Reproduction of wild boar in a cropland and coastal wetland area: implications for management

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Abstract

Reproduction of wild boar in a cropland and coastal wetland area: implications for management.— The reproductive parameters of a wild boar population located in a coastal landscape with a mosaic of cropland and wetland habitats were analysed and compared with those observed in wild boar populations living in other habitats. A total of 296 reproductive tracts of females captured year round at the Aiguamolls de l'Empordà Natural Park were collected and analysed from 2000 to 2010. The foetuses were counted, sexed and aged and the mating and birth periods were determined. The weight and age of each female were also recorded. In accordance with the pattern observed in most European populations, a marked main mating season from October to January was observed. Within this season, there was a peak during November and December, in which 64% of the conception dates were recorded. The proportion of breeding females, ovulation rate and litter size increased with the weight of the reproductive females. A mean litter size of 5.01 ± 1.33 (range from two to eight) foetuses was recorded. This value is the highest known litter size recorded in wild Iberian populations and is similar to values observed in central Europe. Furthermore, it is not in accordance with the pattern reported for other European populations in which a positive correlation between litter size and latitude was observed. The most likely explanation for the high reproductive output in the study area is the availability of food year round, and especially the high consumption of crops such as maize and sunflower. Our results suggest that colonisation of cropland and wetland areas is contributing to the rise in the wild boar population density. Control strategies should consider not only reducing numbers of adult females but also applying measures to reduce food resources available to wild boar.

Key words: Wild boar, *Sus scrofa*, Reproduction, Litter size, Management.

Resumen

Reproducción del jabalí en hábitats de cultivos y humedales costeros: implicaciones sobre la gestión.— Los parámetros reproductivos de una población de jabalí localizada en un paisaje costero, con un mosaico de cultivos y humedales, fueron analizados y comparados con los observados en poblaciones de jabalí que colonizan otros hábitats. Se analizaron un total de 296 tractos reproductivos procedentes de hembras capturadas a lo largo de todo el ciclo anual en el Parque Natural de Els Aiguamolls de l'Empordà entre los años 2000 y 2010. Se contaron los fetos que presentaban las hembras gestantes y se determinó su sexo y edad, así como los períodos de copula y parto. También se registró el peso y edad de cada hembra. De acuerdo con el patrón observado en la mayor parte de poblaciones europeas de la especie, se observó un período de celo principal entre octubre y enero, con un máximo durante noviembre y diciembre, meses que concentraron el 64% de las cópulas. La proporción de hembras gestantes, la tasa de ovulación y el tamaño de camada aumentan con el peso de la hembra. El tamaño medio de camada registrado fue de 5,01 ± 1,33 (rango de dos a ocho) fetos. Este valor es el más elevado registrado en poblaciones salvajes Ibéricas y es parecido al observado en algunas poblaciones del centro de Europa. Además, no se corresponde con el patrón descrito para las poblaciones de jabalí en Europa según el cual se aprecia una correlación positiva entre el aumento del tamaño de la camada y la latitud. La explicación más probable para la alta productividad de la población en la zona de estudio es la gran disponibilidad de alimento a lo largo de todo el año y, especialmente, el elevado consumo de plantas cultivadas, particularmente maíz y girasol. Estos resultados sugieren que la colonización de zonas agrícolas

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y humedales contribuye al aumento de densidad de población del jabalí y las estrategias de control deberían considerar tanto la reducción del número de hembras adultas como la aplicación de medidas para reducir la disponibilidad de recursos tróficos accesibles para el jabalí.

Palabras clave**:** Jabalí, *Sus scrofa*, Reproducción, Tamaño de camada, Gestión.

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Introduction

The wild boar (*Sus scrofa* L., 1758) has become a species of strategic social and economic interest. European populations have increased greatly in recent decades (*e.g.* Genov, 1981; Erkinaro et al., 1982; Saéz–Royuela & Tellería, 1986; Goulding et al., 1998; Melis et al., 2006; Apollonio et al., 2008). The species affects biodiversity and protected areas and has been highlighted as a vertebrate that can modify natural plant communities (*e.g.* Engeman et al., 2007; Muñoz & Bonal, 2007; Webber et al., 2010; Bueno et al., 2010). It also damages crops (*e.g.* Mackin, 1970; Goulding et al., 1998; Schley & Roper, 2003), affects forest regeneration and habitat restoration (Mayer et al., 2000; Gómez & Hódar, 2008), generates conflicts as a result of its presence in urban areas (Cahill & Llimona, 2004; Jansen et al., 2007), and causes traffic accidents due to collisions (Groot Bruinderink & Hazebroek, 1996; Colino et al., 2012). Wild boar also have the potential to transmit disease to livestock (Gortázar et al., 2006; Santos et al., 2009). Control of wild boar populations is thus a major challenge for wildlife managers, and conflict mitigation measures are required (for a review see Massei et al., 2011).

The species has a higher reproductive potential than other ungulates. They show an early onset of puberty, a relatively short gestation period and high mean litter size (Mauget, 1972). This is a key ecological feature that, together with its opportunistic, omnivorous diet (for a review see Schley & Roper, 2003) and its adaptability to a high variety of landscapes, has allowed wild boar to expand its distribution and numbers. Previous studies showed that food availability, determined by habitat features, weather conditions and human influence (the provision of supplementary food and crops), plays a role in wild boar body weight and reproductive parameters (*e.g.* Matschke, 1964; Briedermann, 1971; Pepin et al., 1987; Gaillard et al., 1993; Fernández–LLario & Mateos–Quesada, 2005; Treyer et al., 2012). Weather factors affect the abundance, quality and accessibility of food. Snowfall and low temperatures in winter periods have been found to affect reproductive parameters in North European populations (Oloff, 1951) and the effect of summer drought has been reported in Mediterranean areas (Massei et al., 1996; Fernández–Llario & Carranza, 2000). The influence of diseases on wild boar fertility and reproductive outcome was found to be of minor interest in some German populations (Gethöffer et al., 2007), but ovulation rate was negatively related to the seroprevalence of some protozoan parasites in Spanish populations (Ruiz–Fons et al., 2006).

A strong correlation between wild boar litter size and latitude has been reported in European populations, with litter sizes increasing by an average of about 0.15 offspring per degree of latitude (Bywater et al., 2010). The lowest average litter sizes, around three foetuses per female, are found in southern Spain (Fernández–Llario & Carranza, 2000) and maximum litter sizes, above six foetuses per female, have been reported in Hungary and Germany (Oloff, 1951; Náhlik & Sandor, 2003; Gethöffer et al., 2007). In the Iberian populations, a range from 3.05 (Fernández–Llario & Carranza, 2000) to 4.5 foetuses per reproductive female (Herrero et al., 2008) has been reported.

In this study, we analysed the reproductive parameters of a wild boar population living in a coastal wetland habitat surrounded by cropland. Food availability here is high year round. We assessed whether the productivity of this population is similar to that observed in other Iberian populations inhabiting forest and bush habitats and investigated the influence of female age and weight. Furthermore, we discuss the application of the results to control strategies and adaptive management of wild boar populations.

Material and methods

The study was carried out in the Aiguamolls de l'Empordà Natural Park (42° 13' 28.09'' N, 3° 05' 34.92'' E Catalonia, NE Spain). This is a Mediterranean coastal wetland area that has been declared an Important Bird Area (IBA) and is included in the Natura 2000 network. It has a total surface of 4,824 ha and includes four Integral Nature Reserves. The area is at sea level and is located between the Muga and Fluvià Rivers. The climate is Mediterranean with a total precipitation of 600 mm and dry periods during the summer and the winter. The mean annual temperature is 21.5°C max and 10.7°C min.

The typical habitats of coastal marshland areas are found in the Natural Park, including beaches with sand dunes (5% of the total surface), salt marshes with vegetation dominated by glasswort *Arcthrocnemum fruticosum*, cordgrass *Spartina versicolor* and rush *Juncus maritimus* (35%), coastal lagoons with brackish/salt and fresh water (10%) ,and reed beds covered by reed *Phragmites australis* and lesser bulrush *Typha angustifolia* (35%). Meadows are separated by trees and small forests of tamarisks (*Tamarix gallica* and *Tamarix africana*), and are flooded in some periods (15%). The Natural Park is surrounded by irrigated agricultural land where the main crops are sunflower *Helianthus annuus*, maize *Zea mays*, barley *Hordeum vulgare* and, to a lesser extent, fruit trees such as apple *Malus* sp. and small areas of rice fields *Oryza sativa.*

The area is home to a wide range of vertebrates with species of high conservation value. Two ungulate species are present in the Natural Park: fallow deer *Dama dama*, which was introduced into the area in 1993, and wild boar. Wild boar was only an occasional visitor before 1990, but the population has expanded and it is now one of the most abundant mammals in the area. No supplementary food is given to the population. Population control is required as a result of the high concentration of wild boar in the nature reserves. Since 1998, this has been carried out by rangers in the reserve areas, as hunting is forbidden.

A total of 296 female wild boars captured at the natural reserves were collected from 2000 to 2010. All harvested females were weighed (total weight was recorded before evisceration) and their age was estimated according to tooth eruption and replacement pattern (Matschke, 1967; Saenz de Buruaga et

al., 1991). The reproductive tracts (uteri and ovaries) were collected, preserved in formol 5% and examined in the laboratory. Ovarian activity was recorded and the ovulation rate was estimated as the mean of *corpora lutea* found in both ovaries. The foetuses in the uterus of pregnant females were counted, weighed, measured and sexed (when possible). The foetal age was determined using the formula

$$A = 22.5378 + 0.2893\ L$$

where *A* is the age of the foetuses (in days) and *L* is the average length of the foetuses found in each uterus (Vericad, 1983). Using the female's date of death and the estimated age of the foetuses, the conception and birth (120 days after copulation, Mauget, 1972) dates of each litter were determined and grouped in monthly periods. The litter size was defined by the mean number of foetuses found in the uteri of the pregnant females. Intrauterine mortality was determined following Mauget (1972) and Abaigar (1992) where

$$\text{IUM} = \frac{\text{Ovulation rate} - \text{Litter size}}{\text{Ovulation rate}} \times 100$$

Annual productivity for each weight class was estimated according to Mauget (1982), considering the proportion of breeding females and the mean litter size.

Non–parametric tests were used, as the assumptions of normality (evaluated using the Shapiro–Wilk W test) of the data were not satisfied. Linear correlation between variables was tested using the Spearman R analysis. Differences in breeding status, ovulation rate and litter sizes between weight classes were analysed using the Kruskal–Wallis test. The sex ratio was compared with theoretical distribution 1:1 using the chi–square test. For all the tests, significance was assumed when $p < 0.05$. Analyses were performed using the STATISTICA® (StatSoft Inc., Tulsa, USA) package.

Results

Fifty–two percent of the females analysed were pregnant. The main wild boar rutting period in the study area took place from October to January (80% of the conception dates were recorded in this period) and reached a maximum during November and December (64%). Corresponding to these data, a peak in the birth period was observed during March and April. However, births were recorded year round (fig. 1).

Wild boar females reached puberty at a minimum age of six months (0.69% of total breeding females) and a minimum weight of 30 kg.

The ovulation rate was 5.18 ± 1.46 (mean ± SD; n = 136) and ranged from 1 to 8. Litter size was 5.01 ± 1.33 (mean ± SD; n = 88) and ranged from two to eight, with four to six being the most frequent number of foetuses per female (fig. 2). An 11% intrauterine loss was recorded.

No distorted foetal sex ratio was observed (1.13:1; $\chi^2 = 0.51$; df = 1; $p = 0.475$).

Age and weight of females were positively correlated ($y = 32.89 + 0.84x$; $R_{Spearman} = 0.882$; $p < 0.05$). A positive linear correlation was observed between litter size and female weight ($y = 2.54 + 0.04\ x$; $R_{Spearman} = 0.41$; $p < 0.05$). When females were grouped into the three weight classes most commonly applied in population management, the reproductive parameters increased according to weight class (table 1). Significant differ-

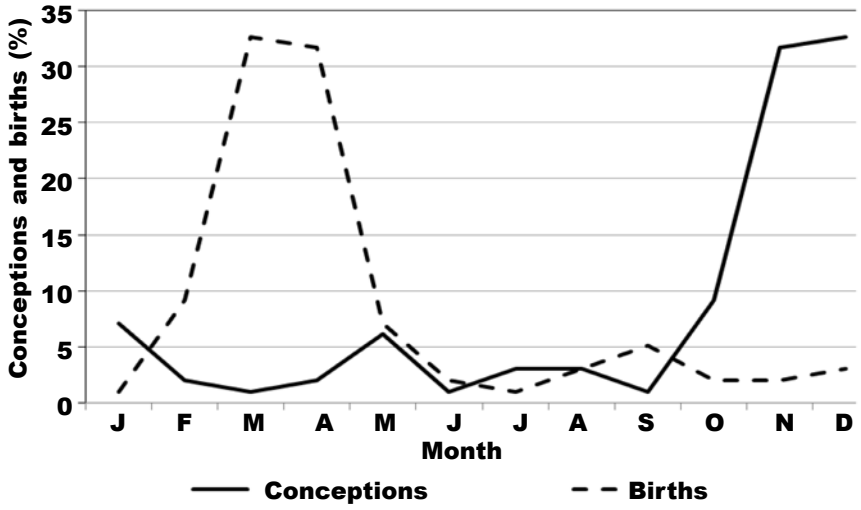

Fig. 1. Female wild boar reproductive phenology in Aiguamolls de l'Empordà Natural Park (n = 296; 2000–2010 period).

Fig. 1. Fenología reproductiva de las hembras de jabalí en el Parque Natural de Aiguamolls de l'Empordà (n = 296; período 2000–2010).

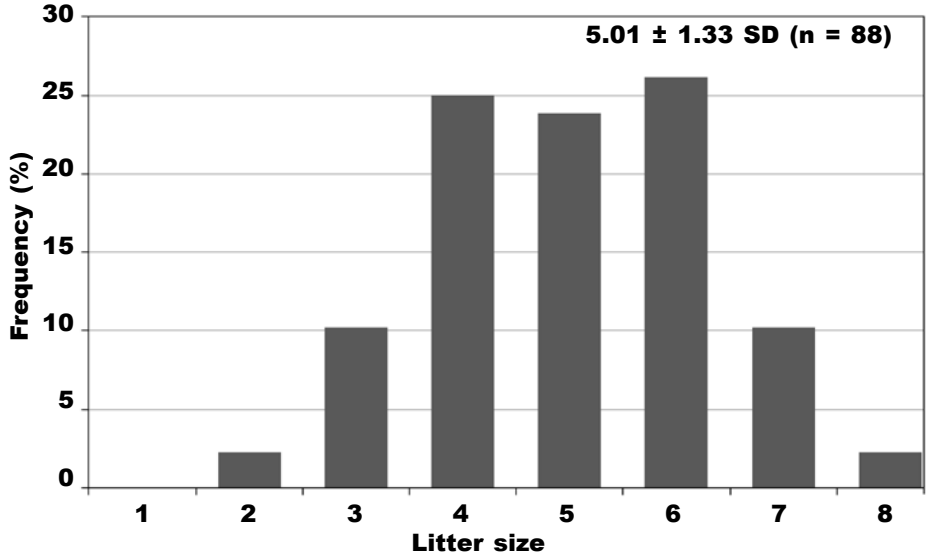

Fig. 2. Distribution of litter size of the wild boar population in the Aiguamolls de l'Empordà Natural Park.

Fig. 2. Distribución del tamaño de camada de la población de jabalíes del Parque Natural de Aiguamolls de l'Empordà.

ences were observed in the percentage of breeding females (χ^2 = 10.48, df = 2, p < 0.01), ovulation rate ($H_{2,N=129}$ = 41.65, p < 0.001) and litter size ($H_{2,N=83}$= 16.52, p < 0.001).

The offspring per 100 females varied from 159.59 foetuses in females under 50 kg to 427.05 in females above 70 kg.

Discussion

The reproductive phenology in the study area showed marked seasonal breeding, with the main rutting period in autumn and winter and births clustered mainly in spring. A few females gave birth in other months of the year. Although the study population is

Table 1. Reproductive parameters of wild boar females considering the weight class. Females weighing over 89 kg were not considered due to the low number of cases: * Foetuses/100 females.

*Tabla 1. Parámetros reproductivos de hembras de jabalí considerando la clase de peso. No se han incluido las hembras de peso superior a 89 kg debido al escaso número de casos: * Fetos/100 hembras.*

		30–49 kg	50–69 kg	70–89 kg
Breeding females (%)		42.22 (n = 90)	64.13 (n = 92)	76.67 (n = 60)
Ovulation rate				
	Mean ± SD	3.94 ± 1.28 (n = 34)	5.21 ± 1.09 (n = 56)	6.13 ± 1.36 (n = 39)
	Median	4	5	6
	range	1–6	2–8	2–8
Litter size				
	Mean ± SD	3.78 ± 1.05 (n = 14)	5.0 ± 1.02 (n = 39)	5.57 ± 1.50 (n = 30)
	Median	4	5	6
	Range	2–6	3–7	2–8
Productivity*		159.59	320.65	427.05

Table 2. Litter size recorded (average, A) in different European wild boar populations.

Tabla 2. Tamaño de camada registrado (media, A) en distintas poblaciones europeas de jabalí.

Location	A	Reference
Germany	6.91	Gethöffer et al., 2007
Hungary	6.7	Náhlik & Sandor, 2003
Germany	6.5	Oloff, 1951
Austria	5.8	Martys, 1982
Germany	5.49	Ahrens, 1984 in Bywater et al., 2010
Germany	5.3	Stubbe & Stubbe, 1977
Germany	5.3	Briedermann, 1971
Luxembourg	5.3	Cellina, 2008
France	5.2	Servanty et al., 2007
Germany	5.11	Gethöffer et al., 2007
Italy	4.95	Boitani et al., 1995
Poland	4.83	Fruzinski, 1995
Switzerland	4.8	Moretti, 1995
Italy	4.7	Monaco et al., 2010
France	4.62	Mauget, 1972
Italy	4.6	Cappai et al., 2008
France	4.6	Aumaitre et al., 1984
France	4.47	Aumaitre et al., 1982
France	4.44	Dardaillon, 1984
Italy	4.2	Focardi et al., 2008
Switzerland	4.17	Neet, 1995
Italy	3.88	Massei et al., 1997
Iberian populations		
Catalonia	5.01	This paper
Aragon (Ebro River valley)	4.5	Herrero et al., 2008
Burgos	4.3	Sáez–Royuela, 1987
Aragon (Pyrenees)	4.25	Herrero et al., 2008
Portugal	4.17	Fonseca et al., 2004
Andalousie	4.1	Abaigar, 1992
Castilla–la Mancha	3.91	Ruiz–Fons et al., 2005
Extremadura	3.88	Garzón, 1991
Catalonia	3.78	Rosell, 1998
Extremadura	3.75	Fernández–Llario & Mateos–Quesada, 2005
Aragón (Pyrenees)	3.27	Vericad, 1983
Andalousie	3.05	Fernández–Llario & Carranza, 2000

located in a mosaic of croplands and marshlands, the seasonal pattern recorded corresponds to patterns observed in Iberian populations in other habitats (see Sáez–Royuela, 1987; Rosell et al., 2001 for a review; Fonseca et al., 2004; Fernández–Llario & Mateos–Quesada, 2005; Fonseca et al., 2011) and to those observed in other European populations (Briedermann, 1971; Aumaitre et al., 1984; Moretti, 1995; Durio et al., 1995; Boitani et al., 1995). The oestrus of female wild boar is greatly influenced by photoperiod and food resources, and the breeding seasonality corresponds to the availability of energy rich foods that provide optimal nutritional conditions for sows at the end of summer and in early autumn (Mauget, 1982; Fernández–Llario & Mateos–Quesada, 1998; Gethöffer et al., 2007; Servanty et al., 2009). The seasonal pattern of reproduction was also observed when energy supply is artificially increased by baiting (Treyer et al., 2012). In the study area, energy foods are provided mainly by crops —maize and sunflower— that account for 37% of the total volume of wild boar stomach contents (Giménez–Anaya et al., 2008). These cultivated plants are mainly consumed from July to October (67.3% of stomach contents in July–August and 64.3% in September–October). Wild boar living in this cropland area consume agricultural plants instead of mast that is the energy–rich food mainly consumed at the beginning of the rutting period in many locations (Schley & Roper, 2003).

The mean litter size observed in the Aiguamolls de l'Empordà population is the highest recorded in the Iberian peninsula and is similar to that observed in Central European countries (table 1; see Bywater et al., 2010 for a review). Litters of above 5 young/reproductive female have been reported in Austria, Germany, northern France and Luxemburg. In these Central European areas, wild boar found optimal environmental conditions and a high availability of natural food resources. Furthermore, supplementary food is often provided (Cellina, 2008; Servanty et al.,

2009). In Italy, Poland, Switzerland and France, lower productivity with less than 5 foetuses per female were reported (table 1). In the Iberian populations, the mean litter size reported reached the minimum in southern Spain under drought conditions (3.05 foetuses per female; Fernández-Llario & Carranza, 2000) and in the Pyrenean habitats (3.27; Vericad, 1983). Iberian populations located mainly in forests and shrublands show a mean litter size of around 4 foetuses/ female and the maximum litter size (4.5) was reported at the population located in the River Ebro valley in a crop landscape (Herrero et al., 2008; table 1).

The most likely explanation for the high litter size observed in the study area may be related to the high availability of energy–rich cultivated foods (maize and sunflower) and the opportunity to obtain stable food sources throughout the year. These foods are provided mainly by crops during summer and autumn and by marshland food resources (underground parts of the wetland plants and animal matter) in winter and spring (Giménez–Anaya et al., 2008).

However, we cannot rule out possible effects such us some degree of crossbreeding with domestic pigs that may have influenced the reproductive output. Slight phenotypic evidence of possible crossbreeding (small parts of the coat with lighter tones than usual in wild boar) was observed in a small proportion of individuals captured (around 5%; unpub.lished data). This issue has not been analysed in other European populations with available reproductive data, and further investigations on chromosome polymorphism among the different wild boar populations would clarify its effect on reproductive output, as other authors have previously suggested (Gethöffer et al., 2007).

The high mean litter size observed in the study area does not fit with the pattern described by Bywater et al. (2010), whereby there is a strong correlation between litter size and latitude for wild boar in Europe. The use of litter sizes predicted on the basis of latitude has been suggested by these authors for management approaches based on population modelling as those proposed by Bieber & Ruff (2005). Nevertheless, according to our data, factors related to human influence affecting wild boar populations (such as high availability of food provided by crops, baiting or crossbreeding with domestic pig) must also be considered in the use of this litter size pattern for demographic modelling.

The female body mass shows a high effect on the reproductive parameters in the study area where an increase was recorded in all the reproductive parameters studied (proportion of breeding females, ovulation rate and litter size) according to weight class. A positive correlation between reproductive output and female weight and age was also reported in many populations (*e.g.* Mauget, 1972; Aumaitre et al., 1982; Sáez–Royuela, 1987; Fonseca et al., 2011) and it was related to the fact that resources available to reproduction increase with female weight and better physical condition (Fernández–Llario & Mateos–Quesada, 1998; Massei et al., 1996). The results suggest that the high availability of food may contribute to the high reproductive output of the study population and to the increase in population density in this area. This observation has implications regarding population control strategies, suggesting that the capture of larger females may be effective in reducing the potential for population growth. Some authors, however, have proposed reduction in the number of piglets as the target for wild boar population control (Sodeikat, et al., 2005). Based on population modelling, it has also been suggested that reducing juvenile survival would have a substantial effect under good environmental conditions, whereas reducing numbers of adult females would be more effective in years when conditions were poor (Bieber & Ruf, 2005).

According to these data, management strategies for reducing wild boar density in protected nature reserves should combine different control techniques. Some, such as trapping, should have the objective of capturing juveniles, whilst others should focus on selective culling of adult females that have the highest reproduction output. Moreover, other measures to reduce reproductive potential should be applied, such as preventing crossbreeding with domestic pig, avoiding supplementary feeding, and applying crop protection measures to reduce the food resources available to wild boar.

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