the patch scale was justified by previous evidences on *Capra* spp. perceptions at this level. As examples, Etzenhouser et al. (1998) showed that *Capra hircus* Linnaeus, 1758 responded to the ligneous structure of plant communities by increasing the complexity and velocity of its foraging paths in patches with high canopy cover and Hochman & Kotler (2006) demonstrated Nubian ibex (*Capra nubiana* F. Cuvier, 1823) skills to detect differences on food quality of simulated patches. Moreover, some studies at the community scale evidenced that a clumped distribution of preferred plants favours their consumption by herbivores (Edwards et al. 1994; Dumont et al. 2002) and that a random distribution of non-preferred resources may shape selective grazing of ruminants by reducing aggregation of preferred plants (Wang et al. 2010). The use of a patch scale also allowed us to examine if food resources were spatially heterogeneous, as it usually occurs in rangelands (Coughenour 1991; Li & Reynolds 1995) or, conversely, dispersed instead of concentrated in discrete patches over the landscape (Senft et al. 1987). Thus, at the patch level we tested: i) if land-cover categories could be discriminated by their vegetation profiles; ii) whether graminoids were clumped in land-cover patches or, conversely, uniformly dispersed over land-cover categories; and iii) whether results varied seasonally. Considering our field observations, we expected to find important differences on vegetation profiles of land-cover categories, within and between areas. We also expected graminoids (our focal resources) to be more abundant in certain land-cover categories of Gerês while more uniformly distributed in categories of Amarela. Later, considering that resources variability across the landscape probably influence ibex foraging decisions at this scale (Turner et al. 1997), we investigated differences on composition and configuration (i.e., spatial arrangement of vegetation units) of landscape mosaics.

Specifically, were measured and compared: i) land-cover categories contribution, shape and edge-contrast and; ii) whether land-cover categories were dispersed or aggregated in the landscape mosaics. Our predictions were that graminoids-rich units were more conspicuous, e.g., presented simpler shape and/or higher edge-contrast, and were more uniformly distributed in Gerês.

MATERIALS AND METHODS

Gerês and Amarela are located in the Peneda-Gerês National Park (PGNP; 41º41'N-42º05'N, 8º25'W-7º53'W; 695.96 km^2; Figure 1). This protected area is included in the Atlantic European province of the Eurosiberian region with influence of temperate oceanic to Submediterranean climate (Rivas-Martínez et al. 2002). PGNP valleys are naturally occupied by oak forests of *Quercion robori-pyrenaicae* alliance and shrubs constitute approximately 74% of its vegetal cover (ICNB 2010). The spatial extent of this study was delimited by the ibex range in Gerês and Amarela (Moço et al. 2006) in 500 m x 500 m Gauss cells (Figure 1).

Assessment of food resources for ibex

Field work for assessment of food resources for ibex was conducted seasonally, i.e. in winter (February), spring (May), summer (August) and autumn (November), from February 2003 to November 2004. Patches were assumed as spatial unities perceived by ibex (see Senft et al.1987; Coughenour 1991) and in accordance sampling was performed at the patch scale. Patches were located between 800 m and 1000 m above sea level and were categorized as forest/shrubland (high vegetal cover with woody vegetation of 100-200 cm height; associated with water streams and temporarily saturated), shrubland (high vegetal cover with shrubs of height ≤ 100 cm; mesic areas), rocks (open rock surfaces or dominated by rock boulders with sparse vegetation of height < 100 cm; mesic to xeric areas) and pastures (open grassland with sparse and well individualized bushes of height ≤ 50 cm; associated with water streams and temporarily flooded). Sampling effort per patch category was stratified in accordance to their floristic and structural heterogeneity. Thus, four sampling sites in Amarela included two rocks, one shrubland and one forest/shrubland patches and five sampling sites in Gerês included two pastures, two rocks and one shrubland patches. Sampling was performed by the same two observers at all times to guaranty measurements consistency. Methods used are detailed in Moço et al. (2013) and resumed here. On each site, one transect of 2 m was permanently set on the ground and two sampling methods were used to address vegetal cover (%). Vegetal resources measured were ligneous species/genera, overall forbs (non graminoid herbs) and overall graminoids. Ligneous vegetation and forbs were assessed using the line-intercept method (Hanley 1978; Floyd & Anderson 1987; Bullock 1996). Graminoids cover was estimated on 1 x 1 m quadrats successively placed on the ground of each transect line (20 quadrats per transect), using a Braun-Blanquet scale (Mueller-Dombois & Ellemberg 1974). The relative cover of resources (% respect to total cover) was obtained per site and averaged per patch category.

Quantification of landscape heterogeneity

Landscape models of Gerês and Amarela were obtained from a land-cover categorical map of PGNP elaborated by CIBIO (2007) (Figure 1). The relationships between patch categories sampled for vegetal resources (see above) and the digital land-cover map categories are described in Table 1.

Table 1. Association between patches sampled for vegetal resources and the digital land-cover categories (class) digital map of CIBIO (2007).

Area	Patch category for food assessment	Land-cover category (CIBIO 2007)
Gerês	Shrubs	Montane shrubland
	Rocks	Montane shrubland with rocky outcrops
	Pastures	Turbary and hygrophilous vegetation; agroforestry grassland rich mosaic
Amarela	Shrubs	Montane shrubland
	Rocks	Montane shrubland with rocky outcrops; foothill shrubland on post-tectonic granitic or schistic terrain, with or without rocky outcrops
	Forest/shrubland	Oak forest

Geoprocessing of the land-cover digital map was performed with ArcView 3.1 (ESRI 1996). Landscape models consisted in independent landscape grids with a grain resolution of 1 m and a spatial extent of, respectively for Gerês and Amarela, 6.82 and 6.78 km^2. Grids included a border and inner and outside background patches. Inside background consisted in a patch of *Taxus baccata* Linnaeus, 1753 not sampled for food resources for ibex but included in total landscape area calculation. Outside background consisted in bordering areas with the Spanish Baixa Límia-Serra do Xurés Natural Park for which land-cover information was unavailable (Figure 1). Water bodies were considered as independent land-cover categories in each area, thus accounting for total landscape area (ha) and included in subsequent analysis at the landscape level (see below). Landscapes heterogeneity was evaluated considering a multilevel (patch, class and landscape) approach (Table 2) using FRAGSTATS 4.2 (McGarigal et al. 2012). Patch level metrics were selected avoiding functional redundancy, i.e., quantification of the same landscape aspect (Li & Reynolds 1995; McGarigal & Marks 1995) and then summarized at the class and landscape levels. The shape index was used as a measure of patches geometrical complexity. This index ranges from 1.0 for a square patch of any size to infinite as the patch becomes more geometrically complex. We used Edge-Contrast index (ECON; %) to quantify the magnitude of structural ("visual" identification and "physical" hindrance to inter-patch movement) and food supply differences for ibex between edges of neighbouring patches. Edge-contrast weights were calculated empirically between pairs of land-cover categories based on the weighted Euclidean distance among ecological attributes (contrast factors).

Table 2. Composition (distribution of land-cover categories) and configuration (arrangement of patches) metrics for assessment of landscape heterogeneity. 1=Composition metrics ; [2]=Configuration metrics.

Level	Metric	Description
Patch	Patch Area (ha) [1]	Area of the focal patch
	Shape index[2]	Perimeter of the focal patch divided by the minimum perimeter possible of a square of the corresponding patch area
	Edge contrast index (ECON; %)[2]	Percentage of maximum contrast along the edge of the focal patch; each segment of edge is weighted by the degree of contrast between adjacent patches
Class	Total Area (ha)[1]	Area occupied by land-cover category
	Proportion of land-cover (%)[1]	Percentage of area occupied by land-cover category in the landscape
	No. of patches[1]	No. of patches of land-cover category
	Mean Patch Area (ha)[2]	Area-weighted mean of patches of land-cover category
	Shape index[2]	Area-weighted mean of shape index of patches of land-cover category
	ECON (%)[2]	Area-weighted mean of ECON index of patches of land-cover category
	Standard deviation of ENN (Std. dev. ENN)	Standard deviation of ENN of patches of land-cover category
	Interspersion and Juxtaposition index (IJI;%)[2]	Magnitude of interspersion of patches in the land-cover category
Landscape	Total Area (ha)[1]	Total landscape area
	No. of patches[1]	No. of patches in the landscape
	Mean Patch Area (ha)[2]	Area-weighted mean of all patches
	Shape index[2]	Area-weighted mean of shape index of all patches
	ECON (%)[2]	Area-weighted mean of ECON index of all patches
	Standard deviation of ENN (Std. dev. ENN)[2]	Standard deviation of ENN of all patches
	Interspersion and Juxtaposition index (IJI; %)[2]	Magnitude of interspersion of patches in the landscape

In our case we considered vegetation structure (see patch description above) and association with water streams (wetness degree) as structural factors and relative % cover of graminoids as the food factor (Appendix 1). To discriminate between their importance in each area we calculated three ECON indexes: i) with structural factors; ii) with food factor and iii) with all factors. Exclusively for class and landscape levels, we used the ENN standard deviation (ENN std. dev.) as a measure of patch dispersion across the landscape mosaics. Small values of ENN std. dev. indicate more uniform or regular distributions while larger values more irregular or contagious distributions. Moreover, we selected Interspersion and Juxtaposition index (IJI; %) to measure the magnitude of interspersion (i.e., spatial intermixing of land-cover categories in the landscape). IJI is a relative index that gives the percentage of the maximum interspersion possible given the total number of patch categories (see McGarigal & Marks 1995). Thus, higher values of IJI occur in landscapes where patches are well interspersed and lower values where distribution of patch adjacencies is disproportionate.

Statistical analysis

To explore spatial (i.e., patch) and seasonal (as previously defined) patterns of vegetal resources (forbs, graminoids and shrubs with mean relative cover ≥ 1%) we used multivariate analyses of variance (MANOVA) based on robust Pillai's trace tests. We tested patch distinction between and within areas considering two types of data sets regarding patch categories: six patch categories, where rocks and shrubland of Gerês and Amarela were treated as distinct land-cover and; respective patch categories (three) per area analysed independently. The response variable was defined as a canonical derived dependent variable from percentages of cover resources assessed by vegetation transects. 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). Basic MANOVA assumptions (lack of residual pattern and normality) were previously checked. In the ANOVAs, patch categories and seasons (as previously defined) and their interaction were the response variables. Statistical analyses were performed with STATISTICA 6.0 ® (StatSoft Inc. 2001).

Regarding the set of metrics selected at the patch level (see above), we inspected their ecological meaning through observation of their frequency distributions. Because patch areas (ha) presented skewed frequencies distributions (see Appendix 2), i.e., extreme patch area values, area-weighted means were used to summarize these metrics at the class and landscape levels, thus providing comparisons from a landscape-centric approach (McGarigal & Marks 1995).

RESULTS

Resources structuring on patches

Food resources for ibex in patch categories are detailed in Appendix 3. These were mainly spatially structured allowing for patch distinctiveness between and within areas (see Figure 2 and Table 3). In Gerês, pastures were characterized by graminoids and small heighted shrubs *Ulex* spp., hygrophilous *Erica* spp. and *Calluna vulgaris* (Linnaeus, 1758) Hull, rocks by *Pterospartum tridentatum* (Linnaeus, 1758) Willk. and *Cytisus* spp. and shrubland by non-hygrophilous *Erica* spp. and *Halimium* spp. In Amarela, forest/shrubland was differentiated by *Ulex* spp., *Arbutus unedo* Linnaeus, 1758 and *Halimium* spp., rocks by *Cytisus* spp. and forbs, and shrubland by *P. tridentatum* and graminoids. Seasonal effects were detected in Amarela (Table 3) and particularly in herbaceous resources (Figure 3). Thus, graminoids were more abundant in winter in all patch categories and forbs were more abundant in spring, principally in rocks. Minor seasonal variations were also detected in *Ulex* spp. and *Halimium* spp. in this area.

Landscape composition and configuration in ibex ranges

Descriptors of landscape heterogeneity of Gerês and Amarela are presented in Table 4 (see Figure 1 to aid interpretation). Both landscape mosaics were dominated by large patches of rocks occurring as a matrix in which other land-covers were embedded, especially in Amarela where this land-cover category was better interspersed. Pastures in Gerês and shrubland in Amarela contributed with the smallest percentages to the landscape mosaics. Compared with other categories of Gerês, pastures had simpler shape, were quite uniformly distributed and intermixed, and had high contrast with neighbouring areas due to food supply (more than 80% of perimeter in maximum contrast with surrounding). Conversely, shrubland in Amarela presented low contrast with neighbouring categories and an aggregated distribution in the SE region of the landscape. In this area, forest/shrubland detached by its geometrical complexity, highest edge-contrast with surroundings (mainly due to structure) and a quite regular spatial S-W distribution. Gerês appeared as a more fragmented and geometrically complex mosaic with land-cover categories more uniformly distributed and better intermixed than Amarela. In the later one, edge-contrast between land-cover categories was mainly determined by structural factors.

DISCUSSION

This study supports the idea that the spatial structuring of resources at a fine-scale may influence their consumption by ungulates. As expected, graminoids clumping was particularly evident in pastures of Gerês and this may have favoured ibex grazing

behaviour in this area (Edwards et al. 1994; Dumont et al. 2002; Moço et al. 2013).

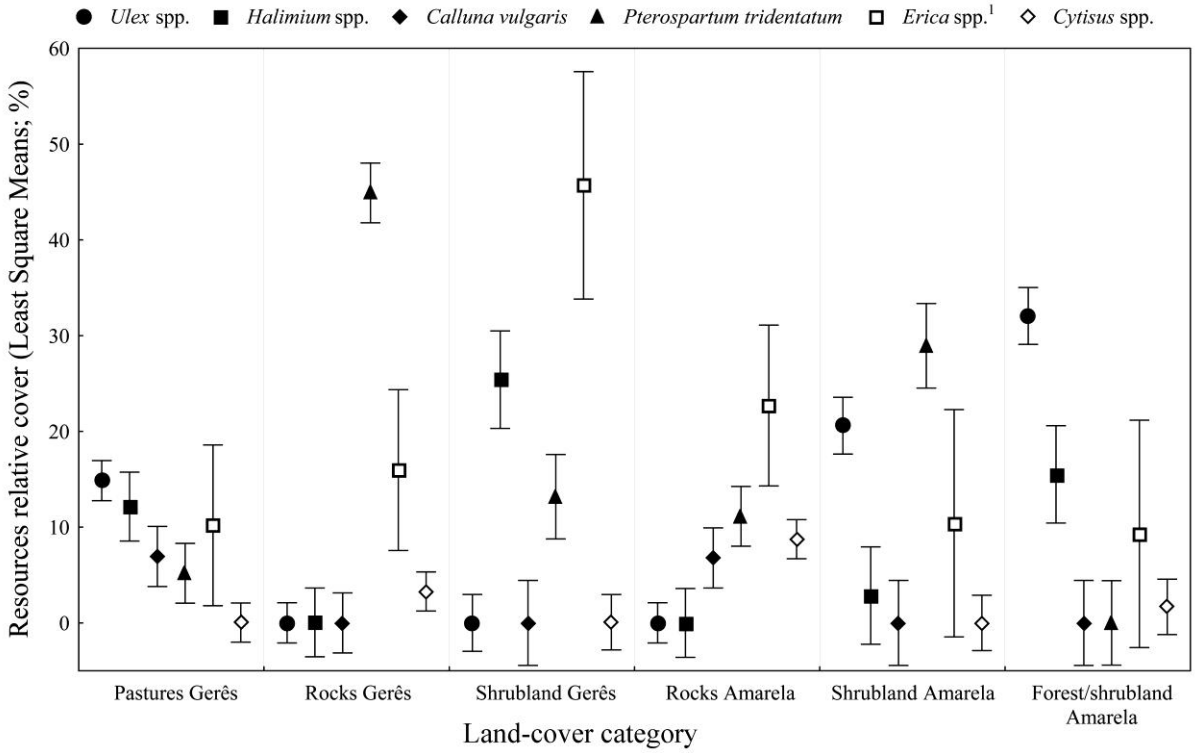

Figure 2. Spatial structuring of food resources for ibex in Gerês and Amarela (PGNP, Portugal) detected with multivariate analyses of variance (MANOVA) based on robust Pillai's trace tests. Erica spp.1 = nonhygrophilous *Erica* spp. Vertical bars denote 95% confidence.

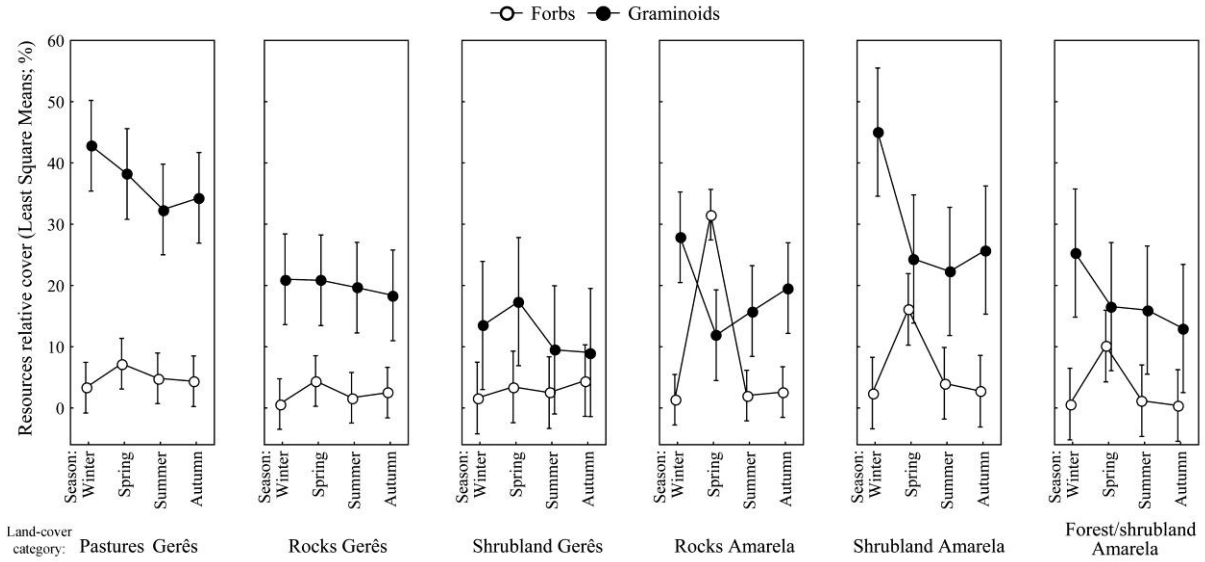

Figure 3. Seasonal structuring of food resources for ibex in Gerês and Amarela (PGNP, Portugal) detected with multivariate analyses of variance (MANOVA) based on robust Pillai's trace tests. Vertical bars denote 95% confidence intervals.

Table 3. Spatial (patch) structuring of the relative percentage cover of resources in Gerês and Amarela evidenced by individual ANOVAs (Pillai statistics for Patch*Season MANOVAs: All patch categories = 2.57, df = 80, P = 0.866; R2 = 0.76; Gerês = 1.04. [1] =Non-hygrophilous *Erica* spp.; [2] =Hygrophilous *Erica* spp. (pooled *E. tetralix* and *E. ciliaris*); [A, G]=Relative cover < 1% in Amarela and Gerês, respectively.

	All patch categories						Patch categories of Gerês						Patch categories of Amarela					
	Patch		Season		Patch*Season		Patch		Season		Patch*Season		Patch		Season		Patch*Season	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Vegetal resource																		
Graminoids	18.39	< 0.000	5.99	0.001	0.97	0.504	27.49	< 0.000	1.12	0.357	0.28	0.942	12.42	< 0.000	13.61	< 0.000	1.18	0.358
Forbs	5.90	< 0.000	29.29	< 0.000	6.34	< 0.000	1.72	0.197	1.21	0.323	0.11	0.994	6.36	0.007	48.78	< 0.000	5.07	0.003
Pterospartum tridentatum	97.12	< 0.000	0.43	0.731	0.12	1.000	151.67	< 0.000	0.15	0.929	0.09	0.997	57.36	< 0.000	0.43	0.736	0.22	0.966
***Halimium* spp.**	21.03	< 0.000	0.20	0.896	0.09	1.000	20.38	< 0.000	0.04	0.989	0.02	1.000	869.25	< 0.000	11.57	< 0.000	11.86	< 0.000
***Cytisus* spp.**	9.96	< 0.000	0.23	0.876	0.14	1.000	7.76	< 0.000	0.03	0.993	0.02	1.000	8.35	0.002	0.27	0.847	0.11	0.994
Calluna vulgaris	4.30	0.003	0.40	0.751	0.13	1.000	7.70	0.002	0.10	0.960	0.07	0.998	3.57	0.047	0.34	0.799	0.17	0.982
***Erica* spp.**[1]	6.16	< 0.000	0.19	0.901	0.02	1.000	20.30	< 0.000	0.11	0.951	0.03	1.000	1.56	0.235	0.09	0.964	0.01	1.000
***Ulex* spp.**	104.70	< 0.000	0.50	0.682	0.32	0.991	38.11	< 0.000	0.11	0.955	0.08	0.998	1061.50	< 0.000	2.23	0.116	3.94	0.009
Thymelaea broteriana [A]	3.15	0.015	0.73	0.539	0.34	0.987	2.32	0.117	0.77	0.522	0.32	0.919	-	-	-	-	-	-
***Erica* spp.**[2; A]	7.34	< 0.000	0.05	0.985	0.03	1.000	8.26	0.002	0.05	0.984	0.04	1.000	-	-	-	-	-	-
Arbutus unedo [G]	203.86	< 0.000	0.62	0.607	0.99	0.483	-	-	-	-	-	-	179.17	< 0.000	0.58	0.636	0.87	0.535
***Quercus* spp.** [G]	6.69	< 0.000	0.13	0.942	0.09	1.000	-	-	-	-	-	-	3.49	0.050	0.12	0.946	0.06	0.999

Table 4. Landscape heterogeneity in Gerês and Amarela at the class and landscape levels. Area, Shape index, ENN (Euclidean Nearest Neighbour distance) and ECON (Edge contrast index) were area-weighted. Std. Dev. = Standard deviation. [1]=Contrast weights: vegetation structure and wetness degree (structural factors); [2]=Contrast weights: graminoids relative cover (%; food factor); [3]=Contrast weights: all factors.

			Landscape composition				Landscape configuration					
Level	**Area**	**Land-cover category**	**Total area (ha)**	**Proportion of land-cover (%)**	**No. of patches**	**Mean Patch Area (ha)**	**Shape index**	**ECON[1] (%)**	**ECON[2] (%)**	**ECON[3] (%)**	**Std. Dev. of ENN**	**IJI (%)**
Class	Gerês	Pastures	30.8	4.5	27	2.0	2.1	47.3	81.8	80.3	0.0	93.8
		Rocks	545.0	80.0	92	78.7	3.9	57.2	52.8	58.7	5.9	76.9
		Shrubland	98.1	14.4	150	4.9	2.9	53.0	52.4	62.1	20.1	72.0
	Amarela	Rocks	485.4	71.6	44	92.3	2.6	47.3	42.8	57.1	33.0	83.7
		Shrubland	36.0	5.3	17	12.0	2.6	28.2	40.8	38.5	51.3	76.7
		Forest/shrubland	151.7	22.4	74	6.5	2.9	75.2	60.9	65.9	8.0	70.7
Landscape	Gerês	-	681.5	-	285	63.8	3.9	56.5	54.6	60.6	27.3	80.8
	Amarela	-	678.3	-	137	68.2	3.2	62.8	47.2	58.3	45.8	75.7

Moreover, when comparing pastures in Gerês with shrubland in Amarela (land-cover category with the higher abundance of graminoids in this area) we observed they presented different ligneous profiles. Because shrubs species encountered in these vegetation units are avoided or consumed by ibex in accordance to areas' availability (Moço et al. 2013), it is unlikely that the floristic composition of pastures and shrubland ligneous strata would influence attractiveness for ibex. But while shrubs constituted small heighted isolated bushes in a graminoids matrix in pastures of Gerês, they had high height and volume and practically roofed herbaceous strata in shrubland of Amarela. Consequently, in the last area the ligneous strata of shrubland patches may have hindered graminoids intake by ibex in two ways: by reducing graminoids visibility and/or assessment (Wang et al. 2010) and by reducing feeding time in these patches (Etzenhouser et al. 1998). The idea that graminoids were important feeding goals for ibex in Gerês is also supported by the different dietary selection of *C. vulgaris*, much appreciated in Amarela and quite indifferent in Gerês (Moço et al. 2013) where it was closely associated with pastures.

At a broader scale, our results strongly suggest that a uniform or regular distribution of preferred resources may favour their consumption by generalist ungulates. In our target population, travelling from any random location to graminoids-rich patches would require traversing shorter straight distances in Gerês. That is, in this area pastures and therefore graminoids may constitute the most accessible sources of proteins for ibex. Conversely, in Amarela forest/shrubland appeared as attractive feeding sites from a ligneous perspective. These patches offered the highest variety of shrubs (see Appendix 3) including species highly preferred by ibex as *A. unedo* and *Cytisus* spp. (Moço et al. 2013) and were easily accessed from any random location.

Our insights on ibex foraging strategies would greatly benefit from individual-based research on feeding patches, i.e., a bounded area where animals invest time and energy in finding food (Turner et al. 1997) expected to be proportional to relative food availability (Senft et al. 1987) and quality (Hochman & Kotler 2006), and on feeding paths, i.e., Ibex movements through the landscape mosaic while feeding. For example, since edge-contrast due to vegetation structure is less pronounced in Gerês, moving through this area is apparently less costly than in Amarela. In addition, assuming graminoids-rich units as a critical protein sources for ibex, the spatial distribution of pastures may favour the decision to leave a patch in case of resources depletion in that patch (Senft et al. 1987). Accordingly, we would expect higher rates of foraging movement in Gerês. Graminoids identification and assessment of food quality parameters at the community level would also enlighten our conclusions, since these may

influence the time spent by ibex at each feeding patch, and consequently its movement pattern and velocity through the landscape (Senft et al. 1987; Turner et al. 1997). The monitoring of this ibex population at a broad temporal scale could also provide important clues about the role of landscape heterogeneity in ungulates dispersion.

We do not disregard that herbivores need to attain other goals than a nutritive and balanced diet (Senft et al. 1987; Hochman & Kotler 2006) and that their available time must be used efficiently in order to accomplish several requirements. In this sense, landscape complementation (Wiens 1989), such as adjacency of non substitutable resources (e.g., rocks for avoiding predation or other disturbances) to feeding patches (Hochman & Kotler 2006; Scillitani et al. 2013) is also to be taken into account in further understanding of ungulates interactions with landscape heterogeneity.

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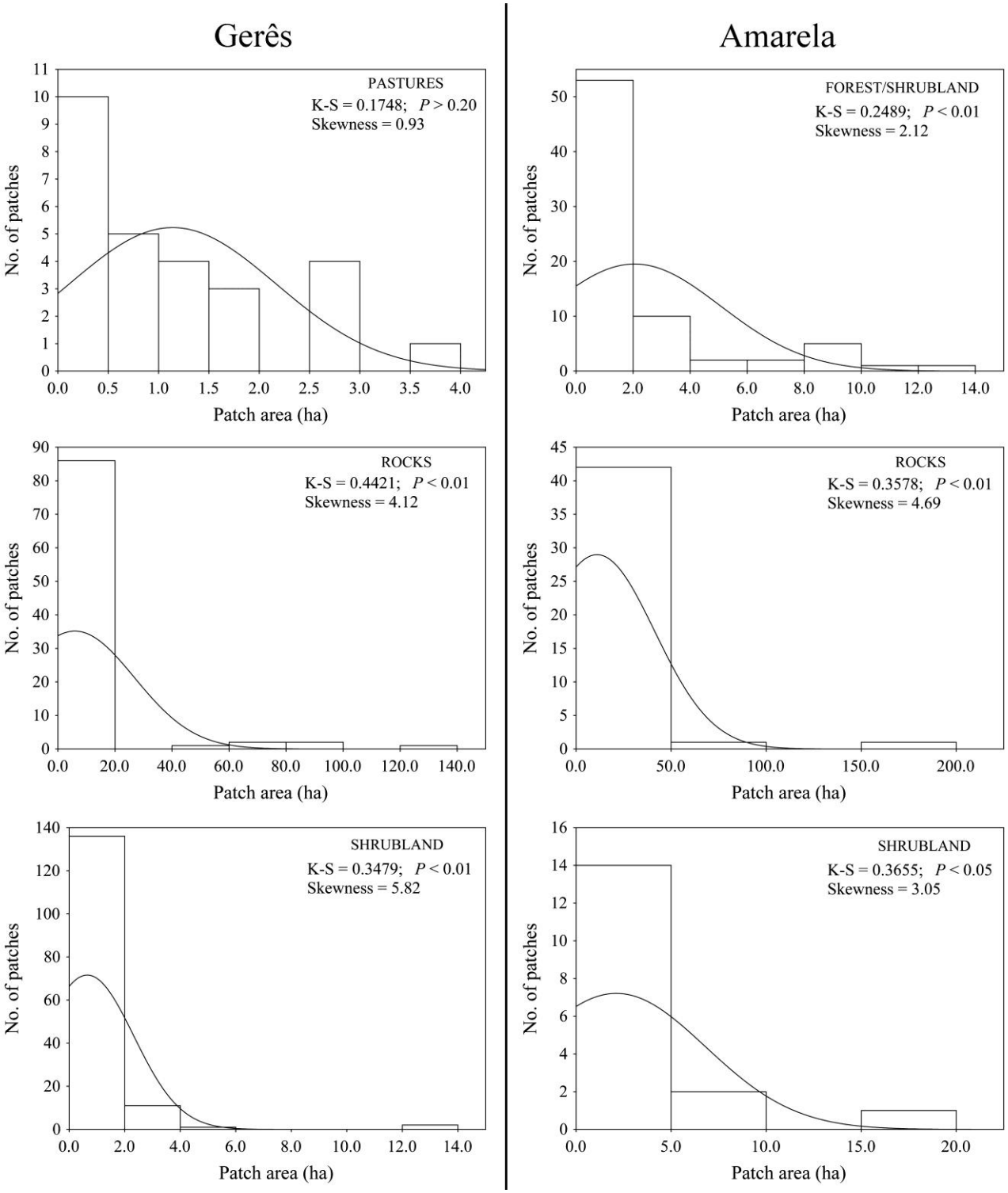
Appendix 1. Parameterization of ecological attributes (factors) to obtain edge contrast weights between land-cover categories in Gerês and Amarela (PGNP, Portugal).

Contrast keys of factors				Score assignment of land-cover categories		
Vegetation structure	Wetness degree	Mean % cover of graminoids	Score	Vegetation structure	Wetness degree	Mean % cover of graminoids
short	dry	low		short	dry	low
unvegetated	xeric		1		Rocks[A,G]	
lichen or moss		12.3	2			Shrubland[G]
herbaceous	mesic	17.7	3	Pastures	Shrubland[A,G]	Forest/shrubland
		18.8-20.0	4	Rocks[A,G]		Rocks[A,G]
shrubs	temporarily saturated		5		Forest/ shrubland	
		29.4	6	Shrubland[A,G]		Shrubland[A]
tree open canopy	temporarily flooded		7		Pastures	
		36.9	8	Forest/shrubland		Pastures
	permanently flooded		9			
tree	deep water		10			
tall	wet	high		tall	wet	high

[A] Amarela
[G] Gerês

Appendix 2. Frequency distributions of patch area (ha) of land-cover categories in Gerês and Amarela (PGNP, Portugal) showing extreme values and justifying the use of area-weighted mean metrics in subsequent comparisons at the class and landscape levels. K-S = Kolmogorov-Smirnov test.



Appendix 3. Resources profiles of patch categories sampled in Gerês and Amarela (PGNP, Portugal). Values indicate mean relative % cover ± standard deviation. *Erica* spp.[1] = non-hygrophilous *Erica* spp.; *Erica* spp.[2] = pooled hygrophilous *Erica tetralix* and *Erica ciliaris*.

Area	Patch category	Herbaceous resources	Shrubs with relative cover ≥ 1%
Gerês	Pastures	Graminoids (36.9 ± 10.6) Forbs (4.9 ± 5.3)	*Ulex* spp. (14.9 ± 7.3) *Halimium* spp. (12.1 ± 12.7) *Erica* spp.[2] (10.2 ± 12.6) *Calluna vulgaris* (6.9 ± 7.6) *Erica spp.* (6.3 ± 6.6) *Pterospartum tridentatum* (5.2 ± 5.5) *Thymus* spp. (1.3 ± 1.4) *Thymelaea broteriana* (1.1 ± 1.7)
	Rocks	Graminoids (20.0 ± 6.4) Forbs (2.3 ± 2.5)	*Pterospartum tridentatum* (44.9 ± 7.3) *Erica* spp.[1] (16.0 ± 16.6) *Sedum* spp. (4.8 ± 5.7) *Cytisus* spp. (3.3 ± 3.5) *Thymus* spp. (2.7 ± 2.5)
	Shrubland	Graminoids (12.3 ± 3.7) Forbs (3.0 ± 1.9)	*Erica* spp.[1] (45.7 ± 5.2) *Halimium* spp. (25.4 ± 2.5) *Pterospartum tridentatum* (13.2 ± 1.9)
Amarela	Forest/shrubland	Graminoids (17.7 ± 5.7) Forbs (3.1 ± 4.4)	*Ulex* spp. (32.1 ± 2.7) *Halimium* spp. (15.5 ± 3.6) *Arbutus unedo* (7.2 ± 1.8) *Erica* spp.[1] (9.3 ± 2.2) *Lithodora prostrata* (4.4 ± 3.1) *Quercus* spp. (2.7 ± 1.1) *Rubus* spp. (2.4 ± 1.5) *Pyrus* spp. (2.1 ± 1.8) *Cytisus* spp. (1.7 ± 0.6)
	Shrubland	Graminoids (29.4 ± 11.2) Forbs (6.3 ± 6.2)	*Pterospartum tridentatum* (28.9 ± 2.5) *Ulex* spp. (20.6 ± 3.6) *Erica* spp.[1] (10.4 ± 5.1) *Halimium* spp. (2.8 ± 1.0) *Lithodora prostrata* (1.5 ± 0.6)
	Rocks	Graminoids (18.8 ± 7.7) Forbs (9.4 ± 14.0)	*Erica* spp.[1] (22.7 ± 23.7) *Pterospartum tridentatum* (11.1 ± 6.5) *Cytisus* spp. (8.7 ± 6.6) *Quercus* spp. (8.2 ± 8.9) *Calluna vulgaris* (6.8 ± 8.7) *Sedum* spp. (4.9 ± 5.4)

CHAPTER 6. GENERAL DISCUSSION

“Many times I've wondered how much there is to know”

Jimmy Page and Robert Plant

GENERAL DISCUSSION

6.1. Some goals to ashes

Field research in Natural Sciences is affected by funding, biotic and abiotic factors and stochasticity. This doctoral thesis was not an exception. Before entering to discuss the main subjects of this work I would like to emphasize the failure in capturing live ibexes in the study area.

The initial goals of this thesis included the settlement of footsnares for ibex in the PGNP. With this task we intended to test and put into practice a capture-marking protocol to monitor the ibex population. As recommended in post-release survey of translocation procedures (Nielsen 1989), marking of the individuals would facilitate their identification in future surveys of the population, e.g., the estimation of its abundance. Footsnares were chosen because they had been successfully used in the Pyrenees with *Rupicapra pyrenaica* (Crampe *et al.* 2007), required a lower economic budget if compared with other methods, were easy to use and the damage expected to the captured individuals was low. Further, no accredited and authorized personal to perform chemical immobilization was available to consider other capture methodology. During almost two years we installed, baited and monitored the snares. Two pilot trapping campaigns were carried out in order to evaluate the protocol procedure and train the technicians that would be involved in further captures. We were aware that ibexes would require a large adaptation time to accept those strange objects on their environment before we had the chance to capture first individuals. Despite the relative low costs of the method this task consumed a considerable amount of one-year budget and human effort. In December of 2005, this literally turned to ashes due to an induced fire before capturing any animal (Figure 1). This event changed significantly the perspectives of this thesis in its second year of "life", and showed that fire is also a menace for researchers' activities and expectations in the PGNP. From that moment forward we had to exclusively rely in non-invasive methods to address our goals, which had to be redefined.

Figure 1. Footsnares for ibex (*Capra pyrenaica*) installed and monitored in PGNP during 2004 and 2005 and destroyed by fire in December of 2005.

6.2. On the common name of *Capra pyrenaica*

Consensus was not yet achieved for the common name of *C. pyrenaica*, as expressed in the lack of uniformity i*n* this thesis, *C. pyrenaica* appearing as "Iberian wild goat" and "Iberian ibex". Following the reasons exposed in Chapter 3, the choice of the vernacular name of the species in each article or manuscript here produced was influenced by authors' and journals' preferences. Other vernacular names for the species are Iberian Wild Goat, Spanish Ibex or Pyrenean Ibex in English, "Bouquetin des Pyrénées" in French and "Cabra Montesa" in Spanish (Herrero & Pérez 2008). Currently, the Iberian geographic character is widely accepted and opinions diverge in the use of "wild goat" and "ibex" (Sarasa *et al.* 2012; Herrero *et al.* 2013). Sarasa *et al.* (2012) point that "wild goat" is less appropriate to *C. pyrenaica* than "ibex" because it relates it with the Bezoar (*Capra aegagrus*) and its use is quite recent. Arguments in favour of "ibex" are its current use for designating several wild *Capra* spp.,

in agreement with the IUCN (2015), and the probable Iberian or Aquitanian origin of the word, in agreement with *C. pyrenaica* historical range (Sarasa *et al.* 2012). This option is supported by molecular studies that suggest the monophyly of European wild *Capra* spp. (Hartl *et al.* 1990; Manceau *et al.* 1999; Pidancier *et al.* 2006; Kazanskaya *et al.* 2007) in opposition to Crégut-Bonnoure (1992, 2005).

Once Caprinae specialists generally agree that the distribution range should be a major criterion defining vernacular names, the reintroduction of *C. pyrenaica* in the French side of the Pyrenees (Crampe *et al.* 2015) may re-open the debate about its vernacular name. Anyway, to call one animal in a single standardized way could be desirable.

6.3. An increasing trend

The outputs of this work contributed to the definition of the regional conservation status of Critically Endangered attributed to ibex in Portugal (Cabral *et al.* 2005). Since then, ibex population in the PGNP continued increasing in numbers and range and these needs urgent review. In 2009, the Baixa Límia- Serra do Xurés Natural Park (BLSXNP, Spain) released another group of ibex near the border with Peneda mountain range. Some individuals soon expanded to the PGNP and are regularly observed (c. 50; Henrique Carvalho, personal communication). A global increasing trend is also reported for ibex in Spain (Herrero & Pérez 2008). In consequence, the conservation status of *C. p. hispanica* and *C. p. victoriae* changed from, respectively, Lower Risk: conservation dependent and Vulnerable (IUCN 2004) to Least Concern (Herrero & Pérez 2008; Acevedo & Cassinello 2009). Despite this optimistic trend, Pérez *et al.* (2002) outline the metapopulation character of the spatial distribution of the ibex in the Iberian Peninsula and recommend demographic research on local extinction and replacement rates, genetic analyses and studies on movements between close mountain ranges.

For *C. p. victoriae* in particular, establishing additional populations would be important to reduce the effect of stochastic events on small and isolated populations (Herrero & Pérez 2008; Acevedo & Cassinello 2009), as it is the case of ibex in PGNP. Considering the high level of inbreeding of this population its long-term viability will be likely compromised by changing selection forces (Almaça 1980).

6.4. Further monitoring on ibex range and numbers

The use of Distance Sampling (DS) to estimate the abundance of ibex in PGNP is advantageous respect to other methods, e.g. total counts. DS is not only cost-efficient, but also provides density estimates with associated precision assessment. However, the pilot study evidenced the need to increase

the number of ibex observations in order to model the detection function and generate reliable estimates of abundance (Loison *et al.* 2006; Litt & Steidl 2009). Because each observation must be an independent event (Buckland *et al.* 2001) and grouped individuals are not independent from each other, the observation unit must be the group (cluster). In the case of PGNP, 74, 109 and 137 individuals were observed in 6, 3 and 13 groups in 2005, 2006 and 2007 respectively. Increasing the number of observations requires increasing the extent of line transects. The effort required to obtain estimates with adequate accuracy (L) can be calculated through the following equation by Buckland *et al.* (2001):

$$L = \frac{b\ x\ L_1}{(CV.D)^2\ x\ n_1},$$

where b is a coefficient of aggregation, L_1 is the effort perfomed, $(CV.D)^2$ is the coefficent of variation associated with the density estimation and n_1 is the number of observations obtained. Asuming b = 2, $(CV.D)^2$ = 20% and using the pilot study transects lengths and No. of observations, L = 327,5; 655 y 157,7 km in 2005, 2006 and 2007, respectively. Such efforts are difficult to perform in one year survey due to logistic and meteorological impediments, as well as counter-productive due to the potential violation of the assumption that observations are independent events. One way to resolve this issue is to increase effort through repeated surveys. Considering that the effort above calculated would be 8.3, 16.7 and 3.8 times the effort performed in 2005, 2006 and 2007, respectively, monthly surveys could sum a sufficient number of observations to obtain a density estimate with adequate accuracy levels.

The molecular approach to estimate species abundance in the PGNP with non-invasive (faecal) samples can be used as an alternative or in conjunction with DS. Costs associated with both methodologies should be estimated and compared. This approach would also allow addressing important issues, such as the identification of dispersing individuals through genotype fingerprinting.

6.5. Ibex coexistence with livestock

Considering guidelines and recommendations for translocations (Nielsen & Brown 1989; IUCN/SSC 2012) feral domestic goats in the mountain ranges of PGNP should be considered introductions. Herrero *et al.* (2013) lists benefits for the presence of feral goats in the Pyrenees, such as their importance as a food resource for predators and for the control of vegetation. Domestic goats in PGNP are also an important food resource for the wolf. Nevertheless, and although the dynamics of the coexistence of feral goats and ibex has not been yet studied, evidences of hybridization with wild *Capra* spp. (e.g., Giacommeti *et al.* 2004) and the potential disease transmission should be sufficient to consider their immediate removal from the mountain ranges

of PGNP. In fact, one ibex male has been frequently observed with feral domestic goats in the Peneda range (Figure 2).

Figure 2. Coexistence of Iberian ibex (*Capra pyrenaica*) and domestic goats (*Capra hircus*) in Peneda-Gerês National Park (Portugal). Photograph by Albino Palhares/PGNP.

The maintenance of the ecological niche left vacant by an extinct population is vital for the success of its reintroduction (Almaça 1980). In the PGNP, the ecological niche of the ibex is probably partly occupied by livestock and may have been changed during the last hundred years by overgrazing and fire. One basic management tool to address this issue is the evaluation of the ecological carrying capacity of PGNP (SNPRCN 1991) to sustain both wild and domestic ungulates, especially of mountain ranges pastures. This task requires the field assessment of livestock stocking rates grazing extensively, because the governmental censuses include animals kept in stables and there is a common disrespect for the traditional pastures limits, as previously alerted by Leal (1874) and Gama (2008).

6.6. Ibex role in the PGNP

The return of the ibex increases the value of the PGNP if it is to lead to improvements of its physical and ecological integrity (Gama 1992, 2008). It is also a privileged opportunity to understand the ecological role of ibex as a prey of top-predators like the wolf and the gold-eagle. One important drawback of wolf's predation on ibex is that it may alleviate the historically source of conflicts between wolf and humans caused by wolf's predation on livestock (Gama 1992, 2008; Álvares 2011). Predation, or at least consumption, of ibex by wolf in the Gerês mountain range has already been confirmed in the PGNP (Figure 3).

Figure 3. Iberian ibex *Capra pyrenaica* male probably predated by wolf *Canis lupus* in Peneda-Gerês National Park, Portugal. Photograph by Lino Gonçalves/PGNP.

6.7. The hunting question

The qualitative analysis of the historical range of *C. p. lusitanica*, ibex relation with humans and changes produced in its former and potential ranges confirmed that hunting pressure was the major cause of its extinction. This was also the case of former extinctions of other wild *Capra* spp., namely the Alpine ibex (Maudet *et al.* 2002) and the Markhor (UNDP 2002). Wild *Capra* spp. continue to suffer overexploitation by humans in many regions, mainly for their horns (trophy), but also for their skin and meat (IUCN 2015). Presently, ibex is already hunted in BLSXNP.

Sport hunting has many implications in wildlife conservation and could be considered an anachronism (Grandy 1986). Hunting supporters consider this activity as socially legitimated, and as a basis for wildlife management in a wide sense (Freese 1997). Hunting has been referred to as a profitable sport (Ramos 1991) and a way to help reducing poaching (Dupré *et al.* 2001). Moreover, some authors opine that commercializing a wild species may become a positive factor regarding its conservation (see Mace & Reynolds 2001). From the contrary perspective, it has been estimated that hunting and destruction of natural habitats are responsible for the 57% of birds' and 62% of mammals' extinctions since 1600. Selective extraction of trophies (as an example, the bighorn sheep males, *Ovis Canadensis* Shaw, 1804) is associated with a reduction of the genetic population variability and its fitness as well (Hartl 1992; Fitzsimmons *et al.* 1995).

In the absence of predators, which is not the case in the PGNP (see Fig. 3), hunting be addressed as an alternative regarding ecosystem functioning.

6.8. Ecological education

Ibex conservation and locals' lifestyle in PGNP may be compatible and even mutually beneficial. Besides its ecological value, the return of the species may promote social and economic improvements in a region where governmental and regional policies have failed to fix population and create jobs (Pôças et al. 2011). One way to approach such aspiration is to integrate conservation and social development in a community-based model, i.e., in which the human community is involved in the planning and execution phases (UNDP 2002; Michel 2010). UNDP (2002) illustrates a well succeeded program of such kind devoted to the conservation of the Markhor (*Capra falconeri* Wagner, 1839) and the Afghan Urial (*Ovis orientalis* Gmelin 1774) in Balochistan (Pakistan). The first lesson to be taken into account from this example is that understanding and appreciation of the character, social organization, needs, constraints and psyche of local populations are crucial to conciliate human and ecological requirements (UNDP 2002).

In the case of the human populations in the PGNP, their ability to subsist on agropastoralism and hunting, readiness to emigrate and frequent opposition to foreign influences in their native territory resulted for the most part from a secular history of exploitation by successive forms of feudalism and a self-sustenance way of life during large periods (Mendes 1968; Ingenium 1990). With such background, governmental restrictions *per se* hardly contribute to the desired balance between conservation principles and the exploitation of natural resources. In fact, more than forty years after the creation of the PGNP, many locals do not recognize this governmental figure as its own. This was well expressed in Guerreiro (1980) when addressing the divergence about the opening of a border road in the 1980's between PGNP (detractors) and locals (supporters): "All this arises because the local populations and governments do not feel participants in the common labour that, for them, was supposed to be the Gerês Park". The present discontent of locals with the management of the PGNP is evident in open letters signed up by locals' associations to the Director of the PGNP and the Ministry of Environment and Territorial Planning of Portugal. It seems that the local populations perceive many restrictions and few benefits from the existence of the National Park. This has frequently resulted in locals retaliations with negative consequences to biodiversity (e.g., poaching, induced-fire).

The coexistence between wildlife and humans in the PGNP requires a consensual management. Assuming that humans are fundamental actors and the main shapers of the region, the cultural and social promotion (here we include economic aspects) of local communities will likely support the promotion of the PGNP aims (Guerreiro 1980; UNDP 2002). Following these authors recommendations and experience we strongly encourage environmental managers of the PGNP to entail a broad-community and long-term conservation approach: i) patiently listen to native's expectations about the PGNP (e.g., the return of the ibex); ii) focus on creating acceptability and promoting a sense of responsibility and ownership toward natural resources by the local community, instead of adopting an authoritarian attitude when defending conservation aims; iii) involve locals and local governments directly, besides the scientific community and non-governmental institutions, in long-term educational, cultural and social promotion and decision making; this aspect in particular was recommended by the Governmental Institution of Portugal for Nature Conservation when planning an ibex reintroduction in 1991 (SNPRCN 1991); iv) directly or indirectly link conservation and economic incentives, in accordance to the expectations of the local communities; for example, seriously consider an ecotourism program focused on ibex and managed by

locals with direct economic benefits for their communities.

6.9. International management

Ideally, wildlife management should be supported on legislation and administrative control from conservation bureaus (SAWMA 1989). The border of more than 100km, great part traversing mountain ranges, has greatly influenced the character of human communities inhabiting the regions of PGNP and BLSXNP (Guerreiro 1980). As described by this author, many sections of the border in the region of Barroso remained imprecise for a long time after the demarcation process of the 13th century. The presence of lands jointly managed by Portuguese and Galician neighbours until the 20th century illustrates their cultural unity. Besides livestock and, historically, contraband (Link 1801; Reichard 1820; Mendes 1968), the PGNP/BLSXNP border is highly permeable to tourism, hunters and fire. Biodiversity conservation needs an appropriate control of these factors, only possible through an international concerted strategy (Gama 2008). As a critical example of the contrary, in 1997 we were informed of the illegal trade of domestic goats that consisted in buying animals infected with brucellosis in Galicia and introducing them in Portugal, where the new owners were able to request governmental compensations for the loss of the animals infected. This event resulted in an outbreak of the disease in livestock and humans in some villages of the Gerês range. We ignore if the wild ungulates community was affected. This example illustrates not only the need for vigilance of livestock movements throughout the border, but also, and most importantly, how the different governmental managing of a livestock disease (in this case, economically compensated in Portugal and not in Spain) generated interests in the black market and, at least, a serious problem of public health. The inclusion of ibex in the list of big game species of the BLSXNP may drive off ibex from this park to the PGNP and hence attract hunters and promote poaching in this last. Also, it will probably generate expectations about hunting permits among the neighbouring communities of PGNP and create new conflicts between the Portuguese population and governmental authorities. These discrepancies strike against conservation purposes and the designations of Gerês-Xurés International Park (since 1997), PGNP and BLSXNP as PanParks (since 2008) and Gerês-Xurés Biosphere Reserve (since 2009).

6.10. References

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CHAPTER 7. CONCLUSIONS

"...tendo chegado à conclusão de serem os portugueses um povo muito estranho: feliz ou infelizmente continuamos a manter em grande parte as mesmas qualidades natas excepcionais a par dos gravíssimos defeitos que igualmente fazem parte da nossa maneira de ser,..."

Baeta Neves

CONCLUSIONS

1) In Portugal, *Capra pyrenaica lusitanica* was restricted to a very limited range in the NW region of the country and probably isolated from neighbouring populations since at least the Middle Ages. Overexploitation was confirmed as the main extinction cause. Other factors that contributed to the extinction of ibex in Portugal are prevailing and species long-term conservation is far from being ensured. Important habitat changes occurred in ibex former and current range related to human presence, livestock density and other disturbance factors such as fires.

2) The Iberian ibex (*Capra pyrenaica victoriae*) returned to the mountain ranges of Gerês and Amarela in the Peneda Gerês National Park (PGNP, Portugal) in 1998 by naturally expanding from the Baixa Límia-Sierra do Xurés Natural Park (BLSXNP, Galicia, Spain). The founder population of BLSXNP consisted on 18 individuals. Three bottlenecks are documented between their place of origin (Gredos National Game Reserve, Salamanca, Spain) in 1992 and PNPG in 1998. The species is considered Critically Endangered in Portugal since 2005. Between 2001 and 2007, the population was increasing and expanding its geographical range.

3) Until recently, vernacular names of *Capra pyrenaica* in scientific literature appeared to be determined by human factors, namely the language of publication and authors' nationalities. Caprinae specialists generally agreed that species vernacular names should respond to species distribution range or morphology, and recommended the use of the "Iberian" term. This aspect may

be conservation responsive by promoting a shared responsibility for the ibex amongst human nations of the Iberian Peninsula.

4) The pilot study conducted with Distance Sampling (DS) did not allow obtaining precise ibex density estimates in PGNP due to low sample sizes. Yet, it has proven to be feasible and adequate in further abundance monitoring of ibex. Groups instead of individuals shall be used as the units of observation to guaranty that each one is an independent event. More precise estimates are expected analyzing data obtained in multiple yearly surveys by using temporal binning.

5) It is possible to obtain genotype fingerprinting of the ibex population in PGNP through faecal samples. The founder individuals of the ibex population in PGNP showed a high level of inbreeding. Quality index of samples and markers used was up to 56%. Outputs obtained may be useful for population abundance estimates and bottleneck detection.

6) Ibex exhibited a generalist and intermediate browse - graze (mixed) feeding behaviour in PGNP. Its dietary choices appeared to respond to seasonal changes on plants phenology, spatial patterns of resources and livestock stocking rates and management. Plant phenology (higher protein content and digestibility) would explain the preference for graminoids in both areas in spring. Ibex appeared to respond to landscape arrangement of resources taking advantage from the "protein-source" more uniformly distributed, i.e., graminoids-rich pastures in Gerês and forest/shrubland patches with high richness on ligneous resources in Amarela. This explained why distinct feeding strategies were observed, namely a more intensive grazing in Gerês while browsing in Amarela. Extensive grazing of cattle and horses in Gerês may have hindered ibex accessibility to pastures and hence graminoids in summer, explaining why preference for graminoids occurred only in Amarela in this season. The considerable overlap between ibex and domestic goats diets mainly due to their

grazing behaviour during spring and summer suggested a potential direct or indirect foraging competition between them in case of spatially concurrence.

7) Potential menaces for ibex in the PGNP are proximity with humans, coexistence with livestock, habitat destruction mainly by fire, poaching and inbreeding. Research priorities are estimates of ecological carrying capacity, livestock feeding ecology, monitoring of ibex diet and density and modelling of potential ecological corridors for ibex inside and beyond the PGNP. Conservation priority should be devoted to guaranty (and if necessary improve) habitat suitability for ibex namely, the removal of feral goats and dogs from wildlife reserves and the improvement of livestock and tourism management; carry out educational programs involving local human population; ibex population reinforcement with individuals from elsewhere. The success of these actions requires collaboration between Portuguese and Spanish protected areas.