SCIENTIFIC OPINION

African swine fever in wild boar

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Abstract

The European Commission requested EFSA to compare the reliability of wild boar density estimates across the EU and to provide guidance to improve data collection methods. Currently, the only EU-wide available data are hunting data. Their collection methods should be harmonised to be comparable and to improve predictive models for wild boar density. These models could be validated by more precise density data, collected at local level e.g. by camera trapping. Based on practical and theoretical considerations, it is currently not possible to establish wild boar density thresholds that do not allow sustaining African swine fever (ASF). There are many drivers determining if ASF can be sustained or not, including heterogeneous population structures and human-mediated spread and there are still unknowns on the importance of different transmission modes in the epidemiology. Based on extensive literature reviews and observations from affected Member States, the efficacy of different wild boar population reduction and separation methods is evaluated. Different wild boar management strategies at different stages of the epidemic are suggested. Preventive measures to reduce and stabilise wild boar density, before ASF introduction, will be beneficial both in reducing the probability of exposure of the population to ASF and the efforts needed for potential emergency actions (i.e. less carcass removal) if an ASF incursion were to occur. Passive surveillance is the most effective and efficient method of surveillance for early detection of ASF in free areas. Following focal ASF introduction, the wild boar populations should be kept undisturbed for a short period (e.g. hunting ban on all species, leave crops unharvested to provide food and shelter within the affected area) and drastic reduction of the wild boar population may be performed only ahead of the ASF advance front, in the free populations. Following the decline in the epidemic, as demonstrated through passive surveillance, active population management should be reconsidered.

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Summary

On 8 February 2018, the European Commission requested European Food Safety Authority (EFSA) to deliver a Scientific Opinion on African swine fever (ASF).

More in particular, the **first Term of Reference** asked to provide an estimate of the wild boar densities in the European Union (EU), to assess the reliability and comparability of the data and to propose possible guidance on a methodology to reach the best estimate.

The reliability and comparability of different methods to assess wild boar density were evaluated by wild boar ecologists from the EnetWild consortium. This assessment was mainly based on expert opinion and a narrative literature review. Brief guidelines were developed for measuring wild boar densities in a comparable and harmonised manner (ENETWILD et al., 2018).

Currently, some information on local wild boar density in Europe exists. However, it is difficult to access because it is mainly present in grey literature and collected with different methods. Therefore, as a proxy of wild boar density estimates, the maximum available numbers of wild boar hunted between 2014 and 2017 in the hunting grounds in the EU were provided, which are currently the only Europe-wide available data indicative of relative wild boar abundance. High quality and harmonised hunting data, however, would be required to make better use of data at large scale and for developing predicting models for wild boar density on a EU scale.

Precise density data can only be collected at local level (e.g. using camera trapping) although these data could also be used to validate large-scale abundance distribution models e.g. based on hunting data. Linking large-scale relative abundance estimates with local density data will provide the basis to produce validated, large-scale density maps.

The **second Term of Reference** requested to review the latest epidemiological data to identify threshold(s) in wild boar density that do not allow sustaining the disease, in different settings.

A short theoretical background section was provided about wild boar density thresholds for virus transmission in the different phases of an epidemic (introduction, spread and fade out). This was based on a narrative literature review. The epidemiological theory for density thresholds for sustaining infection is currently too simple to address the complex ecology of ASF. These theoretical approaches rely on key assumptions, including homogenous and random mixing of wild boar, which cannot be met.

From field observation, there is currently no indication that a density threshold exists for ASF. There are significant gaps in knowledge about the modes of ASF transmission including animal-to-animal transmission, indirect transmission from the contaminated environment or infected carcasses or the role of mechanical vectors in the ASF epidemiology.

Due to the complex ecology of ASF, other drivers apart from density may determine whether this disease can be sustained or not in a particular ecological setting. These could include indirect transmission from infected carcasses and the small-scale social structure of the host population.

Lessons learnt from the affected areas show that ASF spread has occurred in areas of varying, including very low, wild boar density. As yet, there is no evidence that the disease has disappeared from these areas. Furthermore, any derived density threshold would be difficult to translate into practical measures due to difficulty in estimating wild boar density *a priori*.

The **third Term of Reference** requested to review wild boar depopulation methods or population density reduction methods intended to achieve a determined threshold and rank them according to their efficacy, practical applicability in the EU, cost effectiveness and their capacity to minimise the spread of ASF.

As currently it is not possible to establish a density threshold for ASF, the effectiveness of any method that could potentially reduce wild boar density was evaluated. This evaluation was based on data extracted from scientific papers through an extensive literature review and from the lessons learnt from the affected Member States (MSs). Based on the available information, it was currently not possible, however, to rank the methods according to their efficacy, practical applicability or cost effectiveness.

Sus scrofa are called 'wild boar' in the areas where they are endemic and 'feral pigs' in the areas where they are invasive. Generally, control efforts to reduce feral pigs have been more rigorously implemented, often backed up by a different legal background and public attitude. Therefore, distinction between the two has been made throughout this Opinion.

Locally implemented emergency measures for disease control should be distinguished from long-term interventions at larger scale aiming at sustainable population management e.g. through recreational hunting. The literature review concluded that recreational hunting of wild boar and feral swine can be effective as a regulatory measure to keep ASF-free populations stable, but biased hunting preferences

towards large males and the feeding of wild boar should be avoided. Hunting efforts should be maintained in intensity (harvest rate > 67% per year) to stabilise wild boar populations.

In the context of disease control, depopulation of wild boar has been achieved in small, fenced estates, but in larger areas, not more than 50% population reduction was reported. In areas of high habitat quality, maintaining an intense wild boar population control over a prolonged period of time through intervention is expensive and possibly not sustainable in the long term.

Eradication of insular feral swine populations has been achieved on some occasions only through years of intense drive hunting with dogs, with or without the use of other methods such as trapping or shooting from helicopters. In focal feral swine populations, drastic reduction has been reported with up to 80% in control programmes implementing shooting from helicopters or a combination of trapping and intense drive hunting with dogs. Recovery of the population with up to 77% in the year after has been reported and control programmes should be carried out over several years to obtain sustainable reduction of feral swine.

The use of traps has resulted in a harvest of 79% of the population and can be especially interesting in areas where hunting is not recommended.

The parental use of a gonadotropin-releasing hormone (GnRH) immune-contraceptive vaccine has demonstrated promising results to reduce the fertility of feral swine kept under experimental conditions. Research is needed, however, to investigate the presence of potential residues of GnRH in meat and the possibility to develop a vaccine that could be administered orally in a selective way, to minimise bait uptake by non-target species.

Poisoning of wild boar is forbidden in the EU under the legislation of biodiversity conservation. However, poisoning has been demonstrated as highly efficient in reducing feral swine populations. The potential undesirable effects, including welfare aspects of administering the poison and the possible effects of its residues on the health of humans and animals through direct or indirect exposure have not been sufficiently investigated in the European context.

Based on experiences in the MSs, it is not possible to rank the effectiveness of the individual measures applied. The current understanding is that only the combination of measures applied in the Czech Republic resulted in very limited spread from the first detection of ASF in wild boar for less than half a year.

Different actions in terms of wild boar management at different stages of the epidemic are suggested based on the collective experience of the affected MS:

Preventive measures taken to reduce wild boar density will be beneficial both in reducing the probability of exposure of local population to African swine fever virus (ASFV) and reducing the efforts needed for potential emergency actions (i.e. less carcass removal) if an ASF incursion was subsequently to occur.

Following focal introduction, emergency measures should focus on drastic reduction in the wild boar population ahead of the ASF advance front, in the free populations and management of the infected population solely to keep it undisturbed and avoid aggregation of individuals and avoid any spread (e.g. hunting ban, including also hunting on other species, leaving crops unharvested within the affected area) is proposed.

Following the decline in the epidemic, as demonstrated through passive surveillance, active population management could be reconsidered.

The efficacy of these measures could be jeopardised by the continuous introduction of ASV from neighbouring affected areas or through human mediated spread.

The **fourth Term of Reference** requested to review fencing methods, or population separation methods, available for wild boar in different scenarios and for different objectives. Therefore, the effectiveness of the different methods used for separating wild boar was evaluated based on information found in scientific literature, through an extensive review. Additionally, the information available from the affected MS, on the effect of physical or natural barriers on ASF spread in wild boar populations was provided and discussed.

From the extensive literature review, it could be concluded that some electrical fences have demonstrated ability to temporarily protect crops from damage caused by wild boar or feral swine with different levels of efficiency, but no electrical fence design can be considered 100% wild boar proof on a large scale for a prolonged period of time.

Odour repellents have been tested to keep away wild boar and feral swine from crops with divergent results. Five trials could not demonstrate any effect of the repellent on wild boar or feral swine intrusion or on crop damage, while two trials reported damage reduction by wild boar ranging from 55% to 100% and from 26% to 43%.

Light repellent did not show any significant effect on the probability of wild boar visiting luring sites. Sound repellents have been reported to reduce 67% of crop damage caused by wild boar.

Currently, there is no evidence that large fences have been effective for the containment of wild suids. Some new large-scale fences are under construction, and their effectiveness to separate wild boar populations will need to be evaluated in the future.

Natural barriers such as large rivers or straits can be used for demarcation for restricted areas as they have shown to reduce, but not completely impede, the movements of wild boar.

The **fifth Term of Reference** requested to propose and assess a surveillance strategy, provide sample size, frequency of sampling and identify possible risk groups for early detection of ASF in a naive wild boar population. This section was based on a narrative review and concluded that in countries free of infection, the primary surveillance objective is early detection. Once infection occurs, the objective shifts to estimating the prevalence of infection and case finding while, following elimination, the surveillance objective shifts back to early detection and demonstrating freedom of infection.

Passive surveillance is the most effective and efficient method of surveillance for early detection of ASF in wild boar. For early detection through passive surveillance, the aim is to test as many 'found dead' animals as possible. Based on current knowledge and experiences, for an intervention to be successful, there is a need to detect an ASF incursion while it is still spatially contained.

In uninfected populations, there is a need for estimates of wild boar density and normal mortality rates combined with the probability of detecting a 'found dead' animals given its presence. This information could be used to validate the submission rate (i.e. the numbers of wild boar that should be submitted due to natural mortality).

The **sixth Term of Reference** requested to review successful and relevant methodologies used in the past for surveillance programmes in wildlife and identify successful strategies for ensuring the optimal involvement of the main stakeholders. As passive surveillance is the most effective for early detection, positive experiences gained by the ASF-affected MS with passive surveillance programmes were summarised. Successful strategies for ensuring the optimal involvement of the main stakeholders were identified. Enhanced passive surveillance of ASF in wild boar populations demands a continuous dialogue between all involved stakeholders and a shared responsibility in monitoring and control of the disease. Continuous awareness building, incentives and good collaboration with the hunters are essential.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

African swine fever (ASF) is an exotic disease that requires a multisectorial approach to be addressed in an effective manner. The presence of this infection in the Eurasian wild boar (*S. scrofa*) population represents a challenge for the EU that requires some specific tailor-made measures. Some specific knowledge already exists and several areas still need to be further explored. The experiences gained in the EU and outside the EU in managing wild boar populations should be reviewed to identify the tools which are most suitable for the EU scenario.

There is knowledge, legislation, technical and financial tools in the EU to properly face ASF. The main pieces of the EU legislation relevant for ASF have been reviewed in the Commission request for a scientific and technical assistance on African swine fever issued on 1 December 2017.

In addition, an ASF Strategy for the Eastern Part of the EU has been developed based on earlier scientific recommendations by EFSA. This strategy is constantly evolving based on new science available and on new experiences gained.

The current wild boar density in the EU appears to facilitate the onset of ASF and its maintenance *de facto* creating a reservoir for this virus. As indicated in the 2015 EFSA opinion on ASF a reduction of the wild boar density to a certain threshold would bring about a basic reproduction rate for ASF lower than one, leading to the self-extinguishment of the disease in the wild boar meta populations. Any update on what information is available to identify this wild boar density level would be helpful. However this information needs to be contextualised within the limits of the current methods of assessing wild boar densities in the EU.

As recommended in the 2015 EFSA opinion on ASF and the subsequent technical reports, there are several ways to approach wild boar population control. While advantages and disadvantages of hunting have already been assessed, further assessment is needed of other methods to control wild boar population and movements to provide the competent authorities with a broader set of tools to be applied in the field.

Surveillance for ASF in wild boar in the EU is broadly based on passive surveillance. Such an approach should be reviewed against other surveillance methodologies allowing for early detection of the occurrence of ASF in a naïve wild population. Reviewing key aspects used in other wildlife surveillance programmes in the past would be helpful to ensure that the main stakeholders contribute in an optimal manner.

Therefore, in the context of Article 29 of Regulation (EC) No 178/2002, EFSA should provide a Scientific Opinion to the Commission based on the following Terms of Reference (TOR):

1) Provide an estimate of the wild boar densities in the EU and assess the reliability and comparability of the data; propose possible guidance on a methodology to reach the best estimate.
2) Review the latest epidemiological data to identify threshold(s) in wild boar density which do not allow sustaining the disease, in different settings.
3) Review the wild boar depopulation methods, or population density reduction methods intended to achieve a determined threshold, (e.g. poisoning, selective killing and chemical sterilisation) and rank them according to their efficacy, practical applicability in the EU, cost-effectiveness and their capacity to minimise the spread of African swine fever.
4) Review the fencing methods, or population separation methods, available for wild boar (e.g. permanent, electric, odour) in the EU in different scenarios (e.g. forest, farmland, urban area) and for different objectives (e.g. for preventing movement of wild boar) while keeping in mind the wild boar ecology.
5) Considering the wild boar densities identified in ToR 1 and the risk of introduction of African swine fever in naïve wild boar population in the EU, propose and assess a surveillance strategy, provide sample size, frequency of sampling and identify possible risk groups. This surveillance needs to be prioritised for early detection of disease introduction and cost effectiveness.
6) Review of successful and relevant methodologies used in the past for surveillance programmes in wildlife and identify successful strategies for ensuring the optimal involvement of the main stakeholders.

1.2. Interpretation of the Terms of Reference

After the request from the European Commission for a scientific and technical assistance on ASF issued on 1 December 2017 (M-2017-0217), European Food Safety Authority (EFSA) will prepare two reports analysing the latest ASF epidemiological data and assessing disease management options of domestic pigs and wild boar in the ASF-affected countries. These reports will be ready for approval in November 2018 (question number EFSA-Q-2017-00823) and November 2019 (question number EFSA-Q-2018-00053).

Some general background information about ASF, including an update on the geographic distribution, the impact on animal health, modes of transmission, a summary of known information on potential vectors and their distribution and some information about the diagnosis can be found in EFSA's storymap on ASF.

Therefore, this Scientific Opinion will not provide background information on ASF nor will it provide an update on the epidemiological situation in the affected Member State (MS), as this information will be available in the above-mentioned reports or can be consulted in the EFSA storymap on ASF. The ToR are addressed as follows:

ToR 1 requested wild boar density estimates across the European Union Member State (EU MS). Currently, there are no harmonised data pertaining density of wild boar in the different hunting grounds of the EU MS, and therefore, the numbers of wild boar harvested (the relative abundance) between 2014 and 2017 were collected in a harmonised way and mapped as a proxy of the wild boar density. The reliability of relative abundance of wild boar was discussed as well as the comparability with data obtained through other methods. Brief guidance on different methodologies to obtain wild boar density estimates was provided by wild boar ecologists in an External Scientific Report provided to EFSA (ENETWILD et al., 2018).

ToR 2 requested epidemiological data to identify wild boar density thresholds that do not allow sustaining of ASF. A short theoretical section was provided about wild boar density thresholds for any pathogen transmission and the difficulties in estimating a density threshold for African swine fever virus (ASFV) transmission in wild boar populations were elaborated. Some tangential observations from the field demonstrating these difficulties were also provided.

ToR 3 requested a review of wild boar depopulation methods or population density reduction methods intended to achieve a determined density threshold and to rank them. As currently it is not possible to establish a density threshold (the outcome of ToR2), the effectiveness of any method that could potentially reduce the wild boar density was evaluated. This evaluation was based on data extracted from scientific papers through an extensive literature review and from the lessons learnt in the affected MS. It was currently not possible, however, to rank the methods according to their efficacy, practical applicability or cost effectiveness based on the available information.

ToR 4 requested a review of fencing methods, or population separation methods, available for wild boar in different scenarios and for different objectives. Therefore, the effectiveness of the different methods used for separating wild boar was evaluated based on information found in scientific literature, through an extensive review. Additionally, the information available from the affected MS, on the effect of physical or natural barriers on ASF spread in wild boar populations was provided and discussed.

ToR 5 requested to propose and assess a surveillance strategy, to provide sample size, frequency of sampling and to identify possible risk groups in a naive wild boar population for early detection of ASFV introduction, taking into account the cost effectiveness of the surveillance methods. To address this ToR, the role of passive and active surveillance in the different stages of the epidemic was explained and evidence was provided that passive surveillance is the most appropriate approach for early detection of ASF.

ToR 6 requested a review of successful and relevant methodologies used in the past for surveillance programmes in wildlife and to identify successful strategies for ensuring the optimal involvement of the main stakeholders. As passive surveillance is the most effective for early detection of ASF (outcome of ToR 5), the experiences gained by the ASF affected MS with the passive surveillance programmes implemented in their affected wild boar populations or populations at risk were summarised and successful strategies for ensuring the optimal involvement of the main stakeholders were identified.

2. Data and methodologies

2.1. Data

2.1.1. Numbers of harvested wild boar per hunting ground

2.1.1.1. Numbers of harvested wild boar per hunting ground

Data on the maximum available numbers of wild boar harvested between 2014 and 2017 in the hunting grounds of the EU MSs were collected through EnetWild's wild boar data model (WBDM) (http://www.enetwild.com/data-repository/).

2.1.1.2. Efficacy of wild boar population reduction and separation measures

Data on the efficacy of measures applied to reduce or separate wild boar populations were extracted from published scientific papers during an extensive literature review (see Appendix A).

2.2. Methodologies

2.2.1. Wild boar density (ToR 1)

2.2.1.1. Numbers of harvested wild boar per hunting ground

As a proxy of wild boar density estimates, the numbers of wild boar harvested in 2017 in the hunting grounds of the EU MSs were provided and were mapped using ArcGIS software (ESRI). The underlying data are provided in the data repository of EnetWild.

Estimates of wild boar hunting bags trends were calculated using version 3.54 of the TRIM (TRends and Indices for Monitoring data) software package (Pannekoek and Van Strien 2001). TRIM estimates annual counts with missing observation by fitting a generalised linear model with Poisson errors and logarithmic link (McCullagh and Nelder 1989; Pannekoek and Van Strien 2001).

The linear trend model was used with all years as change points and all models were run with serial correlation and overdispersion was taken into account. Yearly indices and an overall trend estimate are presented in Section 3.1.2.2. The annual index uses the first-year arbitrarily set at one and each annual index was calculated in relation to the first, standardising population trends.

2.2.1.2. Reliability and comparability of wild boar density estimation methods

The reliability (i.e. the extent to which the various measures to estimate wild boar density relate to the real wild boar density in the region) and comparability (i.e. how comparable are the data collected by the same methods in different areas) of wild boar density were assessed by the EnetWild consortium. This assessment was mainly based on expert opinion and a narrative literature review.

2.2.1.3. Guidance for estimating wild boar density

Experts from the EnetWild consortium developed guidelines on how to measure wild boar densities in a comparable and harmonised manner. This is described in an External Scientific Report (ENETWILD et al., 2018) delivered to EFSA. A summary of this report is provided in Section 3.1.3.

2.2.2. Wild boar density threshold for ASF transmission (ToR2)

This section was based on a narrative review on the factors driving ASF epidemiology and a short theoretical background section was provided about wild boar density thresholds for virus transmission in the different phases of an epidemic (introduction, spread and fade out). The constraints in estimating density thresholds were drafted (e.g. the interference of human factors or the effect of neighbouring infected areas and possible re-occurrence on estimating the wild boar density threshold for the persistence of the disease in an area) as well as the need for reliable and comparable population density estimates.

2.2.3. Review of wild boar depopulation/density reduction measures (ToR 3) and wild boar separation methods (ToR 4)

2.2.3.1. Extensive review of literature

To answer ToRs 3 and 4, the following review questions were addressed:

Review questions:

1) What are the efficacy, practical applicability and cost effectiveness of wild boar population reduction measures?
2) What are the efficacy, practical applicability and cost effectiveness of wild boar movement restriction/separation methods in different scenarios (e.g. for protecting forest, farmland, pig holdings, urban area, highways) for preventing the movement of wild boar?

Population:

Wild boar *Sus scrofa* populations

Type of interventions:

1) Hunting, trapping, fertility control, feeding ban, poisoning.
2) Artificial separation (e.g. fencing, highway) and natural separation (e.g. river, canals, sea).

Type of outcome measures:

1) Primary outcome: wild boar density (wild boar/km2) reduction.
2) Secondary outcome: practical applicability and cost effectiveness (narrative description).
3) Primary outcome: wild boar presence beyond the fenced area (yes/no); crop damage (% reduction), escape (% of collared animals).
4) Secondary outcome: practical applicability and cost effectiveness (narrative description).

Search methods:

Search strategies were undertaken to identify studies that report methods for wild boar population density reduction or control and separation methods available for wild boar (Table 1).

Table 1: Databases searched for studies pertaining wild boar population reduction measures and separation methods

Databases	Time coverage	Platform
Web of Science Core Collection	1975–present	Web of Science
BIOSIS Citation Index	1926–present	
CABI: CAB Abstracts	1910–present	
Chinese Science Citation Database	1989–present	
Current Contents Connect	1998–present	
Data Citation Index	1900–present	
FSTA – the food science resource	1969–present	
Korean Journal Database	1980–present	
MEDLINE	1950–present	
Russian Science Citation Index	2005–present	
SciELO Citation Index	1997–present	
Zoological Record	1864–present	
Scopus	1970–present	Elsevier (Scopus.com)

The searches were run on 19 February 2018. The search strategies were adapted according to the configuration of each resource of information. No date restriction was applied. Language and type of document limits, together with the full search strategies, are reported in Appendix A.

The search identified 1,338 results retrieved in the Web of Science platform and 503 in Scopus. The search results were downloaded from the information sources and imported into EndNote x8 bibliographic management software (Clarivate Analytics). Deduplication was undertaken using a number of algorithms. The final number of results after removing duplicates was 1,352. The screening of the titles and abstracts of these 1,352 studies by two independent reviewers resulted in the

inclusion of 70 studies for further screening of the full texts. From these 70 studies, 47 were found relevant by two independent reviewers, and part of the information that has been extracted from these papers is provided in Appendix A.

2.2.3.2. Field observations

In addition to an extensive review of literature, a summary of the field experience with different wild boar management measures implemented in the ASF-affected EU MS was provided. A timeline of the implemented measures in the wild boar populations was discussed, and the possible effect on the spread of ASF was noted.

2.2.4. Wild boar surveillance strategy (ToR 5)

2.2.4.1. Theoretical concepts

This section was based on a narrative review and dealt with the following concepts:

- the role of passive and active surveillance in the different stages of the epidemic;
- evidence that passive surveillance is also the most appropriate approach for early detection of ASF;
- a summary of key issues to consider during passive surveillance for early detection.

2.2.5. Optimising involvement of stakeholders in enhancing passive wild boar surveillance (ToR 6)

The experiences gained by the ASF-affected MS with the passive surveillance programmes implemented in their affected wild boar populations or populations at risk were summarised and successful strategies for ensuring the optimal involvement of the main stakeholders were identified in a narrative section.

3. Assessment

3.1. Wild boar density (TOR1)

This section is mainly based on an assessment that was provided by the EnetWild consortium. More details of the assessment can be found in the External Scientific Report provided to EFSA, from which the information was extracted (ENETWILD et al., 2018).

3.1.1. Numbers of harvested wild boar per hunting ground

Some information on local wild boar density in Europe exists. However, these data are difficult to access because it is mainly present in grey literature. Furthermore, this information is based on methods that are not harmonised and an assessment of the methodological quality would be needed.

As a proxy of wild boar abundance estimates, the numbers of wild boar harvested (or relative abundance, see below in Section 3.1.2.2) in 2017 in the hunting grounds of the EU MSs were collected and mapped in Figure 1. The underlying data are provided in the data repository of EnetWild.

From the harvested wild boar, it can be seen that, in many regions of Europe, the relative abundance is very high e.g. above five harvested wild boar/km^2.

Legend

hunted/km^2 suitable habitat

- 0.0 – 0.7
- 0.7 – 1.0
- 1.0 – 1.7
- 1.7 – 3.2
- 3.2 – 12.0
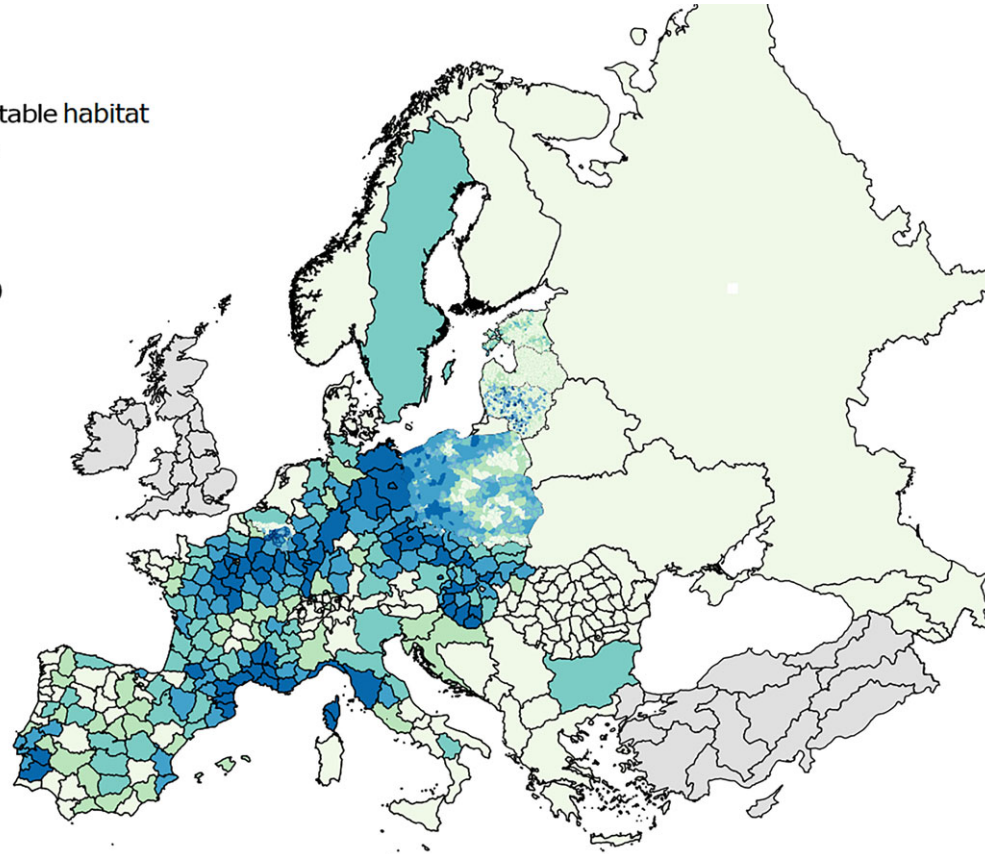
Figure 1: Numbers of wild boar harvested in the hunting grounds in the EU Member States in 2017

3.1.2. Reliability and comparability of wild boar density estimation methods

Animal numbers can be calculated as **density estimates** i.e. the number of individuals per unit of surface (syn. census) or as **relative abundance index** i.e. any measure that relates with density but that does not refer to numbers per surface, for instance the annual hunting bag. Density estimates rather than relative abundance indices are needed to provide density thresholds for disease control.

3.1.2.1. Density estimates

Information on wild boar population density is desirable for risk factor analysis and modelling, for monitoring wildlife populations and for disease management purposes, including the assessment of the effects of disease outbreaks and of the interventions.

However, wild boar are elusive, mostly nocturnal, group-living mammals for which some of the usual procedures for determining the size of wild ungulate populations, for instance distance sampling, are of limited applicability. Moreover, although wild boar reproduction has seasonal peaks, births may take place at any time of the year. Considering that the mean litter size is 4–5 piglets/sow, this introduces further variation in wild boar density.

Whatever the method used (e.g. camera-trapping grids with appropriate algorithms), density calculations are demanding in time and effort and are so viable only at local scales. At larger scales, modelling can produce density estimations suitable for most disease management purposes. Such modelling needs a sufficient and well-distributed set of local density data or comparable data sets of abundance data generated at larger scales for instance through hunting.

While counting wild boar on a large-scale (i.e. regional) is unfeasible, there is need for compiling and validating wild boar density data. Throughout Europe, numerous publications and reports give local density data based on well-described methods. Acquiring and validating as much data as possible is one of the goals of EnetWild's wild boar data model (WBDM). These data, including information on density, site, year, season, habitat, method and reference, should be listed and made available. An evaluation of different census methods based on their characteristics, practicality and applicability to epidemiology is summarised in the External Scientific Report provided to EFSA (ENETWILD et al., 2018).

3.1.2.2. Relative abundance index

Hunting bag data are currently the only Europe-wide available relative abundance index of wild boar. Hunting bags depend on national and regional hunting traditions and regulations, hunting pressure, the geographical extend of the hunting grounds and availability of hunters and are therefore difficult to compare between countries, although they provide useful indicators of long-term national/ regional population trends (Figure 2) and can be sufficient for large-scale spatial epidemiology (Acevedo et al., 2014). Baselines for a future harmonised recording of hunting-derived wild boar density data are currently under preparation by the EnetWild consortium and data are collected in the wild boar data model (WBDC).[1] It is likely that these baselines will include recommendations such as to record the surface of suitable habitat, the number of hunting days, the number of hunters per day and the hunting modality (Boitani et al., 1995). In particular, drive hunts are the hunting method for wild boar whose hunting effort can be most easily measured. In this way, the hunting data can be harmonised across regions and used for developing models.

Figure 2 demonstrates that during the last decades, the annual wild boar hunting bag increased consistently throughout Europe, indicating increasing wild boar abundance trends. Additional data from the EnetWild consortium suggest an unusual concordance between data from affected countries suggesting a decline of wild boar in 2016.

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[1] WBDM: accessible at http://www.enetwild.com/2018/04/25/release-model-collect-data-on-wild-boar-distribution-and-abundance-europe/).

Wild boar hunting bag index
(standardised)
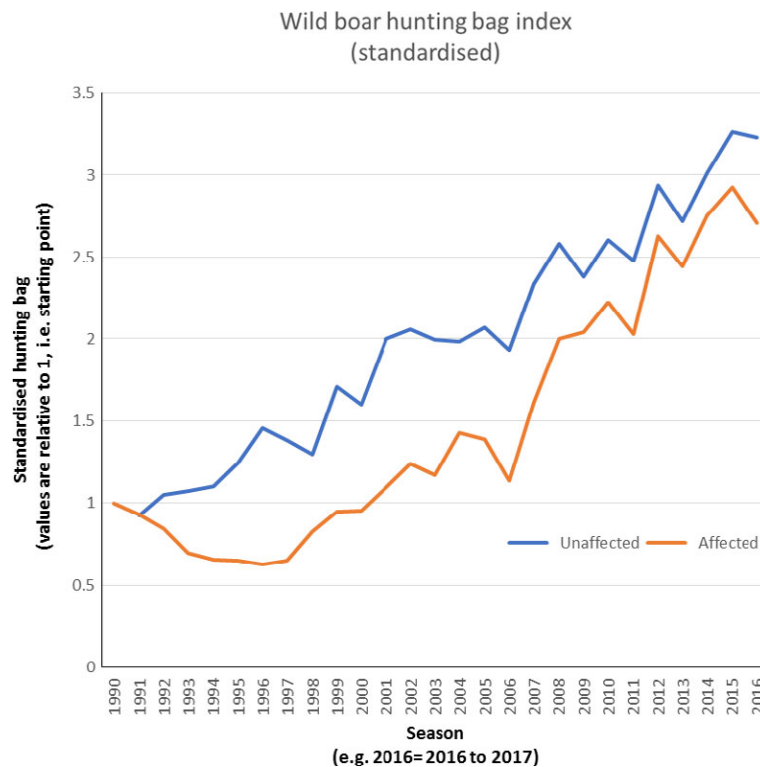
Figure 2: Wild boar population trends in Europe since 1990. The lines represent standardised wild boar hunting bags for currently unaffected (blue) and affected (orange) countries. Each annual index is calculated in relation to the first observation, which is arbitrarily set at 1, thus standardising population trends

To improve the quality of hunting data, parameters such as surface covered, number shot and ideally even the number seen, along with data on hunting effort are needed across Europe. Good documentation to characterise the hunting effort should be available to improve data harmonisation: hunting days, total number of hunters and hunting method. Particularly, for drive hunts, the most comparable method across Europe (in its diverse forms and local adaptations), it is recommended to collect the effort in terms of drive surface, and numbers of animals shot and sighted per hunting event in a number of areas representative of the existing diversity across the continent. There is a need to harmonise hunting data collection frameworks across Europe to make it usable at large scale due to present differences in hunting methodologies and data collection frameworks. This is currently attempted by the EnetWild consortium through the WBDM.[2]

3.1.2.3. Linking relative abundance indices to density estimates

Linking relative abundance estimates (such as hunting bags) with existing density requires assessing hunting data and density both at local and at large scales. By doing this, hunting data (e.g. drive counts) can be calibrated by other methods such as camera-trapping grids. A strong effort is needed to collect comparable data and in the long-term outlook, to harmonise data collection across Europe. There is also potential for a top–down approach: modelling wild boar distribution and habitat suitability or even local densities calculated from drive hunts or camera-trapping grids to obtain predicted relative abundance, distribution and even density, on a large scale. For this purpose, hunting data, especially data derived from drive hunts, have the highest potential to be comparable and used across Europe for spatial modelling.

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[2] WBDM: accessible at http://www.enetwild.com/2018/04/25/release-model-collect-data-on-wild-boar-distribution-and-abundance-europe/

### 3.1.3. Guidance for estimating wild boar population assessment methods

An External Scientific Report provided to EFSA by EnetWild (ENETWILD et al., 2018) provides a detailed description of **direct methods** (based on direct observation of wild boar) and **indirect methods** (not based on direct observation of wild boar) to estimate wild boar population size as well as guidelines for the harmonised implementation of wild boar population assessment methods. Only a few methods are accurate and only a few are practical and affordable.

3.1.3.1. Direct methods

Based on the current state of knowledge, three direct methods are especially recommendable: camera-trapping grids with appropriate algorithms (i.e. random camera setups followed by a proper treatment and interpretation of data), drive counts and distance sampling with thermography. These methods have the potential to be used for cross validation[3] between alternative methods. Density data obtained in this way have the potential to feed spatial modelling of density distribution extrapolated to larger scales. Most important, they can be used to validate models calculating density based on relative abundance index data. Detailed information on the general protocols to be implemented for these three methods is provided in the above-mentioned report.

3.1.3.2. Indirect methods

Indirect methods, i.e. those not based on direct observation, such as genetic capture–recapture may be unbiased and accurate for local population assessment if certain specific parameters are properly calculated (e.g. defecation rate for methods based on pellet counts). Therefore, validated available data derived from indirect methods may be usable as population estimates. The need to adjust measurements to locally specific parameters (e.g. local faecal decay rates, which are not exportable to other locations/seasons) makes their use limited to local surveys.

Throughout the remaining of this opinion, the use of reported density refers to the estimate of the density provided by the local authorities, without further specifying the method to obtain these figures, and should therefore be carefully interpreted, taking into account the above-described difficulties in comparing density data that were not estimated through harmonised collection methods.

3.2. Wild boar density threshold for ASF transmission (ToR2)

3.2.1. Theoretical considerations

Thresholds for disease transmission have been laid down, including the population threshold of invasion (NT; the minimum host population number required for the disease to be able to successfully invade/spread within a host population) (Deredec and Courchamp, 2003; Lloyd-Smith et al., 2005) and the critical community size (CCS; the host population size above which the probability of stochastic fadeout of the disease over a given period is less than 50% (Lloyd-Smith et al., 2005).

Several theoretical approaches have been developed, deemed relevant to these thresholds for disease and are considered in detail by Lloyd-Smith et al. (2005). Using theoretical approaches based on density-dependent transmission (in which the hazard of infection increases linearly with population number (N), measured either as the abundance or density of infectious individuals; McCallum et al., 2001), NT and CCS can each be calculated, but with the key assumption of homogenous and random mixing (that is, each susceptible individual has an equal probability of being in contact with an infected one). CCS is highly sensitive to the demography of the infected host population, persistence is longer in larger populations and in populations with faster demographic turnover (Lloyd-Smith et al., 2005). However, N_T is not applicable when using theoretical approaches based on frequency-dependent transmission (where the hazard of infection is independent of population number (N)) and the probability of successful invasion is determined by characteristics of the infectious agent e.g. limited sexual contacts per individual; McCallum et al., 2001). Ongoing transmission i.e. spread and persistence of the infection in the host population is dependent on rate parameters (e.g. recovery rate of infectious individuals, death rate not associated with infection, transmission coefficient).

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[3] The three recommended methods could be cross-validated against each other and perhaps also with other (published) methods but this would require a case-by-case assessment. Moreover, even these three methods are still the object of continued methodological refinement.

These theoretical approaches have been useful when considering the control of some infectious diseases, such as rabies (Morters et al., 2013). However, these approaches will be difficult to adapt to ASF, for several reasons:

Firstly, it is unclear whether ASF transmission is primarily density dependent. As yet, this issue has been poorly investigated. Extrapolating from experiences gained with classical swine fever in wild boar populations, density-dependent transmission appears to predominate but is not always observed (Rossi et al., 2015).

In addition, the ecology of ASF is complex, as a consequence of:

- The structure of the host population, in particular the influence of social structure both locally and within the broader metapopulation,
- Aspects of viral transmission, with respect to animal-to-animal transmission and the infectivity of carcasses. There remain significant gaps in our knowledge, such as transmission following contact with infected carcasses including the influence of environmental conditions, particularly temperature (i.e. carcass infectiousness decay). These introduce other routes of transmission in addition to the presumably primarily density-dependent transmission.

There is a significant social and spatial structuring of contacts among wild boar. In a recent study from Poland, Germany and Italy, Podgórski et al. (2018) found that contact rates within social groups were 17-fold higher than among animals from different groups. These host contacts are indicative of a metapopulation in which within-group transmission is facilitated and there is limited between-group spread of infection. These authors also found that young wild boar show exceptional connectivity within the population and may contribute to the transmission of infection. Management strategies that affect the social and spatial structure of populations, such as supplementary feeding, have the potential to increase infection transmission rates because they may bring different groups of a metapopulation in contact.

In conclusion, the current epidemiological theory for density thresholds for disease is too simplified to address the complex ecology of ASF. These theoretical approaches rely on key assumptions, including homogenous and random mixing, which cannot be met in wildlife. Due to the complex ecology of ASF, other drivers apart from density may modulate transmission dynamics, such as exposure to infected carcasses, social structure of the host population and mechanical vectors. Therefore, density thresholds may not necessarily reflect directly the sustainability of infection in a particular area.

3.2.2. Field observations

Field observations are the only alternative approach that is available to consider density thresholds for disease in the context of ASF.

However, we should first consider that precise density calculations are feasible only on a local scale and become more imprecise at very low density levels. The numbers of hunted wild boar provide only an approximation of the wild boar abundance, which may be useful for studying global trends, but not for studying these finer epidemiological processes. Furthermore, due to their social nature, animals are likely to cluster. Therefore, there will be the foci of higher density in broader areas where very low densities are being measured.

During the current epidemic, a key finding, which has been evidenced, is that ASF has spread in all known exposed regions, including areas where wild boar densities are stated to be very low:

In Poland, from 2014 to mid-2016, it was suspected that containment of the ASF foci along the eastern boundary may have been a consequence of higher wild boar densities (as reported, 1–4 animals/km^2) in this region and of low wild boar densities ($<$ 0.4 animals/km^2) immediately to the west. At this time, Pejsak et al. (2014) suggested that a density of more than two animals/km^2 was needed to allow sustainable circulation of the virus in wild boar. Subsequently, however, ASF has spread to the west throughout this region of low wild boar density following human-assisted movement in August 2016.

In the Baltic States, there have been sporadic cases of ASF, including defined foci of infection, throughout 2017 in areas that were previously infected. In these areas, wild boar densities are reported to be extremely low (possibly as low as 0.1 animal/km^2) consequent to the initial ASF epidemic.

Nonetheless, in previously infected areas, there is some evidence of a gradient of infection associated with wild boar density. During 2017, ASF virus (polymerase chain reaction (PCR)) prevalence was lower in hunted animals in the east (with density of approximately 0.1 wild boar/km^2, based on the data provided by hunters) compared to the west of Estonia (with density of approximately 1 wild boar/km^2, based on the data provided by hunters). This association may not be entirely

straightforward, however, with the potential for confounding by time since initial virus introduction. ASF has been present in east and central Estonia since 2014/15 and in west Estonia since 2016.

In conclusion, it is not currently possible to estimate density thresholds for ASF from field observations. ASF spread has occurred in areas of varying, including very low, wild boar density and as yet there is no evidence that the disease has disappeared from these areas. These data suggest that wild boar density is but one of a number of several drivers that influence ASF spread. Wild boar density may contribute to ASF spread; however, there appear to be other drivers that determine whether this disease can be sustained or not in a particular ecological setting. These other drivers could include indirect transmission from infected carcasses and the small-scale social structure of the host population. Any derived density threshold would be difficult to translate into practical measures due to difficulty in estimating wild boar density *a priori*.

3.3. Extensive literature review on the reduction or separation of wild boar populations (ToR3 and 4)

3.3.1. Wild boar density reduction/depopulation measures

Considering their different ecological settings, the results of the extensive literature review are discussed for wild boar and feral swine separately. Feral swine and wild boar are the same species (*S. scrofa*), so it can be expected that several aspects of their management are similar, wild boar is an endemic species in the Palearctic, but feral swine is an invasive species in Oceania and the Americas, where they are considered as a widespread pest. Besides different landscape and ecological settings, control efforts to reduce damage to agriculture and the environment are therefore more rigorously implemented in the areas where it is considered as a pest and where a different legal background is in place. Results of the literature review on the efficacy of different measures applied to reduce wild boar population density are reported in Table A.4 (Appendix A).

3.3.1.1. Hunting

- **Wild boar**

    In Europe, a few studies were found through the extensive literature review that investigated wild boar density before and after the intervention. These papers were either dealing with the effect of recreational hunting or were evaluating programmes aimed at substantially reducing the population of wild boar.

    — **Recreational hunting:**

        An increasing wild boar population has been observed in Europe mainly due to changes in land, habitat and feed availability (Monzon and Bento, 2004). This has been reflected in the increased hunting harvests from recreational or commercial hunting activities during the last decade e.g. as reported by Bonet-Arboli et al. (2000). Leránoz and Castién (1996) reported that despite increased efforts through repeated drive hunts, the proportion of the population taken by hunting (harvest rate = 0.37) was small and insufficient even to keep the population stable. The increasing wild boar population trends are also well documented in review papers that fell outside the scope of the extensive literature review (Massei et al., 2015). Keuling et al. (2013) indicated that a 65% annual harvest would be needed to at least stabilise the increasing wild boar trends. These trends may suggest the limited effectiveness of recreational hunting as a regulatory measure to keep wild boar populations stable as a standalone intervention. Besides, bearing in mind the declining numbers of hunters and hence hunting in Europe, managers should be prepared for a growing wild boar population, with associated increasing impacts on several aspects including animal health.

        Nonetheless, the results of the literature review (Table A.4) demonstrated that hunters can also successfully contribute to keep the wild boar population stable, as reported by Quirós-Fernández et al. (2017). To keep wild boar populations at a stable level, different hunting methods can be effective to reach the necessary animal quota, but biased hunting preferences towards large males (e.g. because they are preferred as trophies or because of the specific traditional, ethical or legal context) and feeding of wild boar should be avoided; and hunting efforts should be maintained over years to avoid boosts of population regrowth.

— **Hunting aiming at substantial (> 50%) population reduction:**

Not many studies have been undertaken aiming at drastically reducing or eradicating wild boar populations in Europe (depopulation), which also report the effect on the absolute population density of the intervention and these procedures have been undertaken on a small scale. More controlled and replicated interventions on local wild boar depopulation and its effects on disease dynamics are needed to support decision-makers and hunters in choosing appropriate methods for this purpose.

In the context of disease control, some efforts have been undertaken to drastically reduce wild boar population densities. Garcia-Jimenez et al. (2013) attempted to drastically reduce wild boar populations to control tuberculosis (TB) in one single-fenced hunting estate. Absolute wild boar density measures, however, could not be provided by the researchers. Boadella et al. (2012a) reported the successful eradication of wild boar in a fenced area (about 6 km^2), in the context of control of *Trichinella* spp. Another paper by the same authors (Boadella et al., 2012b) reported the removal of approximately 50% of the wild boar population in a unfenced area of about 543 km^2 in southern Spain by intense and year-round culling in the context of Aujeszky's disease and TB control in wild boar.

- **Feral swine**

Control programmes on feral swine predominantly focus on their eradication, with the aim of protecting local flora and fauna and the health of domestic animals in Australia and the US. This is reflected in the results of the literature review. Only one paper was found that studied the effect of recreational hunting on the population density and all the other papers reported studies undertaken to eradicate feral swine.

— **Recreational hunting:**

Gentle and Pople (2013) analysed commercial harvest data from three consecutive hunting seasons in Australia (drive hunts with dogs) and concluded that the reported harvest rates were inefficient for population reduction and landscape protection. Harvest rates of more than 50% over several years would be needed for the protection of the environment. Interestingly, this figure is roughly in agreement (65%) with the suggested harvest rates that were estimated in a meta-analysis study on wild boar mortality in central Europe (Keuling et al., 2013).

— **Hunting aiming at substantial (> 50%) population reduction:**

There are several examples of programmes aiming at drastic depopulation in Australia through hunting as separated measure or in combination with other population reduction measures (see below Section 3.3.1.3). Reduction of feral swine populations has been reported up to 80% with drastic control programmes implementing helicopter shooting (Saunders, 1993). Recovery of 77% of the population after 1 year, however, was observed, and the author suggested that control programmes should be carried out over several years to obtain sustainable reduction of feral swine.

In the United States, several attempts have been made to eradicate feral swine from Hawaiian National parks with good results. Repeated drive hunts with dogs reduced pig densities to zero or near zero in most of the control zones. However, when reinvasion from neighbouring areas was not prevented through fencing, feral swine immigrated soon after the programme stopped and efforts were not sustainable (Barron et al., 2011).

Burt et al. (2011) modelled the time and probability of success of eradication of feral swine in California, based on 10 years' hunting data. The authors concluded that intense harvesting of feral swine through drive hunts with dogs can be achieved for insular feral pig populations. The median number of years to eradication ranged from 10 (72% annual harvest rate) to 2.5 (95% harvest rate).

Ditchkoff et al. (2017) in contrast, reported an increased feral swine population during a bounty programme that was set up to drastically reduce the population in Fort Benning (Georgia). The authors hypothesised that this was due to increased food availability and reproduction associated with baiting and a strong preference of shooting large adult males as trophies, rather than shooting reproductive females, which could have reduced the population growth.

3.3.1.2. Trapping/snaring

- **Wild boar**

  Alexandrov et al. (2011) reported a harvest of 79% of the local wild boar population using wooden box traps with wire fencing and maize baiting in an area near the river Danube in north-eastern Bulgaria. Up to seven wild boar could be trapped in one trap. The authors suggested that the use of traps can be especially interesting in areas where hunting is not recommended e.g. in focal recently infected areas where intensive drive hunts could result in increased spread of infectious wild boar. Also, Boadella et al. (2012b) suggested that trapping and culling could lead to an up to 50% population reduction and could become part of the disease control strategies, combined with habitat management, game management and vaccination.

- **Feral swine**

  Saunders et al. (1993) reported a proportion of 0.28% of feral swine being trapped and removed from the local population in the Kosciusko National Park in Australia using of 16 portable traps in an area of 300 km^2 placed in baiting stations. The local characteristics of the area where the box traps were placed, and the time of the year had significant effects on the success of the traps. Higher proportions of feral swine were removed when traps were placed in baiting areas, and feral swine were accustomed to baiting.

3.3.1.3. Hunting combined with trapping/snaring for depopulation

The combination of hunting together with the use of traps for depopulation of feral swine has been reported by several authors, with divergent results. No studies for wild boar were found.

- **Feral swine**

  In Australia, drive hunts with dogs in combination with box trapping resulted in a culling efficiency of 27% (proportion of the number of feral swine killed over the feral swine seen during battues). When using radiotracking techniques to spot wild boar (with captured and released 'Judas pigs' with radio-collars to identify hiding places of free feral swine), a higher efficiency of 0.80 was obtained to reduce the population, but the authors reported the need of expensive equipment and special skills to precisely locate collared individuals (McIlroy and Saillard, 1989; McIlroy and Gifford, 1997). Nowadays, however, radio/GPS collars have become more affordable and remote satellite tracking is now readily available to assist in finding location.

  In the USA, Reidy et al. (2011) reported that 2–3 weeks of box trapping and 1 day of shooting of swine from a helicopter in Texas (Fort Hood) resulted in the removal of 31–43% of the estimated feral swine population. McCann and Garcelon (2008) studied the combination of box trapping and hunting with dogs to eradicate feral swine in California (Pinnacles National Monument Park). Trapping techniques removed most pigs, but a combination of both techniques was required for eradication.

  In Hawaii, Hone and Stone (1989) were able to eliminate feral swine from three out of nine management units in the Volcanoes National Park by using a combination of exclusion fencing, drive hunts with dogs, trapping, snaring and baiting. The cost of removing the last animals was high. Also, Katahira et al. (1993) reported the total eradication of feral swine in some control areas of the Volcanoes National Park, primarily by drive hunts with dogs, followed by helicopter hunting, trapping and snaring for the remnant pigs. The mean effort needed to eradicate 175 pigs was 20 worker hours/animal. Eradication occurred after 3 years. Anderson and Stone (1993) used cable snares within fenced areas to achieve a 97% and 99% reduction of wild boar per km^2 in two management units in the Kipahulu Valley in Hawaii. The number of worker hours per pig removed was much higher in the less densely populated management unit. They recommended that transects are more appropriate to be used in the early stages of an eradication programme to determine population density. Issues related to welfare of snared feral pigs were not discussed.

3.3.1.4. Fertility control

In Florida, Killian et al. (2006) investigated the use of a gonadotropin-releasing hormone (GnRH) immune-contraceptive vaccine to reduce the fertility of feral swine kept in an experimental set up. A single injection was effective in reducing fertility. After 36 weeks, none of the eight 2,000-μg-treated females and only 2 of the ten 1,000-μg-treated females were pregnant. Future research is needed on potential residues of GnRH in meat and to investigate the possibility to administer the vaccine orally in a selective manner.

3.3.1.5. Poisoning

Poisoning of animals is forbidden in the EU under the legislation of biodiversity conservation. The authorisation procedures and the use of biocides are regulated by Regulation No 528/2012[4] of the European Parliament and of the Council. As a general approach, a biocide can be used only for the purpose for which it is authorised (specifying e.g. the target species, administration, dosage in Articles 17 and 19). In situations that pose a danger to public health, animal health or the environment which cannot be contained by other means, any MS can derogate (Art. 55) and approve the use of a biocidal product which does not fulfil the conditions for authorisation. The derogation should take into account that the biocidal product or its residues should not have unacceptable effects on the health of humans or animals, directly or through drinking water, food, feed, air or indirectly considering:

- the fate and distribution of the biocidal product in the environment;
- contamination of surface waters (including estuarial and seawater), groundwater and drinking water, air and soil, taking into account locations distant from its use following long-range environmental transportation;
- the impact of the biocidal product on non-target organisms;
- the impact of the biocidal product on biodiversity and the ecosystem.

In addition to this legislative framework, welfare aspects regarding the target species need to be considered in addition to non-target species.

- **Feral swine**

    In countries where feral swine are invasive, toxicants may become an additional, effective control tool. There is extensive experience in the use of poison in non-European countries, indicating that the effectiveness can reach up to 90% population reduction. However, to achieve an effective population reduction, the administration of poison needs to be repeated over years and the impact on non-target species is a very important consideration.

    In Australia, several field studies have been carried out to evaluate the effect of the use of poison to reduce the feral swine population density.

    Twigg et al. (2005) reported a high efficiency of 1,080 baits, containing **sodium fluoroacetate**, to reduce feral swine populations in north-western Australia up to 90% within 4 days and no bait uptake was seen by non-target species. However, the population recovered back to 20–23% of the prebaiting level within 1 year. Cowled et al. (2006) carried out a field trial with baits containing sodium fluoroacetate in the Welford National Park, Australia, and observed a reduction of 73% of feral swine. Almost all feral pigs (34 of 36) died less than 17 h after bait consumption but poisoning of free-ranging wildlife in areas where the feral pigs were baited could not be excluded. The known lethal dose, 50% (LD_{50}) of Australian native animal species to fluoroacetate ranges from 0.11 to over 800 mg/kg. Many native Australian animal species have evolved tolerance to fluoroacetate either through direct ingestion of native plants that contain fluoroacetate or indirectly when preying on animals that consume these plants. During targeted poisoning campaigns, field studies indicate that populations of common non-target animals are not significantly affected. However, further studies are needed to assess the impact of these campaigns on vulnerable species (McIlroy et al., 1989). In the US, primary and secondary poisoning of non-target animals may accompany the use of fluoroacetate. Sensitive mammals, including representative species of livestock, marsupials, felids, rodents and canids, died after receiving single doses of 0.05–0.2 mg/kg body weight. Furthermore, high residues were measured in some poisoned target mammals, and this contributed to secondary poisoning of carnivores that ingested poisoned prey (Eisler, 1995).

    Research is ongoing in the US. **Warfarin** – an anticoagulant that could be effective at low doses – has been registered by the federal US Environmental Protection Agency but is not being used pending additional research results relative to humaneness. McIlroy and Gifford (1997) and McIlroy et al. (1989) reported high proportions of the feral swine populations being removed by providing baits containing Warfarin in the Namadgi National Park, Australia. However, non-native foxes died that fed on the corpses of the poisoned pigs. Warfarin has also been assessed by ECHA regarding Directive 98/8/EC concerning the placing of biocidal products on the market.

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[4] Regulation No 528/2012 of the European Parliament and of the Council (22 May 2012): on the making available on the market and use of biocidal products (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1518880295826&uri=CELEX:02012R0528-20140425).

Finally, a **sodium nitrite** toxicant has been shown to be effective and humane and is in process of being registered in the USA, too (Kurt VerCauteren, personal communication).

3.3.1.6. Feeding bans

The extensive review did not reveal any papers that measured the wild boar density before and after a feeding ban. However, it is well established that food availability is a key driver of wild boar population dynamics (Cellina, 2008), and it is also well known that extensive wild boar feeding with concentrates such as cereals or industrial feed is common in many European countries (e.g. there are 84,665 feeding sites – 12/1,000 ha – in the Czech Republic; Ježek et al., 2016). This suggests that a feeding ban (excluding for baiting for limited situations and feeding of fenced populations) would positively contribute to wild boar population control in the long term (e.g. baiting limitations as presented in the Scientific Opinion of the AHAW Panel (EFSA AHAW Panel, 2015)).

3.3.2. Wild boar separation methods

The results of the literature review on the efficacy of different measures applied to separate wild boar populations are reported in Table A.5 (Appendix A).

3.3.2.1. Fencing

- **Wild boar**

  Wire fencing is often used to limit wildlife movements, for instance in hunting enclosures. However, such fences are almost always permeable to a certain degree, particularly when streams or other structures cross a single fence line. Fencing has been used on very large scales to segregate wildlife from livestock. In southern Africa, wildlife proof fences of over 500 km were set up to prevent disease spread. However, these fences were vulnerable to certain animal species, including suids, which may slip under them, and are expensive to maintain. Moreover, large-scale fencing may be an important impediment to conservation as large barriers seriously interfere with animal movement.

  By contrast, small-scale fencing is a key tool in farm biosecurity. Electrical fencing appears to be the preferably method used to protect vulnerable fields against wild boar-rooting activities. Their effectiveness was tested in some European studies and some fences have shown to be effective in keeping the animals outside the crops. In Tuscany (Italy), crop damage decreased by 93% in the 5 years following the installation of a 16.5 km linear electrical fence to protect cultivated areas (Santilli and Stella, 2006). In Slovenia, three different electric fence designs were tested around an arable area of 0.12 km² where damage was previously reported. Only piglets were able to cross the fences and no new damage was recorded, regardless of the type of fencing in use (Vidrih and Trdan, 2008). However, these types of fences, where piglets can pass, might not prevent the spread of diseases such as ASF.

  The presence of fencing around hunting estates has also been analysed as a protective factor for *Trichinella* prevalence in wild boar population of central Spain. In the study of Boadella et al. (2012a), the prevalence of the parasite was significantly lower in wild boar population of fenced hunting estates than in the unfenced ones.

  The installation of fencing in a particular cultivated area can increase damages in nearby unprotected crops (Vidrih and Trdan, 2008). A positive fence–damage relationship was reported also in a study performed in Thurgau canton (Switzerland): electrical fences composed by two wires, 20–40 and 50–70 cm above the ground, respectively, were put in place for several years from spring to late summer to protect vulnerable fields (Geisser and Reyer, 2004), and, unexpectedly, a 27% increase of damages in the study period was reported. The record was due to a shift of the animals' depredation activities towards less protected areas.

  For studies performed on wild boar fencing outside Europe, the extensive literature review included a study on an electrical fence put in place near the boundaries of the Chitwan National Park (Nepal). The fencing was designated to mitigate the human–wildlife conflict in the area and proved to be effective: the recorded damage caused by wild boar and other wildlife species significantly declined (78%) after its installation (Sapkota et al., 2014). Crop damage caused by Indian wild boar (*Sus scrofa cristatus*) was investigated after the installation of an electric fence in villages located near the Kalakad Mundanthurai Tiger Reserve, in India (Jeyasingh and Davidar, 2003). No significant differences in loss estimates, raiding frequency and wild boar group size between fenced and unfenced villages were reported.

- **Feral pigs**

Two studies performed in Texas (USA) reported the effectiveness of hog panels and electric fencing to contain feral pigs or prevent them raiding cultivated lands. Hog panel fences were evaluated by Lavelle et al. (2011). Captured free-ranging feral pigs were used to test the containing capacity of the hog panels (0.86 m tall) under various levels of human pursuit. The fences proved to be 96.7% (95% confidence interval (CI): 85%, 100%) successful if humans entered the enclosures; 83.3% (CI: 67%, 94%) successful when humans were walking within the enclosure and were discharging paintball projectors; 100% (CI: 48%, 100%) successful when the animals were pursued by gunners in a helicopter. The ability of feral pigs to escape jumping over the fence suggested the use of taller panels to contain them successfully. Reidy et al. (2008) tested the ability of electric fencing to minimise feral pig movements in a captive, rangeland and agriculture environment. No electric fence design tested was 100% pig proof, but they were successful in all the trials. In captivity, the mean number of crosses during the period without electric fencing was 65% greater than the period with the electrified fence and 69% greater than the period after electrification (non-electrified fence). In the rangeland trial, the mean number of daily intrusions was 49% lower with the electric fence and 26% lower in the period after the electrification (non-electrified fence) than during the period without the electric fence, respectively. Lastly, in the agriculture trial, the mean percentage of crop damage at harvest was 64% less in fenced than control fields.

Electric fencing proved to be an effective method to prevent feral pigs to enter cultivated areas in a study performed in Indonesia (Schmidt, 1986). After the fencing installation around two zones of a coconut plantation and a nursery, no feral pigs entered the protected area, despite their presence recorded around it. However, installation and maintenance of electrical fencing imply high costs to the farmer (Schlageter and Haag-Wackernagel, 2011).

Therefore, alternative methods to electrical fencing have been developed and a few studies on their effectiveness were found through the extensive literature review. They rely on olfactory, gustatory, optic and acoustic deterrence and have been grouped as following.

3.3.2.2. Odour and gustatory repellents

- **Wild boar**

Odour repellents were also taken into consideration as a possibility to avoid wild boar entrance in cultivated lands. They are made from different kind of substances: human-derived, predator-derived scents and natural components. Generally, the results are controversial and not significant in many cases.

A commercially available chemical deterrent, reproducing a mixture of several predator odours, was tested in Switzerland (Schlageter and Haag-Wackernagel, 2012b). The investigation was performed in grassland near the forest where some luring sites with attractive food were surrounded by the deterrent system. The control sites remained unprotected. There was no significant reduction of the probability of wild boar visiting the luring sites because of the use of odour repellent. It was suggested that in areas where natural wild boar enemies are rare or absent, any kind of predator–odour-based repellents may not be effective.

In another study performed in Switzerland, Schlageter and Haag-Wackernagel (2012a) evaluated the performance of a gustatory repellent in deterring wild boars from agricultural lands. The gustatory repellent investigated was made by wheat and maize pellets with phosphorus acid. The pellets should attract the animals by their odour; once eaten, the phosphorous acid would reveal its unpleasant flavour and should prompt the animals to avoid the area in the future. A slight damage reduction was observed in the trial, but the repellent was not able to prevent crop damages at a significant level nor did it extend the interval between two consecutive damage events. Moreover, since the commercial product was very costly, the authors advised against the use of it.

In some studies, performed in Poland, the effect of the same type of odour repellents was controversial. Piechowski (1996) tested a predator–odour repellent in different study sites and a weak response to the product was reported, since wild boar presence was attested over the barriers. In another study (Wegorek and Giebel, 2008), human-based and predator-based odour repellents were tested. Both barriers were effective, and the damage reduction recorded ranged from 55% to 100%. However, a certain grade of accustoming to the human odour repellent was highlighted. Different types of odour repellents were tested again in another study (Wegorek et al.,

2014) in two different areas of Poland. In this case, the products proved to be not effective or effective only for a 2–3 days period.

A chemical repellent has been tested as a method to avoid wildlife-vehicle collisions (WVC) in the Czech Republic (Bil et al., 2018), where wild boar is the second most involved species in WVC. The study was performed on eight road segments. A commercially available odour repellent based on isovaleric acid was applied 80 cm above the ground as foam to wooden poles, based on the instructions from the producer. The reduction of WVC ranged from 26% to 43%; therefore, the repellent helped to mitigate the number of WVC in the study period.

The extensive literature review retrieved a study performed in India on a ricinoleic acid odour repellent (Sakthivel et al., 2013). The study was performed around Hyderabad and jute ropes soaked into water mixed with the repellent were used around sorghum crops. No new wild boar damage was reported after the treatment despite the presence of the animals attested nearby the crops.

3.3.2.3. Light and sound repellents

The most common light-repellent systems are reflectors, used to mirror the headlights of sideward approaching cars (Schlageter and Haag-Wackernagel, 2011) to prevent animals crossing the road. Furthermore, commercially available solar blinkers were investigated with specific regards to wild boar in northern Switzerland (Schlageter and Haag-Wackernagel, 2011). The solar-powered light-emitting diodes (LEDs), charging their batteries in daylight and constantly blinking during the night, were set up in grassland near the forests at baiting sites and automatically started blinking at dusk. The deterrent system did not appear to reduce the probability of wild boar visiting the luring sites. A system producing simultaneously a shrill sound and a bright light to discourage wild boars entering cultivated lands was investigated in Bhutan (Dakpa et al., 2009). The deterrent systems had an acoustic range of 300 m and were set around different cultivations. The 67% of farmers of the study area reported no new damage that was recorded only when the device malfunctioned. The repellent proved to be effective and was recommended as a short-term control measure.

3.4. Field observations on measures applied to stop the spread of ASF (ToR3 and 4)

Measures to reduce the spread of ASF in wild boar populations have been implemented in response to two very different epidemiological circumstances, namely after **a focal introduction** in wild boar populations far away from the affected areas, or after **introduction from adjacent affected wild boar populations**. They are discussed separately below.

3.4.1. Focal introduction of ASF in wild boar population (as reported by the Czech Republic)

ASF was confirmed for the first time in the Czech Republic on 26 June 2017, in two wild boar found dead in the Zlín district. In accordance with the Council Directive 2002/60/EC and Commission Implementing Decision (EU) 2017/1162 of 28 June 2017 on certain interim protective measures for ASF in the Czech Republic, the whole District Zlín has been declared as an infected area (1,034 km^2). Different wild boar management zones (i.e. the fenced area, high- and low-risk area and intensive hunting area) have been established as outlined in Figure 3. Ten months after discovery of the index case, ASF is still only located in a very small territory in the Czech Republic and has apparently not spread. A combination of measures was implemented and continuously adjusted to the epidemiological situation.

A

B

C
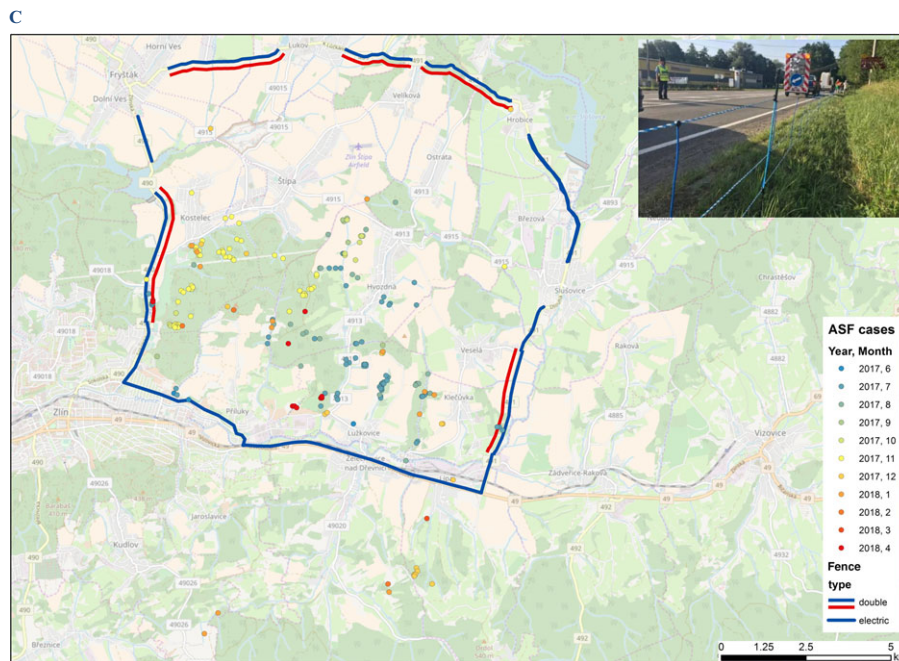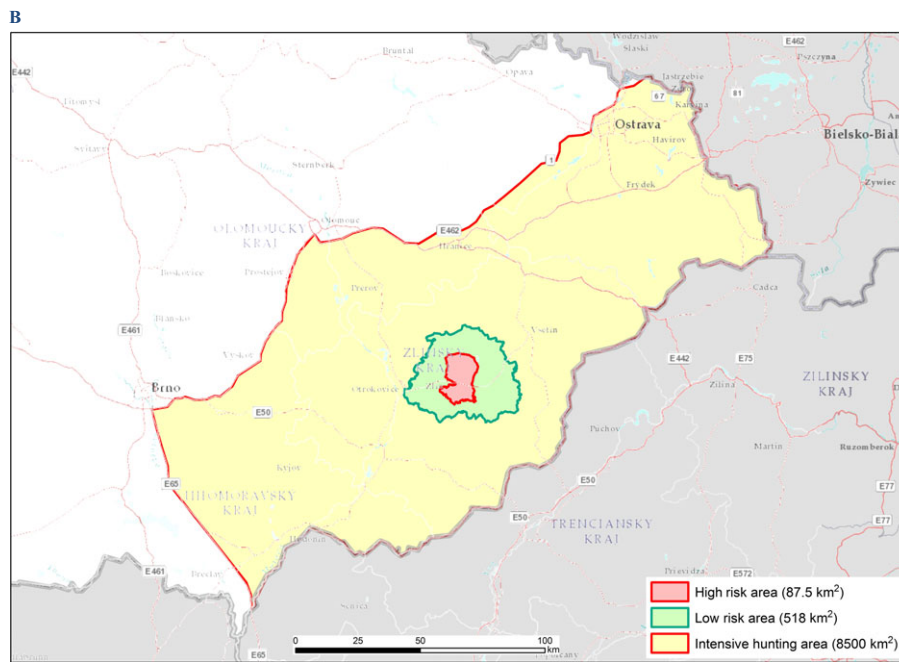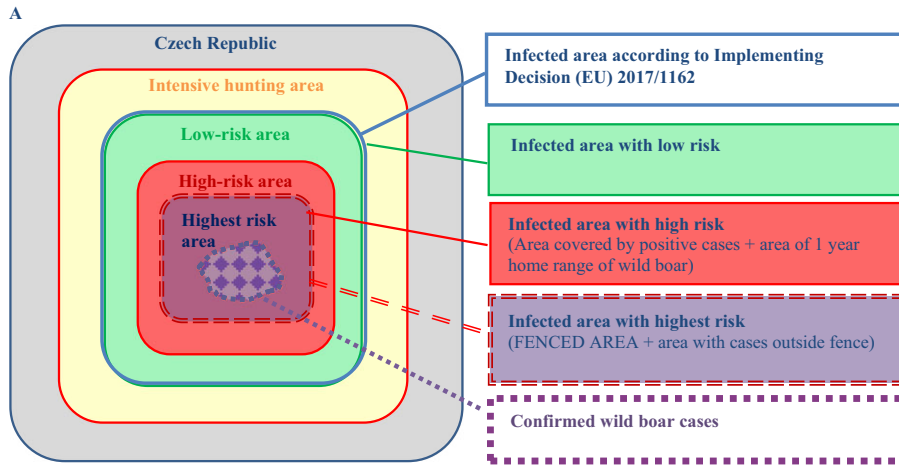
(A) Panel A shows a schematic overview of the management areas at the beginning of the outbreak. The scheme visualises only the logical order and naming of the areas. The relative size is not meant to reflect the real geographic situation.

(B) Panel B shows all the areas in the real geographic context.

(C) Localisation of positive wild boar. Some positive cases were found outside of fenced area; however, they were still in the high-risk area (red area in Figure 3A). In the low-risk area (green area, Figure 3A) or the intensive hunting area (yellow area, Figure 3A), there were no positive results yet.

Figure 3: Wild boar management after a local African swine fever (ASF) outbreak in the Czech Republic

3.4.1.1. Fenced area (high risk area, set up on 18.7.2017)

From the initial phase of the epidemic, an area of 57.2 km^2 has been fenced to limit the possible movement of infectious wild boar with an odour fence ($^®$ Pacholek). The odour fence consisted of a line of simple plastic cups placed at a distance of 5 m from each other. The cups were placed on the ground and were filled with synthetic foam soaked with a chemical substance mimicking the natural odour of predators (including wolf and brown bear) and humans. The foam was resoaked every 4 weeks. Rain does not affect the efficiency of the odour substance according to the producer.

In addition, to increase the odour fence efficiency, an electric fence has been added in the most permeable sections (i.e. on unpaved roads in the forest). The whole perimeter of the fence is about 32 km, with 10 km electric fence.

At the moment of writing this opinion (11 May, 2018), these fences are still in place to protect the high-risk zone wild boars movement. With the exception of 11 infected wild boar found outside the fences, all the other cases have been recorded in the fenced area. In the highest risk area inside the fences, 267 wild boar have been shot and 14 were positive. In the high-risk area outside the fence, 2,858 wild boar have been hunted and 4 were positive. All wild boar found dead outside the infected area were tested – all with negative result.

- *Hunting policy:*

    1) Hunting ban: immediately after confirmation of ASF on 26.6.2017, a hunting ban was implemented in the fenced area forbidding the hunting of any species with any hunting methodology.
    2) Sit and wait hunting: from September 2017, after the initial epidemic, the hunting ban was withdrawn and sit and wait hunting was allowed but only for individual hunters that attended training on biosecurity measures to be implemented during hunting and transport of hunted animals, to prevent spread of infection. No more than three teams of local hunters were allowed to hunt at the same time in each hunting ground.
    3) Intensive hunting: In the fenced area, hunting by snipers from Police started on 16 October 2017 and lasted until 21 December 2017. In total, 158 wild boar were hunted and 8 of them were positive for ASF. The snipers were trained for wild boars hunting and for biosecurity during hunting. They were split in eight teams of two men shooting wild boar with a 3-day interval. All shot wild boar were collected by the State Veterinary Administration and safely transported to the nearest road and then sampled at the rendering plant.
    4) Trapping of wild boar.

Since 24 August 2017, wild boar have been trapped also in the fenced area using home-made box traps.

- *Carcass removal:*

    All found dead and hunted animals were collected under biosecurity measures, marked with hunting seals number, transported into specific wild boar collection centres, dispatched with authorised vehicles to a rendering plant where they were sampled by an official veterinarian and then disposed.

- *Feeding:*

    Within the fenced area, some crops were deliberately left on the fields to provide feed and shelter for the wild boar and prevent them from moving outside the fences. These crops have been harvested after depopulation carried out by police in January 2018.

- *Access for general public:*

    The general public was not allowed to enter the fenced area.

3.4.1.2. Wild boar management zone outside the fence

The perimeter of the buffer zone around the fenced area has been established 1 month after ASF confirmation, when the affected area had been described taking into consideration where the positive wild boar were found, and considering the theoretical maximum annual increase of the home ranges of the wild boar living in the fenced area. The wild boar management zone outside the fence is split into the high-risk zone, the low-risk zone and the intensive hunting area. The initial affected area, as defined according to Commission Implementing Decision 2017/1162, was covering the fenced area, the high- and low-risk area.

The high-risk area covers 160 km^2 and is a buffer zone around the fenced area. It has been calculated considering the maximum annual increase of the home ranges of the wild boar living in the fenced area. The low-risk area is the infected area outside the high-risk area and covers 874 km^2. The intensive hunting area covers 8,500 km^2 and borders the infected area.

- ***Hunting policy:***

  <u>Hunting ban:</u> from 21 July 2017, the hunting ban was withdrawn, and hunting has also been allowed in the low-risk area.
  <u>Intensive hunting:</u> from 13 July 2017, the wild boar management in the intensive hunting area was aiming at a drastic reduction of the population size. All shot wild boar were tested for classical swine fever (CSF) and ASF. In total, 14,884 wild boar were hunted in the area of intensified hunting (from the time of establishment up to the 3 April 2018). No positive case of ASF has been recorded in this area.

- ***Carcass removal:***

  The passive surveillance in the area of intensified hunting (i.e. finding of dead wild boar and its testing) has been generally accepted as one of the most important steps among the approved measures. For this reason, incentives were paid for each wild boar found dead, which were gradually increased.

- ***Feeding:***

  In the low-risk area, only baiting could be performed with not more than 10 kg/month per 1 km^2.

A timeline of the measures applied after the ASF outbreak in the Czech Republic is provided in Appendix B.

3.4.2. Spread from adjacent infected area (other affected MS)

Measures summarising the strategy to be applied in affected wild boar populations were harmonised across MS in the Document SANTE/7113/2015.[5]

3.4.2.1. Within the infected area

- ***Hunting policy***

    1) Targeted hunting:

Targeted hunting of females (subadult and adult) was included in to the ASF Strategy for the Eastern Part of EU, established in 2015 and updated in 2018 (Document SANTE/7113/2015).

Estonia

In Estonia, during the 2014–2015 hunting season, no targeted hunting was implemented, but in the hunting season of 2015–2016 targeted hunting has been introduced. By the Decree of Environmental Board of 31 August 2016, 50% of subadults and adult wild boars shot had to be females and 50% of the total shot animals had to be piglets. A premium for every hunted sow was introduced in January 2016.

According to the hunters' estimates, the density of wild boar in the infected areas in Estonia decreased as a result of intensified hunting and mortality due to ASF below 1.5 wild boar per 1,000 ha of hunting ground by the end of 2017–2018 hunting season. In 2016, the number of hunted adult and subadult sows was 4,315. In 2017 more than 2,800 adult and subadult female wild boars were hunted.

In 2015, the proportion of females in Estonian adult wild boar population (reflected by sex balance among found dead animals) was approximately 60% (see Table C.1, year 2015, found dead).

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[5] https://ec.europa.eu/food/sites/food/files/animals/docs/ad_control-measures_asf_wrk-doc-sante-2015-7113.pdf

According to regulation, the hunting bag had to contain 50% female and 50% male adults. This target was achieved in 2015. As a result, the proportion of females should have increased in adult population (which was opposite of the aim of the applied measure) as proportionally more males from their absolute number was hunted. In 2016, the proportion of females among found dead was 62.6% (see Table C.1, year 2016), which may be the result of the applied target values.

The proportion of hunted female wild boars has been larger than 50% in years 2016–2017 leading to decrease of female population. By 2017, the proportion of adult females was 54.5% among found dead animals – a reduction of 13% on 2015 (see Appendix C).

Lithuania

The whole territory of Lithuania is divided into 931 hunting grounds, each with hunting clubs responsible for the management of the hunting grounds. There is no limitation on the number of wild boar hunted, and wild boar hunting is allowed all year round. Licences or hunting permissions are not needed and no plans or rules for every hunting clubs exist on the obligation to hunt wild boar. Every hunting club decides independently how, when, where and how many wild boar (including females) to hunt. The competent authority of Lithuania can only recommend balancing the hunting bag between males and females.

According to the data presented by Lithuanian hunters, during the season 2015–2016, they have hunted 21,000 males and 14,300 females (proportion between males and females 60% and 40%, respectively) and during the 2016–2017 season, 20,500 males and 13,500 females (proportion between males and females 60% and 40%, respectively). The overall hunting bag in Lithuania was not balanced between male and females (should be 50% each according to the ASF Strategy for the EU). In Lithuania, the use of the night vision equipment including night vision scopes for wild boar hunting is forbidden. Therefore, identifying and targeting female wild boar are not easy, and the number of hunted males is always higher than the number of females.

Lithuania increased the compensation for shooting adult female wild boar during the period between 1 October 2017 and 15 December 2017 (a period when females are less likely to be pregnant or are with small piglets) up to 300 euro to motivate more hunters to hunt female wild boar. Within 2.5 months, hunters requested compensation for 739 hunted females (281 more than in the previous hunting period); however, this increase was not significant.

Poland

Also, in Poland, the strategy of wild boar population reduction is based on hunting directed on adult females in the area located 100 km around the infected zone (part II).

2) Drive hunts:

Initially, drive hunts were forbidden in Estonia in the infected area but in the 2015–2016 hunting season drive hunts were allowed as well as standing shooting from a standing motor vehicle. In addition, the use of artificial light sources, hog traps and steel traps were also permitted for hunting practices. Killing wild boar with ASF clinical signs (which means in practice any signs of disease) was allowed without a hunting permit. The goal was to reduce the wild boar density to 1.5 wild boar per 10 km^2 (1000 ha) of hunting ground by the end of hunting season 2017/2018 (decree of Environmental Board 18.8.2015). The minimum number of wild boar to be hunted was designated by the Environmental Agency for every hunting club.

In Lithuania, in 2014, drive hunts were forbidden, but since 2015, it is allowed from 15 October until 1 February in the infected area: maximum one drive hunt can be performed per month in the same hunting unit (i.e. the same forest district).

Increased hunting of female wild boar has been implemented since 2016. Most of the female wild boar are hunted during the drive hunting season (October–February), and most of them are hunted until 31 December. After this date, targeted hunting of females is not applied.

• **Feeding and baiting**

In Estonia, in the first year after introduction, feeding of wild boar was continued at existing feeding grounds (places), but establishment of new feeding sites was prohibited. However, in 2015, feeding of wild boar was prohibited all over the country. Baiting of wild boar with maximum 10 kg per day (100 kg per slot) was allowed during hunting season (1 October to 30 April).

Since the 2016–2017 hunting season, feed allowed for bating was reduced to maximum 5 kg per feeding slot on ground (max 100 kg in feeding machine) and maximum of 100 kg of feed per feeding slot/place per month. All bating sites had to be registered at the Environmental Board. The distance

between baiting places had to be at least 1 km and only one baiting place per 1000 ha of hunting grounds was permitted. Trail cameras had to be placed at every baiting place.

In Lithuania, immediately after ASF confirmation in the wild boar population at the end of January 2014, the Order of the Director of State Food and Veterinary Service was issued ordering to establish additional places for wild boar feeding and baiting, in order not to increase the movement of wild boar within the infected area. In April 2014, the Hunting Rules on the territory of Lithuania have been amended with the prohibition to feed hunted animals with unusual food which they cannot find in natural conditions, including food of animal origin or other animal by-products, food and food waste. The feeding ban for wild boar in the entire country was implemented since October 2014 by the amendment of the Hunting Rules on the territory of Lithuania and only baiting is allowed to date.

Due to the mild winter conditions and enough food left on the field, the feeding ban did not influence significantly the wild boar population and Hunting Rules have been implemented in Lithuania since April 2015, specifying that in one baiting place no more than 100 kg of natural feed (which an animal can find in the nature) can be provided for hunting purposes to decrease the wild boar movement.

- *Carcass removal*

Since 2013, after the official confirmation of ASF outbreaks in Belarus, Lithuania strengthened the passive surveillance activities and using awareness campaigns informed of the obligation to report wild boar found dead or killed in road accidents. Despite these efforts, the notification of carcasses worked poorly.

At the beginning of 2016, Lithuania established a compensation scheme to motivate the notification of wild boar carcasses and started to pay 30 euro per notification. This resulted in the notification and confirmation of 379 positive wild boars that were found dead in 2016. In the regions where most ASF cases in wild boar were confirmed, people started to actively search for the dead wild boar and the number of reports as part of passive surveillance increased further.

All found dead wild boars were collected and dealt with by the Veterinary Service.

In 2017, ASF was confirmed in 2,146 dead wild boars (more than four times the rate for the years 2014–2016). As the number of found dead wild boars started to increase, the Veterinary Service was no longer able to collect and safely dispose of all cadavers, and since 30 September 2017, Lithuania started to pay the hunters from hunting grounds, where the dead wild boars were found for the carcass destruction by burying.

In Latvia, wild boar carcass removal started immediately after ASF confirmation in June 2014. Initially, the Food and Veterinary Service took samples and collected the carcasses. The carcasses were delivered to containers that were placed throughout the affected area. Then, the contents of the containers were brought to incineration plant. This work required many resources and in March 2015, it was decided to pass this task to the hunters, who received financial compensation. Later, when the ASF-affected territories enlarged, most of the carcasses were buried on the spot. Only when this was not possible (e.g. in a wet area or on frozen ground), the carcasses were placed in containers and later incinerated.

3.4.2.2. Outside infected area

- *Intensive drive hunts to drastic reduce population (increased hunting bag)*

In Latvia, there has been no limitation for wild boar hunting since 2013. The hunting bag is indicative but if hunters fulfil it, they can ask for more licences.

- *Targeted hunting females*

In Latvia, targeted hunting of females was initiated in November 2015. It was applied for the whole country.

- *Feeding*

In Latvia, regulation on feeding ban for wild boar was established in December 2014 for the whole country.

3.4.2.3. Summary of field observations

An overview and comparison of the measures implemented by some MSs to limit the spread of ASFV is described in Table 2.

Table 2: Comparison of measures vs. effect on the spread of ASFV: group experiences

Countries	Hunting allowed in affected area	Application of measures improving biosecurity during hunting	Carcass removal	Impact of the measures on the spread of ASF
Estonia First notification on date: 8 September 2014	2014: drive hunts forbidden but sit-and-wait hunting allowed 2015–2016: intensive hunting in affected and not affected areas 2016–2017: targeted hunting of females in addition	Recommendations for biosecurity (dressing carcasses) during hunting, but implementation not always possible	Applied immediately after first detection, however, the proportion of carcasses found and removed was limited	Spread up to 50% of territory after 1 year, and 90% after 2 years Slow spread in hunting season 2014/2015 (without intensive hunting) Faster spread in 2015/2016 hunting season (intensive hunting with drive hunts)
Latvia First notification on date: June 2014	2014: drive hunts forbidden in areas of 20 km radius from each case but sit-and-wait hunting allowed 2015–2018: during a drive hunt season (15 October to 1 February), drive hunt is allowed in the infected area only if general biosecurity rules are complied with Since November 2015: targeted hunting of female wild boars in addition	Prohibition to leave offal in the forest since June 2014 General biosecurity rules were established for drive hunts in 2015 Regulation on strict biosecurity during the wild boar hunting was approved in April 2018	Applied immediately after first detection	Yearly spread by natural wild boar movement is observed with incidental jumps due to the human factor
Lithuania First notification on date: 24 January 2014	2014: drive hunts forbidden but sit-and-wait hunting allowed 2015–present: during a drive hunt season (15 October to 1 February), drive hunt is allowed in the infected area no more often than once a month in the same part of the hunting unit (in the same forest) Since 2016, target hunt of female wild boars	The rules of biosecurity exist from 2002. Additional stricter requirements are implemented since 2015	Applied immediately after first detection	Yearly spread by natural wild boar movement is observed with incidental jumps due to the human factor (up to 35 km)
Eastern Poland First notification on date: February 2014	Intensive hunting in affected area after initial detection allowed during the whole year	Regulations should be fulfilled for offal disposal and dressing area	Applied immediately after first detection	Remained localised initially
Centre of Poland (Warsaw) First notification on date: November 2017	Hunting forbidden in affected area during the whole year	Regulations should be fulfilled for offal disposal and dressing area	Applied immediately after first detection	Spread continues

Countries	Hunting allowed in affected area	Application of measures improving biosecurity during hunting	Carcass removal	Impact of the measures on the spread of ASF
Northern Poland First notification on date: December 2017	Hunting allowed in affected area during the whole year	Regulations should be fulfilled for offal disposal and dressing area	Applied immediately after first detection	Still early after introduction to assess impact
CR: Isolated infection First notification on date: June 2017	Hunting forbidden for 3 months and 3 months only individual hunting under special conditions in affected area Buffer zone: hunting ban for 1 month and individual hunting under special conditions in affected area Surrounding buffer zone: intensive hunting	In affected and buffer zone, all hunted wild boar disposed to rendering plants	Applied immediately after first detection in affected area and buffer zone	Remains localised

3.5. Field observations on natural and artificial barriers for wild boar

Artificial barriers such as fenced motorways or natural barriers such as large rivers lakes and low density areas have been reported to reduce the spread of other diseases e.g. classical swine fever (Schnyder et al., 2002; Pol et al., 2008). The below section reports on the experiences gained with the efficacy of artificial and natural barriers to reduce the spread of ASF in the affected MS.

3.5.1. Artificial barriers/fences

In Latvia, the option of building fence on the border with ASF-infected eastern neighbouring countries was discussed in 2015. A wide range of experts including biologists and wildlife specialists were invited to discussions on practical aspects and possible consequences of the fence. Final discussions revealed that due to geographical, biological and climate circumstances, a long fence on the border with Russian Federation and Belarus was difficult to build and maintain and thus expensive and impractical.

In Poland, a fence of more than 1,236 km is under construction. According to the decision of Ministry of Agriculture and Rural Development, the fence across the border with Russia – Kaliningrad Oblast, Belarus and Ukraine – may facilitate the stop of further introductions of infected wild boar from the affected Eastern countries. The total length of the fence will be over 1,236 km. The height of the fence should be at least 2 m. Additional gates or doors will be provided for each 5 km of the fence length. The total cost would be 57 million euros. In the opinion of wildlife experts, the fence can partially limit wild boar movement but cannot exclude new incursions.

Lithuania, after official confirmation of two outbreaks in domestic pigs in the neighbouring country Belarus in 2013, has taken different precautionary measures to avoid the ASF virus introduction. As the situation with the ASF in wild boar population in the neighbouring country was not clear and no additional ASF cases in wild boar were reported, it was still considered a potential risk that ASF virus might escape from the outbreak places of domestic pigs in Belarus to the wild boar population. Lithuania has taken the decision to make a 'chemical (odour) fence' at the border to limit the cross-border movement of the wild boar, minimising contacts between healthy and possibly infected wild boars, using repellents (WAM-Porocol®, Austria) consisting of synthetic odorous substances. Those repellents were applied in the eastern border areas of the territory of Lithuania, to prevent the wild boar movement and to deter wild boar from entering the fields. These repellents were used along almost 300 km of the border in October 2013, but despite this repellent application, ASF was detected at the end of January 2014 in wild boar found dead and hunted in two different areas of Lithuania: one male of 12 months old hunted 5 km from the border with Belarus and one female of 3 years old found dead about 40 km north from the border with Belarus. The distance between the two animals was about 36 km. The animals were tested positive for the ASFV genome by real-time PCR at the National Reference Laboratory for ASF in Lithuania (NRL). The results were confirmed by the European Reference Laboratory for ASF (CISA-INIA, Madrid, Spain). Furthermore, the genotyping revealed that the Lithuanian isolates were identical with the ASFV isolates from Georgia (2007), Armenia (2007), Azerbaijan (2008), Russia (2008–2012), Ukraine (2012) and Belarus (2013). Based on the laboratory examination, the infection of the two wild boar must have been introduced more or less at the same time in mid-January.

Due to its close vicinity to Belarus, where ASF was assumed to be present in the wild boar population and based on the genotyping results, it was hypothesised that the infection might have crossed the border from Belarus with infected wild boar or by infected material (e.g. meat or meat products). So far, however, both hypotheses are only based on the sequencing data and geographical vicinity.

A summary of the different artificial barriers put in place by MSs is reported in Table 3.

Table 3: Effectiveness of different barriers in EU Members States

Country	Barrier	Effectiveness
Poland	Old fence in place from USSR time (not intact)	To be evaluated, ASF already present in the country
	New fence under construction, border with Russia, Belarus, Ukraine – 1,236 km	To be evaluated
Lithuania	Chemical (odour) fence – 300 km	Not efficient, ASF entered the country
Denmark	Fence under construction, German border – 70 km	To be evaluated
Czech Republic	Focal ASF area 32 km, 10 electric fence and 22 km odour fence only	Few ASF cases have been detected outside the fence

3.5.2. Natural barriers

ASF was introduced in Latvia in June 2014. Later, the disease spread further to west and north-west in wild boar population locally. However, some long-distance 'jumps' have also been observed. Although ASF cases in wild boar were observed close to the river Daugava (the largest river of Latvia dividing Latvia into two parts), the disease did not cross the river, until December 2015 and in some segments of the river even not until August 2016 Considering these observation, it could be concluded that the river Daugava acted as a temporal natural barrier and kept ASF in the wild boar population at the northern side for 18–26 months.

In Estonia, the water bodies between the islands have generally served as natural barriers for the spread of ASF although it is known that wild boar can pass the straits between the Estonian islands by swimming. ASF introduction to Saaremaa Island in 2016 was most probably human mediated. The neighbouring smaller island of Muhumaa remained probably ASF-free for a longer period: one seropositive wild boar was discovered in August 2017 and the first PCR-positive hunted wild boar was detected on 31 October 2017. Both wild boar were hunted on the western coast of the island. In March 2018, a third positive (antibody positive) animal was detected on the eastern coast of the island. So far, a wider spread of the infection has not been observed on Muhumaa Island.

On Vormsi island, near to the west coast of Läänemaa county, one positive (PCR and antibody positive) wild boar has been detected in 2017. No further spread of the infection has been observed.

3.6. Wild boar surveillance (ToR5)

3.6.1. Surveillance objectives for ASF

As highlighted earlier (Thulke et al., 2009; EFSA AHAW Panel, 2011), the objectives of animal health surveillance will vary depending on the epidemiological circumstances. That is, the phases of infection in a population from infection free (but at risk of an incursion of infection) through to infected, then potentially again to infection free following elimination of the infection. This adaptation has been termed 'situation-based surveillance' (Thulke et al., 2009) and is applied with both domestic animals (EFSA Panel on Animal Health and Welfare, 2011) and wildlife (Thulke et al., 2009). This approach provides the basis of cost-efficient surveillance of contagious diseases, such as ASF.

3.6.1.1. In infection-free populations

In regions or countries that are currently free of infection (for example, before the incursion of a transboundary disease), the primary surveillance objective is early detection, that is, the discovery of new outbreaks of infection or disease. Occurrence (arrival or recurrence) is the key information of interest. In these circumstances, surveillance systems must be sustainable over the long term whenever the disease of interest is absent, while also being able to detect infection (or disease) as quickly as possible when an incursion does occur. These objectives are best achieved through passive surveillance (see below).

3.6.1.2. In infected wild boar populations

In infected regions or countries, the presence of infection is already recognised, at least in some areas. The primary surveillance objectives are to estimate the prevalence of infection (or disease) and for case finding. This information will assist with operational objectives, including establishing the extent of the infected area, identifying potentially useful interventions and monitoring the impact of these interventions on the prevalence of infected animals.

EFSA AHAW Panel (2011) previously subdivided 'infected populations' into three phases, relevant to bluetongue virus infection that could be adopted for ASF. For each, there was adaptation of both the objectives and type of surveillance conducted:

- Infected population with increasing prevalence

  - Objectives: establishing extent of infected area, identifying potentially useful interventions
  - Type: immediate follow-up, investigation of detected outbreaks

- Infected population with prevalence having reached a plateau

  - Objectives: establishing extent of infected area, identifying potentially useful interventions, monitoring the impact of interventions on the prevalence of infected animals
  - Type: active surveillance, including cross-sectional survey

- Infected population with decreasing prevalence
  — Objectives: monitoring the impact of interventions on the prevalence of infected animals
  — Type: active surveillance, including cross-sectional survey or longitudinal sentinel survey

3.6.1.3. In wild boar populations that are likely to be free of infection, following elimination

In these circumstances, there is a gradual shift in the objectives of surveillance, from estimating prevalence and case finding to early detection (the discovery of new outbreaks of infection) and potentially also demonstrating freedom from infection. Here, early detection is again best achieved through passive surveillance, namely laboratory accessions and post-mortem examination of as many indicator animals as possible.

3.6.2. Passive surveillance for early detection of ASF into naïve wild boar populations

3.6.2.1. Passive surveillance

Passive surveillance is the most effective and efficient method of surveillance for early detection of wildlife disease in which cases are easily recognised or case-fatality is high. That is, surveillance is directed towards the identification of 'indicator animals', these being animals suspected of having the disease, animals killed because of presenting clinical signs or suspicious behaviour, animals found dead or killed on roads, those belonging to high-risk species or animals to which humans may have been exposed (Thulke et al., 2009).

In a detailed review, Thulke et al. (2009) outlined a number of reasons why passive surveillance is preferred to active surveillance for the early detection of these diseases:

a) Surveillance effectiveness and efficiency. There is a significant and often very substantial difference in the performance of surveillance focusing on indicator animals (passive surveillance) and hunted animals (active surveillance). To illustrate, see results presented by Thulke et al. (2009) (Table 4).

Table 4: Surveillance effectiveness and efficacy (Thulke et al., 2009)

Disease and context	Test target	Odds ratio*	95% CI
Rabies virus detected in foxes from 1990 to 1995 in five German States	Virology	2.5	2.2–2.9
CSF in wild boar (1995–September 2007, Rhineland-Palatinate in Germany)	Virology prior to vaccination	55	43–71.8
	Virology after vaccination	296	217–403
	Serology before vaccination	0.99	0.5–1.9
Highly pathogenic avian influenza H5N1 in wild bird risk species (February–May 2006, 13 EU Member States)	Virology (PCR)	2.2	1.6–3.1

CI: confidence interval.
*: Odds ratio of detection through passive compared with active surveillance.

b) A risk-based approach. With diseases in which cases are easily recognised, or case-fatality is high, indicator animals are a biased subset of the overall population, being, by definition, those at increased risk of being infected with the infection or disease of concern.

c) System flexibility. During passive surveillance, the source and number of submitted samples are expected to change, as the epidemic evolves. That is, the system would be expected to naturally adapt once, for example, newly infected areas were to emerge.

3.6.2.2. System features

Sample size and frequency of sampling

Sample size calculations for early detection through passive surveillance are not defined statistically. Rather the aim is to test as many 'found dead' animals as possible, based on sample availability and laboratory capacity. In uninfected populations, there is a need for estimates of wild boar density and mortality rate combined with the probability of detecting a 'found dead' animal given its presence. This information could be used to estimate the baseline submission rate.

Keuling et al. (2013) reviewed published radiotracking surveys of wild boar throughout Europe (before ASF introduction) and analysed the estimated mortality. Information on piglets was not representative. Data for yearlings (1–2 year-old) and adults (> 2 years) indicated a 67% survival, i.e. a 33% mortality. Of this mortality, 85% was due to hunting, while only 15% was due to other causes including diseases or starvation, traffic accidents and unknown causes. This means that of a population of 100 wild boar (> 1 year old), 33 will die, of which only five will die due to causes other than hunting. If all 28 hunted wild boar carcasses were taken away by the hunters, only five would be left.

Barasona et al. (2016) radiotracked adult wild boar in regions with a high prevalence of infection with the *Mycobacterium tuberculosis* complex. The annual mortality was 46% of which 53% was due to hunting and 47% due to disease (TB), predation or unknown causes. This means that of a population of 100 adult wild boar, 46 will die, of which 22 will die due to causes other than hunting.

Hence, depending on the site and the sanitary situation, the expected mortality of wild boar yearlings and adults will probably range from 5% to 22%, annually. This range would yield annually, 0.5–2.2 dead wild boar per 10 km^2 (at an estimated low density of 1/km^2) or 5–22 wild boar per 10 km^2 (at an estimated high density of 10/km^2). This calculation excludes piglets (individuals < 1 year) because these are less detectable and easier to remove and destroy by scavengers. If piglets were included, the figures would probably build up to three times the above calculations.

This information is important in 'peacetime', providing assurance that a well-functioning system of passive surveillance is in place, able to rapidly detect ASF following incursion. The sensitivity of passive surveillance systems is affected by the probability that a carcass will be detected if present and the probability that the detected carcass will be submitted for testing (or alternatively that authorities will be advised of the detected carcass). Non-technical factors are particularly important, influenced by awareness campaigns, financial subsidies, etc.

Time to detection

Based on current knowledge and experiences, for an intervention to be successful, there is a need to detect an ASF incursion while it is still spatially contained.

Possible risk areas

Human-mediated spread has been an important feature of the ASF outbreak to date, with the Zlín outbreak being the most dramatic example of spread that is unrelated to the natural movement of wild boar. A similar situation relates to the new cluster of ASF in wild boar around the area of Warsaw. This has important implications for surveillance, in particular the need for caution when assessing possible risk areas. Non-infected areas neighbouring those with ASF infection are clearly at high risk of incursion; however, no area within the EU can be considered risk-free. There is a need for a clearer understanding of drivers for human-mediated spread.

3.7. Optimising involvement of stakeholders in enhanced passive wild boar surveillance for African swine fever (ToR6)

Since ASF introduction in Europe, vast experience has been gained by the EU MS at risk of ASF and the affected MS in motivating different stakeholders to notify dead wild boar as well as enhancing subsequent sampling and carcass removal of positive animals. Below is a summary of this experience, based on expert opinion for enhancing passive surveillance, both in free areas and already affected areas.

3.7.1. Awareness building/communication

Reluctance of different stakeholders (hunters, forest rangers, general public) to notify dead wild boar has often been the result of insufficient understanding of the epidemiology and economic impact of the disease; ignorance of the importance of the notification in terms of early detection to mitigate further spread of the disease; fear for inappropriate or unpractical control measures or simply not knowing how or to whom to notify the dead wild boar. Suitable information is therefore primordial, and different communication channels have proven effective.

3.7.1.1. Organise training workshops, seminars or informal meetings

It has been crucial to clearly set out the practicalities for the control measures that will be implemented after confirming an ASF positive result in dead wild boar, and the consequence of

inappropriate measures on the spread of the disease. For instance, measures such as a hunting ban in the infected area after ASF detection in dead wild boar has at times demotivated hunters to notify concerning dead wild boar, even when they received incentives for notification. Clear communication about the effect of drive hunting on the spread of the disease, and the high mortality paired with ASF infection in wild boar should be communicated, it is understood that not notifying is not a solution.

At the same time, it is fundamental that control measures are feasible and practical, and therefore, the organisation of training workshops, meetings or seminars where the practicalities are discussed in a participatory manner are of outmost importance. Measures to be implemented after detection of ASF in dead wild boar should be justified, logical and proportional and well described to the stakeholders, otherwise there will be no compliance. It is important that the provided information in these meetings is tailor-made.

In areas at risk and newly affected areas by ASF virus, it is very important to meet with every hunting club and provide all the necessary information with regard to enhanced passive and active surveillance and to discuss sampling procedures, incentives and biosecurity measures and possible consequences. All hunters or at least the representatives of all hunting clubs should be provided with training on clinical signs of ASF and post-mortem lesions as well as the actions to be taken in case of suspicion of ASF (notification, sampling, storage of carcass, etc.).

3.7.1.2. Printed information: leaflets, posters, newspapers and brochures

Leaflets, brochures or posters with short and catchy messages (with the use of visual material as pictures of ASF in wild boar) have proven to be very useful to enhance passive surveillance. They should be prepared and distributed to hunters and forest rangers in areas at risk or hung in strategic places (e.g. hunter club, hiking club, forest shelters). Good collaboration with editors of hunting magazines should be established, as these magazines can play a great role in informing hunters and forest rangers.

3.7.1.3. Set up sign boards

Sign boards placed repeatedly in wild boar habitat in both affected areas and areas at risk have proven very useful to enhance passive surveillance. These sign boards should alert passengers not to throw any offal and provide a contact telephone number for notifying the finding of wild boar carcasses.

3.7.1.4. Awareness campaigns in social media and mobile phone applications

To enhance passive surveillance, hunters, other professionals working in forests and possibly the general public could also be involved in carcass detection by making the notification simple through e.g. mobile phone applications. Some applications are already in use for other purposes (e.g. the app developed in Germany: https://www.tierfund-kataster.de/tfk/webgis/script/index.php or in Denmark: https://play.google.com/store/apps/details?id=dk.borgertip.landbrugfoedevarer) and could also be used to report dead wild boar with the possibility to send a photograph and coordinates to a remote database. These methods have been used successfully for passive surveillance of wild birds in Denmark in the context of avian influenza.

3.7.1.5. Awareness campaigns on television and internet

Movies and documentaries developed to inform the general public about the epidemiology and impact of ASF, and the importance of early detection to stop the further spread of the disease in wild boar populations have proven very efficient to enhance passive surveillance. To be most effective, they should be broadcasted regularly on local TV channels, or they can be posted through social media channels, on websites of the hunters and farmers association, hiking clubs or other stakeholders.

3.7.2. Provide incentives for notifying dead wild boar

Incentives have proven to be fundamental to ensure a well-functioning passive surveillance system for ASF in wild boar populations, especially in areas at risk and in areas where the virus was recently introduced.

For instance, in Latvia, incentives for the notification of dead wild boar were introduced in June 2014 for any person that notified a dead wild boar. This helped a lot to start up the enhanced passive surveillance system. Most notifications were received from hunters. This system was in place until March 2015, when incentives were paid for both the notification and disposal of the carcass together

and it was provided exclusively to hunters. Although incentives for any person for the notification of dead wild boar carcass worked really well, it had to be taken into consideration that somebody still had to take samples and collect and dispose the carcasses, so the incentives also included this aspect.

In Estonia, the passive surveillance in officially non-infected areas has been based on voluntary notifications mainly by hunters. Hunters were less motivated to notify found dead wild boar to authorities as long as there were no incentives in place. After the detection of the infection in wild boar and the establishment of the infected area, the financial compensation for hunters for the disposal of wild boar carcasses substantially increased the notification of carcasses testing negative for ASF in the infected area. For example, in one county, the number of notified wild boar carcasses from January to July 2016 was 1, and in the same period in the year before, this was 2. After the first detection of ASF on the 26 August 2016, in 1 week, five negative carcasses were notified (in total, six in September). During the following 3 months, the number of detected negative carcasses was 2, 3 and 5, respectively, bringing the total to 16 in 5 months after infection. In 2015, from September to December, this was in total 7.

On average, in years 2015 and 2016, the number of notifications of ASF virus negative carcasses per month increased in Estonia by 2.6 times following the detection of the infection in a region (county) being in a range of 0.25–1.67 notifications per month per county before and 0.33–3.83 notifications per month per county after the infection had entered the county.

The carcass (sample) submission depends on the notification of the detection of the carcass to the Veterinary Authorities. Once the detection has been notified, the Veterinary Authority assures that the found carcass will be sampled and that the samples are submitted to the official laboratory.

In Estonia, hunters' organisations received compensation for the following three activities:

- Carcass disposal: 70 euro per buried carcass and 42 euro per carcass taken to a container (35 euro until October 2017).
- Selective hunting of female wild boar: 120 euro per hunted female animal (organ sample has to be taken into local veterinary centre as a proof).
- Taking blood sample from hunted animals: 12 euro per one wild boar sampled (since May 2018).

In Lithuania, some surveillance activities on ASF were carried out since 2003, but active surveillance started since 2011, taking the blood samples from hunted wild boar in the entire territory of Lithuania with a 5% of prevalence and 95% of confidence, which resulted in taking not less than 59 samples per region. Passive surveillance was not very well developed and only few cases of wild boar found dead were reported.

Since 2013, after the official confirmation of ASF outbreaks in Belarus, Lithuania strengthened the passive surveillance activities and awareness campaigns informed not only hunters and forest workers about the obligation to notify dead wild boar, but this information was also distributed using other media sources. Despite these efforts, the notification of carcasses worked very weak.

In 2014, ASF was confirmed in four wild boar found dead and in 2015 in 59. At the beginning of 2016, Lithuania established a compensation scheme to motive the notification of wild boar carcasses and started to pay 30 euro per notification. This resulted in the notification and confirmation of 379 positive wild boar that were found dead in 2016. In the regions where most ASF cases in wild boar were confirmed, people started to actively search for the dead wild boar and the number of reports as part of passive surveillance increased further. In 2017, ASF was confirmed in 2,146 dead wild boar (more than four times compared with the years 2014–2016).

As the number of found dead wild boar started to increase, the Veterinary Service was no longer able to collect and safely dispose all cadavers and since 30 September 2017, Lithuania started to pay also the hunters from hunting grounds where the dead wild boar were found for the carcass destruction by burying.

The number of found dead animals increased further due to the presence of ASF, especially found in the territories densely populated by wild boar and until 22 May 2018, ASF was confirmed in 898 places affecting 2,260 wild boar (2,083 found dead and 177 hunted).

3.7.3.   Collaboration with hunters

As mentioned above under 3.6.1.1, appropriate communication and a continuous dialogue with the hunter associates are a perquisite to establish a good collaboration with hunters, and participatory discussions are needed to guarantee that the measures to control the disease are practical and proportionate.

To engage hunters in ASF control measures, ideally, responsibilities and competences should be mapped *a priori* (before disease incursion), and a clear flow of communications and events should be

defined to develop a clear set rules which are more likely to be complied with by the hunters and to avoid misunderstandings.

It is very important to establish trust between the Veterinary Services and the hunters' associations and involve them in the development of awareness campaigns. They are closer to the hunters and are more likely to pass the right message.

For instance, in Estonia, compensations have been paid to hunters for the implication of control measures. The Estonian Veterinary and Food Board has made contracts with either the local hunting clubs or with the Estonian Hunters' Association who distributed the funding to hunting clubs. The compensation did not reach every hunter directly, but it was used in the interest of the hunting club. This kind of compensation schemes has been effective to keep the control measures going. In addition, the government has provided the hunting clubs with containers for disposal of carcasses. Since 2017, it was not allowed to bury ASF positive hunted wild boar in Estonia, and carcasses had to be taken into containers and sent to rendering plants. All hunting clubs have been supplied with containers. There has also been a special government programme facilitating hunting clubs to support the building of hunting lodges and cold storage rooms for carcasses.

3.7.4. Challenges

One of the most important challenges observed in the affected MS was the difficulty for the veterinary service to keep up with the collection and disposal of all wild boar carcasses for a prolonged period after the detection of the index case. Therefore, as soon as possible after the beginning of the first outbreak, other stakeholders need to be involved in the enhanced passive surveillance and responsibilities need to be shared to control the spread of the disease in wild boar populations.

Furthermore, as the density of the wild boar population is never known exactly and the percentage of wild boar found dead that are notified to the veterinary service is also not precisely known, it is difficult to evaluate the exact impact of the ASF infection on wild boar populations and the effect of the control measures.

Finally, despite the awareness campaigns and information distributed through different channels, some people, especially hunters, were still reluctant to notify authorities of wild boar carcass. Perhaps, the reason was the unknown consequences that could have a negative impact on hunting (e.g. hunting bans, trade restrictions, etc.).

Enhanced passive surveillance of ASF in wild boar populations demands for a continuous dialogue between all involved stakeholders, and a shared responsibility in monitoring and the control of the disease.

A summary of these positive experiences gained in the ASF-affected MS, during the field activities to motivate different stakeholders for enhancing passive surveillance is summarised in Box 1.

Box 1: Summary of experience gained during passive surveillance of ASF to motivate stakeholders

Awareness building

- Organise training workshops, seminars or informal meetings with all stakeholders, including hunters
- Printed information: leaflets, posters, newspapers and brochures
- Set up sign boards in infected areas and areas at risk
- Awareness campaigns in social media and mobile phone applications
- Awareness campaigns on television and internet

Provision of incentives

- Reporting of carcasses was strongly linked in time with start of incentives
- Incentives helped in reporting carcasses, but experienced people should be involved in the sampling and removal of carcasses.
- Incentives paid for finding carcasses helped especially in newly infected areas as many carcasses could be found. However, in the later stage, when fewer carcasses can be found, incentives for organised searching events can be more effective.

Collaboration with hunters

- Build on trust
- Continuous communication and feedback about the epidemiology and impact of the measures
- Participatory decision making to guarantee practicability and proportionality of measures
- Clear agreements *a priori* on rules and responsibilities during ASF epidemics
- Enhanced passive surveillance of ASF in wild boar populations demands for a continuous dialogue between all involved stakeholders, and a shared responsibility in monitoring and the control of the disease.

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4. Conclusions

4.1. Wild boar density (ToR1)

- Currently, no unbiased estimates of wild boar density on a European scale are available. Some information on local wild boar density in Europe exists. However, it is difficult to access because it is mainly present in grey literature. Furthermore, this information is based on methods that are not harmonised and an assessment of the methodological quality would be needed.
- Accurate density data can only be collected at local level (e.g. using camera trapping). These data could be used to validate large-scale abundance distribution models and to produce large-scale density maps.
- Hunting bag data are currently the only Europe-wide available index of relative wild boar abundance. However, comparison of hunting bags between areas (MSs and regions) is difficult due to differences in the implemented hunting traditions and regulations, particularly because of the lack of a measurable area covered by each hunting event.
- Future harmonised data on hunting-derived wild boar density should include information on aspects such as the surface covered, the number of hunting days and of hunters per day and the hunting modality. In particular, drive hunts are the method where hunting data can more efficiently be harmonised across regions and used for developing models.
- Direct methods such as camera-trapping grids with appropriate algorithms, drive counts and distance sampling with thermography are especially recommended to collect wild boar density data at local scale.
- Indirect methods (e.g. pellet count) have additional complexity due to the need of measurements of additional parameters (e.g. local pellet decay rate).

4.2. Wild boar density threshold for ASF transmission (ToR2)

- ASF spread has occurred in areas of varying, including very low, reported wild boar density. As yet, there is no evidence that the disease has disappeared from these areas. From field observation, there is no indication that a density threshold exists for ASF.
- There are significant gaps in knowledge about the modes of ASF transmission including animal-to-animal transmission, the role of infected carcasses and contaminated environment and mechanical vectors in ASF epidemiology in wild boar within the EU.
- Theoretical approaches for density threshold rely on key assumptions, including homogenous and random mixing, which cannot be met for ASF. Any derived density threshold would be difficult to translate into practical measures due to difficulty in estimating wild boar density *a priori*.
- Due to the complex ecology of ASF, other drivers apart from density may determine whether this disease can be sustained or not in a particular ecological setting. These could include indirect transmission from infected carcasses and the small-scale social structure of the host population.

4.3. Review of wild boar depopulation/density reduction measures (ToR3)

Extensive literature review

- In the wild, *S. scrofa* are called 'wild boar' in the areas where they are endemic and 'feral pigs' in the areas where they are invasive. Generally, control efforts to reduce feral pigs have been

more rigorously implemented, often backed up by a different legal background and public attitude.

- Recreational hunting of wild boar and feral swine can be effective as a regulatory measure to keep ASF-free populations stable, but biased hunting preferences towards large males and feeding of wild boar should be avoided. Hunting efforts should be increased in intensity (harvest rate > 67% per year) to stabilise wild boar populations.
- Urgent interventions for disease control (i.e. locally implemented emergency measures) should be distinguished from long-term management at larger scale aiming at sustainable population management.
- In the context of disease control, depopulation of wild boar has been achieved in small, fenced estates, but in larger areas, not more than 50% of population reduction was reported.
- In areas of high habitat quality, maintaining an intense wild boar population control over a prolonged period of time through intervention is expensive and possibly not sustainable in the long term.
- Eradication of insular feral swine populations has been achieved on some occasions only, through years of intense drive hunting with dogs, with or without the use of other methods such as trapping or shooting from helicopters.
- Drastic reduction (up to 80%) of feral swine populations has been reported with control programmes implementing shooting swine from a helicopter or a combination of trapping and intense drive hunting with dogs. Recovery of the population up to 77% the year after has been reported.
- The use of traps has resulted in a harvest of wild boar up to 79% of the population and can be especially interesting in areas where hunting is not recommended.
- The parenteral use of a GnRH immune-contraceptive vaccine has been demonstrated to reduce the fertility of feral swine kept under experimental conditions. Research is needed, however, to investigate the presence of potential residues of GnRH in meat and the possibility to develop a vaccine that could be administered orally in a selective way to avoid non-target species.
- Poisoning of wild boar is forbidden in the EU under the legislation of biodiversity conservation. However, poisoning has been demonstrated as highly efficient in reducing local feral swine populations. The potential undesirable effects, including welfare aspects of administering the poison and the possible effects of its residues on the health of humans and animals through direct or indirect exposure, have not been sufficiently investigated in the European context.

Field experience

- Based on experiences in the MSs, it is not possible to rank the effectiveness of the individual measures applied. The combination of measures applied in the Czech Republic is the only one where spread only over a short distance was reported up to less than half a year after the first ASF case in wild boar was detected.
- Different actions in terms of wild boar management at different stages of the epidemic are reported based on the collective experience of the affected MS:
- Preventive: measures taken to reduce wild boar density will be beneficial both in reducing the probability of exposure of local population to ASFV and reducing the efforts needed for potential emergency actions (i.e. less carcass removal) if an ASF incursion was subsequently to occur.
- Following focal introduction: drastic reduction in the wild boar population ahead of the ASF advance front (in the free population), and management of the infected population solely to keep it undisturbed and avoid aggregation of individuals and avoid any spread (e.g. short-term hunting ban of wild boar and other species or leaving crops unharvested within the affected area).
- Following the decline in the epidemic, as demonstrated through passive surveillance, active population management could be reconsidered.
- The efficacy of these measures can be jeopardised by the continuous introduction of ASV from neighbouring affected areas or through human-mediated spread.

4.4. Review of wild boar separation methods (TOR4)

Extensive literature review

- Some electrical fences have been demonstrated to temporarily protect crops from damage caused by wild boar or feral swine with different levels of efficiency, but no electrical fence

design can be considered 100% wild boar proof on a large scale for a prolonged period of time. Fences have been shown to be more effective if wild boar are not disturbed by drastic hunting such as drive hunts with dogs, which increase the movement of wild boar and their urge to escape.

- Odour repellents have been tested to keep away wild boar and feral swine from crops with divergent results.
- Light repellent did not show any significant effect on the probability of wild boar visiting luring sites according to two studies.
- Sound repellents have been shown reported to reduce 67% of crop damage caused by wild boar according to one study.

Field experience

- Currently, there is no evidence that large fences have been effective for the containment of wild suids. Some new large-scale fences are under construction, and their effectiveness to separate wild boar populations will need to be evaluated in the future.
- Natural barriers such as large rivers or straits can be used for demarcation for restricted areas as they have shown to reduce, but not completely impede, the movements of wild boar.

4.5. Wild boar surveillance strategy (ToR5)

- In countries free of infection, the primary surveillance objective is early detection. Once infected, the objective shifts to case finding and estimating the prevalence. Following elimination, the surveillance objective shifts back to early detection and demonstrating freedom of infection.
- Passive surveillance is the most effective and efficient method of surveillance for early detection of ASF in wild boar. For early detection through passive surveillance, the aim is to test as many 'found dead' animals as possible.
- In uninfected populations, there is a need for estimates of wild boar density and mortality rate combined with the probability of detecting 'found dead' animals given its presence. This information could be used to validate the submission rate (i.e. the numbers of wild boar that should be submitted due through natural mortality).
- Based on current knowledge and experiences, for an intervention to be successful, there is a need to detect an ASF incursion while it is still spatially contained.

4.6. Optimising involvement of stakeholders in passive surveillance of wild boar (ToR6)

- All MS stated that awareness building and a good collaboration with the hunters were important, although the effect could not be qualified.
- Reporting of carcasses was strongly linked in time with the start of the incentives.
- Incentives helped in reporting carcasses, but experienced people should be involved in the sampling and removal of carcasses.
- Incentives paid for finding carcasses helped especially in newly infected areas, as many carcasses could be found. However, in the later stages, when fewer carcasses can be found, incentives for organised searching events can be more effective.
- A whole range of other measures was applied, but their impact was not quantified.

5. Recommendations

- To improve the quality of hunting data, parameters such as the surface covered, numbers of wild boar shot along with data on the hunting effort are needed across Europe.
- Any attempt to control wild boar populations should be carried out over several years to obtain sustainable reduction.
- Wild boar feeding should be prohibited in unfenced wild boar populations.

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Glossary and Abbreviations

AHAW Panel	EFSA Panel on Animal Health and Welfare
ASF-affected area	area delineated by confirmed cases of ASF-infected wild boar or domestic pigs
ASF-infected area	area as defined in Commission Implementing Decision of 9 October 2014 (2014/709/EU) (as latest amended by Commission Implementing Decision (EU) 2018/478 of 20 March 2018)
Relative wild boar abundance	index that correlates with density but that does not establish number of wild boar per surface, for instance the annual hunting bag
Wild boar density	number of wild boar individuals per unit of surface (syn. census)
ASF	African swine fever
ASFV	African swine fever virus
CCS	Critical community size
CI	Confidence interval
CSF	Classical swine fever
GnRH	gonadotropin-releasing hormone
LD_{50}	lethal dose, 50%
LEDs	light-emitting diodes
MS	Member State
NRL	National Reference Laboratory
PCR	polymerase chain reactrion
TB	tuberculosis
ToR	Term of Reference
WVC	Wildlife-vehicle collisions
WBDM	Wild Boar Data Model

Appendix A – Extensive literature review of wild boar population reduction and separation methods

A.1.   Search methods

Search strategies were undertaken to identify studies reporting methods for wild boar population density reduction or control and separation methods available for wild boar. Searched databases are provided in Table A.1.

Table A.1:   Searched databases to identify available studies of interest

Name	Time coverage	Platform
Web of Science Core Collection	1975–present	Web of Science
BIOSIS Citation Index	1926–present	
CABI: CAB Abstracts	1910–present	
Chinese Science Citation Database	1989–present	
Current Contents Connect	1998–present	
Data Citation Index	1900–present	
FSTA – the food science resource	1969–present	
Korean Journal Database	1980–present	
MEDLINE	1950–present	
Russian Science Citation Index	2005–present	
SciELO Citation Index	1997–present	
Zoological Record	1864–present	
Scopus	1970–present	Elsevier (Scopus.com)

The searches were run on 19 February 2018. The search strategies were adapted according to the configuration of each resource of information.

The search identified 1,338 results retrieved in the Web of Science platform and 503 in Scopus. The search results were downloaded from the information sources and imported into EndNote x8 bibliographic management software. Deduplication was undertaken using a number of algorithms. The final number of results after removing duplicates was 1,352.

A.1.1.   Web of Science platform[6]

Date of the search: 19/2/2018.

Limit language: Czech, Dutch, English, Estonian, French, German, Italian, Latvian Lithuanian, Polish, Romanian, Russian, Spanish.

Type of study: Article, thesis or book.

The search string used in Web of Science is provided in Table A.2.

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[6] All the databases included in the Web of Science platform, as detailed in the methods section, were searched using the *All databases* search option in Web of Science.

Table A.2: Search string – Web of Science

Set	Query	Results
# 10	#7 OR #4 **Refined by: LANGUAGES:** (ENGLISH OR LITHUANIAN OR UNSPECIFIED OR GERMAN OR LATVIAN OR FRENCH OR DUTCH OR NETHERLANDISH OR RUSSIAN OR CZECH OR SPANISH OR ROMANIAN OR ESTONIAN OR POLISH OR CATALAN OR ITALIAN) AND **DOCUMENT TYPES:** (ARTICLE OR OTHER OR ABSTRACT OR CASE REPORT OR UNSPECIFIED OR REVIEW OR THESIS DISSERTATION OR BOOK) *Timespan=All years* *Search language=Auto*	1,338
# 9	#7 OR #4 **Refined by: LANGUAGES:** (ENGLISH OR LITHUANIAN OR UNSPECIFIED OR GERMAN OR LATVIAN OR FRENCH OR DUTCH OR NETHERLANDISH OR RUSSIAN OR CZECH OR SPANISH OR ROMANIAN OR ESTONIAN OR POLISH OR CATALAN OR ITALIAN) *Timespan=All years* *Search language=Auto*	1,412
# 8	#7 OR #4 *Timespan=All years* *Search language=Auto*	1,462
# 7	#6 AND #5 AND #1 *Timespan=All years* *Search language=Auto*	381
# 6	TS=(Fenc* OR barrier$ OR repel* OR restrain* OR trench* OR ditch* OR channel$ OR river$ OR ((artificial OR natural) NEAR/5 (method* OR strateg*))) *Timespan=All years* *Search language=Auto*	3,368,292
# 5	TS=(separat* OR move* OR moving OR dispers* OR (population$ NEAR/5 (structur* OR control OR management)) OR (protect* AND (field* OR farm* OR crop$ OR road$ OR highway$ OR motorway$)) OR ((prevent* OR reduc*) AND damag*)) *Timespan=All years* *Search language=Auto*	8,149,062
# 4	#3 AND #2 AND #1 *Timespan=All years* *Search language=Auto*	1,177
# 3	TS=((Population$ NEAR/5 (dynamic* OR control OR densit* OR management)) OR ((population$ OR densit*) NEAR/5 (increas* OR reduc* OR decreas* OR lower* OR limit*)) OR "de populat*" OR depopulat* OR cull* OR eliminat* OR extermin*) *Timespan=All years* *Search language=Auto*	2,162,911
# 2	TS=(gunning OR shoot* OR trap* OR snar* OR hunt* OR track* OR harvest* OR poison* OR "judas pig*" OR "judas hog*" OR feed* OR bait* OR steriliz* OR sterilis* OR chemosteril* OR (fertility NEAR/5 control*) OR (lethal NEAR/5 (method* OR strateg*))) *Timespan=All years* *Search language=Auto*	5,594,707
# 1	TS=(((pig$ OR boar$ OR swine OR hog$ OR scrofa) NEAR/5 (wild OR feral OR bush)) OR wildboar$) *Timespan=All years* *Search language=Auto*	16,045

A.1.2. Scopus

Date of the search: 19/2/2018.

Limit language: Czech, Dutch, English, Estonian, French, German, Italian, Latvian Lithuanian, Polish, Romanian, Russian, Spanish.

Type of study: Article, thesis or book.

The search string used in Scopus is provided in Table A.3.

Table A.3: Search string – Scopus

History count	Search terms	Results
9	((TITLE-ABS-KEY (((pig OR pigs OR boar OR boar OR swine OR hog OR hogs OR scrofa) W/5 (wild OR feral OR bush)) OR wildboar*)) AND (TITLE-ABS-KEY (fenc* OR barrier* OR repel* OR restrain* OR trench* OR ditch* OR channel* OR river* OR ((artificial OR natural) W/5 (method* OR strateg*)))) AND (TITLE-ABS-KEY (separat* OR move* OR moving OR dispers* OR (population* W/5 (structure* OR control OR management)) OR (protect* AND (field* OR farm* OR crop* OR road* OR highway* OR motorway*)) OR ((prevent* OR reduc*) AND damag*)))) OR ((TITLE-ABS-KEY (((pig OR pigs OR boar OR boar OR swine OR hog OR hogs OR scrofa) W/5 (wild OR feral OR bush)) OR wildboar*)) AND (TITLE-ABS-KEY (gunning OR shoot* OR trap* OR snar* OR hunt* OR track* OR harvest* OR poison* OR "judas pig*" OR "judas hog*" OR feed* OR bait* OR steriliz* OR sterilis* OR chemosteril* OR (fertility W/5 control*) OR (lethal W/5 (method* OR strateg*)))) AND (TITLE-ABS-KEY ((population* W/5 (dynamic* OR control OR densit* OR management)) OR ((population* OR densit*) W/5 (increas* OR reduc* OR decreas* OR lower* OR limit*)) OR {de-population} OR {de-populated} OR depopulat* OR cull* OR eliminat* OR extermin*))) AND (LIMIT-TO (LANGUAGE, "English") OR LIMIT-TO (LANGUAGE, "German") OR LIMIT-TO (LANGUAGE, "Spanish") OR LIMIT-TO (LANGUAGE, "French") OR LIMIT-TO (LANGUAGE, "Polish") OR LIMIT-TO (LANGUAGE, "Russian") OR LIMIT-TO (LANGUAGE, "Czech") OR LIMIT-TO (LANGUAGE, "Dutch") OR LIMIT-TO (LANGUAGE, "Romanian"))	503 document results
8	((TITLE-ABS-KEY (((pig OR pigs OR boar OR boar OR swine OR hog OR hogs OR scrofa) W/5 (wild OR feral OR bush)) OR wildboar*)) AND (TITLE-ABS-KEY (fenc* OR barrier* OR repel* OR restrain* OR trench* OR ditch* OR channel* OR river* OR ((artificial OR natural) W/5 (method* OR strateg*)))) AND (TITLE-ABS-KEY (separat* OR move* OR moving OR dispers* OR (population* W/5 (structure* OR control OR management)) OR (protect* AND (field* OR farm* OR crop* OR road* OR highway* OR motorway*)) OR ((prevent* OR reduc*) AND damag*)))) OR ((TITLE-ABS-KEY (((pig OR pigs OR boar OR boar OR swine OR hog OR hogs OR scrofa) W/5 (wild OR feral OR bush)) OR wildboar*)) AND (TITLE-ABS-KEY (gunning OR shoot* OR trap* OR snar* OR hunt* OR track* OR harvest* OR poison* OR "judas pig*" OR "judas hog*" OR feed* OR bait* OR steriliz* OR sterilis* OR chemosteril* OR (fertility W/5 control*) OR (lethal W/5 (method* OR strateg*)))) AND (TITLE-ABS-KEY ((population* W/5 (dynamic* OR control OR densit* OR management)) OR ((population* OR densit*) W/5 (increas* OR reduc* OR decreas* OR lower* OR limit*)) OR {de-population} OR {de-populated} OR depopulat* OR cull* OR eliminat* OR extermin*)))	512 document results
7	(TITLE-ABS-KEY (((pig OR pigs OR boar OR boar OR swine OR hog OR hogs OR scrofa) W/5 (wild OR feral OR bush)) OR wildboar*)) AND (TITLE-ABS-KEY (fenc* OR barrier* OR repel* OR restrain* OR trench* OR ditch* OR channel* OR river* OR ((artificial OR natural) W/5 (method* OR strateg*)))) AND (TITLE-ABS-KEY (separat* OR move* OR moving OR dispers* OR (population* W/5 (structure* OR control OR management)) OR (protect* AND (field* OR farm* OR crop* OR road* OR highway* OR motorway*)) OR ((prevent* OR reduc*) AND damag*))	125 document results
6	TITLE-ABS-KEY (separat* OR move* OR moving OR dispers* OR (population* W/5 (structure* OR control OR management)) OR (protect* AND (field* OR farm* OR crop* OR road* OR highway* OR motorway*)) OR ((prevent* OR reduc*) AND damag*))	5,030,637 document results
5	TITLE-ABS-KEY (fenc* OR barrier* OR repel* OR restrain* OR trench* OR ditch* OR channel* OR river* OR ((artificial OR natural) W/5 (method* OR strateg*)))	2,558,423 document results
4	(TITLE-ABS-KEY (((pig OR pigs OR boar OR boar OR swine OR hog OR hogs OR scrofa) W/5 (wild OR feral OR bush)) OR wildboar*)) AND (TITLE-ABS-KEY (gunning OR shoot* OR trap* OR snar* OR hunt* OR track* OR harvest* OR poison* OR "judas pig*" OR "judas hog*" OR feed* OR bait* OR steriliz* OR sterilis* OR chemosteril* OR (fertility W/5 control*) OR (lethal W/5 (method* OR strateg*)))) AND (TITLE-ABS-KEY ((population* W/5 (dynamic* OR control OR densit* OR management)) OR ((population* OR densit*) W/5 (increas* OR reduc* OR decreas* OR lower* OR limit*)) OR {de-population} OR {de-populated} OR depopulat* OR cull* OR eliminat* OR extermin*))	414 document results

History count	Search terms	Results
3	TITLE-ABS-KEY ((population* W/5 (dynamic* OR control OR densit* OR management)) OR ((population* OR densit*) W/5 (increas* OR reduc* OR decreas* OR lower* OR limit*)) OR {de-population} OR {de-populated} OR depopulat* OR cull* OR eliminat* OR extermin*)	1,577,238 document results
2	TITLE-ABS-KEY (gunning OR shoot* OR trap* OR snar* OR hunt* OR track* OR harvest* OR poison* OR "judas pig*" OR "judas hog*" OR feed* OR bait* OR steriliz* OR sterilis* OR chemosteril* OR (fertility W/5 control*) OR (lethal W/5 (method* OR strateg*)))	3,234,721 document results
1	TITLE-ABS-KEY (((pig OR pigs OR boar OR boar OR swine OR hog OR hogs OR scrofa) W/5 (wild OR feral OR bush)) OR wildboar*)	

A.2. Search results

Table A.4: Outcomes of literature review on measure to reduce wild boar population density

Reference	Methods								Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning						Start_year	Start_month	End_year	End_month				
Wild boar																				
Monzon and Bento (2004)	X								Drive hunts	Portugal, Nord, Trás-os-Montes region	12,864	Forest and agricultural land	1996	nr	2001	nr	Not reported	Hunting bag	202	The increase in corn production was the main factor involved in the increase of wild boar hunting bags
Quirós-Fernández et al. (2017)	X								Recreational hunting	Spain, Asturias	124.46	Atlantic ecosystem	2000	9	2014	2	Hunting bag	Population growth rate	0.056	Hunters are able to contribute to reduce wild boar abundance, as shown by reduced growth rate compared with period before hunting ban (but still increasing growth rate of 5.6% per year after hunting ban, despite intensive hunting)

Reference	Methods							Method short description	Location	Area size (km^2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Bonet-Arboli et al. (2000)	X							Recreational hunting	Spain, Catalonia, Collserola	1	Forest and grassland	1978	nr	1999	nr	Hunting bag	Harvest rate	0.85	No calculation of population density but increasing hunting bag over the last years
Garcia-Jimenez et al. (2013)		X						Drive hunts with dogs	Spain, Central Spain, fenced estate near Madrid	30	Mediterranean ecosystem	2007		2012		Hunting bag	nr	nr	bTB prevalence remained high in the remnant wild boar population, despite increased hunting efforts. Absolute density measures were not provided
Leránoz and Castién (1996)		X						Drive hunts	Spain, Navarra	100	Forest, grassland and marshland	1987	nr	1988	nr	Hunting bag	Harvest rate	0.37	Although there has been a gradual increase in hunting bag, the proportion of the population taken by hunting was small and

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
																			insufficient to keep the population at a stable number
Leránoz and Castién (1996)		X						Drive hunts	Spain, Navarra	100	Forest, grassland and marshland	1991	Nr	1992	nr	Hunting bag	Harvest rate	0.25	Although there has been a gradual increase in hunting bag, the proportion of the population taken by hunting was small and insufficient to keep the population at a stable number
Boadella et al. (2012b)		X						Drive hunts (intense and year round culling strategy)	Spain, south-central	542.52	Mediterranean ecosystem	2008	nr	2008	nr	Direct observation	Proportion removed	0.5 approximately	Culling effectively reduced tuberculosis prevalence in wild boar, while Aujeszky's disease prevalence remained unaffected. No

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
																			density estimates before and after intervention were available
Boadella et al. (2012b)		X						Drive hunts and stand hunting	Spain, south-Central	7.23	Mediterranean ecosystem	2005	nr	2011	nr	Transect	Proportion removed	0.5 approximately	Culling effectively reduced tuberculosis prevalence in wild boar, while Aujeszky's disease prevalence remained unaffected. No density estimates before and after intervention were available
Boadella et al. (2012b)			X					Capture and moving of females and juveniles	Spain, south-Central	26.9	Mediterranean ecosystem	2005	nr	2011	nr	Not available	Proportion removed	0.5 approximately	Animal removal effectively reduced Tuberculosis prevalence in wild boar, while Aujeszky's

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
																			disease prevalence remained unaffected No density estimates before and after intervention were available., and trapping technique was not described
Alexandrov et al. (2011)			X					Wooden traps with wire fencing and maize baiting	Bulgaria, river Danube in the north-eastern part	25	Forest and agricultural land (maize)	2009	8	2010	1	Not reported	Harvest rate	79.00	Very efficient. Up to seven wild boar could be trapped in one trap. Feasible in areas where hunting is not recommended (viraemic animals that should not spread)
Hafeez et al. (2007)			X					Panel Trap, Fahad Trap and Loop Trap were tested	Pakistan, Faisalabad Division	nr	Forest, Grassland and Marshland	2002	nr	2002	nr		Trap efficacy	0.49–0.71	Panel trap – 70.83% efficacy Fahad trap – 48.57% Loop trap – 53.84%

Reference	Methods								Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning						Start_year	Start_month	End_year	End_month				
Feral swine																				
Saunders (1993)		X						Helicopter shooting	Australia, New South Wales, Oxley' station	120	Forest, grassland and marshland	1985	4	1985	4	Aerial surveys	Percentage population reduction	0.8	Recovery of 77% of the population after 1 year. More than one control programme should be carried out to obtain sustainable reduction
Saunders (1993)		X						Helicopter shooting	Australia, New South Wales, Oxley' station	120	Forest, grassland and marshland	1986	4	1986	4	Aerial surveys	Percentage population reduction	0.65	Recovery of 77% of the population after 1 year. More than one control programme should be carried out to obtain sustainable reduction
Gentle and Pople (2013)	X							Commercial hunting	Australia, South-western Queensland	246-6000	Mainly grassland with some forest	2007	10	2010	4	Aerial surveys	Harvest rate	0.20	Commercial harvesting is inefficient for population reduction.

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
																			Harvest rates of > 50% are needed over several years to reduce populations
Katahira et al. (1993)		X	X		X			Drive hunts with dogs, followed by helicopter hunting, trapping and snaring	United States, Hawaii, Volcanoes National Park	78	Rainforest, Mixed	1983	11	1989	2	Transect	Proportion removed	1	Pigs were controlled primarily by drive hunts with dogs, followed by other method for remnant pigs. The mean effort needed to eradicate 175 pigs was 20 worker hours/animal. Eradication occurred in 3 years. Transect useful for monitoring population
Burt et al. (2011)		X						Drive hunts with dogs	United States, California, National park	249	Mediterranean ecosystem	1990	11	2000	3	Transect			Model based on hunting data showed that strategy of

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
																			intense harvest for 5 years will likely achieve eradication of many insular feral pig populations
Barron et al. (2011)		X						Drive hunts with dogs	United States, Hawaii, Honomanu Makai	3	Forest	2007	10	2008	2	Capture–recapture	Proportion removed	1	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented
Barron et al. (2011)		X						Drive hunts with dogs	United States, Hawaii, Waikamoi Preserve	8	Forest	2007	10	2008	2	Capture–recapture	Proportion removed	1	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Barron et al. (2011)		X						Drive hunts with dogs	United States, Hawaii, Kamakou Preserve	4	Forest	2008	3	2008	7	Capture–recapture	Proportion removed	97.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented
Barron et al. (2011)		X						Drive hunts with dogs	United States, Hawaii, Moloka'i South Slope	10	Forest	2008	3	2008	7	Capture–recapture	Proportion removed	53.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented
Barron et al. (2011)		X						Drive hunts with dogs	United States, Hawaii, Waikamoi Preserve	2	Forest	2008	3	2009	7	Capture–recapture	Proportion removed	89.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Barron et al. (2011)		X						Drive hunts with dogs	United States, Hawaii, Kapunakea Preserve	5	Forest	2008	2	2008	3	Capture–recapture	Proportion removed	65.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented
Barron et al. (2011)		X						Drive hunts with dogs	United States, Hawaii, Waikamoi Preserve	6	Forest	2007	10	2008	2	Capture–recapture	Proportion removed	nr	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented
Ditchkoff et al. (2017)		X						Not specified	United States, West-central Georgia, Fort Benning Conservation Branch	36	Coastal vegetation	2007	9	2008	2	Camera trapping	% increase density	1.1	Pig population increased during the bounty programme, mainly due to baiting and biased shooting of trophy males

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Ditchkoff et al. (2017)		X	X					Night hunting, trapping and bait usage allowed	United States, West-Central Georgia, Fort Benning Conservation Branch	36	Coastal vegetation	2007	7	2008	2	Camera trapping	% increase density	1.52	Pig population increased during the bounty programme, mainly due to baiting and biased shooting of trophy males
Engeman et al. (2014)		X						Not reported	United States, Florida, Avon Park Air Force Range	400	Forest, grassland and marshland	2009		2012		Passive tracking index	Reduction estimated with passive tracking index	1.00	
Gioeli et al. (2015)		X						Drive hunts	United States, Florida		NR	2013	10	2014		Hunting bag		123 removed	
McIlroy and Saillard (1989)		X	X					Trapping, hunting with dogs	Australia, Capital Territory, Orroral Valley, Namadgi National Park	11	Forest and grassland	1986	9	1986	12	Direct observation	Culling efficiency (number of animals killed per animals seen during battues)	27	The cost of hunting was c. US$312 per pig
McIlroy and Gifford (1997)		X	X					Trapping, hunting with dogs	Australia, Capital Territory, Orroral Valley area,	11	Forest and grassland	1989	6	1990		Radio-tracking	Contact rate with Judas pigs	80.00	Expensive equipment and special skills needed to precisely locate

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
									Namadgi National Park, ACT										collared individuals. However, high efficacy to reduce population
McCann and Garcelon (2008)		X	X					Trapping, hunting with dogs	United States, California, Pinnacles National Monument	57	Forest, mixed	2003	10	2006	3	Transect	Proportion removed	100	Trapping techniques removed most pigs, but a combination of techniques was required for eradication
Reidy et al. (2011)		X	X					Box traps and helicopter hunting	United States, Texas, Fort Hood	10	Marshland	nr	nr	nr	nr	Direct observation	Proportion removed	31	2–3 weeks of trapping and 1 day of shooting swine from a helicopter resulted in removal of 31–43% of the estimated feral swine population
Reidy et al. (2011)		X	X					Box traps and helicopter hunting	United States, Texas, Rob and Bessie Welder	32	Marshland	nr	nr	nr	nr	Direct observation	Proportion removed	43	2–3 weeks of trapping and 1 day of shooting swine from a helicopter

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
									Wildlife Refuge										resulted in removal of 31–43% of the estimated feral swine population
Hone and Stone (1989)		X	X					Exclusion fencing, drive hunts with dogs, trapping, snaring and baiting	United States, Hawaii, Volcanoes National Park	929	Mixed	1980	nr	1983	nr	Dung counts	nr		Pigs were eliminated from 3 of 9 management unit. Cost of removing the last animals is high
Saunders et al. (1993)			X					16 portable traps over 63 bait stations	Australia, New South Wales, Kosciusko National Park	300	Forest and grassland	1988	nr	1988	nr	Capture–recapture	Proportion removed	0.28	Local characteristics and the time of year had significant effects on trapping rate. Higher rates observed when traps placed in baiting area
Hone and Stone (1989)			X				X	2% sodium hydroxide	Australia, Namadgi National Park	910	Mixed	1985	6	1987	11	Dung counts	nr		Significant reduction of pig abundance. No poisoning effects were

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
																			observed on non-targeted species
Anderson and Stone (1993)				X	X			Cable snares 3-96 m in length and 0.3 cm in diameter	United States, Hawaii, Kipahulu Valley, lower unit	6	Forest	1979	11	1980	3	Transect	% reduction of wild boar per km2	0.97	A mean of seven worker hours pig to remove 175 animals from the more densely populated lower unit. We recommend that transects be used in the early stages of an eradication programme to determine population density
Anderson and Stone (1993)				X	X			Cable snares 3-96 m in length and 0.3 cm in diameter	United States, Hawaii, Kipahulu Valley, Upper unit	8	Forest	1979	11	1980	3	Transect	% reduction of wild boar per km²	0.99	A mean effort of 43 worker hours pig was used to remove 53 pigs from the upper management unit. We recommend

Reference	Methods								Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning						Start_year	Start_month	End_year	End_month				
																				that transects be used in the early stages of an eradication programme to determine population density
Killian et al. (2006)						X		GnRH immune-contraceptive vaccine	United States, Florida, (controlled trial)		Captive	2002	1	2002	12	Fertility reduction	% pregnant % weight testis		Single injection effective in reducing fertility. Future research needed on residues in meat and oral form
McIlroy et al. (1989)							X	2% sodium hydroxide	Australia, Capital Territory, Namadgi National Park, Gudgenby area	225	Forest, grassland and marshland	1986	5	1986	5	Radiotracking	Proportion removed	0.91	12/14 pigs carrying transmitters died. Foxes died that fed on the corpses of the poisoned pigs
McIlroy et al. (1989)							X	2% sodium hydroxide	Australia, Capital Territory, Namadgi National Park, Boboyan Valley	140	Forest, Grassland and Marshland	1986	5	1986	5	Radio-tracking	Proportion removed	1	All pigs carrying transmitters died. Foxes died that fed on the corpses of the poisoned pigs

Reference	Methods								Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning						Start_year	Start_month	End_year	End_month				
McIlroy and Gifford (1997)							X	2% sodium hydroxide	Australia, Capital Territory, Orroral Valley area, Namadgi National Park	11	Forest and grassland	1990	10	1990	12	Radio-tracking	Proportion removed	1	All pigs followed up died of poisoning
Twigg et al. (2005)							X	Sodium fluoroacetate	Australia, Western Australia	150	Riverland and grassland	2004	8	2004	8	Direct observation	Daily sighting index	89.00	Pig activity/ abundance was reduced by 89% (81–100%) and no bait uptake by non-target species
Twigg et al. (2005)							X	Sodium fluoroacetate	Australia, North-western Australia	150	Riverland and grassland	2005	8	2005	8	Direct observation	Daily sighting index	90.00	Pig numbers had been reduced by ~ 90% within 4 days. Population recovery of 20–23% of the 2004 prebaiting level
McIlroy et al. (1989)							X	2% sodium hydroxide	Australia, Western Australia, Namadgi National Park, Orroral Valley	19	Forest, grassland and marshland	1986	5	1986	5	Radio-tracking	Proportion removed	0	None of the pigs with transmitters died

Reference	Methods								Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning						Start_year	Start_month	End_year	End_month				
McIlroy and Saillard (1989)							X	2% sodium hydroxide	Australia, Western Australia, Honeysuckle Creek area, Namadgi National Park	5	Forest and grassland	1986	9	1986	12	Radio-tracking	Proportion removed	0.14	The cost of poisoning was c. US$237 per pig
McIlroy and Saillard (1989)							X	2% sodium hydroxide	Australia, Western Australia, Orroral Valley, Namadgi National Park	11	Forest and grassland	1986	9	1986	12	Radio-tracking	Proportion removed	0.19	The cost of poisoning was c. US$237 per pig
Snow et al. (2017)							X	HOGGONE	United States, Texas, Kerr Wildlife Management Area (controlled trial)	0	nr	2015	10	2016	6	Camera trapping	Bait efficacy (%)	0.98	The bait proved lethal, acutely acting and stable in experimental conditions. Field studies needed to investigate any potential non-target risks posed by carcasses of wild pigs that have succumbed to sodium nitrite

Reference	Methods							Method short description	Location	Area size (km²)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Cowled et al. (2006)							X	Sodium fluoroacetate	Australia, Welford National Park	nr	Mixed	2005	1	2005	1	nr	% reduction of wild boar per km²	0.73	Almost all feral pigs (34 of 36) died less than 17 h after bait consumption but of non-target poisoning of other free-ranging wildlife in areas where feral pigs are baited possible not excluded

nr: not reported.

Table A.5: Outcomes of literature review on wild boar population separation methods

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Wild Boar																	
Santilli and Stella (2006)	X					Electric fence	Italy, Tuscany	20	Agricultural land	1999	5	2003	11	Crop damage	% crop damage reduction	93	Damage decreased of 93% during the 5 years following the fence installation
Vidrih and Trdan (2008)	X					Electric fence	Slovenia, Postojna, Western High Karst hunting territory	0.12	Agricultural land	2005	7	2005	10	Crop damage	% crop damage reduction	100	Fences were 100% successful in keeping wild boar from entering the field
Boadella et al. (2012a)	X					Fenced hunting grounds	Spain, Central Spain, Ciudad Real	19,813	Mediterranean ecosystem	1998	NR	2010	NR	Hunting bag	Effect on disease prevalence	−0.709	Risk factor analysis highlighted that the presence of the disease (*Trichinella* spp.) was lower in fenced areas ($\beta = -0.709$)

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Geisser and Reyer (2004)	X					Electric fence	Switzerland, Thurgau	860	Forestland and agricultural land	1994	NR	1996	NR	Crop damage	% crop damage reduction	0	Fences did not decrease the total damage rather they caused the animals to shift their activities to less protected regions in the area (+ 27% in total damage)
Sapkota et al. (2014)	X					Electric fence	Nepal, Chitwan National Park	23 km	Forestland and agricultural land	NR	NR	NR	NR	Crop damage	% crop damage reduction	78	Crop damage caused by wild boar and other wildlife were significantly reduced after the installation of the fence
Schlageter and Haag-Wackernagel (2012b)		X				Predator odour repellent	Switzerland, Basel-Land	518	Forestland and agricultural land	2007	7	2008	12	Direct observation	% effectiveness of the barrier	0.4	The odour repellent reduced the probability of wild boar visits at the luring sites by 0.4%, but the effect was not significant

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Schlageter and Haag-Wackernagel (2012a)		X			X	Pellets with phosphorous acid	Switzerland, Basel-Land	518	Forestland and agricultural land	NR	NR	NR	NR	Crop damage	% crop damage reduction	0	The repellent did not have a significant effect on the frequency of damages events nor it prolonged the interval between two consecutive events
Piechowski (1996)		X				Predator odour repellent	Poland, Masovian Voivodeship	0.0188	Forestland	1995	4	1995	5	Animal traces	% effectiveness of the barrier	0	A weak response of the product was reported
Piechowski (1996)		X				Predator odour repellent	Poland, Lodz Voivodeship	0.01	Forestland	1994	10	1995	5	Crop damage	% crop damage reduction	0	Different wildlife species were observed sporadically over the barrier
Piechowski (1996)		X				Predator odour repellent	Poland, Upper Silesia	3.2 km	Forestland	1994	12	1995	3	Animal traces	% effectiveness of the barrier	0	Wild boar specifically feeding signs were reported all over the barrier
Piechowski (1996)		X				Predator odour repellent	Poland, Upper Silesia	0.4 km	Forestland	1994	12	1995	3	Animal traces	% effectiveness of the barrier	0	Wild boar were observed all over the barrier

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Piechowski (1996)		X				Predator odour repellent	Poland, Warmian-Masurian	0.01	Forestland	1994	10	1995	5	Crop damage	% crop damage reduction	1.6	Reported damage were caused by different wildlife species
Wegorek and Giebel (2008)		X				Human odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	5	2007	5	Crop damage	% crop damage reduction	55	The repellent was effective in keeping the animals away from the crops, even if a certain grade of accustoming was recorded
Wegorek and Giebel (2008)		X				Human odour repellent	Poland, Voivodeship	0.01	Agricultural land	2007	8	2007	9	Crop damage	% crop damage reduction	65	The repellent was effective in keeping the animals away from the crops, even if a certain grade of accustoming was recorded
Wegorek and Giebel (2008)		X				Human odour repellent	Poland, Voivodeship	0.002	Forestland	2007	3	2007	4	Crop damage	% crop damage reduction	55	The repellent was effective in keeping the animals away from the crops, even if a certain grade of accustoming was recorded

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Wegorek and Giebel (2008)		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	8	2007	9	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel (2008)		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	5	2007	5	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel (2008)		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	5	2007	5	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel (2008)		X				Predator odour repellent	Poland, Wielkopolskie	0.002	Forestland	2007	3	2007	4	Crop damage	% crop damage reduction	85	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel (2008)		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	8	2007	9	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel (2008)		X				Predator odour repellent	Poland, Wielkopolskie	0.002	Forestland	2007	3	2007	4	Crop damage	% crop damage reduction	90	The repellent was effective in keeping the animals away from the crops

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Wegorek et al. (2014)		X				Human odour repellent	Poland, Wielkopolskie	NR	Forestland and agricultural land	2012	3	2013	8	Direct observation/ animal traces	% effectiveness of the barrier	0	The product has proven to be not effective
Wegorek et al. (2014)		X				Odour repellent	Poland, Wielkopolskie	NR	Forestland and agricultural land	2012	3	2013	8	Transect	% effectiveness of the barrier	0	The product was effective only for a 2–3 days period, then the animals get used to it
Wegorek et al. (2014)		X				Human odour repellent	Poland, Zachodniopomorskie	NR	Forestland and agricultural land	2012	3	2013	8	Direct observation/ transect	% effectiveness of the barrier	0	The product has proven to be not effective
Wegorek et al. (2014)		X				Odour repellent	Poland, Zachodniopomorskie	NR	Agricultural land	2012	3	2013	8	Transect	% effectiveness of the barrier	0	The product was effective only for a 2–3 days period, then the animals get used to it
Bil et al. (2018)		X				Isovaleric acid odour repellent	Czech Republic	1936 m	Road section	2014	9	2016	10	Carcasses/ crash reported	% crop damage reduction	26-43	The reduction of WVC was 26 –43%; therefore, the odour repellent helps to mitigate the number of accidents

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Sakthivel et al. (2013)		X				Ricinolic acid odour repellent	India, Telangana, Hyderabad	0.000016	Agricultural land	NR	NR	NR	NR	Crop damage	% crop damage reduction	100	After the repellent treatment, no damage was recorded despite the presence of the animals around the crops
Schlageter and Haag-Wackernagel (2011)			X			Solar blinkers near luring sites	Switzerland, Basel-Land	518	Forestland and agricultural land	2007	1	2005	1	Camera trapping	% effectiveness of the barrier	8.1	Blinkers reduced the probability of wild boar visits at the luring sites by 8.1% but the effect was not significant
Dakpa et al. (2009)				X	X	Shrill electrical sound and bright light	Bhutan	NR	Agricultural land	2008	5	2009	2	Crop damage	% crop damage reduction	67	The device is effective when functioning smoothly. It is recommended as short-time measure
Feral Pigs																	
Lavelle et al. (2011)	X					Hog panel mesh	United States, Texas, Kingsville	0.0038	Grassland	2009	7	2009	9	Direct observation	% effectiveness of the barrier	96.7/83/100	Hog panel fences were estimated to be 96.7 effective if humans entering the enclosures,

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
																	83% if humans walking discharging paintball projectors and 100% effective when the animals were pursued by gunners in a helicopter
Reidy et al. (2008)	X					Electric fence, agriculture trial	United States, Texas, King Ranch	24.35	Agricultural land	2006	5	2006	6	Crop damage	% crop damage reduction	64	The mean percentage of crop damage at harvest was 64% less for electric fence treatments than controls
Reidy et al. (2008)	X					Electric fence, rangeland trial	United States, Texas, San Patricio County, Sinton	31.57	Marshland	2006	3	2006	4	Camera trapping	% intrusion reduction	49/26	Mean number of daily intrusions by pigs during the period with electrified fence were 49% less than during period without electric fence, and 26% less than during period after electrification (non-electrified fence)

Reference	Method					Method description	Location	Area size (KMQ if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Reidy et al. (2008)	X					Electric fence, captive trial	United States, Texas, Kleberg County, Kingsville	0.0051	Artificial environment	2005	10	2005	11	Camera trapping	% effectiveness of the barrier	65/69	The mean number of crosses during the period without electric fencing was 65% greater than the period with electrified fence and 69% greater than the period after electrification (non-electrified fence)
Schmidt (1986)	X					Electric fence	Indonesia, West Sumatra	0.32	Agricultural land	NR	NR	NR	NR	Farmer surveys/direct observation	% effectiveness of the barrier	100	After the fencing installation, no feral pigs entered the protected area, despite their presence around the crops
Jeyasingh and Davidar (2003)	X					Electric fence	India, Tamil Nadu, Kalakad-Mundanthurai Tiger Reserve	26 km	Forestland and agricultural land	1998	12	1999	3	Farmer surveys	% crop damage reduction	0	No significant difference in the loss estimates, raiding frequency and wild boar group size between the fenced and unfenced villages

NR: not reported.

Appendix B − ASF timeline in the Czech Republic (situation 3.4.2018)

21 June 2017 − ASF has been suspected in a dead found wild boar in the Municipality of Zlin, District of Zlín, Region of Zlín close to the local hospital.

26 June 2017 − ASF confirmed through Laboratory investigation.

27 June 2017 − A wild boar-infected area has been established. The infected area is the whole district of Zlín (1034 km2, 37 municipalities, 89 hunting grounds).

13 July 2017 − Intensive hunting in a buffer area around the infected area.

18 July 2017 − The infected area has been divided into two subareas: high-risk (including a higher risk fenced area) and low-risk infected subareas.

21 July 2017 − Hunting allowed in the low risk sub-area of the infected area.

11 September 2017 − Individual hunting allowed in the high-risk subarea including the fenced subarea.
In both areas, only trained hunters are allowed to hunt prey. All hunted animals are collected in designed wild boar collecting points, safely dispatched to the rendering plant, sampled by an official veterinarian and disposed.

16 October 2017 − Hunting by police in the high-risk area. Hunting by snipers from police started. Hunted in total 157 wild boar hunted and eight of these were positive for ASF. Snipers were trained for wild boar hunting and for biosecurity during hunting. Police snipers were employed in the high-risk zone. They were split in eight teams of two men shooting wild boar at 3 days interval. All shot wild boar were collected by State veterinary administration, safely transported to the nearest road and then sampled at the rendering plant.

Appendix C – The effect of hunting efforts in Estonia

Table C.1: Effect of hunting efforts to wild boar population structure in Estonia (tested animals 2015–2017)

Year 2015	Female		Male		Total	
	n	**%**	**n**	**%**	**n**	**%**
Found dead						
piglets	115	60%	75	40%	190	34%
Subadults	102	57%	77	43%	179	32%
Adults	112	60%	73	40%	185	33%
Total	329	59%	225	41%	554	100%
Hunted						
Piglets	1,371	52%	1,275	48%	2,646	33%
Subadults	1,440	51%	1,394	49%	2,834	36%
Adults	1,202	49%	1,231	51%	2,433	31%
Total	4,013	51%	3,900	49%	7,913	100%

Year 2016	Female		Male		Total	
	n	**%**	**n**	**%**	**n**	**%**
Found dead						
Piglets	120	61%	76	39%	196	35%
Subadults	96	63%	57	37%	153	28%
Adults	129	63%	77	37%	206	37%
Total	345	62%	210	38%	555	100%
Hunted						
Piglets	2,986	48%	3,191	52%	6,177	43%
Subadults	2,064	57%	1,566	43%	3,630	26%
Adults	2,461	56%	1,959	44%	4,420	31%
Total	7,511	53%	6,716	47%	14,227	100%

Year 2017	Female		Male		Total	
	n	**%**	**n**	**%**	**n**	**%**
Found dead						
Piglets	47	69%	21	31%	68	32%
Subadults	37	57%	28	43%	65	31
Adults	43	54%	36	46%	79	37%
Total	127	60%	85	40%	212	100%
Hunted						
Piglets	1,428	42%	1,931	58%	3,359	38%
Subadults	1,405	55%	1,154	45%	2,559	29%
Adults	1,486	51%	1,422	49%	2,908	33%
Total	4,319	49%	4,507	51%	8,826	100%

Table C.2: Prevalence of ASFV DNA-positive animals among tested hunted wild boar in Estonia in 2017 in the area infected in years 2014 and 2015 compared with the area infected in 2016

Year of infection	County	Tested	Positive	
		n	n	%
2016	Harju maakond	860	45	5.2%
	Laane maakond	1,643	54	3.3%
	Parnu maakond	834	22	2.6%
	Rapla maakond	332	11	3.3%
	Laane-Viru maakond	328	14	4.3%
	Saare maakond	2,487	104	4.2%
	Total (CI 95%)	6,484	250	3.9% (3.4…4.4)
2014–2015	Tartu maakond	164	1	0.6%
	Valga maakond	101	0	0.0%
	Viljandi maakond	119	0	0.0%
	Ida-Viru maakond	336	2	0.6%
	Jarva maakond	62	0	0.0%
	Jõgeva maakond	76	0	0.0%
	Põlva maakond	58	1	1.7%
	Võru maakond	147	2	1.4%
	Total (CI 95%)	1,063	6	0.6% (0.3…1.2)
Grand total (CI 95%)		7,547	256	3.4% (3.0…3.9)