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# Distribution, abundance and density of the wild boar on the Iberian Peninsula, based on the CORINE program and hunting statistics

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**Abstract.** Wild boar population size in the Iberian Peninsula was estimated using hunting bag statistics from Spain and Portugal. Density was estimated assigning the wild boar population size to the "potential resources" or suitable habitats categorized by their importance to provide food and/or shelter to wild boars. Land uses were selected from CORINE, the EU database for land cover, using scientific literature and statistical significance for wild boar presence from published data.
The hunting bag was 176245 and 15167 in Spain and Portugal, respectively. The average density was 0.373/km$^2$ (min 0.014-max 2.22) in Spain and 0.13/km$^2$ (min 0.00048-max 1.99) in Portugal, being 0.31/km$^2$ (0.00048-2.22) over the entire Peninsula. Statistical analysis showed that wild boar presence was significantly ($p < 0.05$) associated to thirteen of the seventeen CORINE land uses selected. Agro-forestry, moors and heathland land use were not statistically significant but were included in the model due to their biological importance. Suitable habitats and distribution of wild boar were mapped for the Iberian Peninsula. This approach is a preliminary step intended to be useful in environmental management and animal health.

**Key words:** habitat modeling, spatial analysis, wildlife, *Sus scrofa*

## Introduction

Over the last century, wild boar populations in many areas of the Palearctic, including the Iberian Peninsula (I.P.), have grown continuously (Rosell 1995, Leránoz & Castién 1996, Spitz 1999, Rosell et al. 2001, Acevedo et al. 2006, Gortázar et al. 2007). Species growth on the I.P. has been linked to the disappearance of traditional agriculture due to emigration from rural areas, which has led to a marked decline in forestry activities; an increase in the number of shelter areas, mostly scrub and wooded areas; and an increase in the total amount of food available (Tellería & Sáez-Royuela 1985, Sáez-Royuela & Tellería 1986, Salces & Markina-Lamonja 1992a, Sáenz de Buruaga 1995). Some of the main reasons for the considerable increase in the wild boar population are: (1) the remarkable adaptability of the wild boar to diverse environments (Genov 1981a, Boitani et al. 1994, Massei et al. 1996, Acevedo et al. 2006, Jansen et al. 2007, Schley et al. 2008); (2) its high reproductive rate (Rosell et al. 2001, Fonseca et al. 2011); (3) an increase in areas dedicated to certain crops, in particular maize, as observed in European countries such as Poland, Sweden and Switzerland (Baettig 1980, Fruzinski 1995, Neet 1995, Saïd et al. 2011, Thurfjell 2011); (4) its varied trophic diet (Mackin 1970, Lemel et al. 2003, Herrero et al. 2006, Schley et al. 2008, Saïd et al. 2011, Thurfjell 2011); (5) warmer winter temperatures (Schley 2000, Melis et al. 2006).
Today, the wild boar constitutes a valuable economic and hunting resource for some countries like Spain and

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Portugal; for example, the 2006-2007 hunting season in Spain generated 29.3 million Euros in revenues (MARM 2007). Furthermore the wild boar is a key element of numerous ecosystems, contributing to soil mixing, nutrient recycling, and dissemination of spores and seeds smaller than 4 mm, thereby assisting the first stages of vegetal succession (Bratton 1975, Genard & Lescourret 1985, Grimal 1987, Onipchenko & Golikov 1996, Schmidt et al. 2004). However, over the last few years, some negative aspects of its expansion have begun to be noted, such as changes in vegetal succession (Onipchenko & Golikov 1996). Recent studies have also linked wild boar movements to decreased ground cover, with serious consequences for livestock grazing (Bueno et al. 2010); to traffic accidents (Vassant et al. 1993, Rosell et al. 2001, Peris et al. 2005, Marques et al. 2010, Sävberger 2010); to invasion of urban areas, attacks on people and pets, and health problems (Tilson & Nyhus 1998, Packer & Birks 1999, Cahill et al. 2003, Jansen et al. 2007, López et al. 2010); and to damage of irrigated crops (Herrero 2003, Schley & Roper 2003).

The need for better knowledge of the wild boar populations has also become more urgent because the species acts as a host of certain economically important diseases that affect domestic pigs, such as African swine fever, classical swine fever and Aujeszky's disease. They also serve as hosts of diseases that affect other mammals, including humans, such as tuberculosis, salmonellosis and brucellosis. Preventive measures to control and eradicate diseases present in wild boars must be a top priority, especially if their population growth makes contact with farm animals more likely, which can lead to transmission and maintenance of diseases in animal populations (Spiecker 1969, Höfle et al. 2004, Gortázar et al. 2007, Vicente et al. 2010).

Despite the importance of understanding wild boar population dynamics, population data are rare, in part because of the difficulty of direct counting in the field. The use of hunting statistics to estimate population indirectly has become a common practice; in fact, several authors recommend this approach (Spitz et al. 1984, Sáez-Royuela & Tellería 1988, Abaigar 1990, Biotema 1990, Garzón 1991, Spitz & Vallet 1991, Lancia et al. 1994).

Many efforts have been made to improve the use of hunting statistics to estimate the boar population, radiotracking to estimate wild boar movements or home range (Markina-Lamonja & Telletxea 2006), indirect measures like paw prints, tracks and traces, fecal drop counts, evidence of bedding (Rosell 1998, Rosell et al. 1998, Hererro 2003, Herrero et al. 2006) and other data as land cover supporting habitats and food of animal. Favored habitats of the wild boar have been identified in Spain (Abaigar et al. 1994, Rosell 1998, Herrero 2001, Rosell et al. 2001) and other European countries (Sodeikat & Pohlmeyer 2004, Keuling et al. 2008, 2009). Land uses favoring the presence of the animal have been identified in the I.P., both in the north (Sáez-Royuela 1989, Sáenz de Buruaga et al. 1991, Herrero 2001) and south (Fernández-Llario 1996). Information is also available on the preferred diet of the wild boar, such as oak woods, agricultural fields (Abaigar 1990, Sáenz de Buruaga 1995, Herrero et al. 2006), plantations of maize and conifers, and scrub (Schley 2000, Herrero et al. 2006, Schley et al. 2008).

The objective of this study was to estimate the distribution of the wild boar population on the I.P. using a combined approach that took into account hunting data (H), animal movement patterns (home range, HR) and ground cover (CORINE, the EU database for land cover) associated to the presence of the animal. The method proposed in this study may be useful for estimating animal density and distribution in other territories of the European Union and such data can inform diverse types of studies in environmental management and animal health.

## Material and Methods

As a first step, a bibliographical and documentary survey was conducted in order to determine the number of wild boar harvested (MARM 2007, Autonomous Community Administrations and National Forestry Authority), potential resource value (PRVs, i.e. land uses favourable to the presence of wild boar), sizes of individual wild boar populations and their home range (HR). To estimate their density on the I.P., an analysis was conducted using Excel (Microsoft® Office 2003-2007) and SPSS v15.0 (SPSS Inc., 1989-2006). Spatial analysis and mapping results on hunting statistics and land use, were performed using ArcGIS 9.3 (ESRI®).

*Study area and hunting data*

The study area comprised Spain and Portugal, which together make up the I.P. Both countries contain two biogeographic regions, Atlantic and Mediterranean bioclimatic levels, with latitudes between 35° and 45° N, a mean altitude of approximately 660 m above sea level (SD 1041.34), a maximum altitude of 3479 m and a total peninsular length of 582603.84 km² (SD 4832.18); of this total length, 493519.54 km² belong to Spain and 89084.3 km² to Portugal.

The province is the administrative unit in Spain, with surface ranging from 1980.35 km² to 21766.3 km² and averaging 10500.41 km² (SD 4699.77), while the unit for Portugal is the district, with areas ranging from 2255 km² to 10225 km² and averaging 4941.33 (SD 2116.27).

Hunting data for each Spanish province was gathered from the Statistical Yearbook of Forestry (MARM 2007), estimated to be 176245 individuals. In Portugal, the hunting data in each administrative district was obtained from the National Forestry Authority (AFN), estimated to be 15167 individuals. Data from 2007 was used in this study for Spain and Portugal, corresponding to the 2006-2007 hunting season (Tables 1, 2), a total of 191412 wild boars for the I.P.

*Potential wild boar habitats based on potential resources value (PRVs)*

To estimate potential resources used by the wild boar, and how well habitats on the I.P. can provide those resources, a literature review was conducted for ground cover and wooded areas that could be suitable as wild boar habitat (Baettig 1980, Tellería & Sáez-Royuela 1985, Fruzinski 1995, Neet 1995, Schley 2000, Herrero et al. 2006), for the surface area of land used for agriculture (Massei & Genov 2004) and for the wild boar's preferred habitats (Santos et al. 2004). The species is omnivorous, though it relies on a vegetable diet more than an animal one, making it essentially a primary consumer (Groot Bruinderink et al. 1994). Stomach and fecal content analyses in various studies indicate that vegetable matter, principally fruits, seeds, roots and tubers, constitutes about 90-99.99 % of the diet (Valet 1994, Rosell 1998, Herrero 2001, 2003). Numerous studies have sought to determine environmental characteristics that determine the presence of the wild boar in Spain and Europe, and these are based on analysis of stomach contents, tracks, markings, bathing areas, rooting holes and feces (Puigdefábregas 1980, Rosell 1998, Herrero 2001, 2003). In Spain, studies have been carried out in the Western Pyrenees (Vericad 1971), Doñana National Park (Garzón et al. 1983, Venero 1984), Sierra Morena (Rodríguez Berrocal et al. 1982), the Almerian Alpujarra (Abaigar 1993, Sáenz de Buruaga 1995), northern Navarra (Leránoz & Castién 1996), Montseny (Valet et al. 1994, Rosell 1998), Vizcaya (Laskurian et al. 1991), Aragón (Herrero 2001, 2003, Herrero et al. 2006) and wetland habitat Aiguamolls Empordà Natural Park (Giménez-Anaya et al. 2008). In Europe, studies have been

***Table 1.** Number of wild boars hunted and estimated populations, by Spanish province.*

| Autonomous Community | Province | Wild boars hunted (2006-2007) |
|---|---|---|
| Andalucía | Almería | 1673 |
| Andalucía | Cádiz | 3797 |
| Andalucía | Córdoba | 5311 |
| Andalucía | Granada | 3072 |
| Andalucía | Huelva | 3388 |
| Andalucía | Jaén | 5278 |
| Andalucía | Málaga | 1137 |
| Andalucía | Sevilla | 3921 |
| Aragón | Huesca | 15832 |
| Aragón | Teruel | 4695 |
| Aragón | Zaragoza | 6618 |
| C. Valenciana | Alicante | 2500 |
| C. Valenciana | Castellón | 650 |
| C. Valenciana | Valencia | 4360 |
| Cantabria | Cantabria | 1242 |
| Castilla la Mancha | Albacete | 3500 |
| Castilla la Mancha | Ciudad Real | 8245 |
| Castilla la Mancha | Cuenca | 1200 |
| Castilla la Mancha | Guadalajara | 2500 |
| Castilla la Mancha | Toledo | 9174 |
| Castilla y León | Ávila | 1628 |
| Castilla y León | Burgos | 4520 |
| Castilla y León | León | 1685 |
| Castilla y León | Palencia | 1074 |
| Castilla y León | Salamanca | 3542 |
| Castilla y León | Segovia | 972 |
| Castilla y León | Soria | 1397 |
| Castilla y León | Valladolid | 398 |
| Castilla y León | Zamora | 2192 |
| Cataluña | Barcelona | 7160 |
| Cataluña | Gerona | 8575 |
| Cataluña | Lérida | 5517 |
| Cataluña | Tarragona | 2807 |
| Extremadura | Badajoz | 6122 |
| Extremadura | Cáceres | 8136 |
| Galicia | La Coruña | 1077 |
| Galicia | Lugo | 3366 |
| Galicia | Orense | 2466 |
| Galicia | Pontevedra | 838 |
| La Rioja | La Rioja | 2386 |
| Madrid | Madrid | 2279 |
| Navarra | Navarra | 6434 |
| P. de Asturias | Asturias | 8356 |
| País Vasco | Álava | 1978 |
| País Vasco | Guipúzcoa | 700 |
| País Vasco | Vizcaya | 1013 |
| R. de Murcia | Murcia | 1534 |
| Total | | 176245 |

*Sources: MARM 2007, Andalusian Institute of hunting and Inland Fisheries, IREC, DMAH, hunting Areas, Xunta Galicia.*

***Table 2.*** *Number of wild boar hunted and estimated population, by Portuguese district.*

| District | Wild boars hunted (2006-2007) |
|---|---|
| Aveiro | 9 |
| Beja | 3284 |
| Braga | 15 |
| Bragança | 206 |
| Castelo Branco | 1346 |
| Coimbra | 142 |
| Évora | 2180 |
| Faro | 1987 |
| Guarda | 206 |
| Leiria | 122 |
| Lisboa | 105 |
| Portalegre | 2697 |
| Porto | 19 |
| Santarém | 1407 |
| Setúbal | 1183 |
| Viana do Castelo | 47 |
| Vila Real | 101 |
| Viseu | 111 |
| Total | 15167 |

*Source: National Forest Authority (Autoridade Florestal Nacional), Portugal.*

done in the Savoy Alps (Baubet et al. 1997), central European Atlantic mixed forests (Groot Bruinderink et al. 1994) and Western Europe (Schley & Roper 2003). Wild boar populations in Europe prefer broad-leafed forests, especially evergreen oak forests, open habitats such as steppe, Mediterranean scrubland, farmland, and areas with nearby water and tree cover Spitz (1999). They are found at altitudes ranging from sea level to 2400 m in the Pyrenees (Palomo & Gisbert 2002). Some important studies in I.P. and France point out that the wild boar occupies nearly all forest habitats (Sáez-Royuela 1987) and has a varied diet (Varin 1980, Valet et al. 1994). Those authors concluded that the animal's distribution is more affected by structural characteristics of vegetation than by other factors, except for human impact (Markina-Lamonja 1998).

Since the wild boar is found in a wide variety of habitats, estimating the population in specific regions requires accurate assessment of that region's ability to support the animals. To this end, we prioritized necessary resources for population survival and determined to what extent possible habitats on the I.P. are likely to provide these resources. Using the CORINE 2000 program (Coordination of Information on the Environment, Land Cover 2000, European Commission), the territory was divided into cells with a surface area of 10000 m² (1 ha = 0.01 km²). An advantage of CORINE is that it contains ground cover information standardized to European Union guidelines. Layers of land use over agricultural, forest and seminatural areas were taken into account since these areas might constitute suitable habitat for the wild boar. For example, the following vegetation constitutes a valuable food resource for wild boar on the I.P. (Rosell 1998, Herrero 2001, 2003) and in other places of Western Europe (Genov 1981, Massei et al. 1996, Schley & Roper 2003): *Quercus ilex*, *Q. suber*, *Q. humilis*, *Fagus sylvatica*, *Castanea sativa*, *Pinus pinea*, *P. communis*, *Juniperus communis*, *Sambucus* sp., and different species of thicket, bushes and gramineous plants such as *Festuca ovina*, *F. arundinacea*, *Agrostis capillaris*, *Brachipodium* sp., *Cyperus rotundus*, *Pteridium aquilinum*, *Tamarix gallica*. Forest zones containing *Pinus* sp. and scrubland containing *Espartium* sp. and *Erica* sp. have also been found to provide food or shelter to wild boar. In order to identify potential wild boar habitats, we assessed the ability of specific regions to support wild boar populations by assigning them a potential resource value (PRV). These PRVs were estimated in two steps: 1) First, selection to the potential resources used by the wild boar, and identification of habitats on the I.P. which can provide those resources was conducted. All the land uses selected from CORINE are based on a literature review including forest and semi natural areas (ground cover and wooded areas) (Baettig 1980, Tellería & Sáez-Royuela 1985, Fruzinski 1995, Neet 1995, Schley 2000, Herrero et al. 2006) and pastures and heterogeneous agricultural areas (Massei & Genov 2004, Herrero et al. 2006). A statistical analysis of association with the CORINE land uses selected and the presence of wild boars estimated by Palomo & Gisbert (2002) in Spain were performed using the Kruskal-Wallis and the Mann-Whitney U tests in SPSS v15.0 (SPSS Inc., 1989-2006). Variables significantly associated ($P < 0.05$) were included as a potential resource in the model. 2) Secondly, a categorical value was assigned to each potential resource according to the literature and expert opinion. A value of 2 was given to a location if it had resources suitable for use as both food and shelter, a value of 1 if it had resources to provide only one or the other, and 0 if it did not possess either type of resource (Fig. 1).

*Home range and unified habitat (HR and UH)*

In order to establish a reliable and conservative HR, which extends from the shelter over the area where

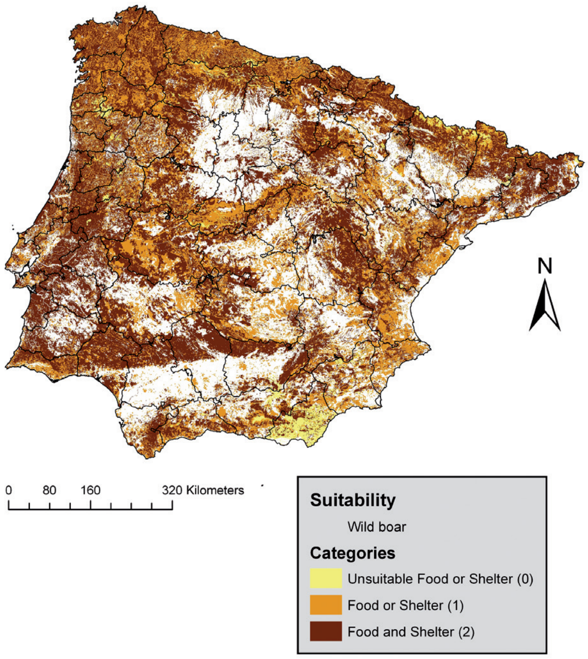


***Fig. 1.*** *Map of potential habitats for wild boar on the Iberian Peninsula, based on analysis of potential resources. Suitability for supporting wild boar was assessed in CORINE by assigning potential resource values (PRVs) of 0 (unlikely suitable for food or shelter), 1 (suitable for food or shelter), or 2 (suitable for both food and shelter). White areas represent locations with no available data.*

the wild boar may roam under normal conditions, the literature on species movements based on radiolocation, radiotelemetry and nesting habits was reviewed (Janeau & Spitz 1984, Russo et al. 1997, Herrero 2001, Markina-Lamonja & García 2006). The surface used was estimated by quadratic modeling of each home range for comparing different measures of length provided by different authors (Table 3). Authors of the studies were contacted in some cases to discuss whether the data were exceptional or normal, to ensure that we selected the most "natural" data not biased by anthropic factors, such as intense pressure from hunting, or by seasonal biological necessities such as mating, searches for food or searches for water under drought conditions. In some studies, home range data were not collected under normal conditions but under hunting conditions; in these cases, the authors measured the mean distance between the shooting site (radiomarking) and the capture site (Table 3). The distance roamed by wild boar under normal conditions was defined as 2 linear km (Boisaubert & Klein 1984, Briedermann 1990, Maillard & Fournie 1995, Caley 1997, Soidekat & Pohlmeyer 1999, 2004, Markina-Lamonja & Telletxea 2006, Keuling et al. 2010). Therefore land uses that CORINE 2000 situated at a distance of 2 km or less were merged together into a unified habitat (UH) providing a more realistic identification of areas where wild population is distributed.

*Model*

Population density (PD) was calculated using hunting data (H) and PRVs. The abundances of wild boar were projected onto territorial units according to the extension of the potential resources in each province (Spain) or district (Portugal). A common denominator was obtained by summing the areas of all cells in CORINE with a given PRV (0, 1 or 2). To estimate an index, these PRVs were multiplied by 0.1, 0.5 and 1,

***Table 3.*** *Measurements of wild boar home range (HR) and lineal distance between two point.*

| Reference | (HR) ($km^2$) | Lineal distance between two point (km) |
|---|---|---|
| Janeau & Spitz (1984) | 120[a]♂-150[a]♂<br>40[a]♀-60[a]♀ | 12.36*♂-13.8*♂<br>7.13*♀-8.74*♀ |
| Briedermann (1990) | | ♂ 4.5[c], ♀ 2.8[c] |
| Markina-Lamonja & Garcia (2006) | 4.55-11[b] | 2.13*-3.31* |
| Sodeikat & Pohlmeyer (1999) | | P < 4.7[c], Y < 10[c] |
| Sodeikat & Pohlmeyer (2004) | | 0.2-4.6 |
| Vicente et al. (2010) | | < 12 per day |
| Keuling et al. (2010) | | ♀ 1.8[c], ♂ 3.2[c] |
| Herrero (2001) | 3.6-12.3[a] | 1.89*-3.51* |
| Caley (1997) | | ♀ 1.6[c], ♂ 3.8[c] |
| Boisaubert & Klein (1984), Spitz et al. (1984) | | < 10[a] |
| Russo et al. (1997) | 0.029[d]-1.081[d] | 0.192[d]*-1.17[d]* |
| Maillard & Fournie (1995) | | 2.010[b] -2.63[b] |

** Equivalence to diameter of the length of the square area model (estimated data), [a] HR without indication of season (annual HR), [b] HR with indication of season, [c] Mean distances between capture and shooting site of marked wild boar, [d] Daily movement size with indication of season, P, piglet; Y, yearling; ♂, male; ♀, female, HR: surface used.*

respectively. For each province/district i, PD was estimated using the formula:

$$PD_i = \frac{\sum H_i}{\sum [(A"2"*1)+(A"1"*0.5)+(A"0"*0.1)]}$$

where $PD_i$ refers to the PD of wild boar in the province or district, H is the number of animals hunted and A is the number of cells assigned a PRV of 0, 1, or 2. PD was distributed throughout each province or district according to land use. In other words, populations were assumed not to be present throughout a province or district, but rather to be restricted to areas with a PRV of 0, 1 or 2.

Ranges of PDs were calculated for each territorial unit based on $H_i$ and PRV. The resulting population distribution map was compared with one based on the presence/absence of wild boars in Spain (Palomo et al. 2007), with a more recent distribution map for Portugal (Vingada et al. 2010) and a recent distribution map for the Euroasiatic zone (Oliver & Leus 2008).

## Results

The density and unified habitat of the wild boar population on the I.P. were estimated. Three parameters were obtained and were illustrated in three maps:

*Potential wild boar habitats based on potential resources value (PRVs)*

Statistical analysis showed that wild boar presence was significantly associated to thirteen out of the seventeen CORINE land uses (Kruskall-Wallis test $P < 0.05$, Mann-Whitney U test $P < 0.05$) and these were subsequently included in the model. Two more CORINE land uses (agro-forestry areas and moors, and heathland) were also considered in the model due to their biological significance. Table 4 summarized the total 15 land uses included in the study together with their surface area on the I.P. and their PRVs. It shows a total of 17 potential resources with a surface of 324821.12 km² for Spain, and 16 resources with a surface of 66002.84 km² for Portugal. The highest PRV of two was assigned to code numbers 23, 24, 28 and 29, with 28 (sclerophyllous vegetation) being

***Table 4.*** *Land uses selected in the CORINE program as potential resources (Grid_Code) for wild boar, together with their surface areas and potential resource values (PRV).*

| Potential Resource (Grid Code) | Land use | PRVs* | Surface area (km²) | | |
|---|---|---|---|---|---|
| | | | Spain | Portugal | Entire Iberian Peninsula |
| 18 | Pastures | 1 | 6181.03 | 378.13 | 6559.16865 |
| 19 | Annual crops associated with permanent crops | 1 | 296.32 | 4204.93 | 4501.256 |
| 20 | Complex cultivation patterns | 1 | 38091.94 | 6227.84 | 44319.782 |
| 21 | Land principally occupied by agriculture, with significant areas of natural vegetation | 2 | 24317.48 | 6807.93 | 31125.41 |
| 22 | Agro-forestry areas | 2 | 24444.48 | 5592.05 | 30036.53 |
| 23 | Broad-leafed forest | 2 | 37718.79 | 12213.08 | 49931.87 |
| 24 | Coniferous forest | 2 | 38343.37 | 6901.91 | 45245.28 |
| 25 | Mixed forest | 2 | 14852.07 | 5255.88 | 20107.95 |
| 26 | Natural grasslands | 1 | 26082.5 | 1851.07 | 27933.57 |
| 27 | Moors and heathland | 1 | 9078.33 | 3364.97 | 12443.3 |
| 28 | Sclerophyllous vegetation | 1 | 49648.41 | 1951.43 | 51599.84 |
| 29 | Transitional woodland-shrub | 2 | 44214.45 | 9631.37 | 53845.82 |
| 30 | Beaches, dunes, sands | 0 | 286.75 | 97.42 | 384.17 |
| 31 | Bare rocks | 0 | 1697.6 | 438.28 | 2135.88 |
| 32 | Sparsely vegetated areas | 0 | 8813.22 | 770.77 | 9583.99 |
| 33 | Burned areas | 0 | 751 | 315.78 | 1066.78 |
| 34 | Glaciers and perennial snow | 0 | 3.36 | 0 | 3.36 |
| Total area (km²) | | | 324821.117 | 66002.84 | 390823.957 |

** See Material and Methods for interpretation of PRVs.*

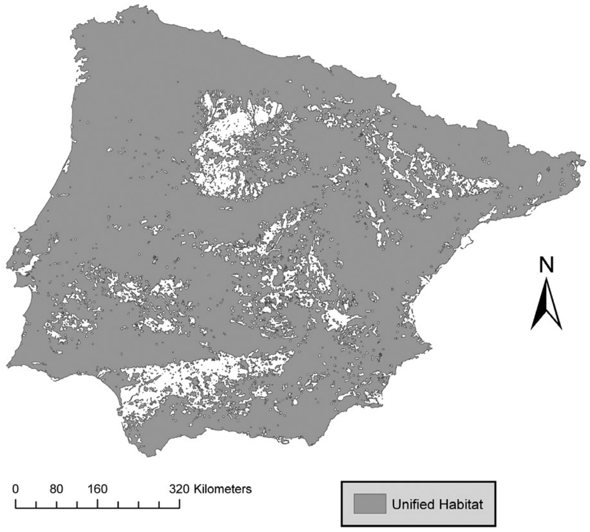


***Fig. 2.*** *Map of unified habitat of the wild boar on the Iberian Peninsula, obtained by applying a home range of 2 km to potential resource.*

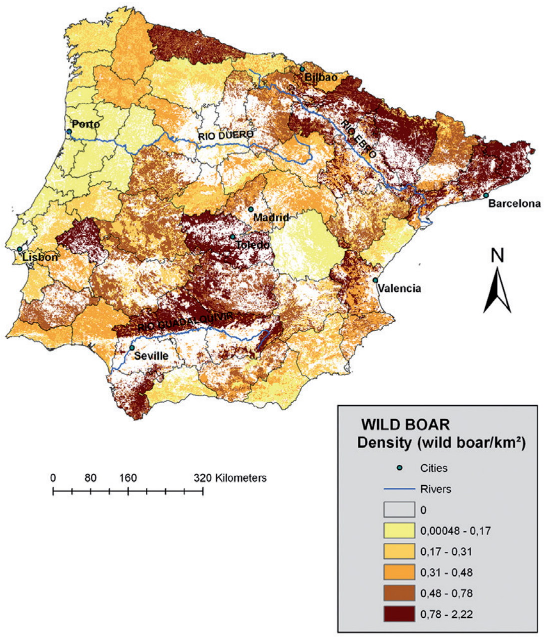


***Fig. 3.*** *Population density of wild boar on the Iberian Peninsula based on potential resource values (PRVs) by province (Spain) or district (Portugal).*

the most extensive in Spain and 23 (broad-leafed forest) the most extensive in Portugal. The least extensive land use in both countries was 34 (glaciers and perpetual snow), with only 3.36 km² in Spain and none in Portugal (Table 4). Potential habitat for wild boar on the I.P. based on potential resources value were mapped (Fig. 2).

*Unified habitat of the wild boar on the I.P.*

Results shows that the species is spread over more than two-thirds of Spain and is absent or less abundant in 34.05 % (167820.46 km²) of the territory (Fig. 2).

*Population density (PD) of wild boar on the I.P.*

The mapping of PD according to potential habitats in Fig. 3 may give the most realistic estimate so far of population density on the I.P. by administrative level. The average density of wild boars within their potential habitat is 0.38 per km² (min 0.014-max 2.22 and SD 0.398) in Spain, 0.13 per km² (min 0.00048-max 1.99 and SD 0.313) in Portugal, and 0.31 per km² (min 0.00048-max 2.22 and SD 0.39) on the I.P. as a whole. There are some differences between adjoining territories that share the same potential resources and therefore would be expected to form part of the same habitat. For example, in the central region of I.P. (Ávila and Toledo), two neighboring units had similar resource types and areas (transitional woodland-shrub, code 29; 5.17 and 5.34 km²), but the results show different PD (0.39 and 1.88). In the eastern region of I.P. (Navarra and Huesca), two neighboring units had similar resource type (coniferous forest, code 24) and areas (167.62 and 165.47 km²), but different PD (1.09 and 2.22). In the southern region of I.P. (Málaga and Cádiz), two neighboring units had broad-leafed forest (code 23) over areas of 204 and 250 km², but substantially different population densities of 0.31 and 1.23. In the western region of I.P. (Santarem and Portalegre), two neighboring units had transitional woodland-shrub over areas of 61.30 and 72.95 km², with densities of 0.22 and 1.99. These differences between neighboring provinces (Spain) or districts (Portugal) with the same potential resources were observed throughout both countries.

## Discussion

An analytical model combining data on hunting and potential resources (land use) was developed in order to assess the population size and density of the wild boar on the I.P. In this approach, raw hunting data are adjusted to the potential habitats. A unified habitat was provided to get a more reliable estimate of distribution. The model sacrifices some local precision in order to take into account the heterogeneity of environmental parameters and hunting behavior across the I.P. However, we assumed the bias to working on a scale as large as the I.P., since the data come from regions with different hunting traditions, which can translate into different approaches and techniques for generating hunting statistics. The use of this method at small scales is limited since, some important local variables, such as the availability of maize crops or whether or not there is hunting in this area, are not considered into the analyses due to the lack of applicable data registered in some provinces or district. This is the reason why the map shows areas without densities where in reality they are locally dense such as the Duero-Ebro-Guadalquivir basin (Fig. 3). On the other hand, several unexpected differences in densities have been shown between adjoining territories that share the same potential resources. This fact, which corresponds with geopolitical provincial borders, is related to the use of hunting bag statistics. This bias derives from data provided by each regional administration in Spain and Portugal, where hunting techniques and management vary. Direct sampling of the wild boar population is one way to obtain a reliable estimate of the population's size and distribution (Franzetti et al. 2010). However, such a direct approach is complex and costly due to the rarity of direct observation, the limited areas in which it can be conducted and the primarily nocturnal habits of the species (Briedermann 1971, Mauget & Sempere 1978, Singer & Ackerman 1981, Janeau & Spitz 1984, McIlroy 1989, Boitani et al. 1992, Boitani et al. 1994, Lemel et al. 2003, Keuling et al. 2008). As a result, estimating the population based on hunting data has become a generalized practice in many countries, and the availability of these data has made this a tool of choice when estimating wild boar populations (Plhal et al. 2010).

The CORINE program has proven useful for analyzing potential distribution of vertebrate fauna (Acevedo et al. 2010). Version 2000 (EEA 2008) was used in this study, which is more complete for our purposes than the more updated previous version (EEA 2007). In any event, the similarity between the two versions is 97.3 % for Spain and 97.84 % for Portugal. In addition, version 2000 allows us to extrapolate the method to other EU countries, since its data are more homogeneous and uniform, making it easier to conduct comparisons. For studies on a more limited scale, it may be preferable to supplement CORINE with local studies in order to increase the accuracy of the relationship between vegetation cover and wildlife (Sáez-Royuela 1987, Markina-Lamonja 1998, Vargas et al. 2006).

The present study used 2 linear km as the minimum distance between separate roaming areas in order to create a UH. This approach led, in several cases, to the fusion of habitat areas that previously were considered separate. Although 2 km is a conservative estimate, our strategy gives a more biologically correct definition of habitat (Fig. 2), which may also provide valuable information for other goals related to reserve management, such as road design to avoid collisions with wild boar, identification of appropriate areas for hunting management and fencing, creation of animal trails or evaluation of crop damage in proximity to wild boar shelter areas.

In this study significant statistical association among the presence of wild boar and the forest and agriculture land uses was found. This finding is consistent with studies of Markina-Lamonja (1998), where the wild boar's distribution is mainly affected by structural characteristics of vegetation. Land use 22 (agro-forestry areas) and 27 (moors and heathland) showed no significant association to presence of wild boar, however both were included in the analysis. Land use 22 represents agro-forestry areas and is widely distributed in Spain covering a 5 % of the total area, and that could be the reason of the non associate result, but its relation with presence of wild boar was described by Herrero (2003) and (Herrero et al. 2006). Land use 27 represents moors and heathland areas that are clustered in a small area in North of I.P. with high quantity of wild boar, and Nores (2010) described a high association in this region between altitude wild boar presence and abundance coinciding with areas of moors and heathland.

Our species distribution maps reflect the extensive presence of Iberian *Quercus* spp. forests, which provide a valuable food resource for wild boar. However, since these forests produce seeds following a masting pattern, they are not a stable food source over time, especially during the summer. In such inversion of shortage and agriculture are secondary food sources for ungulates (Abaigar 1993, Sáenz de Buruaga 1995, Herrero et al. 2006). The presence of such secondary food sources on the I.P. has increased due to the cultivation of maize (*Zea mays*), which provides a stable source of food and land cover for an average of 5-7 months each year when there is a shortage of food or fruits (Briedermann 1976, Onida et al. 1995, Schley & Roper 2003, Herrero et al. 2006, Schley et al. 2008), although these are not the 'traditional' habitats of wild boars. Unfortunately, as mentioned above, CORINE landcover cannot distinguish among types of irrigated crops, and the extent of cornfields is underestimated, especially at river basins such as the Duero-Ebro-Guadalquivir basin in Spain. It is precisely in these areas that the wild boar population has increased in close association with this crop, leading to an increase in hunting and highway collisions (Peris et al. 2005). For these reasons, due to the lack of information about difference in land use and the existence of secondary food sources (e.g. maize crops), the map shows areas without wild boar, where in reality their presence has been observed (Fig. 1). As more information becomes available about maize and other food sources, we can further improve the population distribution maps of wild boar. Despite the lack of the some data, the information included in this study is in fact extensive. Of particular note, comparing the resuts of this study (Figs. 1, 2) with the results of Palomo et al. (2007), based on the presence/absence of wild boar in Spain, we note that wild boar habitat distribution patterns are similar in both studies. Our current study however presents a larger area of potential habitat, most likely derived from a more accurate scale range data.

Our map of wild boar population density shows differences between adjacent territories within the same province or district (Fig. 3). This is surprising, since adjacent territories can be expected to share similar habitats and therefore similar resources. Such territories would therefore be expected to show the same hunting potential, but in fact, differences in hunting capacity (e.g. number of licenses) and intensity of hunting practices appear to give rise to observable differences in density. At the same time, the apparent differences between adjacent territories may reflect, at least in part, variations in hunting effectiveness that has been shown to differ from one region to another on the I.P. (Herrero 2003). Hunting effectiveness varies from northern to southern Iberia as a function of several factors including orography, traditions, or different hunting techniques (e.g. battue and monteria, race and number of dogs), however these factors have not been considered in this paper because the information is not available. In the same way some types of hunt management (i.e. supplementing feed to wild boars) have not been considered in the study but could increase the density of this species disproportionately. To summarize, all of the factors mentioned, combined with the lack of accurate data and information provided by different regions collected in different ways, could be a significant source of variation in the results. This point could not be adressed in this paper. This work has aimed to offer a first analysis of the population size, density and distribution of the wild boar on the I.P., sacrificing some local precision in order to model the effects of environment and hunting across the entire Peninsula. The approach developed here may be applicable to other EU countries and may help generate a population density and distribution map across Europe, allowing comparisons between countries. This approach and the specific results reported here for the I.P., may prove useful for guiding the monitoring and control of diseases for which the wild boar acts as a reservoir (e.g. epidemiological purposes such as target surveillance).

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