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Influence of rainfall on the breeding biology of Wild boar (*Sus scrofa*) in a Mediterranean ecosystem

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A b s t r a c t . For the last few decades, many studies have analysed the important influence of environmental conditions on the breeding biology of ungulates. However, with reference to Mediterranean wild boar populations, there are hardly any studies. In this paper, we will research the effect of rainfall over eight years on some reproductive variables in a wild boar population located in a Mediterranean ecosystem. Our results indicated that the percentage of pregnant females was higher in rainy years than in dry ones and females over 2 years of age significantly increased their litter size in these rainy years. In addition, dry summers and autumns determined an early rut period and a high concentration of births**.** However, rainfall did not influence the foetal sex ratio, although we did observe that the sex of the heaviest piglet within each litter was predominantly male, this circumstance being more significant in dry years than in rainy ones. We believe that these results could be showing the wild boar's survival strategy in the changeable environmental conditions of Mediterranean ecosystems.

Key words: reproduction, sex ratio, Iberian Peninsula, ungulates, environmental condition, suides

Introduction

Traditionally wild boar (*Sus scrofa*) has been considered a highly adaptable species, its presence in different types of ecosystems being evidence of this adaptable character. From predesert zones and salt marshes to cold areas (F e r n á n d e z – L l a r i o & C a r r a n z a 2000, R o s e l l 1998, S a n t o s 2002), this species can reach high densities and this has been attributed to their omnivorous diet and adaptable breeding biology (S á e z - R o y u e l a 1987).

However, when we look into how this adaptation is carried out, we find very few studies. In our opinion, to research into and answer these questions, the study of wild boar populations located in Mediterranean forest ecosystems could provide a good model, as this habitat is subject to important fluctuations in the production of biomass throughout seasons and years. Therefore, we can observe four clearly differentiated seasons, summer being the limiting period (P u l i d o 1999, P u l i d o et al. 2003). Rainfall plays a decisive role as a key for this system, related to the production of herbaceous biomass and ligneous vegetation in autumn (J o f f r e et al. 2001).

Wild boar populations currently inhabiting Mediterranean areas are scarcely known in basic aspects such as population dynamics. There is no deep understanding as to how to they survive in these extreme and changeable conditions. Only a few studies have been carried out in these areas, and they have established and addressed the possible strategies these wild boars could use. Therefore, it appears that in this species, gestation control is based on the rank of the female within its familiar unit (S á e z - R o y u e l a 1987, M a s s e i et al. 1996,

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Rosell 1998, Fernández-Llario & Carranza 2000) and the selection of the foetuses' sex could be determined by physical characteristics of the mother (Fernández-Llario et al. 1999)

For these reasons, the aim of this work is to evaluate whether environmental characteristics have an important influence on some reproductive parameters of wild boar in the Mediterranean forest. We will test whether rainfall, one of the most outstanding variables in the production of grass and acorns (Joffre et al. 2001), is related to the percentage of breeding female, the litter size, seasonality of conception and birth, foetal sex ratio and the sex of the heaviest piglet within each litter.

Study Area, Material and Methods

The data was gathered in western Spain at the locations of Monfragüe and Las Villuercas, in the centre of Cáceres province. Both locations present hill ranges no more than 650 m high and the ground is dominated by Holm oak (*Quercus ilex*), although *Cistus ladanifer, Arbutus unedo* and *Phillyrea angustifolia* are also present. Rainfall is seasonal, which causes summers to be dry, whereas winters are cold and rainy (Buyolo et al. 1998, Pulido 1999). The land is divided into large privately owned estates dedicated mainly to big game hunting. The presence of Imperial eagle (*Aquila adalberti*) indicates a high level of conservation. There are high densities of red deer, which in some estates can surpass 40 per square kilometre. Other species have recently been introduced, such as fallow deer (*Dama dama*) or moufflon (*Ovis ammon*) (Carranza 1998).

All the boars were from hunts carried out from mid October to late February, period when it is allowed to hunt wild boar in our study area. The type of hunting used is called *montería*, where an equal pressure is exerted on both males and females, the females being followed by the young litter, the only boar that must not be hunted. The *monterías* were held on areas of approximately 500 hectares. Hunters wait in fixed positions for the wild boar to pass by close to them after they have been displaced from their resting places by team of dogs guided by one person (Fernández-Llario et al. 2003).

For eight years, we weighed (±1 kg) and measured the females shot in 60 hunts. Likewise, age estimations were calculated based on dental criteria (Dub 1952, Iff 1978). From the females whose state of gestation allowed it, data was collected on the number of foetuses or embryos. In the case of all the foetuses and the majority of embryos, we recorded their weight, as an indicator of the moment of conception, and their sex (for methods see Fernández-Llario & Mateos-Quesada 1998, Fernández-Llario et al. 1999).

The females were divided into different sub-groups based on body development: fully developed females (> = 50 kg) and females with a lower weight (< 50 kg).

Rainfall data was gathered by the National Institute of Meteorology of the Ministry of the Environment at Aldeacentenera, the nearest station to the study area. With 22 years of data, we established a rainfall average (528.40 ± 165.37 l/m^2; mean ± SD). For every year of study, the rainfall was compared to the global average, considering the years to be dry or rainy depending on whether the gathered rain was above or below the global average. Four years were above average and thus, they were considered rainy (1996, 1997, 2000 and 2001); the rest (1994, 1995, 1998 and 1999) were considered dry. The average rainfall (mean ± SD) for the different seasons was 133.85 ± 44.04 l/m^2 for spring; 33.49 ± 36.46 l/m^2 for summer; 182.19 ± 101.23 l/m^2 for autumn; and 180.29 ± 23.78 l/m^2 for winter.

A total of 638 wild boar females were hunted. These hunts took place from 1994–95 to 2001–02. 454 in rainy years and 184 in dry ones. December was the month when the greatest number of females were studied (193) followed by February (173), January (113), November (119) and finally, October (40).

The analyses referring to rainfall were made throughout the year and detailed by seasons. In order to estimate differences in litter size between two female groups, we used an Impaired Students Test. The reproductive phenology valuation was tested by the non-parametric Kolomogorov-Smirnov Test. Finally, the Chi-square Test was employed in analysing of number of pregnant females and also in sex-ratio analysis, not only when we measured the litter as a whole, but also in the sex valuation of the heaviest piglet within the litter. All analyses were performed using the Statistica 5.1 package (97 version).

Results

Number of pregnant females

There were 208 pregnant females (32.6%). Differences were not found in the percentage of pregnant females depending on whether they weighed between 30–50 kg or more (Table 1). Gestation was not more frequent in the heavier females (129) than in those of lighter weight (79) ($\chi^2 = 2.77$, P=0.09).

Table 1. Distribution of pregnant and non-pregnant females with relation to body weight.

	Pregnant	Non-pregnant
Weight		
50 +	129 (41.2%)	184 (58.8%)
30–50 kg	79 (34.2%)	152 (65.8%)
0–30	0 (0%)	94 (100%)
Total	208	430

In the whole population, the number of pregnant animals was higher in rainy years than dry ones ($\chi^2 = 4.20$, P = 0.04). This was also the case when we only considered females less than 1.5 years old ($\chi^2 = 5.01$, P = 0.02) (Table 2).

Table 2. Distribution of pregnant and non-pregnant females with relation to the characteristics of the year (rainy or dry) and age group.

	Pregnant	Non-pregnant
All age classes		
Dry years	127 (30%)	327 (70%)
Rainy years	81 (44%)	103 (56%)
Total	208	430
Only less than 2 years old		
Dry years	19 (15%)	108 (85%)
Rainy years	36 (28%)	92 (72%)
Total	55	238

Litter size

The average number of foetuses was 3.75 ± 1.23 (± SD; max=7). In the whole population, there are no differences in litter size based on rainfall. The litter was no higher in rainy years than dry ones (dry year = 3.75 ± 1.12; rainy year: 3.76 ± 1.50, Impaired Students t = -0.022, df = 185, P = 0.981). In the same way, but testing for different seasons, litter size was not positively related to the summer (dry year: 3.64 ± 1.36; rainy year: 3.82 ± 1.169, Impaired Students t = 1.005, df = 185, P = 0.316), autumn (dry year: 3.72 ± 1.28; rainy year: 3.78 ± 1.22, Impaired

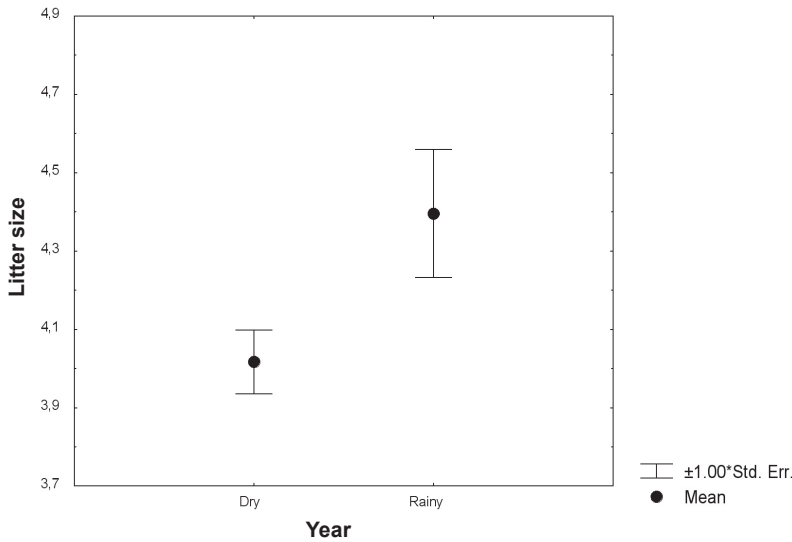

Fig. 1. Litter size for females with more than three piglets in dry and rainy years.

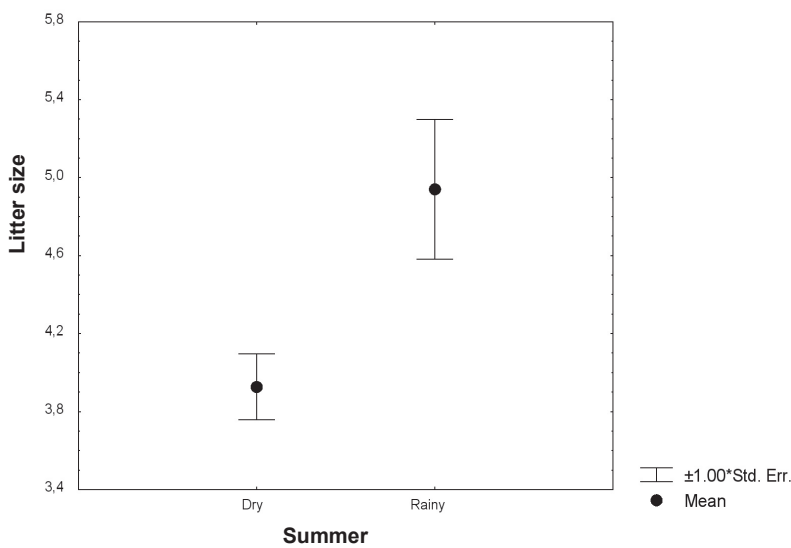

Fig. 2. Litter size for females over 2.5 years in dry and rainy summer.

Students t = -0.405, df = 185, P = 0.685), and winter (dry year: 3.72 ± 1.28; rainy year: 3.79 ± 1.22, Impaired Students t = -0.405, df = 185, P = 0.685) rainfall.

For females with a high reproductive effort (a litter with three or more foetuses), we obtained a higher litter size in rainy years (4.39 ± 1.07) than in dry ones (4.00 ± 0.88) (Impaired Students t = -2.306; df = 156; P = 0,022. Fig. 1). It was not observed in females over 2.5 years of age (dry 4.11 ± 1.18; rainy years 4.57 ± 1.55; Impaired Students t = -1.164, df = 56, P = 0.24), nor females under 2.5 years (dry 3.47 ± 1.01; rainy 3.42 ± 1.20, Impaired Students t = 0.597, df = 81, P = 0.84) or when the female weighed more than 50 kg (3.87 ± 1.14; 3.76 ± 1.49, Impaired Students t = 0.477, df = 138, P = 0.638).

Nevertheless, we found the same significant difference testing females above 2.5 years of age (dry 3.92 ± 1.08; rainy 4.94 ± 1.47, Impaired Students t = -2.91, df = 56, P = 0.005, Fig. 2) when analysing this litter size based on summer rainfall.

Period of conception

Dry summers and autumns show an early period of conception (Fig. 3a, Summer: Kolmogorov-Smirnov Test: Max Neg Difference: 0.00; Max Pos Difference: 0.247, $P < 0.05$. Fig. 3b, Autumn: Kolmogorov-Smirnov Test: Max Neg Difference: -0.380; Max Pos Difference: 0.00, $P < 0.001$). This is valid not only for females under 2.5 years (Summer: Kolmogorov-Smirnov Test: Max Neg Difference: 0.00; Max Pos Difference: 0.370, $P < 0.05$; Autumn: Kolmogorov-Smirnov Test: Max Neg Difference: -0,40; Max Pos Difference: 0.00, $P < 0.025$) but also for those over that age (Summer: Kolmogorov-Smirnov Test: Max Neg Difference: 0.00; Max Pos Difference: 0.54, $p<0.025$. Autumn: Kolmogorov-Smirnov Test: Max Neg Difference: -0.40; Max Pos Difference: 0.00, $P < 0.025$)

In contrast, when analysing all seasons as a whole, annual precipitations have not shown an influence on this conception phenology. (Kolmogorov-Smirnov Test: Max Neg Difference: 0.250; Max Pos Difference: 0.07, $P > 0.05$).

Foetal sex ratio

The foetal sex ratio was 1.46:1 (males: females); thus, there was a certain preference for the production of males, although this relationship did not differ from Fisher's hypothesis (1930) ($\chi^2 = 0.32$, P = 0.57). There was no variation between dry and rainy years (dry years: 1.45:1; rainy years 1.35:1, $\chi^2 = 2.08$, P = 0.14).

No differences were recorded in this value for years with rainier than average autumns and summers. In these cases, there was no tendency to a higher number of males within the litter with respect to the initial proportion (For autumn: dry autumns: 1:1.43; rainy autumns: 1:1.46, $\chi^2 = 2.56$, P = 0.23. For summer: dry summer: 1:1.43, rainy summer 1:1.46, $\chi^2 = 2.66$, P = 0.54)

Sex of the heaviest piglets in each litter

The sex of the heaviest foetuses in the litter was male (3.8:1, $\chi^2 = 27.73$, P = 0.001). Furthermore, we observed a significant difference for this parameter when testing the variation between dry and rainy autumns, the number of males being greater in the dry season (dry autumn: 6.8:1; rainy autumn: 2.46:1, $\chi^2 = 5.00$, P = 0.025, Fig. 4).

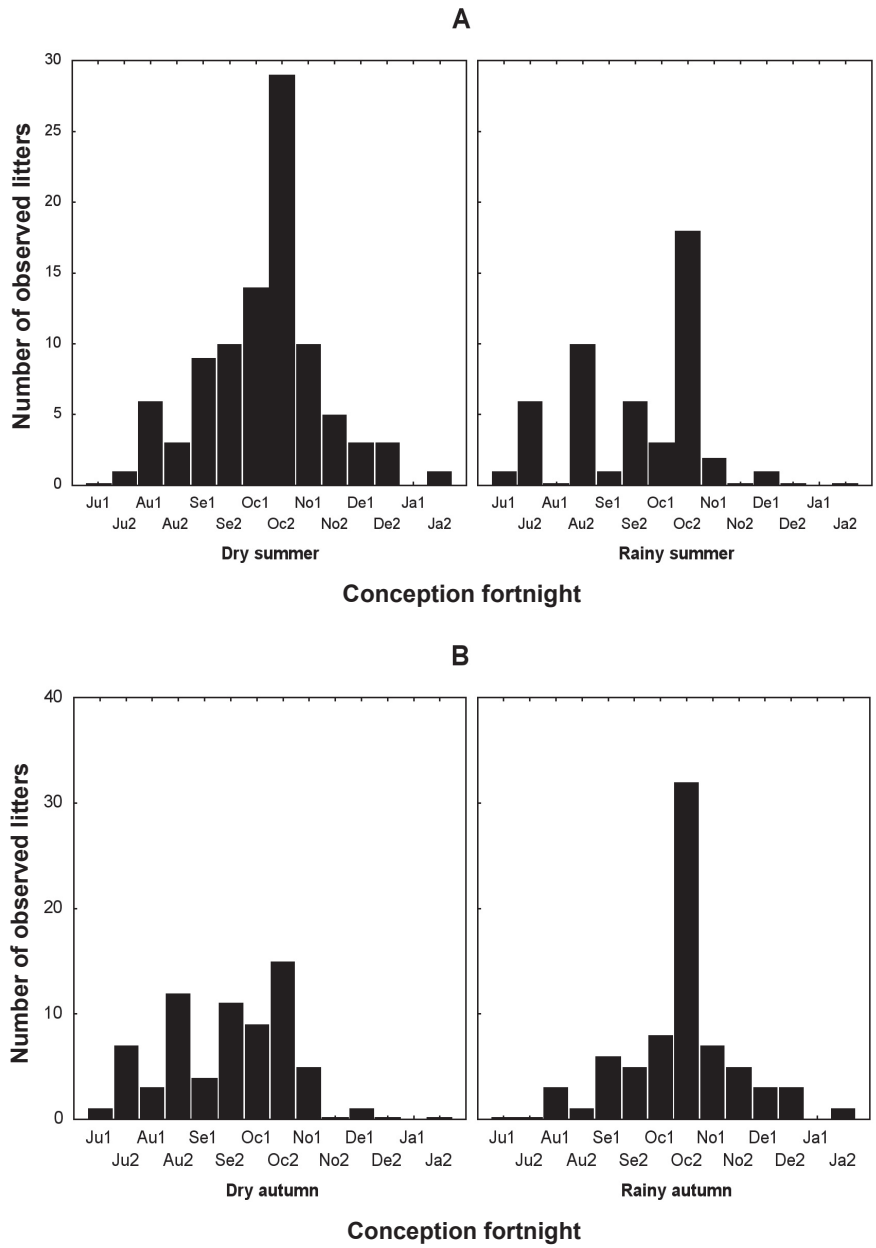

Fig. 3. Conception fortnight in terms of dry or rainy summer (A), Conception fortnight in terms of dry or rainy autumn (B).

Discussion

Our studies point to a relationship between environmental conditions, measured as rainfall, and several reproductive variables in wild boar. These findings are the same as those described by other authors for different species of ungulates -for example, P e t t o r e l l i et al.

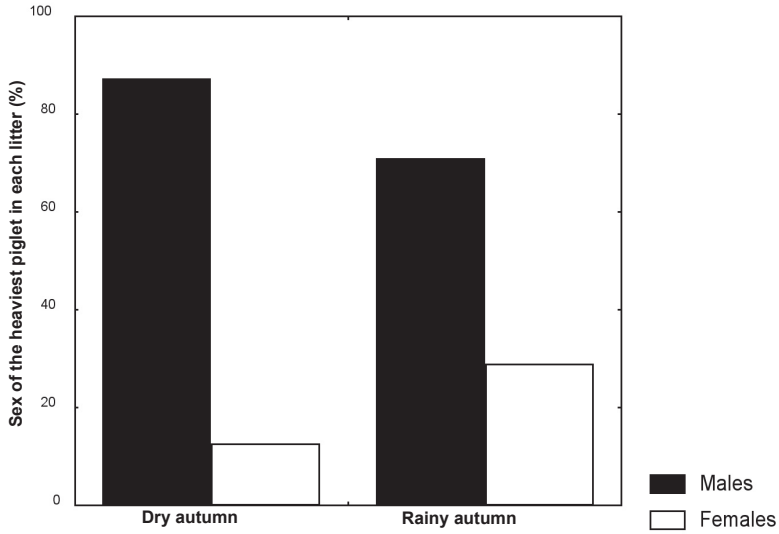

Fig. 4. Male and females proportion of heaviest piglets in dry and rainy autumns.

(2001), Gaillard et al**.** (1997), Wauters et al. (1995), Mateos-Quesada & Carranza (2000)-.

So, we found a link between the environmental conditions and the number of pregnant females. We agree with other researchers such as Sáez-Royuela (1987), who finds a relationship between habitats with abundant food and the number of pregnant females, or Santos (2002), who also confirms this effect in Portugal and especially, Massei et al. (1996), whose study was located in a Mediterranean area. All of them show similar facts to the data we obtained regarding this influence on the number of pregnant females. Our outcome, as Massei et al. (1996) and Fernández-Llario & Carranza (2000) point out, shows oscillations in the proportion of pregnant females according to whether the year was good or not (90%–18%). In this work, we have detected that in dry years, the only females that usually breed are those that have completed their corporal development, while in rainy years, the percentage of pregnant adult females increases.

With regard to the seasonality of conception, we found early conceptions in dry years. This fact may result from the age influence on the breeding females. Different studies have indicated that older females are the earliest breeding boars, as they reach the necessary physical requirements sooner than other younger females (Fernández-Llario & Mateos-Quesada 1998, Santos 2002).

Regarding litter size**,** our results indicate an evident variation of this parameter. It seems that in rainy years the amount of food available is greater, which could be related to the larger litter size we found. It is possible that our results show a major embryonic mortality in the years with scarce rainfall, since in the wild boar, the number of follicles produced is usually double the number of foetus born in normal circumstances.

Continuing with the analysis of litter, the percentage of males and females is almost identical, as it has already been described for this species (Mauget 1980, Dzieciolowski & Clarke 1989, Ahmad et al. 1995, Fernández-Llario et al. 1999, Santos 2002). However, we have observed that the heaviest foetus in each litter is generally male.

This fact has a relevant importance in wild boar due to strong competition in the litter, since the heaviest piglet usually has more possibilities to reach a better mammary gland, thus obtaining more milk. In this study, we noticed that this is even clearer when referring to dry years, when it is possible that only the dominant females are breeding.

These results lead us to value the importance of female wild boar dominance in social groups. It is possible that hierarchy affects many aspects of reproductive biology, such as the selection of an appropriate breeding place, the best places to give birth or a heavier weight in their piglets. For male wild boar, this advantage has already been described and could be related to access to females (Singer & Ackerman 1981).

Finally, we believe that this higher quantity of male piglets in dry years can be explained in our case by Silk's hypothesis (1983). Female wild boar could prefer having a piglet that will leave the family unit when reaching adult state, and thus avoid strong competition with the rest of the litter. However, this aspect of wild boar reproductive biology needs more research than other aspects, it appears that the piglet selection strategies could be adjusting to Trivers & Willard's ideas (1973).

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