Eurasian wild boar, *Sus scrofa*

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Brief description of the species/group of species: basic ecology and its relevance from an epidemiological perspective

The wild boar (*Sus scrofa*) is a widespread native Palaearctic ungulate whose population has sharply increased in the last decades. It is one of the terrestrial mammals with the widest geographical range in Europe (Apollonio et al. 2010). Both through natural expansion and human (re)introductions, the species now occurs in all continents except Antarctica, and on many oceanic islands (Mitchell-Jones et al. 1999; Oliver & Leus 2008).

It occupies a wide variety of habitats, from semi-desert to tropical rain forests or temperate woodlands (e.g. Oliver & Leus 2008), and often uses agricultural land to forage (e.g. Herrero et al. 2006). Its ecological plasticity and growing population trends generate human-ungulate conflicts (Putman et al. 2011), as wild boar may cause significant damage to crops and natural vegetation (e.g. Schley et al. 2008; Bueno et al. 2009), biodiversity (Carpio et al. 2014), road traffic (e.g. Lagos et al. 2012) and livestock and public health (e.g. Gortázar et al. 2007).

This card refers specifically to Eurasian wild boar and not feral domestic swine, but the methods would apply equally to feral pigs. From an epidemiological perspective, wild boar (and feral pigs) are reservoirs for many viral, bacterial and parasitic infections (e.g. Ruiz-Fons et al. 2008).

Recommended method(s) for most accurate population estimation

The estimation of wild boar population density is a difficult task. Traditional methods are neither precise nor accurate enough as for being considered as a gold standard. Methods based on direct observation are limited due to the nocturnal habits of the species. Thus, in this section we are highlighting methods that are not yet well assessed but that, according to the pioneer experiences on this species and their success in monitoring other ungulates, are considered as the most promising tools for wild boar monitoring. One of these methods is the nocturnal line transect using thermal imaging (Franzetti et al. 2012; but see Gill & Brandt 2010). This is a highly demanding method in terms of effort and budget and thus, currently, it is scarcely applied outside the research (for details see Franzetti et al. 2012). Another potentially relevant method is the use of camera trapping to estimate population density without the need for individual recognition (for details see Rowcliffe et al. 2008; Rovero & Marshall 2009).

Mini-review of methods applied in Europe

General reviews

A review was recently published on methods to monitor wild boar (and feral pig) populations (Engeman et al. 2013). Comparisons of several methods have taken place mostly in Central Europe and the Iberian Peninsula (Acevedo et al. 2007; Briederman 2009; Plhal et al. 2011). Most were based on indirect methods, but some focused on the application of direct methods to estimate wild boar population density (e.g. Focardi et al. 2002; Franzetti et al. 2012).

Direct methods (i.e. based on the direct observation of animals)

- *Line transects*: In woodlands, line transect methods are not easily applied and they are usually applied if animals are attracted to open space, for example to feeders. The absence of a reflecting tapetum lucidum makes spotlight counts more difficult as compared to cervids. Nevertheless, in Italy

Franzetti et al. (2012) successfully solved this problem by using infrared cameras. Even if the method works well in Italy, it was suggested that using infrared technologies wild boar detection decreases as distance to observer increases (Gill & Brandt 2010), and thus more efforts are needed for a broader use of this method. The price of new-generation infrared cameras is now more attainable which can increase the cost-effectiveness and applicability of this method once it is fine-tuned.

- *Camera trapping*: Indirect observation of animals with camera traps was recently identified as a promising method to estimate an index of abundance (Rovero & Marshall 2009) and population density, even without the need of individual identification (Rowcliffe et al. 2008). This makes it different from traditional capture-recapture methodologies (Hebeisen et al. 2008). First experiences are available (Plhal et al. 2011), but the procedure needs refinement. Recently, using distance sampling, promising results were obtained applying camera trapping to estimate population density without the need for individual recognition (Gómez-Alfaro et al. in prep.). Further studies are required to define an adequate camera-trapping protocol to monitor wild boar populations, for which a precise data on wild boar movement parameters in a range of different situations in the European context need to be gathered.

- *Drive counts*: Drive counts (e.g. Borkowski et al. 2011) are frequently used to estimate population densities in ungulates inhabiting forested areas. Hunters can be used as experienced observers and therefore the hunting activity, if carried out by instructed and motivated personel, can be a cost-effective alternative to monitor ungulates (e.g. Mysterud et al. 2007). For instance, drive counts by hunters is a method currently used to monitor wild boar population in Atlantic Spain and the Czech Republic (Plhal et al. 2010; Segura et al. 2014).

<u>Indirect methods (i.e. based on the detection of presence signs, but not animals)</u>

- *Pellet counts*: Pellet counts are frequently used to monitor wildlife species. There are lots of methods based on counting the number of pellets or their frequency, along transects or in plots. Some of them are used for wild boar (e.g. Massei et al. 1998). One method successfully evaluated for wild boar is the frequency of feces found on linear transects (Vicente et al. 2004; Acevedo et al. 2007). A proxy of the population aggregation can also be estimated from this method by statistically analyzing the dispersion of feces along the transects (Acevedo et al. 2007). Population abundance and aggregation are two key parameters for epidemiology. Therefore, this method is widely applied in epidemiological studies. Nonetheless, variations of dung persistence rate, which can be very local, need to be assessed in order to make results comparable and to be converted into estimates of wild boar population density.

Pellets can be collected and genetically analyzed for individual genotyping, providing an indirect way to count and indentify individuals in a given population (Broquet et al. 2007). Ebert et al. (2012) developed a first experience with wild boar under a mark-recapture framework. Although costs for DNA analyses have been decreasing in the last years, analyses of multiple samples (as requested to apply mark-recapture approaches) are time-consuming and expensive and therefore this method is scarcely used for wild boar management.

- *Snow tracking*: Transects on snow covered ground have been used to evaluate population abundance and density (e.g. Plhal et al. 2011; Bobek et al. 2014) and could be used, using footprint dimension, also to estimate population structure (Briederman 2009).

<u>Hunting bags (i.e. indices based on data derived from hunting activities)</u>

In hunted populations, bag data analysis (number, sex and age) remains a valid and suitable method to evaluate abundance and also population dynamics and structure. Wild boar age can be calculated based on tooth eruption, and records of reproductive parameters (e.g. number of foetuses) are valuable proxies of population dynamics (e.g. Gethöffer et al. 2007); both parameters can be easily recorded from hunted animals.

On broader scales, hunting statistics can provide time trends on population abundance, but generally no data on actual density. The problems with hunting bags include bias due to (1) different hunting traditions and hunting methods; (2) changes in hunting effort, quotas and hunter saturation; and (3) variability due to non-hunted populations in urban and protected areas. To overcome these barriers, hunting effort should be maintained/standardized and properly defined. In Italy hunting statistics were widely explored by Boitani et al. (1995) and subsequently used to investigate long time-trend series of wild boar (Imperio et al. 2010). In the Iberian Peninsula hunting bag data of wild boar were correlated with indirect methods for a broad range of densities (Acevedo et al. 2007).

<u>Others (i.e. include other relevant methods – direct or indirect – applied or susceptible to be applied on the target species)</u>

Statistical modelling is another way to estimate wild boar population abundance. Modelling allows relating data on the species (presence/absence, abundance, fitness, etc.) with environmental variables in order to obtain an output that is related with the habitat suitability for the species (e.g. Honda &

Kawauchi 2011). Model predictions should be validated with independent data since there are several factors modulating that relation. In the context of epidemiological studies, the distribution of wild boar abundance in Spain was recently obtained using spatially explicit modelling procedures and hunting bag data (Bosch et al. 2012; Acevedo et al. 2014). Future attempts might explore combining modelling with alternative source data, such as camera trapping.

Determining the effective population size by genetics is possible if appropriate sampling and corrections based on population dynamics parameters are applied, nonetheless this approach is time demanding and relatively expensive (Luickart et al. 2010).

APHAEA protocol (for harmonization at large scale)

At large scales, i.e. regions or countries, hunting bag data are currently the only Europe-wide available index of relative wild boar abundance. Such data can be of use for time trend analyses (provided hunting effort is constant). However, hunting methods and available information are too variable and do not allow comparisons among countries. Good documentation to characterize the hunting effort should be available in order to improve data harmonization. At least, in addition to the number of hunted animals basic information should include: hunting days, total number of hunters and hunting modality.

Given the known limitations of hunting bag data, APHAEA therefore recommends using at local scale density estimations, based on scientifically robust and repeatable techniques such as thermal imaging and distance sampling, camera-trapping or drive counts, among others.

Although it is difficult to generalize for a broad range of settings, densities below 1 individual per square km will represent low densities in a European context; those between 1 and 5 wild boar per square km will represent medium densities; and those above this limit will represent high densities. This division, although arbitrary, has important implications for epidemiology and disease control.

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Tables

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Table 1. Peculiarities of the species that modulate the methods to be used.

Characteristic	Observations
Distribution	This species has one of the widest geographic distributions of all terrestrial mammals. Wide distribution in Europe, present in all countries except Cyprus, Iceland and Malta (Mitchell-Jones et al. 1999; Oliver & Leus 2008).
Population trends	Generally increasing throughout Europe (e.g. Saéz-Royuella & Tellería 1986; Apollonio et al. 2010; Keuling et al. 2013).
Density range	From 1 to over 20, exceptionally up to 90 per km2 (e.g. Melis et al. 2006; Acevedo et al. 2007; Plhal et al. 2011). Densities from 1 to 10 per km2 are usual in natural environment; densities of over 10 occur locally in feed-supplemented hunting estates or exceptionally favourable availability of natural or cultivated food.
Main habitat	From semi-desert to tropical rain forests or temperate woodlands (e.g. Oliver & Leus 2008).
Introduction-Releases	Translocations of wild boar are frequent in some countries – not in all regions is allowed – due to hunting interests. This includes trans-frontier movements of both farm reared and wild captured individuals (e.g. Fernandez-de-Mera et al 2003).
Activity rhythms	In general nocturnal with seasonal variation mainly in extreme environments.
Detectability	Low due to the harsh environment, nocturnal activity and lack of a reflectant tapetum lucidum.
Gregarism	Spatio-temporal segregation between sexes excepting piglets and the rutting season. They usually live in familiar group composed by a female and her progeny of the last 2-3 years with their offspring whilst males are solitary (e.g. Fernandez-Llario et al. 1996).

Table 2. Classification of the different methods (all cited in this species' review, incl. the recommended method(s) for most accurate results) based on desirable characteristics for monitoring populations from an epidemiological perspective (1- very low, 5-very high).

Method	Line transects (IR cameras)	Camera trapping (capture_ recapture)	Random encounter model (camera trapping)	Capture-Recapture	Kilometric abundanc e index	Hunting bags
Abundance / **D**ensity	D	A/D	A	D	A	A
Temporal / **S**patial trends	T/S	T/S	T/S	T/S	T	T/S
Info on population structure (Y/N)	y	Y	Y	y	y	n
Precision	5	5	5	5	2	4
Seasonal independence	2	5	1	4	2	2
Visibility independence	4	4	4	4	2	5
Effort effectiveness	1	4	4	2	2	5
Budget effectiveness	2	3	3	1	4	4
Ease of learning	2	4	2	1	5	5
Applicable at large scales	1	2	4	1	3	4
Useful at very low density	2	2	4	2	4	1
Useful at very high density	5	5	5	5	4	5