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Research priorities to fill knowledge gaps in wild boar management measures that could improve the control of African swine fever in wild boar populations

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Abstract

The European Commission asked EFSA to provide study designs for the investigation of four research domains (RDs) according to major gaps in knowledge identified by EFSA in a report published in 2019: (RD 1) African swine fever (ASF) epidemiology in wild boar; (RD 2) ASF transmission by vectors; (RD 3) African swine fever virus (ASFV) survival in the environment, and (RD 4) the patterns of seasonality of ASF in wild boar and domestic pigs in the EU. In this Scientific Opinion, the second RD on ASF epidemiology in wild boar is addressed. Twenty-nine research objectives were proposed by the working group and broader ASF expert networks and 23 of these research objectives met a prespecified inclusion criterion. Fourteen of these 23 research objectives met the predefined threshold for selection and so were prioritised based on the following set of criteria: (1) the impact on ASF management; (2) the feasibility or practicality to carry out the study; (3) the potential implementation of study results in practice; (4) a possible short time-frame study (< 1 year); (5) the novelty of the study; and (6) if it was a priority for risk managers. Finally, after further elimination of three of the proposed research objectives due to overlapping scope of studies published during the development of this opinion, 11 research priorities were elaborated into short research proposals, considering the potential impact on ASF management and the period of one year for the research activities.

Keywords: disease control, ASF, epidemiology, research, study protocols, intervention

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Summary

This Scientific Opinion follows up on a Scientific Report published in 2019 by the European Food Safety Authority (EFSA) titled 'Research gap analysis on African swine fever' (EFSA, 2019). This Scientific Report provided a review of the most significant African swine fever (ASF) knowledge gaps as perceived by the EU Veterinary Services and other stakeholders involved in pig production and wild boar management. The aim was to identify gaps in knowledge that could improve short-term ASF risk management once addressed, and to facilitate evidence-informed decision making to improve ASF prevention and spread.

Based on this report, the European Commission requested EFSA to provide research protocols to investigate and explore in depth four research domains (RDs) according to major gaps in knowledge as identified by EFSA: (RD 1) wild boar management measures with the objective to reduce or stop the spread of ASFV; (RD 2) potential of ASFV transmission by vectors (including arthropod vectors and scavengers; (RD 3) potential survival of ASFV in the environment; and (RD 4) possible factors that determine seasonality of ASF in wild boar and/or domestic pig populations.

In this Scientific Opinion, the first RD is addressed, focussing on ASF epidemiology in wild boar as this could support risk managers in the control of ASF.

To address this first ASF RD on wild boar, 29 specific research objectives (ROs) were proposed by different stakeholders and research working groups such as ASF expert networks, ASF-STOP consortium, ENETWILD consortium, VectorNet, AHAW network and the AHAW Panel Experts. Twenty-three of those ROs met a prespecified inclusion criterion and were ranked according to their priority level using the following set of criteria: (1) the impact on ASF management; (2) the feasibility or practicality to carry out the study; (3) the potential implementation of study results in practice; (4) a possible short time-frame study (< 1 year); (5) the novelty of the study; and (6) if it was a priority for risk managers.

Of the 23 research objectives, 14 met the predefined threshold for selection and so were prioritised. After further elimination of three proposed ROs due to overlapping scope with studies published during the development of this opinion, 11 research priorities were elaborated into a short research proposal. These were: (1) role and efficacy of recreational hunting and professional culling for wild boar population control; (2) implementation of practical methods to estimate wild boar density; (3) holistic assessment of the factors that determine the presence of wild boar near to different pig farm types, including outdoor farms and extensive production systems; (4) acceptance of measures for wild boar management by hunters; (5) assess how to improve coordinated national and international decision-making; (6) basic aspects of wild boar population dynamics all over Europe; (7) the efficacy of different fencing methods with GPS-collared wild boar, considering also the effect on non-target species; (8) biosecurity awareness and implementation among backyard pig farmers; (9) efficacy of wild boar trapping methods including welfare implications and social acceptability; (10) effect of food availability in natural areas in relation to baiting and feeding on wild boar population dynamics; and (11) use of trained dogs in ASF-affected areas to manage wild boar populations. For each of the selected ROs, a research protocol has been proposed considering the potential impact on ASF management and the period of 1 year for the research activities.

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1. Introduction

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

African swine fever (ASF) is an infectious lethal disease affecting domestic pigs and wild boar. It can be transmitted via direct animal contact, dissemination of contaminated food or equipment and, in some regions, via biological vectors. This disease has serious economic implications for pig meat production and related sectors, including indirect costs related to trade restrictions. The persistence of the disease in wild boar and the limited number of control measures available represents a challenge for the pig-breeding sector in the EU, in particular for the pig farming industry. There is no licensed vaccine or cure despite active ongoing research. From the beginning of 2014 up to now, ASF has been notified in the following EU Member States: Belgium (officially free again since October 1, 2020), Bulgaria, the Czech Republic (free again since March 2019), Estonia, Germany, Greece, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia. The disease has also been reported in Belarus, Moldova, Russia, Serbia and Ukraine, which creates a constant risk for all the Member States bordering with these third countries. The virus strains involved in this ongoing epidemic that started in 2007 in Georgia, belong to genotype II. Apart from this, ASF virus strains of genotype I have been present in Italy (Sardinia only) since 1978.

There is knowledge, legislation, scientific, technical, and financial tools in the EU to face properly ASF. In addition, Member States and the Commission are continuously updating the 'Strategic approach to the management of African Swine Fever for the EU' and the related legislation. On 27 August 2019, EFSA published a scientific report titled 'Research gap analysis on African swine fever'.[1] The Scientific Report provided a review of the most significant ASF knowledge gaps as perceived by the EU Veterinary Services and other stakeholders involved in pig production and wild boar management. The aim of this scientific report was to improve short-term ASF risk management and to facilitate evidence-informed decision making on ASF prevention and spread. Four major gaps were identified: 'wild boar', 'African swine fever virus (ASFV) survival and transmission', 'biosecurity', and 'surveillance'. The EU is in need to further address some of the major research gaps as identified by EFSA in the Scientific Report, in particular: 'wild boar' and 'ASFV survival and transmission' are crucial to practically implement risk management actions to prevent and control ASF. For this, it is necessary that EFSA complements its previous Scientific Report providing new scientific input and technical assistance to the Commission on those crucial topics identified by the stakeholders as perceived major research gaps and suggests additional studies to fill the knowledge gaps.

1.2. Terms of Reference

In accordance with Article 29 of Regulation (EC) No 178/2002, EFSA is requested to provide a Scientific Opinion addressing the following three TORs:

1) Design studies needed to evaluate: (i) the impact of reducing the wild boar population densities in relation to transmission of African swine fever virus (ASFV);(ii) the natural behaviour of wild boar to improve effectiveness of wild boar population management. EFSA should assess feasibility and provide support to design studies, or pilot trials, to verify suitability of new methods for wild boar population control such as Immunocontraception (as a tool for population and health control of wild boar) and any other methods, including diverse types of hunting. EFSA should base the Scientific Output or Scientific Technical report on previous EFSA works on this subject and review existing literature, data and information to identify effective methods to reduce and to manage effectively wild boar populations.
2) Design studies needed to understand: (i) the role and impact of vectors, in particular arthropod vectors, in ASF transmission (biological and mechanical); (ii) ASF survival and transmission from contaminated environment and (iii) residual infectivity of buried wild boar carcases, all this assessing its overall [relative] role in the epidemiology of ASF. EFSA should provide the state of the art of what is known and base the Scientific Output, or Scientific Technical report, on previous EFSA works on this subject. EFSA should review existing literature, data and information to investigate the role of vectors and of the environment to clarify the pathways that facilitate ASF persistence and transmission in affected areas over a number of years.

[1] https://www.efsa.europa.eu/en/efsajournal/pub/5811

3) Design studies to investigate patterns of seasonality in wild boar and domestic pigs and identify main factors that determinate these patterns. Provide recommendations in particular in relation to risk mitigation options to address these factors, where relevant. EFSA should focus again its analysis on the European experience. EFSA should investigate if seasonal patterns differ across different areas (e.g. temporal–spatial increase of already infected areas or seasonality of the so-called 'jumps').

1.3. Interpretation of the Terms of Reference

To facilitate the assessment, the three TORs were interpreted and divided into four general research domains (RDs) according to their aim:

1) Wild boar management measures with the objective to reduce or stop the spread of ASFV; TOR 1 (i) and (ii)
2) Potential of ASFV transmission by vectors (including arthropod vectors and scavengers; TOR 2 (i)
3) Potential survival of ASFV in the environment; TOR 2 (ii) and (iii)
4) Possible factors that determine seasonality of ASF in wild boar and/or domestic pig populations; TOR 3.

Each of the four RDs is assessed in a separate Scientific Opinion sharing the same methodology. This Scientific Opinion will answer to RD 1 (TOR 1), more in particular the assessment identifies and prioritises research that could address the knowledge gaps pertaining wild boar (WB) management and control measures that could contribute to the reduction or eradication of ASF in WB populations.

These ROs should be developed in a context-dependent manner, on the basis of the geographical, ecological and management contexts, hereafter called 'WB population bioregions' (Figure 1).

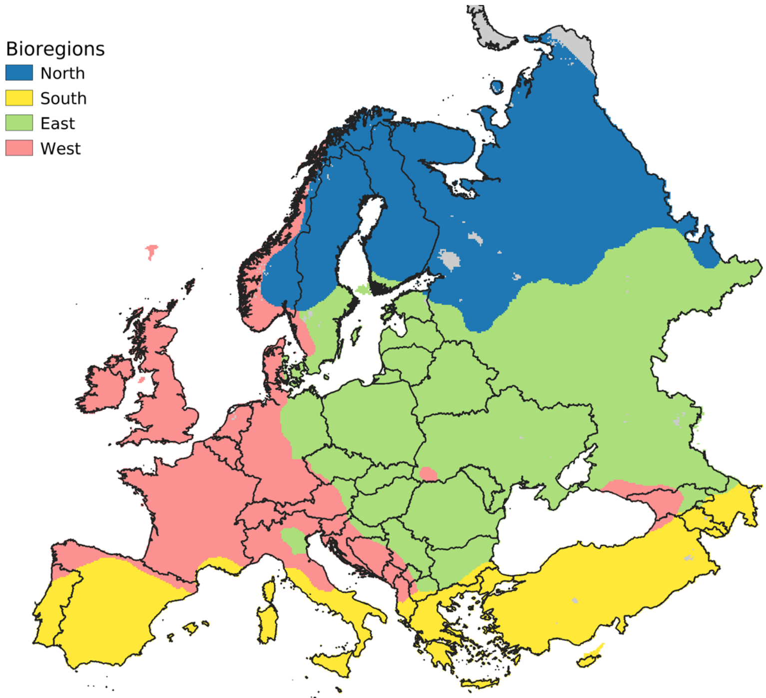

Figure 1: Homogeneous bioclimatic regions (Bioregions) of Europe based on bioclimatic variables, vegetation cover and topographic covariates associated to wild boar density (Source: ENETWILD Consortium et al., 2019a,b, 2020a)

2. Methodologies

To identify, prioritise and develop the guidelines for the studies needed to address the knowledge gaps about WB management to reduce or stop the spread of ASF (TOR 1; RD 1), a methodology including four steps was applied. Step 1 consisted in the identification of the ROs by the experts of the EFSA working group (WG), followed by Step 2, where the list of ROs produced by the WG was circulated among different expert networks that were also able to provide inputs to the list of ROs. Step 3 consisted in the review of all provided information and prioritisation of the collected ROs by the criteria established by the WG. Finally, Step 4 consisted in the development of the guidelines for each of the ROs, either by the WG or by external contractors.

2.1. Step 1: Identification of research objectives by working group

1) Brainstorm session during a web-conference of the working group to identify possible ROs for each research domain.

For each RD (See Section 1.3), specific ROs were identified and discussed. For each research objective, a brief description was provided, focusing on the main aim of the research regarding ASF management. In addition, keywords were defined by the WG to facilitate identification of ROs.

2) Contributions by each individual working group member to the results generated during the brainstorm session

A table for each of the four RD was circulated among the WG members. Each WG member worked separately on-line on the table and proposed all ROs considered to be of interest for the particular research domains that could be achieved in a relatively short timeframe (i.e. less than a year). Thereafter, proposals for each research objective were discussed during a web-conference among all WG members. Overlapping ROs were identified and amended in agreement with the WG. The final version of the table with ROs was agreed among WG members and prepared to be circulated among networks.

2.2. Step 2: Identification of research objectives by broader networks

An online survey (Annex A) based on the table produced by the WG was distributed to the following networks of experts: ASF-STOP, ENETWILD, VectorNet, AHAW network and the AHAW Panel Experts. The experts in the networks had 2 weeks to complete the survey online, using the same tables of the RD and their ROs developed by the WG.

The WG conducted an analysis of the survey results, identifying new potential objectives and merging overlapping ones. The ROs selected for the final list, which combined the ROs suggested by the WG and by the networks were then prioritised according to procedure explained in Section 2.3.

2.3. Step 3: Prioritisation of research objectives

1) Inclusion criterion: The ROs proposed by the working group and the different networks were included if they were related to the particular domain of research. In the case of this Scientific Opinion the inclusion criterion was: Is the research objective related to possible factors that determine WB management measures with the objective to reduce or stop the spread of ASF (RD 1)

If the answer to this question was 'YES', the research objective was included; if it was 'NO' the research objective was excluded.

2) Apply prioritisation criteria listed in Table 1 for each research objective.

The working group scored the ROs proposed by the working group and the different networks using the scoring criteria provided in Table 1. Each member of the WG scored independently all theROs. The criteria for ranking the priority of the ROs and their definitions were discussed and agreed with the requestor of the mandate (the EC). For each criterion, a simplified 5-point Likert scale of either 1 (low), 3 (medium) or 5 (high) was given per research objective according to Table 1. Likert scales are commonly used method to rate people's opinions or perceptions on importance or priorities (Joshi et al., 2015).

For each scoring criterion provided, each of the WG members provided a rationale that was discussed afterwards, collectively, during another on-line meeting. Only Criterion 6 (priority for the risk managers) was scored by one person, the liaison of the European Commission, who attended the working group. A few criteria were not scored by all working group members, but the group scoring was provided by calculating the average of all scores available and provided by the WG (as shown in Annex B) and discussed and agreed upon by the whole working group. The overall average score for each RO, estimated including all scores for all criteria, was selected to estimate central tendency (of the perception of priority of the working group) as a measure for the general opinion of the WG. This ensured that the overall score reduced extreme values in each criterion scoring that may have arisen due to different expertise and/or experience of the WG members. To ensure that the proposed ROs fulfilled the prioritisation requirements mentioned in Table 1, a minimum average score of 3.5 (70% of the maximum score) was agreed *a priori* by the working group as the cut-off for a research objective to be further developed into a protocol. A limitation of this approach is that the average score for each RO is very sensitive to small variations in scoring: this is due to the small number of scores, and the limited range of possible scores (only scores of either 1, 3 or 5 could be chosen). However, a consensus was reached in all cases on the average values of the scores and the WG discussed and agreed on the exclusion of those proposals that did not reach the 3.5 score.

The standard deviation and the coefficient of variation were given to show the uncertainty in the initial judgments by the experts on the criteria for each of the ROs (Table 4).

Table 1: Criteria for prioritising research objectives

No	Criterion	High = 5 points	Medium = 3 points	Low = 1 point
1	Impact on ASF management	The results can have a high impact on the practical management of the disease spread. The topic is part of or is included in one or more of the main strategies for ASF control.	The results can have a medium impact on the practical management of the disease spread. The topic is part of, or includes, one or more of the secondary strategies for ASF control.	The results can have a low impact on the practical management of the disease spread. The topic is not included in any of the main or secondary strategies for ASF control.
2	Feasibility or practicality to carry out the study	Low complexity, methodology fully available	Medium complexity, methodology available but needs further development	High complexity methodology needs to be fully developed
3	Potential implementation of study results in practice	Results can be easily implemented in a short time in the current management of ASF	Results could somehow be implemented in a short time in the current management of ASF	Results are not easily implemented in a short time in the current management of ASF
4	Short time - frame study possible (1 year)	The study can be completely carried out in 1 year	Majority of the study could be done in 1 year (i.e. 50% or more)	The study cannot be completely carried out in 1 year (i.e. less than 50%)
5	Novelty: other studies carried out on the same topic?	No previous studies available	Few previous studies available	High number of previous studies available
6	Priority for risk managers	The research gap was perceived as important by the stakeholders (experts and risk managers) in the previous Gap analysis; experts and funding are available for the research objective and results will be useful in short-term to manage the disease	The research gap was less perceived as important by the stakeholders (experts and risk managers) in the previous Gap analysis; experts and funding are less available for the research objective and results will be less useful in short-term to manage the disease	The research gap was not perceived as important by the stakeholders (experts and risk managers) in the previous Gap analysis; experts and funding are not available for the research objective and results will not be useful in short-term to manage the disease

2.4. Step 4: Development of calls for short research protocols for research priorities

A short research protocol was developed for each of the ROs that scored at least 3.5/5 points on average (and was therefore considered as a research priority). These protocols could be used by research agencies or funding agencies as a call for research proposals.

The development of the research protocol has been outsourced to experts of the ENETWILD Consortium and further discussed and elaborated by the WG. Thereafter, it was reviewed by the Panel on Animal Health and Welfare of EFSA. They can be found in Sections 3.4 until 3.16.

These protocols were anticipated to have should have the following minimum components:

Outline research guidance (3–5 pages per protocol)

- Introduction
  - Summary of what is known on topic up to date, and identification of the research gap(s)
  - Potential impact on ASF control if the gaps of knowledge were to be filled
- Objectives
  - Research hypotheses
- Methodology
  - Study design
  - Suggestions for statistical analysis
- Deliverables and milestones

3. Assessment

3.1. Step 1: Identification of research objectives by working group

During the web meeting/brainstorming exercise and further consultation by email from the working group, eight ROs relevant to RD1 were identified by the working group (Table 2), based on their expertise.

Table 2: Identification of possible research objectives pertaining wild boar by working group for RD 1

No	Research objective	Short description	Keyword
1	Assessment of the effectiveness of WB trapping (professional culling tool) methods including welfare implications	Assess different trapping methods that could aid population management and disease control for their practicability, animal welfare issues, and acceptability by hunters and the public.	Trapping WB population control
2	Influence of crop management on WB presence and distribution	Investigate the effect of possible crop management strategies: adapt crop types, crop distribution, crop protection and harvest timing to reduce food resources available for WB in the long term.	Crop management Feeding
3	Methods to avoid contact between carcasses and WB	Is it possible to keep WB away from carcass sites using simple and effective methods e.g. physical barriers like simple fencing, odour or visual effects	Carcass management
4	Assess the efficacy of different fencing methods with GPS-collared WB, also considering the effect on non-target species	Expand to all kinds of barriers (e.g. highways, fences, electrical fencing, odour fencing. Assess the efficacy both on small scale (e.g. avoiding farm entry) and large-scale applications (e.g. a national border) and their impact on non-target species	Efficacy of fencing
5	Identification of WB population dynamics drivers for effective population managing	Identification of the drivers of WB population dynamics such as food availability, predation, disease or hunting/culling, based on field data analysis and or modelling. Managing of those drivers to achieve a sustainable decline in WB populations	Drivers WB population
6	Assess the effect natural resources and artificial feeding on WB population dynamics and management	Assess the effect of natural resources and artificial feeding on WB population dynamics and management (for instance the effect on reproduction or other demographic parameters)	Drivers WB population Natural feeding Artificial feeding
7	Factors driving the presence of WB near different pig farms types, including outdoor farms and extensive production systems	The aim is to define the factors and interactions that define the WB-pig interface. Also, to identify what attracts the WB (food, sows, etc.) to farms and how the managing of those factors can reduce disease transmission risks.	Pig–WB interface

No	Research objective	Short description	Keyword
8	Role and effectiveness of recreational hunting and professional culling for WB population control.	Hunting is the main driver of mortality for (> 6 months old) WB. However, current recreational hunting is not enough to stop population growth. The proposal should address suitable means to increase recreational hunting efficacy, combinations of recreational hunting and professional culling, and culling only, both at small (local outbreak) and large scale (countries at risk). Methods should combine field data, eventually experimental, with modelling. Carry out a pilot study. Include the effect of season and density of WB	WB population control

3.2. Step 2: Identification of research priorities by broader networks

In addition to the ROs proposed by the working group (Table 2), the following 21 ROs were proposed by broader expert networks (Table 3).

Table 3: Additional research objectives proposed by wider networks for RD 1

No	Research objective	Short description	Keyword
9	Insight in persistence of African swine fever in WB populations	The aim is to characterise factors linked to ASFV persistence, such as survival of the animals, immune reactions, clinical signs, pathology, virus secretion, virus transmission and the role of WB to spread the virus.	Susceptibility, immunity, survival, virus persistence
10	The wild boar/pig interface: Developing biosecurity awareness and implementation among backyard pig farmers	It appears that ASF introduction to and from backyard farms plays a role in spreading and maintaining the disease in certain areas. The aim is to identify common practices of backyard farmers that increase the risk of introduction and spread of ASF, as well as to raise awareness on the use of biosecurity measures to reduce risk.	Biosecurity awareness
11	Social acceptance of WB management measures and their impact on animal welfare	Acceptance of measures for WB management by hunters in the presence of ASF	Participatory epidemiology
12	Further research on extensive production system of pigs – WB interface	The extensive production system of some pig breeds is of great economic importance in some southern European countries. However, the coexistence of this sector in areas with medium-high density of WB poses a high risk for the spread of ASF. Further research would be required to evaluate effective measures to mitigate the risk of contact between pigs and WBs in this setting at the lowest possible cost.	Interface extensive pigs – WB
13	Use of trained dogs in ASF-affected areas for carcass detection	The aim is to assess the efficacy, as well as pros and cons (dispersal effect) of using trained dogs and hunting to reduce WB density in affected zones. Also, to assess the efficacy of using trained dogs to search of carcasses of wild boar therefore contributing to reduce the risk of transmission.	Carcass management and population control

No	Research objective	Short description	Keyword
14	Experimental research about presence of low-virulence strains of ASFV in endemic areas, the possibility of carrier stage occurrence and possible role of these carrier animals.	Occurrence low-pathogenic ASFV strains and their impact on disease dynamics – Clinical courses and disease outcome (recovery, chronic disease, carrier state) upon infection with attenuated strains – Genetic characterisation of strains (natural deletion mutants) – Behaviour of such strains in the field	Low-virulence strains, carrier stages, maintenance of the disease
15	Current and projected WB distributions	Assess the current and projected distribution of WB populations in the EU.	Distribution
16	Evaluation of the measures of passive surveillance and carcass removal on the spread of the disease	Evaluate the effect of searching and removing infected WB carcasses in order to stop the spread of the disease according to the method, human or dog teams, the season and the habitat (low and high visibility)	Passive surveillance, carcass removal
17	Investigate acceptability of farmers and public to fences	Assessment of the acceptability of farmers and public to implement fences for avoiding movement of WB in ASF-affected areas.	Fences acceptability
18	Evaluate the effectiveness of the existing methods of culling according to the season and the WB density	Evaluate the effectiveness of the existing methods of culling according to the season and the WB density	Combination of culling methods, population control
19	Establishment of a freedom-from-ASF-disease status of a WB population	Assessment of the probability that ASF has been locally eradicated from a given area based on quantitative assessment framework.	ASF freedom, eradication,
20	Implementation of practical methods to estimate WB density	Determination of average WB speed (daily distance movement) and activity in different ecological contexts (for instance with different food and shelter availability) and in different seasons, to improve density estimation by, e.g. camera-trapping.	Practical methods to estimate WB density
21	Assess sustainable (i.e. long term effective) strategies for WB population control in different scenarios (hunting areas, protected areas, urban, tec.) incorporating the socio-economic reality, evaluating also future scenarios (▫ hunters).	Once efficacy of control methods is assessed, there is need to integrate socio-economic aspects to evaluate sustainability of WB long-term control strategies, including the possible professionalisation of wildlife population control	Sustainable population control, socio-economic aspects
22	Assess how to improve coordinated national and international decision-taking on ASF prevention and control in wild boar populations	Assess how to improve coordinated national and international decision-taking, since ASF and WB include several stakeholders and administrations such as hunters, agriculture, game management, animal health and public health.	International and national decision taking, stakeholders' participation
23	Assess how to improve data collection to monitor WB	Assess how to improve data collection to monitor WB population management strategies, such as including hunting efforts to hunting statistics.	Data collection to monitor hunting efforts

No	Research objective	Short description	Keyword
24	Studies on basic aspects of WB population dynamics throughout Europe	Parameters on basic aspect of WB population dynamics, which largely vary over Europe, are essential for risk modelling but there is no available information all over its distribution range. Parameters to be considered are: sex and age structure at pre-harvest; mortality combining harvest and natural mortality by the three age categories; size of offspring born by female age class; seasonality of reproduction (by month); litter size distribution; dispersal period and distance by age and sex, female group home range size or female group size.	WB population dynamics
25	Establishment of a European network (study areas) from WB population monitoring (which may extend to other populations), purposely designed, to evaluate trends, continuous improving of monitoring techniques and provide training.	Establishment of a European network (study areas) from WB population monitoring (which may extend to other populations), purposely designed, to evaluate trends, continuous improving of monitoring techniques and provide training	WB, population monitoring network
26	Role of man-made vs ecological barriers in limiting the dispersal of WB	Dispersal of WB across human infrastructures and natural barriers would be indirectly investigated by tracing real-time gene flow across the presumed barrier. This information can assist in defining management units for ASF prevention.	Barrier effectiveness, dispersal, gene flow, management units
27	Reduction of WB population	The efforts should be taken to keep the density of WB population by hunting actions	Population control
28	Application of fencing around the newly identified ASF clusters	Avoidance of migration of infected WB at the newly identified ASF clusters	Fencing, movement restrictions
29	Immunocontraceptives	WB control through administration of immunocontraceptives.	Immunocontraceptives

3.3. Step 3: Prioritisation of research objectives

The results of the ranking of ROs for RD 1 are listed in Table 4. From the total of 29 ROs identified either by the WG (Table 2) and the broader experts' networks (Table 3), 23 ROs met the inclusion criterion, and14 of them received an average score of 3.5 or more. Details of the individual scoring and rationales can be found in Annex B. The ROs with ranks 1 and 9 have been merged, during the development of the protocols, and the RO with rank 12 has been omitted, due to the simultaneous development of a Scientific Opinion of EFSA's AHAW Panel on the ASF exit strategy, which was published in April 2021 (EFSA, 2021). Also, the RO that ranked on the 14th position was omitted during the development of the protocols, as the evaluation of the passive surveillance and carcass removal has been repeatedly investigated by EFSA, using spatially explicit modelling (EFSA, 2017, 2018, 2021; EFSA AHAW Panel, 2015). The evaluation of the effectiveness of carcass removal under field conditions, on the other hand, is cumbersome as it requires the inclusion of a control area without carcass removal, which would not be in line with the current Strategic Approach to the management of African swine fever for the EU (European Commission, 2015). For the RO ranked in 13th position, it was agreed to focus on carcasses, then the title of the research protocol changed to 'Use of trained dogs in ASF-affected areas to detect WB carcasses'. Briefly, after prioritisation of 14 ROs, merging two ROs and elimination of another two ROs *a posteriori*, due to overlapping or published work during the work on this opinion, 11 Research protocols have been developed. Research objectives that were ranked out of the cut off (15 out of 23) were further revised and the WG agreed to exclude them from the list of priority ROs.

Table 4: Results of priority ranking of research objectives pertaining wild boar that met the inclusion criteria

Rank	Research objective	Average score	Standard deviation	CV*	No RO**
1	**Investigate acceptability of fences to public and farmers**	**4.6**	**0.8**	**0.2**	**NA (merged with 9)**
2	**Role and effectiveness of recreational hunting and professional culling for WB population control.**	**3.9**	**1.4**	**0.4**	**5**
3	**Implementation of practical methods to estimate WB density**	**3.9**	**1.0**	**0.3**	**3**
4	**Factors driving the presence of WB near different pig farms types, including outdoor farms and extensive production systems**	**3.9**	**1.2**	**0.3**	**2**
5	**Social acceptance of WB management measures and their impact on animal welfare**	**3.8**	**1.2**	**0.3**	**9**
6	**Assess how to improve coordinated national and international decision-taking on ASF prevention and control in wild boar populations**	**3.8**	**1.3**	**0.3**	**11**
7	**Studies on basic aspects of WB population dynamics throughout Europe**	**3.8**	**1.6**	**0.4**	**1**
8	**Assess the efficacy of different fencing methods with GPS-collared WB, considering also the effect on non-target species**	**3.7**	**1.2**	**0.3**	**7**
9	**The wild boar/pig interface: Developing biosecurity awareness and implementation among backyard pig farmers**	**3.6**	**1.6**	**0.4**	**10**
10	**Assessment of the effectiveness of WB trapping (professional culling tool) methods including welfare implications**	**3.6**	**1.1**	**0.3**	**6**
11	**Assess the effect of natural resources and artificial feeding on WB population dynamics and management**	**3.6**	**1.1**	**0.3**	**4**
12	**Establishment of a freedom-from-ASF-disease status of a WB population**	**3.5**	**1.4**	**0.4**	**NA**
13	**Use of trained dogs in ASF-affected areas WB for carcass detection**	**3.5**	**1.2**	**0.4**	**8**
14	**Evaluation of the measures of passive surveillance and carcass removal on the spread of the disease**	**3.5**	**1.2**	**0.4**	**NA**
15	Identification of WB population dynamics drivers for effective population managing	3.4	1.4	0.4	NA
16	Assess how to improve data collection to monitor WB	3.4	0.8	0.2	NA
17	Insight in persistence of African swine fever in WB populations	3.3	1.5	0.4	NA
18	Influence of crop management on WB presence and distribution	3.1	1.6	0.5	NA
19	Methods to avoid contact between carcasses and WB	3.0	1.5	0.5	NA
20	Assess sustainable (i.e. long term effective) strategies for WB population control in different scenarios (hunting areas, protected areas, urban, tec.) incorporating the socio-economic reality, evaluating also future scenarios (¯ hunters).	2.8	1.4	0.5	NA
21	Experimental research about presence of low-virulence strains of ASFV in endemic areas, the possibility of carrier stage occurrence and possible role of these carrier animals.	2.8	1.4	0.5	NA

Rank	Research objective	Average score	Standard deviation	CV*	No RO**
22	Immunocontraceptives	2.6	1.3	0.5	NA
23	Current and projected WB distributions	2.5	1.5	0.6	NA

NA: not applicable.
*: The coefficient of variation (CV) is the ratio of the standard deviation to the mean. The higher the coefficient of variation, the greater the level of dispersion around the mean.
**: RO: research objectives ordered as they appear in the document from Sections 3.5–3.15.

3.4. Step 4: Development of calls for research proposals (short research protocols) for research priorities

Eleven research protocols have been developed as presented in Sections 3.5–3.15.

3.5. RO1. Studies on basic aspects of wild boar population dynamics throughout Europe

3.5.1. Background

Currently, the lack of standardised information on WB population dynamics covering the necessary range of biogeographical, management, socio-economic and cultural factors prevents data from being reliably used at the European level, hampering risk assessments (ENETWILD Consortium et al., 2018b, 2019b, 2020a). Biased, incomplete, or simulated parameters are often used for these purposes, and their regional variation is not considered. The situation is further complicated by two factors:

- There exists a wide diversity of parameters to describe WB population dynamics and different methods are applied, which are not always appropriate and/or comparable (ENETWILD Consortium et al., 2018a, 2019b, 2020a).
- The temporal frame of available data does not always represent the current situation. WB populations have been increasing over the last decade in the absence of ASF, and in certain regions the direct impact of ASF and/or reactive and proactive policies have led to very different scenarios (EFSA, 2020a).

Compiling and generating valid up-to-date information on WB population dynamics is needed, following harmonised methods and filtering by standards of quality. Recent data collection activities have been restricted to density and distribution data but not to population dynamics (ENETWILD Consortium et al., 2019a, 2019b, 2020a).

3.5.1.1. Evidence available in Europe and worldwide

There is a large body of literature describing basic aspects of WB population dynamics (see Table C.1 in Annex C). However, the literature is extremely biased towards certain regions of its native range (Central Europe) and certain parameters (reproduction and spatial ecology).

WB population parameters are largely determined by different drivers including natural and human-related extrinsic factors influencing ecological processes and population dynamics (see Table C.2 in Annex C). Population models addressing the drivers that may affect WB populations depend on the local and regional variation, and the scarce literature mainly refers to Central European WB populations (Bieber and Ruf, 2005; Vetter et al., 2020).

3.5.1.2. Current situation for the particular research objective in the EU

WBs are an ecologically very plastic species, with potentially rapid population growth rates. WB populations are still growing and expanding despite high mortality rates. They are also able to adapt to a wide array of climatic conditions (ENETWILD Consortium et al., 2019b). All these factors make WB population dynamics highly variable across the continent, requiring a deeper understanding of local and regional variations over its distribution range.

Essential steps to guide ASF control policies are considered to be: (i) defining which basic parameters of WB population dynamics are most relevant, (ii) understanding them in a context-dependent manner, on the basis of their variation in given geographical, ecological and management contexts (see Figure 1 on bioregions of wild boar in Europe) and conditioned by drivers, and finally (iii) quantifying these parameters (once data gaps are identified).

3.5.1.3. Potential impact of the results obtained for ASF management in the EU

The steps (i), (ii) and (iii) described above will allow:

- Planning integrated and harmonised monitoring of WB population dynamics trends and impacts over space and time under different scenarios and drivers occurring in Europe (e.g. protected areas, agricultural land, hunting grounds; management schemes such as artificial feeding or not), and epidemiological situations (pre-ASF, during or post-ASF; at a local outbreak scale and over large frontlines and regions affected by ASF).
- Monitoring the effects of ASF management actions under an adaptive approach, that is, information is collected continuously, and this is used to improve biological (including the human dimension) understanding and to inform future decision-making. For example, changing hunting strategies to achieve the most effective method WB population reduction (Massei et al., 2011).
- Parameterising population dynamics models (disentangling factors regulating population dynamics such as compensatory growth, density dependence, top-down control by predators, stochasticity) and epidemiological models (e.g. risk analysis, control options). Only science-based modelling should be accepted to guide policy, for instance, to develop most efficient cost–benefit strategies: control and eradication of ASF in different scenarios (ASF affecting large areas, local outbreaks, ASF-free zones) and epidemiological stages of ASF (epidemic, endemic).

3.5.2. Objectives

1. To produce a comprehensive compilation and description of data on WB population dynamics throughout Europe (Table C.3 in Annex C) in order to better understand disease dynamics and improving science based ASF management. Hereto, this objective aims to:

- identify and prioritise data gaps over the (bio)regions and contexts of Europe.
- determine the main drivers of WB population dynamics.

2. Short-term field research to address scarcity and/or lack of data on wild boar population dynamics data (gaps).

3.5.3. Methodology

3.5.3.1. Objective 1: comprehensive compilation and description of data on wild boar population dynamics and the main associated demographic drivers throughout Europe

Method

Compilation and description of data on WB population dynamics and long-term data on the drivers (e.g. management strategies, density dependent and stochastic factors, which vary by bioregion) following a standardised data model (ENETWILD Consortium et al., 2020a). Per bioregion (Figure 1), provide a description of parameters and data gaps.

Study design

- Compilation of population dynamics data using a systematic literature review and data collection on WB population dynamics and drivers throughout Europe (including names of researchers, administrations and wildlife managers). The data collection should be done by the applicant following ENETWILD standards (ENETWILD Consortium et al., 2020a), which guarantees that sufficient information (e.g. on methods) is collected to validate data. Data collection should be adapted to the list of parameters indicated in Table C.3 in Annex C. The data model also allows collecting metadata to make an inventory of the WB information that is being collected.
- Identify gaps in data per bioregion in the EU based on population dynamics parameters identified in the previous point and environmental and management data. The compilation of data on drivers will allow a comparison of the population parameters among study areas, or

over time in given areas across European WB population bioregions under different ecological and management conditions (predators presence vs no predators; ASF presence vs ASF-free region; different management strategies applied, global warming) (Nores et al., 2008; Morelle et al., 2016; Tanner et al., 2019a).
- Analysis of the main drivers of population dynamics across the European continent: (i) transversal (according to O'Neill et al., 2020) and (ii) long-term correlational (according to Barroso et al., 2020) (including delayed effect) analyses.

Sample size

The guidelines on systematic reviews (e.g. Pullin and Knight, 2009) must be followed. However, since there may be a large amount of reviewable literature (including grey literature), as WB populations have grown markedly in recent years, and methods (e.g. telemetry) have greatly developed, it would be advisable to limit the literature search to the last twenty years. Reviews should include unpublished and grey literature available through contact with researchers, administrations and wildlife managers.

Spatial range

All of Europe.

Expected duration and study viability

Eight months (if an expert network is already available, e.g. ENETWILD).

3.5.3.2. Objective 2: Short-term field research to address scarcity and/or lack of data on wild boar population dynamics data (gaps)

Method

Based on the identification of knowledge gaps under objective 1, additional field studies may be needed in specific bioregions including the following parameters:

- **Densities**: This work is currently ongoing by ENETWILD (ENETWILD Consortium et al., 2018a, 2019b, 2020a), but an increase in the sample size and coverage of areas in Europe is needed (30 sites in gaps areas, i.e. in countries where data about WB density is not available, such as European Eastern countries), as is the validation of hunting statistics (as a proxy of population density). Protocols, effort required, and sample size are already available on the ENETWILD website, camera trap-based protocols (CTs) being recommendable (ENETWILD Consortium et al., 2018a).
- **Population structure and social behaviour** (group size): for population structure, sex by age class protocols are available (hunting at least 30% of the population and randomly selected; Sáez-Royuela and Tellería, 1988); group size have to be determined by CTs (number of CTs according to study surface area, protocol, effort, sample size available at https://enetwild.com/2021/03/20/ct-protocol-for-wild-boar/) in different seasons to obtain data about group size evolution across the year.
- **Mortality in individuals less than 3-month-old** (piglets), it is necessary to first determine reproductive performance (i.e. litter size), and then compare it to the juvenile population (i.e. surviving piglets > 3 months and < 1-year-old) by CT.
- **Reproductive performance**: direct inspection of litter size (number of foetuses/female) and proportion of pregnant females after hunting event (Fernández-Llario and Carranza, 2000; Fonseca et al., 2011). Minimum 40 hunted female WB per population.

Sample size

Depending on specific parameter and protocol (detailed above). Minimum of 5 sites per parameter or group of parameters considering, if possible, all WB bioregions.

Spatial range

Throughout Europe, attending to data gaps in specific WB bioregions.

Expected duration and on study viability

1 year.

3.5.4. Deliverables

3.5.4.1. Objective 1

- Deliverable 1: Data on WB population dynamics throughout Europe.
- Comprehensive compilation and description of data on WB population dynamics (C.3 on Annex C) and demographic drivers throughout Europe following a standardised data model.
- The completion of this deliverable influences the subsequent deliverable because the collected data will allow the identification of WB population bioregions.
- Deliverable 2: Identification of WB population data gaps per bioregions.
- Report describing patterns of WB population dynamics (bioregions) which should guide data gap collection.
- Validation of classification, limitations and uncertainties: sample size and representativeness of available data.
- Completion of this deliverable influences the subsequent deliverable because drivers of population dynamics will be analysed considering and/or within the bioregion.
- Deliverable 3: Report on the analysis of the main drivers of population dynamics throughout Europe.

3.5.4.2. Objective 2

- Deliverable 1: Report on short-term field research to address data gaps on population dynamics
- Limitations and uncertainties: need for efficient local collaborators in gap areas (mainly Eastern Europe).

3.6. RO2. Factors driving the presence of wild boars near to different pig farm types, including outdoor farms and extensive production systems

3.6.1. Background

In the context of WB population growth and the presence of ASF in Europe (EFSA, 2014), it is urgent to understand factors affecting the presence of wild boars in areas close to pig farms. These areas, also known as the wild/domestic interface, are key in the appropriate, rapid and effective control of ASF outbreaks due to the risk of transmission between domestic pigs and their wild relatives (Boklund et al., 2020; ENETWILD Consortium et al., 2020b).

Across Europe, pig farms vary according to their production system, herd management and/or size (ENETWILD Consortium et al., 2020b). In many cases, these differences are related to local practices, climatic conditions (e.g. cold winters require pigs to be kept inside) and the legislation in each country (e.g. biosecurity measures to avoid ASF spread in risk areas or where the disease is present).

Outdoor pig farms, backyard farms and extensive production systems are relevant socio-economic activities in some areas of Europe, particularly in Eastern Europe (ENETWILD Consortium et al., 2020b). The current ASF epidemiological situation presents a huge threat for disease spill-over at the wild/domestic pig interface (Kukielka et al., 2013; Barasona et al., 2014).

3.6.1.1. Evidence available in Europe and worldwide

At a large scale (continental), the main factors affecting WB presence are environmental factors such as climatic variables, land cover, topography and human footprint (e.g. human population density, proximity to urban areas, roads) (ENETWILD Consortium et al., 2019a).

At a local scale, however, the presence of WB in certain areas is associated mainly with vegetation (i.e. some specific plant communities that offer cover and are a source of food) and water availability in natural areas (Wu et al., 2012; Barasona et al., 2014; Keuling et al., 2017). Moreover, WB presence is affected also by human factors such as socio-economic conditions and management strategies (Oja et al., 2014; Massei et al., 2015). Thus, increasing access to anthropogenic food resources and some hunting strategies are positively related with WB presence and local abundance (Table 5). The resource-limited season in South Europe is summer, and in North and Central Europe, it is winter (Gortázar et al., 2007; Kukielka et al., 2013). Furthermore, WB/pig interactions could vary spatially and temporally across Europe. Local husbandry practices for pigs (e.g. *in situ* seasonal feeding on the mast) also determine the frequency and intensity of these interactions (Jori et al., 2017b; Triguero-Ocaña et al., 2020).

3.6.1.2. Current situation for the particular research objective in the EU

The interest focuses on outdoor farms, which are defined as establishments in which pigs are kept temporarily or permanently outdoors (European Commission, 2015). Outdoor farms allow various types of outdoor access to the pigs (e.g. to pastures, forests, runs/yards, open-air buildings or buildings that allow the pigs to have access to open air or to the external environment as defined by the working document of the European Commission (2015). The following types of outdoor pig farms have been reported to EFSA by EU member states (MS): (a) animals have access to woodlands/forests without any fencing, (b) animals have access to fenced areas in woodlands/forests, (c) animals have access to fields or pastures without any fencing, (d) animals have access to fenced areas in fields or pastures, (e) animals are held in open buildings that are fenced with no access to outside forests, and (f) animals are held in closed buildings with access to a fenced concrete outdoor run/yard (EFSA AHAW Panel, 2021). The types of farms that are considered outdoor farms in several MS are: free ranging farms, backyards, kept WB farms, organic pig farms, farms with specific (native) breeds and pigs kept as pets or for hobby (EFSA AHAW Panel, 2021).

Definition of distribution and characteristics of the WB and pig interface at a large scale is being addressed by ENETWILD Consortium et al. (2020b). This RO will allow the quantification of the overlap of WB and pigs therein on different production systems. To date, the interface has been spatially depicted in only a few countries, and considering the typology of pig farms, only in Romania (ENETWILD-consortium et al., 2021).

The presence and visits of the WB to pig farms could be related to farm type and resource access, such as food or water points (Table 5). It has been determined that proximity of forest to the farm and distance between pig enclosures and houses are factors that influence WB intrusions (Wu et al., 2012; Kukielka et al., 2013). Moreover, physical barriers such as fences of minimum height or electrified fences could be measures to reduce or avoid direct WB-pig interactions.

Even though direct contact is uncommon (Cadenas-Fernández et al., 2019; Triguero-Ocaña et al., 2020), indirect contact could be an important factor in disease transmission (Kukielka et al., 2013).

It has been found that WBs are generally more attracted to sows in oestrus than to other resources such as food (Wyckoff et al., 2009; Wu et al., 2012). Thus, mating purposes could be a factor of attraction for the WB to the pig farms.

Table 5: Main factors related to WB presence near pig farms already identified

Variable	Sub-variable	Hypothesis	Reference
Farm management and structures	Water/feeding points	Aggregation points could favour diseases transmission. WB visits these points for eating, drinking water or wallowing, especially during resource-scarce seasons/periods (attractive factor).	Kukielka et al. (2013), Carrasco-Garcia et al. (2016)
Farm management and structures	Carrion	Carcasses (as attractive factor) can be removed from the farm area or left in nature.	Jori et al. (2017a)
Mating purposes	Na	Male WB attracted by sows in oestrus, increasing contacts between WB and pigs. Hybridisation as a consequence and an indicator.	Wu et al. (2012), Nikolov et al. (2017)
Farm location	Na	Pigs located away from buildings and/or close to forests (refugee effect) could be at risk for indirect contact with WB.	Wu et al. (2012)
WB artificial feeding in proximity of pig farms	Artificial feeding for big game hunting	WB at high densities (favoured by hunting management, such as artificial feeding) in farming areas could favour contacts and disease transmission. Artificial feeding aimed at big game may attract pigs when farming and game uses are not separated.	Vicente et al. (2007)

Na: not applicable.

3.6.1.3. Potential impact of the results obtained for ASF management in the EU

Determining which factors affect the presence of WB close to pig farms will allow:

- The establishment and improvement of management measures to reduce pig farm attractiveness to WB and to minimise the risk of disease transmission, especially under different epidemiological scenarios (recent ASF outbreak, endemic stage of ASF, ASF-free areas).
- Demonstration to stakeholders, such as pig farmers and hunters, of the necessity for avoiding and minimising WB and pig interactions through structures and human behaviour changes (i.e. fencing or carcass removal) to reduce ASF risk transmission. This is an essential step toward developing biosecurity awareness and further implementation among backyard and outdoor pig farmers.

3.6.2. Objectives

To determine which environmental and human factors (e.g. farm structure, building characteristics, open-air access, land use in and around farm, see Table 5) attract WB to pig farms or farming areas, and to assess spatial behaviour of WB and domestic pigs at pig farms, and how they interact spatially and temporally.

3.6.3. Methodology

Study site

Among the types of outdoor farms that have been reported to EFSA by EU MS (EFSA AHAW Panel, 2021), the farms included in this study are those fulfilling any of these characteristics: (i) pigs have access to woodlands/forests without fencing, (ii) pigs have access to fenced areas in woodlands/forests, (iii) animals have access to fields or pastures without fencing, (iv) animals have access to fenced areas in fields or pastures.

Data collections should be performed in at least two bioregions (Figure 1):

— East Bioregion: focusing on abundance of backyards farming including outdoor conditions part of the year.
— West Bioregion: Focusing on the Atlantic habitat.

The Mediterranean areas can be excluded since comparable information is already available (Kukielka et al., 2013; Carrasco-Garcia et al., 2016; Cadenas-Fernández et al., 2019).

Study design

For each region the following three methods can be used:

- Farmer questionnaires: structured into sections including (a) farming characteristics (number of pigs, typology of farm, following our classification, surface area, description of outdoor practices and grazing management along the year, hunting activities inside and/or around the farm, feeding and wallowing practices, management of carcasses); (b) observations of WB (Jori et al., 2017b); (c) identification by the owner of the 'risk points' (facilities or areas attractive to WB and areas of animal congregation where WB can directly or indirectly came into contact with pigs such as feeders, troughs or fences) (Payne et al., 2016; Cadenas-Fernández et al., 2019); (d) socio-demographic characteristics (sex, age) following the classification by ELSTAT (2011, www.statistics.gr).
- WB abundance should be estimated as an index, based on hunting data in the area (ENETWILD Consortium et al., 2018b, 2019b, 2020a).
- Camera trapping: Assessment of WB visits to pig farms and characterisation of interactions with pigs by CT. Previous studies have demonstrated the practical value of CTs when they are used in pig management systems, where there is *a priori* understanding of where potential WB–pig interactions may take place (Kukielka et al., 2013; Carrasco-Garcia et al., 2016; Payne et al., 2016; Cadenas-Fernández et al., 2019).

CTs should be placed at farm facilities at *a priori* attraction points (e.g. water/feeding points, feed stores) and risk contact areas (e.g. resting areas) (Kukielka et al., 2013; Payne et al., 2016; Podgórski et al., 2018; Triguero-Ocaña et al., 2020). CTs need also to be placed in unclassified areas that could be used by WB but are not, apparently, aggregation points (random points are those where food and water are not present), which act as control CTs for comparison purposes (Carrasco-Garcia et al., 2016). As an indication, the number of CTs depends on farm size and number of risk points. CT should cover the farm proportionally following these criteria: 50% of plots (fenced areas), 33% of 'risk points' and a minimum 3 CTs in control sites. Control CTs should be distributed to cover the range of distances from the furthest point to the nearest woodland to the farm (or vegetation covered area), then at least one at the woodland-grazing plot ecotone, and finally, one inside the woodland (at least 100 m from the grazing plots). CT must be operative for at least 15 days at each farm (revised weekly) covering the four seasons, especially when pigs are outside. Control CTs will be operative for at least 30 days each season, even when pigs are not outside. CTs will allow the characterisation of sex and age WB/pig contacts (mainly indirect, see Kukielka et al., 2013 and Carrasco-Garcia et al., 2016).

Sample size

Minimum of 10 farms per study region, of which 5 are type i or ii (pig access to woodland/forest) and 5 are type iii or iv (outdoor access to field or pastures). At least 15 CTs per farm. This is about 75–90 CTs placed at one time at five farms in each region, and a second round where CTs can be moved to the remaining five farms within a given season.

Spatial range

At least Atlantic and East European bioregions (ENETWILD Consortium et al., 2019a,b, 2020a) as described above.

Expected duration

1 year for data compilation.

Deliverables

Description of the use of key outdoor farm resources (e.g. attraction points and risk contact areas) in a set of representative farms in different bioregions and pig outdoor management typologies, and identification of their potential for interspecific interactions between WB and pigs (e.g. number of contacts per day; related to risk of disease transmission for specific areas and seasons).

3.7. RO3. Implementation of practical methods to estimate wild boar density

3.7.1. Background

Relative abundance is commonly estimated for a species in a particular ecosystem, but this is a proxy of the density or the population size, which only indicates the trend of the population size (O'Brien, 2011). Accurate and unbiased estimates of population size can only be achieved by calculating the absolute abundance (total number in the population) or the density (population size per area unit). Since counting WB on a large regional scale is unfeasible, estimations of density and abundance are reliable only at a local scale in specific habitats.

3.7.1.1. Evidences available in Europe and worldwide

Generally, the density estimates of WB are based on hunting bags, and from different sources and scales (ENETWILD Consortium et al., 2018b, 2019b, 2020a). Moreover, data collection does not follow any scientific or harmonised methodology (Melis et al., 2006).

Given the diversity of available methods and the geographical diversity of Europe, harmonisation of such methods is essential. A recent report reviewed the accuracy and comparability of methods to estimate relative abundance and density of WB populations and guidelines for their implementation (ENETWILD Consortium et al., 2018b, 2019b, 2020a). Three methods (CT, drive counts and distance sampling with thermography) were recommended to estimate WB density on a local scale.

CT allows an easy and non-invasive way to study the WB population, including density. Despite the potential of CT methods to generate harmonised and comparable density values over a wide range of situations, difficulty in data processing and analysis of CT methods limits their use.

However, different computational tools are being developed to organise and process images automatically and through collaborators (e.g. Norouzzadeh et al., 2018). These systems can facilitate and accelerate research projects, overcoming the bottleneck that prevents most wildlife professionals from calculating reliable CT-based densities of WB and other mammals.

3.7.1.2. Current situation in the EU for the particular research objective

WB population density values for Europe are scarce in the literature (ENETWILD Consortium et al., 2018b, 2019b, 2020a). ENETWILD is partially addressing WB population density in 15–20 locations with 1–2 sites per country (Figure 2) during 2020 and 2021.

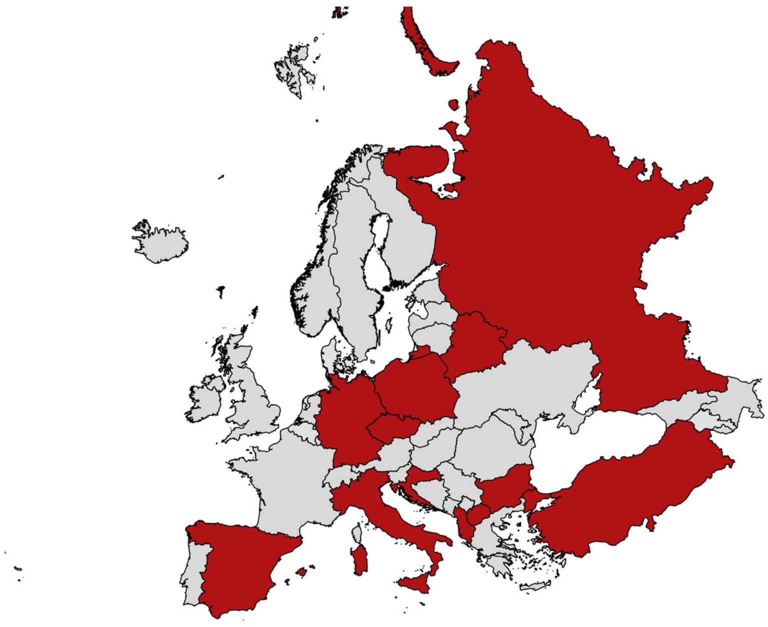

Figure 2: Representation of the countries (red shading) where reliable values of WB density are being calculated (as a pilot), by CT in 15–20 WB populations with 1–2 sites per country during 2020 and 2021 by ENETWILD (www.enetwild.com)

It is necessary to increase the number of study sites, expanding into areas represented in the Figure 2 in grey to ensure representative values across Europe: Austria, Belgium, Bosnia and Herzegovina, Estonia, Finland, France, Greece, Hungary, Latvia, Lithuania, Moldova, Montenegro, Norway, Portugal, Romania, Serbia, Slovakia, Slovenia, Sweden, Switzerland, the Netherlands, the UK and Ukraine. Some recently developed CT methods without the need for individual recognition provide an independent, low disturbance and practical way to collect robust data (ENETWILD Consortium et al., 2018a; Palencia et al., 2019; Rowcliffe et al., 2008). They are usable across most of the distribution range of WB in Europe, and when applied following a robust study design, they provide accurate and unbiased estimates of WB density, which are useful for spatiotemporal comparisons (Howe et al., 2017; Nakashima et al., 2018).

Tools for processing images captured with CT are in development, and first steps have been taken in Europe for organising images, developing automated animal recognition and solving associated challenges, e.g. adverse environmental conditions, partially visible animals, etc. (Hoebeke et al., 2018).

3.7.1.3. Potential impact of the results obtained for ASF management in the EU

In the case of ASF, values of absolute abundance or density are needed for robust risk assessment, and they are essential to improve wild boar management strategies, which have now been successful in two locations (the Czech Republic and Belgium). The numbers and distribution of WB across Europe and in specific areas (e.g. in case of outbreak) are needed for conducting and assessing efficient WB population management for disease prevention and control.

Density values will also enable the validation of hunting statistics (the most available data with potential to be compared across Europe) to estimate density, which will make possible the use of a large amount of available data.

3.7.2. Objectives

1) To improve WB density estimation and to increase the number of study sites in those areas where knowledge gaps exist across Europe, through facilitating the use of CT analytical tools by professionals.
2) To calibrate hunting statistics against CT analytics

3.7.3. Methodology

Study design

Methods are based on CT analytical tools (Random Encounter Model CT-REM, Random Encounter rate and Staying Time CT-REST, and Distance Sampling CT-DS). In addition, high-quality hunting statistics (see ENETWILD Consortium et al., 2018a, 2019b, 2020a) should be collected.

A study network must be composed of organisations, such as research centres and wildlife management professionals, which will apply the CT protocol designed by ENETWILD to determine WB density. This protocol is compatible with CT-REM, CT-REST and CT-DS methods to estimate WB density based on CT data without the need for individual recognition. Details of the protocol are available: ENETWILD Consortium et al. (2018a); Rowcliffe et al. (2008, 2013); https://www.efsa.europa.eu/en/supporting/pub/en-1449; see ENETWILD Consortium et al., 2018a, 2019b, 2020a.

Development of analytical tools to harmonise procedures and promote collaborative science:

- Harmonising the generation of databases prior to analyses will be done by means of CT image management application (e.g. Agoutí). This requires (i) the development of a web platform for participants of the wildlife network to create their own CT projects and (ii) incorporating functionalities to generate standardised CT databases ready for statistical analyses. This application will allow the easy export of CT records into a format that can be used to analyse and estimate density.
- Data visualisation and automated measurement of distances.
- Development of an external interface for running CT density models (CT-REM, CT-REST and CT-DS).
- Create interactive online maps in an institutional portal.

Hunting statistics: high-quality hunting statistics (i.e. sampled at high spatial resolution) should also be collected by participants of the network at sampling sites during collective hunts. Hunting statistics will then be calibrated against reliable CT density data following ENETWILD Consortium et al. (2019b) (see ENETWILD Consortium et al., 2018a, 2019b, 2020a). In this way, the density data generated by this network will be used to validate high quality hunting statistics.

Study sites

Gap countries/regions (mainly in Eastern Europe, see Figure 2) are already identified and CT protocols are available at: ENETWILD Consortium et al., 2018a, 2019b, 2020a.

At least 15 study sites in total, ranging from 1,000 to 5,000 ha.

Sample size

35–45 CTs at each study site over a study period of 2 months during autumn/early winter (ENETWILD Consortium et al., 2018a; Rowcliffe et al., 2008; Wearn and Glover-Kapfer, 2017).

Spatial range

Focusing on the gaps in Figure 2, mainly in Eastern Europe.

Expected duration: 1 year.

3.7.4. Deliverables

- Deliverable 1: Density values estimated by CT for at least 15 populations in gap countries and calibration with density values obtained from high quality hunting statistics.
- Deliverable 2: Development of a web platform to manage photo-trappings and generate standardised CT databases, and an external interface for running CT density models (CT-REM, CT-REST and CT-DS).

3.8. RO4. Assess the effect of natural resources and artificial feeding on wild boar population dynamics and management

3.8.1. Background

WB is an opportunistic omnivore feeding on all types of organic matter (plant, animal and fungi) of natural or anthropogenic origin (Ballari and Barrios-García, 2014). Natural food availability is a strong factor influencing WB population dynamics, which, in turn, are related to environmental conditions (Oja et al., 2014; Touzot et al., 2020). However, human presence and activities have facilitated WB population access to a vast amount of food resources (e.g. crops or artificial feeding; Fruziński and Łabudzki, 2002; Rosvold and Andersen, 2008). The highly plastic feeding behaviour of WB explains its particularly high adaptability to different ecological conditions and thus its wide geographical distribution (Ballari and Barrios-García, 2014).

3.8.1.1. Evidences available in Europe and worldwide

Food availability can affect WB demography mainly in three ways: reducing juvenile mortality, increasing fertility and litter size, and advancing reproductive age (Tack, 2018). Even when natural resources are available, WB use anthropogenic resources (e.g. agricultural products, supplementary feeding for hunting or management purposes, garbage in urban areas). It has been found that, even during years characterised by abundant mast productivity, populations receiving artificial feeding have higher recruitment than populations receiving no artificial feeding (Groot Bruinderink et al., 1994).

WB or wild pig population control activities (e.g. trapping, shooting or toxic baiting) frequently involve the deployment of bait to attract them (Snow and VerCauteren, 2019). When the supply of feed is limited (to not affect WB population dynamics) and the objective is to increase contact with WB for hunting or culling, then the term baiting is used. The main differences between baiting and feeding are the required quantities of food employed, but there is no exact threshold to distinguish these (EFSA AHAW Panel, 2015). Reducing the number of wild pigs and WB following baiting is an effective strategy for population control (Snow and VerCauteren, 2019).

3.8.1.2. Current situation for the particular research objective in the EU

Recent literature addressing the effect of natural resources and artificial feeding on WB population dynamics and management is scarce and not representative for all bioregions. Rules and purposes concerning feeding of WB vary between different European countries; it is banned in some countries and obligatory in others. At the European level, it has been reported that the WB diet consists primarily in vegetation, including all aerial parts, including stems in annual plants, roots, bulbs, fruits and seeds. Different studies have related mast productivity with a greater WB female breeding proportion (Gamelon et al., 2013; Touzot et al., 2020). Even if the proportion of animal matter was reported to be relatively low in the WB diet, it is thought to be an essential dietary component (Ballari and Barrios-García, 2014).

Crops also represent a key food resource for WB in Europe. For instance, maize is one of the most important crops at the European level, and it has increased drastically over the last decades (Oja et al., 2014; Tack, 2018). The range of cultivations WB can feed on are diverse and occur in different seasons, making use of what is available.

As there is no clear boundary between baiting and feeding, European countries have developed different regulations and recommendations limiting the quantity of food to bait, particularly in areas where ASF is present (EFSA, 2017, 2018, EFSA AHAW Panel, 2015; SANTE/7113/2015 – Rev 12). Table 6 shows some examples of these limits.

Table 6: Bait limits at the European level and in some European countries

Country	Bait limit	Other information
All Europe	10 kg/km^2/month	Na
Latvia	40 L/km^2	Spatial restrictions; WB limited access to food.
Poland	10 kg/km^2 per month	Restricted areas; 143 million tonnes/year for the entire country and all ungulates.
Lithuania	100 kg per baiting place (specially designed content)	20 kg/ha is allowed (apples or vegetables).
Estonia	100 kg/WB or 100 kg/month per place	Locations separated by at least 1 km.
Czech Republic	5 kg/km^2	Na

Na: not available; kg: kilogram; L: litre; km: kilometre; ha: hectare.

Different baits and attractants have been employed in Europe (Geisser and Reyer, 2004; Massei et al., 2010; Ballesteros et al., 2011) to attract WB for hunting/culling or to reduce crop damage (i.e. diversionary feeding; Massei et al., 2011). There is no information about the most effective baits or WB preferences, although WB shows preference for sweet flavour and chemicals such as monosodium-glutamate (Lavelle et al., 2017).

3.8.1.3. Potential impact of the results obtained for ASF management in the EU

Limiting food availability is of direct application to reduce WB population size and growth rate. A better understanding of how resource availability (natural or artificial) affects WB social-spatial behaviour is fundamental to design the strategy of population control. To explore effectiveness of baits (quantity and type) and baiting strategy, in combination with non-edible attractants would allow increased efficacy and so optimisation of efforts on culling to reduce WB populations.

3.8.2. Objectives

1) To determine, for different scenarios across Europe (ASF situation, bioregion, social), how different available feed resources affect:
   a) Population dynamics parameters
   b) Social and spatial behaviour
2) To assess the efficacy of different baiting strategies developed by hunters to concentrate WB in an area for collective hunt.

3.8.3. Methodology

Objective 1.a.: Quantify the impact of natural resources, crops, and artificial feeding on WB population dynamics.

Method

Correlational study of WB population dynamics (density, female breeding proportion, growth rate or recruitment on WB populations) under three different feed availability conditions: (1) natural resources; (2) agriculture resources and (3) artificial feeding (see ENETWILD Consortium et al., 2019a; Miloš et al., 2016; Oja et al., 2014; Touzot et al., 2020).

This study should be carried out together with a cross-sectional study of the wild boar diet, using barcoding techniques of non-invasive faecal samples over different seasons (Monterroso et al., 2019; Ando et al., 2020).

Sample size

Minimum 12 sites per bioregion (see Figure 1) including the three conditions mentioned (if possible, four study sites per food availability condition). Thirty faecal samples per site should be collected per season and must be spatially independent (Ferreira et al., 2018; Robeson et al., 2018).

Spatial range

Across the four wild boar population bioregions because artificial feeding practices, crops and WB population dynamics vary across the continent.

Expected duration

One year.

Objective 1.b: Quantify the impact of natural resources, crops and artificial feeding on WB social and spatial behaviour.

Method

GPS-collared WB for the assessment of spatial parameters such as home range, daily activity, habitat selection, interactions among groups (Podgórski et al., 2013, 2014) (protocols available at: Barasona et al., 2014; Baubet et al., 2004; Morelle et al., 2014; Triguero-Ocaña et al., 2020), (see ENETWILD Consortium et al., 2019a).

Study design

Comparative studies including three feed availability conditions: natural without crop access vs. natural with crop access vs. artificial feeding. Minimum three sites in one of the three conditions.

Sample size

Minimum 15 females individually collared in each condition for six months.

Spatial range

One of the four bioregions.

Expected duration

One year.

Objective 2: Evaluation of baiting strategies to improve collective hunting efficiency.

Method

Field-testing of different attractant strategies by using CT to assess bait detection time, consumption time, or the number of individuals, as well as their effect on WB hunting/culling (collective events) efficiency.

Study design

- Cafeteria experiment: as a preliminary study before the hunting season to determine in the different bioregions, the most effective attractant (e.g. Martinez-Guijosa et al., 2020). This consists of offering to WB several attractants and assessing their preferences, which is monitored by CT (video mode). Different attractants are deployed in a small area, separated from each other by 100 m and weekly rotated (i.e. four different attractants in 1 ha). Attractants to test may include: cinnamon-truffle (Ballesteros et al., 2009), strawberry-flavoured and fish-flavoured (Campbell and Long, 2009).
- Baiting comparative study of hunting efficacy:
- Corn as bait with the most effective attractant (established in the previous cafeteria experiment) covered by medium-large stones to hinder access to the bait (Ballesteros et al., 2009).
- Amount of bait employed: 25 kg of corn/250 ha × week (resembling current EU advice in the context of ASF) vs 100 kg of corn/250 ha × week vs a control area where there is not baiting.
- Surface area baited (or under study in the control site): twice the size of a typically large beaten area (minimum 500 ha). The beaten area is systematically 'driven' or beaten. By the hunters forcing the WB out of their cover by calling and knocking.
- Number of baiting points: all of those that fit in the area, separated by 500 m and visited once per week (20–25 baiting points in a typical 500 ha area).
- Duration of baiting: three weeks prior to hunting. The first and second weeks, baiting points must be regularly distributed across the study area (twice the size of beaten area). The third week, baiting points must be placed only in the area to beat, creating corn trails (in the second week) leading to this area from the area that received bait in the first 2 weeks, using bait and attractant for the trials

The instructions for the placement of CTs and calculation of density of WB without individual recognition can be found in Figure 3.

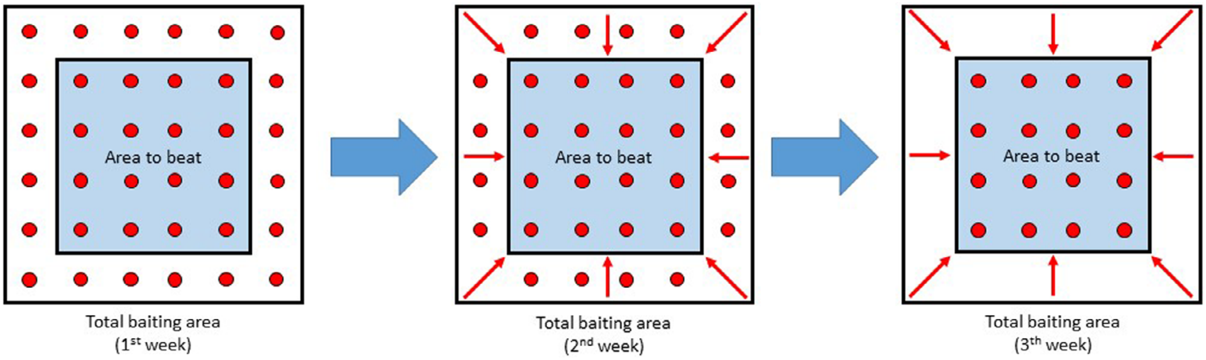

Figure 3: Schematic diagram of surface to bait. The duration of baiting is three weeks (previous to hunting) and this is the temporal succession of actions: (i) the first week baiting points are regularly distributed across the whole study area (~ 500 ha); (ii) the second week corn trails are created from the external area towards the internal, and finally (iii), the third week, baiting points must be placed only in the area to beat

WB density in the study areas (~ 2,500 ha) should be calculated by CT (by a random encounter model, CT-REM, REST or DS-CT (ENETWILD Consortium et al., 2018a) before and during the baiting period to detect changes in WB spatial behaviour due to attractive effect of baiting. One third of baiting points should be monitored by CT. Baiting places should be moved each week, because, according to some experts, it increases the efficiency and decreases the need for large amounts of bait (EFSA AHAW Panel, 2015).

Sample size

Minimum three countries for the cafeteria trial and field baiting experiments, one per main bioregion (ENETWILD Consortium et al., 2019a,b, 2020a), including the three treatments mentioned during the regular hunting season. 35-45 CTs at each study site over a study period of two months (ENETWILD Consortium et al., 2018a; Wearn and Glover-Kapfer, 2017).

Spatial range

Across all of Europe at different bioregions, at least in the three main bioregions.

Expected duration

1 year.

3.8.4. Deliverables

Objective 1.a

Description of WB population dynamics and diet in relation to three different feed availability conditions across Europe: natural resources only, crops and artificial feeding. Management recommendations.

Objective 1.b

Quantification of the impact of natural resources only, crops and artificial feeding on WB spatial behaviour relevant to disease transmission. Management recommendations.

Objective 2

Evaluation of baiting strategies to improve hunting efficiency.

3.9. RO5. Role and effectiveness of recreational hunting and professional culling for wild boar population control

3.9.1. Background

Recreational hunting is linked to culture across the globe including Europe and is considered an important management tool to control WB populations and to reduce disease prevalence (Boadella et al., 2012; Cowled et al., 2012; García-Jiménez et al., 2013; Mentaberre et al., 2014). The ability of recreational hunters to control ungulate populations is of increasing concern, particularly when facing severe wildlife disease epidemics, such as ASF, and the effectiveness of hunting plans to control ungulate populations is still debated (Brown et al., 2000; Stedman et al., 2004; Lebel et al., 2012).

3.9.1.1. Evidences available in Europe and worldwide

There are few empirical studies about the benefits and limitations of using recreational hunters (RH) to achieve specific management objectives in general, and for WB in particular (Solberg and Saether, 1999; Hothorn and Müller, 2010; Keuling et al., 2010; Boadella et al., 2012; Strand et al., 2012; Massei et al., 2015; Quirós-Fernández et al., 2017; Mysterud et al., 2019).

Harvest simulations have been carried out to investigate the effects of varied culls among animal categories on growth rate and total harvest levels (Magnusson, 2010; Quirós-Fernández et al., 2017). However, the implementation of theoretically developed strategies normally collides with the reality of limitations, such as practical, cultural, psychological and legislative aspects. Therefore, culling strategies need to be assessed in real situations.

On the other hand, professional culling is a complementary management strategy to control wildlife populations and carried out by professional hunters (PH). No data about effectiveness and acceptability of this management option is easily available, and there are no recent examples of this strategy to manage WB, although it has been applied to different species (e.g. Hodnett, 2006; Hampton et al., 2017; Mysterud et al., 2019).

3.9.1.2. Current situation for the particular research objective in the EU

Several studies detected an important effect of hunting on WB population dynamics (Keuling et al., 2013; Quirós-Fernández et al., 2017), since hunting is the main cause of mortality (Nores et al., 2008; Bassi et al., 2020). However, others pointed to the fact that recreational hunting, as it is currently practiced, is insufficient to control the abundant WB population and could be improved (Massei et al., 2011, 2015; Vajas et al., 2020). Practised in a concerted and sustainable way, ordinary hunting might be able to manage WB populations across Europe. However, this requires science-based expertise, resources and the willingness of society (hunters) to be involved. In the case of professional culling, Mysterud and Rolandsen (2018) showed that this was effective to eradicate an entire population of reindeer affected by chronic wasting disease. Thus, this methodology deserves evaluation for its application to manage ASF in WB populations. However, it requires a legal basis and social acceptability.

3.9.1.3. Potential impact of the results obtained for ASF management in the EU

The combination of recreational hunting and professional culling to reduce WB populations may be more effective than recreational hunting alone. Using a combined approach, a drastic reduction of the WB boar population should be feasible. Such a reduction is needed to prevent incursion and subsequent spread of ASF.

3.9.2. Objectives

To assess and compare the effects of recreational hunting and professional culling on WB populations.

3.9.3. Methodology

Method

To analyse and compare the effectiveness of RH and PH to reduce the population density in selected management areas of Europe. Effectiveness can be estimated based on the number of animals sighted and shot, and the development of local density (in the absence of ASF). Local density can be estimated by CT (REM method, ENETWILD Consortium et al., 2018a, 2019b, 2020a). This approach needs high quality hunting and culling statistics for the estimation of reliable preharvest densities to enable a comparison: the number, age group, sex, and kill date of harvested WB (reported by hunters using a standard reporting system).

Study design

The factors to consider are the type of hunters (recreational hunters-professional hunters), the type of day (weekend-workday) and visibility (e.g. related especially to weather conditions according to the protocol by Mysterud et al. (2019)).

Sample size

Minimum two study sites per WB bioregion where recreational hunting and professional culling are performed, respectively (Figure 2).

Spatial range

Three main European WB bioregions.

Expected duration

1 year.

3.9.4. Deliverables

Deliverable 1: quantification and comparison of the effectiveness of RH (recreational hunting) and PH (in terms of the number of harvested WB per time) in the context of current WB management schemes across Europe.

3.10. RO6. Assessment of the effectiveness of wild boar trapping (professional culling tool) methods, including welfare implications

3.10.1. Background

In the context of ASF management, trapping of wild boar can be applied in sites where shooting is not allowed, and could offer increased biosecurity. In addition, it entails a lower risk of wild boar-mediated infection dispersion than other strategies (e.g. those that may favour the movement of animals to other areas). However, trapping also has some limitations: it can be costly and time-consuming to monitor traps and managing captures (Guberti et al., 2019).

The characteristics of WB trapping techniques (and their specificity) are variable (e.g. corral traps, cage traps, funnel traps; Hampton et al., 2019; Seward et al., 2004; Torres-Blas et al., 2020) and present different advantages. Trap capture of WB should minimise negative effects on animal welfare, irrespective of whether the animals are trapped for hunting, research, or management purposes.

3.10.1.1. Evidences available in Europe and worldwide

Trapping has been used to control/eradicate *Sus scrofa* (including WB and feral swine) globally (McCann and Garcelon, 2008; Alexandrov et al., 2011; Ballari et al., 2015). Trapping is more effective if it is used in conjunction with other methods, such as hunting/culling or tracking dogs (McCann and Garcelon, 2008). Trapping efficiency is better at higher WB density, and thus, varies according to ASF-epidemiological situation in each area. Moreover, the effectiveness is seasonal due to fluctuations in food availability, with higher effectiveness when the feeding resources are scarce (Barret and Birmingham, 1994).

While trapping is a common management tool, the data and literature available on trapping normally report effort and trapping success, but not effectiveness in terms of the proportion of the population controlled (i.e. proper population monitoring is not performed) (Licoppe et al., 2020). Comparisons of the performance of trapping systems have been conducted in wild pigs (e.g. Gaskamp, 2012; Bodenchuk, 2014), but not for European WB in non-urban environments.

3.10.1.2. Current situation for the particular research objective in the EU

At the European scale, trapping has been demonstrated as a useful management strategy to mitigate the spread of WB diseases. For instance, trapping facilitated classical swine fever (CSF) eradication in a WB population in Bulgaria (Alexandrov et al., 2011). However, live-trap capture of WB followed by killing inside the trap (e.g. by gunshot) may be considered a controversial hunting method (Fahlman et al., 2020).

The assessment of the effectiveness of WB trapping as a sustainable culling method has yet to be done in the EU, particularly, in non-urban or peri-urban environments (Torres-Blas et al., 2020). The key question is whether programmed and sustained WB trapping can control WB populations in the long term across Europe. Therefore, its effectiveness should be evaluated in the context of other measures (e.g. artificial feeding, hunting).

European trapping regulations vary among countries. In ASF-affected areas, trapping requires strict biosecurity measures to avoid disease spread to non-affected areas through fomites (e.g. traps, clothes) (Guberti et al., 2018, 2019).

The most common types of traps used in the field include (Fenati et al., 2008, Barasona, 2015, Torres-Blas et al., 2020):

- Cage (box) traps (individual or small group capture method) from wood and/or metal, which are easily transportable, size 2–3 m^2.
- Corral traps (collective physical capture method), ranging from medium-size pens (size 5–15 m^2), which can be fixed or transportable (metal or combining wood and metal) and large-size pens (up to 60–70 m^2, metal or combining wood and metal) which are fixed. To minimise injuries to caught animals, the internal side of corral traps should be covered with wood panels or branches.
- Drop-net (collective physical capture method) may provoke less trap shyness and can capture large numbers in a single drop. However, this is also complicated by the need to manage many animals at once (which should be shot or anaesthetised), and normally requires continuous camera monitoring systems and sophisticated drop triggering devices. Similar to other physical capture methods (corral traps), it requires habituation of complete family groups, and normally it should be displaced to other placement after capture events.

Behavioural (during and post-release), pathological, haematological and biochemical assessments after capture events of WB (Fenati et al., 2008, Barasona, 2015, Fahlman et al., 2020, Torres-Blas et al., 2020) are required to evaluate capture-induced stress in WB. Trap-related pathological findings due to trauma and other indicators reveal that, under appropriate management conditions (e.g. impeding escape behaviours and severe reactions to external stimuli, like charging against the mesh walls of the trap or long exposure to adverse climatological conditions, such as severe heat), capture-induced stress and physical injuries would be minor, and therefore, compatible with ethical capture and management procedures (Decision 98/142/CE). There can also be challenges to animal welfare for not caught group members such as juveniles, but these will be not be addressed in this study.

3.10.1.3. Potential impact of the results obtained for ASF management in the EU

Trapping can contribute to long-term, sustainable depopulation and control of WB populations synergistically with other means. In areas where no other population management methods are available (e.g. hunting in urban areas or public parks), trapping is a feasible option for controlling WB population (Cahill et al., 2012; Torres-Blas et al., 2020).

The proper and timely use of trapping in the context of ASF disease may avoid dispersive behaviour as happens with some hunting modalities (Artois et al., 2001; Moennig, 2015).

3.10.2. Objectives

To assess effectiveness (in terms of population proportion captured) and welfare impact of wild boar trapping in each European bioregion.

3.10.3. Methodology

Method

Analysis of the effectiveness (proportion of population captured) of trapping during WB population control on selected management areas of Europe, where trapping operations (different methods and intensity, and their combinations with other methods) are being performed. Monitoring of population density is needed (ENETWILD Consortium et al., 2018b, 2019b, 2020a). Effectiveness of WB trapping is estimated considering factors that may affect efficacy such as the type of trap, season, local practices, intensity and modality of culling (e.g. artificial feeding, hunting).

Study design

The aim is to install a network of traps targeting a density of 1 trap/300 ha, while ensuring the best possible distribution (Licoppe et al., 2020).

Different types of traps can be used for comparison in areas of similar size (3,000–4,000 ha). A minimum of 10 cage (box) traps (minimum separation 500 m from each other), 3 corral traps (separated by 1 km) and 3 drop nets (separated by 1 km) per study site are advised. The bait (corn) could be used according to Licoppe et al. (2020). The drop-net installation, monitoring and triggering should follow Torres-Blas et al. (2020) and cage and corral trap should follow Barasona (2015). If remote triggering is not applied, trap deactivation must follow welfare regulations in place.

Performance measures and variables to assess the methods: WB captured per operation, proportion of population captured, time spent working, cost per capture event, cost per individual captured, safety for operators and animals, ease to cull animals, specificity, ability to conduct trapping with few operators, among other measures.

Performance measures to assess animal welfare: at least 20 WB per study site selected to be comparable in terms of age and sex and methods are sampled after euthanasia following Fahlman et al. (2020) and Decision 98/142/CE.

Spatial range

A minimum of two study sites with four trap types each (drop trap, corral trap, box trap and control), in the same European bioregion.

Expected duration

1 year.

3.10.4. Deliverables

Deliverable 1: Effectiveness of trapping as a management tool to control WB population, and the welfare implications.

3.11. RO7. Assess the efficacy of different fencing methods with GPS-collared wild boar, considering the impact on non-target species

3.11.1. Background

Different kinds of barriers can affect the movement of wildlife species. Some are installed deliberately to limit spatial behaviour and interactions among WB populations and/or with domestic pigs, such as WB-proof fences (Mysterud and Rolandsen, 2019).

In recent cases, in Belgium, the Czech Republic and Germany, the use of permanent, mobile and already present fences (such as highway fences) has been shown to play a key role in the reduction and spatial containment of the disease to specific areas (Dellicour et al., 2020).

3.11.1.1. Evidences available in Europe and worldwide

Integrated research investigating the impact of different barriers on wildlife, and particularly WB, has thus far been scarce (Rosell et al., 2018; Rosell, 2019). The efficacy of fencing for WB containment is variable (Geisser and Reyer, 2004; Vidrih and Trdan, 2008; Honda et al., 2009), and results depend on the scale (large fences of hundreds of km are highly vulnerable to WB), environmental conditions (e.g. snow could lead to lowering the barrier) and fence structure (Mysterud and Rolandsen, 2019). Moreover, fencing may have an effect on non-target species movement, or may conflict with conservation policies (Mbaiwa and Mbaiwa, 2006; Jakes et al., 2018).

Different types and designs of fences are available, varying by fence height, single or double fence line, electrification, woven or barbed wire, and other aspects (Paige and Stevensville, 2008; Mysterud and Rolandsen, 2019). Associated costs for fence construction and maintenance are also variable (e.g. Honda et al., 2009, 2011).

3.11.1.2. Current situation for the particular research objective in the EU

WB-proof fences have mainly been used to reduce agricultural damage or ecological impacts in Europe (Geisser and Reyer, 2004; Vidrih and Trdan, 2008; Rosell et al., 2018; Rosell, 2019). Different MS have built fences to avoid ASF spread among countries, for instance between Belgium and France, Denmark and Germany, Germany and Poland, or around affected areas within a country, such as the Czech Republic, Belgium and Germany to control ASF outbreak.

3.11.1.3. Potential impact of the results obtained for ASF management in the EU

Management is vital to restrict European WB populations in relation to controlling ASF spread, because it can reduce the likelihood of contact among individuals between different zones of intervention (e.g. an ASF outbreak) or between different populations by reducing spatial movement. Moreover, fences in ASF-areas could be used for capturing WB, if used as guiding structures and leading them to traps.

Investigating more accurately the relative role of different types of barriers on WB movement is a crucial component of an integrated approach to control the disease once an outbreak has occurred in a particular area.

3.11.2. Objectives

1) To evaluate the effect of different types of fences on the movement of WB.
2) To determine which non-target species interact with fences and how they could be affected.

3.11.3. Methodology

Methods

Available movement data (GPS-VHF, earmark, CTs) combined with information on existing fences/ barriers (natural and human-made) should be used to evaluate the effectiveness ~~efficien~~cy of fencing in terms of permeability to WB.

It is recommended to evaluate the different types of fences and barriers for preventing WB access to certain areas at small scales, with the possibility to extrapolate results to large scale fencing. Tracking of WB by telemetry from areas close to the fences should be used to analyse their movement and to detect passage points (if they cross the fence). CT should be used to check WB as well as non-target species (e.g. other ungulates and carnivores) interactions with the fence. It is recommended that already installed fences should be leveraged.

Study design

Fence type: include different types of fences: single/double line fence (commercial fencing advertised as big game proof; Mysterud and Rolandsen, 2019), electrified fences, and dig fences.

Telemetry: tracking WB where artificial passive barriers are already present, including some installed to restrict WB access, such as the fence constructed between France and Belgium (already built to prevent ASF spread). GPS monitoring for 6 months, including the hunting season (i.e. August–January). Calculation of fence crossings by WB is estimated considering GPS positioning error.

Camera trap: installation of CT (video) to monitor specific points that are more appropriate for wildlife passage (e.g. in streams, or where underpasses are detected or signs of ungulate presence) to check interactions of non-target species and WB with fences (Laskin et al., 2020). This is complemented with weekly visits to fences to check breaks caused by WB or other species, identify new underpasses and subsequent placement of CTs to monitor wildlife behaviour. In specific points where there is evidence of suspected overpasses by other ungulates, CTs must also be placed. Although CTs can be moved based on evidence of passage, they must remain for a minimum of 2 weeks in the same location. It is important to pay special attention to fence efficacy when hunting is practiced, especially with dogs. Wildlife behaviour at the fences is assessed by the crossing success (cross/not-cross) and crossing method (over/under/through).

Sample size

Select one study site where the different types of above-mentioned fences are present, including at least big game proof and WB proof fence types. At least 15 animals (half males and half females) with access to fences (captured < 2 km from fences) should be tracked. Thirty camera traps installed at fences at each study site for 6 months in parallel to telemetry.

Spatial range

In parts of Europe where big game fences are pre-existent, e.g. in fenced hunting grounds of Spain or Hungary, or installed fences on international borders.

Expected duration

1 year.

3.11.4. Deliverables

- Deliverable 1: report on fence permeability to WB by different types of fences, patterns of fences crossing by WB (when/where and animals' characteristics, age/sex).
- Deliverable 2: report on non-target species affected by different types of fences assessed by CT.

3.12. RO8. Use of trained dogs in ASF-affected areas for carcass detection

3.12.1. Background

In areas where ASF is present, carcasses of ASF-infected WB are a risk for further transmission, especially in European regions where environmental temperatures are low and persistence of carcasses is prolonged (Probst et al., 2017, 2019). Presence of infected carcasses allows the persistence of ASFV even after the WB population is reduced to very low numbers. It is assumed that this contact is more important for ASF spread than direct contact between live infectious individuals. Models suggest that reduced hunting effort is required in the intensive hunting area (in the context of ASF outbreaks) to reduce spread of disease, when carcass removal is being implemented in the core area (Lange et al., 2018). Thus, carcass detection and removal is an effective strategy to reduce ASF transmission (EFSA, 2018; Morelle et al., 2019).

3.12.1.1. Evidences available in Europe and worldwide

Detection of carcasses in natural areas is difficult due to low accessibility of the terrain and/or lack of visibility of carcasses, especially for human searchers. Scientific literature regarding WB carcass localisation in ASF-affected areas is almost absent, although carcass localisation has been tested in other species and contexts. ASF-infected WB deathbeds are mostly found in cool and moist habitats (Morelle et al., 2019), underlining the difficulties of carcass detection under real conditions in the field. Among the detection methods and techniques to find WB carcasses, the use of detection dogs held promise and was therefore applied in affected regions, e.g. Germany.

The search for carcasses by dog handlers with trained dogs is an effective tool for carcass detection, even in closed vegetation environments and for small carcasses (Homan et al., 2001; Dahlgren et al., 2012; Mathews et al., 2013; Barrientos et al., 2018; Domínguez del Valle et al., 2020). Detection dogs have been employed to find chamois (*Rupicapra pyrenaica*) carcasses during an outbreak of sarcoptic mange (Alasaad et al., 2012). There are also working groups using dogs to detect diseased animals (https://wd4c.org/our-work/biosecurity-invasives) and humans (for COVID-19 see Federal Government of Germany, 2020; Grandjean et al., 2020; Jendrny et al., 2020).

Well-trained dogs are portable and versatile tools for odour detection (Marchal et al., 2016; Rosell, 2018; Schüler and Kaul, 2019; Bálint et al., 2020) and were shown to outperform other detection methods (Smallwood et al., 2020). Nevertheless, the use of the dogs has disadvantages. For example, operational working under field conditions is limited, and the efficacy to locate an odour is highly variable from dog to dog. In addition, biosecurity measures have to be taken into consideration to avoid mechanical transmission of the disease agent.

3.12.1.2. Current situation for the particular research objective in the EU

Scientific evidence is lacking and urgently needed to assess the potential benefit of the use of dogs for carcass detection and their possible integration into ASF control strategies. Specific data are missing on detection rates, deployment times, searchable areas and searching strategies. First experiences under real operating conditions are available as unpublished reports from dog-handler teams (e.g. for dog-handler teams from the federal state of Schleswig-Holstein which worked in ASF-affected areas in 2020; Karsten and Orlowski, 2020; Niemann, 2020, 2021).

It is necessary to identify the pros and cons of using dogs in ASF management and compare their use with other techniques under different environmental conditions. Private organisations or individuals step into the ASF carcass-detection-dog business without defined and harmonised standards for training, testing, certification and practical field work. Defining common international standards for decontamination procedures of detection dog teams after fieldwork do not exist.

3.12.1.3. Potential impact of the results obtained for ASF management in the EU

A faster and more effective intervention in early ASF epidemic stages to stop/mitigate disease spread through contacts between carcasses and live WB.

The development of a decision matrix for a best practice approach in carcass detection: carcass detection method or combinations of different methods for given environmental conditions to achieve optimal WB carcass detection rates in ASF-affected areas.

3.12.2. Objectives

1) Definition of standards for training, testing and the certification of reliable carcass detection by dogs.
2) Comparison of different carcass detection techniques, including dogs, in terms of efficacy and required time to detection.

3.12.3. Methodology

Method

Objective 1: Review of literature and available data on practical experiences and scientific approaches in the use of detection dogs in ASF management should be compiled. Moreover, interviews/questionnaires should be sent to organisations and individuals involved in training and use of carcass detection dogs in current ASF management throughout Europe to assess the current situation regarding WB carcass detection (training of dogs and handlers, operational experiences, quality assurance, coordination, testing of different detection options, biosecurity issues, etc.).

Objective 2: Field trials should be developed to compare different carcass detection techniques (dogs, humans versus drones with thermographic sensors and optical imaging) for WB carcass detection under different environmental conditions (different habitat, seasonal and weather conditions, and different decomposition stages). Each detection method should be characterised in terms of precision, sensitivity, effort and cost.

Study design

Monitoring of the dog search to estimate detection time and search area (dogs equipped with GPS collars or trackers and dog handlers), and other parameters affecting detection success (wind conditions, carcass density etc.). A comparison between the tracked versus the untracked area of the complete search area allows the calculation of the detection effectiveness in an area where a predefined number of WB carcasses (1–5 per dog/search) are previously laid out. This will be compared to human searchers and other detection techniques (drones). The searching methods (human chain, systematic area search) and the given searching times could be varied as well to identify optimal searching routines.

Sample size

The sample size per field trial should contain 10 detection dog teams with varying working times and predefined area sizes searched per each trial. Analyses must control for the dog-handler team. Up to 10 search repetitions should be made in each of the 5–10 different study areas representing different habitats in the same bioregion (ENETWILD Consortium et al., 2019a).

Spatial range

Where specifically trained dogs are available (e.g. Germany).

Expected duration

1 year.

3.12.4. Deliverables

- Deliverable 1: Report on: (i) literature review of available scientific papers and grey literature/ reports dealing with detection dogs used in ASF management and (ii) interviews/ questionnaires to collect standardised data from organisations and individuals involved in different carcass detection dog programmes in European countries.

- Deliverable 2: Scientific analysis of field trials on the detection of WB carcasses under different habitats, seasonal and weather conditions, including a comparison of different biological (dogs, humans) and technical detection systems (drones with thermographic sensors and optical imaging) in terms of precision, sensitivity, effort and cost.

3.13. RO9. Social acceptance of wild boar management measures and their impact on animal welfare (qualitative and quantitative approaches)

3.13.1. Background

The 'human–wildlife conflicts' are conflicts among humans over wildlife management issues (Redpath et al., 2013). A wildlife management strategy should be effective to successfully address such conflicts, and, at the same time, interested parties support, or at least tolerate, its application (Redpath et al., 2015). This is closely linked to the existing wider debate over the need (or not) for human intervention to manage nature (Deary and Warren, 2017; Linnell et al., 2015). Managing wild boar over-abundance (see glossary) is a paradigmatic example of human-wildlife conflict Caughley (1981).

According to Bruskotter et al. (2009), acceptability is a judgement or decision regarding the appropriateness of a particular action or policy. This acceptability in relation to wildlife management and welfare varies among stakeholder groups and different management scenarios (i.e. depending on the species, proposed management actions), or socio-economic and cultural contexts (e.g. it has become important in modern societies; Dandy et al., 2011; Delibes-Mateos et al., 2013; Wallach et al., 2018).

To assess the social acceptability of wildlife management strategies, including their possible impact on animal welfare, there are two possible approaches, the ethnographic and the quantitative. The ethnographic approach extends the usual concept of 'social acceptance' from a mere fixed statement of opinion into a dynamic stance taken up in daily life, socially enacted, and publicly performed in different settings and encompassing multiple dimensions (social, cultural, economic, ecological, political, ethical). Rather than imposing a pre-conceived set of questions 'top-down' from outside stakeholders' life worlds, such an approach is primarily 'bottom-up', explorative and explicative. The quantitative approach allows a quantitative analysis of the acceptance and preferences of different stakeholders about different management scenarios. The ethnographic perspective and the quantitative approach are complementary as the qualitative findings will be very helpful in designing the questionnaires and in the interpretation of the responses. On the other hand, the quantitative approach will allow estimates of the representativeness of opinions, perceptions, and preferences that stakeholders express during the ethnographic interviews and discussions.

3.13.1.1. Evidence available in Europe and worldwide

Currently, short-term theoretically informed ethnography is emerging as an approach useful for applied research projects designed to lead to informed interventions, which save time and resources. It is characterised by forms of intensity that lead to deep and valid ways of short-term knowing (Knight, 2000; Pink, 2006; Pink and Morgan, 2013).

Management tools are usually more acceptable when the negative impacts or damage caused by wildlife increase in severity (Liordos et al., 2020). In addition, acceptability of wildlife management options generally decreases with increasing invasiveness of management strategies and decreasing welfare of animals; e.g. from the less invasive fencing to the highly invasive culling (Treves et al., 2006; Heneghan and Morse, 2019; Martínez-Jauregui et al., 2020). In general, in developed countries, hunters and farmers are more supportive of wildlife management strategies, including lethal actions, than are the general public (Frye, 2006; Keuling et al., 2016). Nevertheless, some studies in Europe showed that farmers and the general public are in favour of preventive measures against wildlife conflicts, such as fencing (Frank et al., 2015). Moreover, farmers consider these types of management tools effective to protect livestock from wildlife (Liordos et al., 2020).

3.13.1.2. Current situation for the particular research objective in the EU

WB is one of the most popular game species across Europe and WB hunting has deep historical and cultural roots. Wild boar feature regularly in European public discourse, because their numbers and impacts have been rising markedly across the continent (e.g. Jansen et al., 2007; González-Crespo et al., 2018; Torres-Blas et al., 2020).

Currently, fencing and trapping are common management tools for WB in the specific case of ASF outbreaks, and control of other diseases in Europe (Alexandrov et al., 2011; Rosell, 2019). However, the acceptability of these tools is limited or has not been evaluated, and possible consequences for animal welfare are often disregarded (e.g. see Cassidy, 2019 for similar issues relating to badger culling in the context of bovine tuberculosis in the UK). In the current scenario of ASF spread, these management tools, among others, could be employed to manage WB populations. Social acceptability can be related to animal welfare. However, animal welfare during capture should not be included directly in this RO as it is addressed in another RO.

Hunters may be less willing than farmers and the general public to accept the management of game WB than of non-game species (e.g. European badger *Meles meles* in Greece; Kontsiotis et al., 2020). However, little literature is available on the issue, and therefore, it is needed a better understanding of differences in the acceptability of WB management strategies between and within public groups.

3.13.1.3. Potential impact of the results obtained for ASF management in the EU

The results from the research objective proposed here will allow to characterise the stakeholders in WB management (current and alternative strategies) in different European contexts, and it can indicate which policies are likely to be positively accepted – where and by whom. This, in turn, can lead to differentiation of those policies so they are adjusted to particular contexts rather than pursuing a 'one size fits all' approach.

The results of the quantitative evaluation are essential to incorporate social acceptability into the process of decision-making regarding WB/ASF management. So, it will guide to a better communication with stakeholders in relation to WB/ASF management in addition to enhancing their awareness and making them part of decision-making process. Acceptability and involvement will increase the probability of success in WB/ASF management.

3.13.2. Objectives

1) To obtain a detailed information about the perceptions of stakeholders related to WB management.
2) To determine the degree of acceptability of different management strategies for WB and ASF among different stakeholder groups in different contexts, and the level of agreement and potential for consensus both between and within stakeholder groups.

3.13.3. Methodology

Objective 1: *Focused/Short-term ethnographic research (qualitative approach)*

Through the presence in the field, applied ethnography will mobilise mixed-methods and a variety of data in a holistic approach to understand the complexity of peoples' lifeworlds. Specifically, a 'focused' (Knoblauch, 2005)/short-term ethnographic research strategy (Pink, 2006) takes account of such applied contexts and compensates for the necessary short-term nature of the fieldwork with a stronger emphasis on extensive documentation, especially through audio-visual means. The researchers conducting the project should be ethnographers already familiar with the respective country, including language skills and, ideally, with previous research experience in rural economies and on hunters and/or farmers. This should enable the ethnographers to gain access and build the rapport and trust with stakeholders necessary to conduct fieldwork.

Methods

Ethnographic research values ecological validity over methodological rigidity. As it cannot be expected that stakeholders will fully adhere to protocols of scientific research, ethnographers need some flexibility in the range and application of methods applied during fieldwork. The research design should, therefore, leave room for adjustments in the field when necessary and not be predetermined.

Desk Research: In preparation for field research, ethnographers start by reviewing existing anthropological/social scientific literature about the field, complemented by researching and collecting 'grey literature' from the field (including media reports, social media, local and regional newspapers). In addition, research into stakeholders' social networks and the local institutional infrastructure is conducted (What are relevant stakeholder organisations? What institutions are involved in WB management/ASF management?).

Field Research: Ethnographic studies will be performed in specific hunting areas. The ethnographers will contact and establish rapport and trust with a number of stakeholders such as hunters, farmers, local residents (local villagers), visitors and workers (but not residents) in the area, to explore their everyday lifeworld through a range of methods, including participant observation, informal conversations and semi-structured interviews, focus groups, and audio-visual documentation.

Study design

A pilot ethnographic fieldwork is grounded in the prolonged, continual participant observation of stakeholders' everyday activities, which are described and documented in written field reports and, where possible, through audio and video recordings. Ethnographers distribute their time in the field to get to know stakeholders such as hunters, farmers, local residents (local villagers), visitors and workers (but not residents) in the area.

Sample size

Sample size is irrelevant as qualitative research is not meant to be representative but explorative. Two to four ethnographic studies (e.g. observation of activities and interviews) per group of interest per country are recommended.

Spatial range

As this is a pilot study, the aim is not to be completely representative of the diversity of situations across Europe but select a few countries with contrasting realities. Two to four ethnographic studies in four ASF-affected countries are recommended:

- A Baltic state: a small country affected by ASF since the virus arrived in Europe, with a modest pig industry.
- Poland: large country affected by ASF since the virus arrived in Europe. This country has a large pig industry, and outdoor and backyard pig farms greatly affected by ASF and the latter tend to disappear. Social conflict emerged because the government proposed massive WB culling and the general public objected (Schmidt et al., 2019; Walker, 2019).
- Romania: ASF present since 2017. Important backyard farming production, related to the significant rural population.
- Germany: large country and relevant pork industry. ASF has been introduced recently in the country (September 2020).

Expected duration

1 year.

Objective 2. Case study: collection and analysis of perceptions, opinions and preferences of different stakeholders on the practicability and acceptability of fencing, trapping, culling with different methods, and other management options to control ASF in WB populations (quantitative approach).

Method

Questionnaires (in the local language) administered to farmers (pig industry), hunters and the general public (including the general population, animal welfare organisations and NGOs) to determine attitudes towards tools used to manage WB and ASF spread, and the level of agreement and potential for consensus both between and within stakeholder groups.

Study design

Survey participants classified into general public and specific stakeholder group: farmers and hunters. Questionnaires should include questions about (a) knowledge on the ASF situation in Europe; (b) perception of the ASF problem; (c) general perception about the need for intervention; (c) opinion about acceptability of a range of interventions, (d) opinion about effectiveness of a range of interventions; (e) preferences for different management interventions under different scenarios; (f) socio-demographic characteristics (gender, age) following the classification by ELSTAT (2011, www.statistics.gr). Selection of participants is detailed below.

An online questionnaire will be designed using available information about WB and ASF management in the scientific literature and EFSA reports. In addition, findings obtained in the qualitative approach will help identify key issues, e.g. to define a complete list of potential management interventions. This list will be redefined in consultation with experts (i.e. researchers, wildlife managers, etc.) on WB and ASF management. The questionnaire should be adapted to each group (i.e. general public, hunters and farmers). A stratified consumer's panel attending to rural–urban areas, age and gender will be used to achieve the best representation of society in each of the countries involved in the study (see an example in Martínez-Jauregui et al., 2020). It is strongly recommended that formal contacts with national representatives of farmers and hunters be established for collaboration in the distribution of the questionnaires (hardcopies and online) among those collectives in addition to enhancing their willingness to participate in the survey (Redpath et al., 2013). The questionnaire, once designed, must be pre-tested to optimise subsequent data collection, reduce bias and improve the reliability of the questions. The analysis of preferences requires the use of discrete choice experiments (e.g. Delibes-Mateos et al., 2014). Analyses will test whether attitudes, perceptions and preferences vary in relation to age, social group (rural/urban), activity (hunting, farming, etc.), education and nationality.

Sample size

Answers from 440 people (including 10% of the sample for a pilot study) will be used in each country to obtain a representative sample of the general public. This sample will attend to rural-urban areas, age and gender (see above). Additionally, 220 questionnaires will be implemented for other stakeholder groups (farmers and hunters), including a subsample of 10% for the pilot study.

Spatial range

Three to four case studies. As this is a pilot study, the aim is not to be completely representative of the diversity of situations across Europe but select a few countries with contrasting realities (preferably to be selected among these recommended countries: a Baltic state, Romania, Poland, Germany).

Expected duration

1–1.5 years.

3.13.4. Deliverables

Objective 1

Deliverable 1: each ethnographic study should lead to a separate in-depth report that will analyse in detail the studied context with its WB management practices. A separate report should compare the socio-ecological variability (perceptions) among pilot countries. The comparative report should also formulate which findings can lead to a meaningful quantitative survey.

Objective 2

Deliverable 2: report on hunters, farmers and general public acceptance and preferences about ecological and management scenarios to control ASF in WB populations, identifying the level of agreement and potential for consensus both between and within stakeholder groups.

3.14. RO10. The wild boar/pig interface: Developing biosecurity awareness and implementation among backyard and outdoor pig farmers

3.14.1. Background

The wild boar/pig interface is the environment close to farming areas, where they both can interact (directly or indirectly, often human-mediated), and presents a risk for the spread of disease, such as ASF. The EU pig meat sector alone accounts for nearly half of total EU meat production [over 150 million pigs reared in 2018 (EPRS and Augère-Granier, 2020)]. The sector is highly diverse, with huge differences in rearing methods and farm sizes across the European countries: from backyard farming (non-commercial) to industrial indoor installations with thousands of animals.

In terms of numbers, while only 3% of the pigs in the EU are kept in backyard farms, there is a large number producing meat for home consumption or the local market (EPRS and Augère-Granier, 2020), and this represents an important risk for the pig industry. Backyard farms present particular challenges in the context of an ASF eradication programme, including uncontrolled movements of pigs and people, poor biosecurity and the identification of holdings (EFSA, 2020b).

In outdoor production, pigs have access to places outside the rearing structure, with contact to the external environment, regardless of the amount of time spent outside (generally speaking, we will use the term backyards to also refer to outdoor).

The characteristics of domestic pig production farms together with other influences (geographical, land uses and habitats conditions, WB populations), determine local specific WB/pig interfaces. At that interface, indirect interactions due to behaviour of stakeholders, such as hunters and farmers (e.g. carcass manipulation or swill feeding) can also contribute to maintaining and spreading infections (Pozio, 2014).

3.14.1.1. Evidences available in Europe and worldwide

Among the strategies to control ASF, reducing the risks of direct and indirect interaction (as well as human-mediated) at the WB-domestic pig interface in Europe is a key (Prodanov-Radulović et al., 2018). Biosecurity in backyard farms, and often in commercial outdoor farms, is usually scarce and the owners lack knowledge about animal disease control and preventive measures (Blome et al., 2010).

Some authorities have developed communication campaigns to promote awareness about ASF, targeting to pig owners and other stakeholders (such as hunters and the general public) as a preventive ASF control strategy (Bellini et al., 2016; Cwynar et al., 2019). These campaigns work to get farmers and other stakeholders involved in ASF management and to become part of the solution, while at the same time, increasing management acceptability and the likelihood of successfully achieving management objectives (Beierle and Konisky, 2001; Ansell and Gash, 2008).

3.14.1.2. Current situation for the particular research objective in the EU

Detailed protocols to assess and implement farm-specific biosecurity to protect against WB (wildlife in general) are lacking in backyards and/or outdoor production systems. Biosecurity plans for protection from WB diseases at farms must be developed applying a standardised protocol that guides assessment of risks for wildlife-livestock interactions *in situ*.

Such protocols must be designed so their application is practical and feasible in different contexts, easily transferable to professionals and adapted to epidemiological systems. After applying this protocol, the implementation of specific plans is proposed to farmers to reduce the risk of interaction and transmission of pathogens at the interface.

On-farm wildlife risk mitigation protocols are scientifically based and standardised technical procedures to (i) gather information, identify and evaluate risks for wildlife–livestock interaction and pathogens transmission, and (ii) develop farm-specific actions to reduce the probability of interaction and transmission of pathogens between wildlife and livestock. This leads to a Farm-specific Action Plan (FsAP), which consists of management measures to reduce interactions at the wildlife-livestock interface and is farm-specific. The subsequent evaluation of such plans in terms of efficacy, cost-effectiveness and acceptance by farmers, are necessary for further development of ASF Risk Mitigation Programs at national and Europe-wide levels.

3.14.1.3. Potential impact of the results obtained for ASF management in the EU

Developing for the first time a systematic protocol for on-farm ASF risk assessment at the WB-backyard pig interface in different scenarios across Europe is needed to:

- o describe the most relevant and specific epidemiological features of the farms, their management and risks, attending to their variability across Europe.
- o standardise the development of FsAP, key to improving general farm management, and specifically localised risks.
- o rank the priority of alternative management options as a function of their expected efficacy and practical value, essential to focus limited resources and efforts on those actions that better reduce risk of interaction at the WB/pig interface and that are welcome by farmers.

All of this will facilitate farmers' understanding of the need to avoid and minimise WB and pig interactions through active management, structures, and human behaviour changes (i.e. fencing, carcass removal, swill feeding) to reduce ASF risk transmission.

3.14.2. Objectives

1) To develop and test an on-farm WB risk mitigation protocol in backyard/outdoor pig farms under different management and epidemiological scenarios across European environments:

- To evaluate the risks of WB-pig interactions and ASF transmission at specific farms.
- To develop an on-farm Wildlife Risk Mitigation Protocol that is flexible and adaptable to the existing range of characteristics of backyards/outdoor pig farms across the continent.
- To test the protocol by generating FsAP at these farms, evaluate their potential implementation in terms of practical feasibility and acceptability by farmers.

2) To develop information technology tools to facilitate the standardised generation of science based FsAP in backyard/outdoor pig farms across Europe.

3.14.3. Methodology

Objective 1: To develop and test an on-farm WB risk mitigation protocol in backyards/outdoor pig farms under different management and epidemiological scenarios across European environments.

Method

By visiting backyard/outdoor pig farms in ASF-affected countries across European environments, to develop a protocol for on-farm specific evaluation of risk and implementation of FsAP, adaptable to local circumstances, including informative campaigns about ASF and the transmission risk at the WB/pig interface.

Study design

On-farm Wildlife Risk Mitigation Protocol. The protocol consists of three steps:

a) Before farm visit: gathering information from veterinary and/or the forestry/wildlife authorities: census, sanitary status, origin of movements, georeferenced information including farm size, perimeter, location, and land uses, including information on neighbouring properties, information on wildlife (WB abundance, density, hunting records) at the farm and/or surrounding areas.
b) Farm visit: to conduct an interview (questionnaire) to gather information on livestock, wildlife, land use, feed and water distribution and management to identify potential sources of risk. Use a printed map to locate plots, land uses, *a priori* risk sites and any other management issue of relevance. To place CTs at four risk points on three farms per study site for one month during the season that risk is perceived as highest.
c) After the interview, to visit each plot and each potential risk point accompanied by the responder. Each potential risk point georeferenced, photographed and its characteristics and signs of use by wildlife described in detail. To score the risk based on available information on farm resource uses by WB and/or epidemiological evidence (e.g. Barasona, 2015; Carrasco-Garcia et al., 2016; Payne et al., 2016; Barasona et al., 2017; Cadenas-Fernández et al., 2020). For this purpose, a risk scoring system needs to be developed and tested for application at each specific risk point. This approach will help in the scoring of risk as objectively as possible, and to design the appropriate specific actions to minimise interaction risk with WB. The final action during the field visit consists of summarising in a concise description of the main risks detected and any observations that would later be helpful to develop the action plan.

For each farm, an FsAP report should be developed, including the general background on ASF status and farm biosafety, listing and ranking the specific risks identified, as well as the mitigation actions proposed. Mitigation actions should be listed as 'Priority actions' (preferred) or 'Alternative actions'. 'Priority actions' refer to those that, with a minimum *a priori* cost have the greatest potential to prevent interaction between WB and pigs. 'Alternative actions' are those that, despite being useful for controlling interactions, are theoretically less efficient than 'Priority actions'. Mitigation actions can also be classified into 'general' and 'specific'. 'General actions' refer to those that involve comprehensive management of the farm, or at least affect the management of resources or pigs; 'Specific actions' refer to those that focus on controlling the interaction at a single point (e.g. a feeder or waterer).

Within 2 months after the farm visit, the FsAP report should be delivered to the farmer, and permanent contact with farmers (telephone and e-mail) should be established to report any incidents, ask any pending questions, and provide an opportunity to the farmers to convey their concerns. Six months after the report is delivered, the farmers will be asked which of the proposed actions have been implemented, which difficulties were encountered and the estimated costs of the implementation.

Alternative or new actions adopted by the farmers should be reported, together with their motivations for those actions. The interviewers will visit 20% of the farms again to verify the implementation of actions, including changes in habits (how frequently an action has been performed). Farmers should be asked about their general perceptions on the FsAP (effectiveness, practicability and acceptability; Ciaravino et al., 2020).

To elaborate informative/dissemination material, including the protocol, which can be used at European and/or national scales for campaigns through different communication channels to raise awareness about ASF control and biosecurity at the WB/pig interface.

Sample size

Minimum 20 farms per type of production (backyards and outdoor). They should be selected randomly (but where WB is present) in collaboration with national veterinary authorities.

Spatial range

Across Europe in four European countries covering the three bioregions (ENETWILD Consortium et al., 2019a), respectively, and at least one country in the Balkans area.

Expected duration

1 year.

Objective 2: To develop information technology tools to facilitate the standardised generation of science based FsAP in backyards/outdoor pig farms across Europe.

Method

To develop an application (for tablet and/or mobile devices) to collect information *in situ* to apply the on-farm Wildlife Risk Mitigation Protocol when visiting the backyard/outdoor pig farms under different ASF and WB management and epidemiological scenarios across European environments. This is complemented with a computer screen app to draft the FsAP. The apps should be flexible to easily adapt to local characteristics of backyards and outdoor farms across Europe, and languages.

Study design

- To format the On-farm Wildlife Risk Mitigation Protocols (protocol 1) as an application (optimally to be used in a tablet in the field) to record information on maps and collect information from the questionnaire conducted during the on-farm visit: information on livestock, wildlife, land use, feed and water distribution and management to identify potential sources of risk. The application must be able to incorporate the pictures of risk points taken *in situ* during the field visit.
- To develop an interface, such as a computer screen app, to draft the FsAP report. This application is connected to the tablet/mobile app. As described above, the FsAP is report for each farm including the general background on ASF and farm biosafety, listing and ranking the specific risks identified, as well as the mitigation actions proposed.

Sample size

The application will be tested on 20 farms.

Spatial range

The application could be translated into national languages across Europe, initially at least in English and in four European countries from NW, NW, SW and SE regions, respectively, two of which are ASF-affected.

Expected duration

1 year.

3.14.4. Deliverables

- Deliverable 1: An on-farm Wildlife Risk Mitigation Protocol based on 40 farms (20 per type of production backyards and outdoor; written report and protocol, including the FsAP and dissemination material per farm) under different ASF management and epidemiological scenarios across European environments.

- Deliverable 2: Information technology tools (applications for tablet/mobile, and computer screen, respectively) to facilitate the standardised generation of science-based FsAP in backyard/outdoor pig farms across Europe.

3.15. RO11. Assess how to improve coordinated national and international decision-taking on ASF prevention and control in wild boar populations

3.15.1. Background

Factors that govern wildlife abundance are not bound by national borders, and neither is their impact on disease spread (Vicente et al., 2019). Management of spatial and temporal drivers of wildlife diseases must be compatible with the management of ecological and socio-economic drivers, including human–wildlife interactions. This is essential to develop sustainable wildlife management from a holistic and integrated point of view (Linnell et al., 2020).

Wildlife management is evolving from population management, based on population estimates and population models, towards impact management, focussing on those impacts (positive and negative) resulting from interactions between and among species, habitats and humans, that matter to stakeholder groups (Decker et al., 2014; Riley et al., 2002).

3.15.1.1. Evidences available in Europe and worldwide

Wildlife management in the international context is often not of ecological and socio-economic relevance and institutional decisions are not always coordinated both vertically (i.e. from local to international levels) and horizontally (i.e. among interest or sectors at each level) to generate collective action (Beierle and Konisky, 2001; Ansell and Gash, 2008; Sandström, 2012).

Wild boar and feral pig populations are widely distributed, and their density is increasing in most areas of their distribution range, which concurs with increasing negative impacts, such as pathogen/vector spread, environmental and agricultural damage, and road accidents. Worldwide, this situation requires an effective, rapid and coordinated national and international response. International approaches and information exchange also favour proactive wildlife management models, instead of reactive (Jacobsen et al., 2016). To improve coordinated national and international decision-taking (Biegus and Bueger, 2017):

i) the international community must develop a common focussed approach.
ii) the approach taken should be inclusive, created in a forum where all relevant stakeholders (e.g. regional, states and international organisation representatives, technical experts, wildlife authorities, game managers, wildlife ecologists, hunters and veterinary professionals) participate and share their agenda, activities and analysis.
iii) from the created forum and its participants, ideas and strategies emerge due to information exchange, and collaborative guidelines and concrete projects should be development and;
iv) finally, an institutional structure and plan to respond to the problem is needed.

3.15.1.2. Current situation for the particular research objective in the EU

The European Commission developed a strategy for the management of ASF in the EU (European Commission, 2015), which includes guidance of management of wild boar populations in the context of ASF control and prevention. It also provides some guidance for the development of national action plans in the context of ASF prevention, control and eradication.

In addition, the handbook developed by the FAO and the OIE suggests approaches for the wild boar population management in areas affected by ASF, biosecurity measures during hunting, data collection and effective communication between veterinary services and hunters (FAO, OIE and EC, 2019).

According to the EU Nature Restoration Plan, key actions must be taken in relation to WB management. An appropriate Pan-European WB management plan will contribute to the EU 2030 nature protection targets (European Commission, 2020). This plan must be intended to serve as a guiding framework on the Pan-European level, and not to replace national or regional plans in existence. National and/or regional WB plans can provide a more detailed description of measures to be taken as well as milestones, to be achieved. The national plans can also address and incorporate the roles of responsible organisations in more detail. A coordinated approach for adaptive WB management does not require uniform regulations (i.e. hunting legislation), since adaptive management is only part of the process of a sustainable management process, which can differ among contexts. However, hunting is an essential tool within a broader wildlife management system, and to revert this situation, hunters need to be trained and motivated to regulate wild boar populations.

3.15.1.3. Potential impact of the results obtained for ASF management in the EU

Improving vertical and horizontal coordination of decision-making at national and European level can improve proactive WB management and benefit to coordinated responses to emergency situations such as ASF outbreaks. A clear distribution of responsibilities of the international and national governmental authorities that work with wildlife management (WB in particular), will allow (i) to engage a broad range of stakeholders with clear responsibilities for the implementation of necessary measures, (ii) refine their tasks in line with agreed responsibilities to operate as efficiently as possible.

3.15.2. Objectives

1) To improve, at international and national level, the coordination of European decision-making among involved institutions and social actors to manage wild boar populations.
2) To provide the basis for a comprehensive and integrated Pan-European WB management plan.

3.15.3. Methodology

Method

Use of questionnaires for detecting heterogeneities in WB management across Europe. This will be complemented by an international discussion during a physical workshop (which can be replaced by small online workshops). The participants, specific topics, format (workshops = working groups) and expected outcomes are discussed below. The analysis of the outcome of the workshop and questionnaire and subsequent work meetings with key stakeholders and European policy makers will inform the drafting of a proposal for a Pan-European wild boar management plan supported by the main national decision-making agents and stakeholders, which will be presented to the EU.

Study design

As for the questionnaire, respondents will represent the administrations and hunting sectors of all European Countries. Participants invited to complete the questionnaires and participate in the workshops will be representative policy makers of the EU national governmental institutions as well as the sectors involved in WB management, all connected in the framework of Europe. All participants, previously allocated to different working groups, will receive detailed information in advance on the different topics that will be analysed and presented at the convention by the organisers, and expectations of their participation. They will be asked to prepare a short presentation (following templates for the working group) to present their wild boar management systems in place and will fill out a questionnaire to record data on their respective WB management system before the workshop. The first results of the questionnaire and a brief report with the main scientific evidence and statistics (objective data) will be provided in advance to participants to have a common evidence-base starting point for discussion. The main expected outcomes are related to:

i) Inter-institutional and intersectorial coordination at the international level about wildlife management
ii) Decision-making by wildlife managers and politicians based on scientific knowledge and interdisciplinary research into all aspects of management
iii) Pan-European wild boar population monitoring systems in place and analysis to determine best approaches
iv) Coordinated management across jurisdictional borders and adequate national and international, mutually compatible legislative frames
v) Education and public awareness programmes
vi) Draft a proposal for a WB Pan-European management plan to be presented to the EU supported by the main national decision-taking agents and stakeholders.

Sample size

All involved institutions, 150 participants involved through online workshops/working groups.

Spatial range

Across Europe.

Expected duration

1 year.

3.15.4. Deliverables

- Deliverable 1: Description of local, national and European differences in the management system of WB.
- Deliverable 2: Outcome of the International discussion on WB management, as guidance to improve, at national and international levels, the coordination of European decision-making among involved institutions and social actors in relation to WB.
- Deliverable 3: To provide a proposal for a comprehensive and integrated Pan-European wild boar management plan

4. Conclusions

From the total of 29 ROs identified either by the WG and the broader experts' networks, 23 ROs met the inclusion criterion for TOR 1 on research priorities. Fourteen of them received an average score of 3.5 or more (the threshold for selection). After merging two ROs and elimination of another two ROs *a posteriori*, due to overlapping or published work during the work on this opinion, 11 Research protocols have been developed. These eleven protocols are:

- RO1. Studies on basic parameters of WB population dynamics throughout Europe: Protocols can be addressed separately, or, preferably, consecutively (first, identification of data gaps, and then, collection of data to fill these gaps).
- RO2. Factors driving the presence of wild boars near to different pig farm types, including outdoor farms and extensive production systems.
- RO3. Implementation of practical methods to estimate WB density.
- RO4. Assess the effect of natural resources and artificial feeding on wild boar population dynamics and management.
- RO5. Role and effectiveness of recreational hunting and professional culling for wild boar population control.
- RO6. Assessment of the effectiveness of wild boar trapping (professional culling tool) methods, including welfare implications.
- RO7. Assess the efficacy of different fencing methods with GPS-collared wild boar, considering the impact on non-target species.
- RO8. Use of trained dogs in ASF-affected areas for carcass detection.
- RO9. Social acceptance of wild boar management measures and their impact on animal welfare (qualitative and quantitative approaches).
- RO10. The WB/pig interface: Developing biosecurity awareness and implementation among backyard and outdoor pig farmers.
- RO11. Assess how to improve coordinated national and international decision-taking on ASF prevention and control in wild boar populations.

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Abbreviations

ASF	African swine fever
ASFV	African swine fever virus
CSF	classical swine fever
CT	camera trapping
CTs	camera traps
DS	distance sampling
ELSTAT	Hellenic Statistical Authority
ENETWILD	European Network of Wildlife
EPRS	European Parliamentary Research Service
FsAP	farm-specific action plan
MS	Member states
PH	professional hunter
REM	random encounter model
REST	random encounter rate and staying time
RH	recreational hunter
RO	research objective
WB	wild boar

Glossary

Overabundance	Overabundance of a given wildlife species occurs when (a) this affects human life or well-being, (b) it affects the fitness of the overabundant species, (c) it reduces the density of species with an economic or esthetic value or (d) it causes dysfunctions in the ecosystem.

Annex A – Questionnaire: Request for Scientific and Technical Assistance on African Swine Fever

Why this questionnaire?

On 27 August 2019, EFSA published a scientific report titled 'Research gap analysis on African swine fever'. The Scientific Report provided a review of the most significant ASF knowledge gaps as perceived by the EU Veterinary Services and other stakeholders involved in pig production and wild boar management. The aim of this scientific report was to identify research gaps which could benefit **short-term ASF risk management** if addressed and which can facilitate evidence-informed decision-making on ASF prevention and spread. The EU is in need to further address some of the major research gaps as identified by EFSA in the Scientific Report, in particular related to the research domains: '**wild boar management**', '**ASFV transmission by arthropods**', '**ASFV survival in the environment and carcasses**', and '**risk factors contributing to ASF seasonality**'. In May 2020, EFSA was mandated by the European Commission to complements its previous Scientific Report providing new scientific input and technical assistance on those crucial topics identified by the stakeholders by identifying additional studies to fill the knowledge gaps, and to propose research protocols for the key ROs.

EFSA has established a working group, which has started to identify possible research objectives for each of those domains in the attached file. We would kindly like to seek your expertise to verify if no research objectives are missing for any of the 4 research domains. If you would have additional suggestions, please could you provide a short tittle for the objective, a short description, a key word and possible references to similar studies LINK TO SURVEY?

The next steps will be to prioritise all research objectives based on several criteria, such as their possible impact on ASF management, the feasibility or practicality to carry out the study, the possibility for a short-time frame study (1 year), the novelty of the study and if the topic is a priority for risk managers. After prioritisation, short study protocols will be developed by experts from the working group and/or EFSA's networks, which will be published in June 2021 possibly identifying future calls for research proposals.

RESEARCH DOMAINS

Please consult the research objectives provided in the document attached. If you think some objectives are missing, kindly complete the table below.

Download

EFSA_-_List_with_possible_research_objectives.pdf

Research objectives pertaining wild boar management in view of ASF control

	Research objective	Short description	Key word	References
1				
2				
3				
4				

Research objectives pertaining ASFV transmission by arthropods

	Research objective	Short description	Key word	References
1				
2				
3				
4				

Research objectives pertaining ASFV survival in the environment and wild boar carcasses

	Research objective	Short description	Key word	References
1				
2				
3				
4				

Research objectives pertaining risk factors contributing to ASF seasonality

	Research objective	Short description	Key word	References
1				
2				
3				
4				

Annex B – Scoring of criteria for prioritisation of research objectives

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
Investigate acceptability of farmers and public to fences	3	Yes, there is some literature on fencing and related issues (Sprem in EJWR, Mysterud's recent review, etc.)					3.0		
		No rationale reported	3.0						
	5	Sound results can be obtained in one year				5.0			
		Easy to perform via surveys		5.0					
		No previous studies					5.0		
		One of the current methods used for control	5.0						
		Results are easily implemented in ASF current control			5.0				
		No rationale reported	5.0	5.0	5.0	5.0			
Investigate acceptability of farmers and public to fences									4.6 (0.8)
Role and effectiveness of recreational hunting and professional culling for wild boar population control.	1	Especially the recreational hunting study needs several years				1.0			
		No rationale reported				1.0			
	3	complex study, in different habitats, involving many stakeholders		3.0					
		Natural populations are difficult to assess as well as hunting effort		3.0					
		One Europe-wide paper not assessing efficacy, plus very few local studies and one					3.0		

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		modelling paper. More field information is needed, from a variety of sites throughout EU							
		some studies exist					3.0		
	5	Hunting is a current practice for ASF			5.0				
		Improved wild boar management strategy			5.0				
		One of the current measure used for ASF control	5.0						
		One year may be enough to see results				5.0			
		There is usually no information about the efficacy in terms of hunting effort					5.0		
		No rationale reported	5.0	5.0	5.0				
Role and efficacy of recreational hunting and professional culling for wild boar population control									3.9 (1.4)
	3	Feasible, but resource intensive/effort intensive		3.0					
		One season my lead to limited results				3.0			
		Some previous information is available					3.0		
		Yes, but improvement is needed					3.0		
		No rationale reported		3.0		3.0	3.0		

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
	5	Despite all efforts and improvements, the perfect method is still not defined. Probably it will be a simplification of current photo-trapping protocols which are now too time-consuming. More research is duly needed, probably in collaboration with ENETWILD	5.0						
		Easy to implement at managing level			5.0				
		Important because of the role of wild boars	5.0						
		Techniques are available		5.0					
		We need data on the population, is required by the old law to design a control plan	5.0						
		No rationale reported			5.0				
Implementation of practical methods to estimate WB density									3.9 (1.0)
Factors driving the presence of wild boars near different pig farms types, including outdoor farms and extensive production systems	1	A holistic approach may need more time				1.0			
	3	Complex study, methods need to be developed		3.0					
		If there is a combination of factors, it will difficult to implement			3.0				
		Locally yes					3.0		

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		One season my lead to limited results				3.0			
		The number of factors could be high		3.0					
		yearly fluctuations				3.0			
		No rationale reported	3.0	3.0			3.0		
	5	Comprehensive studies are missing					5.0		
		Few or no previous studies					5.0		
		It is important to understanding the risk of transmission of ASF from wild boar to pig farms	5.0						
		Known risk factors can be prevented			5.0				
		Reduced transmission	5.0						
		No rationale reported	5.0	5.0	5.0	5.0			
Holistic assessment of the factors that determine the presence of wild boars near to different pig farms types, including outdoor farms and extensive production systems									3.9 (1.2)
Social acceptance of WB management measures and their impact on animal welfare	1	No rationale reported			1.0				
	3	Dealing with different stakeholders may be complex		3.0					
		Dealing with different stakeholders may be difficult			3.0				
		Hunting is just one of the measures for ASF control	3.0						
		In many countries, hunters are important part of ASF	3.0						

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		control and it is important to understand their motivation. However, it might not be easy to change direction.							
		Some related papers are available					3.0		
		There are/were studies but other are needed.					3.0		
		No rationale reported	3.0		3.0		3.0		
	5	One year may be enough to see results				5.0			
		No rationale reported	5.0	5.0	5.0	5.0			
Acceptance of measures for wild boar management by hunters									3.8 (1.2)
Assess how to improve coordinated national and international decision-taking on ASF prevention and control in wild boar populations	1	Seems not realistic in one year				1.0			
	3	Complexity makes difficult to be conducted		3.0					
		Complexity makes difficult to be implemented			3.0				
		No rationale reported		3.0		3.0			
	5	Important for implementation of ASF control strategies considering all stakeholders	5.0						
		No previous information about this topic					5.0		
		There is much space for improvement in inter-agency collaboration, at all levels			5.0				
		No rationale reported	5.0				5.0		

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
Assess how to improve coordinated national and international decision-taking									3.8 (1.3)
Studies on basic aspects of wild boar population dynamics throughout Europe	1	One year seems little time to perform this study				1.0			
		There are previous studies on this topic in different MS					1.0		
	3	Some parameters may be difficult to obtain		3.0					
		Yes – but still there is no comprehensive overview of the drivers. Food availability, reproduction, mortality and their links.					3.0		
	5	Important to understand wild boar dynamics and risk of dispersal and maintenance of ASF	5.0						
		Once parameters are assessed, models can be developed f			5.0				
		Review and modelling	5.0						
		No rationale reported		5.0	5.0	5.0			
Studies on basic aspects of wild boar population dynamics all over Europe									3.8 (1.6)
Assess the efficacy of different fencing methods with GPS-collared wild boar, considering the effect on non-target species	1	Again, prior and posterior situations need to be compared, over more than one year given seasonality in wild boar movements				1.0			
	3	complex and expensive study		3.0					

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		For me it is between moderate and high. We have already seen that fencing can be beneficial and may even implement it if new studies indicate a lesser impact	3.0						
		High for small scale, low for large scale		3.0					
		One season my lead to limited results				3.0			
		resource intensive			3.0				
		see above, could be high if we find the optimal way			3.0				
		Some but there is room for more.					3.0		
		some studies available					3.0		
		study results should be available after 1 year, but long term is more interesting				3.0			
		There are previous some studies, i.e. Dellicour et al. (2020)					3.0		
	5	Effective fences should contribute to halt spread of ASF	5.0						
		It is one of the current ASF management approaches in the EU	5.0						

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		Mostly at small scale, and not too many					5.0		
		Techniques are available at routinely basis		5.0					
		This method has been used already in ASF-affected MS with variable results			5.0				
		No rationale reported		5.0	5.0	5.0			
Assess the efficacy of different fencing methods with GPS-collared wild boar, considering also the effect on non-target species									3.7 (1.2)
The wild boar/pig interface: Developing biosecurity awareness and implementation among backyard pig farmers	1	No rationale reported	1.0		1.0				
	3	No rationale reported		3.0		3.0	3.0		
	5	Analysis of biosecurity is possible in one year				5.0			
		Feasible to implement at farm level			5.0				
		Lack of biosecurity in farms, in particular backyards, including illegal movements are considered to be one of the main drivers of ASF persistence and dispersal	5.0						
		No previous info about this topic					5.0		
		The study is feasible in different ASF-affected MS		5.0					
Developing biosecurity awareness and implementation among backyard pig farmers									3.6 (1.6)
Assessment of the efficacy of wild boar trapping methods including welfare	1	Long term study preferred – would need to account for				1.0			

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
implications and social acceptability		immigration and other time effects							
	3	Easy to put traps but resource intensive			3.0				
		Easy to put traps but resource intensive and effect of wild boar abundance complicated to measure,		3.0					
		Methodology can be part of the current methods for ASF management but with limitations because of complexity of wild boar distribution			3.0				
		Results obtained in one year can be not sufficient				3.0			
		Should be possible to do over 1 year, but better over several years to avoid impact of weather of feed availability				3.0			
		Some parts could be seasonal, and trapping works best when 'trained' (wild boar may need time to accept traps)				3.0			
		Some studies are available					3.0		
		Some studies available on trapping					3.0		
		The impact on ASF management will depend on	3.0						

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		the effectiveness of the trapping methods							
		Trapping is probably only useful in local circumstances, when lethal control is impossible.	3.0						
		Yes – though mostly local and generally without a proper efficacy assessment. i.e. population size prior to and after intervention					3.0		
		Yes, see e.g. information from Germany. However, more data is needed.					3.0		
	5	Decisions will be based on results			5.0				
		Experience from Belgium shows high efficacy. Solving welfare issues and increase acceptance could be key in some regions and in 'hot zones'	5.0						
		Improved wild boar reduction method will reduce transmission ASF	5.0						
		Is a technique that is used currently by MS		5.0					
		Traps are in use and game research centres are looking into this matter anyway.		5.0					
		No rationale reported		5.0	5.0				

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
Assessment of the efficacy of wild boar trapping methods including welfare implications and social acceptability									3.6 (1.1)
Assess the effect of natural resources and artificial feeding on wild boar population dynamics and management	1	Better over many years to include yearly fluctuations feed availability				1.0			
	3	Complex study, many stakeholders, but possible		3.0	3.0				
		Resources are difficult to manage. It would be feasible for artificial ones, less for natural ones.		3.0					
		One season my lead to limited results				3.0			
		Practicality good for artificial food sources. Difficult for natural ones			3.0				
		There are some studies					3.0		
		No rationale reported	3.0	3.0		3.0	3.0		
	5	Allow to understand wild boar population dynamics	5.0						
		comprehensive studies are missing					5.0		
		How much does feeding/ baiting represent in terms of the total food available for wild boar? The answer would help (combined with the info on crops) in managing feeding and baiting and perhaps also in mapping wild boar habitat suitability	5.0						

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		Hunting management will have impact on population control	5.0						
		There are some, but much more information is needed.					5.0		
		No rationale reported			5.0				
Effect of food availability in natural areas in relation to baiting and feeding in wild boar population dynamics									3.6 (1.1)
Establishment of a freedom-from-ASF-disease status of a wild boar population	1	Low if field data needed, better prospects if models are used,				1.0			
		One season my lead to limited results				1.0			
	3	. . .if only models, novelty is limited					3.0		
		Difficult to put in place due to environmental persistence		3.0					
		Difficult to put in place due to environmental persistence of the virus.			3.0				
		Some studies were done. See Schulz et al. (2020)					3.0		
		No rationale reported		3.0		3.0			
	5	Important to understand virus persistence	5.0						
		No previous studies demonstrating ASF freedom					5.0		
		No rationale reported	5.0		5.0				

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
Establishment of a freedom-from-ASF-disease status of a wild boar population									3.5 (1.4)
Use of trained dogs in ASF-affected areas For carcass detection	1	Difficult to assess performance in practice, under realistic conditions		1.0					
		Using trained dogs may be limited to some type of hunters and some areas			1.0				
	3	Dog are being used, but results not published					3.0		
		Effort of hunting is needed to assess the effectiveness		3.0					
		Hunting and carcass removal are just part of the ASF control measures	3.0						
		Not sure trained dogs are needed. Controversially discussed.	3.0						
		One season my lead to limited results to show control of ASF				3.0			
		Takes time to train dogs, resource intensive		3.0	3.0	3.0			
		There is something in grey literature, but some objective studies are still needed.					3.0		
		No rationale reported	3.0			3.0			
	5	Dogs can be trained to find carcasses	5.0						
		If trained dogs are found to be highly beneficial, they will			5.0				

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		be used more frequently. However, probably most dogs would find a carcass.							
		No (not in scientific literature)					5.0		
		No previous info about this topic					5.0		
		No rationale reported		5.0	5.0	5.0			
Use of trained dogs in ASF-affected areas to manage wild boar populations									3.5 (1.2)
Evaluation of the measures of passive surveillance and carcass removal on the spread of the disease	1	Carcasses are difficult to be found and costly to remove			1.0				
		One season my lead to limited results to show control of ASF				1.0			
	3	Carcasses are difficult to be found		3.0					
		O'Neill et al. (2020) Sci Rep					3.0		
		There are previous studies					3.0		
		There is already evidence, but probably more could be done					3.0		
		We know we need passive surveillance and should remove carcasses. What can we do about reporting and detection of carcasses...			3.0				
		No rationale reported		3.0	3.0	3.0	3.0		
	5	These are only part of the measures to control ASF but showed to be effective in some MS	5.0						

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		High if modelling		5.0					
		High, but is this still an open question?	5.0						
		If modelling is implemented				5.0			
		No rationale reported	5.0		5.0				
Evaluation of the measures of passive surveillance and carcass removal on the spread of the disease									3.5 (1.2)
Identification of wild boar population dynamics drivers for effective population managing	1	Complex studies giving limited data after one season				1.0			
		Should be over several years to include yearly fluctuations				1.0			
		Some drivers cannot be changed (e.g. climate)			1.0				
	3	If drivers are known, some could be managed (e.g. feeding)	3.0						
		Important more in general	3.0						
		Not sure one year will be enough				3.0			
		Relatively easy to implement for some aspects, culling/ hunting, difficult for other, food availability			3.0				
		Some facts are already known, and it might be difficult to combine it to a full picture.		3.0					
		Some of the drivers (i.e. food availability) are difficult to be managed		3.0					
		There are some studies					3.0		

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		Yes – but still there is no comprehensive overview of the drivers. Food availability, reproduction, mortality, and their links.					3.0		
		Yes, there are, but so far, the full picture is not clear.					3.0		
		No rationale reported			3.0				
	5	Comprehensive studies are missing					5.0		
		Experimental designs needed	5.0						
		Important to understand ASF dynamics	5.0						
		Management of wild boar is needed in general and would be put to practice (long-term)			5.0				
		Only review and modelling can be done in one year				5.0			
		Very complex study		5.0					
		No rationale reported		5.0					
Identification of wild boar population dynamics drivers for effective population managing									3.4 (1.4)
Assess how to improve data collection to monitor wild boar	3	Diversity of hunting practices		3.0					
		Hunting is just a part a of ASF control	3.0						
		Implementation can be challenging due to complexity of hunting organisations, aims, interest, etc.			3.0				
		Local/regional. . .					3.0		

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		One season my lead to limited results				3.0			
		This is already a goal of ENETWILD, isn't it?	3.0						
		No rationale reported		3.0		3.0			
	5	Most of data on hunting is not related to the effort					5.0		
		No rationale reported			5.0				
Assess how to improve data collection to monitor wild boar									3.4 (0.8)
Insight in persistence of African swine fever in wild boar populations	1	Biological factors that cannot be easily managed			1.0				
		Field studies very complex, but experimental studies should be straightforward		1.0					
		Persistence studies need many years				1.0			
		No rationale reported			1.0				
	3	Several experimental infections to test virulence of ASFV, but few on immunity					3.0		
		It could be difficult to deduce actions			3.0				
		One season my lead to limited results				3.0			
		Parameters are then difficult to measure in wild boar populations and would be difficult to be implemented in ASF management			3.0				
						3.0			

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		Some effects are long-term, to better understand disease dynamics, things like maternal immunity etc. need to be investigated. These studies need more time.							
		There are some previous studies					3.0		
		There are/were studies but other are needed.					3.0		
		Yes – O'Neill et al. (2020) SciRep – though only modelling					3.0		
		No rationale reported		3.0					
	5	Freedom of disease surveillance will depend on this knowledge	5.0						
		If models are used for this target				5.0			
		Important to know the role of WB populations in dispersal and persistence of ASF	5.0						
		Knowledge would impact strategy design and the anticipated 'fate' of ongoing epidemics	5.0						
		Techniques are available at routinely basis		5.0					
		No rationale reported	5.0	5.0					

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
Insight in persistence of African swine fever in wild boar populations									3.3 (1.5)
Influence of crop management on wild boar presence and distribution	1	Agriculture practices may be conditioned by other factors and not ASF management in particular			1.0				
		Change of cropping because of ASF and wild boar seems utopic			1.0				
		different stakeholders		1.0					
		Difficult to show relation crop/wild boar in one year				1.0			
		Long term study_				1.0			
		Studies of this kind require medium-long term, in order to assess the situation before and after intervention				1.0			
	3	Could probably be done with GPS collars etc. Yet, healthy wild boar will act different from sick ones		3.0					
		Feasible, but work intensive (and resource intensive)		3.0					
		It is a logic option but the impact for me is not completely clear	3.0						
		Not easy as season will influence the outcome.				3.0			
		Spanish study exists					3.0		
		Wild boar populations per se are difficult to follow, when		3.0					

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		related to crops would be also difficult since there are known and unknown drivers that may modify presence and abundance							
		Wild boar reduction should help in ASF control	3.0						
	5	Crops are a source of food that keeps and attract wild boars to farms	5.0						
		Crops are the main human-origin food source benefiting wild boar. Assessing means of reducing crop availability should be priority – yet it remains very challenging	5.0						
		If the results indicate that crop management will keep e.g. wild boar at a certain terrain, this could feed into strategy design			5.0				
		No previous studies					5.0		
		Not at larger scales					5.0		
		Not really, to my knowledge					5.0		
		No rationale reported			5.0				
Influence of crop management on wild boar presence and distribution									3.1 (1.6)
Methods to avoid contact between carcasses and wild boar	1	Difficult to find carcasses			1.0				
		I know of studies but so far, there is room for more and the issue was not solved.					1.0		

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		If we put things to scare off wild boar, we could also remove the carcass. Could be of temporal importance.	1.0						
		Searching carcasses and avoiding contact with wild boars seems very difficult. Only a 10% of carcases is estimated to be found.			1.0				
		The study is feasible in controlled conditions		1.0					
		No rationale reported			1.0				
	3	If ways are identified, short term implementation should be feasible			3.0				
		May depend on habitat and season		3.0					
		Probst et al. (2017)					3.0		
		The disturbance of carcasses can be assessed in one session				3.0			
		There are some studies about scavengers approaching carcasses and wild boars					3.0		
		No rationale reported	3.0			3.0	3.0		
	5	Carcasses are considered to improve the persistence in the environment. Removing carcasses proved to be effective in the Czech	5.0						

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		Republic. Avoiding contact may also lead to success							
		Reduced transmission	5.0						
		Should be possible to investigate with camera trapping		5.0					
		No rationale reported		5.0		5.0			
Methods to avoid contact between carcasses and wild boar									3.0 (1.5)
Assess sustainable (i.e. long term effective) strategies for WB population control in different scenarios (hunting areas, protected areas, urban, tec.) incorporating the socio-economic reality, evaluating also future scenarios (¯ hunters).	1	Complexity of scenarios and socioeconomics components makes difficult to be implemented			1.0				
		Complexity of scenarios and socioeconomics components makes low feasibility		1.0					
		One season my lead to limited results to show control of wild boar population				1.0			
	3	More focus in long term than in short term outbreaks	3.0						
		There are studies in some of the socio-economic aspects, impact of ASF on pig industry, etc.					3.0		
		No rationale reported		3.0		3.0	3.0		
	5	No rationale reported	5.0		5.0				

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
Assess sustainable (i.e. long term effective) strategies for WB population control in different scenarios (hunting areas, protected areas, urban, tec.) incorporating the socio-economic reality, evaluating also future scenarios (¯ hunters)									2.8 (1.4)
Experimental research about presence of low-virulence strains of ASFV in endemic areas, the possibility of carrier stage occurrence and possible role of these carrier animals.	1	Carriers have not been identified until now		1.0					
		Even if carriers are identified, implementation will be difficult			1.0				
		One season my lead to limited results				1.0			
		Relative role in epidemic low	1.0						
		Role of potential carriers is unclear	1.0						
		See EFSA opinion 2015 for review about carriers.					1.0		
	3	Evolution could take longer, experimental assessment of existing strains is possible, but some aspects require long-term studies (carriers etc.)				3.0			
		Experimental studies are easier, but field studies more complex		3.0					
		Low virulent strains: what are the practical implications? Serological testing of all animals and culling ELISA positive animals is already done at the tail of the epidemic?			3.0				

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		Low-virulent strains were always discussed as detrimental. However, our recent studies indicated that those strains die out. They lead to more recovered animals that are, at least for a medium term, protected from re-challenge. No indications exist that these strains led to carrier animals that shed virus.	3.0						
		What to do about virulence. . ., however, data will feed into models and thus risk assessment and strategy design.			3.0				
		Yes: experimental, few field studies					3.0		
		No rationale reported		3.0	3.0	3.0	3.0		
	5	Definitively. . . e.g. in my lab :-)					5.0		
		High for experimental studies with existing strains		5.0					
		Possible short-term experimental infections				5.0			
		No rationale reported	5.0						
Experimental research about presence of low-virulence strains of ASFV in endemic areas, the possibility of carrier stage occurrence and possible role of these carrier animals									2.8 (1.4)
Immunocontraceptives	1	Administration of contraceptive represents a			1.0				

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		limitation and also its regulation at EU level							
		We know there is no feasible drug at present. For me, it is also related to population control in peace time rather than animal disease control	1.0						
		No rationale reported		1.0	1.0	1.0			
	3	Consistent results can be obtained in one year, but for the effect on ASF long term may be needed				3.0			
		More is needed					3.0		
		Some references are available					3.0		
		The study itself could be done		3.0					
		This a part of the ASF control measures	3.0						
		No rationale reported				3.0	3.0		
	5	Limited impact unless oral formulations are available and safe... which is rather unlikely	5.0						
		Possible to be conducted in controlled conditions, even simplified ones.		5.0					
Immunocontraceptives									2.6 (1.3)
Current and projected wild boar distributions	1	Already being addressed by ENETWILD?	1.0				1.0		

Research objective	Score	Rational	1. Impact on ASF management	2. Feasibility or practicality to carry out the study	3. Potential implementation of study results in practice	4. Short time - frame study possible (1 year)	5. Are there already other studies carried out on the same topic?	6. Priority for risk managers	Average (SD)
		ENETWILD working on this					1.0		
		One season my lead to limited results				1.0			
		No rationale reported		1.0		1.0			
	3	It is a dynamic system, difficult to predict as the drivers are diverse and variable		3.0					
		Some previous information is available					3.0		
		No rationale reported	3.0	3.0	3.0				
	5	Easy to implement in current control measures			5.0				
		Important for preparedness of control strategies	5.0						
		No rationale reported			5.0				
Current and projected wild boar distributions									2.5 (1.5)

Annex C – Studies on basic aspects of wild boar population dynamics all over Europe

Table C.1: Key review papers and reports describing the basic parameters of wild boar population dynamics in Europe[(a)]

Type of parameter	Parameter	Spatial context	Observations	Refences
Population characteristic	Density (WB/km^2)	West and Central Europe	Ranged from 1.2 to 90.9[(b)] based mostly on not reliable data.	Acevedo et al. (2007), Ruiz-Fons et al. (2008)
	(Hunting) Annual growth rate	Europe	Growth rate varied from 0.9 to 1.46, based on hunting bag statistics	Massei et al. (2015)
	(Hunting) Growth rate	West Europe (Spain)	Growth rate varied from 2.1 to 40.3, based on hunting bag statistics	Quirós-Fernández et al., 2017
	Growth rate	West and Central Europe, and Asia	Based on projection matrix models, growth rate varied from 0.85 to 1.63.	Bieber and Ruf (2005)
Mortality	By harvest	Central Europe	Based on hunted tracked WB, average mortality rate was 0.53.	Keuling et al. (2013)
	By harvest and disease	West Europe (Spain)	Average mortality rate was 0.53 by harvest; and 0.30 by disease (tuberculosis).	Barasona et al. (2016)
Reproductive	Litter size	Europe	Mean ranged from 3.58 to 6.5.	Bieber and Ruf (2005)
	Litter size	West and Central Europe	Mean ranged from 2.2 to 4.	Rosell et al. (2001)
	Litter size	Europe	Mean ranged from 3.6 to 7.6.	Fonseca et al. (2011)
	Litter size	West and Central Europe	Mean ranged from 3.1 to 6.9.	Bywater et al. (2010)
Spatial behaviour	-	Global	Research tendencies and gaps, no values provided.	Morelle et al. (2014), Morelle and Lejeune (2015)

(a): Extensive literature is also available for feral pig population dynamics, especially in the USA, but of very low application to WB populations in the EU.
(b): This value is reached under artificial conditions, such as fenced game estates with artificial feeding.

Table C.2: Main drivers identified that could influence significantly on Wild Boar (WB) population dynamics

Type of driver	Driver	Observations	Reference
Interspecific interactions	Predation	Lack of top-down control can favour population growth.	Bassi et al. (2020), Jędrzejewski et al. (1992), Segura et al. (2014)
	Diseases & parasites	Effects on survival, reproductive or mortality rates.	Barasona et al. (2016), Ruiz-Fons et al. (2008)
Landscape	Land use change Urban expansion Rural abandonment	Easier food access or the increment of available and favourable habitat could contribute on WB population growth.	Acevedo et al. (2011), Hearn et al. (2014), Kodera et al. (2010)
Climatic	Global warming	Favourable climatic conditions increasing winter survival and food availability throughout the year.	Bieber and Ruf (2005), Melis et al. (2006), Vetter et al. (2020, 2015)
	Drought episodes	Effect on reproductive performance.	Fernández-Llario and Carranza (2000)
Food availability	Productivity	Related with climatic conditions.	Barbosa et al. (2020), Frauendorf et al. (2016)
	Supplementary feeding	Associated with higher recruitment rate and litter size.	Massei et al. (2015)
Management	Hunting	Hunting induces mortality and affects WB dynamic. A decrease in the number of hunters, difficult population management.	Cromsigt et al. (2013), Holland et al. (2009), Merli et al. (2017)
	Conservation or agroforestry policy	Differential effect on population dynamic among different applied policies.	Vicente et al. (2005)

Table C.3: Parameters describing the basic aspects of WB population dynamics relevant to understanding disease dynamics and improve science based ASF management

Population parameters	Trait	Sex by age class	Temporal	Spatial resolution	Units	Why is important?	Reference
Population characteristics	Local density		Optimally pre-harvest season (for standardisation)	Management or ecological unit	ind/km^2 or social group/km^2	– Disease transmission is a density-dependent process. Population and individual traits are density dependent. Management is based on numbers (abundance indexes are not sufficient or comparable) – It could further elucidate complex species-habitat-management relationships in spatial distribution models	Kramer-Schadt et al. (2009)
	Absolute abundance				No individuals		Yu et al. (2020)
	Carrying capacity		Lowest over the year	Ecological unit	Maximum population size or density (*K*)	– Variable due to habitat perturbations and environmental factors (e.g. resource availability and climate). Theoretically, maximum productivity (i.e. population growth rate) is achieved when the population is approx. 50% of the K (basic logistic growth models). Useful for modelling scenarios of potential population growth and consequences for disease spread, maintenance and control.	Groot Bruinderink et al. (1994)
	Sex ratio	Juvenile (< 1 year) Yearling (1–2 years) Adult (> 2 year) Male	Optimally pre-harvest season (for standardisation)	Management or ecological unit	ff:mm	– Essential to rebuild population structure and model population dynamics	Hema et al. (2020), Mortensen et al. (2016)

Population parameters	Trait	Sex by age class	Temporal	Spatial resolution	Units	Why is important?	Reference
	Group size		Average annual and by month or season		Mean number of individuals, assumed 1	– Influence on the spatial behaviour and interactions among social units (groups) and modulate the spread of infectious diseases – Each sex by age class has distinct properties in terms of their demographic and infection dynamics – Key parameters to define population control strategy – These parameters are among those presenting larger variation over geographical distribution and management	Loehle. (1995), Pepin et al. (2020), Podgórski et al. (2018)
		Maternal groups			Mean number of individuals		
	Age structure	By sex	Pre-harvest season		%		Hoy et al. (2020)
	Population growth rate		Yearly		% or increase rate (r)		Fonseca et al. (2011)
	Recruitment rate				Coefficient of young/adult		DeCesare et al. (2012)
Population characteristics: mortality	Natural: predation/ disease	Sex by age. Especially on piglets (< 3 months old)	Yearly		% mortality (1/survival)		Bassi et al. (2020), Keuling et al. (2013), Lange et al. (2012), Merli et al. (2017), Tanner et al. (2019b)
	By harvest						
	Other: e.g. road kills						
Reproduction (productivity)	Litter size	By age	Yearly		Number of offspring born by female age class		Fernández-Llario and Mateos-Quesada (1998), Frauendorf et al. (2016)
	Pregnant females		Yearly and monthly		% of females becoming pregnant by age class		Fernández-Llario and Mateos-Quesada (2005), Lombardini et al. (2014)
Spatial behaviour	Proportion of dispersants	Sex by age	Yearly		%	– Related with species geographical and disease dispersion. – Spatial behaviour determines interactions (within and among groups)	Casas-Díaz et al. (2013), Truvé and Lemel (2003), Truvé et al. (2004)
	Dispersal period	Sex by age			Month/season		
	Dispersal distance				Km		

Population parameters	Trait	Sex by age class	Temporal	Spatial resolution	Units	Why is important?	Reference
						– Spatial behaviour is relevant to implement effective management strategies. – Influenced by land uses and human activities among other factors, including population control and response to ASF	
	Home range (50 & 95%K)	Sex by age (males, maternal groups)	Seasonal		km^2		Bisi et al. (2018), Keuling et al. (2008)