SCIENTIFIC OPINION

EFSA Journal

ADOPTED: 23 June 2015 PUBLISHED: 14 July 2015

doi:10.2903/j.efsa.2015.4163

African swine fever

EFSA Panel on Animal Health and Welfare (AHAW)

Abstract

Since entering the eastern EU at the start of 2014, African swine fever (ASF) has spread locally in the wild boar population, independently of outbreaks in domestic pigs. No correlation between the density of the wild boar population and the case notification in an area has been observed. The source of virus introduction appeared to be the low biosecurity level in backyard farms; yet, direct contact between pigs and wild boar has not been reported. Potential wild boar management strategies aimed at controlling ASF were evaluated. First, the published literature was searched for evidence of changes in wild boar demography after implementing different management strategies. A reduction in a wild boar population of more than 60 % as a result of conventional hunting has not been documented in Europe. Secondly, during a consultation meeting, 30 experts identified different wild boar management tools to indirectly combat ASF spread. In the third step, an epidemiological simulation model was developed, to compare the effects of implementing individual or combinations of management tools to control ASF. The model demonstrated that measures such as attempts to reduce the wild boar populations more than 70 % would, in theory, be effective in controlling ASF, but in practice would impossible to be achieved in one hunting season. On the other hand, conventional management strategies, such as implementing a feeding ban or targeted hunting of females, can effectively prevent the spread of ASF in the control area only after multiple years of application. The model predicted that a combination of different tools, such as the exclusion of contact to carcasses and the intensification of conventional hunting, reducing reproduction in the following year by 30-40%, would be effective to stop the spread of ASF in wild boar.

Keywords: African swine fever, wild boar, epidemiology, management strategies

Requestor: European Commission

Question number: EFSA-Q-2014-00897

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Competing interests: In line with EFSA's policy on declarations of interest, Panel member Klaus Depner did not participate in the development and adoption of this scientific output.

Acknowledgements: The Panel wishes to thank the members of the Working Group on African swine fever—Luisa Arias Maria, Sandra Blome, Ana De La Torre, Vittorio Guberti, Claire Guinat, Sergei Khomenko, Frank Koenen, Iwona Markowska-Daniel, Giovanna Massei, András Nahlik, Mary Louise Penrith, Tomasz Podgorski, Carola Sauter-Louis, Hans-Hermann Thulke and José Manuel Vizcaino—for the preparatory work on this scientific output and hearing experts Olgirda Belova, Sandra Cellina, Linda Dombrovska, Carlos Fonseca, Dragan Gacic, Ulf Hohmann, Jiri Kamler, Maarjia Kristian, Karolin Lillemae, Nickolay Markov, Marius Masiulis, Anton Mezhnev, Andrea Monaco, Edvins Olsevskis, Janis Ozolins, Männil Peep, Radim Plhal, Boštjan Pokorny, Carme Rosell, Eugenijus Tijusas and EFSA staff members Andrea Baù, Alessandro Broglia, Sofie Dhollander, Andrey Gogin, Sanel Ramović and Matthew Watts for the support provided to this scientific output.

Suggested citation: EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare), 2015. Scientific opinion on African swine fever. EFSA Journal 2015;13(7):4163, 92 pp. doi:10.2903/j.efsa.2015.4163

ISSN: 1831–4732

The EFSA Journal is a publication of the European Food Safety Authority, an agency of the European Union.

Summary

On 1 December 2014, the European Commission requested scientific advice from the European Food Safety Authority (EFSA) on African swine fever (ASF).

In particular, EFSA was asked to assess the epidemiological characteristics of the outbreaks of ASF in Estonia, Latvia, Lithuania and Poland and to clarify the evolution of the epidemic since its first introduction, at the beginning of 2014, in the eastern EU countries (Term of Reference 1). To this end, a short summary of the chronology of ASF outbreaks in domestic pigs and wild boar up to June 2015 was provided. The chronology of ASF outbreaks provided no evidence that the virus persisted in the backyard farms of EU countries.

From the introduction of ASF virus (ASFV) in the affected EU MSs in January 2014 until September, there were 2014 notifications in domestic pigs and wild boar. In several cases, notifications were located too far from each other to be explained by direct contact between wild boar. This indicated human involvement in spread of ASFV during the period of ASF outbreaks in domestic pig populations. From September 2014 until March 2015, the expansion of ASF remained local, and was mediated by wild boar. This was confirmed by the spatio-temporal analysis.

The epidemiological picture of ASF in the EU indicates that ASF spreads locally in the wild boar population, independent of outbreaks in domestic pigs. No correlation was observed between density of the wild boar and the case notifications in an area. Observations related to the wild boar–domestic pig interface indicated that all ASF notifications in domestic pig holdings were situated in areas with suitable wild boar habitat. However, there were no reports of direct contacts between wild boar and domestic pigs which could have introduced ASF directly in the domestic pig holdings. The low biosecurity level of backyard farms, including practices such as feeding of kitchen waste or contaminated grass, was therefore considered to be the more likely means of introduction in these farms.

Analysis of ASF detections demonstrated clearly that passive surveillance is more effective than active surveillance in detecting ASFV-infected wild boar or domestic pigs. All primary ASF outbreaks in pig holdings or cases in wild boar were found by passive surveillance. The virus prevalence appears to be higher in the summer months than during the rest of the year, based on the limited data available.

Serology data were inconclusive with regards to any temporal trend in seroprevalence because of the different sampling strategies used and the accumulation in the population of seropositive animals that survive the ASFV infection.

Finally, the factors which could contribute to the spread of ASFV between sub-populations of a wild boar meta-population were assessed by 30 experts in wild boar ecology and management and were ranked according to their importance. Most experts considered there was a high likelihood that contact of susceptible wild boar with infectious material (e.g. an infected carcass or the blood or excreta of an infected animal) in the environment will lead to further spread of ASFV between sub-populations of a wild boar meta-population. Additionally, most experts considered there was a moderate to high likelihood that direct contact between wild boar will lead to further spread of ASFV between sub-populations of a wild boar meta-population, especially in places where animals gather, such as feeding places. The experts judged there was a moderate to high likelihood that susceptible wild boar will come in contact with ASFV-contaminated material dispersed by humans (such as dumped swill or offal spread by hunters in the environment) and that this will lead to further spread of ASFV between sub-populations of a wild boar meta-population. When comparing the effect of different hunting strategies, the experts judged that very intense and frequent drive hunts during depopulation campaigns can lead to dispersal of wild boar and possible spread of ASFV between sub-populations of a wild boar meta-population. However, individual contact hunting was not considered to play a role in the further spread of ASFV between sub-populations.

The second Term of Reference requested EFSA to assess the possible risk of spread by carriers of the ASFV genotype II strain currently affecting the wild boar populations in eastern Europe. By looking at experimental infections with the ASFV genotype II strain, it was concluded that this ASF strain is highly virulent and induces an acute form of ASF with high lethality in both wild and domestic pigs. One pig experimentally infected by inoculation survived up to 61 days, and DNA of genotype II ASFV

was identified in tissues for 61 days post infection. To date there are no scientific data demonstrating shedding by carriers of ASFV genotype II in the eastern European Union. Even if there are no carriers, there are several mechanisms that can lead to long-term circulation of ASFV in pig or wild boar populations. The most important factors are human induced, such as illegal movements of infected pork meat , low biosecurity levels in pig holdings and aggregation of wild boar around feeding places. Moreover, carcasses of infected wild boar in the environment may remain infectious for several weeks (e.g. in winter months).

The third Term of Reference requested EFSA to describe the trends in wild boar population dynamics in the EU and its eastern neighbouring territories. An increase in the number of harvested wild boar in most European countries has been reported in the literature, and is likely to reflect increased numbers of wild boar. Hunting has been suggested to be the main cause of mortality in wild boar, but a decrease in the number of hunters in most European countries was observed. Given the reported wild boar population trends over the last 30 years, it was concluded that there is no indication that population growth will slow down in the next few years. Additionally, the third Term of Reference requested EFSA to provide an updated description of the distribution of ASF competent vectors and their possible role in the ASF epidemiology, especially in Russia and the Baltic States. Based on a systematic literature review, it was concluded that there is no published report indicating the occurrence of *Ornithodoros* spp. in the four affected Member States. Ticks of the *O. erraticus* complex and of the species *O. tholozani* have been reported only in some countries around the Mediterranean Basin (Portugal, Spain and Italy and Turkey) and the Black Sea (Moldova, Romania, Georgia), and in Armenia and Azerbaijan. These ticks, however, were not considered to play an active role in the geographical spread of the virus, but they could play an important role in maintaining the local foci of the ASFV.

The fourth Term of Reference requested EFSA to assess different wild boar management options to control ASF, taking into consideration its ecology, in the Baltic States and Poland. A three-step approach was used to address this ToR.

First, the published literature was searched for quantitative information on possible changes in wild boar demography after implementing particular management strategies, such as conventional hunting, trapping and a feeding ban. A review of the scientific literature on hunting and trapping of wild boar revealed that a reduction of a wild boar population by more than 60 % has not been documented in Europe. Frequent and intense drive hunts can reduce the population by over 60 % but lead to adaptive behaviour of the hunted wild boar, compensatory growth of the population, influx of wild boar from adjacent areas and extensive movements of wild boar outside the focal area. It was concluded that, to reduce wild boar populations, feeding should be prohibited and hunting rates should be increased for several consecutive years, especially of females, since all age classes of females are highly reproductive.

Secondly, an expert consultation (made up of ecologists and veterinarians involved in the management of wild boar populations) was organised to obtain unpublished information, e.g. to discuss the suitability, effectiveness and the practical aspects of implementing the available wild boar management options. It was concluded that there is no single feasible wild boar management strategy that is capable of controlling the spread of ASF. The experts judged that there is currently not enough evidence to state the maximum volume of feed which could differentiate baiting for hunting purposes from feeding. The required baiting quantities may differ greatly between different habitats and hunting practices and depending on the type of feed provided. However, the experts agreed that baiting should not result in increased survival and reproduction in populations and should be limited to its principal aim: hunting.

Finally, the published and unpublished information, together with the data described, were used to parameterise the wild boar ecology and ASFV components of an epidemiological simulation model, with the aim of evaluating the effect of the different management options on the behaviour of ASF in the wild boar populations.

Proposed strategies were of two types: rapid control measures, such as preventing the occurrence of infectious carcasses in the environment by 'depopulation', i.e. reducing the boar population by more than 70 % (as opposed to conventional hunting) or fast removal or infectious carcasses; and long-term preventative measures to achieve a sustainable reduction in the population size (i.e. feeding ban and targeted hunting of reproductive females).

In general, any wild boar management strategy aiming at controlling ASF in wild boar populations has to be applied both inside the area where ASF has been detected and in a zone surrounding this area. The critical extent of the surrounding zone depends on which strategy will be applied.

Short-term depopulation is capable of controlling ASF, since the future production of infected carcasses will be limited. The same control success can be achieved by the immediate removal of carcasses from the control area.

However, the effort required to achieve short-term depopulation would necessitate drastic measures that are neither acceptable nor conventional wildlife management practices (e.g. poisoning or shooting with night vision). On the other hand, systematic prevention of wild boar contact with infected carcasses would require a greater effort over a longer time period than massive depopulation.

The strategies based on conventional wild boar management options (i.e. a feeding ban or targeted hunting) would need to be implemented over a very long period of time to be efficient. These measures reduce population numbers by influencing reproduction, which naturally requires multiple generations to become effective. During this time spread of the infection in wild boar cannot be avoided. Thus, sufficiently large zones surrounding the affected area and time horizons should be foreseen for these control strategies (e.g. zones of more than 200 km surrounding the affected area and several consecutive years in the model simulations).

A ban on feeding animals to reduce the reproductive performance of a population may be deemed effective only in regions where the habitat is unsuitable for wild boar and where feeding caused artificial population establishment. In other regions naturally suitable for wild boar, although a feeding ban would reduce population numbers, the achievable reduction will not affect the spread of ASF.

In areas with naturally established wild boar populations, hunting that targets adult and sub-adult females to reduce population size is the only long-term option. This strategy requires several generation times to achieve population regulation, and therefore needs to be extended to large zones surrounding the affected area to compensate for the forward spread of the infection before it is slowed or stopped. In addition, it is uncertain if wild boar will alter its reproductive ecology in response to this long-term measure.

Summarising the observations from the modelling study, ASF control in wild boar may require strategic measures applied over areas of several hundreds of square kilometres, for at least two to five years. In theory, the following combination of alternative strategies would be effective in halting the spread of ASF in wild boar: immediate exclusion of contact with carcasses within a 50 km radius of the affected area of more than 50 km combined with intensification of conventional hunting which would reduce reproduction in the following year by 30–40 %. The feasibility of these measures will depend on the characteristics of the area where it is applied.

Table of contents

1. Introduction

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

1.1.1. Background

ASF is a devastating infectious disease of domestic pigs and of the wild boar, usually fatal. No vaccine exists to combat this virus. It does not affect humans nor does it affect any animal species other than members of the *Suidae* family.

From the beginning of 2014 up to 31/10/2014 ASF has spread in Estonia, Latvia, Lithuania and Poland, mainly in the wild boar, causing concerns. The information available suggests that the disease originated from Russia via Belarus from where there have been several introductions of the virus with the creation of a number of clusters of disease in those Member States.

There is knowledge, legislation, technical and financial tools in the EU to properly face ASF. EU legislation primarily targets domestic pig and addresses, when needed, lays down specific aspects related to wild boar. The main pieces of the EU legislation relevant for ASF are:

1. Council Directive 2002/60/EC[1] of 27 June 2002 laying down specific provisions for the control of African swine fever and amending Directive 92/119/EEC as regards Teschen disease and African swine fever: it mainly covers prevention and control measures to be applied where ASF is suspected or confirmed either in holdings or in wild boar to control and eradicate the disease.

2. Commission Implementing Decision 2014/709/EU[2] of 9 October 2014 concerning animal health control measures relating to African swine fever in certain Member States and repealing Implementing Decision 2014/178/EU: it provides the animal health control measures relating to ASF in certain Member States by setting up a regionalisation mechanism in the EU. These measures involve mainly pigs, pig products and wild boar products. A map summarising the current regionalisation applied is available online[3].

The current epidemiological situation requires risk managers to take into account several aspects related to pig production, encompassing both industrial pig production as well as backyard. While these are obviously crucial aspects when addressing ASF, another aspect that needs to be addressed is the management of wild boar populations, both in areas affected by ASF and in bordering areas.

Several aspects related to wild boar were already addressed in the EFSA opinion on ASF of 2010 and in the EFSA scientific report of March 2014; these are proving quite useful in supporting risk managers in defining the EU approach to ASF. Nevertheless there are aspects of wild boar ecology and management that need to be addressed in the light of the latest scientific information and of the evolution of ASF in the Eastern part of the EU.

New epidemiological data collected since the beginning of this event in the EU, including laboratory data and experiments of the EU Reference Laboratory for ASF, should be used to get a better understanding of how this ASF strain interacts with the local wildlife population and how Community Veterinary Emergency Team that went on the spot for ASF specific missions could be provided to EFSA by the Commission.

The current ASF epidemiological situation in the four affected Member States and at the Eastern border of the EU represents a threat to the EU livestock sector and a challenge for animal health risk managers. Therefore, in order to better target the control and preventive measures it is necessary to assess the measures that could be put in place to mitigate the risk of ASF spread from the infected

area to non-infected area via wild boar. At the same time the best approaches to wild boar management in the infected areas needs to be assessed in view of controlling and eradicating ASF.

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:192:0027:0046:EN:PDF
[2] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014D0709&from=EN
[3] http:/7ec.eiiropa.eii/lbod/animal/diseases/african swine fever/docs/joland liihuania asf regionalization en.pclf

Therefore, in view of the above, and in accordance with Article 29 of Regulation (EC) No 178/2002, the Commission asks EFSA for a scientific opinion, revising and updating as appropriate previous scientific opinions focusing on the following aspects of ASF:

1.1.2. Terms or reference

1) Evaluate the epidemiological data on ASF from Lithuania, Poland, Latvia and Estonia in order to obtain indications on the local behaviour of ASF in the wild boar population and its interaction with domestic pigs.
2) Assess the possible risk of spread of ASF-Genotype II strains/isolates currently or recently circulating in Europe, and especially in Russia or the Baltic States, by pigs or wild boar becoming "carrier" that might play a role in virus transmission while remaining non-symptomatic.
3) Where new data is available, provide an update of previous Scientific Opinions on ASF, in particular: i) describe identifiable relevant trends in wild boar population dynamics in the EU and its Eastern neighbouring territories; and ii) provide an updated distribution of ASF competent vectors (soft ticks) and its possible role on ASF epidemiology specially in Russia or the Baltic States.
4) In view of controlling ASF, assess the best management options for wild boar both in infected areas and in the bordering risk areas, taking into account the local climatic conditions and wild boar ecology. Assess in particular the suitability, effectiveness and the practical aspects of implementation of the main measures, in particular different tailor-made feed ban(s) for wild boar, selective well-described hunting practices, taking into account the local situations and giving quantitative baseline indications on these measures as well as spatial and temporal parameters.

1.1.3. Interpretation of the Terms of Reference

Previous opinions of the Animal Health and Welfare Panel of EFSA have assessed the risk of endemicity of ASF in areas neighbouring the EU, and the risk of introduction into the EU (EFSA AHAW Panel, 2010a; EFSA, AHAW Panel 2014a). Additionally, EFSA has issued a scientific report on the possible mitigation measures to prevent introduction and spread of ASF through wild boar in 2014 (EFSA, 2014b).

Term of Reference 1 (ToR1) of this mandate requires EFSA to assess the epidemiological characteristics of the outbreaks of ASF in Estonia, Latvia, Lithuania and Poland and to clarify the evolution of the epidemic since its first introduction at the beginning of 2014 in the eastern EU countries. Firstly, a short summary of the chronology of the outbreaks in the four affected countries is provided (section 2.3.1). Then, the spatio-temporal patterns of the notifications in these countries are described (section 2.3.2), including a description of the wild boar–domestic pig interface, the short- and long-distance spread of ASFV and clustering of ASF notifications. Observations on the prevalence are provided in section 2.3.3. Finally, factors which could contribute to the spread of ASFV to connected wild boar meta-populations are assessed, based on expert opinion, and ranked according to their importance (section 2.3.4).

Term of Reference 2 (ToR2) requires EFSA to assess the possible risk of spread of the ASFV genotype II strains currently circulating in eastern Europe via carrier pigs or wild boar. Furthermore, the role that carriers may play in the spread and long-term circulation of ASFV in the pig and wild boar population is addressed and put into the general context of ASF epidemiology.

The term "carrier" is used to describe an animal that is infected by a disease agent and is capable of disseminating (shedding) that disease agent, but which itself shows no sign of clinical disease. Carriers can be classified into "true carriers" (shedding animals which never develop clinical signs), "convalescent carriers" (shedding animals in which clinical signs have disappeared) or incubatory carriers (shedding animals for which the disease is still in the incubatory stage) (FAO, 1987).

Firstly, to assess if shedding of the circulating ASFV genotype II strain by carriers has been demonstrated, experimental infections with the ASFV genotype II strain that is currently circulating in eastern European countries are described in section 3.3.1. Next, section 3.3.2 provides an overview of experimental infections with a range of other genotypes that can be found in the literature and possible evidence of shedding and transmission by carriers is provided. It should be noted that, during field observations, it is not possible to determine if a clinically healthy animal in which antibodies to ASFV are detected is an animal that has recovered from the disease (such animals do not necessarily shed ASFV) or a carrier. If, during field observations, the clinically healthy animal is seropositive and DNA of ASFV has been detected by polymerase chain reaction (PCR), the animal can still be either a recovered animal which is not shedding ASFV, but has detectable ASFV DNA in its tissues, or a carrier shedding infectious ASF virus.

The section addressing Term of Reference 3 (ToR3) describes the trends in wild boar population dynamics in the EU and its eastern neighbouring territories (section 4). Furthermore, an updated description of the distribution of ASF competent vectors (*O. erraticus* complex) and their possible role in ASF epidemiology, especially in Russia and the Baltic States, is provided (section 5).

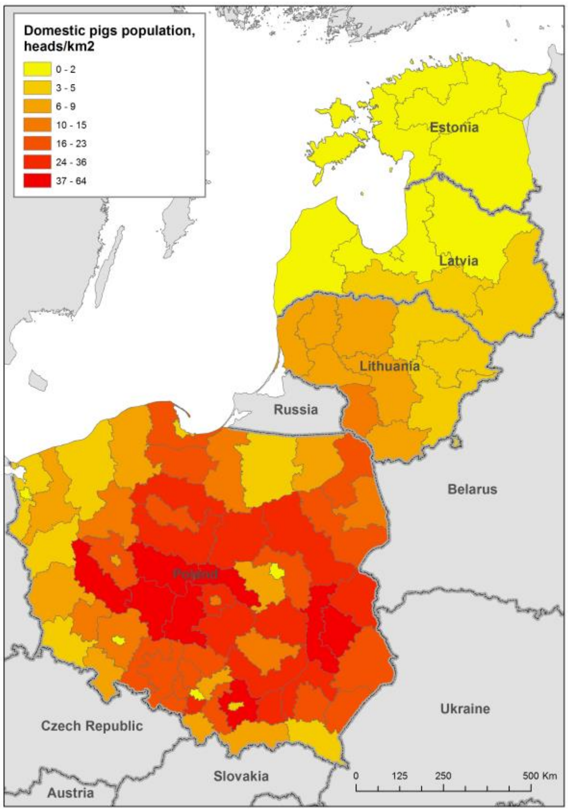
Term of Reference 4 (ToR4) requests EFSA to assess the best management options for wild boar in the specific ecology of both the Baltic States and Poland. The suitability, effectiveness and the practical aspects of implementation of the main measures needed to be addressed. Bearing in mind the uncertainty around several quantitative aspects of wild boar ecology and behaviour, ASFV transmission in wild boar populations, as well as the uncertainty related to the efficacy of wild boar management options themselves, a three-step approach was used to address this ToR (section 6). Firstly, the published literature was searched for quantitative information on the efficacy of different wild boar management options (section 6.3.1). Secondly, an expert consultation was organised to obtain unpublished information, e.g. from ecologists and veterinarians involved in the management of wild boar populations (section 6.3.2). Finally, the published and unpublished information, together with the data described, were used to parameterise wild boar ecology and the ASFV components of an epidemiological simulation model, with the aim of evaluating the effect of the different management options on the behaviour of ASF in the wild boar populations (section 6.3.3).

2. Behaviour of ASF in the wild boar and domestic pig populations in Lithuania, Poland, Latvia and Estonia (ToR1)

2.1. Data

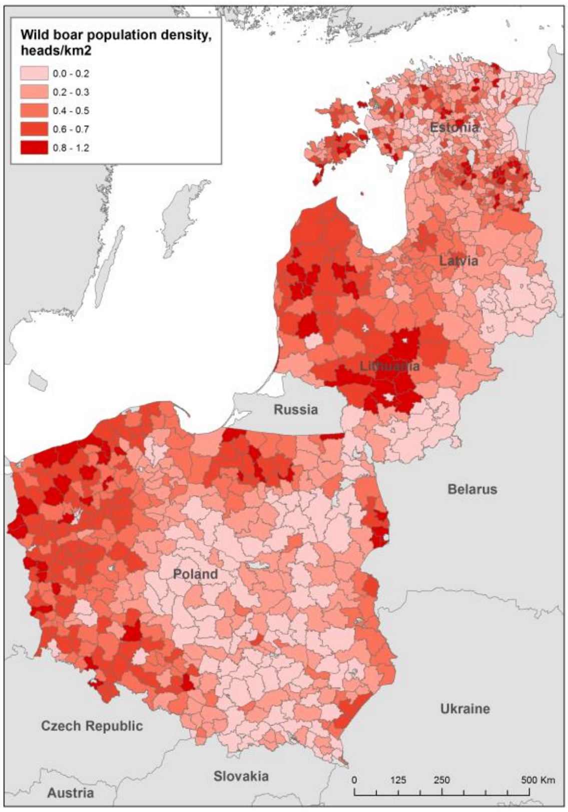
2.1.1. Distribution data of *Suidae* populations in the affected countries

Data on the domestic pig population distribution in Latvia, Poland, Lithuania and Estonia were provided by Eurostat (2010 census data) at the NUTS 3 level (Figure 1). Data obtained on the wild boar population were collected from literature and/or the statistical national offices and/or wildlife management institutions (Figure 2).



Source: Eurostat, 30 November 2014.

Figure 1: Density of domestic pig population in the Baltic States and Poland



Source: collected from literature and/or the statistical national offices and/or wildlife management institutions.

Figure 2: Estimated wild boar density in the Baltic States and Poland in 2014

2.1.2. Data on suitable wild boar habitat

Figure 3 presents data that were used to estimate the wild boar density in eastern Europe based on modelled habitat suitability, with a raster at 5 km spatial resolution. The model to predict the wild boar habitat suitability was developed by the Food and Agriculture Organization (FAO) under the ASFORCE project funded by the European Union's Seventh Framework Programme. Data at district resolution were used for the validation of this spatial distribution model. A two-step downscaling approach was developed to disaggregate wild boar population data from coarse-scale administrative units to fine-resolution raster maps (1 to 5 km) by incorporating auxiliary fine-resolution bioclimatic and environmental variables.

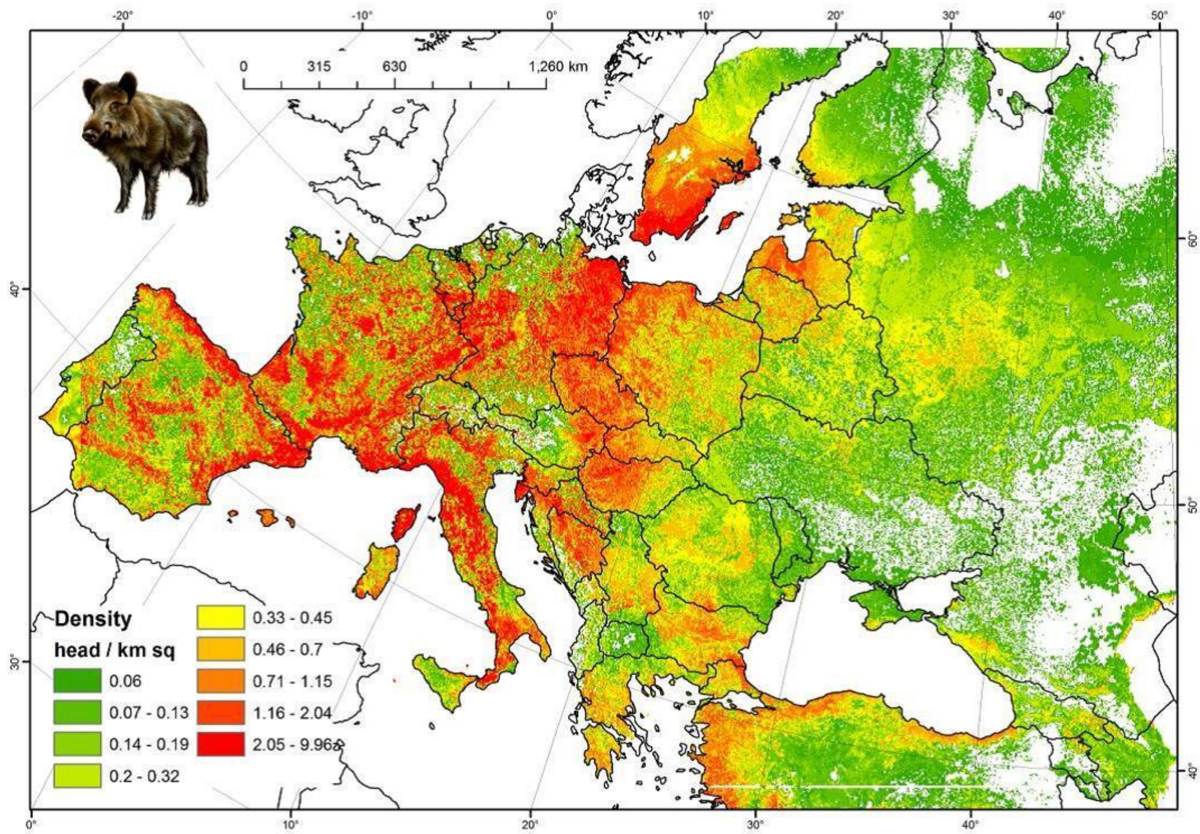


Figure 3: Modelled wild boar population density in Europe (source: FAO/ASFORCE, May 2015)

2.1.3. Data on ASFV detections in wild boar and domestic pigs

Data on ASFV detections in wild boar and pigs were extracted from the Animal Disease Notification System (ADNS) from 1 January 2014 until 10 March 2015 and circulated to the affected EU Member States as a template for additional epidemiological data collection.

Council Directive 2002/60/EC lays down specific provisions for the control of ASF. A 'case of African swine fever' means any pig or pig carcass (both wild and domestic) in which clinical symptoms or post-mortem lesions attributed to ASF have been officially confirmed, or in which the presence of the disease has been officially confirmed as the result of a laboratory examination carried out in accordance with the diagnostic manual. An 'outbreak of African swine fever' means one or more cases of ASF detected in a pig holding.

The distributions of ASF cases in wild boar and outbreaks of ASF in domestic pigs (as reported in ADNS) are displayed in Figure 4. As an additional source of data on the ASF situation, the OIE notification database has been used.

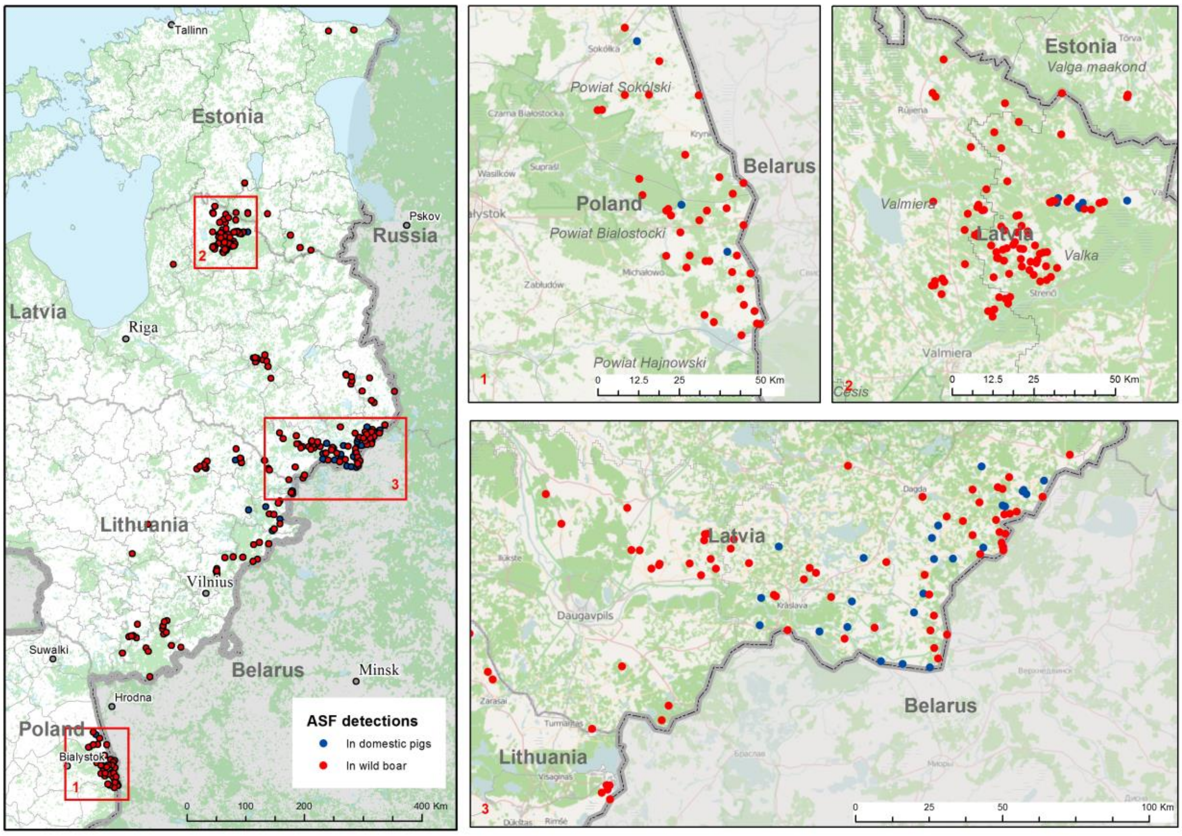
Additionally, data on tested wild boar and domestic pigs were provided by the veterinary services of Estonia, Latvia, Lithuania and Poland. Data from laboratory tests conducted between 1 February and 28 February 2015 were included in the analysis. Data were collated in MS Excel and displayed in ArcGIS (Esri, Redlands, CA, USA).

There are discrepancies between the numbers of animals reported in ADNS and the number of positive animals in the laboratory data. These can be explained partly by the way in which data are entered in ADNS (Table 1). ADNS is structured such that each notification can include one or several cases as long as they are part of the same outbreak. Sometimes, if several animals are found dead in one location, only one outbreak or case is entered into ADNS, even though several entries are made into the laboratory database. There were 358 notifications of ASF in wild boar and 41 notifications of outbreaks in domestic pig holdings recorded in the ADNS database for Estonia, Latvia, Lithuania and Poland between 24 January 2014 and 10 March 2015.

Table 1: Number of ASF notifications in the four affected EU Member States

Country	Number of wild boar cases notified	Date of first confirmation in wild boar	Number of domestic pigs outbreaks notified	Date of first confirmation in domestic pigs
Lithuania	61	24/01/2014	6	24/07/2014
Poland	39	17/02/2014	3	23/07/2014
Latvia	188	26/06/2014	32	26/06/2014
Estonia	70	08/09/2014	0	–
Total	358		41	

Source: data extracted from the Animal Disease Notification System from 24 January 2014 until 10 March 2015.



Source: data extracted from the Animal Disease Notification System from 24 January 2014 until 10 March 2015.

Figure 4: Notifications of cases in wild boar or outbreaks in domestic pigs in Estonia, Latvia, Lithuania and Poland

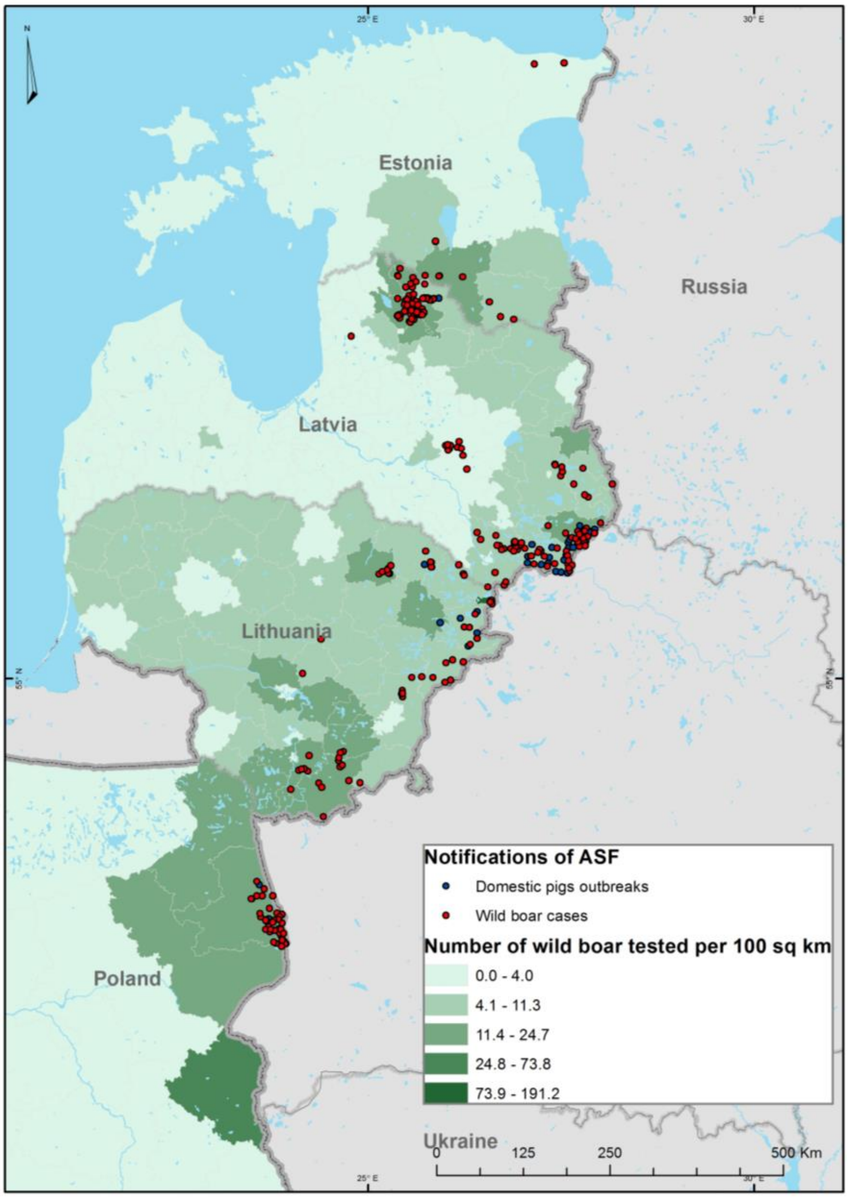
Affected countries base their monitoring strategy on passive surveillance in wild boar. In the framework of passive surveillance, all wild boar found dead, killed in road accidents or shot while showing abnormal behaviour are tested for ASFV and anti-ASFV antibodies.

In addition to passive surveillance, all wild boar shot in infected regions and surrounding areas (the size of which varies among countries) are tested for both virus and anti-AFSV antibody. In a few countries a proportion of wild boar hunted outside infected and surrounding areas are also tested (e.g. Lithuania 2 % of shot animals). Figure 5 shows the wild boar cases and domestic pig outbreaks in Estonia, Latvia, Lithuania and Poland notified to the ADNS and the number of tested wild boar per 100 km^2. In total, 38 021 hunted wild boar and 4 065 wild boar that were found dead were sampled and tested for ASF using polymerase chain reaction (PCR) (Table 2). The geographical area where the animals were sampled is shown in Figure 5.

Table 2: Number of wild boar hunted and found dead and tested with PCR for ASF in the four countries

	Hunted wild boar		Found dead wild boar	
Country	Number tested by PCR	Number positive	Number tested by PCR	Number positive
Latvia	7 443	49	393	229
Poland	15 514	9	2 088	56
Lithuania	13 870	94	1 345	53
Estonia	1 194	63	239	94
Total	3 8021	215	4 065	432

Source: data extracted from the national laboratories from 1 February 2014 until 28 February 2015.



Source: data extracted from the Animal Disease Notification System from 24 January 2014 until 10 March 2015.

Figure 5: Number of wild boar tested per 100 square km in each of the NUTS 3 level regions

2.2. Methodologies

2.2.1. Chronological description of the ASF outbreaks

The description of the chronology of the outbreaks was based on a review of the reports submitted by the Community Veterinary Emergency Team (CVET), the reports presented at the Standing Committee on Plants, Animals, Food and Feed (PAFF) meetings and the notifications submitted to the World Animal Health Information System (WAHIS). Based on this information, possible wild boar–domestic pig interactions were described.

2.2.2. Spatio-temporal observations

The kernel density function was applied to calculate the density of notifications (hotspots) applying radii of 29 km. These radii were estimated using the k Ripley function (Ripley, 1977), which allows the maximum distance for significant spatial association between ASF notifications to be identified (Iglesias et al., 2015). A linear correlation analysis was performed to identify the possible relation between the wild boar density and the case notification density.

The kernel density analysis was also used to describe the temporality of the clusters of notifications in the four affected EU Member States, and to investigate the spread of the disease in the wild boar populations.

To describe the local behaviour of ASF in the wild boar population, the notifications to OIE for three consecutive periods (January to June 2014, June to December 2014 and January to May 2015) were mapped with a radius of 20 km, which is about twice of the maximum daily movement of wild boar, based on a mean daily movement of 2 to 10 km (Bosch et al., 2012).

2.2.3. Variations in ASF prevalence in wild boar

To evaluate if potential seasonal variations in virus prevalence in the hunted wild boar populations occur, data obtained from PCR tests carried out on samples from wild boar over a period of one year (from February 2014 to February 2015) were pooled for Latvia and Poland. Potential statistical differences in the yearly, monthly or seasonal prevalences were assessed using the chi-squared test with Yates' correction. Fisher's exact test was used to evaluate potential statistical differences between seasonal detection of virus-positive dead wild boar in Latvia and Poland.

2.2.4. Assessment of carcass detection rate

Virus detection has been shown to be more likely in wild boar carcasses than in live animals. Thus, carcass detection plays a very important role in assessing both the geographical distribution of the virus and its spread. Since not all carcasses are detected, a simple simulation was developed to estimate the proportion of carcasses that could have been detected in the affected areas.

The simulation runs with a time step of one week, and considers:

- T0: 1 April, pre-reproductive estimate;
- T1: reproductive season, 1 April to 30 May;
- T2: hunting season, which lasts from 1 April to 30 March of the next year; and
- T3: the weekly number of hunted animals and retrieved carcasses was subtracted from the initial population (T1);

It was assumed that, over the course of the whole hunting season, virus prevalence among the boar population was 1 % and lethality was 90 %. The simulated numbers of carcasses (average, maximum and minimum numbers based on prevalence and 95 % confidence interval (CI)) were compared with the actual number of dead animals retrieved and the detection rates were calculated.

The simulation runs under several assumptions:

- The wild boar population doubles (which is an approximation of the biological reproductive wild boar strategy) during the period 1 April to 30 May.

- The wild boar population is closed (there is no immigration or emigration).
- Prevalence and lethality are seasonally constant.

2.2.5. Factors contributing to further spread of ASFV from affected wild boar meta-populations

A questionnaire was sent to 40 experts in wild boar ecology and ASF epidemiology in wild boar populations. The experts were asked to rank possible factors leading to further spread of ASFV from affected wild boar meta-populations according to importance (from 1 = not important to 5 = very important). Furthermore, the experts were asked to assess the likelihood (negligible (N), low (L), moderate (M), high (H)) and the uncertainty (low (L), moderate (M), high (H)) of their judgement.

2.3. Assessment

2.3.1. Chronological description of the ASF outbreaks in Lithuania, Poland, Latvia and Estonia

Lithuania

On 24 January 2014, Lithuania's National Food and Veterinary Risk Assessment Institute (NFVRAI) confirmed two cases of ASFV using real-time PCR (OIE validated). The first case was a three-year-old female wild boar found dead in Varena district (at the border with Alytus region) about 40 km north from the border with Belarus on 20 January 2014. The second case was a male wild boar (12 months old) which was shot during hunting about 5 km from the border on 20 January 2014. The distance between the locations of the two animals was about 36 km. Analysis performed at the ASF-EURL confirmed the presence of ASFV in the dead wild boar found in Varena region (at the border with the Alytus region). The Lithuanian viruses were found to have a 100 % sequence homology with the Belarus ASFV isolate responsible for the outbreak that occurred in Grodno region during June 2013 (CVET, 2014a).

From January to July 2014 no new cases of ASF were reported. At the end of July, two ASF outbreaks unexpectedly occurred in pig farms in the Ignalina and Utena districts, 160–180 km from the first notified cases in wild boar. On 24 July 2014, an ASF primary outbreak was confirmed in a large commercial pig farm (19 137 pigs). The farm is located between the border with Latvia and the south-eastern part of Lithuania. This farm had a high biosecurity level. It should be mentioned that on 23 June, during routine serological testing for ASF, all samples tested were negative for ASF antibodies. However, between 14 and 20 July, 18 pigs died in the weaner unit. On 23 July, the owner informed the veterinary services about his suspicion of a contagious pig disease. On 24 July, the ASF outbreak was confirmed at the National Food and Veterinary Risk Assessment Institute (NRL for ASF). ASV was probably introduced to the farms by human involvement.

The next ASF outbreak was reported on 5 August 2014, in Utena district (bordering Ignalina district, approximately 17 km from previous outbreak). A backyard farm which kept two pigs reported that a five-month-old pig exhibiting clinical signs similar to ASF had died on 4 August 2014. The other pig (a five-month-old female) was found to be clinically healthy. Samples from both pigs were taken for PCR and enzyme-linked immunosorbent assay (ELISA). On 6 August 2014, the NFVRAI confirmed ASF in the dead pig using real-time PCR and found ASFV antibodies using ELISA. The clinically healthy pig was killed and destroyed. It tested negative by PCR and ELISA.

Between 10 and 13 August, two ASF outbreaks in domestic pigs were detected in the surveillance zone in Ignalina district. It was assumed that the outbreak was caused by a lack of biosecurity measures on the holding, and hunting had regularly taken place near the holding (close to the border with Belarus).

At the end of August, another outbreak was reported in a backyard farm in the previously unaffected Panevezys county in Rokiskis district.

The last outbreak to occur in a domestic holding was registered in a backyard farm in Ignalia district, located at a distance of 1 km from the border with Belarus. Two weeks later, a sow and three fatteners slaughtered for self-consumption were tested for ASF by PCR and ELISA, with negative results. The four remaining pigs (two months old) tested positive using RT-PCR in the NRL. Three days later, on 3 September, a dead wild boar was discovered in the surveillance zone and tested positive for ASFV.

After the series of outbreaks in domestic pigs, no more outbreaks in domestic pigs were notified in the counties in the Part II and III area as described by the Commission Implementing Decision 2014/178/EU, until June 2015. However, a number of cases in wild boar were reported, forming clusters which still exist (June 2015).

In December 2014 and at the end of February 2015, two ASFV-positive wild boar (one hunted and one found dead) were detected on opposite sides of Jonava district, a region with high wild boar density, which lies around 100 km from the Belarusian border and lies outside the buffer zone.

Up to May 2015, there were no new cases of ASF in this region, but new detections of the disease were registered in the neighbouring districts in May (Kedainiai) and June (Kaunas) 2015; therefore, this region can be considered as a new cluster (OIE, 2015).

The total numbers of notifications/cases in the affected regions of Lithuania in the period from January 2014 to May 2015 are presented in Table 3. More details about the outcomes of the epidemiological investigations in Lithuania are provided in Appendix A.

Table 3: Notifications/cases of ASF in wild boar and domestic pigs in Lithuania, from 24 January 2014 to 31 May 2015

Region	**Cluster**	**2014**							**2015**			
District		**Jan**	**Jul**	**Aug**	**Sep**		**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Alytus													
Varena	9	1/1						3/3	5/10	1/1	2/2		1/1
Alytus	9					2/7	1/9	1/1		2/5			
Total		1/1				2/7	1/9	4/4	5/10	3/6	2/2		1/1
Vilnius													
Salcininkai	9	1/1											
Svencionys	11					2/2	1/5	1/1		2/2	1/1		1/1
Vilnius	8						2/2	2/3					
Trakai	9								1/2				2/2
Total		1/1				2/2	3/7	3/4	1/2	2/2	1/1		3/3
Utena													
Utena	7		1/1										
Ignalina	7		1/36	4/6	1/1	1/1		2/2	6/7			2/2	
Zarasai	7									2/2	1/1	2/2	
Total			2/37	4/6	1/1	1/1		2/2	6/7	2/2	1/1	4/4	
Panevezhys													
Kupiskis	6						1/1		2/2	1/1	3/7	1/5	
Rokiskis	6			1/1				2/8	3/10				2/3
Total				1/1			1/1	2/8	5/12	1/1	3/7	1/5	2/3
Kaunas													
Jonava	–								1/1		1/1		
Total									1/1		1/1		

The clusters referred to are shown in Figure 7.
Red box: number of notifications/cases of ASF in domestic pig farms in that month.
Orange box: number of notifications/cases of infected wild boar in that month.
Source: outbreaks and cases reported to the World Animal Health Information Database (WAHID) Interface from 24 January 2014 until 31 May 2015. Available online: http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home.

Poland

The first case of ASF was confirmed at the NRL on 14 February 2014, following the detection of ASFV DNA in samples from a wild boar that was found dead on 3 February, 2014. The animal was found in the vicinity of Grzybowszczyzna, in Sokólski county, approximately 900 m from the border with Belarus. The wild boar was found by the owner of a nearby holding, in a swampy area about 100 m behind his backyard. It is very likely that the animal picked up the infection in the second half of January, 2014 (CVET, 2014b; Pejsak et al., 2014a, b).

The second case was detected three days later in a fresh wild boar carcass found about 3 km from the border with Belarus, about 15 km from the location of the previous case. Within five days of diagnosing the two cases of ASF, blood samples collected from 623 pigs from 118 farms in 57 localities were examined. All of the samples were negative. At the same time, a search for dead wild boar was conducted within a radius of 40 km around the first two ASF cases. All wild boar shot within 40 km of the Polish border with Belarus and Lithuania were subjected to laboratory tests. In total, from 18 February to 16 April 2014 (58 days following the confirmation of the second case of ASF) 1 033 samples from domestic pigs and 2 868 samples from wild boar were examined and all the results were negative.

More than three months later, on 21 May 2014, an ASFV-positive dead wild boar was recovered from the river flowing along the Poland–Belarus border, approximately 4.5 km from the site where the second infected wild boar had been found.

During the next 12 months another 40 cases of ASF in wild boar were confirmed. The distance to the first case was never more than 30 km. In most cases only individual wild boar were found, but in some cases groups of up to six dead animals were discovered (Pejsak et al., 2014b).

The first outbreak of ASF in domestic pigs was confirmed on 23 July 2014 (suspicion on 19 July 2014) in a holding of eight pigs. Three pigs had already died by this time, and were buried near the holding. The veterinary authorities were not notified of this until the symptoms of the disease were visible in the next two pigs. The second outbreak of ASF in domestic pigs was identified on 6 August 2014, in a holding with only one pig in the village of Józefowo, in Gródek municipality, approximately 13 km north of the location of the first outbreak. The ASF-affected holding was located close to the forest and had a very poor biosecurity level (Pejsak et al., 2014a, b).

The third outbreak occurred in a backyard holding with seven pigs. Within five days of diagnosing the two cases of ASF, blood samples collected from 623 pigs from 118 farms in 57 localities were examined. All of the samples were negative. At the same time, a search for dead wild boar was conducted within a radius of 40 km around the first two ASF cases. All wild boar shot within 40 km of the Polish borders with Belarus and Lithuania were subjected to laboratory tests. In total, from 18 February to 16 April 2014 (58 days following the confirmation of the second case of ASF), 1 033 samples from domestic pigs and 2 868 samples from wild boar were examined and all the results were negative.

Since the first detection of ASF in Poland, up to May 2015, ASF has been detected in an area running 70 km along the Poland–Belarus border, and spanning 30 km from the Poland–Belarus border (SCoFCAH, 6-7 Feb 2014, SCPAFF, 04 Feb 2015) The total number of notified outbreaks from these regions between January 2014 and May 2015 are is in Table 4. More details about the outcomes of the epidemiological investigations in Poland are provided in Appendix A.

Table 4: Notifications/cases of ASF in wild boar and domestic pigs in Poland

Region	**Cluster**	**2014**											**2015**				
District		**Feb**	**May**	**Jun**	**Jul**		**Aug**		**Sep**	**Oct**	**Nov**	**Dec**	**Jan**		**Feb**	**Mar**	**Apr**
Podlaskie																	
Sokólski	10	2/2	2/4	1/1				1/3			1/1	2/3	1/5		2/2	1/1	4/4
Bialostocki	10			1/4	1/5	6/18	1/1	1/1	1/1	4/21	4/4	4/4		2/2	4/8	7/16	7/10
Hajnowski	10															1/1	
Total		2/2	2/4	2/5	1/5	6/18	1/1	2/4	1/1	4/21	5/5	6/7	1/5	2/2	6/10	9/18	11/14

The clusters referred to are shown in Figure 7.
Red box: number of notifications/cases of ASF in domestic pig farms in that month.
Orange box: number of notifications/cases of infected wild boar in that month.
Source: outbreaks and cases reported to the World Animal Health Information Database (WAHID) Interface from 24 January 2014 until 31 May 2015. Available online: http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home.

Latvia

The ASF epidemic in Latvia started with the introduction of the virus in the wild boar and domestic pig populations in the southern part of the country. The first ASF cases were detected in Dagdas county, in Latgale region, at the area bordering Belarus, at the end of June 2014.

On 25 June 2014, three wild boar were found dead near the river near the border with Belarus, in Kepova parish (Dagda county), and the next day ASF was confirmed by the NRL. Moreover, on the same day, a farmer notified the inspector of the local food and veterinary services about clinical signs which had appeared in two of his pigs. On 26 June, the NRL confirmed three primary cases of ASF in domestic pigs in Kraslavas county (Robeznieku parish), in a backyard farm.

In the first weeks of July 2014, ASF entered into the northern part of Latvia bordering Estonia in the Valka and Valmieria regions. This appeared to occur simultaneously in the domestic pig and wild boar populations. About one month later, ASF was detected in the central part of the country, in Madona region, and in the Ludza and Rezeknes regions bordering the Russian Federation.

On 16 July 2014, a suspected case of ASF was reported in a dead wild boar, and on 17 July suspected ASF was reported in a pig farm (58 pigs). The next day, both the wild boar case and the pig outbreak were confirmed. Contaminated grass used as feed was suspected to be the source of infection in the pig farm. Four further outbreaks were epidemiologically linked to this outbreak. The farms belonged to brothers who were in daily contact with each other.

Outbreaks in domestic pigs in the counties of Kraslavas and Valka were recorded from June to September. Mainly small backyard farms with up to three pigs were affected. The largest affected farm had 196 pigs. Nearly all outbreaks in the domestic pig sector were primary outbreaks (CVET, 2014c). Most of the ASF outbreaks in the domestic pig holdings were in backyard farms in Kraslava region, bordering Belarus. Most of the outbreaks in Dagdas region were notified by the owners at the very start of the outbreak. One outbreak was detected by veterinary inspectors during active surveillance surveys. At the same time as the domestic pig outbreaks, 41 ASF-positive wild boar cases were detected. Most cases were found in a belt of about 20 km near the border with Belarus. Several outbreaks of ASF occurred in backyard holdings during a very short period of time (about six weeks).

In the Indras community (Kraslava county), eight ASF-positive wild boar were detected during the period between 29 June and 2 July. Some of the animals were still alive when found but showed severe clinical signs and were not able to move. This is a forested area, not far from human settlements. Large amounts of illegally disposed waste were also found in the forest close to the places where the sick and dead animals were found.

From July 2014 to the beginning of May 2015, cases in wild boar were regularly reported in Latgale region.

Madona region is located about 150 km west of Kraslavas region and it is the region where five infected wild boar were found in August 2014. The dead animals were found on 5 August by a farmer in a rye field while he was harvesting the crop. Since the carcasses were not fresh it can be assumed that the infection of these animals occurred during in the second half of July. The possible source of the infection remains unclear.

Nearly all outbreaks were reported by the owners at a very early stage of infection (e.g. with one sick animal in the stable). Only in a very few cases could epidemiological links between outbreaks be found. Feeding animals kitchen waste and uncontrolled movements of people from the backyard area represent the main risks of virus spread (Olsevskis, 2015).

Nearly all outbreaks in the domestic pig sector in Latvia were primary outbreaks, and several outbreaks occurred within a short period. To date three infected areas have been identified in Latvia:

- Kraslavas region: in the south-east of Latvia at the Border with Belarus;
- Valka region: in the north-east of Latvia, at the border with Estonia;
- Madona region: about 150 km west of Kraslavas region and the border with Belarus;

The total number of notified outbreaks and cases in domestic pigs and in wild boar in the affected Latvian regions in the period from January 2014 to May 2015 is presented in Table 5. More details about the outcomes of the epidemiological investigations in Latvia are provided in Appendix A.

Table 5: Notifications/cases of ASF in domestic pigs and wild boar in Latvia

Region County		**2014**											**2015**			
	Cluster	**Jun**		**Jul**		**Aug**		**Sep**		**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Latgale																
Kraslava	5	1/3	1/2	8/13	7/13	5/17	6/9		1/1	1/1		3/7	2/2	2/2	1/3	1/1
Dagdas	5		2/5	5/6	14/16	6/14	2/2		2/2	2/2	1/2	2/4				
Cibla	3						1/1									
Daugavpils	5						5/7		4/7	3/3	1/1		3/5	3/3		1/1
Ludza	3						1/2			3/3			1/2	2/2		
Rezekne	3						2/3							1/1	2/2	
Krustpils	4									1/5						
Aglona	5														1/1	
Total		1/3	3/7	13/19	21/29	11/31	17/24		10/10	10/14	2/3	5/11	6/9	8	4/6	2/2
Vidzeme																
Valka	2			4/7	2/3	2/2	3/5	1/6	4/4			3/6	2/2		4/6	2/2
Madona	4						3/5		1/1		1/1	1/1	1/1	2/3		1/3
Burtnieki	2								12/14	8/18	3/3	7/16	4/16	8/19	11/48	11/16
Strenci	2						1/1		6/8	4/4	7/13	6/13	1/1			
Aluksne											1/1					
Naukseni	2										1/1	1/1	2/2	2/4		1/1
Koceni	2															1/1
Total				4/77	2/3	2/2	7/11	6	27	12/22	13/19	18/37	10/22	12/26	15/54	16/23
Pieriga																
Limbazi	2														2/6	1/1

Red box: number of notifications/cases of ASF in domestic pig farms in that month.
Orange box: number of notifications/cases of infected wild boar in that month.
Source: outbreaks and cases reported to the World Animal Health Information Database (WAHID) Interface from 24 January 2014 until 31 May 2015. Available online: http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home.

Estonia

On 2 September, one wild boar piglet was found dead in Valga county in the parish of Hummuli, 6 km from the Latvian border, in a region which was under restriction because of the high risk of introduction of ASF from neighbouring Valka county in Latvia. On 5 September 2014, ASF was confirmed. Since then, a number of other notifications of ASF in wild boar have been submitted to the ADNS notification system for Valga county.

On 7 September, one dead wild boar was found in Viljandi district (Tarvastu parish), 25 km from the first wild boar location. On 10 September this case of ASF was also confirmed.

On 14 September, a dead wild boar was found in Ida-Virumaa district (Lüganuse parish), 220 km from the second wild boar case location. On 18 September, the first ASF wild boar case was confirmed in this county. This affected area is located in the north-east of the country and borders Russia. It is a forested area, with a mixture of swamps and dense forest.

On 18 September, one abnormally behaving wild boar was shot in Valgamaa district (Õru parish) 18 km from the first infected wild boar location.

On the 26 October, four dead wild boar were found in Võrumaa district, in Varstu parish.

Wild boar cases continue to be reported in Estonia. All the ASF detections up to 31 May 2015 are listed by month of notification in Table 6. More details about the outcomes of the epidemiological investigations in Estonia are provided in Appendix A.

Table 6: Notifications of ASF in wild boar and domestic pigs in Estonia

Region	Cluster	2014				2015				
		Sep	Oct	Nov	Dec	Jan	Feb	March	April	May
Valga	2	3/3	2/3	1/1	3/3	2/6	2/4	3/6	4/12	4/9
Viljandi	2	4/7	7/14	8/19	3/6	2/2	4/12	5/37	3/4	3/16
Ida-Viru	1	1/1		1/1	2/2	1/4	3/14	2/2		1/1
Võru			1/4	1/1	2/4		4/5	2/6		
Tartu								1/1		1/3
Pärnu										1/1

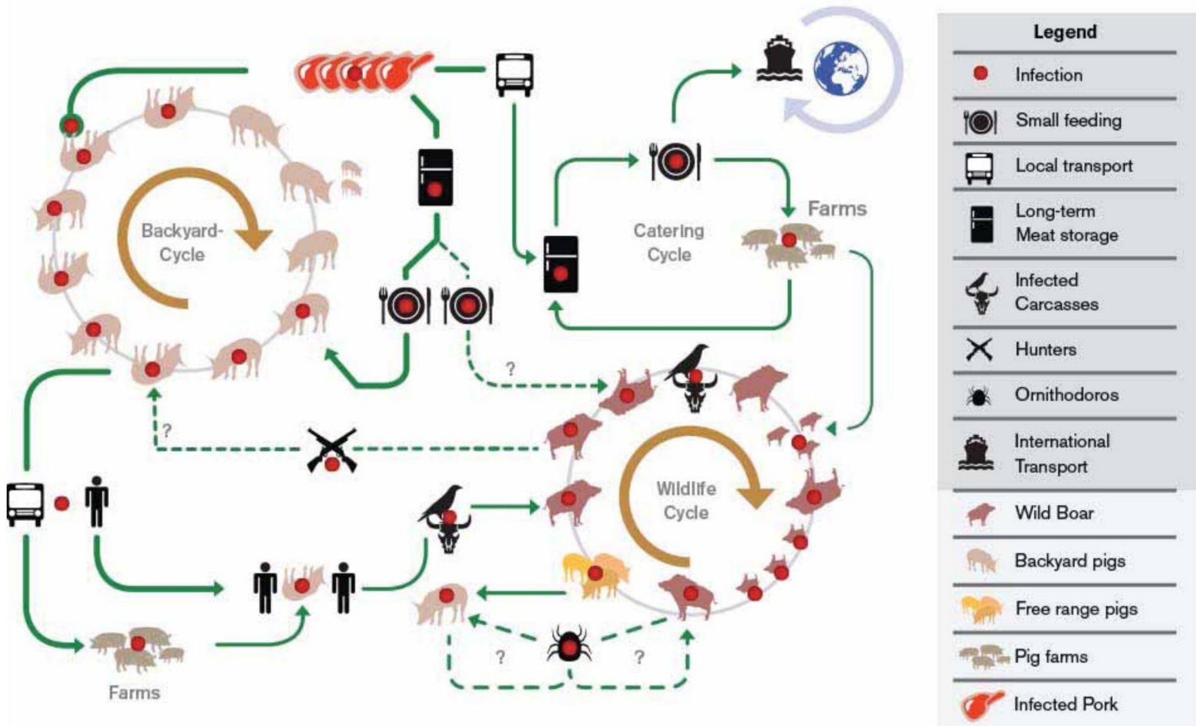
Orange box: number of notifications/cases of infected wild boar in that month.
Source: outbreaks and cases reported to the World Animal Health Information Database (WAHID) Interface from 24 January 2014 until 31 May 2015. Available online: http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home

2.3.2. Spatio-temporal observations

Wild boar–domestic pig interface

The above summary of notifications (section 2.3.1) demonstrates that infection among wild boar populations has not waned in any of the affected Member States, and notifications of ASF cases in wild boar have continued since the first notification, in January 2014. The maximum interval between two notifications of ASF cases in wild boar in the same district/county of the affected EU Member States was six months.

Factors that may lead to spread of ASFV in the Russian Federation have been described in detail (Gulenkin et al., 2011; Sánchez-Vizcaíno et al., 2012, 2013; FAO, 2013; Gogin et al., 2013; Oganesyan et al., 2013; EFSA, 2014; Korennoy et al., 2014; Iglesias et al., 2015). The involvement of different mechanisms leading to long-term circulation of ASFV is shown in Figure 6. The figure illustrates the interaction between backyard farms and wildlife in this country. It elucidates the importance of strict implementation of biosecurity principles in pig holdings, especially in areas at risk owing to circulation of ASFV in the wild boar populations in the vicinity. It also shows the importance of building awareness among all stakeholders involved in pig rearing, wild boar management, catering or transport of pork in order to control the spread of ASFV.



Source: Empress Watch, 2013.

Figure 6: Transmission cycle of ASF in the Russian Federation, involving low biosecurity pig production systems

In contrast, there is currently no evidence that the virus persists in backyard farms in the four affected EU countries. Most outbreaks in domestic pig holdings have occurred in backyard farms, and were stamped out relatively quickly. Poor biosecurity measures in these holdings, including practices such as illegal swill feeding (Oļševskis, 2015) and feeding of freshly harvested grass, are thought to be the main sources of virus entry in these holdings, rather than direct contacts between domestic pigs and wild boar. Moreover, there are no free-ranging pigs in the whole of Lithuania. In Estonia, the role of backyard farming is minimal, as only 0.6 % of the pig population is kept in holdings with fewer than 10 pigs, whereas 94 % of the pig population is kept in herds of more than 2 000 head. This is probably why, in Estonia, ASF has so far been detected only in the wild boar population. The area of Latvia bordering Belarus, where ASF outbreaks in domestic pigs were observed, is the area with the highest density of backyard farms, with a low total number of pigs. In Poland, introduction and spread of ASF have been wild boar mediated, with few outbreaks in backyard farms.

Recently, Poland,[4] Lithuania[5] and Latvia[6] have implemented more stringent measures in an effort to increase biosecurity in pig holdings in infected areas. These measures should further mitigate of the risk of virus entry in pig holdings in areas where the disease is still spreading in the wild boar populations.

Short- and long-distance spread of ASFV

Short-distance spread of ASFV (i.e. 50 km/year or 1 km/week) can be attributed to direct contact between infected animals, whereas sudden long-distance spread (i.e. between clusters 3 and 4 in Figure. 7) obviously cannot be explained by direct contact between wild boar alone. Kernel density analysis resulted in 11 clusters of notifications. From the notification data, the emergence of most new clusters of notifications (hotspots) of ASF could not be explained only by direct contact, because of the long distance between the clusters.

Most of these clusters were established during the period when ASF still occurred in the domestic pig populations in the affected Member States (i.e. before September 2014 in Estonia, Latvia and Lithuania and until January 2015 in Poland). In Figure 7, these clusters are highlighted in red. All outbreaks in the pig holdings had been resolved by September 2014 in Latvia and Lithuania, and by January 2015 in Poland.

4 Regulation of the Minister of Agriculture and Rural Development of 25 May 2015 according to activities connected with the African swine fever (Dz. U. 2015, poz. 711).

5 Food and Veterinary Services. Order on biosecurity measures for pigs, 2011. Official Journal, 1992 , no. 2–15 , 2010 , no. 148-7563

6 Regulation of the Cabinet of Ministers No. 291 (30.06.2015) on the complex of biosecurity requirements for animal holdings (https://www.vestnesis.lv/op/2015/124.13).

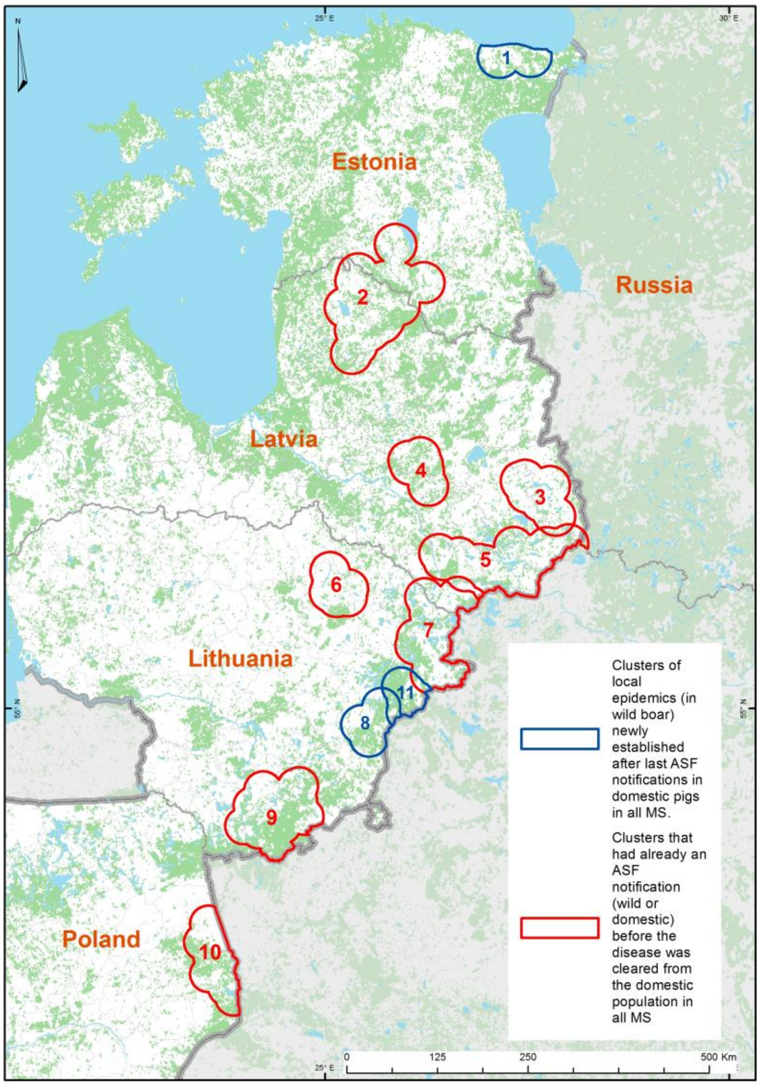


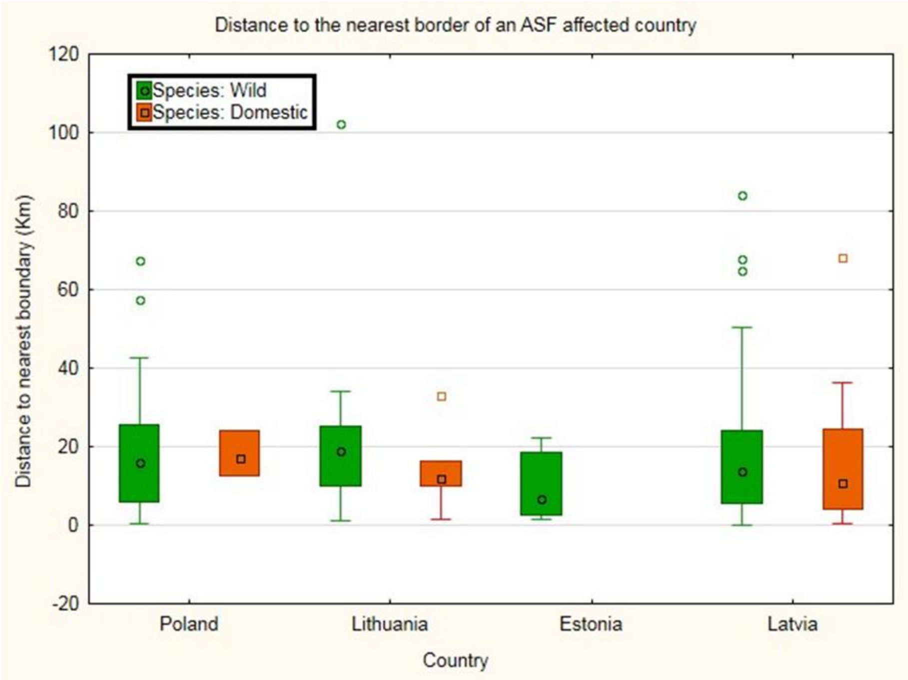
Figure 7: Temporality of clusters of notifications in the four affected EU Member States until May 2015

There is also evidence of spread at a local scale, mediated by wild boar. This is demonstrated in Figure 8, where ASF notifications to OIE for three consecutive periods are mapped with radius of 20 km, which is about twice the maximum daily movement of wild boar, based on a mean daily movement of 2 to 10 km (Bosch et al., 2012). There is local spread of wild boar cases, as demonstrated by the outward movement of the circles over the three periods in the southern part of Lithuania (Figure 8a and cluster 9 in Figure 7) in the cluster located on the border between Latvia and Estonia (Figure 8b and cluster 2 in Figure 7) and the cluster located on the border between Belarus and Poland (Figure 8c and cluster 10 in Figure 7).

The radius was set at 20 km; grey circles: notifications from January to May. 2014; yellow circles: notifications from Jun. to Oct. 2014; red circles: notifications from Nov. 2014 to May. 2015; yellow and red dots – notification in the first and second period respectively.

Figure 8: Changes in the spatial pattern of four main sub-clusters of ASF outbreaks and cases

Seventy-five per cent of the notifications were located less than 13 km from the border with Belarus and the Russian Federation, confirming the hypothesis of transboundary spread of ASFV via connected wild boar sub-populations. Further evidence of transboundary spread is illustrated by single or multiple entries of ASFV through infected wild boar close to the border with Belarus and/or the Russian Federation (Figure 9).

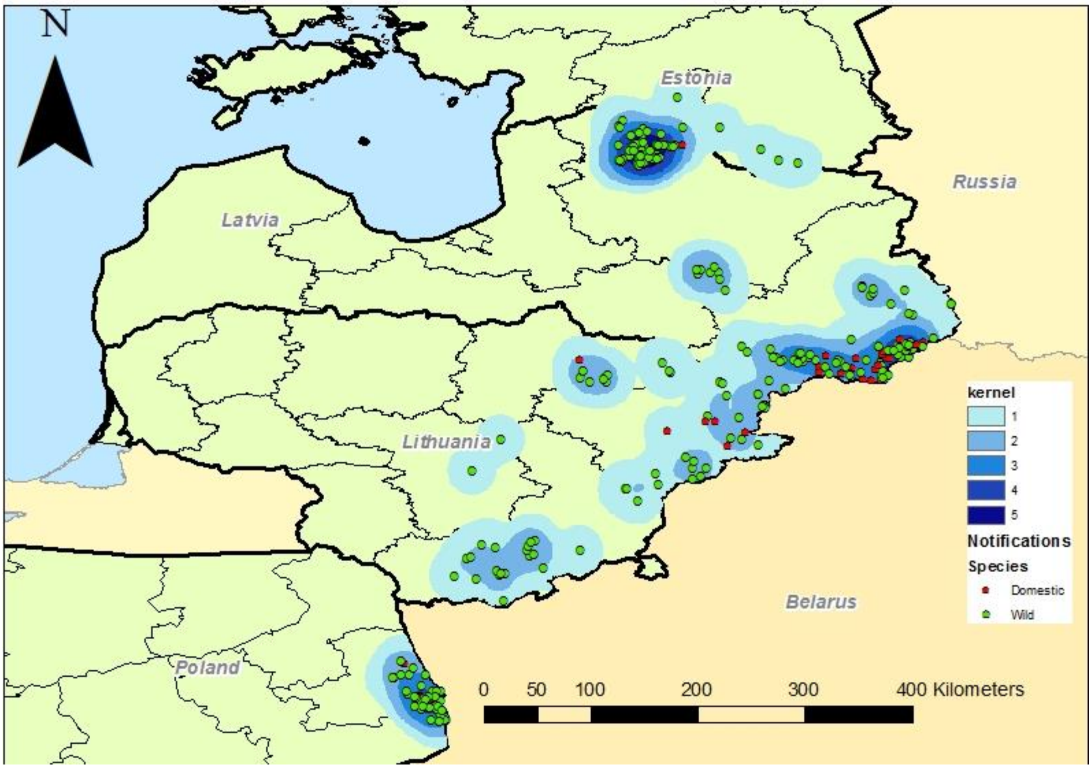


Black circles, median; boxes, 25–75% range of observations, whiskers, the non-outlier range; coloured circles and squares, outliers.

Figure 9: Distances from ASF notifications in clusters located in bordering regions to the nearest border of ASF affected country

Clustering of ASF notifications

Kernel density analysis illustrates areas of higher and lower notification density. The highest notification density occurred in Latvia, followed by Poland, Lithuania and Estonia (Figure 10). It should be noted that a higher kernel density value does not always correspond to a higher number of notifications. Poland has a higher spatial concentration of notifications than Lithuania, although it has reported a lower number of ASF cases (42 and 63 notifications respectively).



Blue shading illustrates five classes of notification density (kernels) from 5 (high density) to 1 (low density).

Figure 10: Density of notifications in the four affected EU Member States

As yet, the results of data analysis do not support a relationship between wild boar density and case notification density at the district level (R^2 of the linear model 0.08). Appendix B illustrates the number of notifications by domestic pig (see Figure 28) and wild boar (see Figure 29) density.

All notified outbreaks in domestic pig holdings occurred in suitable wild boar habitat. Most of the notifications of ASF cases in wild boar were located in forest areas (46.07 %), followed by heterogeneous agricultural areas (20.00 %), arable lands (15.36 %), pastures (13.21 %) and scrub and/or herbaceous vegetation associations (3.93 %) (Figure 11). These areas provide good shelter and/or food for wild boar (Bosch et al., 2012, 2014). Additionally, comparing these observations with the available habitat map for wild boar developed by INIA-CISA under the ASFORCE project funded by the European Union's Seventh Framework Programme (http://www.cisa-inia.weebly.com/), 74.3 % of the notifications occurred in areas where available wild boar habitat is classified as being of the highest quality.

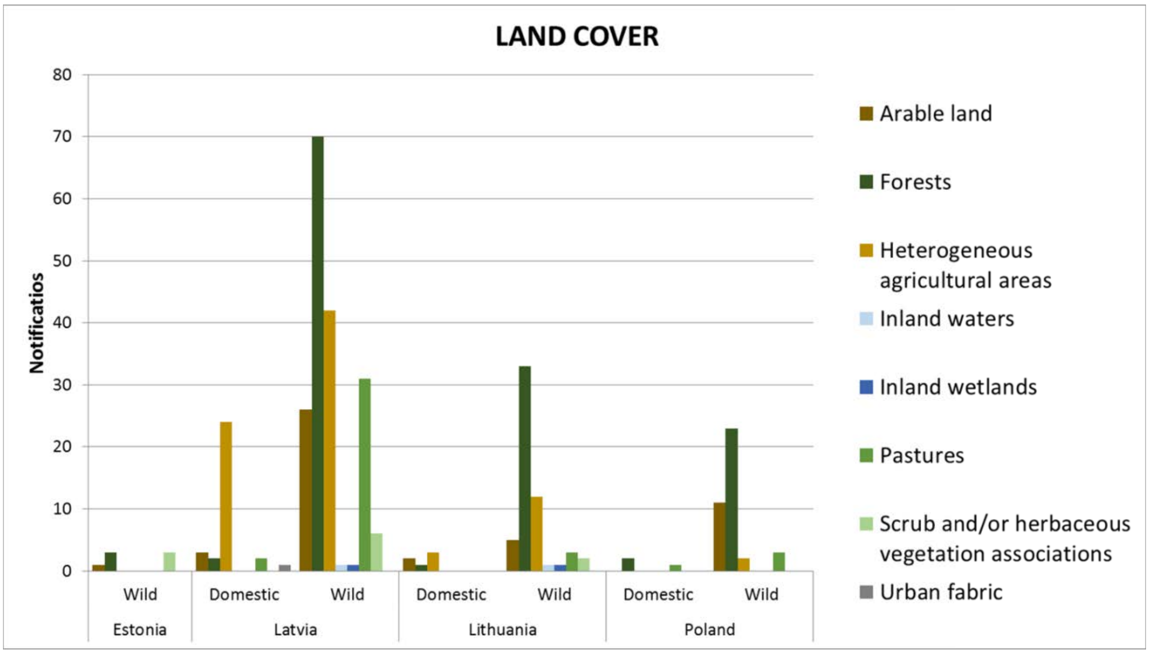


Figure 11: Number of notifications by land cover (CORINE land cover map)

2.3.3. Observations on ASF prevalence

Passive versus active surveillance

The surveillance data (section 2.1.3 and Table 7) show that there is a higher probability of detecting ASFV in dead than in live wild boar. The probability of detecting the virus was 55 times higher in dead animals than in animals shot during hunting.

Table 7: Summary of wild boar data (June–December, 2014) within the infected areas (Part II and Part III) LATVIA

Wild boar	Number of tested animals	Number of positive results
Found dead	227	178
Hunted	2 733	39

Source: data extracted from the Animal Disease Notification System from 24 January 2014 until 10 March 2015.

From the calculations as explained in section 2.2.4, it was estimated that the average carcass detection rate was 8.9 % (n = 13, range 2.7–19.3 %). The estimated carcass detection rates did not show a significant correlation with prevalence or with the reported population density, suggesting that factors other than disease activity or abundance of animals (such as season or habitat type) determine how many dead carcasses are discovered in the ASF-affected areas. Awareness building campaigns, for example, can drastically increase the carcass detection rate.

Observations on antibody positive animals

In total, 22 152 wild boar were hunted and tested for antibodies with ELISA and 574 wild boar were found dead and tested with ELISA for ASF by the national laboratories (Table 8). This antibody ELISA test (Ingezim PPA Compac, Ingenasa) is not accredited for use in haemolysed samples from wild boar, and is known to result in a high rate of false-positive animals. Since not all samples which tested positive with the antibody ELISA test were further tested with a confirmatory test in all four affected Member States (i.e. the indirect immunoperoxidase test (IPT), further calculations and comparisons of the seroprevalence were not performed. Such a comparison may overestimate the number of seropositive animals. Additionally, the sampling strategies were not harmonised in the different areas, which could result in biased inferences.

Table 8: Number of antibody ELISA tests carried out on samples from hunted wild boar or wild boar found dead in the four countries

Country	Hunted wild boar		Wild boar found dead	
	Number tested	Number positive	Number tested	Number positive
Latvia	7 443	44	143	24
Lithuania	5 892	25	15	0
Poland	7 036	226	358	58
Estonia	1 781	35	58	10
Total	22 152	338	574	92

Source: data extracted from the National laboratories from 1 February 2014 until 28 February 2015.

From January 2014 up to April 2015, the European Union Reference Laboratory (EURL) received 433 blood, serum and tissue samples collected from 237 wild boar and 108 samples obtained from 39 domestic pigs for confirmatory diagnosis. The tissue samples mainly originated from spleen (37.37 %) bone marrow (23.23 %), kidney (14.14 %), lung (7.07 %), lymph nodes (7.07 %), tonsils (5.05 %), meat (1.36 %) and other tissues (4.71 %). Of the 237 wild boar samples received, 80.17 % were analysed in parallel for ASFV genome (DNA) and antibodies to ASFV. The presence of antibodies was confirmed by IPT in 55.26 % of the wild boar. Of the domestic pig samples, 87.18% (n = 34) were confirmed as ASFV (DNA) positive and were tested for antibodies, and 44.12 % (n = 15) were positive for specific antibodies by IPT. Moreover, the wild boar samples generally had higher antibody titres than domestic pigs samples, probably as a result of the timely culling in the infected holdings. Wild boar blood samples showing the highest antibody titres had been previously diagnosed with titres over the cut-off value or were negative, by using the virus DNA detection tests (real-time PCR, according to the OIE; King et al., 2003).

Table 9: Results from samples obtained from 64 wild boar analysed by PCR and IPT at the EURL, during two periods of the ASF epidemic in Eastern EU countries

January 2014 to August 2014				September 2014 to April 2015			
PCR+		PCR–		PCR+		PCR–	
8		0		41		15	
IPT+	IPT–	IPT+	IPT–	IPT+	IPT–	IPT+	IPT–
4	4	–	–	20	21	10	5

Table 9 shows the results for 64 wild boar blood or serum samples analysed at the EURL for the presence of ASFV DNA and antibodies. The data suggest that seroprevalence increased from the first to the second period. However, comparison of these two time periods is inadvisable because sample collection was not representative of the reference wild boar population. Moreover, differentiation between a possible increase in seroprevalence due to either an increased accumulated incidence, a changing immune status of the population or a decrease in virulence of the strain would not have been possible with the available data. Such temporal inferences would need appropriately designed surveys.

Observations on PCR-positive animals

Regional differences of virus (DNA) prevalence in dead animals

In Poland and Latvia, a total of 485 animals were found dead and tested with PCR. The average virus prevalence in these animals was 58.6 % (95 % CI 54.0–63.0 %). Prevalence in Latvia was twice that in Poland (69.7 % and 35.4 %, respectively), and this difference was statistically significant (Fisher's exact test, P = 0.001). It should be pointed out that Latvia has experienced 10 times more ASF outbreaks in domestic pigs (32) than Poland (3), a finding that could be explained by the higher prevalence observed in the Latvian wild boar population and the correspondent higher viral load in the environment together with the very low biosecurity in the back yard pig sector.

Temporal variations in virus (DNA) prevalence

At the time of writing, ASF has been circulating in the four EU MS for a little more than one year. Therefore, the seasonality of the ASF detections has not yet been evaluated.

Furthermore, data submission was not randomised over the year because of differences in the intensity of sampling activities (hunting in autumn and winter), differences in vegetation cover, resulting in differences in the probability of detecting an infected carcass, and different population dynamics which could not be corrected for.

Even with the limited data available, however, the virus prevalence in the summer months was significantly different from the rest of the year. Further data exploration is provided in Appendix C but the statistical observations are inconclusive.

Table 10: Seasonal variation in ASF virus prevalence (PCR+) in hunted wild boar in Poland and Latvia from February 2014 to February 2015 and results of chi-squared test with Yates' correction

Season	ASF virus prevalence (%)					Chi-squared test with Yates' correction, P-values		
	"–"	"+"	Total	Mean	95 % CI	Spring	Summer	Autumn
Winter	4469	15	4484	0,3	0.19–0.55	0.3093	0.0001	0.1979
Spring	599	0	599	0,0	0.0–0.61		0.0171	0.1333
Summer	2162	25	2187	1,1	0.74–1.68			0.0248
Autumn	3228	18	3246	0,6	0.32–0.87			

Variations in prevalence by gender and age of wild boar

Among hunted animals, there was no significant difference in virus prevalence between males and females (mean 0.65 %, 95 % CI 0.42–0.97%, and mean 0.38 %, 95% CI 0.18–0.69 %, respectively; Fisher's exact test, P = 0.1639). However, there was evidence of age-related differences. Among the sub-sample of known age (n = 6 450), prevalence was significantly different among adults, sub-adults (n = 2 655) and piglets (n = 21) (Fisher's exact test, P > 0.02): adults 0.32 % (95% CI 0.2 0.6%), sub-adults 0.94 % (95% CI 0.6–1.4 %) and piglets 14.3 % (95% CI 3.1–36.3 %).

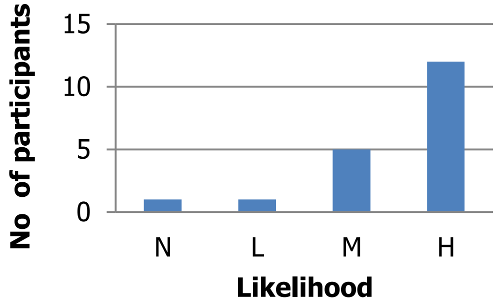
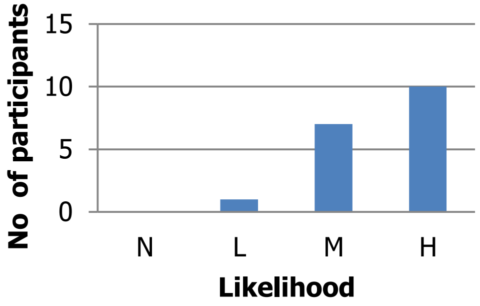
Among the animals found dead in Latvia (n = 121), there was also no significant difference in virus prevalence between males (n = 52) and females (mean 32.7 %, 95% CI 20.3–47.1 %, and mean 50.7 %, 95% CI 38.4–63.0 %, respectively; Fisher's exact test, P = 0.0635). The virus prevalence was highest in sub-adults (70.5 %, 95 % CI 61.9–78.2 %), and was significantly higher than in adults (47.7 %, 95 % CI 38.1–57.5 %; Fisher's exact test, P < 0.002), but not piglets (66.7 %, 95 % CI 44.7– 84.4 %).

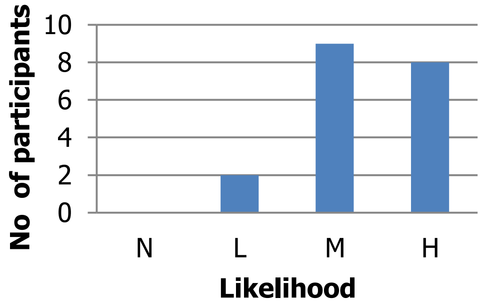
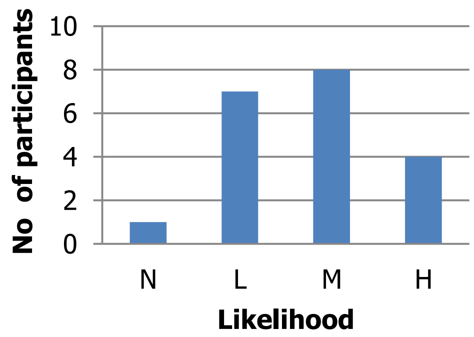
More data are needed to better understand if these age-related differences imply any difference in the epidemiological roles, in sampling rates or disease exposure risks of animals of different sex or age (e.g. dispersal of first-year males during rut, probability of contacting infected carcasses, etc.).

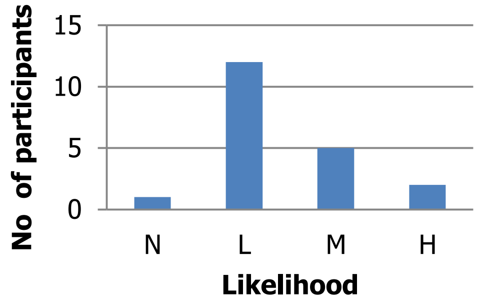
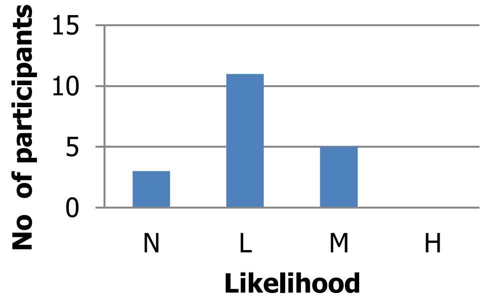
2.3.4. Expert opinion on factors contributing to further spread of ASFV between sub-populations of a wild boar meta-population

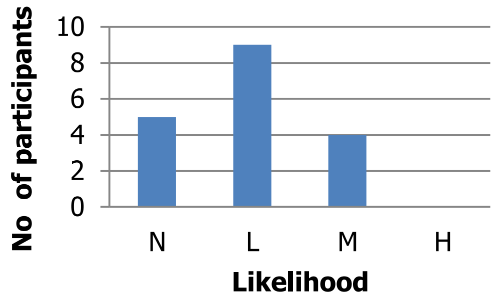
The results of the ranking and evaluation of factors possibly contributing to further spread of ASFV between sub-populations of a wild boar meta-population are shown in Table 11.

Table 11: Assessment of the likelihood that factors will lead to further spread of ASFV between sub-populations of a wild boar meta-population

Average rank	Reasons	Likelihood that factor will lead to further spread of ASFV between sub-populations of a wild boar meta-population, based on expert opinion [(a)]
Indirect contact between ASFV in environment and wild boar: contact of susceptible wild boar with infectious carcass, blood, excreta from infected animals in environment		
4.4	Most experts considered the likelihood to be high that contact of susceptible wild boar with infectious material (carcass, blood or excreta from an infected animal) in the environment will lead to further spread of ASFV between sub-populations of a wild boar meta-population. The experts also judged that the likelihood of contact between a naive boar and infectious material in the environment increases with the population density. Although wild boar do normally not scavenge on larger carcasses (unless conditions are unfavourable), small amounts of infectious blood and bloody excretions are sufficient to infect a naive boar. Further, ASFV is a very resistant virus and can survive for long time in carcasses, especially at low temperatures. One expert mentioned that carcasses do not remain in forest for long, however, as they will quickly be eaten by other wild animals and birds. These scavengers, on the other hand, could also contribute to the spread of the virus. In addition, a disrupted carcass is more attractive to wild boar.	
Direct contact between infectious and a susceptible wild boar		
4.1	Most experts considered the likelihood to be moderate to high that direct contact between an infectious boar and a susceptible boar will lead to further spread of ASFV between sub-populations of a wild boar meta-population. The experts also judged that the likelihood of contact between an infectious boar and a susceptible boar increases with the population density. The chances that this will happen can be amplified by any measures leading to aggregation of animals, such as supplementary feeding. The experts judged that wild boar are an aggregate species which live in large matrilineal groups. These family groups are quite stable and there is a little direct contact between groups. However, the home ranges of different matrilineal groups overlap. Infectious wild boar could easily infect naive boar of other family groups directly on the feeding sites. Further, long-distance movement and fast dispersal of sub-adults (yearlings) and also some females with sounders has been described (Jerina et al., 2014). However, there is no general agreement and there is high uncertainty about the distance these animals might travel. The experts reasoned that it is very likely that an infected wild boar will have contacts with other animals in a group before the disease will reach the peak stage. However, they judged that virus transmission through aerosol, saliva, etc., is not as efficient as transmission through ingestion of blood or meat.	

Average rank	Reasons	Likelihood that factor will lead to further spread of ASFV between sub-populations of a wild boar meta-population, based on expert opinion [(a)]
Indirect contact between ASFV in environment and humans: contact of susceptible wild boar with contaminated material spread by humans, such as dumping of swill, tourism, offal left behind by hunters		
3.8	The experts judged that the likelihood is moderate to high that contact of susceptible wild boar with ASFV-contaminated material spread by humans (such as dumping of swill, tourism, offal spread by hunters in the environment) will lead to further spread of ASFV between sub-populations of a wild boar meta-population. It was suggested that this is the most important factor leading to spread of ASFV over long distances and that this is mostly due to transportation of infected pigs or pork and other contaminated materials, and less to tourism and hunting. The long survival of the virus in fomites facilitates the spread of ASFV, leading to indirect contact transmission. One expert stated that very low doses of ASFV may be sufficient to infect a wild boar orally, but studies with contaminated meat found that ingestion of sausages, etc. did not result in infection Human-related spread of ASFV has been observed in Russia, resulting from improper disposal of infected domestic pigs or wild boar carcasses by pig farmers (Gogin et al., 2013; Oganesyan et al., 2013). The great importance of public awareness was stressed by many experts as well as the social background of the farmers or other stakeholders involved in respecting the sanitary measures. Given an example, it is forbidden for pig farmers to take home hunted wild boar, though this rule has not always been respected by backyard farmers.	
Depopulation efforts (e.g. more than 70 %, leading to dispersal of wild boar		
3.3	The answer of the experts on the role of wild boar depopulation efforts in spread of ASFV between sub-populations of a wild boar meta-population was heterogenous. This because some experts judged instead the feasibility of the measure of 'depopulation'. Depopulation, i.e. reducing the boar population by more than 70 %, would involve intense and frequent drive hunt campaigns, and some experts considered it unlikely that depopulation of more than 70 % over a short time period can be achieved at all. Further, this type of spread would require continuous wild boar population habitat (connected sub-populations). But if depopulation efforts are undertaken (i.e. intense and frequent drive hunt campaigns in connected wild boar meta-populations), it is considered that the likelihood is high that this will lead to increased dispersal of wild boar, and possibly disease spread. Some experts gave examples where this phenomenon has been observed for classical swine fever (CSF) and other infectious diseases. Recent attempts to reduce wild boar populations in Russia and Belarus, in fact, led to an increase in ASFV spread (FAO, 2013; Oganesyan et al. 2013), including to the EU. On the other hand, one expert also reasoned that occasional drive hunts/battues do not provoke long-distance and long-term movement of wild boar outside the home range (see Keuling et al., 2008; Thurfjell et al., 2013). Furthermore, the distances (< 20 km) covered by hunted wild boar seem to be much less than those travelled during self-occurring dispersal of sub-adults and some sounders (e.g. Jerina et al., 2014). However, the same expert considered that occasional battues will not lead to depopulation, and more frequent and intense depopulation campaigns would probably cause more dispersal of wild boar.	

Average rank	Reasons	Likelihood that factor will lead to further spread of ASFV between sub-populations of a wild boar meta-population, based on expert opinion [(a)]
Targeted soft hunting (targeting more females)		
2.5	It was judged by most experts that targeted individual hunting (targeting more females) would have only low likelihood of leading to spread of ASFV to other wild boar sub-populations. Although individual hunters can disturb wild boar through their presence, the experts judged that this type of hunting is not likely to cause serious disturbances of the population and the social organisation. The experts considered, however, that the alteration of the population structure by harvesting large numbers of leading, "alpha", sows may affect the movements of sounders and, consequently, lead to increased contact rates. However, data on this subject are rather scarce, and it is unlikely that the young animals will move large distances. The experts considered that the effective long-term reduction in the number of females will stabilise the wild boar population in the area (halt an increase in the population), and thus will also reduce the spread of the disease in the long term. In line with the above observation on drive hunts, one expert reasoned that, based on GPS observations, wild boar will return on the same or the next day to their home range after individual hunting. The use of traps was suggested by one expert to facilitate targeted hunting on females.	
Non-targeted soft hunting (e.g. individual hunters, tower hunting)		
2.1	Most experts considered that non-targeted individual hunting would only have a low likelihood of leading to further spread of ASFV between sub-populations of a wild boar meta-population. With this type of hunting, mostly juveniles (piglets, also some yearlings) are harvested, and therefore it does not modify the population structure. It would not provoke any moderate- to long-distance movement of wild boar. In line with the above observation on drive hunts, one expert reasoned that, based on GPS observations, wild boar will return on the same or the next day to their home range after individual hunting. It was also considered that inappropriate hunting practices could lead to higher disturbance of the structure and social organisation of the wild boar population.	

Average rank	Reasons	Likelihood that factor will lead to further spread of ASFV between sub-populations of a wild boar meta-population, based on expert opinion [(a)]
Ticks (bites by infectious ticks)		
1.7	Until now, *Ornithodoros* species have *not* been reported in the affected EU countries and, even if they were present, an association with wild boar is very unlikely. Further, considering their biology, their role in the spread of the disease would be minimal, as they feed for only very short periods. The experts considered that the likelihood that ticks would lead to further spread of ASFV between sub-populations of a wild boar meta-population is negligible to low.	

N, negligible; L, low; M, moderate; H, high.

2.4. Discussion

More than a year after the introduction of ASF in the eastern EU, the disease continues to spread slowly through the wild boar populations in these countries. In contrast, ASF outbreaks in the domestic pig holdings in the affected EU countries have been resolved efficiently. The implemented measures appeared to efficiently control and prevent further spread in the domestic pig population. Based on the currently available data, ASFV spread in the wild boar population seems to be independent of the density of the wild boar populations. Therefore, the introduction of ASFV into a new region is the most critical part of the disease epidemiology, particularly if the infection pressure remains high in neighbouring areas.

The introduction and transboundary spread of ASFV has occurred through wild boar sub-populations, given the location of hotspots of notifications near the EU border, and the single and multiple introduction of the virus in the affected EU countries though infected wild boar.

The sudden long-distance spread of ASFV is most probably the result of human involvement, e.g. through movement of infected pigs or of meat or products of infected pigs or wild boar (e.g. hunting trophies), rather than direct transmission of ASFV between wild boar. Furthermore, it seems that most of the spatio-temporal clusters of ASF notifications in the EU emerged during the period when ASF outbreaks in domestic pig holdings were observed. This is also consistent with human involvement in the spread of the disease. There have been no reports of direct contact between wild boar and domestic pigs which could have resulted in the direct introduction of ASF into domestic pig holdings. It is more likely that the introduction ASFV in backyard farms is the result of poor levels of biosecurity, e.g. feeding of kitchen waste or feeding of contaminated grass.

It should be stressed that hotspots of notifications should not be confused with hotspots of disease prevalence. Many carcasses of infected wild boar are not found or notified, as reflected in the carcass detection rate. Additionally, the density of the wild boar population may influence the probability of detection of infected wild boar or their carcasses. It can be expected that a lower wild boar density would result in a lower carcass detection rate. Based on available data, however, a lower wild board density does not necessary lead to disease fade out.

The analysis of the data provided has clearly shown the higher efficacy of passive versus active surveillance to detect ASFV-infected animals. Nonetheless, data from passive surveillance should be interpreted with caution, especially when comparing prevalences between regions.

When carrying out seroprevalence surveys, it is necessary to use appropriate serological tests, including the use of accredited confirmatory tests, in order for achieve homogeneity, which is crucial for maintaining validity when comparing different sets of results. Furthermore, the use of harmonised sampling schemes with sufficiently large sample size is also essential. The latter is especially important considering the generally low ASFV prevalence.

It seems that ASF in summer is different, which is in partial agreement with patterns reported previously (FAO, 2013). There are two peaks of observed disease detections, one during the cold (December–February) months and another in the warm months (May–July) of the year. However, the winter peak of notifications could be driven by human activity patterns while the summer spike is intrinsic to the epidemiological system.

It seems that, as the range of ASF continued to expand to the zone of temperate forests in 2012–2015, the summer peak in disease detections also became increasingly evident, particularly in the Russian Federation in 2012–2014. Although this might be due to the seasonal biases in surveillance efforts (e.g. targeted hunting in the infected area in summer and reporting of a large number of shot positive animals; Dudnikov et al., 2012), it should be noted that most summer detections of ASF in wild boar in the Russian Federation during this period were spatially and temporally associated with outbreaks in backyards farms and might have been due to multiple disease spill-overs from domestic pigs.

Finally, the experts were asked to provide their opinion on possible factors that may contribute to further spread of ASFV to connected wild boar sub-populations and to rank these factors according to their importance. As a result of this exercise, the spread of the infection through indirect contact with infectious material in the environment (such as infected wild boar carcasses or blood) was considered to play the most important role in the spread of the disease. However, direct contact was also considered to be very important, especially in situations where wild boar groups are gathered, e.g. at artificial feeding places. Infected material that is dispersed by humans can also play an important role in the spread of the disease. In terms of different hunting strategies, frequent and intensive drive hunts were considered to play the most important role in the spread of the disease, in contrast to individual contact-based hunting, which, according to the experts, does not result in increased dispersal of the wild boar, and would be less likely contribute to spread of ASFV.

2.5. Conclusions

- In the four affected EU countries, there is currently no evidence that the virus persists in backyard farms. The emergence of most new clusters of notifications (hotspots) of ASF cannot be explained by direct contact because of the long distances between these clusters.
- Spread of ASFV to new areas which could not be related to wild boar movement occurred mostly during periods of outbreaks in domestic pig populations.
- So far, no correlation between the density of wild boar in an area and the number of case notifications has been observed.
- The current epidemiological picture of ASF in the EU suggests that ASF spreads locally in the wild boar population, independent of outbreaks in domestic pigs.
- Notifications of ASF in domestic pig holdings have all occurred in areas of suitable wild boar habitat.
- Infections in backyard farms were related to practices such as feeding of contaminated grass or kitchen waste, rather than direct contact between wild boar and domestic pigs
- Passive surveillance is more effective than active surveillance in detecting ASFV-infected wild boar or domestic pigs. All primary ASF outbreaks in pig holdings or cases in wild boar have been found by passive surveillance.
- It was estimated that less than 10 % of infected wild boar carcasses are found. Variation patterns suggest that factors other than disease dynamics or abundance of animals determine how many dead carcasses are discovered in the ASF-affected areas.
- There is no significant difference in ASF (PCR positive) prevalence between males and females.
- The highest virus prevalence (70.5 %, 95 % CI 61.9–78.2%) is in dead sub-adults, and is significantly higher than in adults.
- Most experts considered there is a high likelihood that between susceptible wild boar and infectious material (e.g. blood, carcass or excreta from an infected animal) in the environment will lead to further spread of ASFV between sub-populations of a wild boar meta-population.
- Most experts considered there was is a moderate to high likelihood that direct contact between wild boar will lead to further spread of ASFV between sub-populations of a wild boar meta-population, especially in places where animals gather, such as feeding places.
- The experts judged that there is a moderate to high likelihood that contact between susceptible wild boar and ASFV-contaminated material spread by humans (such as dumped swill, or offal spread by people in the environment) will lead to further spread of ASFV between sub-populations of a wild boar meta-population.
- Experts considered that very intense and frequent drive hunts during depopulation campaigns are lead to the movement of wild boar and possible spread of ASFV between sub-populations of a wild boar meta-population.

2.6. Recommendations

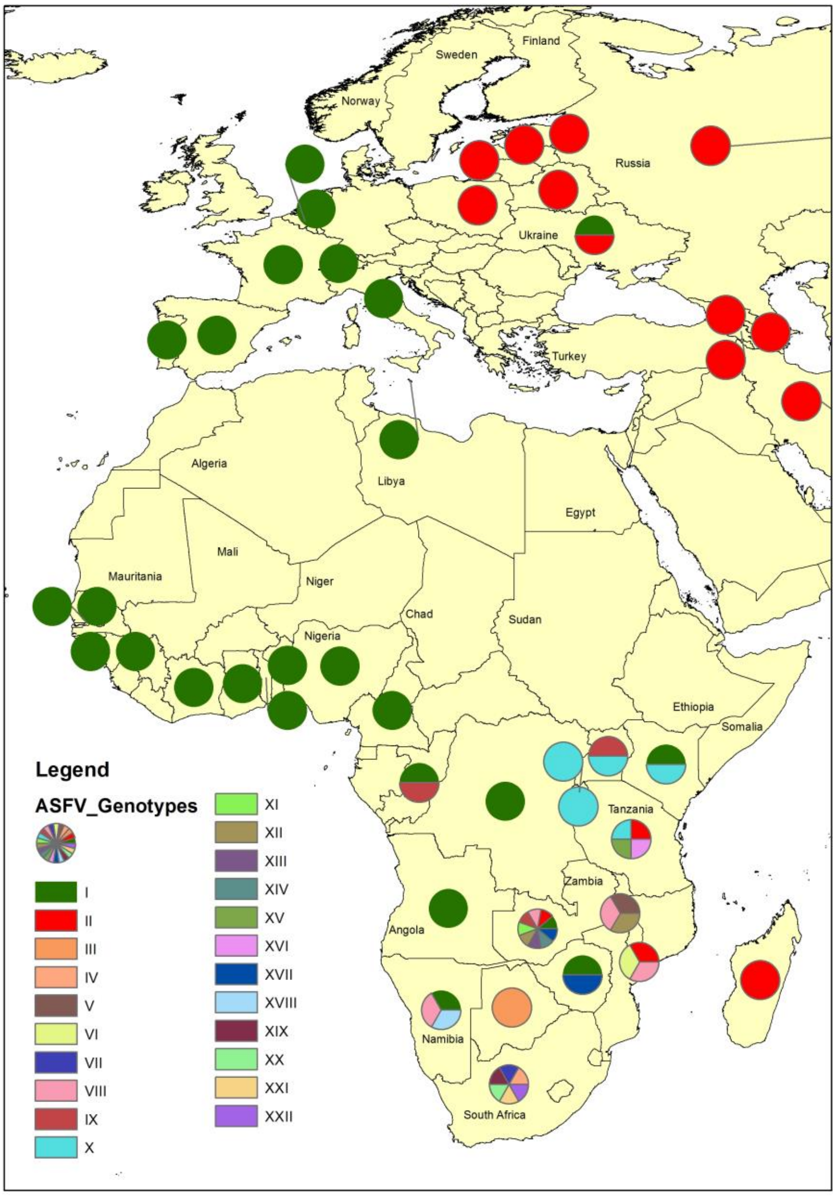
- Avoid the artificial concentration of wild boar, e.g. through feeding.

- Increase the awareness of hunters and involve them in the control of the disease, i.e. by avoiding virus dissemination through good practice.
- Increase the awareness of hunters, forest rangers and people visiting forests of the role of carcasses in the spread of ASFV and promote the notification of carcass locations to enable their appropriate removal.
- To enable regional risk assessment and comparison of prevalence data, harmonised surveillance and data collection in domestic pigs and wild boar in high risk areas in the four affected EU Member States is a prerequisite.

3. Assessment of the possible risk of spread of ASF genotype II strains currently or recently circulating in eastern Europe by pigs or wild boar becoming "carriers" and the role of non-symptomatic carriers in virus transmission (ToR2)

The ASFV genotype II strain was the first to be identified from an outbreak of ASF in Lusaka, Zambia (LUS 93/1), and subsequently in Madagascar (1998 after introduction in 1997), Mozambique (1998 and subsequently), southern Tanzania (2010) and after introduction to Mauritius (2007) (Rousset et al., 2001; Bastos et al., 2004; Lubisi et al., 2005, 2007; Boshoff et al., 2007; Misinzo et al., 2012; Uttenthal et al., 2013). The historical distribution of ASFV genotypes from 1957 to date is illustrated in Figure 12.

Current available molecular data generated by using standardised genotyping procedures (Gallardo et al., 2009) indicate the presence of only one genotype, the p72 genotype II, in eastern European countries. This genotype has been circulating in eastern Europe since the introduction of ASFV into Georgia in 2007 (Rowlands et al., 2008; Malogolovkin et al., 2012). Deeper molecular analysis of a variable region between I73R and I329L genes, characterised by the presence of tandem repeat sequences (TRS), has showed the presence of two variants of this genotype II in virus circulating in the eastern European countries (Gallardo et al., 2014a).



Modified from Costard et al., 2009.

Figure 12: Historical distribution of African swine fever virus genotypes, from 1957 to 30 June 2015

p72-Based genotyping is a molecular tool used to identify the origin of viruses during ASF outbreaks and to trace the spread of the infection. Conventional ASFV genotyping, however, is not informative in terms of virus virulence.

3.1. Methodologies

To determine whether carriers of the ASFV strains that are currently affecting the wild boar populations in eastern Europe may occur and to assess their possible contribution to the spread and long-term circulation of ASFV, a review of published and unpublished information on ASFV infections in both pig and wild boar populations was carried out. Observations from studies looking at the course of the infection through experimental infections in pigs or wild boar were summarised and observations from studies in which samples collected from pigs or wild boar during field surveys were subsequently analysed using serological and molecular (PCR) tests were summarised.

3.2. Assessment

3.2.1. Description of experimental infections with ASFV genotype II strains currently circulating in eastern European countries

Several experiments have been performed to characterise the virulence and the clinical appearance of infections caused by genotype II ASFV isolates which have been circulating in eastern Europe in wild boar and domestic pig populations since 2007 (Gabriel et al., 2011; Blome et al., 2012, 2013; Gallardo et al., 2014b, 2015; Guinat et al., 2014; Vlasova et al., 2015).

From the experimental trials using genotype II ASFV isolates collected over a seven-year period in Europe (most of them from 2007–2012), it can be concluded that the ASFV strain affecting the eastern European countries is highly virulent and induces an acute form of ASF which results in a mortality rate of 94.5–100 % in both wild and domestic pigs, and generally in a short time (within 36 days). Most of these animals die prior to the development of measurable ASFV-specific antibodies (Gabriel et al., 2011; Blome et al., 2012, 2013; Guinat et al., 2014). Experimental infections with recent ASFV isolates (2013 and 2014) also result in an acute form of the disease, with animals dying within the second and third weeks post infection. Antibodies are detected in up to 33 % of infected animals, either in serum or in tissue exudates (Gallardo et al., 2014b, 2015; Mur et al., 2014; Pietschmann et al., 2015).

Gallardo et al. (2014b, 2015) reported that, of 10 pigs experimentally infected with ASFV, only one remained asymptomatic throughout the experiment and survived the infection. This animal showed weak and intermittent peaks of viraemia. ASFV DNA was detected at values above the cut-off in 9 out of 20 tissues examined up to 61 days post infection (dpi) (end of experiment) although virus isolation was not achieved. Thus, so far, out of all experiments recently carried out with the circulating genotype II ASFV isolates in eastern Europe, only one animal has been able to remain sub-clinically infected (Gallardo et al, 2014b, 2015), but shedding of these isolates by carriers has not been yet studied.

3.2.2. Observations on possible shedding of ASFV by experimentally infected animals

A review was carried out to investigate if shedding by carriers of any genotype has been demonstrated in the past. Table 12 illustrates that shedding by carriers and transmission has been demonstrated for the lowly virulent virus NH/P68 strain for more than three months post infection (Gallardo et al., 2014b). A recent phylogenetic study hypothesises that the low-virulence strain NH/P68 is likely to have originated from a vaccine virus dispersed in Portugal in the early 1960s (Portugal et al., 2015).

de Carvalho Ferreira et al. (2012, 2013) studied the infectiousness of two moderately virulent virus isolates (Malta 1978 and Netherland 1986). DNA was detected in the oropharyngeal fluid at levels above the cut-off value (1.92) for up to 70 days post inoculation. The authors calculated a minimum infection period that ranged from six to seven days and an average maximum infectious period ranging from 20 to 40 days.

Table 12: Experimental infections investigating transmission to in-contact animals

ASFV strain	Route/doses	Inoculated animals				Animals in contact					Reference
		No of animals	No shedding	Maximum days shedding (dpi)	No of seropositive survivors	No of animals	Moment of contact (0 dpi = day 0)	No of days in contact	No infected	No of seropositive survivors	
Genotype II 2008 isolate from Armenia	Oral/2 mL of a spleen suspension containing 10^6 median tissue culture infectious dose (TCDI) ASFV/mL	6	5	7	0	NA	NA	NA	NA	NA	Gabriel et al., 2011
Genotype II 2009 virus isolate from the Chechen Republic	Intramuscular/1 ,000 HAD_{50}	4	NK (died 5 dpi)	NK	0	NA	NA	NA	NA	NA	Gabriel et al., 2011
Genotype II ASFV Caucasus isolate	Oral/3 × 10^6 50 % tissue culture infectious dose	4	NK (died 8–9 dpi)	NK	0	NA	NA	NA	NA	NA	Blome et al., 2012
Genotype II Georgia 2007/1 ASFV strain	Intramuscular/10^2 HAD_{50}	16	NK (euthanised by day 9–18 dpi)	NK	0	16	At day 0	9–18	16	0	Guinat et al., 2014
Genotype II LT14/1490 (Lithuania, high virulence)	Intramuscular/10 HAD_{50}/mL	8		Seven animals died or were euthanised between 7 and 9 dpi, one died between 14 and 22 dpi	0	10	At day 0	14–22	10	One animal survived up to 61 dpe	Gallardo et al., 2014b, 2015
Genotype II "Armenia08"	Oronasal/10 HAU	12	12	Disease course in individuals lasted 7–12 days	0	NA	NA	NA	NA	NA	Pietschmann et al., 2015
	Oronasal/100 HAU	12	6	Mortality reached 100 % in group at 30 dpi							

ASFV strain	Route/doses	Inoculated animals				Animals in contact					Reference
		No of animals	No shedding	Maximum days shedding (dpi)	No of seropositive survivors	No of animals	Moment of contact (0 dpi = day 0)	No of days in contact	No infected	No of seropositive survivors	
Genotype II Kashino 04/13	Intramuscular/ intranasal/5.0 lg HAD_{50}/cm^3	4	NK	Animals died between 9 and 22 dpi	?	2	At day 6	NK	NK	NK	Vlasova et al., 2015
Boguchary 06/13	Intramuscular/ intranasal/5.0 lg HAD_{50}/cm^3	6		Animals died between 9 and 12 dpi		2					
Karamzino 06/13	Intramuscular/ intranasal/4.5 lg HAD_{50}/cm^3	6		Animals died between 11 and 22 dpi		2					
Vyazma 08/13	Intramuscular/ intranasal/5.0 lg HAD_{50}/cm^3	6		Animals died between 8 and 15 dpi		2					
Genotype II Kashino	Oronasal/50 HAD	1		Died on 21 dpi	1	2	At day 0	19–21	2	2	Mur et al., 2014
Genotype II Karamzino	Oronasal/5 000 HAD	2		21	0	1	At day 0	20	1	0	Mur et al., 2014
	Oronasal/50 HAD	1			1	2	At day 0	19	2	2	Mur et al., 2014
Lazarevskoe	Intramuscular/5000 HAD	2		9	0						
	Oronasal/50 HAD	2		16	0						
	Oronasal/5000 HAD	1		17	1						
Genotype I NHVP68	Intramuscular/10^5 $TCDI_{50}$	4	NK	NK	2 (2 out 4 previously slaughtered to evaluate virus presence tissues at different times pi	2	At day 65	62	2	2 (virus was detected in blood 28–35 dpe)	Gallardo et al., 2014a
Brazil'78 (moderately virulent)	Intranasal/4.5 log_{10} $TCID_{50}$	10	10	10 [(a)]	0	0	At day 0	NA	NA	NA	de Carvalho Ferreira et al., 2012, 2013
Malta'78 (moderately virulent)	Intranasal/3 log_{10} $TCID_{50}$	3	3	70 [(a)]	3 (until 70 dpi, at the end of the experiment)	7	At day 0	70 [(a)]	7	2	de Carvalho Ferreira et al., 2012, 2013

ASFV strain	Route/doses	Inoculated animals				Animals in contact					Reference
		No of animals	No shedding	Maximum days shedding (dpi)	No of seropositive survivors	No of animals	Moment of contact (0 dpi = day 0)	No of days in contact	No infected	No of seropositive survivors	
Malta'78 (moderately virulent)	Intranasal/4 log_{10} $TCID_{50}$	5	5	70 [(a)]	4 (until 70 dpi, at the end of the experiment)	5	At day 0	70 [(a)]	5	4	de Carvalho Ferreira et al., 2012, 2013
Netherlands'86 (moderately virulent)	Intranasal/3.5 log_{10} $TCID_{50}$	3	3	70 [(a)]	3 (until 70 dpi, at the end of the experiment)	7	At day 0	70 [(a)]	7	1	de Carvalho Ferreira et al., 2012, 2013
Spain 1980 Isolate from infected farm	NA	NA	NA	NA	3	4	6 months after diagnosis in farms	6–9 months after diagnosis	0	NA	Ordás et al', 1981
Malta/78 (moderately virulent)	Intranasal/10^4–10^5 HAD_{50}	1	1	13	1	2	At day 6	12–18 dpi	1	NK	Wilkinson et al., 1981
Malta/78 (moderately virulent)	Intranasal/10^4–10^5 HAD_{50}	1	1	28	1	2	Between day 2 and	19–28 dpi	2	NK	Wilkinson et al., 1981
Malta/78 (moderately virulent)	Intranasal/10^4–10^5 HAD_{50}	1	0	–	1	2	Between day 3 and 40	29–69 dpi	0	NA	Wilkinson et al., 1981
Genotype VIII [MOZ 1/98] and genotype II	Intramuscular and intranasal/10^4 HAD_{50}	66 (VIII)	NK (all but one died by 19.5 dpi)	NK	1 (genotype II)						
[MAD 1/98] from infected farms in Mozambique		39 (II)				The pig that survived infection with genotype II virus was placed in contact about 21 dpi with a pig that had survived inoculation with both genotype II and genotype VIII ASVF and was seropositive and healthy; the two pigs were in contact for approximately one year and at necropsy neither showed and lesions or presence of ASV DNA but remained serologically positive					Penrith et al., 2004

ASFV strain	Route/doses	Inoculated animals				Animals in contact					Reference
		No of animals	No shedding	Maximum days shedding (dpi)	No of seropositive survivors	No of animals	Moment of contact (0 dpi = day 0)	No of days in contact	No infected	No of seropositive survivors	
Isolate from infected farm **Spain 1980**	NA	NA	NA	NA	47 (three animals died at eight months of isolation of acute ASFV infection)	NK	NK	1 year	0	NA	Vigario, 1980
Brazilian ASFV isolate	NK	9	NK	Only blood samples, max. VI until 39 dpi	5 (max. until 135 dpi)	5	135	NK	0	NA	Mebus and Dardiri, 1979, 1980
	Same group as above as donor animals					2	149	NK	0	NK	Mebus and Dardiri, 1979, 1980
Dominican Republic ASFV isolate	NK	10	NK	NK	7	NK	124	NK	0	NK	Mebus and Dardiri, 1979, 1980
Dominican Republic ASFV isolate	Same group as above as donor animals					5	110	NK	0	NK	Mebus and Dardiri, 1979, 1980

NK, not known; NA, not applicable; VI, virus isolation; dpi, days post inoculation; dpe; days post exposure. HAD_{50}, hemadsorbing units 50%
(a): End of observation period.

3.1. Discussion

Several researchers have reviewed the role of carriers in the epidemiology of ASF (Hess, 1981; Sanchez Botija; 1981; Arias and Sanchez-Vizcaíno, 2002). Although evidence of transmission by long-term carriers in the field has not been obtained, experimental studies have demonstrated transmission of low-virulence ASFV strains from both field carriers and experimental seropositive surviving pigs to susceptible pigs up to three months after inoculation (Gallardo et al., 2014b). In addition, evidence of apparently healthy seropositive pigs surviving past ASF outbreaks in different parts of the world is abundant. In order to become an effective carrier of ASFV according to the definition of 'carrier' agreed in section 1.2, a wild boar would require the following characteristics:

1) the ability to recover fully from infection with ASFV (i.e. not just to survive long enough to be found to be antibody positive), which would require inhibition of viral replication;
2) the ability to remain a reservoir of infective (i.e. viable) virus, i.e. virus replication inhibition would not result in elimination of the virus, which would be retained at least in lymphoid tissues, probably primarily lymph nodes and spleen;
3) the ability to at least periodically shed infective quantities of virus, which would involve developing sufficiently high viraemia.

Studies on resistant bushpigs (Oura et al., 1998a) have indicated that ASFV targets monocyte–macrophages, but replication of ASFVis markedly inhibited. Therefore, destruction of macrophages with massive release of cytokines, which have been shown to be important in the pathogenesis of the disease, does not occur (Oura et al., 1998a, b). The immune mechanism involved in minimising replication has not been identified with certainty, but Oura et al. (1998b) suggested that a 'host evasion gene' encoded by ASFV that downregulates the release of pro-inflammatory cytokines (Powell et al., 1996) but which does not protect the domestic pig functions more efficiently in bushpigs and warthogs. It seems reasonable to suppose that increased resistance in individual wild boarsboar and domestic pigs may be due to the same mechanism.

ASFV has been demonstrated to persist in tissues for several months and can be infectious in susceptible animals fed with the meat (Mebus and Dardiri, 1980). The virus is likely to persist longest in lymphoid tissues (lymph nodes and spleen, tonsils), where the highest concentration of suitable macrophages is found. Persistence in bone marrow is possible, but the published data refer to frozen bone marrow, not live animals. Oura et al. (1998a) demonstrated persistence of the virus in lymphoid tissues for up to 48 days dpi, while Wilkinson et al. (1981, 1983), Hamdy and Dardiri (1984) and Wilkinson (1984) found virus in lymphoid and some other tissues for six months.

Finally, there are several mechanisms, in addition to the presence of carrier animals, that can lead to long-term circulation of ASFV in pig or wild boar populations. The most important factors are human induced, such as illegal movements of infected pork meat and swill feeding (Sánchez-Vizcaíno et al., 2012, 2013; Empress Watch, 2013; Gogin et al., 2013; Gulenkin et al., 2011; Oganesyan et al., 2013; EFSA, 2014; Korennoy et al., 2014; Iglesias et al., 2015), as well as free-range pig management systems. Furthermore, the interaction between wild boar and domestic pigs can prolong ASF circulation in both swine populations, as observed in many outbreaks in the Russian Federation and Sardinia (FAO, 2013). Close contact between wild boar and backyard or free-ranging pigs is proved by the presence of mixed offspring (FAO, 2013). Additionally, ASF cases in the wild boar and domestic pig populations in the Russian Federation were closely related in term of time–space occurrence (Gogin et al., 2013). The role that ticks play in the prolongation of ASFV circulation is discussed in section 3.3.2.

3.2. Conclusions

- As yet, no scientific data have demonstrated the presence in the eastern EU of carrier pigs infected with ASFV genotype II and capable of intermittent viral shedding.
- Intermittent viraemia following survival from experimental inoculation with genotype II ASFV has been observed in one animal and DNA could be identified in tissues for 61 days post infection.

- Even if there are no carriers, there are several mechanisms that can lead to long-term circulation of ASFV in pig or wild boar populations The most important factors are human induced, such as illegal movements of infected pork meat, low biosecurity levels in pig holdings and aggregation of wild boar promoted by feeding.
- ASFV has been demonstrated to persist in tissues for up to six months and can be infectious for susceptible animals fed with the meat.

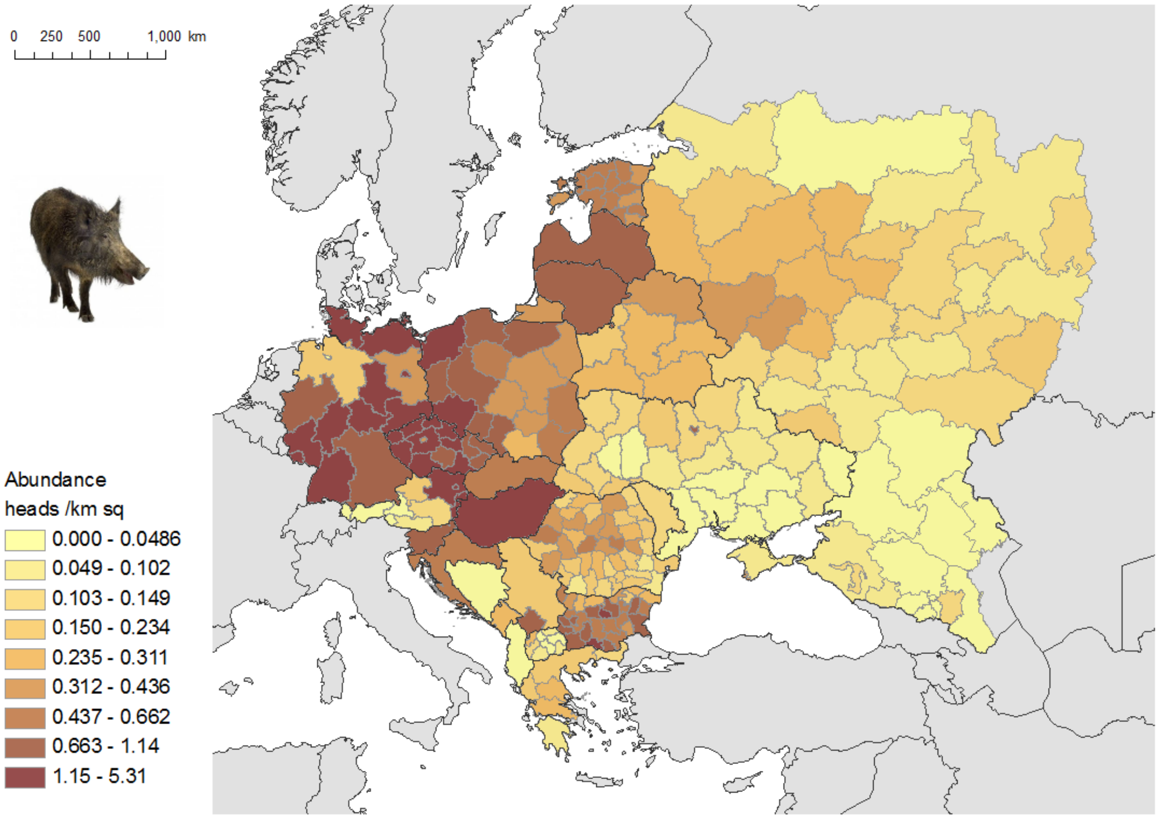
3.3. Recommendations

- More research is needed to clarify the potential existence of carriers of genotype II and the role they may play in the ASF epidemiology in eastern Europe
- More research is needed to better understand the possible mechanism leading to change in virulence of the virus:
  - animal experiments studying long-term survivors/carriers; oral infections using tissue samples from carriers or studying indirect transmission mechanisms
  - immunological experiments focusing on cellular responses after ASFV infection.

4. Trends in wild boar population dynamics in the EU and its eastern neighbouring territories (ToR3)

4.1. Data

Figure 13 shows the wild boar abundance based on the national wildlife statistics.



See Appendix D for details of sources.

Figure 13: Wild boar population abundance (head per km^2) based on available population estimates

4.2. Methodology

The trends in wild boar population dynamics in the EU are described and graphically displayed based on data collected from published information and data from game management institutions in different countries.

4.3. Assessment

4.3.1. Relative abundance of wild boar in eastern European countries

There is a south to north gradient in wild boar relative abundance in the eastern European countries, which is apparent in Figure 13. The population densities in these countries are relatively moderate on a European scale, going from low (less than 0.2 wild boar per km^2) in Ukraine to moderate in Belarus and in the central and north-western parts of the Russian Federation (0.3–0.4 head per km^2).

In the Baltic countries and Poland (Figures 3 and 18), population densities are higher than in Belarus and Russia. The density increases from Estonia (0.1–0.17 per km^2) towards Poland, which has the highest density of the affected EU countries (0.5–0.6 head per square km). It should also be noted that these are average densities, but there is a high variation between regions in each country.

Additionally, according to some media reports, depopulation campaigns carried out in some regions in Belarus and the Russian Federation may have altered these figures (available online: http://www.otr-online.ru/news/news_22564.html and http://www.otr-online.ru/news/news_22564.html)

4.3.2. Temporal trends in harvested wild boar

A review of wild boar population trends carried out in the 1980s showed simultaneous increases in wild boar numbers in several European countries from the 1960s to 1980s, with a sharp increase in growth rate between 1965 and 1975 and a stabilisation in numbers in the following decade (Saez-Royuela and Telleria, 2008).

A recent publication by several authors from different wildlife management institutions in 18 European countries describes wild boar population trends in European countries over the last three decades (Massei et al., 2015). Throughout Europe, hunting is the main cause of mortality in this species. The paper also compared wild boar trends with hunter population trends in the same timeframe and discussed the implications of wild boar and hunter population trends for the mitigation of human–wild boar conflicts (Massei et al., 2015). These wild boar population trends are shown in Figure 14. Wild boar population estimates are based on hunting bags provided by local and national hunters associations or by focal points (academic and research institutions, local authorities, etc.). The accuracy of population estimates based on hunting bags could vary significantly between countries, but it was assumed that potential biases would be relatively constant within each country over time and that the hunting bags estimates would provide the best available indicators of wild boar population temporal trends (Figure 14).

In general, wild boar numbers have increased in all European countries, as has their impact on crops and road traffic accidents (Massei and Genov, 2004; Massei et al., 2011).

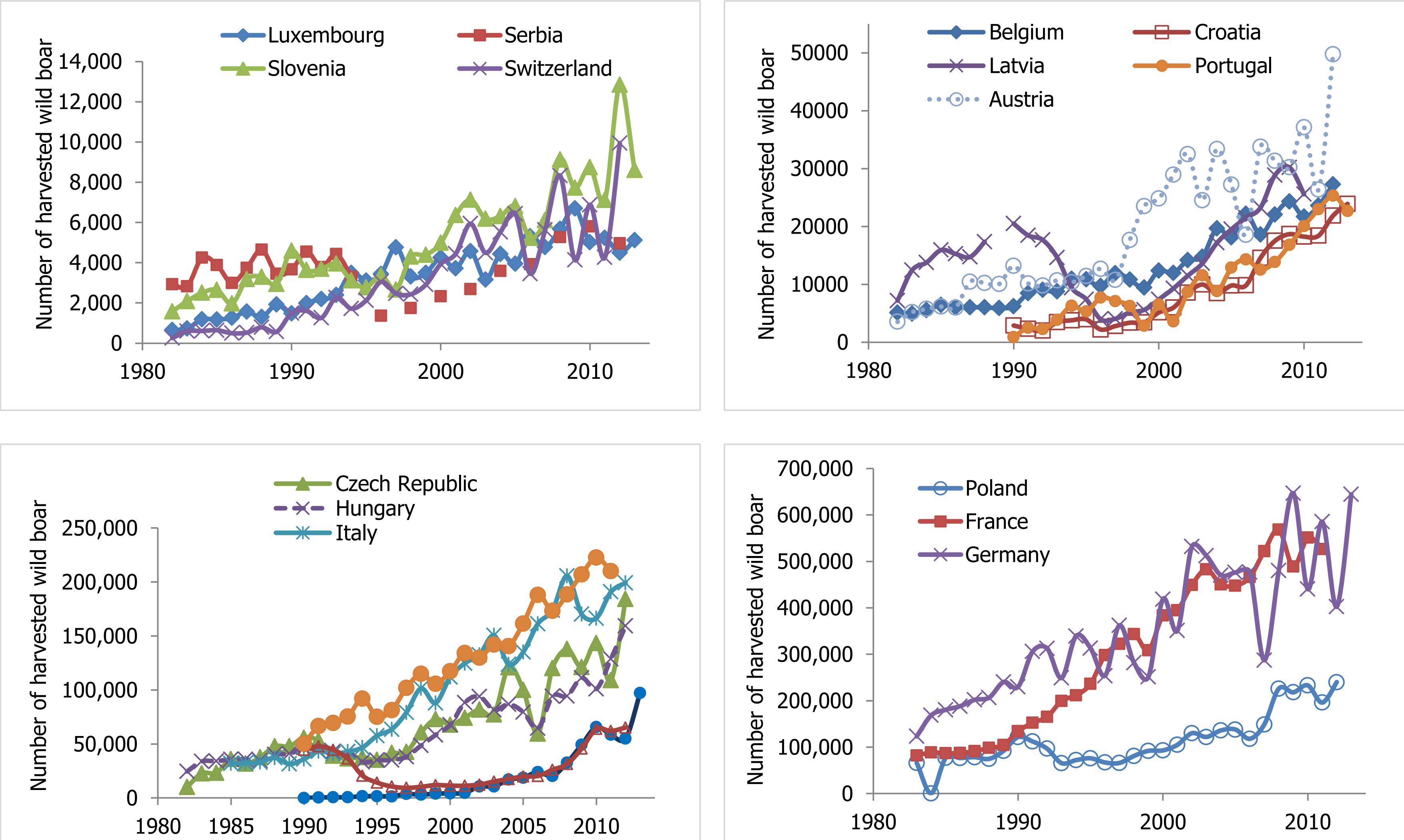


Figure 14: Wild boar hunting bags from selected European countries

These trends can be attributed to a combination of species-specific biological factors such as the very high reproductive output, behavioural and dietary plasticity and dispersal potential, as well as other changes linked mostly to human activities, which include changes in agro-forest land use, deliberate releases for sport hunting, supplementary feeding, habitat alteration due to human activities, lack of large predators and mild winters, which improve survival.

In the same publication by Massei et al. (2015), an index of annual and quinquennial population growth rate for the 1983–2012 period was estimated for each country by dividing the number of wild boar harvested in one year by the number harvested the previous year (Figure 15).

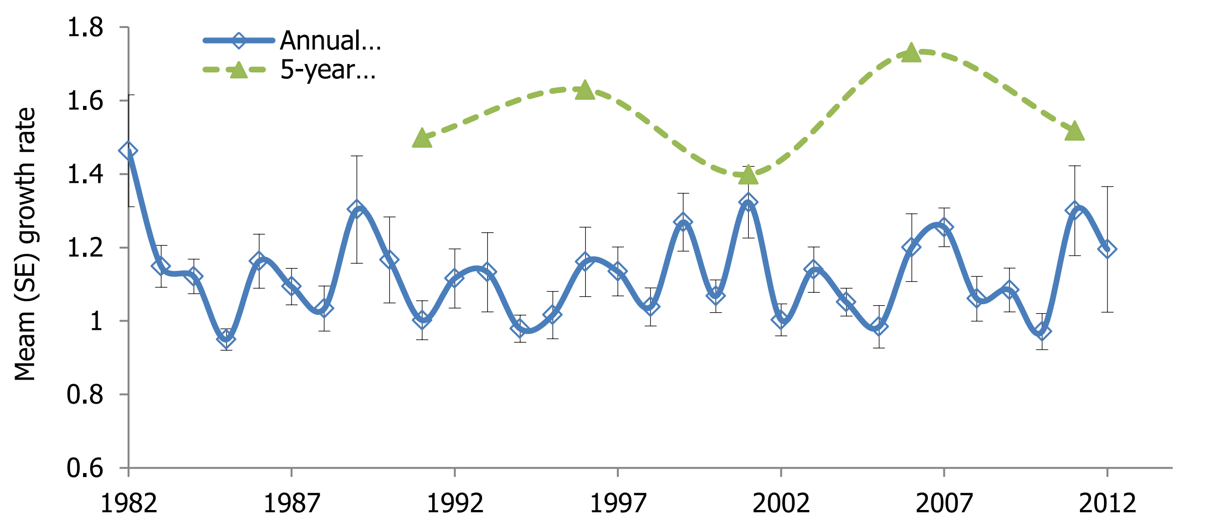


Figure 15: Mean (SE) estimated growth rate of wild boar populations in Europe, derived from hunting bag statistics calculated for each country and averaged across 18 countries

The review showed the continued growth of wild boar numbers throughout Europe between 1982 and 2013. Although numbers are expected eventually to stabilise, the average growth rate index, expressed as annual or quinquennial rate, has consistently exceeded 1 over the past three decades. This growth in the number of harvested wild boar across Europe was not matched by the number of hunters, which in most countries was found to be stable or declining. The increased number of harvested wild boar, suggesting an increased wild boar population, is supported by the increase in the number of vehicle collisions and crop damage involving wild boar (Apollonio et al., 2010; Geisser and Reyer, 2015). This evidence may suggest that new strategies may be required if the number of wild boar and their impacts are to be controlled.

4.1. Conclusions

- There is an increase in the number of harvested wild boar in most European countries, which probably reflects increased numbers of wild boar.
- Although hunting is the main cause of mortality in wild boar, the number of hunters is decreasing in most European countries.
- Given the reported trend in wild boar populations over the last 30 years, there is no indication that population growth will slow down in the next few years.

4.2. Recommendation

- Wild boar distribution data of different regions should be harmonised.
- If the wild boar populations in a region are to be regulated, means other than recreational hunting could be considered, such as a dedicated task force or integrated methods of population control, such as shooting and trapping.

- When a wild boar population has to be reduced, feeding of wild boar, resulting in reproductive increase and survival over the winter, should be avoided.
- More research is needed to assess the impact of discontinuing the feeding of wild boar on local wild boar densities and on the species' spatial behaviour.

5. Distribution of ASF competent vectors in Europe and their possible role in ASF epidemiology (ToR3)

5.1. Data

Data on the reported presence of ticks specimens of the *O. erraticus* complex and specimens of *O. tholozani* (Figure 16) were provided by VectorNet. Details of the locations where the specimens were collected are provided in Appendix E.

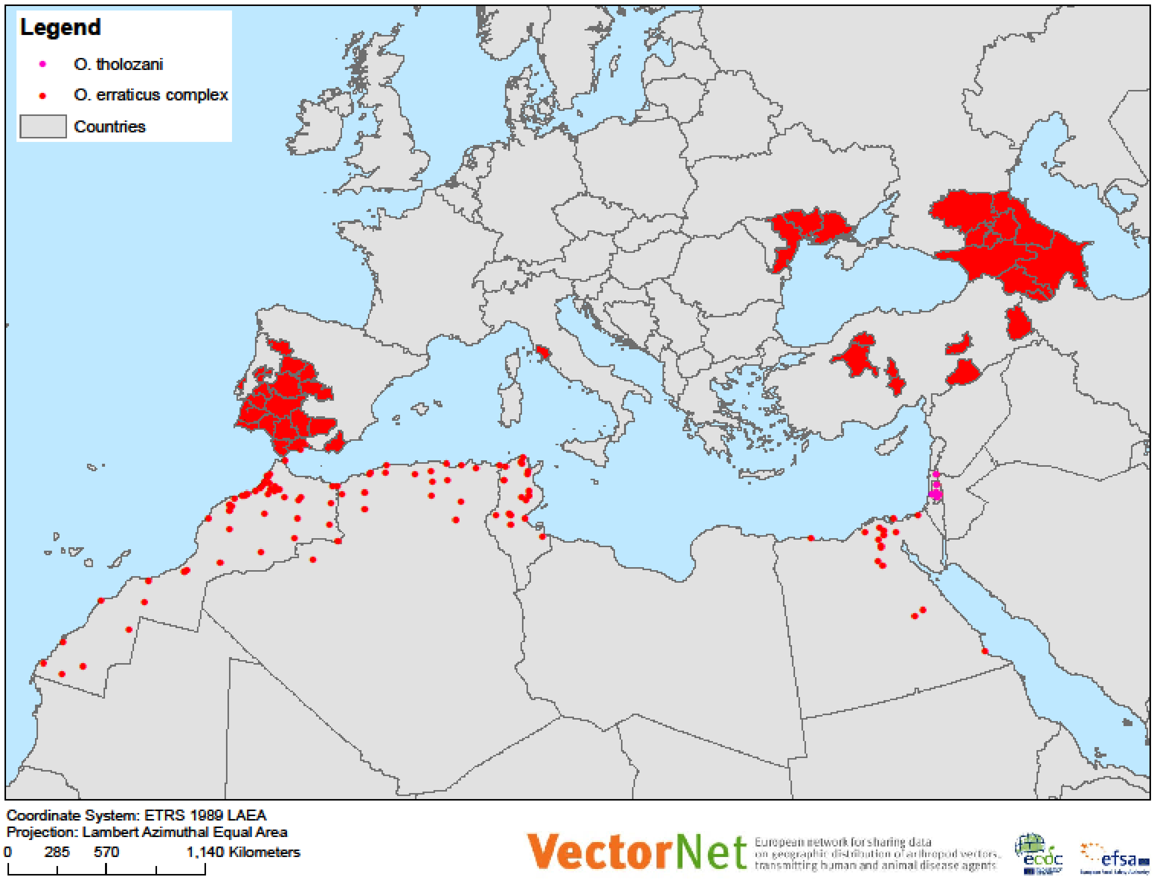


Figure 16: Reported presence of ticks specimens of the *O. erraticus* complex and specimens of *O. tholozani*

5.2. Methodologies

Data on the tick distribution were actively collected through a systematic literature review, which was updated to 31 March 2015. This review was an update of a previous systematic literature review carried out in 2010 (EFSA AHAW Panel, 2010).

5.3. Assessment

Of all the invertebrates tested to date, only the soft ticks of the genus *Ornithodoros* have been found to be susceptible to ASFV infection, either naturally or experimentally. Other soft ticks remain untested under laboratory conditions. All the *Ornithodoros* species investigated so far can become infectious under laboratory conditions. The roles they may play as potential biological vectors of ASF are various. All species in the *Ornithodoros* genus are xerophilous ticks, living in open and dry habitats, commonly associated with rodent burrows. Only the *O. erraticus* complex is found in Europe. The distribution of these ticks in Europe is not well reported. In Europe, ticks of the *O. erraticus* complex have been reported in some countries around the Mediterranean Basin (Portugal, Spain and Italy and Turkey) and the Black Sea (Moldavia, Romania, Georgia), and in Armenia and Azerbaijan (see Figure 18).

Ornithodoros ticks mainly feed on animal species living in burrows, such as rodents and reptiles. Pigs are mostly accidental hosts, from which the ticks can be infected. Wild boar have never been found infested by *Ornithodoros* spp., since wild boar normally rest not inside burrows, but on the surface.

Ticks of the *O. erraticus* complex are important in maintaining the local foci of the ASFV (and can lead to endemicity in a region) because they are long lived and can survive for long periods without feeding and because they can harbour the ASF virus for up to five years. However, they do not play an active role in the geographical spread of the virus (EFSA, 2010).

The epidemiological role played by soft ticks becomes important where pigs are managed under traditional systems or backyard farms. Argasids are fast feeders and spend very little time (minutes) attached to their hosts. They are endophilous/nidicolous and live in both wild and domestic habitats, hidden in holes, cracks and fissures inside and around animal burrows or premises. This means that otherwise efficient trapping methods, such as vegetation dragging and removal from animals, are inefficient as direct methods for argasid surveillance. Therefore, it is necessary to explore all possible tick refuges in the area sampled before such an area can be considered *Ornithodorus* free (Oleaga-Pérez et al., 1990; Vial et al., 2006). Clearly, this is an impractical and resource-intensive procedure and led to the development of serological tests (ELISA) as indirect methods for tick surveillance, especially for argasid ticks.

Serological methods are based on the detection of specific antibodies against tick salivary proteins in serum samples taken from animal hosts—or humans—living in the area under study. *O. erraticus* salivary gland extracts (SGEs) are a suitable source of antigens for indirect serological surveillance of these ticks by ELISAs, but they have some drawbacks. Firstly, the collection of SGEs is time-consuming and difficult to standardise, and their composition is poorly known and may include non-specific antigens, giving rise to unexpected cross-reactivity (Jori et al., 2013). Deglycosylation of these extracts can eliminate some false-positive reactions, but the more promising tools are the new purified salivary antigens Oe260 for *O. erraticus* (Jori et al., 2013). Another issue in the use of any anti-tick ELISA is the relatively short duration of the pig immune reaction against tick saliva, which has been reported to be, on average, three months only (Canals et al., 1990).

Serological studies to detect specific antibodies against tick salivary proteins were recently carried out in the Caucasus under the ASFORCE FP7 project, but at the time of writing the results have not yet been published.

5.4. Conclusions

- Wild boar have never been found infested by *Ornithodoros* spp. because wild boar are not normally found inside burrows, but only on the surface.
- In Europe, ticks of the *O. erraticus* complex have been reported in some countries around the Mediterranean Basin (Portugal, Spain and Italy and Turkey) and the Black Sea (Moldavia, Romania, Georgia), and in Armenia and Azerbaijan.
- There is no report indicating the occurrence of *Ornithodoros* spp. in the four affected Member States.
- Ticks of the *O. erraticus* complex do not play an active role in the geographical spread of the virus; however, they can play an important role in maintaining the local foci of ASFV.

6. Assessment of the suitability, effectiveness and the practical aspects of implementation of the main wild boar management measures in ASF-infected areas and bordering high-risk areas (ToR4)

6.1. Data

The data used to address this ToR are the same as described in section 2.1 for the description of the epidemiology of ASF in the four affected countries in the east of the EU.

6.2. Methodologies

A three-step approach was used to evaluate the suitability, the effectiveness and the practical aspects of potential wild boar management opinions, taking into account the local conditions and giving quantitative baseline indications on these measures as well as spatial and temporal parameters.

Firstly, the published literature was searched for quantitative information on the efficacy of different wild boar management options. Secondly, an expert consultation was organised to obtain unpublished information, e.g. from ecologists and veterinarians involved in the management of wild boar populations. Finally, the published and unpublished information, together with the data described in section 2.1 was used to parameterise the wild boar and ASFV components of an epidemiological simulation model, with the aim of evaluating the effect of the different management options on the behaviour of ASF in the wild boar populations (Figure 17).

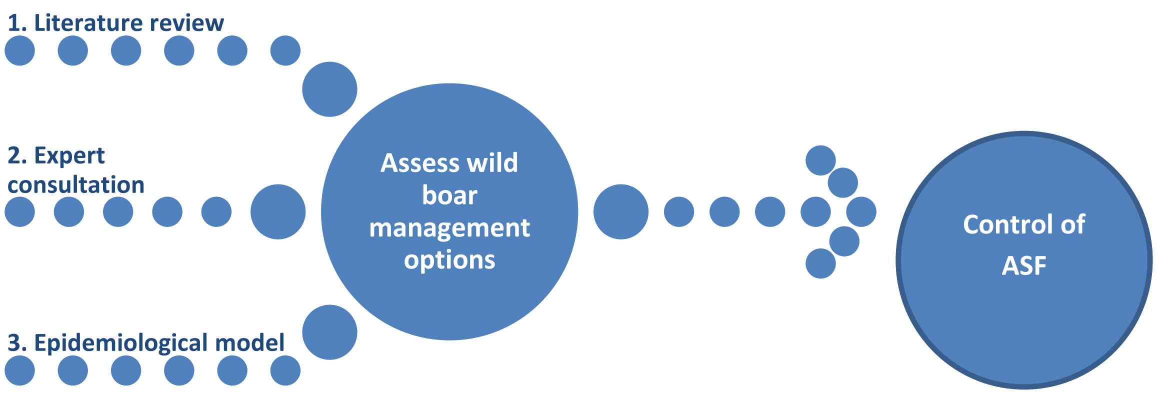


Figure 17: Methodology to assess wild boar management options to control ASF

Disease monitoring in wildlife has to cope with the limited access to potentially infected hosts. Therefore, data collected on the distribution of infected hosts are per se an imperfect approximation of the precise situation. Management measures are usually applied to a spatial zone defined based on detections and extended by an extra safety margin. When alternative management strategies are evaluated, it is useful to distinguish the area defined for management ("infected area") and the minimum area containing the ASF detections ("affected area"). The following definitions were used for this assessment:

- Affected area—the area containing all the ASF detections and requiring dedicated control effort. It is assumed that the wildlife population inside the area is uniformly affected by ASF and that case detections have occurred throughout the area. The clusters in Figures 7 and 8 provide examples.
- Zone surrounding the affected area—the uniform extension of the affected area into the unaffected part applying a certain width.
- Control area—area assigned for the application of control measures in the model scenarios (usually the affected area plus a certain zone surrounding the affected area).

- (Control) measures—the strategic options proposed by experts: feeding ban, soft hunting, targeted hunting, depopulation, carcass removal.
- Supplementary feeding—any amount of feed providing energy to the animals that changes the ecological capacity of a habitat (e.g. winter feeding to sustain the animals)
- Baiting—limited supply of feed that is assumed not to change the ecological capacity of a habitat unit and is meant to attract local animals, e.g. for contact hunting.

6.2.1. Literature review

Quantitative evidence on the efficacy of wild boar management options was collected from published literature that reported on changes in demography after implementing particular wild boar management strategies. Therefore, an extensive literature review was carried out to describe the efficacy of different wild boar management options. Methods of population control, objectives of the management measures, and the effectiveness and feasibility of these methods in terms of demographic changes were derived from the papers identified (Appendix F).

6.2.2. Expert consultation

Firstly, the efficacy of different wild boar management options under different habitat conditions was discussed with the experts and summarised, including the practical aspects of potential wild boar management options. Subsequently, an on-line questionnaire, enquiring about the on-going wild boar management objectives and practices, was sent out to the experts (round 1). Feedback was provided to the experts and the questions were further clarified where needed. The experts were given the opportunity to revise their answers (round 2). Finally, in a third step, a workshop was organised, to discuss the results of the questionnaire. Through group sessions, the participants suggested a list of measures which were, according to them, the most appropriate to be implemented in the eastern EU countries affected by ASF at the time of the mandate. These measures were then to be tested as scenarios in the epidemiological model.

6.2.3. Epidemiological model

The epidemiological model used to evaluate possible control measures in an ASF-affected population was compiled from a spatially explicit, stochastic, individual-based demographic model of wild boar ecology in a structured landscape of habitat units. Superimposed was a transmission and disease course model of ASFV infections. The model was documented following the ODD (overview, design, details) protocol (Grimm et al., 2006, 2010). The complete documentation (ODD protocol) of the model and the list of all technical parameters can be found at http://ecoepi.eu/ASFWB.

Wild boar ecology model

The model represents the wild boar population as individuals and follows each individual's life cycle from birth to death and takes account of sub-adult dispersal in females and males, annual reproduction and litter sizes. All processes are driven by parameter distributions obtained from the literature or from expert knowledge. Mortality varies annually depending on whether environmental conditions are good or bad for wild boar. Female wild boar groups are assigned spatially to core areas of their home range, which is represented by 2 km × 2 km patches in the model landscape; thus, the model reflects the reality that home ranges of neighbouring female groups may overlap substantially. Male wild boar explicitly roam over multiple female groups. The habitat quality is expressed as breeding capacity for each single core home range. The breeding capacity determines the maximum number of breeding sows in a group and subsequently drives the local population density. Cell-wise breeding capacity can be derived from available wild boar density distribution maps or, alternatively, from real landscape vegetation mapping. The wild boar ecology model has on several occasions been validated for the central European situation by various experts (Alban et al., 2005; Fernandez et al., 2006; EFSA 2009, 2012; Kramer-Schadt et al., 2009; Lange et al., 2012, 2014, Lange and Thulke, 2015; Dhollander et al., 2014). The details of the model design, the procedures and the parameters of wild boar ecology can be found in the ODD documentation (e.g. http://www.ecoepi.eu/ASFWB).

ASF transmission model

The modelled population of wild boar was superimposed by an individual-based SEIR sub-model of ASF to simulate disease transmission and the disease course in all affected individuals. The ASF transmission model parameters are summarised in Table 13. The course of ASF lasts around one week in each infected individual ($t_{\inf}$) and the infection will be ended by the death of the animal with probability p_L. The model simulates direct ASFV transmission within social groups ($P^{(i)}_{\inf}$ $P^{(i)}_{\inf}$ $P^{(i)}_{\inf}$), between group contacts when infected males join a female group, by infected sub-adult females when they establish a new group during dispersal and by contact with the carcasses of infectious animals ($P^{(c)}_{\inf}$ $P^{(c)}_{\inf}$ $P^{(c)}_{\inf}$). Carcass distribution is driven by the probability that an ASF-moribund animal will retreat into the shelter of its core home range (p_{core} p_{core} p_{core} or not $\hat{p}_{core}$ p_{core} $\hat{p}_{core}$ $\hat{p}_{core}$ = 1- p_{core} p_{core}) and the time until disappearance or non-infectiousness of carcass material (t_{carc}). If a carcass lays outside the core home range (i.e. $\hat{p}_{core}$ $\hat{p}_{core}$ $\hat{p}_{core}$ = 1- p_{core} p_{core} p_{core}) it was assumed to die in the overlapping area direct to neighbouring groups enabling carcass contact transmission to adjacent animals. Additionally, in special scenarios a moribund animal may be forced to leave its core home range by intensive drive hunts (expert scenario). This could cause the animal to move further away (Sodeikat and Pohlmeyer, 2003). Thus their carcass finally will be in contact with more distant wild boar groups.

Table 13: Parameter values used in the ASF transmission model [(a)]

Name	Description	Value	Source/details
p_L	Probability of lethal infection	0.95	Blome et al., 2012; Gailardo et al., 2015
$t_{\inf}$	Average period between infection and death	1 week	Blome et al., 2012
$P^{(i)}_{\inf}$ $P^{(i)}_{\inf}$ $P^{(i)}_{\inf}$	Probability that a susceptible individual becomes infected if there is one infectious individual in its social group per time step	0.05	Ad hoc, reflecting the limited contact transmission but permanent direct contact (see Blome et al., 2012) (results not sensitive to the parameter choice)
$P^{(c)}_{\inf}$ $P^{(c)}_{\inf}$ $P^{(c)}_{\inf}$	Probability that a susceptible animal acquires infection from a carcass lying in its home range per time step (including contact and transmission)	0.2	Selected according to best fitting model explaining observed spatial spread
t_{carc}	Time of carcass persistence: period of time a carcass may be source of transmission of if of an animal dead after diseased by ASF	6 weeks	Selected according to best-fitting model explaining observed spatial spread
p_{core} p_{core} p_{core}	Probability that animals dying from ASFV infection will fall **inside** their home range	0.2	Selected according to best-fitting model explaining observed spatial spread
$\hat{p}_{core}$ $\hat{p}_{core}$ $\hat{p}_{core}$	1- p_{core} p_{core} p_{core}; probability that animals dying from ASFV infection will fall **outside** their home range	0.8	Dependent on p_{core} p_{core} p_{core}
p_{neigh} p_{neigh} p_{neigh}	Probability that animals dying from ASF will fall in a neighbouring cell after being chased off their home range as a result of large-scale disturbance	0.5	(Sodeikat and Pohlmeyer, 2003)

(a): Fertility reduction if ill, 0.625; probability of prenatal infection, 0.5; maximum duration of immunity by maternal antibodies, 12 weeks (unknown for ASF, all copied from CSF, irrelevant as long as short course of individual infections is valid),

Model justification

The parameters of the ASF transmission model ($P_{\inf}^{(i)}\ P_{\inf}^{(i)}\ P_{\inf}^{(i)}$; $P_{\inf}^{(c)}\ p_{core}\ P_{\inf}^{(c)}\ P_{\inf}^{(c)}$; $p_{core}\ p_{core}$; t_{carc}) were tested and calibrated against the spatio-temporal dynamics of the available confirmed ASFV detections in wild boar from the eastern European outbreaks (see Lange, 2015). Model quality was assessed against the observed spatio-temporal distribution of ASF detections. Measures were the likelihood of true detections given the spatial and temporal simulation output and agreement by the area covered and annual distance spread. Parameters to which these simulated patterns of spatio-temporal spread were found insensitive were further fixed to the most plausible value suggested by the literature or by expert opinion (e.g. $P_{\inf}^{(i)}\ P_{\inf}^{(i)}\ P_{\inf}^{(i)}$; t_{carc}; $p_{core}\ p_{core}\ p_{core}$). For the other parameters, results will be reported with their values systematically varied.

Simulation protocol

To assess proposed control strategies, all model scenarios were simulated on a standardised model landscape (Figure 18). Indicative simulations revealed the importance for the control outcome of the width of the zone surrounding the affected area. Therefore, the simulation landscape was designed to allow the distance from the last case detections to vary between 0 km and 200 km. Simulation landscape covered 150 × 50 wild boar group areas (i.e. 300 km × 100 km in the central European context). Habitat quality was distributed randomly across the landscape, but reflecting the overall density suggested for the study area (see Figure 3—FAO-density map). The total ecological capacity of simulation landscape, as regulated by the breeding capacity of habitat cells, was set to mimic the January density reported for the current ASF-affected regions (Estonia, Latvia, Lithuania, Poland). Features of landscape structure were not mimicked because the suggested strategy options did not consider the exploitation of certain landscape structures for control planning owing to uncertain relevance for future ASF occurrences.

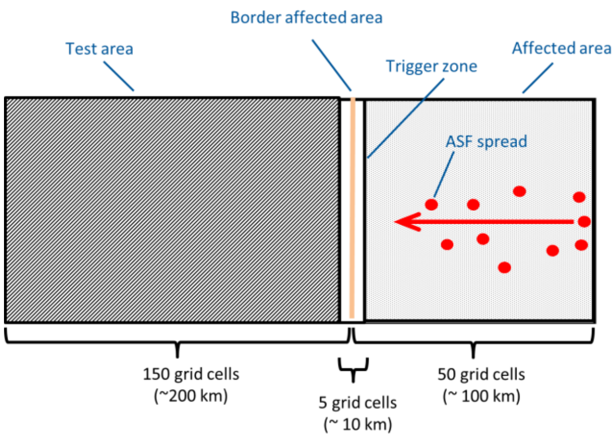


Figure 18: Schematic representation of the simulation landscape for the comparative assessment of control strategies. From right to left, the first one-third (dotted area) comprises the affected area at the start of control measures, including a trigger zone (white area) at the border between the affected area and test area (control measures are triggered if infected animals enter the trigger zone) and the remaining two-thirds of the landscape comprises the test zone (striped area). The test zone was used to compare different widths of the zones surrounding the affected area between 0 km and 200 km. Note: The size of the test zone does not imply that the zone surrounding the affected area to be used for the simulations must always be 200 km

Each simulation scenario was repeated 120 times (i.e. fixing the minimum precision for percentage estimates out of all runs). In addition to the management scenarios, a control scenario, in which no measure was applied, was simulated. The output was used to compare management effects against unmanaged ASF spread and mortality not due to ASF, by age class. The latter parallels the age structure of hunted animals under normal conditions and allowed us to quantify the effects of increasing conventional soft hunting compared with the unreported level of natural mortality (i.e. the framework of most survival data available in wild boar; see, for example, Annex 1 of Toigo et al. (2008), in which both mortalities are estimated separately, but only for intensive drive hunts).

The infection was seeded towards the right of the affected area (dotted segment in the scheme above) and spatial spread simulated. Control measures were simulated from the time step when infected animals initially hit the trigger zone (white segment). The trigger zone corresponds to the moment in time when control decisions are taken rather than the moment of ASF detection. Each simulated control measure was activated in the subsequent time step across the complete landscape, i.e. starting with the same situation regarding population and disease.

Based on the outcomes of the expert consultation meeting regarding wild boar management options (see section 6.2.2 for the detailed outcome of the expert consultation meeting), the following technical control strategies were assessed

- A: Massive depopulation subsequently addressing either one-quarter or one-sixteenth of all female group cells of the control area (i.e. zones surrounding the affected area + affected area). Thus, the depopulation campaign was performed within four weeks or four months. Depopulation was assigned starting from the zones surrounding the affected area towards the right until the control area was treated completely. Based on the density in the non-affected area at start of measures, the scenario-specific target density is determined. Animals are then randomly removed to achieve that target density. Maximum disturbance was assumed, resulting in about half of infected animals dying out of their natural home range.
- B-FB: "Feeding ban": Fertility reduction = reproduction capacity reduced. In all female group habitats, the reproductive capacity, i.e. the number of females allowed to breed in a wild boar group, was reduced in proportion to the assumed reduction in fertility (i.e. 30 %, 50 %, 70 %, 90 %).
- B-TH: "Targeted hunting": The total size of the hunting bag remains unchanged. However, in accordance with the efficiency parameter, a proportion of adult (adult + sub-adult) females that would have survived in the current year were removed (extra mortality to target group). The corresponding number of "normally" dying piglets was simulated as surviving in order to maintain the size of the hunting bag.
- If one assumes 20–30 % natural mortality as included in literature estimates or that nearly 80 % annual mortality comes from hunting efforts (Vittorio Guberti, Institute for Environmental Protection and Research (ISPRA), 2015, personal communication) the size of each of the age classes in the hunting bag can be approximated from the simulated dead animals whose death is not related to ASF.
- C-CR: "Carcass removal" implied the exclusion of carcasses immediately (C-CR-0) or after one week (C-CR-1) randomly across the control area (i.e. zones surrounding the affected area + affected area) at severl levelsof efficiency efficiency.
- C-CR+CH: "Carcass removal" combined with "increased soft hunting" implied the application of C-CR, i.e. the exclusion of wild boar access to carcasses immediately and randomly across the control area with the appropriate efficiency, plus B-CH, i.e. the intensity of the conventional hunting was assumed to be increased on all age classes proportional to the hunting bag structure.

Based on the outcome of the expert consultation meeting, the following strategies were analysed: massive depopulation in four weeks, massive depopulation in four months, targeted hunting, feed ban, instantaneous carcass removal and carcass removal after one week. Each control measure was simulated assuming 30 %, 50 %, 70 % or 90 % efficiency, e.g. removing 90 % of the current population in the case of massive depopulation strategy, or reducing the hunting bag size by 90 % of the previously non-hunted adult + sub-adult females in targeted hunting, or reducing each local breeding capacity by 90 % in feeding ban, or excluding live wild boar from access to 90 % of wild boar carcasses in the carcass removal scenario.

Output

The following details were recorded from all simulations to demonstrate the results: time-series of number of animals removed other than by disease; time-series of number of animals infected with ASFV or killed by ASF; time-series of distance spread into the test area; duration of virus circulation.

6.3. Assessment

6.3.1. Literature review

Variations of wild boar population sizes over time and space are likely to affect the efficiency and complicate the monitoring of depopulation programmes. Wild boar are one of the more intensively hunted ungulate species in Europe. Nevertheless, this species has been expanding throughout Europe over the last 40 years.

A review of the scientific literature on hunting wild boar (Appendix A) revealed that a reduction of a wild boar population by more than 60 % within a period of one hunting season has not yet been documented in a European context. Annual hunting in the French forest of Châteauvillain-Arc-en-Barrois (11 000 ha) resulted in reduction of more than 40 % (post-reproduction) of the population harvested annually in the period 1982–2004 (Toigo et al., 2008). The annual mortality of wild boar differs between Member States and can reach levels up to 60 % (Keuling et al., 2013). Given the high reproductive rate, it is estimated that, unless at least 65 % of the European wild boar population is harvested, the population will increase (Keuling et al., 2013). The highest reported reduction of a European wild boar population in a hunt (56.8 %, post-reproduction) was achieved in a fenced Spanish hunting estate of 723 ha (Boadella et al., 2012). Although this study aimed to eliminate the entire wild boar population during a hunting season, it could not reduce the population by more than 60 %. Aerial shooting has been reported to achieve an 80 % (post-reproduction) reduction of wild boar in five days but can be applied only in areas of sparse vegetation (e.g. dry regions of Australia or the USA), and certainly not in areas of relatively high human population density (Saunders and Bryant, 1988). Consequently, it seems unlikely in the European context that hunting carried out only by recreational or private hunters will be able to reduce a wild boar population by 70 %, i.e. to a level far below what is estimated to be necessary keep the population stable in Europe.

Traps are also used in attempts to control wild boar populations, often in combination with hunting or poisoning (West et al., 2009). The literature review (see Appendix A) did not reveal any study that could reduce the wild boar population by 70 % within a trapping season. The success of trapping depends on a variety of factors, including topography, time of year, type of trap used, availability of alternative food, number and density of traps deployed, trap location, number of nights each trap is used, type of bait used and duration of pre-feeding before the traps are set (Massei et al., 2011). Alexandrov et al. (2011) suggested the use of trapping in addition to management by hunting and vaccination to eradicate CSF. Although a lack of data hampers a proper assessment of the efficiency of trapping as stand-alone measure to reduce a wild boar population in the European context, it is in general considered more costly and less efficient than hunting, certainly at a large scale (Coblentz and Baber, 1987). However, there is an example in Europe where trapping carried out with 30 traps per 20 000 ha from February to May has captured one-third of the harvested population, mainly juveniles and female piglets (András Náhlik, University of West Hungary, Sopron, personal communication, 2014).

Taken together, it seems unlikely that trapping alone, particularly on very larger areas, will be able to reduce a wild boar population by 70 % in a short period of time. Reducing female survival appears to be the most effective approach to population control (Sweitzer et al., 2000; Bieber and Ruf, 2005; Toigo et al., 2008; Gamelon et al., 2012), but hunting can often result in selective removal of healthy adult male wild boar and, especially, in insufficient harvest of piglets (Toigo et al., 2008; Servanty et al., 2011; Keuling et al., 2013). Moreover, hunting and trapping could lead to adaptation of wild boar behaviour, for instance by becoming more active during the night, increased home range sizes (Calenge et al., 2002; Sodeikat and Polheimer, 2002; Scillitani et al., 2010) and/or increased reproduction (Bieber and Ruf, 2005; Hanson et al. 2009; Gamelon et al., 2011; Servanty et al., 2011). In addition, an increase in effort is required to hunt or trap wild boar when the animal density reduces (Cruz et al., 2005), but maintaining an intense hunting or trapping pressure during several seasons could be difficult for practical and/or social reasons (Fonseca et al., 2011; Boadella et al., 2012). No papers could be found which reported the time period over which population reductions could be maintained in Europe.

In conclusion, a review of the scientific literature on hunting and trapping of wild boar revealed that a reduction of 70 % in a wild boar population has not been documented in Europe. Depopulation efforts can even lead to adaptive behaviour of the hunted wild boar, compensatory growth of the population, influx of wild boar from adjacent areas and extensive movements of wild boar outside the focal area. To reduce wild boar populations, supplemental feeding should be reduced and hunting rates increased especially for females, as all age classes of females are highly reproductive.

6.3.2. Expert consultation

Outcomes of the questionnaire

Table 14 illustrates data that could be extracted from a questionnaire sent to experts involved in the wild boar management in the four ASFV-affected countries of eastern EU.

Table 14: Information provided through questionnaire about currently applied wild boar management practices in affected Eastern EU countries

Country	Latvia	Poland	Lithuania	Estonia
Strategy of wild boar management	Decrease/ keep stable population	Decrease /keep stable population	Decrease/ keep stable population	
Objectives of the wild boar management strategy	Disease control/damage prevention/recreational hunting	Game management and disease control	Game management and disease control	Game management and disease control
How the following management measures contribute to the achievement of the objectives				
Hunting	Slow effect	Expert 1: it is well achieved; expert 2: not sufficiently	Selective hunting is more efficient	Depends on willingness
Trapping	Not done	Not done	Not done	Not done
Hunting				
Drive hunting (in infected areas)	Forbidden	Forbidden	Forbidden	Forbidden
Maximum quota (per cent of population)	100 %	Yes (variable)	No	No
Minimum number targeted (per cent of population)	No	No	No	50 %
Penalties when not achieving target?	No	No	No	No
Hunting season	Year-round	No data	No data	All year round except females with piglets (open season 1 September to 28 February)
Hunting bag (2014)	37 000	242 000	43 555	24 909
Structure of hunting bag				
Adult (male + female)	30–35 %	20–40 %	0–20 %	21 %
Female (all age classes)	30 %	50 %		47 %
Male (all age classes)	70 %	50 %		53 %

Country	Latvia	Poland	Lithuania	Estonia
Yearlings (> 1 year old)	20–30 %	60 %	80–100 %	50 %
Piglets (< 1 year old)	35–40	–	–	–
Baiting	There are restrictions on where baiting can take place, the wild boar should not be able to access food places for other animals, access to food for wild boar should be limited. 400 l/1 000 ha	10 kg per km^2per month, only in restricted area; 143 million tonnes/year for the entire country and all ungulates	No data	0.1 ton/1 wild boar
Feeding				
feeding ban in infected area	Yes	Yes	Yes	No
feeding ban in I and II zones	No	No	No	No
Feeding season	Whole year	October to March	Whole year	Whole year
Trapping	No	No	No	No

Outcomes of the discussions during the consultation meeting

Baiting versus feeding

As defined above, baiting is the provision of a limited supply of feed to attract animals for contact hunting purposes. The amount supplied is assumed not to change the ecological capacity of a habitat, the reproductive potential of the local population or the winter survival of piglets.

Required baiting quantities may differ greatly between different habitats and hunting practices and the type of feed provided. Currently there is not enough evidence to state the exact threshold separating baiting and feeding. However, the experts agreed that proper baiting must not increase survival and reproduction in the populations. There are examples in Europe that, on 1 000 ha, three places with 1 kg of bait per day per baiting place (~1 kg/ha/year) is sufficient to fulfil the requirement for attracting animals in contact hunting (András Náhlik, University of West Hungary, Sopron, personal communication, 2015). Other experts suggested that moving the baiting place also increases the efficiency and thus decreases the need for large amounts of bait. The Lithuanian experts gave the example that, in Lithuania, the provision of up to 20 kg per ha of natural feed (e.g. apples or vegetables) for baiting purposes is allowed.

Advantages and disadvantages of different wild boar management options

The experts were divided in two groups for focused group discussions. Both groups focused on the wild boar management options that should be applied in the ASFV-infected areas of the four eastern EU countries (e.g. convex polygon of past detections) and purposefully sized zones surrounding the affected area (e.g. width of two wild boar group home ranges). The experts discussed the possible strategic options that can be useful and could be combined in ASF control strategies. Advantages and disadvantages were noted for a list of possible wild boar management options (Table 15).

Table 15: Advantages and disadvantages of different wild boar management options in affected Eastern EU countries

Measure	Advantages	Disadvantages
(a) Measures meant to reduce animal movements and avoid abnormal home-range expansions in the affected area		
Ban on large-scale drive hunting of any species	Reduced probability of hunting-induced, extensive movements outside the home range and less risk of spread of ASF to free areas	Drive hunts are considered by hunters the most efficient hunting method to reduce population size (in terms of harvest per day)
Ban of supplementary feeding	Decreasing of feed resources (decreasing of winter carrying capacity) Not creating artificial aggregation spots and hence reducing contact rates	Reduced encounter probability between hunters and wild boar Difficult to be accepted and sustained for long time by hunters These two advantages were considered less important if baiting is allowed
(b) Measures meant to reduce numbers of animals in the control area (better zones surrounding the affected area, because control area includes affected area)		
Soft hunting, i.e. using the (regionally) conventional hunting practice based on individual contact approaches that do not chase the animals (e.g. individual hunters, tower hunting)	No dispersal and less risk of increased spread of ASF to free areas	Has never been documented to reduce the wild boar population in Europe
Targeted hunting reversing the age structure of the hunting bag, i.e. mostly adult and sub-adult females	No dispersal and less risk for increased spread of ASF to free areas Higher probability of reducing population size than non-selective hunting	Could lead to disruption of family groups and higher risk of dispersal of young ones, particularly if the leading sow is shot
(c) Measures meant to reduce contact with contaminated carcasses		
Carcass removal	Considered a very efficient way to reduce spread of disease	Carcasses difficult to find. The use of trained dogs was suggested

The experts proposed that control measures to mitigate the spread of ASFV should for a period be targeted in and around the area where the infection has already spread. Strategy options therefore were proposed, assuming that the affected area can be encircled and controlled immediately. Success was measured by comparing the situation before and after the application of control measures and also took into account the level of resources used. The fact that control measures cannot be implemented in neighbouring countries, or that counterproductive activities may even be implemented, was not discussed and such a scenario may necessitate alternative scenarios, with strategies and measures applied differently.

It was concluded that there no single strategy is ideal, having only advantages while being efficient and 100 % feasible. Therefore, it was suggested that the epidemiological model was run based on the following four theoretical scenarios, with different levels of efficiency of implementation, ranging from 30 % to 90 %. Further, it was suggested that the model be run different widths of zones surrounding the affected area.

These suggested strategic options were combined into the simulated control scenarios as specified in section 6.2:

- A: "Massive depopulation" within one or four months, assuming different target density levels.
- B-FB: "Feeding ban" reducing fertility reduction of sub-adult females and therefore the reproductive capacity of local female groups, assuming different levels of effect.
- B-TH: "Targeted hunting" such that the total size of the hunting bag is maintained but an increased proportion of females (adult + sub-adult) that would otherwise survive the current

year are shot (extra mortality in the female target group). Assuming that the hunting bag remains constant, this implies that a decreased proportion of piglets are shot and will survive.

- B-CH: "Conventional hunting" continues the same hunting strategy as usual but raises the total hunting effort to the maximum feasible within the framework of individual contact hunting without disturbing the animals (no quantitative specifications of intensity increase were available from the expert consultation meeting).
- C: "Carcass removal" across the controlled area.

6.3.3. Epidemiological model

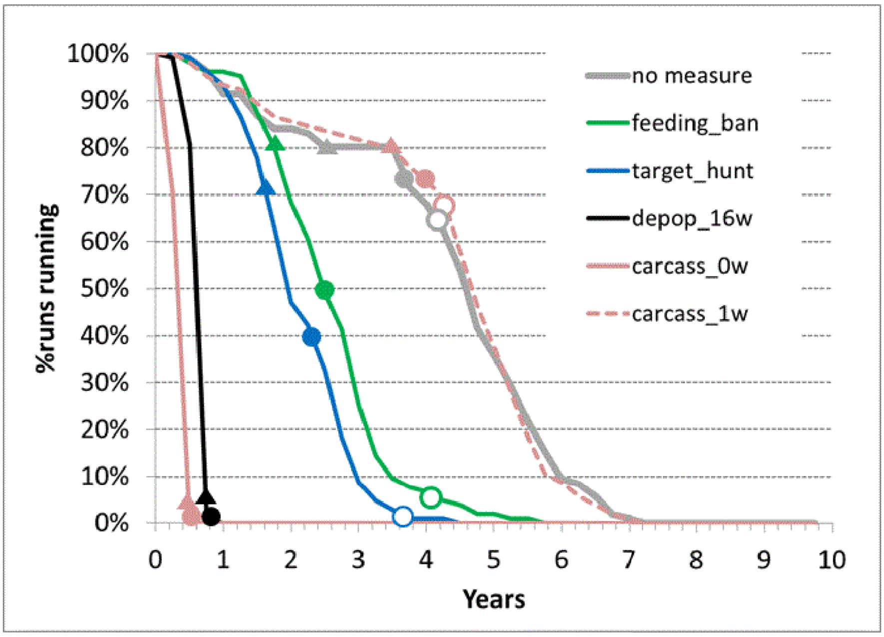
Table 16 was read from the set of diagrams shown below in Figure 21. The performance of the control strategies is compared for varying width of zones surrounding the affected area between 0 and about 200 km. The simulation results summarising the likelihood of halting ASF forward spread are expressed as the percentage of runs in which the infection did not spread beyond the zones surrounding the affected area (i.e. once 100 % success was achieved and can be scaled up to larger zones surrounding the affected area).The sizes of the zones surrounding the affected area can be found in more detail in the diagrams in Lange (2015). Table 16 provides the simulation outputs for the most plausible parameterisation (density 1.5/km²; carcass infectivity 0.9 i.e. $P_{\text{inf}}^{(c)}$ $P_{\text{inf}}^{(c)}$ $P_{\text{inf}}^{(c)}$) as well as the same outputs including uncertainty ranges for the parameters (density between 1 and 2/km²; $P_{\text{inf}}^{(c)}$ $P_{\text{inf}}^{(c)}$ $P_{\text{inf}}^{(c)}$ between 0.3 and 0.9). The uncertainty did not affect the general insights from the simulation data.

Table 16: Simulation output (elimination success rate) for alternative control strategies and different sizes of zones surrounding the affected area added to the affected area and continuously treated together with the affected area

Strategy	Per cent runs ASF halted inside the zones surrounding the affected area assuming 90 % effectiveness and applying the width of the zones surrounding the affected area									
	0 km		40 km		100 km		140 km		200 km	
No measures	12 %	*3 %*	22 %	*6 %*	27 %	*12 %*	29 %	*15 %*	35 %	*17 %*
Feeding ban	15 %	*3 %*	19 %	*15 %*	50 %	*48 %*	73 %	*72 %*	95 %	*91 %*
Targeted hunting	16 %	*5 %*	29 %	*19 %*	60 %	*54 %*	85 %	*74 %*	99 %	*91 %*
Massive depopulation, 16 weeks	22 %	*17 %*	97 %	*97 %*	100 %	*100 %*	100 %	*100 %*	100 %	*100 %*
Carcass removal, 0 weeks	62 %	*66 %*	100 %	*100 %*	100 %	*100 %*	100 %	*100 %*	100 %	*100 %*
Carcass removal, 1 week	17 %	*5 %*	22 %	*23 %*	27 %	*21 %*	29 %	*24 %*	32 %	*29 %*

The values are given for the most plausible parameterisation (i.e. average population density 1.5 animals per km² and carcass infectivity of 0.9). The values in italics are the average outcomes taking into account uncertainty regarding population density (i.e. 1.0 to 2.0 animals per km²) and carcass infectivity (i.e. between 0.1 and 0.9)

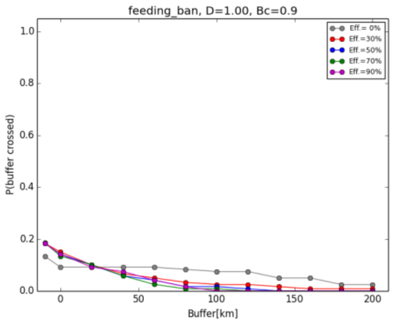
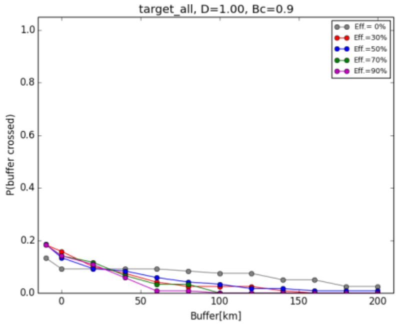
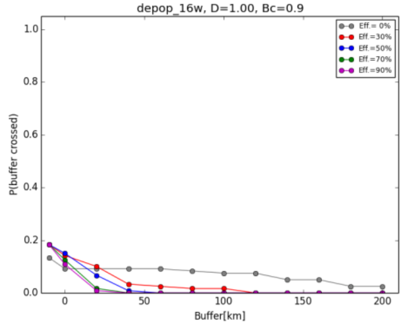
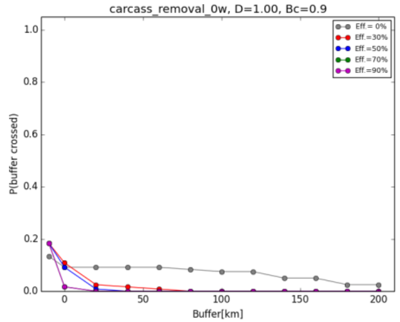
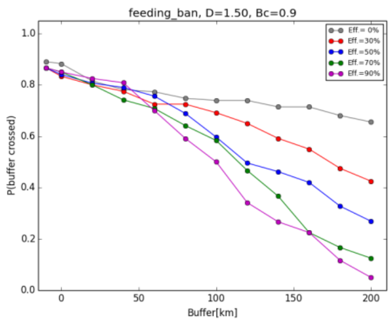
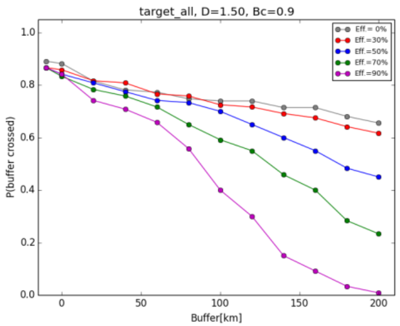
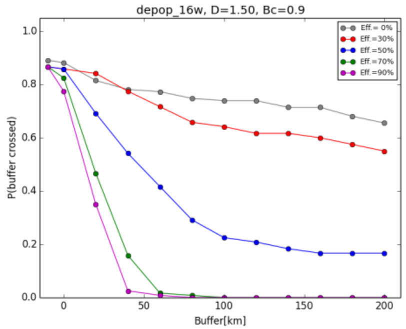
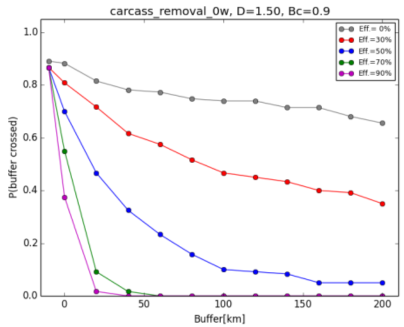
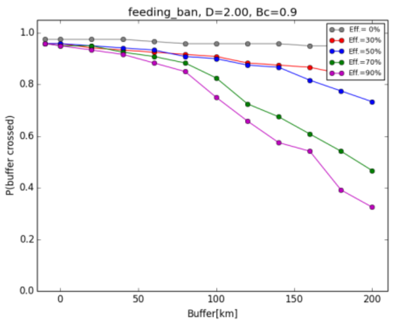
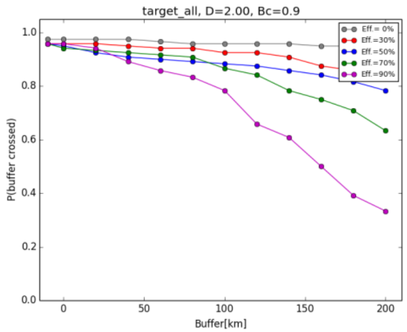
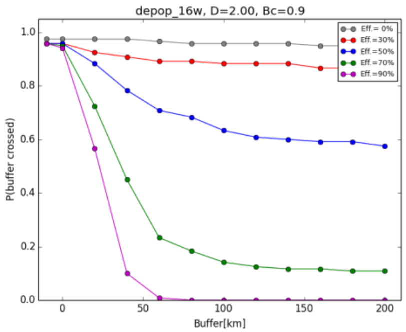
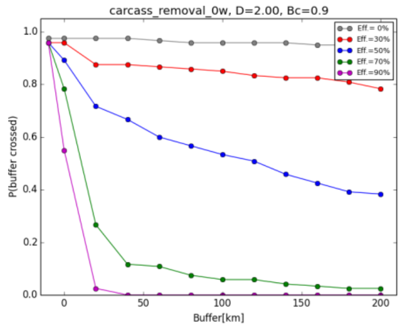
Figure 20 shows the duration of the simulated ASF epidemics in wildlife for the alternative control strategies.



Points, circles and triangles mark the proportion of runs that were halted within 50, 100 and 200 km, respectively (see Table 18). Note that not all simulated local ASF epidemics were successfully controlled, even with the maximum buffer width of 200 km. The grey graph representing ASF spread in the absence of any control measures demonstrates the forward spread resulting from most plausible model parameterisation (i.e. average population density 1.5 animals per km² and carcass infectivity of 0.9)

Figure 19: Duration of simulated local ASF epidemics in wildlife under the alternative control strategies

There are two general observations from the simulation output that will be highlighted in the following diagrams (Figure 21). In the case of medium and high densities (1.5–2.0/km²), only those strategies that prevented targeted release of infectious carcasses were successful (i.e. massive depopulation and carcass removal) and even then only if the effectiveness of implementing the measures was high (i.e. here 70 % or more).

Dens/km²	Feeding ban	Targeted hunting	Massive depopulation	Instantaneous carcass removal
1.0				
1.5				
2.0				

The line graphs depict the risk that the various control measures will fail to halt ASF in the control area in the model simulations. The results are shown for scenarios applying different alternative strategies for different average population densities and increasing effectiveness of the measures (top line to lowest line in the diagram: grey, 0 % effective; red, 30 % effective; blue, 50 % effective; green, 70 % effective; pink, 90 % effective) and different widths of the zones surrounding the affected area between 0 km and 200 km.

Figure 20: Summary graphs of 120 repetitions of simulation scenarios including the width of the zones surrounding the affected area and the size of the affected area at the onset of the measures

Alternative strategies aimed at reducing the population by reducing reproductive performance (i.e. feeding ban and targeted hunting of adult and sub-adult females) require very large zones surrounding the affected area (of at least 100 to 200 km), even for low to medium boar densities (1–1.5 km²). Even a 200-km zone surrounding the affected area is insufficient when there are larger numbers of animals per area unit. The underperformance is because it takes a long time for this strategy to achieve the envisaged effect on the population structure. These strategies can be used only well in advance of an ASF incursion as a preventative measure, but must then be maintained as long as the possible risk of introduction exists.

In a follow-up simulation, carcass removal was combined with slightly increased intensity of conventional hunting (between 10 % and 40 %; mixing the strategies C-CR-0 with B-CH). The intention of this hypothetical scenario was to achieve eradication with relaxed assumptions with an effectiveness that may be closer to what can be achieved in practice. As expected, the results are more positive than for the single measure application (see Lange, 2015). Assuming minimum zones surrounding the affected area of 30 km and carcass removal efficiency of more than 50 %, in combination with conventional hunting intensity increased to remove at least 30 % of the normal survivors in a year, eradication was very likely with this simulated mixed strategy. The outcome suggests a way of thinking further towards a strategy combining reasonable width of the zones surrounding the affected area, reasonable management effort and sustainable time horizons with ethical reservation of stakeholders in the system (including wild boar).

6.4. Discussion

Overall, the experimental data imply that direct contact with live infectious animals as a transmission pathway of ASF would probably result in a density-dependent spread. Density thresholds for this type of transmission are not yet established, but have been suggested to be much greater than for CSF, i.e about six animals per square km (Gortazar, Universidad de Castilla, La Mancha, 2015 personal communication) compared with about two animals per square km estimated for CSF (Guberti et al., 1998). This is reasonable because the effectiveness of the live animals contact transmission pathway is much reduced in comparison with transmission of CSF in wild boar. However, in the case of ASF, spread through contact with carcasses is expected to play an even more important role. Carcasses of infected animals provide a storage of infectious material until the material is broken up by other predators (Selva et al, 2015), which may take several weeks, e.g. in winter. Subsequently, contacts with open carcasses provides direct access to blood-related highly infectious material. This type of spread is suggested to be dependent on the frequency at which naive animals have contact with infected carcasses within their range of daily movements. Even one infectious carcass within the spatial movement range of wild boar groups of a certain number will cause a large number of secondary infections, regardless of the density of animals at that the spot. Thus, it is still inconclusive whether any threshold may be involved in this process and whether it can usefully be estimated (i.e. Lloyd-Smith et al., 2005).

According to estimates of the overall reproductive rate of ASF in wild boar of Russian Federation (Iglesias et al., 2015), the wild boar density required to stop spread of ASF in wild boar would be between 0.1 and 0.2 animals per square km (see the density map in Figure 19). Literally translated, the same transmission dynamics would require 80–90 % of the wild boar population in the affected Member States to be culled (see scenario 'massive short-term population destruction'). The difficulties of implementing such destructive strategies are already well recognised and have already been demonstrated for other infectious diseases of wild boar (EFSA, 2014b).

Alternative strategies proposed for the model-based assessment were either rapid control measures aimed at prevention of the occurrence, or removal, of infectious carcasses in the environment (i.e. through drastic depopulation (>70 %) or fast carcass removal) or long-term preventative measures aimed at achieving a sustainable reduction in the population (i.e. feeding ban and targeted hunting of reproductive females).

In general, any wild boar management strategy aiming to control ASF in wild boar populations has to foresee measures inside the area of ASF detections and in a zone surrounding this area. The critical extent of the zone surrounding the affected area depends on which strategy will be applied. Applying any of the proposed measures only within the area where ASF detections were reported (i.e. see Table 19, width of the zones surrounding the affected area 0 km), there would be an 80 % chance that the measure would fail to halt the spread of the infection.

The two sustainable strategies—a ban on feeding and targeted hunting—were found to be effective only very slowly, requiring time for multiple generations of reproduction. This is reasonable because the measures change the number of breeding females or the number of piglets. Thus, to take effect, more than one generation cycle is necessary, i.e. the measure must be continued for multiple years. However, during that time the disease will have spread forward (in the model about 50 km each year of control), overwhelming great parts of the control area. Thus, when these strategies are started in and around the area of ASF detections, measures should also be implemented in a zone surrounding the affected area to compensate for this forward spread. Depending on the size of the control area, and to maximise the chance of final success, a zone of width 100–200 km should be treated. If a smaller zone width is preferred, then the chance of success will be correspondingly reduced (Table 19 and Figure 25).

The rapid response strategy of massive population destruction (i.e. destruction of more than 70% of the population in the control area within four months using any available technique) performed rather well, with a reasonable success rate, and meant that the width of the zones surrounding the affected area could be limited to below 50 km^2. The reason for the success found in the simulation was not the massive reduction of population density but the implicit exclusion of infectious carcasses. This was demonstrated by the scenarios of instantaneous exclusion of contacts within infectious carcasses throughout the control area (within one week), which showed the same outcome as the depopulation scenario. Again, this is reasonable as depopulation destroys all animals that later could become infectious carcasses. Hence, in the model, the depopulation strategy worked equally as well as instantaneous carcass removal because the depopulation strategy "implicitly" prevents/removes most carcasses.

In the model, however, the carcass removal must happen very quickly (within a week), and everywhere in the control area. It was reported that during the period 1 January to 15 May 2015, and in one hunting ground of Latvia, 39 carcasses were removed out of 80 wild boar estimated to have died of ASF during the same period and in the same hunting area (an effective carcass detection/elimination success rate of 49 %). Carcass removal was, therefore, simulated with limited effectiveness (up to 50 %) but together with slight increase in the hunting bag of the conventional hunting methods (i.e. 20–30 % greater hunting bag) for about one year. These results indicated that there might be a way to determine a least practical + minimum effective combined strategy. This was not further developed.

In agreement with recent observations from the ASF-infected MSs, the infection as defined by the model assumptions was found unambiguously to in all simulations spread as long as suitable wild boar habitat remained adjacent, although direct contact infection between live animals is reported to be very low (Blome et al., 2012; Gallardo et al., 2015) compared with other infectious diseases in wild boar that spread via direct contact (e.g. foot and mouth disease, CSF). The spatio-temporal ASF detection history suggests, for the vast majority of plausible wild boar-mediated spreading events, a velocity below 50 km per year, as replicated by the model calibration.

Despite the high lethality of individual infections (i.e. greater than 90 %), ASF does not spontaneously decline, either in the model or in the field. As suggested already, there are other mechanisms involved in the transmission of the infection that drive the slow but forward spread of the infection on the landscape scale. Virus can survive with the carcass in the environment. Although there is a low probability that a wild boar will contact an infectious carcass, there is a high probability that the contact will lead to infection. This scenario was found in the model calibration exercise using field data on ASF detections, which resulted in different carcass persistence time but always minimal contact/transmission rate.

The importance of carcasses for the modelled epidemiological systems was demonstrated by the comparison of the effect of massive depopulation and instantaneous carcass removal, which showed similar results. The outcome indicates that it was the avoidance of infected carcass deposition implicit in the depopulation scenario that was driving the success, rather than density reduction. If, theoretically, carcasses could be removed instantaneously, then, as in the massive depopulation scenario, the infection came to halt and was eradicated from the control area. It might be worth noting that of wild boar accessing from carcasses throughout the control area until the infection is eliminated may require greater efforts for a longer period of time than short-term massive depopulation.

The relevance of carcasses in the epidemiology of ASF is different from that for other wildlife diseases such as foot and mouth disease. Foot and mouth disease is transmitted either through direct contact or through contact with the contaminated environment before any carcass would be of importance. If carcasses are deemed as relevant as discussed here (i.e. contact transmission prior to clinical disease is limited; Blome et al., 2012; Gallardo et al., 2015), then the effect on the control measures found with the simulations is plausible. There will be no immediately effective measure if carcasses are not excluded from the systems. Therefore, all other alternatives (i.e. feeding ban, targeted hunting) require a substantial build-up time before these can affect ASF spread, seen as large zones surrounding the affected area in the simulation outcome.

The problem arises with measures aimed at reducing reproductive capacity (i.e. feeding ban) or changing the age structure of animals targeted by conventional hunting (i.e. targeting reproductive females). To be effective, these measures require more time than it takes for forward spread of the “non-enclosed” infection to break out from the control area. Therefore, for example, the measure meant to reduce annual reproduction may first become effective only a year after its implementation. Hence, the strategy applying this measure needs to compensate for the delayed effectiveness by a increasing the width of the zones surrounding the affected area. Whether it is feasible to implement measures such as targeted hunting of the female reproductive pool throughout a zone surrounding the affected area that extends up to 200 km, and to comply with these for about five years, cannot be answered through model analysis.

It appeared worthwhile to assess combined strategies that maximise population reduction by conventional hunting and barrier-like zones of carcass removal. The resulting theoretical simulation, in which carcass removal rate and increase in effectiveness of conventional hunting methods were varied, provided useful results. However, for the moment the lack of suggestions for appropriate values for the feasibility of coordinated carcass removal and the maximum plausible increase in conventional hunting effort limits the precision of such simulations regarding detailed predictions of success or failure. The general result of the model implies that single-measure strategies are insufficient for control because the necessary dimensions are either impractical (size or speed or precision) or unethical (population destruction or extinction). Nevertheless, a strategy is needed that combines reasonable zones surrounding the affected area, reasonable management effort and sustainable time horizons with ethical reservation of experts in the system (including wild boar—in German: “eierlegende Wollmilchsau”). Model simulations have suggested that the critical mechanism of the ASF wild boar system is the infectious carcass. A effective approach may be to combine carcass-free zones surrounding the affected area, or at least carcass thinning, with any supportive approach that further reduces the abundance of infectious carcasses without disturbing the population. The simulation of a theoretic mixed strategy reflects this way of thinking further. However, the very practical parameters of the strategy assumed for the simulations still need the commitment of the practitioners involved. Examples area feasible increase in conventional hunting intensity (non-disturbing) or useful efforts to ban carcasses from being accessed by other wild boar throughout the zones surrounding the affected area and, ideally, the affected area. Quantitative suggestions for these parameters are not yet accessible from literature or expert discussion (i.e. can conventional hunting actually harvest a further one-third of the animals surviving after one hunting seasonand maintain the effort over one to two years). Moreover, even if these commitments are obtained, the unknown parameters affecting spread of ASF in wild boar (e.g. carcass accessibility to wild boar, infectiousness “period” of carcasses in the field) still need to be explored to determine quantitative baseline indications on the expected performance of the mixed strategies as well as predictive spatial and temporal parameterisations.

Unfortunately, the feasibility of immediate measures, such as fast massive depopulation or instantaneous carcass removal, is already open to debate (EFSA, 2014b). Options not yet assessed in the model simulations include exploiting barriers provided by the natural landscape (Rossi et al., 2005) and implementing precautionary soft measures in currently affected regions.

The data evaluated here, and also the design of the simulation experiments, focused on the situation, ecological and epidemiological, of the Member States recently affected by ASF genotype II. Other areas in the EU may have a much greater number of wild boar (see Figure 19), which may make application of the proposed measures more difficult (i.e. removing even more carcasses or reducing greater reproductive performance). However, in terms of wild boar-mediated forward spread of the infection, these regions have more time to prepare. Therefore, reconsideration of the proposed strategies, which were simulated for the affected MSs, where the virus is already present and where there is not much time, might be worthwhile to increase preparedness for future incursions in other MSs.

6.5. Conclusions

Literature review

- As yet, a reduction in the wild boar population to below 60 % has never been documented in Europe with conventional hunting methods.
- Frequent and intense drive hunts can lead to adaptive behaviour among hunted wild boar, compensatory growth of the population, influx of wild boar from adjacent areas and extensive movements of wild boar outside the focal area.
- To reduce wild boar populations, feeding should be prohibited and hunting rates increased for several consecutive years, especially of females, as all age classes of females are highly reproductive.

Expert consultation

- Currently there is not enough evidence to state the exact quantitative threshold separating baiting and feeding amounts of supplied feed resources.
- Required baiting quantities may differ greatly between different habitats and hunting practices and depending on the type of feed provided. However, the experts agreed that baiting should not result in increased survival and reproduction in the populations.
- It was concluded that no single feasible strategy has only advantages and is effective in controlling the spread of ASF.

Epidemiological model

- Any strategy aiming to control ASF in wild boar populations should address the area where ASF has been detected and the zone surrounding the affected area. The width of an effective zone surrounding the affected area depends on the applied strategy.
- Massive depopulation of wild boar and subsequent disposal of carcasses within a very short time span will limit the production of untreated infected carcasses and should therefore halt the spread of ASF beyond the control area.
- However, the effort required to achieve effective massive depopulation would necessitate measures that are not acceptable or conventional in management of wildlife populations (e.g. poisoning or shooting with night vision).
- Strategies based on conventional wild boar management options (i.e. feeding ban or targeted hunting) would need to be implemented over a very long period of time. This is because they require multiple wild boar generations to become effective. The spread of the infection would continue unaltered throughout this period.
- A tailor-made ban on feeding animals to reduce the reproductive performance of a population is likely to be effective only in regions where the wild boar habitat is rather unsuitable, and where feeding supports artificial population establishment.
- Targeted hunting practices selecting adult and sub-adult females affect the reproductive pool after several wild boar generations. Before the measure become effective, however, the infection will probably continue to spread forward. Zones surrounding the affected area need

to be sized sufficiently to compensate for forward spread. This may require hunting zones greater than 200 km in some simulation scenarios.

- Conceptually, alternative strategies should be implemented in a zone surrounding the affected area extending beyond 50 km and foreseeing about two to three years of management, including:
  - the effective removal of carcasses (i.e. up to 50 % of fallen wild boar) and
  - intensified conventional hunting approaches leading to annual removal of 30–40 % of new entrants to the population.

The feasibility of these measures will depend on the characteristics of the area where they are to be applied.

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Appendix A – Epidemiological investigations of ASF outbreaks in four EU MSs

Table 17: Epidemiological investigations of ASF outbreaks in Latvia, Lithuania, Poland and Estoia

Latvia

Region	Community	Date of suspicion	Date of confirmation	Symptomatic	Feeding	Housing	Kitchen wastes feeding?	Hunting	Travel to east	Travel date	Travel country	New workers
Latgale	Krāslava	21/06/2014	26/06/2014	Yes	Bought feed (compound feed), home-made feed (potatoes, cereal flour)	Indoor controlled environment	No	No	Yes	Often	Belarus	No
Latgale	Krāslava	01/07/2014	03/07/2014	Yes	Grass, home-made feed (potatoes, cereal flour, milk)	Indoor open to environment	No	Unclear	No			No
Latgale	Krāslava	10/07/2014	11/07/2014	Yes	Grass, home-made feed (potatoes, cereal flour)	Indoor open to environment	Yes	No	Yes	28/06/2014	Belarus	No
Latgale	Krāslava	11/07/2014	12/07/2014	Yes	Bought feed (cereal flour), home-made feed (potatoes, cereal flour)	Indoor controlled environment	Unclear	No	Yes	Often	Belarus	No
Latgale	Krāslava	11/07/2014	13/07/2014	Yes	Bought feed (cereal flour, grass), home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Yes	No	Unclear			No
Latgale	Krāslava	14/07/2014	16/07/2014	Yes	Bought feed (cereal flour, grass), home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	Unclear	No			No

www.efsa.europa.eu/efsajournal 75 EFSA Journal 2015;14(7):4163

Region	Community	Date of suspicion	Date of confirmation	Symptomatic	Feeding	Housing	Kitchen wastes feeding?	Hunting	Travel to east	Travel date	Travel country	New workers
Latgale	Krāslava	15/07/2014	17/07/2014	Yes	Home made feed (cereal flour)	Indoor controlled environment	Unclear	No	No			No
Latgale	Krāslava	16/07/2014	17/07/2014	Yes	Bought feed (compound feed, cereal flour), home-made feed (cereal flour, potatoes)	Indoor controlled environment	Yes	No	No			No
Vidzeme	Valka	14/07/2014	18/07/2014	Yes	Grass, home-made feed (cereal flour), bought feed (cereal flour)	Indoor controlled environment	Unclear	Unclear	No			No
Latgale	Krāslava	17/07/2014	19/07/2014	Yes	Bought feed (cereal flour), home-made feed (milk, cereal flour)	Indoor controlled environment	Unclear	Unclear	Yes	In June	Russia	No
Latgale	Krāslava	17/07/2014	19/07/2014	Yes	Grass, home-made feed (potatoes, cereal flour, milk)	Indoor controlled environment	Unclear	Unclear	No			No
Latgale	Krāslava	18/07/2014	22/07/2014	Yes	Home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	No	No			No
Latgale	Krāslava	18/07/2014	22/07/2014	Yes	Grass, home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	No	Yes	12/07/2014	Belarus	No
Vidzeme	Valka	24/07/2014	25/07/2014	Yes	Bought feed (compound feed), home-made feed (potatoes, cereal flour)	Indoor controlled environment	Yes	No	No			No

www.efsa.europa.eu/efsajournal 76 EFSA Journal 2015;14(7):4163

Region	Community	Date of suspicion	Date of confirmation	Symptomatic	Feeding	Housing	Kitchen wastes feeding?	Hunting	Travel to east	Travel date	Travel country	New workers
Vidzeme	Valka	28/07/2014	29/07/2014	Yes	Bought feed (compound feed), home-made feed (cereal flour)	Indoor controlled environment	Unclear	Unclear	No			No
Latgale	Krāslava	27/07/2014	29/07/2014	Yes	Grass, home-made feed (potatoes, cereal flour)	Indoor controlled environment	Unclear	No	No			No
Vidzeme	Valka	28/07/2014	29/07/2014	Yes	Home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	Unclear	No			No
Latgale	Krāslava	27/07/2014	29/07/2014	Yes	Bought feed (cereal flour, grass), home-made feed (potatoes, cereal flour)	Indoor controlled environment	Yes	No	Yes	In June	Belarus	No
Latgale	Krāslava	28/07/2014	01/08/2014	Yes	Home-made feed (cereal flour)	Indoor controlled environment	Unclear	No	No			No
Latgale	Krāslava	25/07/2014	01/08/2014	Yes	Bought feed (compound feed), home-made feed (cereal flour, fodder beet)	Indoor controlled environment	Unclear	No	No			No
Latgale	Krāslava	29/07/2014	02/08/2014	Yes	Home-made feed (potatoes, cereal flour)	Indoor controlled environment	Unclear	No	No			No
Latgale	Krāslava	26/07/2014	01/08/2014	Yes	Grass, home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	No	No			No

www.efsa.europa.eu/efsajournal 77 EFSA Journal 2015;14(7):4163

Region	Community	Date of suspicion	Date of confirmation	Symptomatic	Feeding	Housing	Kitchen wastes feeding?	Hunting	Travel to east	Travel date	Travel country	New workers
Latgale	Krāslava	27/07/2014	01/08/2014	Yes	Grass, home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	No	Yes	18/07/2014	Belarus	No
Latgale	Krāslava	24/07/2014	01/08/2014	Yes	Bought feed (compound feed), home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	No	No			No
Latgale	Krāslava	02/08/2014	05/08/2014	Yes	Bought feed (compound feed, cereal flour), home-made feed (cereal flour)	Indoor controlled environment	No	Unclear	Unclear			No
Vidzeme	Valka	03/08/2014	06/08/2014	Yes	Grass, home-made feed (cereal flour, potatoes, fodder beet)	Indoor controlled environment	Unclear	No	No			No
Latgale	Krāslava	05/08/2014	11/08/2014	Yes	Bought feed (cereal flour), home-made feed (cereal flour, potatoes, fodder beet)	Indoor controlled environment	Unclear	No	Yes	21/07/2014	Russia	No
Vidzeme	Valka	11/08/2014	12/08/2014	Yes	Bought feed (compound feed), home-made feed (cereal flour)	Indoor controlled environment	No	No	No			No
Latgale	Krāslava	18/08/2014	25/08/2014	Yes	Grass, home-made feed (cereal flour, potatoes, fodder beet, milk)	Indoor controlled environment	Yes	No	No			No

www.efsa.europa.eu/efsajournal 78 EFSA Journal 2015;14(7):4163

Region	Community	Date of suspicion	Date of confirmation	Symptomatic	Feeding	Housing	Kitchen wastes feeding?	Hunting	Travel to east	Travel date	Travel country	New workers
Latgale	Krāslava	17/08/2014	25/08/2014	Yes	Bought feed (compound feed), home-made feed (cereal flour)	Indoor controlled environment	Unclear	No	Yes	01/08/2014	Belarus	No
Latgale	Krāslava	27/08/2014	29/08/2014	Yes	Bought feed (cereal flour), home-made feed (potatoes, milk, cereal flour)	Indoor controlled environment	Unclear	No	No			No
Vidzeme	Valka	14/09/2014	17/09/2014	Yes	Home-made feed (potatoes, cereal flour)	Indoor controlled environment	Unclear	No	No			No

Source: Food and Veterinary Service. Veterinary Surveillance Department.

www.efsa.europa.eu/efsajournal 79 EFSA Journal 2015;14(7):4163

Lithuania

Event	Date	District	Hunted/found dead	Distance to backyard	Dist to the previous	Potential source of infection (most likely)	Reference
WB1 [(a)]	24/01/2014	Salcininkai	Found	5		Movement from Belarus	SCoFCAH Present (February 2014)
WB2	24/01/2014	Varena	Hunted	42	36	Unknown	SCoFCAH Present (February 2014)
DP1 [(b)]	24/07/2014	Ignalina	Farm	22	160–180	Human factor	SCoFCAH Present (August 2014)
DP2	29/07/2014	Utena	Backyard		17 km	Human factor—the owner is an active hunter (mostly illegal)	SCoFCAH Present (August 2014)
DP3	10/08/2014	Ignalina	Backyard			Human factor—introduction of contaminated material	SCoFCAH Present (September 2014)
DP4	11/08/2014	Ignalina	Backyard			Human factor—introduction of contaminated material	SCoFCAH Present (September 2014)
DP5	22/08/2014	Rokiskis	Backyard			Human factor—introduction of contaminated material	SCoFCAH Present (September 2014)
DP6	30/08/2014	Ignalina	Farm	1		Contact with contaminated material from wild nature	SCoFCAH Present (September 2014)
WB3,4	08/08/2014 03/09/2014	Ignalina	1 dead 1 dead		7.5–8 (DP1)		SCoFCAH Present (September 2014)
WB/5	22/09/2014	Švenčionys	Hunted	1		Movement of infected wild boar from infected area	SCoFCAH Present (October2014)
WB/6	23/09/2014	Švenčionys	Hunted	8.8		Movement of infected wild boar from infected area	SCoFCAH Present (October 2014)
WB7	24/09/2014	Alytus	Hunted		8 (WB1)	Re-infection of the wild boar from previous cases (undetected dead wild boar)	SCoFCAH Present

SCoFCAH Present : presentation given at the standing Committee of Food Chain and Animal Health
(a): WB1 = first wild boar case.
(b): DP 1: first outbreak in domestic pigs.

www.efsa.europa.eu/efsajournal 80 EFSA Journal 2015;14(7):4163

Poland

Event	Date	District	Hunted/found dead	Distance to Belarusian border	di	Potential source of infection (most likely)	Ref
WB1	Found 03.02.2014 Sampled 13.02.2014 Confirmed 17.02.2014	near the Grzybowszczyzna village (municipality Szudziałowo, district sokólski, podlaskie region)	Found dead	900 m from the border with Belarus		A lot of evidence support the hypothesis that the source of infection are wild boar from Belarus: - The virus is identical as in BY and LT - The cases in Poland and in Lithuania are located very close to the border with BY - Information that in BY, near the border area hunts on wild boar with beaters were carried out.	SCoFCAH, 2014 (4-5 March)
WB2	Found 15.02.2014 Confirmed 18.02.2014	municipality Krynki, district sokólski, podlaskie region	dead	3	15		
WB3	found 19 May 2014 confirmed 29 May 2014,	800 m from the Rudaki village (Krynki, municipality sokólski district, Podlaskie region	dead		appr. 4,5 km from WB2	Direct contact of the wild boar in 3. and 4. case with the first two cases of ASF is highly unlikely as in both recent cases the infection is rather fresh & the carcasses were not old. The source of infection could not be determined with 100% certainty, however the most probable source of infection - transboundary movement of wild boar.	SCFCAH, 2014 (6 June)
WB4	30 May 2014 ASF has been confirmed	All infected animals found in 4 communitiescommu nities located in 2 (out of 15) districts	dead	3	3		
WB5	Found 24.06.204 Confirmed 26.06.2014	Near the village Słoja	dead	9 km	25	Movement of infected wild boar from other infected areas (Belarus) is the most likely hypothesis of ASF introduction and occurence in Poland The wild boar could not have got infected from pigs.	SCPAFF, 2014 (21 August)
WB6	Found 24-30.06.2014 Confirmed 27.06-1.07.2014	Near the border river, Bobrowniki	4 dead	5 m from the border	32		
WB7	Found 04.07.2014 Results 07.07.2014	Municipality of Gródek, 1 km from the Łużany	6 dead WB	4 km	5		

www.efsa.europa.eu/efsajournal 81 EFSA Journal 2015;14(7):4163

Event	Date	District	Hunted/found dead	Distance to Belarusian border	di	Potential source of infection (most likely)	Ref
WB8	Found 08.07.2014 Result 10.07.2014	Municipality of Gródek	dead	4	18		
WB9	15.07.2014 16.07.2014	1,5 km from village Skroblaki	6 dead wildboar	7.5	3.5 to WB7		
WB10	Found: 29.07.2014 Result: 31.07.2014	forestareainthemuni cipalityofGródek	1deadwildboar	11.5			
WB11	Found: 29.07.2014 Result: 31.07.2014	municipalityofMichał owo	1deadwildboar	3.5			
WB12	Found 30.07.2014/ 11.08.2014 Result 1.08.2014/ 12.08.2014	2,5 km from the village Zubry and Wiejki	3 dead	7	0.7 from WB8		
WB13	Found 08.08.2014 Confirmed 11.08.2014	Near the village of Horczaki, Górne municipality of Szudziałowo	dead	5.5	6.5 from WB5		
DB1	Susp. 19.08.2014 Conf. 23.08.2014	Outskirts of the village Zielona (Gródek municipalityof)	5(8) pigs, clin. signs	2.5	4 km from WB8	The holdings are situated on the edge of the forest, with low level of biosecurity No evidence of infection in pigs has been found (intensive surveillance in place since 2013). In accordance with available information in BY, near the border area, intensive hunts on wild boar were being carried out in2014.	SCPAFF, 2014 (21 August)
DB2	Susp. 06.08.2014 Result 08.08.2014	Outskirts of thevillage Józefów (Gródek municipality)	1 pig	13	5 km to WB9		
WB14	Found: 24.08.2014 Results: 26.08.2014	near the Mostowlany village (municipality of Michałowo)	One dead wild boar	3.5		No information	SCPAFF, 2014 (11-12 Sept)

www.efsa.europa.eu/efsajournal 82 EFSA Journal 2015;14(7):4163

Event	Date	District	Hunted/found dead	Distance to Belarusian border	di	Potential source of infection (most likely)	Ref
WB15	Found: 12.09.2014 Result: 17.09.2014	near the village of Zaleszany Kolonia (Michałowo municipality)	1 shot wild boar	on the border		No information	SCPAFF, 2014 6-7.10 2014 Brussels
WB16	Hunted: 22.09.2014 Result: 6.10.2014	Near the villages of Straszewo i Gródek	1 shot wild boar			No information	SCPAFF, 3-4. 11 2014 Brussels
WB17	Found: 04 and 08.10.2014 Result: 08.10.2014 / 10.10.2014	near the villages of Nowosady -Kolonia	2 dead wild boar	1.2			
WB18	6 and 8.10.2014 8 and 10. 10.2014	near the village of Piłatowszczyzna	16 dead wild boar				
WB9	Found: 19.10.2014 Result: 22.10.2014	ear the village of Zaleszany Kolonia	1 dead wild boar				
WB20	Hunted: 11.11.2014 Result: 18.11.2014	Near the village of Zaleszany (municipality of Michałowo)	1 shot wild boar	0.6		No information	SCPAFF, 5.12. 2014 Brussels
WB21	Found: 21.11.2014 Result: 24.11.2014	in a forest area near the village of Wiejki	1 dead wild boar	6			
WB22	Found: 11.11.2014 Result: 18.11.2014	near the village of Zaleszany		0.6			
WB23	03.12.2014		1 shot wild boar	14		No information	SCPAFF, 13-14.01.2015 Brussels
WB24	05.12.2014		1 shot wild boar	14			
WB25	05.12.2014		1 dead wild boar	18			
WB26	12.12.2014		1 shot wild boar	1			
WB27	15.12.2014		1 shot wild boar	14			

www.efsa.europa.eu/efsajournal 83 EFSA Journal 2015;14(7):4163

Event	Date	District	Hunted/found dead	Distance to Belarusian border	di	Potential source of infection (most likely)	Ref
WB28	15.12.2014		1 shot wild boar	3			
WB29	15.12.2014		1 shot wild boar	7.5			
WB30	24.12.2014		1 dead wild boar	19			
DP3	Susp. 30.01.2015 31.01.2015	Puciłki (municipality of Sokółka)	7 pigs kept in the holding)	8		Epidemiological investigation is being carried out	SCPAFF, 4.02.2015 Brussels
WB31	20.01.2015		1 dead wild boar	16			

Estonia

Infected area/Num of case	District	Date of start of the event	Week	Cases	Dist from Lat (Rus) border	Dist from prev. outbrk, km	Potential source of infection (most likely)	Ref
Infected area 1	Valgamaa	02/09/2014	36	22	6		movement of infected wild board from infected area (Latvia)	SCPAFF 6.10.2014 SCPAFF 3-4.11.2014
Infected area 2	Viljandimaa	09/09/2014	37	98	30	25	"spill-over" from the Latvian cluster	SCPAFF 6.10.2014
Infected area 3	Ida-Virumaa	17/09/2014	38	20	50	220	unknown, possible human interaction	SCPAFF 6.10.2014 SCPAFF 3-4.11.2014
Infected area 4	Valgamaa	18/09/2014	38	6		18	"spill-over" from the Latvian cluster	CVET, 2014d
Infected area 5	Võrumaa	26/10/2014	43	15	20	20	No information	SCPAFF 3-4.11.2014
Infected area 6	Võrumaa	27/11/2014	48	6			No information	PAFF Committee 13.01.2015
Infected area 7	Ida-Virumaa	10/12/2014	50	3			No information	PAFF Committee 13.01.2015

www.efsa.europa.eu/efsajournal 84 EFSA Journal 2015;14(7):4163

Appendix B – Number of notifications in the four affected EU MSs by domestic pig and wild boar density

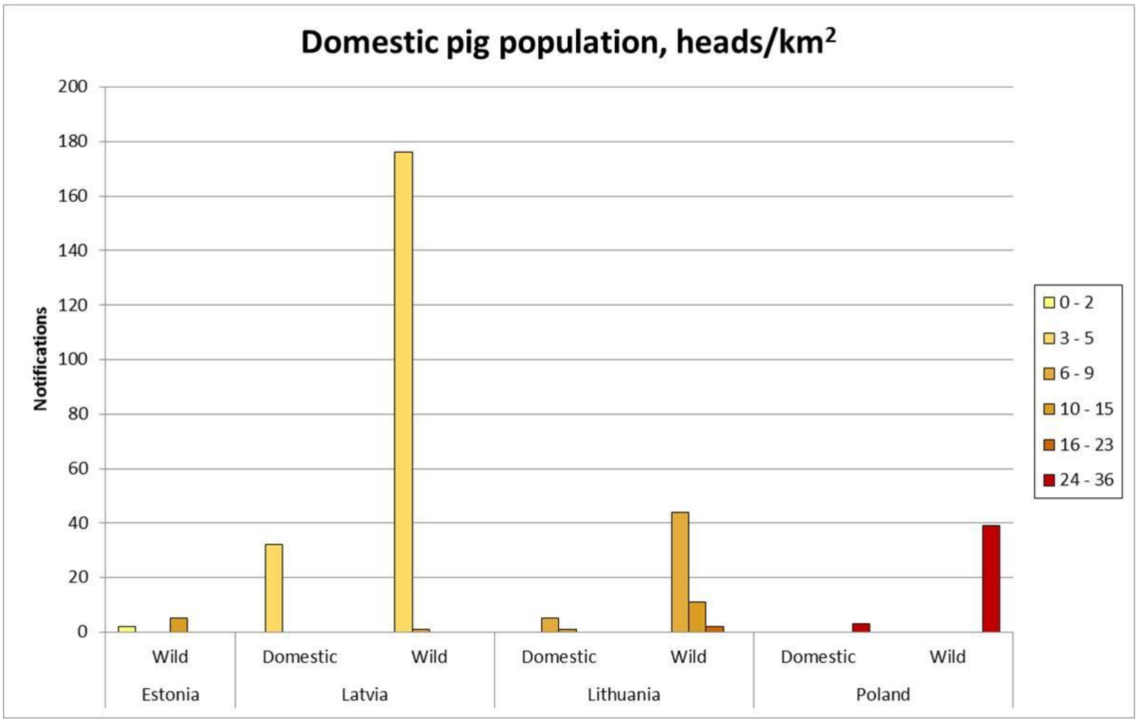
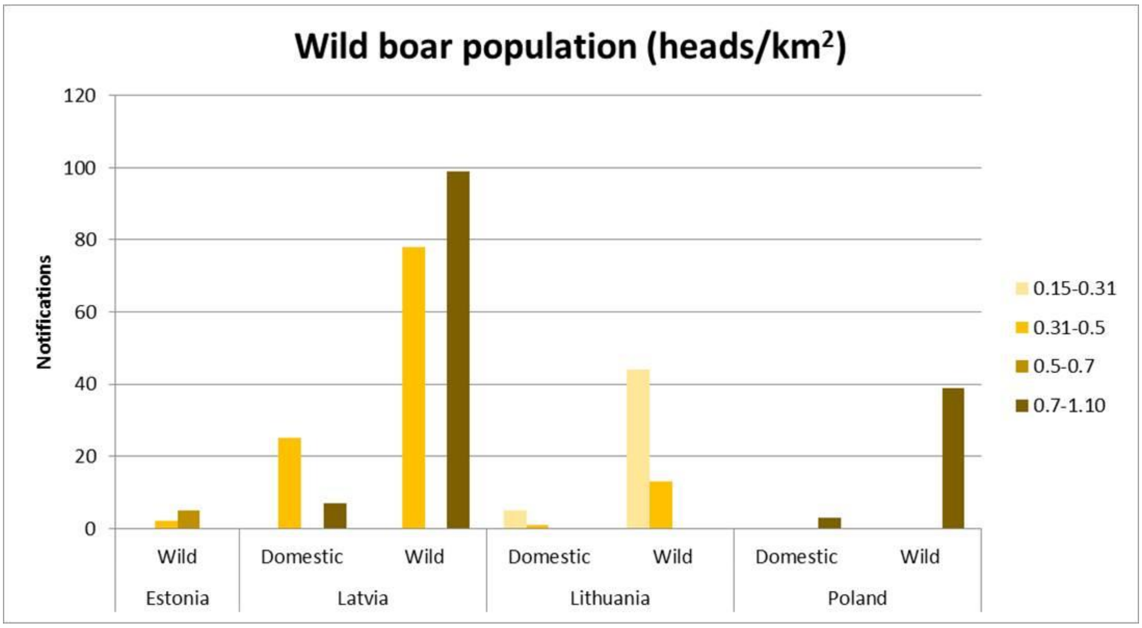


Figure 21: Number of notifications by domestic pig population density



Source: population density (see section 2.1.1)

Figure 22: Number of notifications by wild boar population density

Appendix C – Temporal variations of virus (DNA) prevalence

Seasonal variation in the virus (DNA) prevalence in hunted animals

The average virus (PCR positive) prevalence in the hunted wild boar in the affected regions of Latvia and Poland was very low, being 0.95 % and 0.17 % respectively.

Table 18: Numbers of hunted wild boar in Latvia and Poland tested with PCR for ASFV in 2014–2015 with laboratory testing results arranged by months of hunting

Month*	Poland			Latvia			Total		
	Negative	**Positive**	**Total**	**Negative**	**Positive**	**Total**	**Negative**	**Positive**	**Total**
January	565		565	849	6	855	1 414	6	1 420
February	514	1	515	762	2	764	1 276	3	1279
March	41		41	167		167	208	0	208
April	69		69	41		41	110	0	110
May	131		131	150		150	281	0	281
June	102		102	170		170	272	0	272
July	211		211	662	10	672	873	10	883
August	405		405	612	15	627	1 017	15	1 032
September	587		587	476	7	483	1 063	7	1 070
October	742	1	743	320	6	326	1 062	7	1 069
November	741	2	743	362	2	364	1 103	4	1 107
December	1 215	5	1220	564	1	565	1779	6	1785
Total	**5 323**	**9**	**5 332**	**5 135**	**49**	**5 184**	**10 458**	**58**	**10 516**

Source: data were obtained from the affected administrative units in Latvia and Poland spanning period from February 2014 to February 2015.

When data were pooled, the lowest monthly prevalence was observed to be in the spring and early summer months (Figure 23). During these periods, however, the sample size was low, and precision of prevalence estimates substantially reduced, as shown in Table 18. ASFV-positive animals were not detected in March–June, but a rapid increase between July and August was observed.

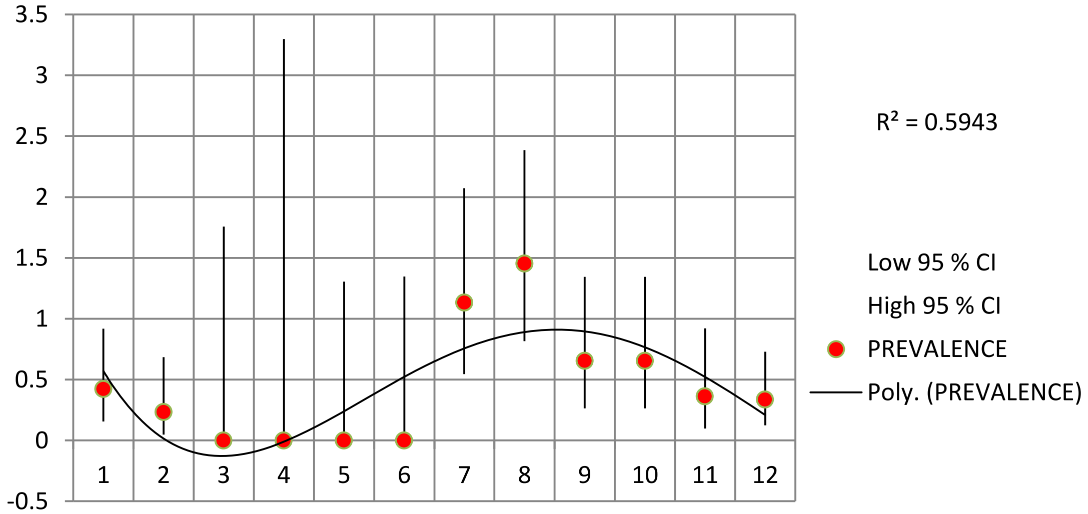


Figure 23: Monthly variation in virus prevalence in wild boar hunted in Poland and Latvia from February 2014 to February 2015 with 95 % CI fitted with fourth-order polynomial curve (R^2 = 0.59)

When the prevalence data were pooled by season, a statistically significant difference in prevalence was found to occur in summer (1.1 %, followed by a decline to 0.6 % in autumn (P = 0.025) and further to zero in spring). However, the peak in summer prevalence is determined by cases detected in Latvia, where the infection was firstly reported in July. The increased number of cases in summer may be the result of initial spread of the virus in a fully susceptible and relatively dense wild boar population, thus mimicking a seasonal pattern. Given such a seasonal prevalence pattern, the lack of virus-positive wild boar detections in the spring months might be related to an insufficiently large sample size (Table 19).

The difference between the "summer + autumn" and "winter + spring" periods (0.8 % and 0.3 % respectively) is also statistically significant ($\chi 2$ = 11.3, df = 1, P = 0.0008; statistical power 99.9).

Table 19: Seasonal variation of ASF virus prevalence (PCR+) in hunted wild boar in Poland and Latvia from February 2014 to February 2015 and results of a chi-squared test with Yates' correction

Season	ASF virus prevalence (%)					Chi-squared test with Yates' correction, P-values		
	"–"	"+"	Total	Mean	95 % CI	Spring	Summer	Autumn
Winter	4 469	15	4 484	0.3	0.19–0.55	0.3093	0.0001	0.1979
Spring	599	0	599	0.0	0.0–0.61		0.0171	0.1333
Summer	2162	25	2 187	.,1	0.74–1.68			0.0248
Autumn	3 228	18	3 246	0.6	0.32–0.87			

Regional variation in virus (DNA) prevalence in dead animals

Table 20: Seasonal variation in virus prevalence (PCR+) in wild boar found dead in Poland and Latvia from February 2014 to February 2015 and results of Fisher's exact test

Season	ASF virus prevalence (%)					Fisher's exact test, P-values		
	"–"	"+"	Total	Mean	95 % CI	Spring	Summer	Autumn
Latvia								
Winter	23	95	118	80.5	72.2–87,.2	0.0090	0.0001	0.2107
Spring	3	0	3	0.0	0–70.8		0.1003	0.0218
Summer	44	53	97	54.6	44.2–64.8			0.0057
Autumn	29	80	109	73.4	64.1–81.4			
Poland								
Winter	25	13	38	34.2	19.6–51.4	0.3659	0.0794	0.3526
Spring	16	4	20	20.0	5.7–43.7		0.0145	0.7660
Summer	21	26	47	55.3	40.1–69.8			0.0021
Autumn	40	13	53	24.5	13.8–38.3			
Latvia + Poland								
Winter	48	108	156	69.2	61.4–76.4	0.0001	0.0123	0.0361
Spring	19	4	23	17.4	4.9–38.8		0.0012	0.0005
Summer	65	79	144	54.9	46.4–63,.1			0.7292
Autumn	69	93	162	57.4	49.4–65.1			

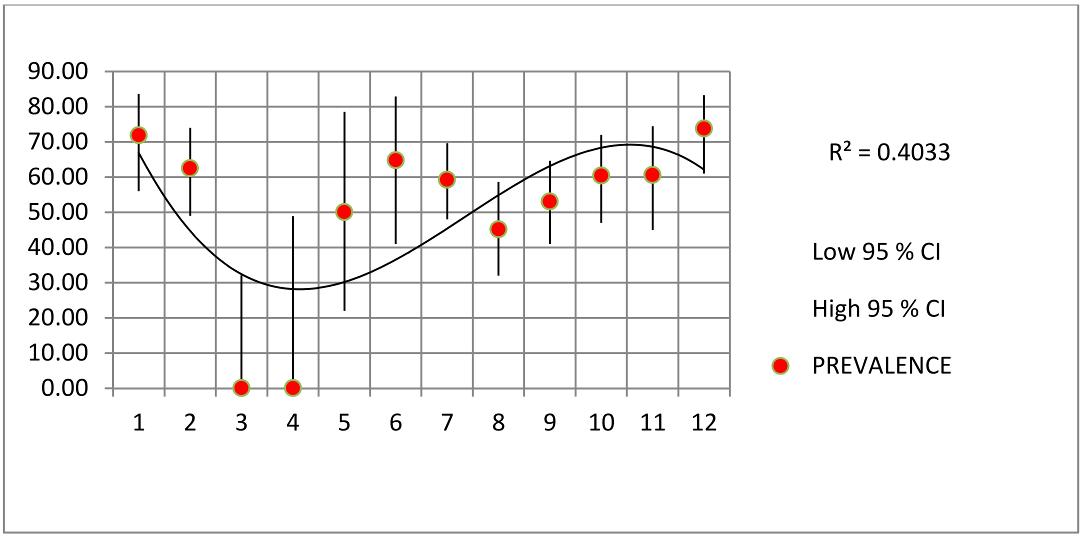


Figure 24: Monthly variation in virus prevalence (PCR+) in dead wild boar found in Poland and Latvia from February 2014 to February 2015 with 95 % CI fitted with fourth-order polynomial curve (R^2 = 0.40)

Seasonal variation in disease notifications (case detection) rates

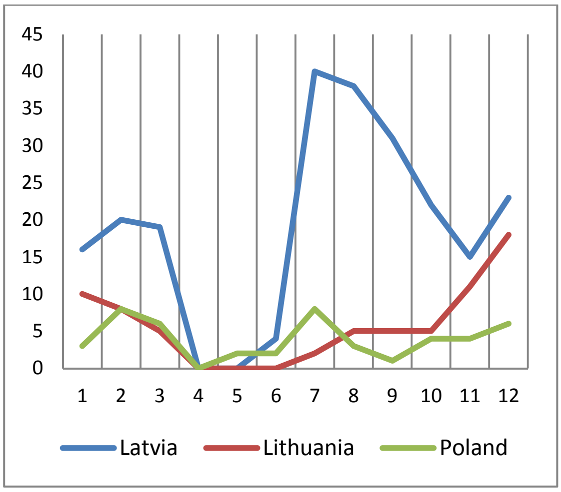


Figure 25: Distribution of ASF notifications in wild boar in Latvia, Lithuania and Poland from February 2014 to February 2015 (number of notifications monthly)

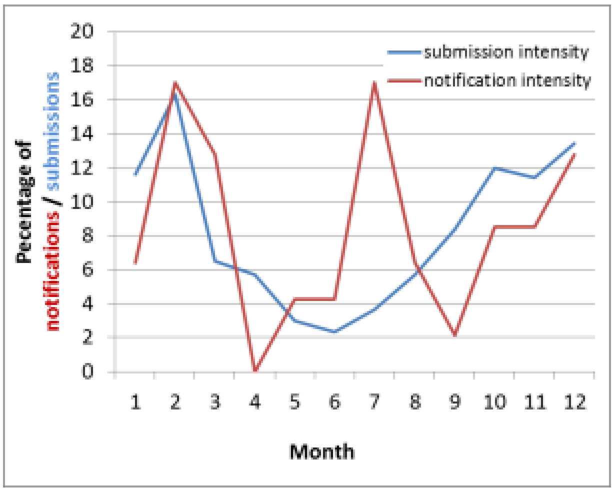


Figure 26: Comparison of sample submission intensity versus case notification intensity of ASF in Poland

Notifications of ASF in wild boar in the EU Member States (n = 351) were not randomly distributed throughout the year (Figure 25). Though quite variable, the monthly percentage of notifications showed a generally consistent pattern among the countries with (a) similar bi-modality in Poland and Latvia; (b) more notifications in autumn and winter and a gap in disease reporting in spring, particularly from April to June.

Figure 26 shows the monthly portion of sample submissions versus case notifications in wild boar for the Polish data. The red line illustrates the monthly notification intensity (same data as the green line in Figure 25); the blue line shows the monthly submission intensity for surveillance diagnosis (data provided by Poland). The data indicate that the winter increase in observed notifications is driven by the human activity patterns while the summer peak is intrinsic to the epidemiological system.

These patterns closely resemble observations in other affected countries (Russian Federation and Ukraine), which are compared at a monthly and seasonal resolution. A common feature in the monthly distribution of disease detections throughout the year is that they are bi-modal, with one peak falling in the cold months (December–February) and another in the warm part (May–July) of the year, separated by two periods of lower frequency of disease detections in autumn and, particularly, in spring.

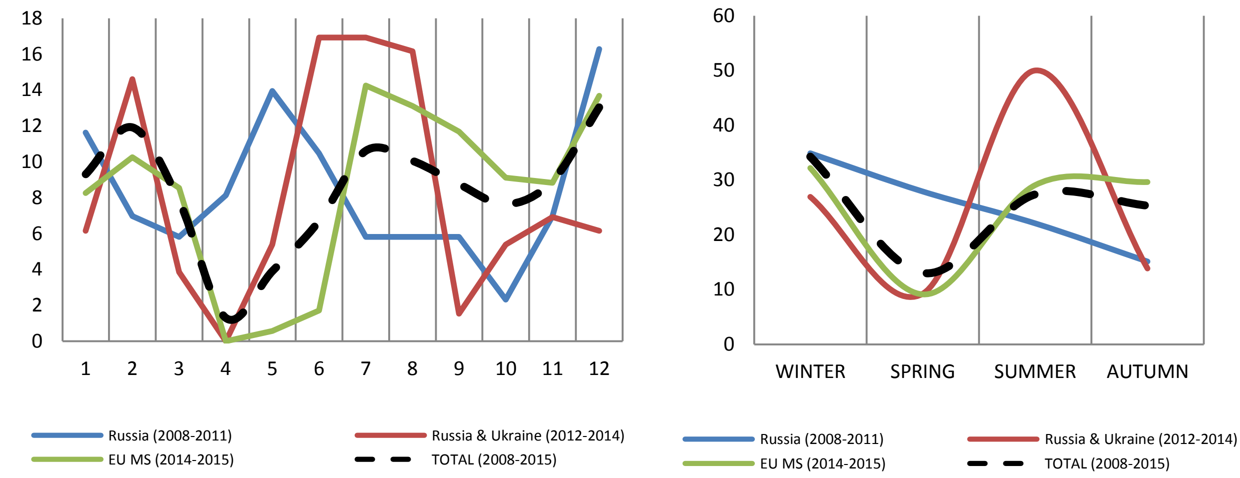


Figure 27: Distribution of ASF notifications in wild boar in the Russian Federation (2008–2011), Russian Federation and Ukraine (2012–2014), in the EU MSs (2014–2015, four countries pooled together) and in the whole of eastern Europe (2008–2015) at monthly (left) and seasonal (right) resolution

Interestingly, the seasonal variation in disease detections in both hunted and dead wild boar in Latvia and Poland is also in a good agreement with the seasonal distribution of disease detections in Russia and Ukraine (from 2012 to 1014) It is also worthwhile noting that virus prevalence among wild boar found dead is higher in winter (70 %) than in the summer–autumn period (50 %), which is the opposite of the pattern observed in hunted animals, among which virus prevalence in the summer is nearly twice as high as in the winter (Figure 27).

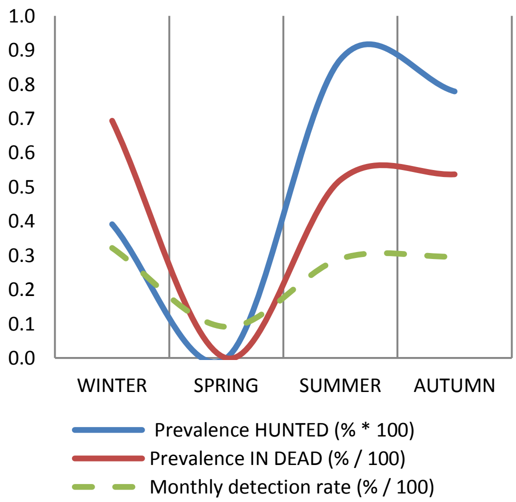


Figure 28: Seasonal variation in virus prevalence (PCR+) in hunted and found dead animals compared with monthly detection rate of ASF-positive wild boar (scaled to fit the range 0–1.0, to make comparison of patterns easier).

Appendix D – Sources of wild boar population estimates

Country	Data	Year(s) estimate	Population (counted or estimated)	Harvest (actual or estimated)	Reference
Albania	Population	2000	1 000	636	Bego et al; 2004
Austria	Harvest	2009 (2005)	60 000	30 212	Weidwerk, Jagdstatistik in Österreich, 2009.
Belarus	Both	2008 (2010)	69 100	25 949	Alekhnovich et al, 2011
Bosnia & Herzegovina	Harvest	2009	2 212	1406	Statistical Yearbook, 2010
Bulgaria	Both	2010	68 903	20 851	Ministry of Agriculture Bulgaria, 2010
Croatia	Harvest	2009	28 707	18 243	Croatian Bureau of Statistics, 2011
Czech Republic	Both	2010	121 690	57 880	Czech Statistical Office, 2011
Estonia	Both	2010	22 650	17 028	Statistics Estonia, 2011
Germany	Harvest	2010	1 000 000	340 706	Deutche Jagdverband , 2012
Greece	Population	2009	19 033	12 095	TSACHALID et al 2009
Hungary	Both	2009	106 700	111 200	Hungarian Central Statistical Office, 2010
Latvia	Both	2010	67 200	30 201	Statistics Latvia, 2010
Lithuania	Both	2009	54 608	41 441	Statistics Lithuania, 2009
Macedonia	Both	2009	1 889	490	Forestry, 2009
Moldova	Both	2000	5 000	1 000	Danilkin, 2002
Montenegro	Both	2009	3 584	482	Central Statistical Office of Poland, 2009
Poland	Both	2009	227 900	197 977	Central Statistical Office of Poland, 2009
Romania	Both	2009	589 88	13 787	National Inctitute of Statistics, , 2009
Russian Federation	Both	2010	404 570	63 957	State of the hunting resources in the Russian Federation in 2008-2010, 2011
Serbia	Both	2009	17 475	5 811	Statistical Office of the Republic of Serbia, 2009
Slovakia	Both	2009	31 652	31 473	Statistical Office of the Slovak Republic, 2009
Slovenia	Harvest	2008	14 370	9 132	Statistical Office of the Republic of Slovenia, 2008
Ukraine	Both	2007	48 982	4 547	Biodiversity monitoring in Ukraine, 2010

Appendix E – Reported presence of tick specimens of the *O. erraticus* complex

Country	Location	Species	Year	References
Algeria	Vieille Calle	*O. erraticus*	2009	Trape et al., 2013
	Salah Bouchaour	*O. erraticus*	2010	
	Taher	*O. erraticus*	2010	
	M'Chounèche	*O. sonrai*, *O. normandi*	2009	
	Oued Melah	*O. sonrai*	2009	
	Abadla	*O. sonrai*	2012	
	Oued Saket	*O. erraticus*	2010	
	Sétif	*O. normandi*	2010	
	Bouira	*O. occidentalis*	2010	
	Melouza	*O. normandi*	2010	
	Oued Magtaa	*O. sonrai*	2010	
	Berrouaghia	*O. occidentalis*	2010	
	Chlef	*O. occidentalis*	2010	
	Ténès	*O. occidentalis*	2010	
	Ghazaouet	*O. marocanus*	2012	
	Beni-Bahdel	*O. marocanus*	2012	
	Bougtob	*O. sonrai*	2012	
	Saïda Mt Daïa	*O. rupestris*	2012	
	Mostaganem 1	*O. rupestris*	2012	
	Mostaganem 2	*O. costalis*	2012	
Armenia		*Ornithodoros* complex	2007	EFSA, 2010
Azerbaijan		*Ornithodoros* complex		Morel, 2003
Egypt	Shalateen, Hayaleb	*O. savignyi*		Shanbaky and Helmy, 2000
	Dahshur, Giza	*O. savignyi*	2005–2006	Adham et al., 2010
	Dahshur, Giza	*O. savignyi*	1996–1997	Helmy, 2000
Georgia		*Ornithodoros* complex	1936	Morel, 2003
Israel	Ma'ale Adumim	*O. tholozani*		Assous et al., 2006
	Makoh, Jericho	*O. tholozani*		
	Gimzo	*O. tholozani*		
	Migdal	*O. tholozani*		
	Horvat Kasif, Be'er Sheva	*O. tholozani*		
	Lod (Gimzo)	*O. tholozani*		Safdie et al., 2010
	Bethlehem	*O. tholozani*		
	Tubas	*O. tholozani*		
	Ramallah	*O. tholozani*		
Italy	Grosetto, Tuscany	*Ornithodoros* complex	1956	Morel, 2003
Morocco	Tetouan	*O. marocanus*	2009	Diatta et al., 2012; Trape et al., 2013
	Izemmourèn	*O. marocanus*	2009	
	Berkane Oued Kiss	*O. marocanus*	2006	
	Ghouazi/ Garba	*O. costalis*	2010	
	Kenitra	*O. costalis*	2006	
	Rabat	*O. occidentalis*	2010	
	West Aiti Yadine	*O. sonrai*	2010	
	Fes (Diamant Vert)	*O. occidentalis*	2010	
	Beb-Lerba	*O. occidentalis*	2010	
	Aïn-Benimathar	*O. marocanus*, *O. sonrai*	2006	
	Oued Mellah	*O. occidentalis*	2010	
	Bir-Jdid	*O. marocanus*	2009	
	Oued Oum Er-Rbiat	*O. marocanus*	2010	
	Oued Grou 1	*O. occidentalis*	2010	

Country	Location	Species	Year	References
	Oued Choufcherk	*O. marocanus, O. occidentalis*	2010	
	Tendrara	*O. sonrai*	2006	
	Figuig	*O. sonrai*	2006	
	Boudnib	*O. sonrai*	2006	
	Marrakech	*O. marocanus, O. sonrai*	2009	
	Oued Tensift	*O. costalis, O. sonrai*	2009	
	Jbel Sarhro	*O. sonrai*	2006	
	Tata	*O. sonrai*	2006	
	Guelmin	*O. merionesi*	2006	
	Sidi Akhfennir	*O. merionesi, O. costalis*	2006	
	Sidi Ahmed	*O. merionesi*	2006	
	Boujdour	*O. costalis*	2006	
	Galtat Zemmour	*O. sonrai*	2006	
	El Argoub	*O. costalis*	2006	
	Lahmiris	*O. costalis*	2011	
	Adrar Souttouf	*O. sonrai* spp.	2011	
	Oued Ouerrha	*O. erraticus sensu lato*	2009	
	Ouled Ziane	*O. erraticus sensu lato*	2009	
	Aousserd	*O. erraticus sensu lato*	2011	
	Kenitra, Gharb	*O. marocanus* complex	2008–2012	Souidi et al., 2014
	Had Ouled Jelloul, Gharb	*O. marocanus* complex	2008–2012	
	Ouled Slama, Gharb	*O. marocanus* complex	2008–2012	
	Sidi Allal Tazi, Gharb	*O. marocanus* complex	2008–2012	
	Sidi Sliman, Gharb	*O. marocanus* complex	2008–2012	
	Sidi Kacem, Gharb	*O. marocanus* complex	2008–2012	
	Zirara, Gharb	*O. marocanus* complex	2008–2012	
	Beksiri, Gharb	*O. marocanus* complex	2008–2012	
	Moulay Bouselham, Gharb	*O. marocanus* complex	2008–2012	
Portugal	Baixo Alentejo	*O. erraticus*	2009–2010	EFSA, 2010; Palma et al., 2012; Boinas et al., 2014; Milhano et al. ,2014
		O. erraticus	2009–2011	
	Faro (Silves)			
	Portalegre (Elvas, Marvao)			
		O. erraticus	2009–2011	
		O. erraticus	2009–2011	
	Alto Trás-Os-Montes		2002	
	Algarve		2007	
	Pinhal Interior Norte		2007	
	Pinhal Interior Sul		2007	
	Cova da Beira		2007	
	Oeste		2007	
	Alentejo Littoral		2007	
	Alta Alentejo		2007	
	Alentejo Central		2007	
	Baixo Alentejo		2007	

Country	Location	Species	Year	References
Russia	Dagestan resp.	*Ornithodoros* complex	1931	Morel, 2003; EFSA, 2010
	Kabardino-Balkanskaja resp.	*Ornithodoros* complex	2007	
	Severnaja Osetija-Alanija resp.	*Ornithodoros* complex	2007	
	Cecenskaja resp.	*Ornithodoros* complex	2007	
Spain	Colmenar	*Ornithodoros* complex	2010	Trape et al., 2013
	Torremolinos	*Ornithodoros* complex	2010	
	Avilla	*Ornithodoros* complex	2007	Morel, 2003; EFSA, 2010
	Salamanca	*Ornithodoros* complex	1938	
	Toledo	*Ornithodoros* complex	1938	
	Badajoz	*Ornithodoros* complex	2007	
	Almeria	*Ornithodoros* complex	2007	
	Cádiz	*Ornithodoros* complex	1938	
	Córdoba	*Ornithodoros* complex	1938	
	Huelva	*Ornithodoros* complex	1938	
	Jaén	*Ornithodoros* complex	1938	
	Málaga	*Ornithodoros* complex	1938	
	Sevilla	*Ornithodoros* complex	1938	
Tunisia	Bizerte	*O. normandi*	2010	Trape et al., 2013
	Tabarka	*O. erraticus*	2010	
	Oudhna (Tunis)	*O. normandi, O. costalis*	2010	
	Le Kef	*O. normandi*	2010	
	Kairouan Sud	*O. kairouanensis*	2010	
	Oued Ramel	*O. sonrai*	2010	
	Tozeur	*O. sonrai*	2010	
	Ben Guerdane	*O. sonrai*	2010	
	Gafsa	*O. normandi*	2010	
	Jbel El Hnouch	*O. normandi* and *O erraticus*	2005–2006	Bouattour et al., 2010
	Saba El Aouinet	*O. normandi*	2005–2006	
	Oued Remel	*O. normandi*	2005–2006	
	Oued Errebh	*O. normandi*	2005–2006	
	Echahda El Gharbia	*O. erraticus*	2005–2006	
	Sabkhet El Khsima	*O. erraticus*	2005–2006	
	Sabkhet Bhir	*O. erraticus*	2005–2006	
	Sebket Echrita	*O. erraticus*	2005–2006	
	El Guettar	*O. erraticus*	2005–2006	
	Limaguess	*O. erraticus*	2005–2006	
Turkey	Pinarbasi, Kayseri	*O. lahorensis*	1997–1999	Morel, 2003; Aydin and Bakirci, 2007; Inci et al., 2008; Sayin et al., 2009
		Ornithodoros complex	2007	
	Cankiri	*Ornithodoros* complex	1997	
	Elazig	*Ornithodoros* complex	1997	
	Van	*Ornithodoros* complex	1997	
	Adiyaman	*Ornithodoros* complex	1954	
	Ankara	*Ornithodoros* complex	1997	
	Nigde	*Ornithodoros* complex	1999	
	Nevsehir	*Ornithodoros* complex	1961	
Ukraine	Nikolayevskaja o.	*Ornithodoros* complex	1961	Morel, 2003
	Khersonskaja o.	*Ornithodoros* complex	1959	

Appendix F – Results of the extensive literature review

Extensive literature review on hunting and trapping

Publications in Scopus and Web of Knowledge and papers provided by experts were screened using the search string (((gunning or shoot* or trap* or hunt* or track* or game or harvest*))) AND (((cull* OR eradication OR elimination OR depopulation or reduction or extermin* or control))) AND ((pig$ or boar$ or swine or hog$ or scrofa)) AND (wild or feral or bush or razorback). Twenty-five papers were identified via independent screening by two scientists for relevance to assess feasibility to reduce wild boar populations by culling or trapping. From the selected papers, three papers could not be retrieved, 12 papers contained information on hunting and population management and the remainder were deemed not relevant when the full-text article was screened. The studies performed in Europe are summarised in Table 20.

Table 21: Examples of studies focussing on the feasibility to reduce wild boar populations by culling or trapping in Europe

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

Reference	Time period	Geographical area	Landscape	Population	Objective	Method of density estimation	Method	Results	Issues
Hadjisterkotis, 2004	1997–2000	Cyprus	Forest	Wild boar illegally released in 1996	Eradicate wild boar (danger of transmitting diseases and environmental impact)	Not estimated	Hunting was permitted and the game wardens were instructed to eliminate free-ranging animals	No reduction achieved	Consistent policy for eradication programme
Hadjisterkotis, . 2004	1997–2004	Cyprus	Forest	Wild boar illegally released in 1996	Eradicate wild boar (danger of transmitting diseases and environmental impact)	Signs of wild boar and interviews with foresters, farmers, hunters, monks	Hunting was permitted and the game wardens were instructed to eliminate free-ranging animals using improved ammunition	2001–200: population estimated at 80 animals; 2004-–2005: no sightings of boar	
Mentaberre et al., 2013	2007–2011	Ports de Tortos ai Beseit National Game Reserve, Spain	Calcareous mountain range, pine and oak forest	Wild boar	Effect of host management strategies on *Salmonella* serovar prevalence	Direct Abundance Index = wild boars/hunter and game season	Increase hunting and baited box trapping	Median = 0.47 ± 0.06 before management; median = 0.32 ± 0.06 after management	
Sodeikat and Pohlmeyer, 2003	1998–2002	Lower Saxony, Germany	4 000 ha: 50 % forest and 50 % farmland	4–5 wild boar per 100 ha	Movements after trapping	Hunting bag	Trapping baited with corn	No evaluation of trapping	Flight after trapping 0.2– 4.6 km

Reference	Time period	Geographical area	Landscape	Population	Objective	Method of density estimation	Method	Results	Issues
Boadella et al., 2012	2008–2009	South-central Spain	Mediterranean ecosystem	10 control sites, three sites with culling	Reduction in the prevalence of two chronic infectious diseases through increased culling	Wild boar pellet counts on transects. Site 4: direct wild boar counts converted into kilometric abundance indices (KAI)	Intense and year-round wild boar culling	Site 4: mean estimated wild boar abundance (KAI) diminished by 47.5 %. Significant reduction in TB seropositivity as determined by ELISA and culture of sampled animals. Site 8: mean wild boar abundance diminished by 56.8 %. Significant reduction in TB lesions found on culture of sampled animals. Site 9: significant reduction in TB seropositivity by ELISA in sampled animals	Culling alone, especially in large areas, is not likely to be a sustainable long-term option
Alexandrov et al., 2011	August to November 2009	Silistra region of Bulgaria	25-km^2 oak forest surrounded by crops (mainly maize)	Wild boar	Eradicate CSF from an area where hunting and vaccination alone might not be sufficient	Not described	Trapping as an addition to management by hunting	Approximately six animals per km^2 reduced to below two animals per km^2. 119 head (out of 156 head estimated at the beginning) trapped in three months (76 % reduction), 20 % < 6 months of age, 59 % between 6 and 12 months, 14 % between 12 and 24 months, 7 % over 24 months	Not reported

Reference	Time period	Geographical area	Landscape	Population	Objective	Method of density estimation	Method	Results	Issues
Csanyi, 1995	1969–1992	Hungary		Wild boar	Trends in harvest rates between state enterprises and private hunting associations. 110–160 % harvest rate in order to keep population stable assuming 1:1 sex ratio, 2.5–3.5 reared piglets/reproductive female, 5 % natural mortality	Reported spring population size and number of wild boar shot in the year	Hunting	Harvest rates ranging from 50 % to 35 %, with highest harvest rates in the 1970s	The harvest rate of wild boar populations was generally lower than that necessary to stabilise the population
Keuling et al., 2013	1998–2009	Sweden, Poland, Germany, Belgium, France, Switzerland, Austria, Italy		Wild boar	Comparison of mortality rates in central Europe. Suggest harvest rate in order to regulate the population assuming 200 % reproductive rate	NA: paper compares mortality rates from published papers	Population control not assessed	Mortality rates higher or males ($P = 0.019$) and especially male yearlings. Harvest rate needed to stabilise the population 65 % of summer population; 80 % hunting rate of piglets	Bias between reproductive and harvest rates leads to growing wild boar populations; high harvest rates required to regulate populations

Reference	Time period	Geographical area	Landscape	Population	Objective	Method of density estimation	Method	Results	Issues
Keuling et al., 2008	2002–2006	South-western Mecklenburg–Western Pomerania	Agriculture and grassland (63 %) and forest (34 %)	The mean annual harvest increased from 2.83 individuals per 100 ha in 1999/2000 to 5.13 individuals per 100 ha in 2005/06	Test the impact of different hunting methods on seasonal home range sizes		Battues (8.3 hunters, 5.3 beaters and 2.7 dogs per 100 ha driven forest area)	Battues did not significantly influence the spatial utilisation before and after hunt	To reduce populations and, thus, damage, supplementary feeding should be reduced and hunting rates increased especially for females, as all age classes of females are highly reproductive
Rosell et al., 2001	October 1998 to December 2005	Aiguamolls del Empordà Natural park (Spain), 4 828 ha	Coastal Mediterranean marshland	Captures increased by 275 % in 15 years	Population control in order to reduce bird predation, crop damage, car accident		Night shooting and drive hunting	307 individuals were culled, 265 by night shooting (0.5 individuals per shooting session) and 62 by drive hunting (8.9 individuals caught per actuation)	Despite lower efficiency, night shooting has the advantage of the facility of organisation, minimum disturbance and selective shooting. The two systems could be used in complementarity, night shooting year-round and drive hunts during specific periods (e.g. December to January)

Extensive literature review on artificial feeding and fencing

An extensive literature search was performed in Scopus and Web of Knowledge and the papers identified were provided to experts to look for studies on 'feeding' and 'fencing' in relation to movement of wild boar. Two searches were performed:

- The same search string as menstioned in the section on hunting and trapping revealed 25 papers related to 'feeding' or 'fencing'
- The additional search string ((("supplementary feed*" or fenc* or barrier*))) AND (movement or dispersal) AND ((pig$ or boar$ or swine or hog$ or scrofa)) AND ((wild or feral or bush or razorback)) revealed 64 additional papers related to 'feeding' or 'fencing' that were not identified in the first search

Titles and abstracts were independently screened by two scientists for relevance to assess feasibility of 'feeding' and 'fencing' to restrict wild boar movement and hence risk of ASF spread. Of the 14 papers identified, one paper could not be retrieved. The studies on 'fencing' performed in Europe are summarised in Table 21. No study could be identified that was performed in Europe with the aim of assessing directly the effect of 'feeding' on the restriction of wild boar movement.

Table 22: Data extraction of studies relevant to assess the effect of fencing on movement of wild boar in Europe

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