

# Iron, fire and sheep: their effects on the Holocene expansion of open vegetation in the Iberian Peninsula

La dispersió de llavors per ovelles, cabres i gossos domèstics va ser estudiada en tres ramats en el municipi d'Abrera, situat a la província de Barcelona, al nord-est de la península Ibèrica. S'hi va trobar un total de 3.267 llavors i altres estructures reproductores pertanyents a 37 espècies de plantes herbàcies i gramínies adherides al pelatge de les ovelles, els gossos i a la roba dels pastors. Diverses de les espècies de plantes dispersades pels ramats d'ovelles es troben àmpliament repartides en hàbitats de tipus obert a Euràsia. Les dades recollides suggereixen que la dispersió de llavors associada als ramats d'ovelles ha contribuït, de forma significativa, a l'expansió de les àrees de distribució de diverses espècies de plantes herbàcies i gramínies, de l'est a l'oest d'Europa i possiblement també entre el nord d'Àfrica i el sud d'Europa. La desforestació, a llarga escala, i els incendis produïts en la península Ibèrica entre 2.400 i 1.500 anys enrere, així com també la dispersió de llavors per ramats d'ovelles, van ser tres factors importants de transformació primerenca del paisatge silvícola que va propiciar l'aparició de formacions vegetals similars a les estepàries. Es planteja la hipòtesi que, durant el període de grans interferències antròpiques a la península Ibèrica (entre 2.500 i 50 anys enrere) les formacions de tipus estepari van incorporar diverses espècies de plantes procedents de l'est d'Europa, l'Orient mitjà i d'Àsia. Actualment, els ramats d'ovelles encara juguen un important paper en la dispersió de llavors tant de les espècies arqueòfites com de les neòfites.

Paraules clau: arqueòfits, epizoocòria, brostejadors, ecologia històrica, *Ovis aries*, transformació del paisatge, sistemes planta-herbívor, dispersió de llavors.

Seed dispersal by sheep, goats and domestic dogs was studied in three herds in the municipality of Abrera, located in the province of Barcelona, Northeastern Iberian Peninsula. A total of 3,267 seeds and other reproductive structures belonging to 37 epizoochoric species of herbaceous and gramineous plants were found attached to the fur of sheep and dogs and on the clothing of herdsmen. Several of these plant species are widely distributed in open habitats in Eurasia. Data suggest that seed dispersal associated to sheep herds contributed significantly to the expansion of the distribution areas of several herbaceous and gramineous plant species, from Eastern to Western Europe and possibly between Northern Africa and Southern Europe. Large-scale deforestations and repeated burnings promoted in the Iberian Peninsula between 2400 and 1500 B.P. as well as seed dispersal performed by domestic sheep were three important factors of early landscape transformation from forests to steppe like formations. It is hypothesised that during the period of major anthropogenic interferences in the Iberian Peninsula (2500 to 50 B.P.), the steppe like formations of this region incorporated several plant species coming from Eastern Europe, the Middle East and Asia. Nowadays, sheep herds still play an important role on seed dispersal of both archaeophyte and neophyte species.

Key words: archaeophytes, epizoochory, grazers, historical ecology, *Ovis aries*, landscape transformation, plant-herbivore systems, seed dispersal.

## Introduction

Analyses of palaeopollen data from the Holocene indicate that many of the currently existing open plant formations in the Iberian Peninsula, such as grasslands, steppes, heaths and low shrub lands, have mainly resulted from the degradation of woodland over the past 4,000 years (BIRKS 1986, BURJACHS 1994, BURJACHS *et al.* 1997, ADAMS & FAURE 1998, YLL *et al.*,

2003). Here I assess archaeological information using data on seed dispersal by herds in order to investigate the mechanisms involved in the degradation of woodland towards steppe-like stages.

## A case study in Abrera

Between March 2001 and October 2006, seed dispersal by sheep (*Ovis aries*), domestic goats (*Ca-*



Fig. 1. Map of Catalonia showing the main rivers. The black dot represents the location of the municipality of Abrera, a 19.89 km<sup>2</sup> study area in the province of Barcelona, Northeastern Iberian Peninsula.

*pra hircus*) and dogs (*Canis lupus familiaris*) was studied in three herds in the municipality of Abrera (41° 31' N, 1° 55' E), a 19.89 km<sup>2</sup> area located in the province of Barcelona, Northeastern Iberian Peninsula (fig. 1).

Seeds attached to the fur of sheep, goats and dogs and to herdsmen's clothing were collected, identified and counted. Moreover, seeds found in faeces of sheep and goats were examined in order to determine structural damage on seed coat during mastication. Some seeds found attached to animals and herdsmen were planted in receptacles containing organic soil (grains < 4 mm) to identify plant species.

A total of 3,267 seeds and other reproductive structures belonging to 37 species of herbaceous and gramineous plants were found attached to the fur of sheep and dogs and on the clothing of herdsmen (epizoochory). Of these, the most frequent species (found in more than 50% of the sheep examined during at least one fruiting period) were: *Xanthium echinatum* subsp. *italicum*, *Xanthium spinosum*, *Crupina vulgaris*, *Centaurea* cf. *aspera* (Asteraceae), *Galium* spp. (including *G. aparine* and *G. parisiense*, Rubiaceae), *Trifolium* cf. *angustifolium* (Fabaceae), *Agrimonia eupatoria* (Rosaceae), *Oenothera biennis* (Onagraceae), *Cerastium* cf. *gracile* (Caryophyllaceae),

*Daucus carota* (Apiaceae), *Hordeum murinum*, *Hyparrhenia hirta*, *Aegilops geniculata*, *Holcus lanatus*, *Stipa pennata*, *Stipa* sp. (Poaceae), *Erica* spp. (*E. arborea/multiflora/scoparia*, Ericaceae) and *Plantago lagopus* (Plantaginaceae). Seeds and other reproductive structures less frequently or occasionally found attached to the fur of sheep and dogs and on the clothing of herdsmen (less than 50% of the sheep examined during one or more fruiting periods) were: *Pennisetum setaceum*, *Sorghum halepense*, *Cynosurus echinatus*, *Cortaderia selloana*, *Melica ciliata*, *Polypogon monspeliensis*, *Brachypodium* spp., *Echinochloa* spp., *Paspalum* spp. (Poaceae), *Oxalis pes-caprae* (Oxalidaceae), *Typha latifolia* (Typhaceae), *Bidens* cf. *pilosa*, *Amaranthus* spp. (Amaranthaceae), *Silybum marianum* (Asteraceae), *Conyza* spp. (Asteraceae), *Populus* sp. (Salicaceae), and *Tamarix* sp. (Tamaricaceae).

Whole seeds of *Salvia verbenaca*, *Lycopus europaeus* (Lamiaceae), *Urtica dioica* (Urticaceae), *Ceratonia siliqua* (Leguminosae), *Abutilon theophrasti* (Malvaceae) and *Poa* spp. (Poaceae) were found in the faeces of sheep, and whole seeds of *Rubus ulmifolius* (Rosaceae), and *Ficus carica* (Moraceae) were found in the faeces of goats.

Recent archaeological findings in the study area (cf. SOLER *et al.* 2000, GUIX *et al.* 2001, BERMÚDEZ-LÓPEZ



Fig. 2. Roman *villa* of Sant Hilari (Abrera). The geometric figure indicates the area where Roman ceramic fragments were found.

*et al.* 2003) were associated with large landscape transformations occurred between 2400 and 1500 B.P. Archaeological sites: (1) Iberian settlement located between the Torrent Gran d'Abrera and the Hostal del Pi Street ( $41^{\circ} 30' 48''$  N,  $1^{\circ} 53' 58''$  E; altitude: 119 m). New findings included the following items: clumped broken stones that contained mineral iron, remains of iron manufacture (with large amounts of cast iron), and at least 16 underground silos for grain storage, which contained ceramic fragments attributed to the third and second centuries B.C.; (2) the Roman *villa* of Sant Hilari ( $41^{\circ} 31' 18''$  N,  $1^{\circ} 54' 46''$  E; altitude: 69 m); (a) large numbers of Roman ceramic fragments preliminarily attributed to the period between the first century B.C. and the fifth century A.D; (b) the remains of a large oven for ceramic production and another one (presumably for lime production); (c) cast iron and slag; (d) ceramic fragments of amphoras found in river margins and islands of the Llobregat river at Abrera (fig. 2). Also, the finding of fragments of Roman "African ceramics" suggests trade of agriculture products between the study area and the Roman possessions of Northern Africa across the Mediterranean Sea (see also BLÁZQUEZ-MARTÍNEZ 2002, for other localities in the province of Barcelona).

Like other human settlements of the 2400-2100 B.P. period in the Llobregat river valley, the Iberian settlement of Abrera (Hostal del Pi Street) is located in high lands, far away from the river, while the Roman *villa* (Sant Hilari) is placed on the river margin. Nevertheless, both human settlements probably established regular interchange and trade of agricultural products and sheep with other regions throughout the Llobregat river and the Mediterranean Sea (GUIX *et al.* 2001, BERMÚDEZ-LÓPEZ *et al.* 2003).

The Torrent Gran d'Abrera and its tributaries are a Mediterranean drainage system that presents several water emergences with high concentrations of iron oxide (from 20.7 to 94.3 mg Fe/litre), which indicates the existence of large amounts of underground iron in the zone. This iron availability could have influenced or even conditioned the Iberian occupation and the existence of the settlement of the Hostal del Pi Street (in fact, nowadays, large amounts of yellow ochre clay are still found at the surface soil in this archaeological settlement). On the other hand, many of the Roman settlements of the Comarca del Baix Llobregat, such as the Sant Hilari *villa* were highly associated to the Llobregat river, not only because of the floodplain fertility and water irrigation, but also, and especially due to the trade of agricultural

products (e.g., olive oil, wine), through this fluvial route and with the Mediterranean sea.

## An assessment within the framework of the Iberian Peninsula

The role of sheep as long-distance seed-dispersal vectors of several plant species by means of seeds and propagules transported on the fur and in the gut has been shown in the last few years (FISCHER *et al.* 1996, MANZANO *et al.* 2005, MOUSSIÉ *et al.* 2005, MANZANO & MALO 2006). In fact, seeds attached to the fur of nowadays traditional nomadic sheep herds in Spain can be transported over hundreds of kilometres in this way (MANZANO & MALO 2006).

Seed attachment to sheep fur is often higher than that of goats, dogs associated to herds and herdsmen's clothing. Even seeds and other plant parts without apparent structures for attachment can be found on the fur of these animals, especially when they lie on the ground to rest or to give birth. Nevertheless, goats consume large amounts of seedlings and leaves of juvenile shrubs and trees. Thus, the role of goats in mixed herds has been crucial to the degradation of Mediterranean woodland.

In general, palaeontological data show that domestic sheep breeds during the first millennium B.C. were smaller and lower than the current sheep varieties (PELLÓN 2006). Thus, these ancient breeds browsed closer to the ground and could collect and transport more propagules attached to their fur than the current larger varieties.

Wool was an important product for the inhabitants of Europe and the Middle East during the first millennium B.C., and it is probable that both the Phoenicians and the Romans actively transported sheep herds between Africa and Southern Europe, by ship (PELLÓN 2006, PEREIRA *et al.* 2006). In such circumstances seed transport across the Mediterranean Sea probably promoted the expansion of the distribution areas of several plant species associated to sheep herds between both continents.

On the other hand, the harvesting of wood to be used as fuel in iron and ceramic manufacturing played an important role in landscape transformation processes in European Mediterranean lands. Smelting iron and lime needs high temperatures and therefore large amounts of wood as fuel. Thus, the archaeological sites and remains found in Abrera suggest large anthropogenic impacts in native vegetation during the Iron Age and the Roman period (GUIX *et al.* 2001).

Large anthropogenic landscape changes in the Iberian Peninsula were associated to the arrival of nomadic herdsmen of sheep and goats, during the Neolithic, coming from the Eastern Mediterranean region. In fact, several ritual burials containing domestic sheep and goat remains thought to be dated between 425 and 300 B.C. were found in the Iberian settlement of Penya del Moro (Parc de Collserola, Sant Just Desvern), 19 km from Abrera (BARBERÀ & MOLIST 2002). The transition from nomadic herding (Bronze Age) to cereal based agriculture and non-nomadic herding (Iberians—Iron Age— and Roman times) probably increased landscape transformation in

several Mediterranean areas of the Iberian Peninsula. Nevertheless, transhumant herding systems and sedentary agro-pastoral systems that included small-scale seasonal movements of herds probably coexisted in the Iberian Peninsula during, at least, the last 2,500 years (WAINWRIGHT & THORNES 2004).

Current results suggest that the expansion of steppe and grassland vegetation in the Iberian Peninsula during the last 3,000 years were associated with the increase of three related processes during the Iron Age and Roman times: (a) wood-cutting for iron, lime and ceramic manufacturing; (b) anthropogenic fires for pasture creation/renovation and cereal cultivation; and (c) seed dispersal by sheep (including plants from Eastern Europe, Middle East, Asia and Northern Africa). The intensification of sheep and goat grazing favoured those plants that were unpalatable (e.g., *Pinus* spp.; Pinaceae) or toxic for these animals (e.g., Euphorbiaceae) and chamaephytic under shrubs and pseudo-steppe invasive vegetation. Otherwise, soil degradation by overgrazing, during the last three centuries, could have induced new changes on vegetation and plant-herbivore equilibrium, favouring the colonisation of neophytes (e.g., *Xanthium spinosum*, *Conyza* spp., Asteraceae, from the New World; fig. 3).

At the end of the last ice age (18,000 years ago), the Iberian Peninsula was dominated by temperate and montane steppes (mainly short-grass steppe and dense tall-grass steppe; ADAMS & FAURE 1998). Despite the fact that the last ice age finished 14,000 years ago, the Iberian Peninsula has been subject to other minor climatic fluctuations that have influenced plant communities and plant distributions during the last 10,000 years. During the first half of the Holocene (10,000–6,000 years ago) the Iberian Peninsula experienced an expansion of forests (first with the expansion of *Pinus* and *Betula* and then with *Quercus robur* and *Corylus*) (ADAMS & FAURE 1998; TERRADAS 2001). In the pollen record of the Barcelona region coming from soil strata corresponding to the period comprised between 6000 and 4000 B.P., there is a high representation of deciduous oaks (*Quercus* spp.), hazels (genus *Corylus*), holm oak (*Quercus ilex*) and pines (genus *Pinus*; most of them were probably *Pinus halepensis*) (RIERA 1994, TERRADAS 2001). In the context of the Holocene climatic fluctuations, some remnants of the late Pleistocene steppes and steppe like formations experienced local expansions during dry periods, but several of them were replaced by forest formations during wet periods. Nevertheless, between 2500 and 50 B.P., when the climate was probably similar to the one now, steppe like formations expanded into woodlands by the effect of anthropogenic fires. I hypothesise that during this period of major anthropogenic interferences, steppe like formations in the Iberian Peninsula incorporated several taxa elements from Eastern Europe, the Middle East and Asia. In fact, many of the steppe species found in the Abrera study area and dispersed by sheep and goat herds, are widely distributed across Eurasia. Wool sheep breeds and goat herds could have entered the Iberian Peninsula coming from the east in successive surges during the last 3,000 years, both



Fig. 3. Adhesive fruiting body of *Xanthium spinosum* (Asteraceae), a native species from South America, often found attached to the fur of sheep in the municipality of Abrera, province of Barcelona, Northeastern Iberian Peninsula.

by land through some river valleys of Catalonia such as the Segre, Ter, Llobregat, Cardener or the Muga, and by ship through the Mediterranean Sea (see also PEREIRA *et al.* 2006). Thus, multiple introductions of alien plants associated to sheep herds in the Iberian Peninsula could have occurred.

In fact, it could be possible that *Crupina vulgaris* (Asteraceae) had been introduced in grasslands and other open habitats of western North America coming from the Iberian Peninsula through domestic herds (GARNATJE *et al.* 2002).

Traditional sheep and goat herds may be considered as ecological units in which each species involved in this mutualistic relationship (man, sheep, goats and dogs) played and still plays an important role in seed dispersal and the landscape transformation of the Iberian Peninsula. Thus, new epizoochoric plant species introduced in the Iberian Peninsula could potentially be widely dispersed by sheep and goat herds.

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## References

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ADAMS & FAURE 1998

J. M. Adams & H. Faure, *The Global atlas of palaeovegetation*. Quaternary Environments Network. Oak Ridge National Laboratory. Oak Ridge, 1998. <<http://www.esd.ornl.gov/projects/qen/adams1.html>>.

BARBERÀ & MOLIST 2002

J. Barberà & N. Molist, *La Penya del Moro; selecció de materials de 20 anys d'excavacions al poblat iber de Sant Just Desvern*, catàleg de l'exposició. Fundació Privada Catalana per a l'Arqueologia Ibèrica i Ajuntament de Sant Just Desvern, Sant Just Desvern, 2002.

BERMÚDEZ-LOPEZ *et al.* 2003

X. Bermúdez-López, J. Sales-Carbonell, M. Soler-Sala, S. C. A. Guix & J. C. Guix, "Agricultura i comerç en època ibèrica al curs mig del Llobregat. Estudi del probable camp de sitges del carrer de l'Hostal del Pi (Abrera, Baix Llobregat)", *Revista d'Arqueologia de Ponent* 13: 211-222, Lleida, 2003.

BIRKS 1986

J. H. B. Birks, "Late Quaternary biotic changes in terrestrial and lacustrine environments, with particular reference to north-west Europe", *Handbook of Holocene palaeoecology and palaeohydrology* (B. E. Berglund, ed.), 3-65, Chichester, Wiley, 1986

BLÁZQUEZ-MARTÍNEZ 2002

J. M. Blázquez-Martínez, "Relaciones de España en la tarda antigüedad con África y el Oriente. Últimas aportaciones de la cerámica", *Humana sapit. Études d'Antiquité tardive offertes à Lellia Cracco Ruggini* (J. M. Carrié & R. Lizzi, eds.), 299-307, Turnhout, 2002.

BURJACHS 1994

F. Burjachs, "Palynology of the upper Pleistocene and Holocene of the north-east Iberian Peninsula: Pla de l'Estany (Catalonia)", *Historical Biology* 9, 17-33, 1994.

BURJACHS *et al.* 1997

F. Burjachs, S. Giralt, J. R. Roca, G. Seret & R. Julià, Palinología holocénica y desertización en el Mediterráneo Occidental, *El paisaje mediterráneo a través del espacio y del tiempo. Implicaciones en la desertificación* (J. J. Ibáñez, B. L. Valero & C. Machado, eds.), 379-394, Geoforma, Logroño, 1997.

FISCHER *et al.* 1996

S. F. Fischer, P. Poschlod & B. Beinlich, "Experimental studies on the dispersal of plants and animals on sheep in calcareous grassland", *J. Appl. Ecol.* 33, 1206-1222, 1996.

GARNATJE *et al.* 2002

T. Garnatje, R. Vilatersana, C. T. Roché, N. Garcia-Jacas, A. Susanna & D. C. Thill, "Multiple introductions from the Iberian peninsula are responsible for invasion of *Crupina vulgaris* in western North America", *New Phytologist*, 154, 419-428, 2002.

GUIX *et al.* 2001

J. C. Guix, M. Soler, M. Martín, M. Fosalba & A. Mauri, "Introducción y colonización de plantas alóctonas en un área mediterránea: evidencias históricas y análisis cuantitativo", *Orsis*, 16, 145-185, Bellaterra, 2001.

LE HOUÉROU 1993

H. N. Le Houérou, "Grazing lands of the Mediterranean basin, *Natural grasslands; eastern hemisphere and résumé* (R. T. Coupland, ed.), 171-196, *Ecosystems of the world* 8B, Elsevier, Amsterdam, 1993.

MANZANO *et al.* 2005

P. Manzano, J. E. Malo & B. Peco, "Sheep gut passage and survival of Mediterranean shrub seeds", *Seed Sci. Res.*, 15, 21-28, 2005.

MANZANO & MALO 2006

P. Manzano & J. E. Malo, "Extreme long-distance seed dispersal via sheep", *Front. Ecol. Environ.*, 4(5), 244-248, 2006.

MOUISSIE *et al.* 2005

A. M. Mouissie, W. Lengkeek & R. Van Diggelen, "Estimating adhesive seed-dispersal distances: field experiments and correlated random walks", *Functional Ecology* 19(3), 478-486, 2005.

PELLÓN 2006

J. R. Pellón, *Íberos de la A a la Z; la vida en Iberia durante el primer milenio antes de Cristo*, Espasa Calpe, Madrid, 2006.

PEREIRA *et al.* 2006

F. Pereira, S. J. M. Davis, L. Pereira, B. McEvoy, D. G. Bradley & A. Amorim, "Genetic signatures of a Mediterranean influence in Iberian Peninsula sheep husbandry", *Molecular Biology and Evolution* 23, 1420-1426, 2006.

RIERA 1994

S. Riera, "Estudi de les restes botàniques; paleobiogeografia, pertorbacions i acció antròpica durant l'holocè mitjà al delta del riu Llobregat: l'anàlisi pol·línica del sondatge Mercabarna (MBA)" (Bosch, J. & Estrada, A., eds.). *Rubricatum* 0, 195-223, Gavà, 1994.

SANTOS & SUÁREZ 2005

T. Santos & F. Suárez, "Biogeography and population trends of Iberian steppe birds", *Ecology and conservation of steppe-land birds* (G. Bota, M. B. Morales, S. Mañosa & J. Camprodon, eds.), Lynx Edicions & Centre Tecnològic Forestal de Catalunya, Barcelona, 2005.

SOLER *et al.* 2000

M. Soler, J. C. Guix & S. C. A. Guix, "Restes arqueològiques d'època ibèrica al polígon Barcelonès (Abrera)". *Resums de la XLIII Assemblea Intercomarcal d'Estudiosos*, Ajuntament de Martorell, Martorell, 2000.

TERRADAS 2001

J. Terradas, *Ecología de la vegetación; de la ecofisiología de las plantas a la dinámica de comunidades y paisajes*, Ediciones Omega, Barcelona, 2001.

WAINWRIGHT & THORNES 2004

J. Wainwright & J. B. Thornes, *Environmental issues in the Mediterranean; processes and perspectives from the past to present*, Routledge, London, 2004.

YII *et al.* 2003

R. YII, J. S. Carrión, J. Pantaleón, M. Dupré, N. La Roca, J. M. Roure, R. Pérez-Obiol, "Palinología del Cuaternario reciente en la Laguna de Villena (Alicante, España)", *Anales de Biología*, 25, 65-72, 2003.