SCIENTIFIC REPORT OF EFSA

Evaluation of possible mitigation measures to prevent introduction and spread of African swine fever virus through wild boar[1]

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ABSTRACT

This scientific report has been prepared in response to a request for urgent scientific and technical assistance under Art 31 of Regulation (EC) No 178/2002, in relation to possible mitigation measures to prevent introduction and spread of African swine fever virus (ASFV). It was requested to assess the feasibility to drastically reduce the wild boar population by hunting or by the use of traps, and to assess if prevention of movement of wild boars by feeding or by artificial physical barriers reduces the risk of spread of ASFV. No evidence was found in scientific literature proving that wild boar populations can be drastically reduced by hunting or trapping in Europe. The main reasons are the adaptive behaviour of wild boar, compensatory growth of the population and the possible influx of wild boar from adjacent areas. Thus, drastic hunting is not a tool to reduce the risk for introduction and spread of ASFV in wild boar populations. Furthermore, wild boar density thresholds for introduction, spread and persistence of ASFV in the wild boar populations are currently impossible to establish, due to the uncertainty regarding the extent of the spread and maintenance of ASFV, the biases in population datasets, the complex population structures and dynamics. Furthermore, attempts to drastically reduce wild boar populations may even increase transmission and facilitate progressive geographical spread of ASFV, since intensive hunting pressure on wild boar populations leads to dispersion of groups and individuals. Artificial feeding of wild boar might increase the risk of ASFV spread. Fencing can restrict wild boar movements, however further knowledge of the ASF epidemiology and spatial distribution of wild boar is required to identify the areas where fencing could be used as one possible element of a control programme and to assess the feasibility of its implementation.

Key words

African swine fever, wild boar, introduction, spread, mitigation, hunting

[1] On request from the European Commission, Question EFSA-Q-2014-00149 approved on 14 March 2014.

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[3] Acknowledgement: EFSA wishes to thank the hearing experts: Christian Gortázar, Vittorio Guberti, Sophie Rossi, Jose Francisco Ruiz-Fons and Timothee Vergne, and the EFSA Animal Health and Welfare Panel member: Frank Koenen for reviewing this scientific output, and EFSA staff: Andrea Bau, Alessandro Broglia, Sofie Dhollander, Andrea Gervelmeyer, Andrey Gogin, Jane Richardson, Frank Verdonck and Didier Verloo for the support provided to this scientific output.

Suggested citation: European Food Safety Authority, 2014. Evaluation of possible mitigation measures to prevent introduction and spread of African swine fever virus through wild boar. EFSA Journal 2014;12(3):3616, 23 pp., doi:10.2903/j.efsa.2014.3616

Available online: www.efsa.europa.eu/efsajournal

SUMMARY

This scientific report has been prepared in response to a request for urgent scientific and technical assistance under Art 31 of Regulation (EC) No 178/2002, in relation to possible mitigation measures to prevent introduction and spread of African swine fever virus (ASFV). More specifically, it was requested to assess the feasibility to drastically reduce the wild boar population by hunting or by the use of traps, and to assess if prevention of movement of wild boars by feeding or by artificial physical barriers reduces the risk of spread of ASFV.

A review of the scientific literature on hunting and trapping of wild boar revealed that hunting and trapping has never achieved a drastic reduction in a wild boar population in Europe. Depopulation efforts can lead to adaptive behaviour of the hunted wild boar, compensatory growth of the population and the influx of wild boar from adjacent areas.

Introduction of ASFV through wild boar is a form of progressive spread of ASFV through the same wild boar meta-population, i.e., through direct or indirect contact transmission of ASFV between wild boar. Considering the above, drastic hunting is not a tool to reduce the risk for introduction and spread of ASFV in wild boar populations. Furthermore, wild boar density thresholds for introduction, spread and persistence of ASFV in the wild boar populations are impossible to establish. This is due to the uncertainty on the extent of the spread and maintenance of ASFV in wild boar populations, the bias in population datasets and the complex population structures and dynamics. If depopulation attempts were to be undertaken, these can even increase transmission and facilitate progressive geographical spread of ASFV. It is well known that intensive hunting pressure on wild boar population leads to dispersal of groups and individuals.

Artificial feeding of wild boar might rather increase than reduce the risk of ASFV spread. Fencing can restrict wild boar movement but the practical feasibility of implementing (emergency) fencing in North East Europe is not clear at the moment. Better knowledge on the ASF epidemiologic situation and spatial distribution of the wild boars is required to identify the areas where fencing could be used as one element of a control programme and to assess the feasibility of its implementation.

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Background as provided by the European Commission

At the end of January 2014 two African swine fever (ASF) cases were detected in the wild boar population in Lithuania, at the border with Belarus. After few days two further cases were reported in the wild boar in Poland, still in the border area with Belarus. The ASF virus detected in the wild boar in Lithuania has 100 % sequence homology with the one identified in Belarus in June 2013.

In Lithuania and Poland, measures to limit the spread of the disease were immediately implemented. In accordance with EU legislation an infected area has been established in both Member States, and within 90 days of the confirmation of the primary cases, the concerned Member States shall submit to the Commission a plan for the eradication of ASF from the feral pig population with the measures to be taken to eradicate the disease in the infected area, and to prevent its spread in non-affected areas.

However, the ASF epidemiological situation at the EU border is going to represent a threat to the EU livestock and a challenge for animal health risk manager. Member States bordering the Russian Federation, Belarus or Ukraine are directly threatened by ASF and the presence of the disease in the bordering areas is going to represent a risk for them. Therefore, in order to better target the preventive measures it is necessary to carry out an evaluation of some of the measures that could be put in place to mitigate the risk of ASF spread from the infected area to non-infected area via wild boar, such as increased wild boar hunting.

Terms of reference as provided by the European Commission

1. Is it feasible to drastically reduce the wild boar population by hunting or by the use of traps? In case of positive reply, for how long that strategy would need to be put in place in order to prevent a new increase of the density of the population?

2. Could increased hunting pressure be a proper disease management tool in disease free areas adjacent to area(s) where the occurrence of virus has been confirmed in the wild boar, to minimise the risk of ASF introduction?

3. Would hunting significantly reduce the risk of ASF introduction and its spread?

4. Would prevention of movement of wild boars by feeding or artificial physical barriers reduce the risk of spread of ASF?

ASSESSMENT

1. Feasibility to drastically reduce the wild boar population by hunting or by the use of traps (Term of reference TOR 1)

Estimating a wild boar **population size** is a challenge because of their complex social structure, nocturnal activity pattern and preference for dense vegetation (e.g. Cahill et al., 2003). In many studies, there is a high uncertainty on population size estimates as they are obtained by extrapolating direct animal counts from only a part of the area under consideration or by extrapolating data obtained via indirect methods like hunting bags analysis (Boitani et al., 1995; Acevedo et al., 2014), pellet counts (Vicente et al., 2004; Acevedo et al., 2007) and capture–recapture approaches (Ebert et al., 2010). This variation in the precision of population size estimations makes it very difficult to compare the efficiency of depopulation methods between studies. In addition, wild boar have a high reproductive rate, and populations can double in size after the reproduction season (Gethöffer et al., 2007; Keuling et al., 2013). The more the estimated population size differs from the true population size, the larger the error in assessing the efficiency of a method to reduce the wild boar population. Variations of wild boar population sizes over time and space are likely to affect the efficiency and complicate monitoring of depopulation programmes.

Wild boars are one of the more intensively hunted ungulate species in Europe. Nevertheless, this species has been expanding throughout Europe during the last 40 years. A review of the scientific literature on **hunting** wild boars (Appendix A) revealed that a drastic reduction of a wild boar population within a period of one hunt has not been documented up to now in a European context. Annual hunting in the French forest of Châteauvillain-Arc-en-Barrois (11 000 ha) has reported a more than 40 % reduction (post-reproduction) of the population harvested annually in the period 1982-2004 (Toigo et al., 2008). The annual mortality of wild boar differs between Member States and can reach levels up to 60 % (Keuling et al., 2013). Given the high reproductive rate, it is estimated that if less than the 65 % of the European wild boar population is harvested the population will increase (Keuling et al., 2013). The highest reported reduction of a European wild boar population in a hunt (56.8 %, post-reproduction) was achieved in a fenced Spanish hunting estate of 723 ha (Boadella et al., 2012). Although this study aimed to eliminate the entire wild boar population during a hunting season, it could not drastically reduce the population. Aerial shooting has been reported to achieve an 80 % (post-reproduction) reduction of wild boar in five days but can only be applied in areas of sparse vegetation (e.g. dry regions of Australia or United States) (Saunders and Bryant, 1988). Altogether, in the European context, it seems unlikely that hunting alone will be able to drastically reduce a wild boar population in a hunt to a size far below what is estimated to keep the population stable in Europe.

Traps are also used in attempts to control wild boar populations, often in combination with hunting or poisoning (West et al., 2009). A literature review (see Appendix A) did not reveal any study that could drastically reduce the wild boar population within a hunt. The success of trapping depends on a variety of factors, including topography, time of year, type of trap used, number and density of traps deployed, trap location, number of nights each trap is used, type of bait used and duration of pre-feeding before the traps are set (Massei et al., 2011). Although a lack of data hampers a proper assessment of the efficiency of trapping as stand alone measure to reduce a wild boar population in the European context, it is in general considered more costly and less efficient than hunting, certainly at a large scale (Coblentz and Baber, 1987). Furthermore, there is a clear lack of knowledge to facilitate the design and implementation of traps to drastically reduce the wild boar population in a European context. Taken together, it seems unlikely that trapping alone will be able to drastically reduce a wild boar population in a short period of time to a size far below what is estimated to keep the population stable in Europe

Hunting and trapping could aggravate the **increase of the population size**, possibly through artificial feeding, the selection of the most mature juvenile females, adaptation of the wild boar behaviour and concurrent artificial feeding. Reducing juvenile and female survival appears to be the most effective approach to population control (Sweitzer et al., 2000; Bieber and Ruf, 2005; Toigo et al., 2008;

Gamelon et al., 2012), but hunting can result in selective removal of healthy adult male wild boar and especially in insufficient harvest of piglets (Toigo et al., 2008; Servanty et al., 2011; Keuling et al., 2013). Moreover, hunting and trapping could lead to adaptation of wild boar behaviour for instance by becoming more active during the night, increased home range sizes (Calenge et al., 2002; Sodeikat and Polheimer, 2002; Scillitani et al., 2010) and/or increased reproduction (Bieber and Ruf, 2005; Hanson et al. 2009; Gamelon et al., 2011; Servanty et al., 2011). In addition, an increase in effort is required to hunt or trap wild boar when the animal density reduces (Cruz et al., 2005), but maintaining an intense hunting or trapping pressure during several seasons could be difficult for practical and/or social reasons (Fonseca et al., 2011; Boadella et al., 2012). No papers could be found which reported the time period over which population reductions could be maintained.

2. Effect of an increased hunting pressure in an African swine fever virus (ASFV) free area on the risk of introduction and spread of ASFV (TOR 2 and 3)

2.1. Interpretation of TOR 2 and 3

There are different pathways for introduction of ASFV into a free area, e.g., introduction of ASFV through movement of ASFV-contaminated vehicles, meat, meat products, fomites, people, or movement of infected wild boar or domestic pigs. TOR 2 focuses on increased hunting as a mitigation measure to avoid introduction of the virus from an '**adjacent infected wild boar area'**, and thus the only pathway considered relevant to answer this question was the introduction through infected wild boar. The wild boar population in North-East Europe could be considered as **one large population,** composed by several meta-populations, connected through natural corridors in continuing suitable habitat (Scandura et al., 2011). When speaking about 'adjacent wild boar areas' in administrative or political terms, connected wild boar (sub-) populations are meant in ecological terms**. Introduction of ASFV through wild boar (Figure 1, step A) thus is, in fact, a form of progressive spread of ASFV through the same wild boar population (Figure 1, step B), i.e. through direct or indirect contact transmission of ASFV between wild boar. TOR 2 and 3 are therefore dealt with together in Section 2.2.**

The possible introduction of ASFV through movements of infected pigs, contaminated pork, people, fomites, vehicles, feed, etc., into a susceptible wild boar population was not addressed in this report.

For the assessment of the risk of introduction through these other possible pathways, reference is made to several research projects which have focused on the introduction of ASFV into the EU, e.g. through legal movement of live pigs (Mur et al., 2012b); through other transport-associated routes, such as returning trucks and waste from international ships and planes (Mur et al., 2012c); through illegal transport of animal products (Costard et al., 2013), using semi-quantitative approaches, except for the legal import pathway that was estimated quantitatively. Furthermore, several detailed risk profiles were developed on a European and national level, such as the risk assessment developed by the European Food Safety Authority (EFSA AHAW Panel, 2010); the risk profile developed by the Finnish Food Safety Authority (EVIRA, 2011); the Estonian Institute of Veterinary Medicine and Animal Sciences (Viltrop and Jeremejeva, 2011); the Federal Research Institute for Animal Health of Germany (FLI, 2014), and the All-Russian Institute for Animal Health (Dudnikov et al., 2011).

Additionally, De la Torre et al. (2013) assessed the risk of introduction of ASFV into the EU through movement of infected wild boar. Available wild boar habitat in the free areas and outbreak density in wild boar and domestic pigs in the infected areas were found to be the most important risk factors.

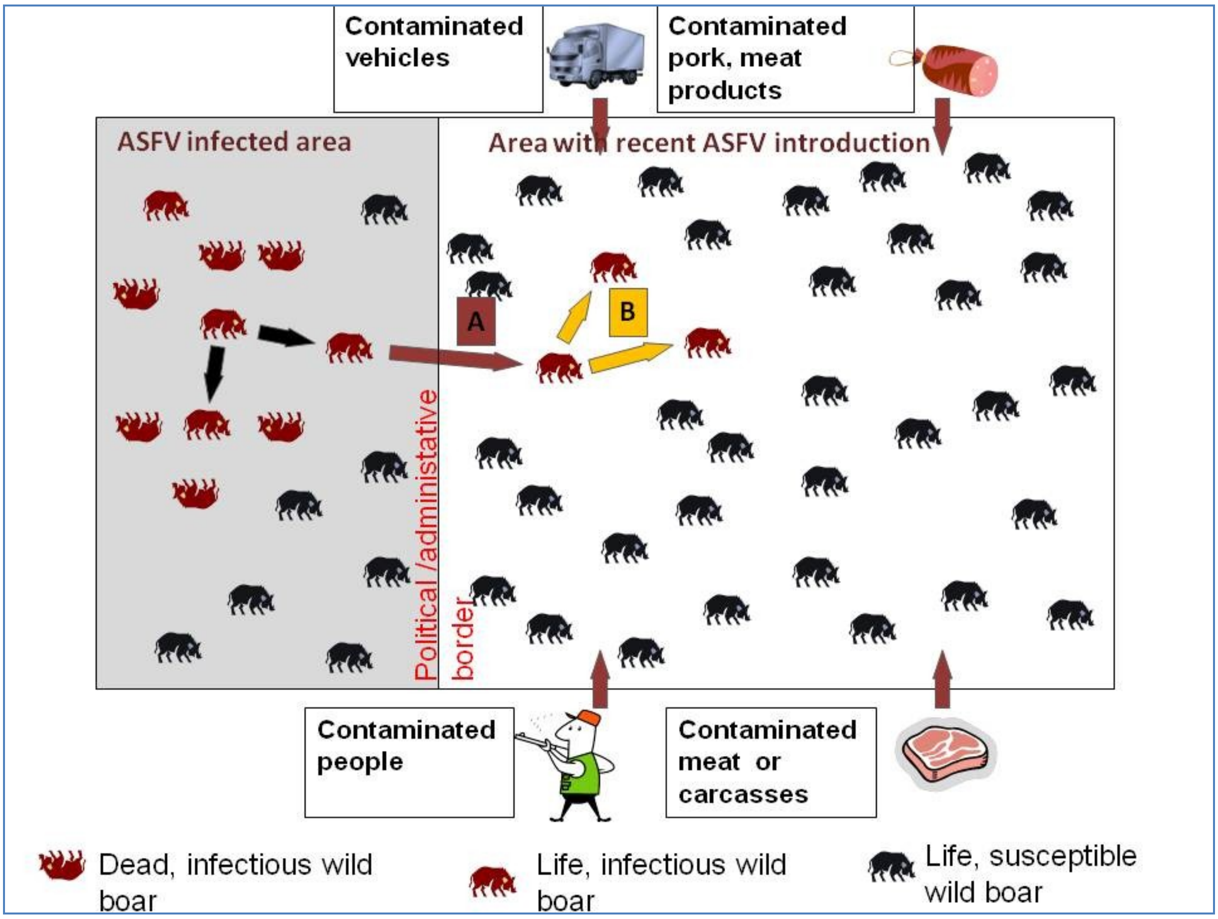

Figure 1: Spread of ASFV in meta-populations

2.2. The effect of drastic hunting pressure in an ASFV free area on the introduction and spread of ASFV

The extent of ASFV spread in wild boar populations is not well known. FAO Empress (2013) reported that in the Russian Federation, once ASFV enters the wild boar population, which is generally thought to be through spill-over from the domestic population, it spreads as a result of active social interactions between wild boar populations, leading to localized epidemics where most of the wild boar population dies. The authors observed that wild boar are capable of sustaining limited transmission for several months, where there is a high population density, during favourable timing for virus introduction. The extent of the spread of ASFV in infected wild boar populations in the Russian Federation, and the possibility of a year round transmission cycle, however, still needs to be evaluated through appropriately designed field surveillance schemes (Dudnikov et al., 2011).

Many studies carried out in other ASFV infected areas in Europe, suggest that ASFV tends to disappear in wild boar populations, when the interaction with infected domestic or free range pigs is limited (Laddomada et al., 1994; Manelli et al., 1997, 1998; Rolesu et al., 2007; Mur et al., 2012a). In addition, the correlation between the wild boar density and the possible presence and duration of other infectious diseases, such as Aujeszky's disease, classical swine fever, foot and mouth disease, porcine circovirus type 2 and tuberculosis, has been described (Vicente et al., 2004, 2007; Rossi et al, 2005; Gortázar et al., 2006; Acevedo et al., 2007; EFSA AHAW Panel, 2010; Boadella et al., 2012).

The probability of transmission of ASFV through direct or indirect contact between susceptible wild boar populations depends on many factors, including the population density, factors affecting infectiousness and susceptibility, the length of the infectious period and contact patterns between wild boar populations (Diekman et al., 1995). Factors that influence space use of wild boar have been subject to many studies (Massei et al., 1997; Keuling et al., 2008 a, b, 2010).

The theory to drastically reduce the population density, i.e. through intensive hunting efforts, to a sufficiently low level (threshold) to hinder spread of ASFV, unfortunately, has both theoretical and practical drawbacks.

First of all, **it is impossible to know the exact threshold for ASFV spread in wild boar populations,** since, as explained above, the exact population size, the population dynamics, as well as the epidemiology of ASF in wild boar, and the extent of potential spread and maintenance in the population are not well understood. Lloyd-Smith et al. (2005) reviewed the theoretical bases and available empirical evidence for disease thresholds for the introduction, spread and persistence of infectious diseases of wildlife. The authors concluded that:

(1) There are no abrupt population thresholds for disease spread in most natural systems. In theory, invasion thresholds exist if the reproduction number of a disease increases with N and the host population is large and well-mixed, but in reality these are blurred by stochastic and finite population effects.

(2) Efforts to identify thresholds for wildlife disease are impeded by limited replication and biases in population datasets, complex population structures, alternative host species and other complications.

(3) Control policies predicted solely on thresholds are not supported by evidence (Lloyd-Smith et al., 2005).

In other words, the uncertainty around establishing precise disease thresholds is high and, furthermore, the uncertainty to confirm that a given threshold has been reached by drastic hunting is even higher.

Secondly, the major practical drawback for drastic reduction of the population through intensive hunting has already been described in Section 1, namely, up to present, there is **no evidence available that drastic population reduction can be achieved** through intensive hunting *per se*. The main reasons why drastic depopulation attempts are not feasible are the adaptive behaviour of wild boar, the compensatory growth of the population, and the influx of wild boar from adjacent areas.

Additionally, if depopulation attempts were to be undertaken, this may even increase transmission and facilitate progressive geographical spread of ASFV. It is well known that intensive hunting pressure on wild boar populations leads to dispersion of groups and individuals (Sodeikat and Pohlmeyer, 2003; Braga et al., 2010; Thurfjell et al., 2013).

3. Effect of feeding or artificial physical barriers in an ASF infected area on the risk of further spread of ASFV (TOR 4)

A literature search could not identify a study that was performed in Europe with the aim to assess directly the effect of **artificial feeding** on the restriction of wild boar movement (Appendix B). However, a study with GPS-tagged wild boar performed in south-central Spain in three different estates (no artificial feeding and no fencing, no artificial feeding but fencing, and artificial feeding and fencing) found that wild boar movements in the state with intensive artificial feeding and fencing were significantly lower than movements on neighbour populations without artificial feeding. This study was performed over a homogeneous habitat corridor with similar food and shelter resources (Joaquín Vicente, personal communication, 2014). Further research is required to confirm these preliminary results.

Artificial feeding is mainly used to facilitate trapping, shooting and/or to distract wild boar from agricultural fields (Calenge et al., 2004; Geisser and Reyer, 2004; Massei et al., 2011). Density and location of feeding stations seem to be important factors affecting the efficiency of artificial feeding on prevention of crop damage (negative, neutral and positive effects reported; see Geisser and Reyer, 2004). In most cases, additional feed is only provided temporarily since the fraction of the wild boar population that will be attracted to feeding stations varies in time. A study analysing the attraction of wild boar to artificial feeding reported that only 62 % of wild boar trapped in the proximity to the feeding points (station) use the feeding points whereas 38 % of the wild boars living in the same areas (having the home range encompassing the feeding points) do not frequent the feeding points (Campbell et al., 2012). In the period that maize and wheat are ready to harvest, wild boar hardly visit feeding stations no matter what food was offered (Geisser, 2000). Neither of these identified reports on the implementation of artificial feeding predicts its effect on movement of wild boars in a European context during longer periods. Additionally, no reports could be identified describing the use of artificial feeding to prevent spread of infectious diseases by wild boar.

On the contrary, artificial feeding will attract wild boar to the same location. In ASFV-infected areas, this could probably facilitate ASFV transmission as has been reported for bovine tuberculosis (Vicente et al., 2007). Abundant food supply can enhance wild boar population growth through improved survival during winter and reproductive output (Groot Bruinderink et al., 1994; Geisser and Reyer, 2005; Gamelon et al., 2013a, b).

A review of the scientific literature (Appendix B) revealed that **fencing** is able to restrict wild boar movement, with an efficiency that is depending on the used fencing system. Wild boar-proof fences are described and have mainly been used to protect valuable agricultural or ecological environments or to facilitate shooting in Europe and elsewhere (Hone and Atkinson, 1983; Reidy et al., 2008; Bruland et al., 2010; Saito et al., 2011; Honda et al., 2009, 2011; Lavelle et al., 2011). This is usually small-scale fencing. Large fences of hundreds of km are highly vulnerable to wild boar and other species, and also raise conservation concerns leading to conflict of interests. A recent simulation study indicated that preventing wild boar movement is at least as effective to prevent ASFV spread as 100 % wild boar depopulation, whereas movement barriers outperformed depopulation as a control measure when less complete depopulation was performed in the treatment area (Hans-Hermann Thulke, personal communication, 2014). Existing fences might help in reducing the movement of wild boar but the practical feasibility of implementing (emergency) fencing in North East Europe is not clear at the moment due to a lack of epidemiological data on ASF in the region. As long as there is no clear view for instance on the size of the area where animal movement should be restricted, estimations on efficiency, costs and construction time will be inaccurate. Furthermore, wild boar also quickly learn to avoid (electric) fences (Hone and Atkinson, 1983), and double-fencing with an animal-free exclusion zone is usually required to prevent close contact between wild boar and domestic animals. Altogether, a better knowledge on the ASF epidemiologic situation in North East Europe is required to identify the areas where fencing could be used as one element of a control programme and to assess the feasibility of its implementation.

Conclusions and recommendations

Conclusions

TOR 1. Feasibility to drastically reduce the wild boar population by hunting or by the use of traps:

- A review of the scientific literature on hunting and trapping of wild boar revealed that hunting and trapping has never achieved a drastic reduction in a wild boar population in the Europe.
- Depopulation efforts can lead to adaptive behaviour of the hunted wild boar, compensatory growth of the population and the influx of wild boar from adjacent areas.

TOR 2 and 3. Effect of an increased hunting pressure in an African swine fever virus (ASFV) free area on the risk of introduction and spread of ASFV:

- Considering the above, drastic hunting is not a feasible mitigation measure to reduce the risk for introduction and spread of ASFV in wild boar populations.

- Considering the uncertainty on the extent of the spread and maintenance of ASFV in wild boar populations, the biased population datasets and the complex population structures and dynamics, density thresholds for the introduction, spread and persistence of ASFV in the wild boar populations are difficult, if not impossible to establish.

- If depopulation attempts were to be undertaken, this can increase transmission and facilitate progressive geographical spread of ASFV. It is well known that intensive hunting pressure on wild boar population leads to dispersal of groups and individuals.

TOR 4. Effect of feeding or artificial physical barriers in an ASF infected area on the risk of further spread of ASFV:

- Artificial feeding of wild boar might rather increase than reduce the risk of ASFV spread

- Fencing can restrict wild boar movement but the practical feasibility of implementing (emergency) fencing in North East Europe is not clear at the moment. Better knowledge on the ASF epidemiologic situation and spatial distribution of the wild boar is required to identify the areas where fencing could be used as one element of a control programme and to assess the feasibility of its implementation.

RECOMMENDATIONS

- Population management strategies, to avoid introduction and spread of ASFV should be based on keeping the current wild boar population density and dynamics stable.

- The possible introduction of ASFV, e.g. through movements of infected pigs, contaminated pork, people, fomites, vehicles, feed, etc., into a susceptible wild boar population was not addressed in this report, but needs to be considered when designing preventive intervention measures to protect wild boar populations.

- Better knowledge on the ASF epidemiologic situation is required in order to design a control programme composed of several control measures and targeting all relevant risk factors.

- Better monitoring tools for wild boar population density, possibly not based on hunting-derived data, are needed.

- Wild boar population dynamics and means for wild boar population control require further research.

- Environmental/agricultural European-wide policies should bear in mind the effects on wildlife population dynamics in wildlife disease management.

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APPENDICES

Appendix A. Extensive literature review on hunting and trapping

A screen of publications in Scopus, Web of Science (Web of Science Core Collection, BIOSIS Citation Index, CABI: CAB Abstracts, Chinese Science Citation Database, Current Contents Connect, Data Citation Index, FSTA – the food science resource, MEDLINE, SciELO Citation Index and Zoological Record) and papers provided by experts was done using the search string (cull* or eradicat* or eliminat* or depopulat* or reduct* or extermin* or "population dynamic") AND (gunning or shoot* or trap* or hunt* or track* or game or harvest*) AND (pig$ or boar$ or swine or hog$ or scrofa) AND (wild or feral or bush or razorback) for Web of Science revealed 419 papers and (TITLE-ABS-KEY(wild OR feral OR bush OR razorback)) AND (TITLE-ABS-KEY(pig? OR boar? OR swine OR hog? OR scrofa)) AND (TITLE-ABS-KEY(gunning OR shoot* OR trap* OR hunt* OR track* OR game OR harvest*)) AND (TITLE-ABS-KEY(cull* OR eradicat* OR eliminat* OR depopulat* OR reduct* OR extermin* OR "population dynamic")) for Scopus revealed 128 papers. Twenty-five papers were identified via independent screening by two scientists for relevance to assess feasibility to reduce wild boar populations by culling or trapping. From the selected papers, three papers could not be retrieved, twelve papers contained information on hunting and population management, the remainder were not relevant when the full text article was screened. The studies performed in Europe are summarised in Table 1.

Table 1: Data extraction of studies relevant to assess the feasibility to reduce wild boar populations by culling or trapping in Europe

Reference	Time period	Geographical area	Landscape	Population	Objective	Method for density estimation	Method of depopulation	Results	Maintenance issues
García-Jiménez et al. (2013)	2007–2012	Large hunting estate in Central Spain	Mediterranean forest	Wild boar and fallow deer	Assess bTB prevalence in wild boar and fallow deer	Population density based on hunting bag	Two hunting events (20 hunters plus dogs) un restricted hunting wild boar	2007-2008: 37 = 1.22 wild boar hunted per 100 ha 2011–2012: 18 0.59 wild boar hunted per 100 ha	Second season and third season increase in the wild boar hunting bag
Braga et al. (2010)	2005 – 2009	Alentejo, Portugal	Not reported	Wild boar	Investigated the sex ratio and age class structure in hunting bags of wild boar harvested by *espera*	Not estimated	*Espera* hunting - uses of bait (wheat grain and almonds) to attract wild boar to the shooting range of 15 elevated hunting stands at night	Number of wild boar harvested per 100 ha 2.83 - 7.60 *espera* hunting bags higher odds of harvesting an adult male	Removing adult males, however, may bias the population sex ratio towards females, reduce male life expectancy and raise the degree of polygyny.
Toigo et al. (2008)	1982-2004	Châteauvillain-Arc en Barrois, eastern France	Forest	Wild boars	Disentangling natural from hunting mortality in an intensively hunted wild boar population	Mark-recapture-recovery	Annual hunting	A wild boar had a > 40 % of chance of being harvested annually and this risk was as high as 70 % for adult males.	Despite high hunting mortality, the study population increased

Table 1: Data extraction of studies relevant to assess the feasibility to reduce wild boar populations by culling or trapping in Europe (continued)

Reference	Time period	Geographical area	Landscape	Population	Objective	Method for density estimation	Method of depopulation	Results	Maintenance issues
Hadjisterkotis (2004)	1997 - 2000	Cyprus	Forest	Wild boars illegally released in 1996	Eradicate wild boar (danger of transmitting diseases and environmental destruction)	Not estimated	Hunting was permitted and the game wardens were instructed to eliminate free-ranging animals	No reduction achieved	Consistent policy for eradication programme
Hadjisterkotis (2004)	1997 - 2004	Cyprus	Forest	Wild boars illegally released in 1996	Eradicate wild boar (danger of transmitting diseases and environmental destruction)	Signs of wild boar and interviews of foresters, farmers, hunters, monks	Hunting was permitted and the game wardens were instructed to eliminate free-ranging animals – improved ammunition	2001–2002: estimated 80 animals 2004- 2005: No sightings of boar	
Mentaberre et al. (2013)	2007-2011	Ports de Tortosa i Beseit National Game Reserve, Spain	abrupt calcareous mountain range, pine and oak forest	Wild boar	Effect of hosts management strategies on Salmonella serovar prevalence	Direct Abundance Index = wild boars/hunter and game season	Increase hunting and baited box trapping	Median = 0.47 ± 0.06 before management; Median = 0.32 ± 0.06, after management	
Sodeikat and Pohlmeyer (2003)	1998 - 2002	Lower Saxony, Germany	4000 ha 50 % forestland and 50 % farmland	4 - 5 wild boars per 100 ha	Movements after trapping	Hunting bag	Trapping baited with corn	No evaluation of trapping	Flight after trapping: 0.2 km – 4.6 km

Table 1: Data extraction of studies relevant to assess the feasibility to reduce wild boar populations by culling or trapping in Europe (continued)

Reference	Time period	Geographical area	Landscape	Population	Objective	Method Density estimation	Method of depopulation	Results	Maintenance issues
Boadella et al. (2012)	2008 - 2009	South-central Spain	Mediterranean ecosystem	10 control sites, 3 sites with culling	Abundance reduction through increased culling on the prevalence of two chronic infectious diseases	Presence frequency of wild boar faecal droppings on transects site 4, direct wild boar counts converted into kilometric abundance indices	Intense and year round wild boar culling strategy	Site 4, the mean estimated wild boar abundance (KAI) diminished by 47.5 % site 8, mean wild boar abundance (FBII) diminished by 56.8 % Site 9 not reported	Culling alone, especially in large areas, is likely not a sustainable long term option
Alexandrov et al. (2011)	08/2009 – 11/2009	Silistra region, Bulgaria	25-km^2 oak forest surrounded by crops (mainly maize)	Wild boar	Eradicate CSF from an area where hunting and vaccination alone might not be sufficient	Not described	Trapping as an addition to management by hunting	Approx. 6 animals per km^2 Reduced to below 2 animals per km^2	Not reported

Table 1: Data extraction of studies relevant to assess the feasibility to reduce wild boar populations by culling or trapping in Europe (continued)

Reference	Time period	Geographical area	Landscape	Population	Objective	Method for density estimation	Method of depopulation	Results	Maintenance issues
Csanyi (1995)	1969 - 1992	Hungary		Wild boar	Trends in harvest rates between state enterprises and private hunting associations	Reported spring population size and number of wild boars shot in the year.	Hunting	Harvest rates ranging from 50 % to 30 % with highest harvest rates in the 1970s.	The harvest rate of wild boar populations was generally lower than that necessary to stabilise the population
Keuling et al. (2013)	1998–2009	Sweden, Poland, Germany, Belgium, France, Switzerland, Austria, Italy		Wild boar	Comparison of mortality rates in Central Europe	NA: Paper compares mortality rates from published papers.	Population control not assessed	mortality rates higher for males ($p = 0.019$) and especially male yearlings.	bias between reproductive and harvest rates leads to growing wild boar populations, high harvest rates required to regulate populations.
Keuling et al. (2009)	2002 - 2006	Southwestern Mecklenburg–Western Pomerania, Germany	Agriculture and grassland 63 % forest 34 %	The mean annual harvest increased from 2.83 individuals per 100 ha in 1999/2000 to 5.13 individuals per 100 ha in 2005/2006.	Test the impact of different hunting methods on seasonal home range sizes		Battues (8.3 hunters, 5.3 beaters and 2.7 dogs per 100 ha driven forest area)	Battues did not significantly influence the spatial utilisation before and after hunt.	To reduce populations and thus, damages, supplemental feeding should be reduced and hunting rates have to be increased especially for females, as all age classes of females are highly reproductive.

bTB: bovine tuberculosis; CSF: Classical Swine Fever; NA: not applicable.

Appendix B. Extensive literature review on artificial feeding and fencing

An extensive literature search was performed in Scopus, Web of Science and papers provided by experts to identify studies on 'feeding' and 'fencing' in relation to movement of wild boars. Two searches were performed:

- the same search string as used in Appendix A revealed twenty-five papers related to 'feeding' or 'fencing';
- the additional search string in Web of Science ((("supplementary feed*" or fenc* or barrier*))) AND (movement or dispersal) AND ((pig$ or boar$ or swine or hog$ or scrofa)) AND ((wild or feral or bush or razorback)) revealed 64 additional papers related to 'feeding' or 'fencing' that were not identified in the first search.

Titles and abstracts were independently screened by two scientists for relevance to assess feasibility of 'feeding' and 'fencing' to restrict wild boar movement and hence risk of ASF spread. From the fourteen papers, one paper could not be retrieved. The studies on 'fencing' performed in Europe are summarised in Table 2. No study could be identified that was performed in Europe with the aim to assess directly the effect of 'feeding' on the restriction of wild boar movement.

Table 2: Data extraction of studies relevant to assess the effect of fencing on movement of wild boars in Europe

Reference	Time period	Geographical area	Landscape	Population	Objective	Method movement estimation	Method of fencing	Results	Maintenance issues
Vidrih and Trdan (2008)	2005, from July until harvest of maize	Area of Smihel near Postojna, Slovenia	Agricultural land (maize)	Wild boar	Electric fence to prevent wild boar from entering a maize field	Boar tracks on the ground	Electric fence systems	No breaks through fencing were observed, although boar tracks on the outside of the fenced field were observed. Damage to arable fields in the vicinity of the protected field was also recorded.	Not reported
Santilli and Stella (2006)	1999-2003	Southern Tuscany, Italy	Agricultural land (maize)	Wild boar	Evaluate the effectiveness of 16.5 km linear electrical fence installed to farmland cultivated with maize	Not reported	Electric fence	93 % damage reduction was observed during the five years after fence installation without significant damage increase in the neighbouring areas	High price and intensive labour for installing and maintaining the electric fences

ABBREVIATIONS

ASF	African swine fever
ASFV	African swine fever virus
bTB	Bovine tuberculosis
CSF	Classical swine fever
EU	European Union
NA	Not applicable
TOR	Term of reference