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Reproductive and demographic parameters in Sardinian wild boar, *Sus scrofa meridionalis*

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Abstract. In Sardinia island (Central Italy) the wild boar is originally present with an endemic subspecies, *Sus scrofa meridionalis*. To evaluate its demographic and reproductive characteristics, we analysed data on the harvest bags of two hunting seasons (2011-2012 and 2012-2013) in the province of Olbia-Tempio (North-Eastern Sardinia). We collected data of 325 Sardinian wild boars. Sex-ratio did not differ significantly from the theoretical distribution 1:1. We examined 175 females; thirty-five percent of them were in breeding condition, with 56 pregnant and five lactating females. Gestation was more frequent in heavier females than in the lighter ones. The mean number of foetuses per litter was 4.2 ± 1.2 (range two-seven), with no differences between the hunting seasons. There was an evidence of seasonality in reproduction period; the mating season appeared to occur primarily in late autumn and in winter, whereas farrowing mainly occurred from March to May (56 % of births), with a minimum in summer (5 % of births).

Key words: breeding biology, litter size, hunting bags

Introduction

At the beginning of the 1950s wild boar (*Sus scrofa*) in Italy was reduced to some fragmented, small populations. From the 1960s onwards, however, because of its adaptability to a wide range of environmental conditions, a great reproductive capacity, repeated releases for hunting purposes and escapes of individuals from farming fences, the wild boar expanded rapidly its range, occupying all the hilly and mountainous areas of the Italian peninsula and, more recently, also several zones of the Alps (Merli & Meriggi 2006, Monaco et al. 2006). Moreover, it is present on many Italian islands, including Sicily, Elba, Sardinia, La Maddalena, Caprera, Asinara and Sant'Antioco (Carnevali et al. 2009, Apollonio et al. 2012).

In Sardinia the wild boar is present with an endemic subspecies, the Sardinian wild boar *Sus scrofa meridionalis*. The Sardinian population probably originated in the early Neolithic, when pigs escaped from man's control and became feral (Scandura et al. 2011); the evolution in isolation led them to diverge from continental populations, both morphologically (e.g. small body size, small size of teeth) (Apollonio et al. 1988, Albarella et al. 2009) and genetically (Scandura et al. 2008, 2011). Today the Sardinian wild boar is common and widespread in the whole island, and frequents different habitats including woodlands, low Mediterranean maquis, garrigue, untilled lands, pastures and cultivated areas (Apollonio et al. 2012). The main threat for the conservation of the subspecies is represented by the crossbreeding with continental wild boars and domestic pigs. The Sardinian wild boar, in fact, shows the effects of a strong extent of illegal introductions and gene introgressions, mainly concerning the Eastern part of the island (Scandura et al. 2011). An adequate wildlife sustainable management requires an understanding of the species biology, so that human activities can be conveniently exploited and carried on (Bieber & Ruf 2005, Fonseca et al. 2011). The wild boar represents a critical issue in the social life because it causes traffic accidents due to collisions, alters the structure of ecosystems, affects plant communities, damages agricultural crops and can transmit diseases to livestock and humans (e.g. Rosell et al. 2001, Gortázar et al. 2007, Bueno et al. 2009, Puerta-Piñero et al. 2012, Ficetola et al. 2014). Reproduction is an important factor to consider in defining management strategies, because it directly affects the dynamics of wild populations (Maillard & Fournier 2004). Compared to other European ungulates, the wild boar has a greater reproductive

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capacity: it reaches sexual maturity earlier (in females it is achieved between five and ten months of age) (Ahmad et al. 1995, Herrero et al. 2008, Fonseca et al. 2011), has a relatively short gestation period (about four months) (Rosell et al. 2001) and a higher litter size, with mean values ranging from three to seven piglets per litter, increasing from Southern to Northern Europe (for details see the review of Bywater et al. (2010)). Nevertheless, other factors, like environmental conditions (e.g. climate, food availability), the density of populations, the level of hybridization with domestic pigs and the female physical condition can influence the fertility of females, the litter size and the reproductive phenology (Maillard & Fournier 2004, Bieber & Ruf 2005, Fernández-Llario & Mateos-Quesada 2005, Cutini et al. 2013).

To our knowledge, there are no published data on demographic parameters and reproductive biology of *Sus scrofa meridionalis*. In this study we analysed a Sardinian wild boar population to (i) analyse the population structure (ii) evaluate the reproductive performance of the subspecies (percentage of breeding females and litter size) and (ii) determine the seasonality of conceptions and births.

Study Area

The study was carried out in Sardinia, in the province of Olbia-Tempio (Central Italy), which extends for 3404 km^2 with altitude ranging from sea level to 1359 m a.s.l. (Mount Limbara) (Fig. 1). The climate is Mediterranean, with a mean yearly temperature of 14.7 °C (minimum 6.8 °C in December, maximum 22.8 °C in July) and a mean yearly precipitation of 832 mm (minimum 8 mm in July, maximum 126 mm in December) (Meriggi et al. 2012). Vegetation is typically Mediterranean; the area is covered by garrigue and low maquis with *Phillyrea* sp., cistus *Cistus* spp., lentisk *Pistacia lentiscus* and heather *Erica arborea* (34.0 %), deciduous woods dominated by holm-oak (*Quercus ilex*) and cork oak (*Quercus suber*) (18.7 %), arable lands (15.2 %), grasslands (13.2 %), rocky areas (6.0 %) and urban areas (5.5 %). In the study area the wild boar is widespread and abundant: in 2012, after battue censuses, it was estimated a density of about 14 individuals per km^2 (Meriggi et al. 2013).

Material and Methods

The research has been focused on the harvest bags of two hunting seasons (2011-2012 and 2012-2013). In Sardinia hunting is performed from November to January, for a total of about 15-18 days per season, by drives with hunting dogs. The hunt takes place in areas of approximately 35-90 hectares; 15-20 hunters, armed and located in fixed positions, wait for the arrival of boars that are moved from their resting places by teams of dogs guided by four-six persons. The possibility of using hunting bags to draw conclusions concerning biology of the Sardinian wild boar is useful, since hunted animals are selected at random.

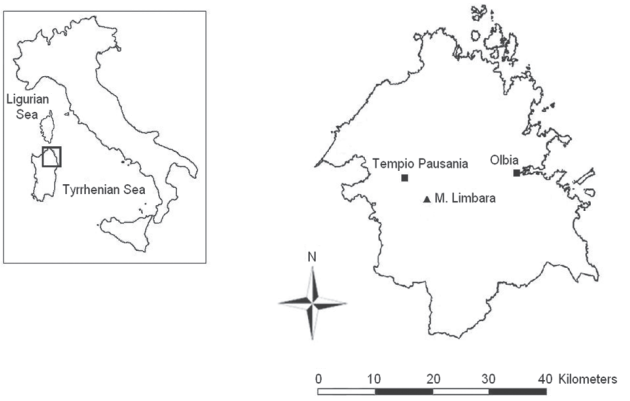

Fig. 1. Location of the study area (province of Olbia-Tempio, NE Sardinia, Central Italy).

Hunted boars were sexed, measured (from snout to tail), weighed and aged according to tooth eruption (Boitani & Mattei 1992). To analyse the population structure in the study area, data were pooled in three classes (1 – piglets: 0-12 months, 2 – second year: 13-24 months, 3 – adults: > 24 months). For the whole sample and for every class of age the sex-ratio was compared with the theoretical distribution 1:1 using a goodness-of-fit Chi-square test with permutation (Moretti 1995, Rosell et al. 2012).

We evaluated the percentage of pregnant and lactating females in the population; a Chi-square test for contingency tables with permutation was performed to verify the existence of differences between the percentages of the two hunting seasons. We evaluated whether environmental characteristics were related with the percentage of pregnant females. We gathered rainfall data for 2011 and 2012 from "Sardegna Clima ONLUS" (http://www.sardegna-clima.it); rainfalls in 2012 were more abundant than in 2011 (mean ± standard deviation SD 2011: 721.6 ± 125.7 mm, 2012: 790.5 ± 153.8 mm). Rainfall is one of the most outstanding variables in the production of grass and acorns (Alejano et al. 2008, Koenig et al. 2013), the main source of food for the wild boar in southern Europe (Massei et al. 1996, Herrero et al. 2005), so we hypothesize the presence of a higher percentage of breeding females in 2012-2013 season than in the previous one.

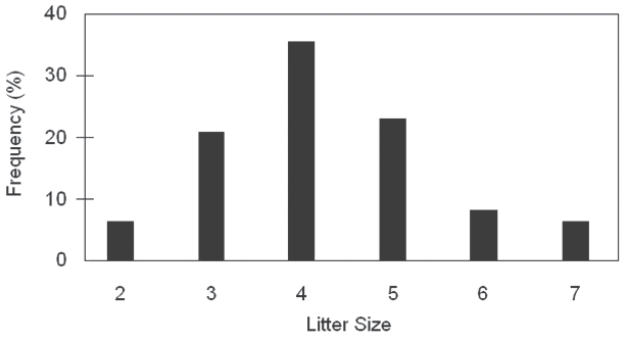

Fig. 2. Frequency distribution of litter size.

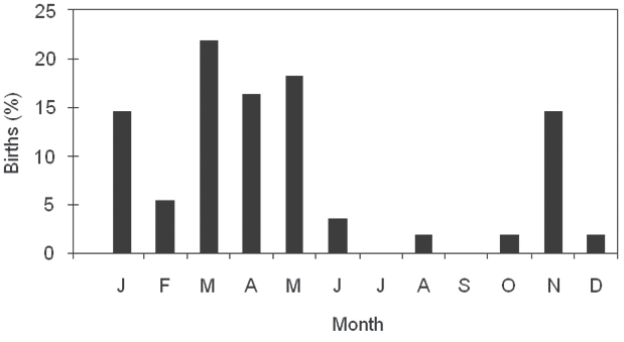

Fig. 3. Monthly distribution of births, determined from the age of animals at death.

birth distribution analyses, to obtain accurate data for every month (Clarke et al. 1992, Boitani et al. 1995). It was tested the null hypothesis H_0 that birth frequency was uniform throughout the year; birth dates were grouped in four periods, spring (March-May), summer (June-August), autumn (September-November) and winter (December-February), and the existence of differences in the frequency of events per period was verified applying a goodness-of-fit Chi-square test (Manly et al. 2002, Carbajal-Borges et al. 2014).
For all tests, significance was assumed when $p < 0.05$. All analyses were carried out using R software version 3.0.1 (R Development Core Team 2013).

Results

During the two hunting seasons we collected 325 Sardinian wild boars: 175 females, 141 males and nine undetermined. Both cumulating all the animals and considering every class of age, sex-ratio was balanced; it was nearly significantly female-biased for cumulated data and for piglets, and nearly significantly male-biased for second-year boars. The age composition of 243 animals (82 of the total were of unknown age) was 40.3 % from 1 to 12 months, 22.7 % from 13 to 24 months and 37.0 % > 24 months (Table 1).
Of 175 females analysed, 114 (65.1 %) were not in reproduction, 56 (32.0 %) were pregnant and five

Table 1. Age composition and sex-ratio in Sardinian wild boars collected in two hunting seasons from the province of Olbia-Tempio.

Age (months)	Total	Undetermined sex	Males	Females	Sex-ratio	P
1-12	98	0	40	58	0.7:1	0.07
13-24	55	0	34	21	1.6:1	0.08
> 24	90	0	38	52	0.7:1	0.14
Unknown age	82	9	29	44	-	-
Total	325	9	141	175	0.8:1	0.06

From the pregnant females we collected data on the number of foetuses and we calculated the litter size as the mean number of foetuses found in the uteri. The existence of differences in the average litter size between the two hunting seasons was tested using the non parametric Mann-Whitney test, as the assumption of data normality was not satisfied (Kolmogorov-Smirnov Normality test, $p = 0.04$).
Then, females were divided into two different groups based on body development: fully developed females (> = 35 kg) and females with a lower weight (< 35 kg), and a Chi-square test for contingency tables with permutation was used to verify if the gestation was more frequent in the heavier females than in the lighter ones (Fernández-Llario & Mateos-Quesada 2005).
Birth dates were obtained from the age of the animals at death. In order to reduce the age assessment error, only the animals up to 24 months old were considered for

Table 2. Distribution of pregnant and non-pregnant females with relation to the hunting season (n = 175).

Hunting season	Pregnant	Non-pregnant
2011-2012	14 (20.9 %)	53 (79.1 %)
2012-2013	42 (38.9 %)	66 (61.1 %)

Table 3. Distribution of pregnant and non-pregnant females with relation to body weight (n = 117).

Weight	Pregnant	Non-pregnant
> = 35 kg	28 (51.8 %)	26 (48.2 %)
< 35 kg	12 (19.0 %)	51 (81.0 %)

(2.9 %) were lactating. Pregnant females were more abundant in the hunting season 2012-2013 than in 2011-2012 ($\chi^2 = 5.46$, df = 1, $p = 0.02$) (Table 2).
The weight of 117 females was measured; the mean weight was 34.8 (±12.0 SD) kg, with a minimum of 7 kg and a maximum of 65 kg. Gestation was more frequent in heavier females than in the lighter ones ($\chi^2 = 43.09$, df = 1, $p < 0.001$) (Table 3).
Litter size varied between two and seven foetuses (mean: 4.2 ± 1.2 SD), with three to five being the most frequent number of foetuses per female (Fig. 2). No differences were observed in the mean number of foetuses between the two hunting seasons (2011-2012 = 4.3 ± 1.4 SD; 2012-2013 = 4.2 ± 1.2 SD; Mann-Whitney test, $p = 0.85$).
It was rejected the null hypothesis H_0 that birth distribution was uniform throughout the year: births occurred during whole year, but it was recorded a peak in spring (56.4 % of events) and a minimum in summer (5.4 % of events) (Chi-square test: $\chi^2 = 31.91$, df = 3, $p < 0.001$) (Fig. 3).

Discussion

Our study aims to describe the reproduction and some demographic parameters in the Sardinian wild boar. The age pyramid has a broad base, which is true of *Sus scrofa* populations elsewhere, independent of the sampling method used, direct observations (Massei et al. 1997, Merta et al. 2015) or hunting bags from non-selective collective hunts (Merli & Meriggi 2006, Herrero et al. 2008, Merta et al. 2015). Typically, wild boar populations consist predominantly of young animals. The life history of the wild boar is unusual among ungulates, being more typical of short-lived vertebrates than the long-lived ones (Focardi et al. 2008); it is characterized by high reproductive rates and a high mortality of young animals in the first year of life, with the consequence of a relevant annual turnover of individuals (Herrero et al. 2008, Servanty et al. 2011). Moreover, the population structure in our study area is influenced by the absence of large carnivores; in fact, the presence of predators such as wolves *Canis lupus* can change the age composition of a wild boar population, because they prey preferentially on less-than-a-year individuals (Barja 2009, Mattioli et al. 2011). The sex-ratio presents many similarities with others described in Asia and in the rest of Europe (Ahmad et al. 1995, Fernández-Llario & Mateos-Quesada 2003, Cahill & Llimona 2004, Fonseca et al. 2011, Merta et al. 2015), with a higher proportion of females, with the exception only of second-year individuals. In hunted populations it has been suggested that mortality rates can be higher in adult females (Cahill & Llimona 2004); females live in matriarchal groups composed of relative females and young of the year (Poteaux et al. 2009), and they are considered to be more vulnerable and exposed to disturbance during hunting battues than adult males (Scillitani et al. 2010, Säid et al. 2012). The importance of second-year males in the population might be due to their greater mobility and, consequently, their increased vulnerability to hunting (Herrero et al. 2008), or to the hunting destructuring process (Massolo & Mazzoni Della Stella 2006).
Differences in the percentage of pregnant females were found between the two hunting seasons. Abundant rainfalls recorded in 2012 probably had a positive effect on the higher percentage of pregnant females observed in 2012-2013, because they ensured a higher production of acorns, the main source of food for the Sardinian wild boar (Pinna et al. 2007). Our findings are similar to those described by other authors for different species of ungulates (e.g. Mateos-Quesada & Carranza 2000, Pettorelli et al. 2001, Fernández-Llario & Mateos-Quesada 2005).
The mean litter size observed in this study for the Sardinian wild boar is comparable with values found in other wild boar Mediterranean populations (e.g. Abáigar 1992, Fonseca et al. 2004, Fernández-Llario & Mateos-Quesada 2005, Focardi et al. 2008, Herrero et al. 2008, Fonseca et al. 2011), but is lower than values recorded in Central and Northern Europe, where mean litters of more than five foetuses per female have been reported (e.g. Náhlik & Sandor 2003, Gethöffer et al. 2007, Servanty et al. 2007). Our data fit with the pattern described by Bywater et al. (2010); they highlighted a strong positive effect of latitude on mean litter size of wild boar within Europe, explaining this latitudinal gradient with different seasonal fluctuations in food availability between high and low latitudes.
The reproductive phenology of Sardinian wild boar showed a marked seasonal breeding, with the main conception period in autumn and winter and births clustered chiefly in spring, with a minimum in summer. The spring peak observed agrees with pattern observed both in other Mediterranean populations (Fonseca et al. 2011, Rosell et al. 2012) and in Central Europe (Moretti 1995), whereas the low number of summer births is typical of Mediterranean countries (Fonseca et al. 2004, Rosell et al. 2012). Birth frequency distribution might be determined by resources availability throughout the year: in Southern Europe in fact, summer corresponds

with the period of lowest availability of food and water, and this lack of resources can affect negatively reproductive parameters, reducing the percentage of breeding females, the number of births and the mean litter size (Massei et al. 1996, Fernández-Llario & Mateos-Quesada 2005, Fonseca et al. 2011).

Data obtained from the analysis of hunting bags could have a potential application to Sardinian wild boar management. In Northern Sardinia the major problems linked to the presence of Sardinian wild boar are collisions with vehicles, damage to croplands and the negative effect of trampling on endangered endemic plants (Pisanu et al. 2012, Meriggi et al. 2013). For all these reasons, management strategies should combine the reduction of conflicts with humans, the maintenance of plant biodiversity and the conservation of the endemic subspecies *Sus scrofa meridionalis*.

In our population larger females gave a strong contribution to population growth: they were reproductive in higher proportion than the lighter ones, presumably indicating that the amount of resources available for reproduction increases once body development has reached its peak (Fernández-Llario & Mateos-Quesada 1998, Servanty et al. 2009). Qualitative management targeting particular classes of individuals might reduce the size of populations, because demographic performance, and hence contribution on population growth, depends on body weight (Gamelon et al. 2012). Gamelon et al. (2012) proposed a body weight-structured model to develop management rules for wild boar across Europe, and they demonstrate that a slight increase of the hunting pressure on medium-sized and large females could reliably control population growth. In accordance with their conclusions, we propose a selective culling of medium and large females to keep the Sardinian population within sustainable values of density.

Preventing crossbreeding with domestic pigs and continental boars is essential for the maintenance of the peculiar genetic composition of the Sardinian wild boar. Pigs in Sardinia are reared in semi-wild conditions, and crossbreeding with the wild form is possible (Scandura et al. 2008). Moreover, the prevention of crossbreeding is important to avoid the spreading of the *Trichinella* infection among Sardinian boars. In last years, in fact, it has been detected the presence of *Trichinella britovi* in few free-ranging pigs in Central Sardinia, not far from our study area (Pozio et al. 2009).

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