Reproductive performance of wild boar females in Portugal

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Abstract Reproductive tracts of 214 female wild boars collected in Central Portugal between October and February over the period 1997 to 2001 were examined. From this material, we were able to determine reproductive phenology (conception and birth periods) as well as age and weight of sows at puberty, ovulation rates of adults, foetal sex ratio, levels of intrauterine mortality, final litter size and postnatal mortality. Differences between year, region, age and body weight were analysed. A total of 66.8% of the females examined were gestating or lactating and 96.3% of these weighed >40 kg. The highest proportions of pregnant sows were found in the adult age/weight classes (74%). None of the juvenile females (1 year old and younger) were lactating and only 7% was pregnant. The average number of foetuses/female (4.1±1.2SD) and that of corpora lutea per female (4.6±1.7SD) increased from lighter and younger to heavier and older wild sows. Foetal sex ratio was biased towards males (1.3:1). Observed intrauterine mortality rate (9.7%) and postnatal mortality (6.3%) were among the lowest recorded in European wild boar populations. The productivity rate of the Central Portuguese wild boar population was calculated as 1.1 young per individual in the population. Conception and birth periods did not differ significantly between the considered 4 years. Birth synchronisation was pronounced in all the years, with a peak of births occurring in March.

Keywords Reproductive phenology · Litter size · Wild boar management · *Sus scrofa* · Central Portugal

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Introduction

In the last four decades, wild boar *Sus scrofa* L. populations have shown a significant increase in number and distribution in almost every country within their European range (Sáez-Royuela and Tellería 1986; Apollonio et al. 2010). In Portugal, as in other European countries, wild boars have shown the same pattern of increase in the number of animals and the range they occupy (Fonseca 1999). Current management strategies seem, in most cases, unable to regulate population increase (Apollonio et al. 2010), perhaps due to incomplete understanding of population demography (Spitz et al. 1992; Fonseca et al. 2004).

Compared to other European ungulates (e.g. roe deer *Capreolus capreolus*, red deer *Cervus elaphus*), wild boars reach sexual maturity earlier, have a relatively short gestation period, higher litter size and short lactation period (Fernández-Llario and Mateos-Quesada 1998; Gerard et al. 1991; Abáigar 1992; Dzieciolowski et al. 1992; Gaillard and Jullien 1993; Rosell et al. 2001). Sexual maturity in females is achieved between 5 and 10 months of age, although it is assumed that a minimum body weight of 15–35 kg (e.g. Mauget and Pépin 1991; Appelius 1995; Gethöffer et al. 2007), influenced by food availability, must be attained before puberty can occur (Sweeney et al. 1979; Aumaitre et al. 1982; Kanzaki 1991; Groot Bruinderink et al. 1994).

An understanding of female reproductive parameters is one of the most important aspects in management of any wildlife population and better understanding of the reproductive performance of this species would thus improve the basis of management, for instance by modelling the impact of hunting pressure on population dynamics. The purpose of this study was to analyse reproductive parameters of a wild boar female population monitored over four consecutive years in Central Portugal.

Study area

The study area was located in Central Portugal, approximately between the Douro and Tejo Rivers, and covers an area of 23,668 km^2 from 0 to 1,993 m a.s.l. (Fig. 1). This region, which is in the Mediterranean Ibero Atlantic Province (Rivas-Martínez and Loidi 1999), includes two agricultural and forestry administrative subregions: Beira Interior and Beira Litoral (INE 1997).

Beira Interior is characterised as a mountainous region with typical vast rangelands in the foothills, mean annual temperatures of 7.8°C minimum and 16.7°C maximum, and average annual rainfall is 1,137.7 mm (INMG 1991). Its forest covers around 36% of this subregion and is mainly composed of maritime pine *Pinus pinaster* (57%), eucalyptus *Eucalyptus* sp. (18%), holm oak *Quercus rotundifolia* (8%), cork oak *Quercus suber* (7%), other oaks *Quercus* sp. (8%) and chestnut *Castanea sativa* (1%). Its agricultural land represents 27% of the total area and is characterized by medium and large-sized farms of cereals (maize *Zea mays* and rye *Secale cereal*, around 42%), vineyards *Vitis vinifera* (35%), olive trees *Olea europaea* (19%) and horticultures (DGF 2001; Painho and Caetano 2006).

Beira Litoral, on the Atlantic Ocean coast, has a mean annual temperature ranging from 9.0°C minimum to 18.5°C

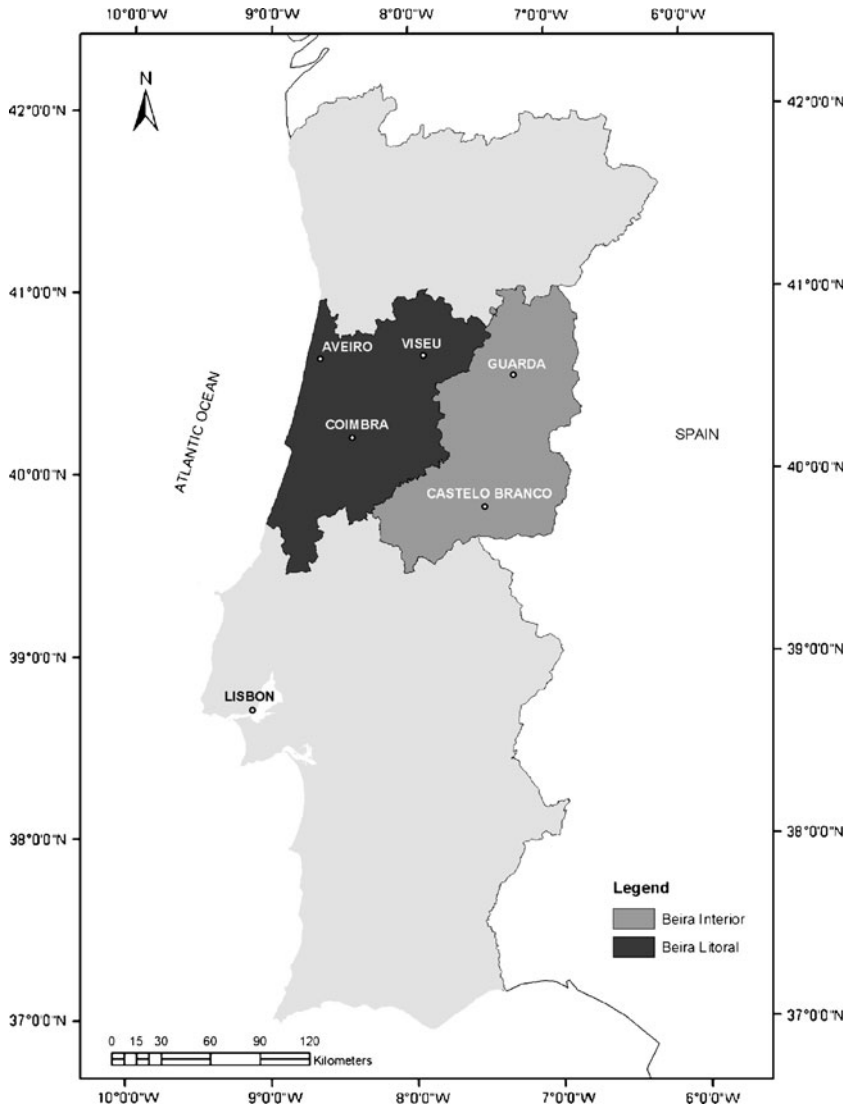

Fig. 1 Map of the study area (Central Portugal) showing the Beira Litoral and Beira Interior subregions

maximum and an average annual rainfall of 1,399.6 mm (INMG 1990). Its agricultural land is 26% of the total area and the production of small-sized farms includes four major cultures of maize *Z. mays*, rice *Oryza* sp., potato *Solanum tuberosum* and bean *Phaseolus vulgaris* (64%), olive trees *O. europaea* (21%) and vineyards *V. vinifera* (13%). Its forests cover about 48% of the subregion, and the major tree species are *Pinus pinaster* (63%), *Quercus* sp. (5%), *C. sativa* (1%) and more recently *Eucalyptus* sp. (28%) (DGF 2001; Painho and Caetano 2006).

In terms of diet composition, the principal food items differ between the two subregions. In Beira Interior, the diet is mainly composed of fruits of *Quercus* sp. (48%) and *O. europaea* (22%) while in Beira Litoral the principal food items are *Z. mays* (37%) and *O. europaea* (34%). The source of *Z. mays* in Beira Litoral do not come from agricultural damage, but it is primarily provided as artificial food during the hunting season as bait (Alves da Silva 2008).

Wild boar hunting is traditionally carried out in both study areas between October and February mainly by *montaria* (hunting drive with dogs).

Materials and methods

A total of 365 wild boars (151 males and 214 females) were collected from the study area during four hunting seasons from 1997/1998 to 2000/2001. All females were aged based on tooth eruption, replacement and wear patterns (Matscheke 1967; Boitani and Mattei 1992; Pedone et al. 1995; Vassant 1995) in three age classes: juveniles (under 12 months old), yearlings (between 12 and 24 months old) and adults (over 24 months old).

In the field, the number of extended teats was recorded and later used in the evaluation of postnatal mortality. Reproductive tracts (uteri and ovaries) were removed and preserved by freezing (−20°C) for laboratory analyses. The physiological stage (pregnant, lactating or non-breeding—neither pregnant nor lactating) of females was determined by direct analysis in the field and subsequent ovarian analysis and the number of corpora lutea was counted and recorded to estimate the ovulation rate (in mean number of corpora lutea).

Intrauterine mortality (IUM) was determined following Mauget (1972) and Abáigar (1990) where IUM=(ovulation rate−litter size)/ovulation rate×100. As suggested by Bouldoire and Vassant (1989), Pavlov (1991) and Dzieciolowski et al. (1992), the number of piglets surviving 1–2 months after birth can be estimated from the number of suckled teats, assuming that each piglet uses a single teat exclusively and will defend the teat against other piglets until weaning. Thus, the differences between the observed average litter size and the average number of teats extended would give an estimate of the natural postnatal mortality rate. Postnatal mortality (PNM) was calculated after Dzieciolowski et al. 1992 as follows: PNM=(average litter size−average extended teats)/average litter size×100. This way of access to postnatal mortality is still controversial since other authors reported the possibility that piglets could suck the teats of other females from the group (Hartmuth 1962; Meynardt 1990). Being aware of this issue, caution will be taken in the interpretation and discussion of our results. The population productivity (PR) was estimated after Mauget (1972) as follows: PR=$n\times P\times$ number of pregnant females/total sampled animals, where n is the mean number of adult female foetuses and P is the rate of pregnant adult females.

The embryos or foetuses in the uteri of the pregnant females were counted to calculate the potential fertility rate (in mean number of foetuses per litter) (Groot Bruinderink et al. 1994), sexed (when possible), weighed (to the nearest gramme) and aged. The age of the foetuses (T) in days was determined using the following formula of Vericad (1983): $T=(\mathrm{Ps}^{1/3}+2.3377)/0.097$, where Ps is the foetus' average fresh weight (g) of the litter. Conception and birth dates were calculated assuming a mean gestation period of 120 days (Vericad 1983; Sáez-Royuela and Tellería 1987; Rosell et al. 2001; Markina et al. 2003).

Statistical analyses

Data analyses were performed using the software package MINITAB® Release 13 (Minitab 2000). Parametric tests (ANOVA) were used when assumptions of the normality (evaluated using the Shapiro–Wilk test) and homoscedasticity (evaluated using the Levene test) of the data (or transformed data) were satisfied. Differences in breeding status, litter sizes and sex ratios between years, subregions and age classes were analysed using the χ^2 test.

A three-way ANOVA without interactions was used to test for differences in mean number of the corpora lutea and mean number of the extended visible teats between years, subregions and age classes.

The seasonal and monthly effects on conception and birth periods were tested by a two-way ANOVA (conception and birth frequencies were first transformed using the square root arcsine transformation).

Finally, within the combined total data set, we investigated the effect of female body weight on the proportions of non-reproductive, pregnant and lactating females, using a one-way ANOVA and linear regression analysis (Zar 1996) to explore the relationships between female total body weight and litter size, between ovulation and fertility rates, and female total body weight and mean number of extended teats.

Results

During four hunting seasons (1997/1998 to 2000/2001) 214 females were collected during the driven hunts (Table 1).

Breeding status

From the total of 214 females, 71 (33.2%) were non-reproductive, 115 (53.7%) were pregnant and 28 (13.1%) were lactating. The proportion of breeding females did not vary among hunting seasons (χ^2=1.234, df=6, p=0.975) or between the subregions (χ^2=0.217, df=2, p=0.897). Breeding status varied among age classes (χ^2=87.195, df=4, p<0.05).

No juvenile females were found lactating and only 7% were pregnant (Fig. 2). The highest percentages of pregnant and lactating females were found in adults, at 74% and 17%, respectively.

Onset of pregnancy

No juvenile females under 32 kg were reproductively active. The three youngest pregnant females that weighed between 33 and 37 kg were killed in the same hunting area (Beira Interior) and represented 7.7% of the females less than 1 year old.

Fertility rate

From 115 pregnant females harvested we collected 481 foetuses. The average number of foetuses per litter was 4.1±1.2 standard deviation (SD) and litter size ranged from two to eight. Litter size did not differ among hunting seasons (χ^2=14.303, df=18, p=0.709) but differed between subregions (χ^2=13.246, df=6, p<0.05) and among age classes (χ^2=8.920, df=12, p<0.05). Female wild boars in Beira Litoral had larger litters (mean=4.2, range=2–8 foetuses, with three and four most frequent) than females in Beira Interior (mean=4.0, range=2–6, with four and five most frequent). Fertility rate or average litter size of females under 12 months old was lower than that of yearlings and of the females more than 2 years old (Table 2).

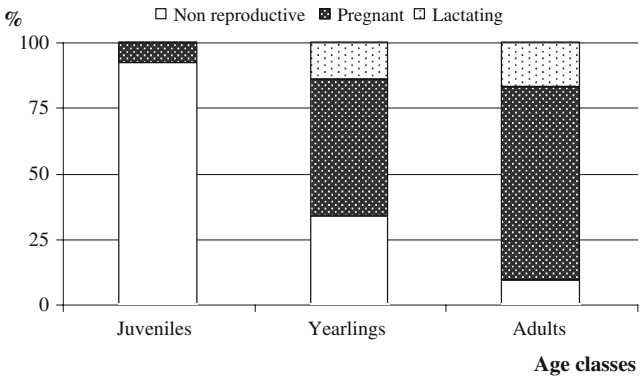

Fig. 2 Proportions (%) of pregnant, lactating and non-reproductive female wild boars in three age classes (juveniles: n=39, yearlings: n=77 and adults: n=98)

The number of foetuses of pregnant females was positively correlated with body weight (r=0.48; n=113; p<0.01). Litter size varied ($F_{5,107}$=5.74; p<0.05) among the six weight classes. It increased with weight from 3.0 foetuses per litter among lighter females to 4.9 foetuses per litter among the heaviest females (Table 3).

Sex determination was possible for 141 of 418 foetuses (over 40 days old). The foetal sex ratio was 79 males to 62 females (1.3:1). The foetal sex ratio did not differ significantly (χ^2=1.82, df=1, p>0.05) from parity or between subregions (χ^2=0.646, df=4, p=0.422) despite the different ratios (1.06 in Beira Litoral and 1.48 in Beira Interior), both of which were biased toward males.

Intrauterine mortality

An analysis of the ovaries of 80 pregnant females revealed 364 corpora lutea (Table 1). The number of corpora lutea found in the ovaries ranged from two to nine and the mean was 4.6±1.7SD. Ovulation rate and fertility rate were positively correlated (r=0.56; n=55; p<0.01).

A three-way ANOVA without interaction revealed significant differences in ovulation rate between hunting seasons ($F_{3,73}$=4.14, p<0.05) and age classes ($F_{2,73}$=4.08,

Table 1 Total number of females, foetuses and corpora lutea examined from a wild boar population in Central Portugal, from 1997/1998 to 2000/2001

	Females	Foetuses	Corpora lutea
1997/1998	73	170	84
1998/1999	39	92	48
1999/2000	46	88	106
2000/2001	56	131	126
Total	214	481	364

Table 2 Ovulation rate, fertility rate and IUM in three age classes of female wild boar in Central Portugal (values represent mean±SD)

	Ovulation rate	Fertility rate	IUM (%)
Juveniles	4.0±2.4 (n=6)	2.3±0.6 (n=3)	41.8
Yearlings	4.2±1.6 (n=36)	3.3±0,9 (n=41)	20.3
Adults	5.0±1.6 (n=38)	4.6±1.0 (n=73)	13.1

Table 3 Ovulation rate, fertility rate and IUM in six weight classes of female wild boar in Central Portugal (values represent mean±SD)

	Ovulation rate	Fertility rate	IUM (%)
<34 kg	4.7±2.5 (n=3)	3.0 (n=1)	35.8
35–44 kg	3.4±1.5 (n=13)	3.1±1.0 (n=8)	7.4
45–54 kg	4.4±1.5 (n=16)	3.5±0.9 (n=22)	22.3
55–64 kg	4.5±1.6 (n=19)	4.1±0.9 (n=36)	9.9
65–74 kg	4.6±1.3 (n=11)	4.2±1.0 (n=20)	7.7
>74 kg	5.5±2.0 (n=15)	4.9±1.4 (n=26)	12.3

$p<0.05$), but no significant differences were found between the subregions ($F_{1,73}=0.94$, $p=0.334$).

The ovulation rate increased with age (Table 2) and total body weight (Table 3). In the population studied, mean intrauterine mortality was 9.7%. Intrauterine mortality was highest in juveniles (41.8%) and lowest in adult females (13.1%) (Table 2). The same pattern was observed among weight classes (35.8% of 0–34 kg females and 12.3% in 74 kg females) (Table 3).

Postnatal mortality

The mean number of extended visible teats among 39 females was 3.9±1.3SD (range=1–7), which suggests that an average of 3.9 piglets per litter survived the first months of life.

This parameter did not vary among hunting seasons ($F_{3,32}=0.27$, $p>0.05$) or subregions ($F_{1,32}=0.01$, $p>0.05$); however, the number of extended teats differed among age classes ($F_{1,32}=5.63$, $p<0.05$). No extended teats were found in juvenile females. After linear regression it was observed that the number of extended teats was significantly lower in yearlings (3.2±1.4SD; range=1–5) than in females over 24 months (4.2±1.1SD, range=2–7 teats/female). Female total body weight and the number of extended teats were significantly positively correlated ($r=0.44$, $n=38$, $p<0.05$).

From the difference between average litter size and average extended teats, we may calculate that postnatal mortality of piglets in the Central Portuguese wild boar population reached 6.3%. Postnatal mortality of piglets during, approximately, the 2 months after birth was 5.1% in yearling females and 10.2% in older females. Early mortality increased with female age.

Population offspring productivity

In the four hunting seasons, we collected 365 wild boars (151 males; 214 females). Given that the average number of foetuses per adult female (4.6) and the proportion of pregnant adult females (74%), the productivity rate was 1.1 young per individual in the population.

Conception and birth dates—phenology of reproduction

Conception and birth periods did not vary significantly among the four hunting seasons ($F_{3,15}=0.63$, $p>0.05$). Conception and birth dates varied significantly among the months sampled ($F_{5,15}=7.24$, $p<0.05$). Fig. 3 shows the seasonal conception and birth distribution pattern as derived by extrapolation from foetal age.

Mating activity seems to begin in August, reaching a peak in November and decreasing in December and January. In this study, the main rut period occurred in November, which represented almost 40% of the pregnant females. The data indicated a pronounced seasonality in births, with a peak in March, which represented 37.5% of the female breeding population. Most piglets (85.4%) were born from February to April inclusive.

Piglet births occurred in the period from December to February (32% of cases), overlapping the main hunting season for wild boar (October to February inclusive).

Discussion

In this study, we found similar reproductive patterns (e.g. percentage of breeding females per age classes) to those reported for several other European wild boar populations (Pedone et al. 1991; Gaillard and Jullien 1993; Rosell 1998; Herrero et al. 2008).

The proportion of breeding females did not vary significantly among the four hunting seasons or between the two subregions, which reflects a general breeding homogeneity in the Central Portuguese wild boar population. The significant differences obtained in breeding status among age classes were interrelated with the minimum body weight of sexually active females observed in our study, which is similar to those observed in Asian and other European wild boar populations (Table 4); however, the

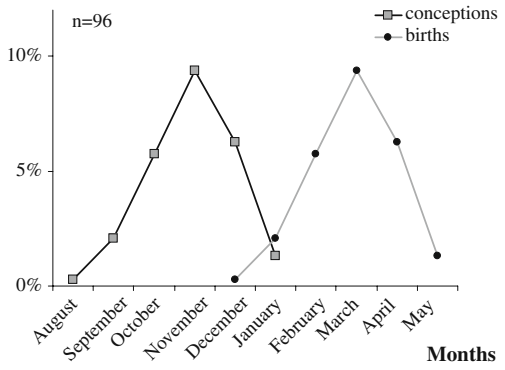

Fig. 3 Mean proportions (%) of conceptions and births in each month of four wild boar hunting seasons (1997/1998 to 2000/2001) in Central Portugal

Table 4 Minimum body weight (MBW) of sexually active females, mean litter size, intrauterine mortality and postnatal mortality for European and Asian wild boar populations

Location	Reference	MBW (kg)	Litter size	Intrauterine mortality (%)	Postnatal mortality (%)
Portugal	Present study	32	4.1	9.7	6.3
Spain	Sáez-Royuela and Tellería 1987		4.3		
	Abáigar 1990				31.0
	Garzón-Heydt 1991		3.9		
	Abáigar 1992		4.1	31.0	
	Rosell 1998	35	3.6	24.5	
		30	4.1	12.5	13.8
	Fernández-Llario et al. 1999		3.7		
	Markina et al. 2003		3.9		
	Herrero et al. 2008[a]		4.0	40.0	
			4.0	39.0	
France	Mauget 1972			14.0	
	Aumaitre et al. 1982			13.4	
	Aumaitre et al. 1984		4.6		
	Dardaillon 1988		4.4		
	Mauget and Pépin 1991	35			
Italy	Pedone et al. 1991	28	4.9		
	Boitani et al. 1995		5.0		
Germany	Briedermann 1971		5.0		5.0–25.0
	Appelius 1995	30	4.4	7.4–8.4	
	Gethöffer et al. 2007	15	5.2–7.6	8.0	
		15	4.6–6.7	6.0–18.0	
Austria	Martys 1982		5.8		17.0
Poland	Dzieciolowski 1991		5.2		
Hungary	Náhlik and Sándor 2003		6.7	12.0	55.1–60.9
Pakistan	Ahmad et al. 1995			16.0	
Japan	Kanzaki 1991	25			

[a] Median values

minimum body weight of sexually active females may vary according to the population structure, food availability, hunting/predation pressure and clime in wild boar populations. In fact, Gethöffer et al. (2007) make refererence to piglets sexually active (15 kg) in Germany, perhaps reflecting the structure and density of the population as well as optimal enviromental conditions for this species. There is thus found to be a high percentage of non-reproductive juveniles with higher proportions of pregnant or lactating females among yearlings and adults. The higher proportion of breeding adult females might be directly related to the higher body mass and better physical condition of the older females, which has been reported by Fernández-Llario and Mateos-Quesada (1998) and Massei et al. (1996). Those authors indicate that the resources available for reproduction increase with the weight and physical condition increment and consequently with age. Several studies showed that the proportion of older females is very important for production in wild boar populations (Sáez-Royuela and Tellería 1987; Gerard et al. 1991; Boitani et al. 1995).

The mean litter size observed in our study reflects the relatively low reproductive capacity of the Central Portuguese wild boar population compared to central and northern European wild boar populations but comparable with other Iberian populations (Table 4) and suggests there is a latitudinal gradient in the reproductive potential of this species, as suggested by Sáez-Royuela and Tellería (1987) and Abáigar (1992). Those authors considered differences in female body size, a consequence of favourable climatic and food conditions to be the main factor producing the reproductive latitudinal gradient. Litter sizes in wild boar populations in Spain are very similar to those observed in Central Portugal, which emphasizes the similarities among wild boar populations on the Iberian Peninsula. In Central Portugal, there was no statistically significant seasonal

variation in fertility rate (foetuses/litter); however, the higher number of foetuses/litter observed in Beira Litoral and the wide range of foetuses/litter suggests that the wild boar population in Beira Litoral has a larger proportion of older females than does the population in Beira Interior, which is confirmed by data on population structure. The reproductive capacity of the wild boar population sampled in Central Portugal appears to be dependent on body weight and, consequently, on female age as suggested by Mauget (1972), Aumaitre et al. (1982), Boitani et al. (1995) and Massei et al. (1996). Apart from the low proportion of pregnant juveniles and the low litter sizes of the lighter females, yearlings did not have more than five foetuses/litter, and only females over 55 kg had more than six foetuses per litter. This emphasised the importance of older females for wild boar population management.

Mean number of corpora lutea per female is much lower than the values reported for wild boar populations in France (Mauget 1972; Aumaitre et al. 1982, 1984), but similar to the values for Spanish populations (Garzón-Heydt 1991; Abáigar 1992; Rosell 1998; Herrero et al. 2008).

The ovulation rates differ significantly between hunting seasons, with the highest value (5.3) occurring in 1998/1999, which was a very wet autumn and winter with exceptionally good mast productivity throughout Portugal (Cancela, personal communication). This recognition was emphasised by several authors such as Aumaitre et al. (1982) and Herrero et al. 2008, who indicated a high positive correlation between ovulation rate and seasonal food availability. Notwithstanding the fact that ovulation rate and the average number of foetuses per litter increase with increasing female total body weight and age class, the two significant effects ($p<0.05$) of these two factors are the average value of ovulation rate and fertility rate between light and heavy females, and consequently, between young and adult females. The only exception was females whose weight was below 34 kg, which showed a relatively high production of corpora lutea and reflected high intrauterine mortality. The intrauterine mortality rate is among the lowest values reported (Table 4) and is different to other studies and regions, suggesting that intrauterine mortality is a highly variable trait.

Differences observed in intrauterine mortality between age and weight classes were the consequence of the positive correlation between fertility and ovulation rates, which was reported by Abáigar (1992). Generally, as ovulation rate increases intrauterine mortality decreases. That relationship is especially evident when analysed according to age class. While the average production of corpora lutea per female increases from juveniles to adults, intrauterine mortality decreases between the same age classes. The low intrauterine mortality in adult females might be due to their generally better physical condition, which is reflected in their higher body weight. The positive correlation between the fertility and ovulation rates indicated that the increase in average number of the corpora lutea with age is not as strong as the relationship between age and the average number of foetuses per litter.

In the wild boar population studied in Central Portugal, the natural postnatal mortality rate corresponds to 6.3%, which suggests that an average of 3.9 piglets per litter survived the first months of life. This natural postnatal mortality is in the range of 5% to 25%, suggested by Briedermann (1971) and depending on several predation and seasonal climatic factors; however, according to other authors (Hartmuth 1962; Meynardt 1990) our postnatal mortality estimate can be influenced by the fact that piglets older than 14 days and motherless piglets could suck on teats of other females from the group. If this is the case, the postnatal mortality achieved with this methodology may be underestimated, reaching values higher than thus reported by us but still within the normal parameters for the species.

Adult females showed a higher piglet mortality rate compared to that of yearling sows, which might be due to a smaller litter size in yearling females relative to older sows (as indicated, above) and individual piglets of young sows obtain enough milk and, therefore, are in better condition and have a higher probability of survival.

The offspring productivity rate falls within the production rate for wild boar populations in France (Vassant 1995), but is higher than the one reported by Mauget (1972) and Boitani et al. (1995) (0.9 and 0.7, respectively). In addition, the low intrauterine mortality contributes to the high production rate of the Central Portuguese wild boar population.

This wild boar population exhibited a seasonal breeding pattern. Such breeding phenomena might be directly related to the strong seasonality in climate, photoperiod (Mauget et al. 1984) and food availability. Summers are warm and the most limiting season for food resources. In autumn and winter, cold winds and rain are very common (Rivas-Martinez and Loidi 1999), and food availability is high due to *C. sativa*, *Quercus* spp. and *O. europaea* fruit fall. These fruits are high in carbohydrates and lipids, which are essential for reproduction and maintenance of good physical condition (Massei et al. 1996). As reported by other studies (Sáez-Royuella and Tellería 1987; Garzón-Heydt 1992; Rosell 1998; Aumaitre et al. 1984; Vassant et al. 1994) in Spain and France, the Portuguese wild boar population also exhibits cyclic sexual activity, with one rutting peak in fall, and one birthing peak in late winter/early spring (February–April). The highest natality occurred in late winter and most females were pregnant or suckling from April through May. A breeding 'rest' period can occur during the warmer and longer daylight months, referred to by Aumaitre et al. (1984), Mauget et al. (1984) and Pépin

et al. (1987) as the summer anoestrus; however, the presence of three piglets 3 months old and five piglets 6 months old in the January and December Central Portuguese hunting bags, indicates that some females can be pregnant or give birth in summer. In most wild boar populations, the summer births are related to excellent mast crop years and favourable environmental and climatic factors, and also to the puberty body weight and the length of the lactation period (Mauget 1972; Singer and Ackerman 1981; Ahmad et al. 1995; Durio et al. 1992).

Data obtained in our study provided the basis for managing the population of wild boar in Portugal as it quantified the temporal patterns of reproduction. These data could be used to model population dynamics and recommend options to manage wild boar populations.

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References

Abáigar T (1990) Características biológicas y ecológicas de una población de jabalíes (*Sus scrofa* L.) en el SE Ibérico. (Biological and ecological features of a wild boar (*Sus scrofa* L., 1758) in South-eastern Iberian Peninsula). PhD Thesis, Universidad de Navarra

Abáigar T (1992) Paramètres de la reproduction chez le sanglier (*Sus scrofa*) dans le sud-est de la Péninsule Ibérique. Mammalia 56:245–250

Ahmad E, Brooks JE, Hussain I, Khan MH (1995) Reproduction in Eurasian wild boar in central Punjab, Pakistan. Acta Theriol 40:163–173

Alves da Silva A (2008) Dinâmica Alimentar de Javali (*Sus scrofa* L.) no Centro de Portugal. MSc Thesis, Universidade de Coimbra

Apollonio M, Andersen R, Putman RJ (2010) European ungulates and their management in the 21st century. Cambridge University Press, London

Appelius M (1995) Einflüsse auf die Populationsdynamik von weiblichen Schwarzwild-Frischlingen aus dem nördlichen Regierungsbezirk Braunschweig und dem Forstamt Saupark. Thesis, Tierärztliche Hochschule Hannover

Aumaitre A, Morvan C, Quéré JP, Peiniau J, Vallet G (1982) Productivité potentielle et reproduction hivernale chez la laie (*Sus scrofa scrofa*) en milieu sauvage. Journées Rech Porcine en France 14:109–124

Aumaitre A, Quéré JP, Peiniau J (1984) Influence du milieu sur la reproduction hivernale et la prolificité de la laie. In: Spitz F, Pépin D Symposium International sur le Sanglier. Les Colloques de l'INRA 22:71–78

Boitani L, Mattei L (1992) Aging wild boar (*Sus scrofa*) by tooth eruption. In: Spitz F, Janeau G, González G, Aulagnier S (eds) Ongules/Ungulates 91. SFEPM-IRGM, Toulouse, pp 419–421

Boitani L, Trapanese P, Mattei L, Nonis D (1995) Demography of a wild boar (*Sus scrofa* L.) population in Tuscany, Italy. Gibier Faune Sauvage. Game Wildl 12:109–132

Bouldoire JL, Vassant J (1989) Le Sanglier. Éditions Hatier. Collection Faune Sauvage, Paris

Briedermann L (1971) Zur Reproduktion des Schwarzwildes in der Deutschen Demokratischen Republik. Tag Ber dt Akad Berlin 113:169–186

Dardaillon M (1988) Wild boar social groupings and their seasonal changes in the Camargue, southern France. Z Säugetierkunde 53:22–30

DGF (2001) Inventário Florestal Nacional: Portugal Continental 3ª Revisão. Direcção-Geral das Florestas, Lisboa

Durio P, Gallo-Orsi U, Macchi E, Perrone A (1992) Monthly birth distribution and structure of an alpine population of wild boar (*Sus scrofa*) in North-West Italy. In: Spitz F, Janeau G, González G, Aulagnier S (eds) Ongules/Ungulates 91. SFEPM-IRGM, Toulouse, pp 395–397

Dzieciolowski RM (1991) Ecological niches of five big ungulate in a forest tract. Folia For Pol 33:56–70

Dzieciolowski RM, Clarke CM, Frampton CM (1992) Reproductive characteristics of feral pigs in New Zealand. Acta Theriol 37:259–270

Fernández-Llario P, Mateos-Quesada P (1998) Body size and reproductive parameters in the wild boar *Sus scrofa*. Acta Theriol 43:439–444

Fernández-Llario P, Carranza J, Mateos-Quesada P (1999) Sex allocation in a polygynous mammal with large litters: the wild boar. Anim Behav 58:1079–1084

Fonseca CMMS (1999) Ecologia de javali (*Sus scrofa Linnaeus*, 1758) na região Centro de Portugal (Wild Boar ecology in central Portugal). MSc Thesis, Universidade de Coimbra

Fonseca C, Herrero J, Luís A, Soares AMVM (2004) Wild Boar Research 2002. A selection and edited papers from the 4th International Wild Boar Symposium. Galemys 16 Special Issue, Málaga

Gaillard JM, Jullien JM (1993) Body weight effect on reproduction of young wild boar (*Sus scrofa*) females: a comparative analysis. Folia Zool 42:204–212

Garzón-Heydt P (1991) Biology and ecology of wild boar (*Sus scrofa* L., 1758) in Monfragüe Natural Park. PhD Thesis, Universidad Autonoma de Madrid

Garzón-Heydt P (1992) Study of a population of wild boar *Sus scrofa castilianus* Thomas, 1912 in Spain, based on hunting data. In: Bobek B, Perzanowski K, Regelion W (eds) Global trends in wildlife management. Trans. 18th IUGB Congress 1987. Swiat, Krakow-Warszawa, pp 489–492

Gerard JF, Teillaud P, Spitz F, Mauget R, Campan R (1991) Le Sanglier. Rev Ecol (Terre Vie) 6:11–65

Gethöffer F, Sodeikat G, Pohlmeyer K (2007) Reproductive parameters of wild boar (*Sus scrofa*) in three different parts of Germany. Eur J Wildl Res 53:287–297

Groot Bruinderink GWTA, Hazebroek E, van der Voot H (1994) Diet and condition of wild boar, *Sus scrofa scrofa*, without supplementary feeding. J Zool (Lond) 233:631–648

Hartmuth D (1962) Verhaltensstudien an Wildschweinen im Zoologischen Garten zu Berlin. Dissertation, Freie Universität Berlin

Herrero J, García-Serrano A, García-González R (2008) Reproductive and demographic parametres in two Iberian wild boar populations. Acta Theriol 53:355–364

INE (1997) Statistical year-book of the central region. Instituto Nacional de Estatística, Direcção Regional do Centro, Coimbra

INMG (1990) The Portuguese climate—Climatological patterns of "Entre Douro e Minho e Beira Litoral" from 1951 to1980, Fascículo XLIX, vol 1. Instituto Nacional de Meteorologia e Geofísica, Lisboa

INMG (1991) The Portuguese climate—Climatological patterns of "Trás-os-Montes e Alto Douro e Beira Interior" from 1951 to

1980, Fascículo XLIX, vol 3. Instituto Nacional de Meteorologia e Geofísica, Lisboa
Kanzaki N (1991) Timing of puberty of Japanese wild boar in Western Honsyu. In: Csanyi S, Ernhaft J (eds) Transactions of the XXth IUGB Congress Part II. University of Agricultural Sciences, Godöllö, pp 576–581
Markina FA, Sáez-Royuela C, De Garnica R (2003) Reproductive phenology of wild boar (*Sus scrofa* L.) in the cantabric mountains (Álava, North Spain). Galemys 15:145–155
Martys M (1982) Observations on parturition and reproductive biology in captive European wild boars (*Sus scrofa* L.). Z Säug 47:100–113
Massei G, Genov PV, Staines BW (1996) Diet, food availability and reproduction of wild boar in a Mediterranean costal area. Acta Theriol 41:307–320
Matschke GH (1967) Aging European wild hogs by dentition. J Wildl Manage 31:109–113
Mauget R (1972) Observations sur la reprodution du sanglier (*Sus scrofa* L.) a l`état sauvage. Ann Biol Anim Bioch Biophys 12 (2):195–202
Mauget R, Pépin D (1991) Energy intake, growth and timing of puberty in the European wild boar *Sus scrofa* L. In: Bobek B, Perzanowski K, Regelion W (eds) Global trends in wildlife management. Trans. 18th IUGB Congress 1987. Swiat, Krakow-Warszawa, pp 205–209
Mauget R, Campan R, Spitz F, Dardaillon M, Janeau G, Pépin D (1984) Synthèse des connaissances actuelles sur la biologie du sanglier, perspectives de recherce. In: Spitz F, Pépin D (eds) Les Colloques de l'INRA, nº 22. Symposium International sur le Sanglier. INRA, Toulouse, pp 15–50
Meynardt H (1990) Schwarzwild-Report. Mein Leben unter Wildschweinen. Neumann Verlag, Radebeul
Minitab (2000) Minitab user's guide. Minitab, New York
Náhlik A, Sándor G (2003) Birth rate and offspring survival in a free-ranging wild boar *Sus scrofa* population. Wildl Biol 9(1):37–42
Painho M, Caetano M (2006) Cartografia de ocupação do solo, Portugal continental 1985-2000, CORINE Land Cover 2000. Instituto do Ambiente, Amadora
Pavlov P (1991) Reproduction of feral pigs from eastern Australia. In: Bobek B, Perzanowski K, Regelion W (eds) Global trends in wildlife management. Trans. 18th IUGB Congress 1987. Swiat, Krakow-Warszawa, pp 215–218
Pedone P, Mattioli L, Mattioli S, Siemoni N, Lovari C, Mazzarone V (1991) Body growth and fertility in wild boars of Tuscany, central Italy. In: Csanyi S, Ernhaft J (eds) Transactions of the XXth IUGB Congress Part II. University of Agricultural Sciences, Godöllö, pp 604–609
Pedone P, Mattioli L, Mattioli S (1995) Body size and growth patterns in wild boars of Tuscany, central Italy. IBEX JME 3:66–68
Pépin D, Spitz F, Janeau G, Vallet G (1987) Dynamics of reproduction and development of weight in the wild boar (*Sus scrofa*) in southwest France. Z Säugetierkunde 52:21–30
Rivas-Martínez S, Loidi J (1999) Bioclimatology of the Iberian Peninsula. Itinera Geobotanica 13:41–47
Rosell C (1998) Biology and Ecology of wild boar (*Sus scrofa* L., 1758) from two northeast Iberian populations: Management purposes. PhD. Thesis, Universitat de Barcelona
Rosell C, Fernández-Llario P, Herrero J (2001) The wild boar (*Sus scrofa* Linnaeus, 1758). Galemys 13:1–25
Sáez-Royuela C, Tellería JL (1986) The increased population of the Wild Boar (*Sus scrofa*) in Europe. Mamm Rev 16:97–101
Sáez-Royuela C, Tellería JL (1987) Reproductive trends of the wild boar (*Sus scrofa*) in Spain. Folia Zool 36:21–25
Singer FJ, Ackerman BB (1981) Food availability, reproduction and condition of European wild boar in Great Smoky Mountains National Park. Res Resour Manage Rep 43:1–52
Spitz F, Janeau G, González G, Aulagnier S (1992) Ongules/ Ungulates 91. SFEPM-IRGM, Toulouse
Sweeney JM, Sweeney JR, Provost EE (1979) Reproductive biology of a feral hog population. J Wildl Manage 43:555–559
Vassant J (1995) Le Sanglier. Brochure Technique nº 14. Office National de la Chasse, Paris
Vassant J, Brandt S, Courthial JJ (1994) Influence de la production de faines et de glands sur les dates de mise bas des laies adultes. Office National de la Chasse. Bulletin Mensuel 187:11–17
Vericad R (1983) Fetal age, conception and birth period estimation on wild boar (*Sus scrofa*) in West Pyrenees. In: Actas del XV Congresso Int. Fauna Cinegética y Silvestre. Trujillo, pp 811–820
Zar JH (1996) Biostatistical analysis, 3rd edn. Prentice-Hall Intern, London