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Epidemiological analyses of African swine fever in the European Union (November 2018 to October 2019)

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Abstract

This report provides an update of the epidemiology of African swine fever (ASF) in the European Union during the period November 2018 to October 2019. In this period, ASF has been confirmed in Slovakia, whereas Czechia became officially ASF-free in March 2019, bringing the number of affected countries in the EU to nine. The report provides a narrative update of the situation in the different countries and an analysis of the temporal and spatial patterns of the disease. There has been no increase in the proportion of seropositive hunted wild boar in the affected areas. In hunted animals, the proportions of wild boar testing polymerase chain reaction-positive and enzyme-linked immunosorbent assay-positive has remained low (< 0.05). In addition to the obvious seasonal peak in summer in domestic pigs, seasonality of ASF in wild boar was statistically confirmed. A network analysis demonstrated that the median velocity of the natural propagation of the disease in wild boar populations was between 2.9 and 11.7 km/year. Human-mediated spread, both in pigs and wild boar, however, remains important. Several wild boar- and domestic pig-related risk factors for ASF occurrence in non-commercial farms in Romania were identified with a case–control study. This report also updates an extensive literature review on control measures to stop the spread of the disease in wild boar and on measures to separate wild boar populations. Several new studies have been identified in this reporting period, but these did not alter the conclusions of the previous reporting period. Field experience with the use of fences as part of the control strategy deployed in the Belgian focal outbreak of ASF in wild boar is described. So far, the measures have proven effective to keep ASF virus inside the affected area. This strategy included a combination of different measures, namely zoning, carcass removal, a complete feeding ban, specific hunting regulations and depopulation actions depending on the zone, a partial ban of people and logging, and setting up a network of concentric fences.

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Summary

The European Commission requested the European Food Safety Authority (EFSA) to provide an updated analysis of the epidemiology of African swine fever (ASF) in the Member States (MSs) of the European Union (EU) affected by African swine fever virus (ASFV) Genotype II.

Term of Reference 1 (TOR1) of the mandate requested insights into possible temporal and spatial patterns of ASF in the EU. Since its introduction into the EU in 2014, ASFV Genotype II has progressively spread through eastern Europe and reaching a peak in 2018, when a considerable number of outbreaks were registered in Romania; a jump to western Europe was reported for the first time, bringing the disease to wild boar in Belgium. ASF is present in each of the non-member countries on the eastern border of the EU, except Turkey. New introductions from these non-member countries can be suspected.

During this reporting period (November 2018 to October 2019), ASF was also confirmed in Slovakia and in Serbia, adding to the list of affected countries in the EU, whereas Czechia was recognised as officially ASF-free in March 2019. ASF has been progressively, but slowly, expanding mainly in a south-westerly direction. All ASF-affected areas are essentially contiguous, except for isolated introductions in Czechia (now resolved), western Poland and Belgium. Within the EU, all phases of the ASF epidemic are now represented, including non-affected areas, areas recently affected either following an isolated introduction or following geographic expansion from affected areas, affected areas that are progressively expanding, and areas where ASF infection has been present in most/all of the territory for a relatively short or for a longer period of time.

In Estonia, Latvia, Lithuania and Poland, there has been an interval of approximately 5 years since the initial introduction of infection. In some areas in the Baltic countries, it is unclear whether ASFV is still present. In Estonia, for instance, the numbers of wild boar have drastically reduced, as shown by the very low numbers of hunted wild boar per hunting ground (e.g. estimated average between 0 and 0.1 wild boar/km^2 in Estonia). In the affected areas, on average, less than 2.4% of hunted wild boar were seropositive in Estonia, and polymerase chain reaction (PCR)-positive animals were relatively rare (i.e. only 10 PCR-positive wild boar were found in Estonia during the last reporting period).

The ASF situation varies substantially between EU MSs, due to multiple influences including the nature of domestic pig production (in particular, the proportion of backyard holdings), geographic considerations (including topography, natural barriers) and the characteristics of the wild boar population.

Backyard farms present particular challenges in an ASF eradication programme, including uncontrolled movements of pigs and people, poor biosecurity and the identification of holdings. Human-mediated spread, for example between local villages, has been a feature of the ASF epidemic in areas where backyard farms are particularly common.

To provide an insight into temporal trends, time profiles are presented for each affected country of the evolution since initial ASF detection of the proportions of samples testing positive either to PCR or to antibody-enzyme-linked immunosorbent assay (ELISA). As in the previous reporting periods, the proportion of ASF-positive wild boar has always been higher among found-dead animals compared with hunted animals, regardless of the testing method. In affected areas, the proportion of wild boar testing positive by PCR has always been much higher than the proportions testing positive to ELISA. During the observation period for this particular analysis (Jan 2016-Aug 2019), there has been no increase in the proportion of seropositive (i.e. ELISA-positive) hunted wild boar. In hunted animals, the proportions of wild boar testing both PCR and ELISA positive have remained low, although minor seasonal peaks were observed.

In addition, possible patterns of seasonality were investigated, both visually and statistically in countries where the disease has been present in wild boar for more than 2 years. A visual inspection was conducted comparing the seasonal pattern of presentation of wild boar cases and domestic pig outbreaks (as notified to the Animal Disease Notification System, ADNS) in the Baltic countries, Poland and Romania. The numbers of notifications of ASF in wild boar were highest in winter and summer and lowest in spring. In domestic pigs, only a summer peak was evident based on notified outbreaks in these countries.

By using local regression or local fitting (LOESS) smoothing techniques on the data submitted to EFSA's Data Collection Framework, an apparent summer peak in the proportion of PCR-positive wild boar found dead was also observed in Latvia and Estonia, but not in the other countries. Using the same technique, for hunted wild boar, seasonal fluctuations in the proportion of found to be PCR

positive were less pronounced over the year but appeared to be lower during spring in the Baltic countries, and higher in late summer and winter. In the other countries, this pattern was not visible.

Using Tukey's test to compare the different seasons statistically, it was shown that the probability of notifying ASF in wild boar, either found dead or hunted, is not equally observed across the year; this result confirms the presence of seasonality in ASF detections.

A network analysis was performed for all the affected countries based on the cases reported to the ADNS database to assess the speed of natural propagation of ASF in wild boar populations. The median velocity of infection in Belgium, Czechia, Estonia, Hungary, Latvia, Lithuania and Poland was between 2.9 and 11.7 km/year.

There is evidence in all affected MSs that is suggestive of human-mediated translocation of the virus. The most obvious examples of this include the introduction of ASFV into Belgium, Czechia and western Poland. To evaluate less obvious occurrences of possible human-mediated translocations of ASFV in wild boar, the cases reported to the ADNS were used to calculate extreme distances and velocities between consecutive cases in time in wild boar populations. This was used to identify cases that had spread with extreme high velocity, and that were not likely to be explainable by natural spread between wild boar and therefore were probably caused by humans. The analysis revealed that human-mediated translocation of ASFV remains a very important factor in contributing to the translocations of ASFV both within and between wild boar populations. In the Baltic States, however, this type of human-translocated ASFV in wild boar has dropped in comparison with previous reporting periods, whereas they are important in the south-eastern affected MSs.

Term of Reference 2 (TOR2) requested the identification of risk factors for occurrence of the ASF virus in the wild boar population and at the domestic/wildlife interface with a view to strengthen biosecurity and other risk mitigation measures. A Besag, York and Mollié (BYM) model was fitted to identify risk factors for ASF occurrence in wild boar in Estonia, incorporating data from 2014 to 2019. Several non-significant risk factors that did not contribute to the model were eliminated from the model, including average quality of available habitat of wild boar, average yearly snow depth, average yearly minimum temperature, the number of wild boar hunted per hunting ground and risk factors related to hunting activity and wild boar management. However, there was an 18-fold increase in the probability of observing an ASF-positive wild boar for each unit increase in the density of pigs in small holdings per local administrative unit (LAU) 2 (animals in small holdings/km^2). A generalised additive model was also performed with similar results. These results were particularly influenced by the conditions of the domestic pig sector in 2014.

Term of Reference 6 (TOR6) also requested an assessment of potential risk factors for ASF occurrence but with a particular focus on ASF incursion in domestic pig holdings in Romania. A case–control study was conducted over the summer in 2019 in Romania, to study such potential risk factors. Based on the results of a logistic regression model, based on data collected from and register data collected for 655 case and control farms, ASF occurrence in the area surrounding the farm was identified as an important risk factor of ASF occurrence in backyard farms in Romania. Key risk factors for ASF occurrence in non-commercial farms of Romania included the number of outbreaks within a radius of 2 km of the farm and the distance to the nearest outbreak in domestic herds or the nearest case in wild boar. Herd size, the number of wild boar hunted per hunting ground (as proxy for the local wild boar density), the numbers of professional visits (private veterinarians, consultants, maintenance workers) during the high-risk period (2 weeks before the confirmation of ASF) on the farm, growing attractive crops around the farm, and the feeding of forage harvested in areas with ASF, were also identified as significant risk factors in non-commercial farms.

The only significant risk factor for ASF occurrence in commercial herds was the distance to nearest domestic pig outbreak.

Term of Reference 3 (TOR3) requested a review of the control measures applied by affected MSs to control the spread of ASF in wild boar and to eradicate infection. In the previous reporting period (EFSA, 2018), this assessment was based on a spatiotemporally explicit individual-based model approach in structured geographic landscapes. No contradicting evidence has subsequently emerged and, therefore, the earlier conclusions and recommendations are still valid.

In the previous report (EFSA, 2018), an extensive literature review had been undertaken to study the efficacy of different methods to control ASF spread through reducing wild boar population densities. The review was updated in this reporting period, but no conflicting evidence was found. The key conclusions are repeated here:

- In the wild, *Sus scrofa* are called 'wild boar' in areas where they are endemic and 'feral pigs' in areas where they are invasive. Generally, control efforts to reduce feral pigs have been more rigorously implemented than those to control wild boar, often with a differing legal background and differing public attitudes.
- In non-infected populations, recreational hunting of wild boar and feral pigs can be effective as a means to maintain population stability; however biased hunting preferences towards large males and feeding of wild boar should be avoided. Hunting efforts should be increased in intensity (harvest rate > 67% per year) to stabilise wild boar populations.
- Urgent interventions for disease control (i.e. locally implemented emergency measures) are different from, and should not be confused with, long-term management at larger scale associated with sustainable population management.
- In the context of disease control, depopulation of wild boar has been achieved in small, fenced estates, but in larger areas, not more than 50% of population reduction was reported.
- In areas of high habitat quality, the maintenance over a prolonged period of time of intense measures for wild boar population control is expensive and possibly not sustainable in the long term.
- Eradication of isolated feral pig populations has occasionally been achieved through intense drive hunting with dogs conducted over a number of years, with or without the use of other methods such as trapping or shooting from helicopters.
- Drastic reduction (up to 80%) of feral pig populations has been reported with control programmes in which pig hunting is conducted from a helicopter or through a combination of trapping and intense drive hunting with dogs. Rapid recovery of the population has been reported, up to 77% the year following these interventions.
- The use of traps has resulted in a harvest of up to 79% of the wild boar population, offering potential in areas where hunting is not recommended.
- The parenteral use of a gonadotrophin-releasing hormone (GnRH) immunocontraceptive vaccine has been demonstrated to reduce the fertility of feral pigs kept under experimental conditions. Research is needed, however, to investigate the presence of potential residues of GnRH in meat, and the potential of oral vaccine delivery in a selective manner to avoid non-target species.
- Poisoning of feral pigs has been shown to be a highly efficient method to reduce local populations. In the EU, however, poisoning of wild boar is forbidden under biodiversity conservation legislation. The potential undesirable effects of poisoning have not been sufficiently investigated in the European context, including welfare concerns on the administration of the poison and the possible effects of residues on the health of humans and animals through direct or indirect exposure.

Term of Reference 4 (TOR4) required a review and assessment of the robustness and effectiveness of different types of geographical artificial or natural boundaries that are being used to define restricted areas. A predictive epidemiological model was used in the previous report (EFSA, 2018) to assess if spread through the wild boar populations with barriers in the modelled landscape were more similar to the spread observed from the ADNS data, than spread without the barriers. Based on this comparison in the model, it was not possible to demonstrate an effect of natural barriers on ASF spread in 2018. However, anecdotal evidence from the field (e.g. example is Estonian islands that did not get affected due to the straits separating them from the mainland), suggested the temporarily hampering effect of rivers or straits, suggesting that these could be used for demarcation for restricted areas as they have shown to reduce, but not completely impede, the movements of wild boar.

In addition, the effectiveness of different artificial barriers that are used to separate wild boar were evaluated based on information found in the scientific literature. As for the previous report (EFSA, 2018), this was carried out by updating the literature review and new publications were identified, but the conclusions did not alter:

- It was concluded that electric fences have a demonstrated ability to temporarily protect crops from damage caused by wild boar or feral swine with different levels of efficiency. However, no electrical fence design can be considered 100% wild boar proof on a large scale for a prolonged period of time.
- Odour repellents have been tested as a method to protect crops from wild boar and feral swine but with divergent results. In five trials, no effect of the repellent on wild boar or feral swine

intrusion or on crop damage, was found, whereas with two trials reported damage reduction by wild boar ranged from 55 to 100% and from 26 to 43%.

- Light repellent did not show any significant effect on the probability of wild boar visiting luring sites. Sound repellents have been reported to lead to a 67% reduction in crop damage caused by wild boar.
- Currently, there is no evidence that large fences have been effective for the containment of wild suids. Some new large-scale fences are under construction, and their effectiveness in separating wild boar populations will need to be evaluated in the future.
- Additionally, field experience with the use of fences as part of the control strategy deployed in the Belgian focal outbreak of ASF in wild boar was summarised. So far, the measures have proven effective in keeping ASFV within the affected area and avoiding further spread. This strategy has included a combination of different measures, namely zoning, carcass removal, a complete feeding ban, specific hunting regulations and depopulation actions depending on the zone, a partial ban of circulation and logging, and setting up a network of concentric fences. Fencing (120 cm high, mesh size 15 × 20 cm, unburied and not fixed to the ground) contributed to slowing down of ASF spread and allowed compartments to be created in which depopulation could be carried out without risking long distance wild boar movements.

Term of Reference 5 (TOR5) required the development of recommendations of measures to manage wild boar populations in four separate geographical areas. These recommendations are listed in Section 6.1.

Table of Contents

1. Introduction

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

African swine fever (ASF) is a devastating disease occurring for the first time in certain eastern areas of the European Union (EU). The persistence of the disease in wild boar and the limited number of control measures available represents a challenge for the whole EU agricultural sector, in particular the pig farming industry.

From the beginning of 2014 to date,[1] African swine fever virus (ASFV) Genotype II has been notified in the Czechia, Estonia, Latvia, Lithuania, Poland and Romania, causing very serious concerns. The disease has also been reported in Belarus, Moldova, Russia and Ukraine and creates a constant risk for all the Member States (MSs) bordering with these non-member countries. There is knowledge, legislation, technical and financial tools in the EU to properly face ASF.

EU legislation primarily targets domestic pigs and, 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[2] of 27 June 2002 laying down specific provisions for the control of ASF and amending Directive 92/119/EEC as regards Teschen disease and ASF: it mainly covers prevention and control measures to be applied when ASF is suspected or confirmed either in holdings or in wild boars in order to control and eradicate the disease.
2) Commission Implementing Decision 2014/709/EU[3] of 9 October 2014 on animal health control measures for ASF in certain MSs and repealing Implementing Decision 2014/178/EU: it provides the animal health control measures for ASF in certain MSs 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.[4]
3) Council Directive No. 82/894/EEC[5] of 21 December 1982 on the notification of animal diseases within the EU that has the obligation for MSs to notify the Commission of the confirmation of any outbreak or infection of ASF in pigs or wild boar.

In addition, an ASF Strategy for the EU[6] has been developed based on earlier scientific recommendations by EFSA. This strategy is constantly evolving based on new science available and on new experiences gained.

The Commission is in need of an updated epidemiological analysis based on the data collected from the MSs affected by ASFV Genotype II. This analysis should take into account the previous EFSA opinions and technical reports on ASF. The use of the EFSA Data Collection Framework is encouraged, given it promotes the harmonisation of data collection. Any data that are available from neighbouring non-EU countries should be used as well.

Therefore, in the context of Article 31 of Regulation (EC) No. 178/2002, EFSA should provide the technical and scientific assistance to the Commission based on the following Terms of Reference (TOR):

1) Analyse the epidemiological data on ASF from MS and non-EU countries affected by ASFV Genotype II. Include an analysis of the temporal and spatial patterns of ASF in wild boar with a view to identifying patterns (ranges and speed) of transmission and also introduction of the virus in different types of domestic pig holdings.
2) Review the previously identified risk factors involved in the occurrence, spread and persistence of the ASFV in the wild boar population and in the domestic/wildlife interface with a view to strengthening biosecurity and other risk mitigation measures.

[1] Since the moment of reception of this mandate, when this background section was written (11 December 2017), ASF was also introduced in four more MSs: Hungary (21 April 2018), Bulgaria (31 August 2018), Slovakia (24 July 2019) and Belgium (13 September 2018). In addition, ASF was introduced into Serbia (31 July 2019) and on 21 March 2019 Czechia was officially declared to be free of ASF.

[2] https://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=cYgZJK7B4SNcQymnVLgT3h8tjP1S2gyQ4ZLbGZD4dtV4LycYy1cr!1552189148?uri=CELEX:02002L0060-20080903

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/;ELX_SESSIONID = 2Rj9J8mWmydm5yCx5zLSq7J7YTSzw8BLLznxbxjvLs27QrB3SLr9!1404494154?uri=uriserv:OJ.L_.2014.295.01.0063.01.ENG

[4] https://ec.europa.eu/food/animal/diseases/african_swine_fever/docs/poland_lithuania_asf_regionalization_en.pdf

[5] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid = 1454430116453&uri=CELEX:31982L0894

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

3) Review the control measures applied by the affected MS for controlling the spread of the disease in wild boar and for eradicating it. Assess their effectiveness and review scientific literature addressing these measures.
4) Review and assess the robustness and effectiveness of the different types of geographical artificial or natural boundaries used for the determination/demarcation of the restricted areas.
5) Based on the latest science and epidemiological data, review the measures for managing the wild boar populations in four separate geographical areas:

- Disease-free areas, far away from any ASF occurrence, which should take long-term actions for preparing for a future possible incursion of the disease considering the human factor.
- Disease-free areas neighbouring affected or restricted areas at higher risk of getting the infection mainly via natural spread of the disease through wild boar.
- Areas where the disease was recently introduced in wild boar.
- Areas where the disease has been present in the wild boar population for quite some time (more than 1 year).

In addition, the Commission requests in accordance with Article 31 of Regulation (EC) No. 178/2002, EFSA is requested to provide a Scientific Report to:

6) Review the epidemiological data and available information on the development of ASF in Romania and include an analysis of the temporal and spatial patterns of ASF in domestic pigs. Analyse the risk factors involved in the occurrence, spread and persistence of the ASFV in the domestic population.

1.2. Interpretation of the Terms of Reference (if appropriate)

TOR1: Analyse the epidemiological data on ASF from MSs and non-EU countries affected by ASFV Genotype II. Include an analysis of the temporal and spatial patterns of ASF in wild boar with a view to identifying patterns (ranges and speed) of transmission and also introduction of the virus in different types of domestic pig holdings.

As epidemiological data were provided by the affected MS of the EU, this report focuses on the ASF occurrence in EU countries only. A narrative update of the situation was provided for 10 MSs (Belgium, Czechia, Bulgaria, Estonia, Latvia, Lithuania, Hungary, Romania Slovakia and Poland). To provide an insight into temporal trends, the time profiles showing the evolution of the proportions of positive samples since the first detection were provided and possible patterns of seasonality were investigated, both visually and statistically. A network analysis and a predictive epidemiological model assessed the speed of propagation of the ASF infections in the wild boar population. To study possible sources of introduction of ASFV into pig holdings, information generated through the epidemiological investigations in the affected MS was used for a narrative description, as this information did not allow any quantitative analysis. A systematic literature review of survival time and the infectious period of ASFV in swine was carried out to update the current knowledge on the possible duration in which different matrices or live swine could be a potential source of introduction of ASFV into domestic pig holdings.

TOR2: Review the previously identified risk factors involved in the occurrence, spread and persistence of the ASF virus in the wild boar population and in the domestic/wildlife interface with a view to strengthening biosecurity and other risk mitigation measures.

The risk factor analysis was updated for the occurrence of ASF in wild boar populations with both a Bayesian hierarchical model and a General Additive Model, carried out on data provided by Estonia. These were the most complete data with sufficient spatial and temporal resolution, allowing the analysis to be performed.

TOR3: Review the control measures applied by the affected MSs for controlling the spread of the disease in wild boar and for eradicating it. Assess their effectiveness and review the scientific literature addressing these measures.

A predictive epidemiological model was used to evaluate the control measures to stop the spread of ASF in wild boar in four different scenarios:

- Disease-free areas, far away from any ASF occurrence, which should take long-term actions for preparing for a future possible incursion of the disease considering the human factor.

- Disease-free areas neighbouring affected or restricted areas at higher risk of getting the infection mainly via natural spread of the disease through wild boar.
- Areas where the disease was recently introduced in wild boar (following isolated introduction or as a consequence of geographic expansion of known affected areas).
- Areas where the disease has been present in the wild boar population for quite some time (more than 1 year).

TOR4: Review and assess the robustness and effectiveness of the different types of geographical artificial or natural boundaries used for the determination/demarcation of the restricted areas.

The extensive literature review (EFSA, 2018) to study the efficacy of different methods to reduce wild boar population densities to control ASF spread was updated in this reporting period to evaluate if the conclusions were still pertinent.

TOR5: Based on the latest science and epidemiological data, *review the measures for managing the wild boar populations in separate geographical areas*.

Based on the above analysis, recommendations for the measures for managing the wild boar populations in separate geographical areas were provided in a narrative section.

TOR6: Review the epidemiological data and available information on the development of ASF in Romania and include an analysis of the temporal and spatial patterns of ASF in domestic pigs. *Analyse the risk factors involved in the occurrence*, *spread and persistence of the ASF virus in the domestic population*.

During this reporting period, a case–control study was carried out to study potential risk factors for the incursion of ASF into Romanian pig holdings.

2. Data

2.1. Descriptive epidemiology

2.1.1. Information used to describe the ASF situation in the affected Member States and neighbouring countries of the EU

Section 4.1.1 provides a narrative update of the evolution of the ASF epidemic in the individual MSs, since the last report of EFSA published in 2018 (EFSA, 2018). These narrative sections were provided by the experts appointed by each affected MSs in the EU and two neighbouring countries of the EU (Serbia and the Russian Federation).

2.1.2. Data used to create the time profiles of proportions of positive samples tested with antibody-ELISA or PCR in wild boar hunted and found dead and seasonality

The time profiles in Section 4.1.2.1 displaying the evolution of proportions of positive samples over time since the first introduction in each MS were based on sample-based date provided by each affected MS.

2.1.2.1. Sample-based data

The data on ASFV tests on samples taken from wild boar from the Laboratory Information Management System (LIMS) of the national laboratories of the affected MSs were collected in EFSA's Data Collection Framework (DCF) (EFSA, 2017). The data reported to the DCF by the different MSs contained information on samples tested for ASFV between January 2014 and 31 August 2019.

Samples were tested for ASFV using polymerase chain reaction (PCR) (testing for virus) and antibody-enzyme-linked immunosorbent assay (Ab-ELISA), immunoblotting (IB), and immunoperoxidase (IPT) (tests for antibodies). It should be noted that the Ab-ELISA test has not been validated for testing samples taken from carcass fluids from wild boar and the results should be interpreted with caution.

The analysis in Section 4.1.2.1 was performed based on the test results submitted to the DCF only from areas after the first ASF case occurred (Table 2). The same analysis was carried out from samples that were submitted to the DCF from the whole country (Appendix A) (displayed in Table 1). The difference between the total number of samples listed in Tables 1 and 2 was the number of samples taken from wild boar in non-affected areas in the countries.

Table 1: Number of samples tested by ELISA and PCR in wild boar since the first occurrence in the countries that were submitted to EFSA's DCF from 2014 to 31 August 2019 (from all tested samples in the whole country)

Country	Found dead						Hunted					
	PCR			ELISA			PCR			ELISA		
	Total	No. positive	% positive	Total	No. positive	% positive	Total	No. positive	% positive	Total	No. positive	% positive
LT	15,995	4,388	27.4	5,456	3	0.1	62,695	714	1.1	51,508	754	1.5
PL	28,128	8,370	29.8	1,162	131	11.3	141,776	394	0.3	90,263	1,203	1.3
LV	2,890	2,003	69.3	376	65	17.3	64,361	1,164	1.8	63,131	3,154	5.0
EE	2,509	1,858	74.1	266	25	9.4	41,459	1,163	2.8	41,343	1,287	3.1
CZ	1,384	233	16.8	303	1	0.3	3,439	18	0.5	2,508	22	0.9
RO	205	0	0.0	50	0	0.0	4,592	0	0.0	4,574	0	0.0
HU	2,377	1,306	54.9	0	0	0	29,830	150	0.5	0	0	0
BG	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SK	1,397	1	0.1	0	0	0	36,644	3	0.0	0	0	0
BE	1,001	798	79.7	0	ND	ND	2,335	29	1.2	0	NA	ND

PCR: polymerase chain reaction; ELISA: enzyme-linked immunosorbent assay; DCF: Data Collection Framework; ND: no data.

Table 2: Numbers of samples tested by ELISA and PCR in wild boar since the first occurrence in the countries that were submitted to EFSA's DCF from 2014 to 31 August 2019 (from all tested samples in the affected areas since the first ASF)

Country	Found dead						Hunted					
	PCR			ELISA*			PCR			ELISA*		
	Total	No. positive	% positive	Total	No. positive	% positive	Total	No. positive	% positive	Total	No. positive	% positive
LT	7,379	4,388	59.47	5,456	3	0.05	28,928	714	2.47	51,508	754	1.46
PL	11,335	8,370	73.84	1,162	131	11.27	44,843	394	0.88	90,263	1,203	1.33
LV	2,453	2,003	81.66	376	65	17.29	63,255	1,164	3.21	63,194	3,155	4.99
EE	2,245	1,858	82.76	266	25	9.40	30,797	1,163	3.78	41,343	1,287	3.11
CZ	384	233	60.68	303	1	0.33	643	18	2.80	2,508	22	0.88
RO	2	0	0.00	50	0	0.00	679	0	0.00	4,574	0	0.00
HU	2,120	1,306	61.60	0	ND	ND	25,533	150	0.59	0	ND	ND
BG	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Country	Found dead						Hunted					
	PCR			ELISA*			PCR			ELISA*		
	Total	No. positive	% positive	Total	No. positive	% positive	Total	No. positive	% positive	Total	No. positive	% positive
SK	1	1	100.00	0	ND	ND	5	3	60.00	0	ND	ND
BE	986	798	80.93	0	ND	ND	2,313	29	1.25	0	ND	ND

PCR: polymerase chain reaction; ELISA: enzyme-linked immunosorbent assay; ASF: African swine fever; ND: no data.
*: All these samples were tested by ELISA for antibodies, some of these were confirmed by indirect immunoperoxidase test (IPT); however, these results are not shown.

2.1.3. Data used to evaluate the seasonality

The Baltic countries and Poland were selected for the evaluation of seasonal patterns given the occurrence for ASF since 2014. Romania was analysed separately due to the high number of cases registered for more than 2 years. Figures 18 and 19 in Section 4.1.2.2 compare visually the seasonality in wild boars and domestic pigs based on the data extracted from the ADNS database.

2.1.3.1. ASF notifications in the Animal Disease Notification System Database

Data on ASF cases and outbreaks in wild boar and domestic pigs, respectively, notified between 1 January 2014 and 31 August 2019, were extracted from the ADNS database. The numbers of ASF outbreaks in domestic pigs and wild boar cases are presented in Table 3.

The table displays the notifications in the period from 1 November 2018 to 31 August 2019, i.e. the update of the disease since the last report of 2018 (EFSA, 2018)) compared with the total number of outbreaks and cases reported from the first incursion of ASFV into the EU, on 24 January 2014 to 31 August 2019.

Table 3: Number of African swine fever (ASF) outbreaks in domestic pigs and cases in wild boar notified to the Animal Disease Notification System

Country	Date of first incursion in the country (DFI)	Number of outbreaks[(a)] domestic pigs in period		Number of cases[(b)] in wild boar in period	
		DFI–31 Oct 19	1 Nov 2018–31 Oct 2019	DFI–31 Oct 19	1 Nov 2018–31 Oct 2019
Lithuania	24/01/2014 (WB)	138	19	3,645	555
Poland	17/02/2014 (WB)	261	48	5,264	2,296
Latvia	26/06/2014 (DP and WB)*	64	1	3,687	382
Estonia	08/09/2014 (WB)	27	0	2,757	98
Ukraine	07/01/2017 (DP)	268	48	88	15
Czechia	26/06/2017 (WB)	0	0	230	0
Romania	31/07/2017 (DP)	2,726	1,651	729	643
Hungary	21/04/2018 (WB)	0	0	1,412	1,367
Bulgaria	31/08/2018 (DP)	42	41	88	85
Slovakia	24/07/2019 (DP)	11	11	15	15
Serbia	31/07/2019 (DP)	18	18	0	0
Belgium	13/09/2018 (WB)	0	0	643	558

DFI: date of first incursion; DP: domestic pigs; WB: wild boar.
(a): An outbreak of ASF in domestic pigs refers to one or more confirmed cases detected in a pig holding.
(b): A case of ASF in wild boar refers to a notification of a wild boar (killed, hunted) or one or more wild boar carcass (found dead in one location) 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 according to the diagnostic manual.
*: The first case in wild boar and outbreak in domestic pig case and detection appeared at the same day. In addition, the sample-based data as described in Section 2.1.2.1 were used to investigate the possible seasonality in wild boar (see Section 3.1.3 for the methodology).

2.1.4. Data used to evaluate the speed of propagation

Data on ASFV detections in wild boar reported between 1 January 2014 and 23 September 2019 extracted from the ADNS database were used to evaluate the speed of propagations (see Section 2.1.3.1).

2.1.5. Data used to evaluate human-mediated spread

Data on ASFV detections in wild boar and domestic pigs reported between 1 January 2014 and 31 August 2019 extracted from the ADNS database were used to evaluate human-mediated spread (see Section 4.1.2.4).

2.2. Risk factor analysis

2.2.1. Data collected to assess the risk factors of ASF occurrence in wild boar in Estonia

A risk factor analysis for the occurrence of ASF in wild boar was carried out for Estonia, this being the only country with sufficient detailed data, with the temporal and spatial resolution, to allow the risk factor analysis to be performed. The following data were collected for the analysis.

2.2.1.1. Domestic pig population data

The number of domestic pigs per herd as well as the number of herds and its geographical coordinates were provided by the Estonian Agricultural Registers and Information Board for the years 2014 to 2019.

Besides the number of pig farms, the number of small pig farms (< 10 head) has been used as a potential risk factor as it was assumed that these small farms would often implement suboptimal biosecurity measures (Ribbens et al., 2008; Correia-Gomes et al., 2017; Nurmoja et al., 2018). In addition, the pig density (from all farms) as well as the number of pigs in the small farms, was used as a potential risk factor. It should be noted that the potential risk factors were determined for the whole period that Estonia was affected and even if there were no outbreaks in pig farms in the last reporting period, the number of pigs or pig farms could still be a potential risk factors in the overall period assessed.

2.2.1.2. Wild boar population data

Data on wild boar population (based on estimates from the national hunters' organisations of the population size in the springs of 2014–2019) were provided by the Estonian Environment Agency. The data were provided with sufficient detail per hunting ground, including the hunting efforts (i.e. dogs, baiting places, number of hunters as well as a monthly wild boar hunted per hunting ground was provided by the Estonian Environmental Board) to carry out the risk factor analysis. The average number of wild boar hunted in 2019 per hunting ground ranged between 0 and 0.1 wild boar per km^2.

2.2.1.3. Available wild boar habitat and regional roads

A raster map of the quality of available habitats (QAHs), developed by CISA-INIA (Spain), was used (Bosch et al., 2016; EFSA, 2017). The average QAH was calculated based on the raster inputs for each of the spatial regions considered using the zonal statistics tool of the ArcMap software (ESRI). The shape files of the roads were obtained from the website of the GIS-LAB Project specialising in geographic information systems (GIS) (NEXTGIS, online). The total length of all type of roads was measured for each administrative unit and used as an indicator of human activity.

2.2.1.4. Demographic data and density of settlements

The 2015 data on the human population at district (local administrative unit (LAU) 2) level were extracted from the official website of the National Statistic Institution of Estonia (Statistics Estonia, online).

The locations of settlements were obtained from the website of the GIS-LAB Project (GIS-Lab, online) as shape files.

2.2.1.5. Meteorological data

Data on minimum air temperature (°C) and average snow depth (cm) per Nomenclature of Territorial Units for Statistics (NUTS) code version 2016 was provided through the Agri4Cast resources compiled by the Joint Research Centre. They were assembled as annual averages starting from 1 October to 30 September for each year (2014–2019). The averages used for 2019 have a preliminary characteristic given the lack of the validation that is usually performed at the end of a calendar year.

2.2.2. Data collected to assess the risk factors of ASF occurrence in domestic pigs in Romania

2.2.2.1. Domestic pig holdings in Romania

The locations and description of the pig holdings types was provided by the National Sanitary Veterinary and Food Safety Authority of Romania. This data set also contained the number of pigs per holding. Based on this information the pig and holding density per LAU 2 was also calculated. Furthermore, the control farms were randomly selected from these files.

According to Order No. 16/2010 of the National Sanitary Veterinary and Food Safety Authority changed by Order No. 112/2010, the type of pig farms, at the moment of the assessment, and were defined as following:

1) **Non-commercial pig farm:** holding used for domestic purposes, with animals registered in the National System of Identification and Registration of Animals (SNIIA) held by the people who are not registered at the Trade Registry Office.
2) **Commercial type A pig farm:** pig farm registered in the SNIIA and registered by the Sanitary Veterinary and Food Safety Directorates in the counties. These farms comply with the specific biosecurity norms, and fulfil the conditions given in Annex 50, held by authorised people, individual companies, family businesses or legal people organised according to the law, registered and authorised at the Trade Registry Office.
3) **Commercial pig farm:** pig farm registered in the SNIIA, which fulfils the specific biosecurity norms and is authorised by the Sanitary Veterinary and Food Safety Directorates in the counties; owned by authorised people, individual companies, family enterprises or legal people organised according to the law; registered and authorised by the Trade Register Office.

2.2.2.2. Forest cover and water bodies in Romania

The forest cover was calculated as a percentage for each hunting ground unit in which case and control farms were located. The proximity to water bodies was expressed as a Yes/No presence within a radius of 1 km. Both items were extracted from the 2018 raster version of CORINE Land Cover data.

2.2.2.3. Wild boar density in Romania

Hunting data were provided by the Romanian Ministry of Waters and Forests. The numbers of hunted wild boar per hunting ground in the hunting season 2018–2019 were used to estimate the relative abundance of wild boar in the hunting grounds.

2.2.2.4. Outbreak data

The date and location of the new case farms were provided by the National Sanitary Veterinary and Food Safety Authority of Romania on a weekly basis.

3. Methodologies

3.1. Descriptive epidemiology – TOR1

3.1.1. Update of the ASF situation

A narrative section was provided, describing the ASF situation in each affected MS since the last report of EFSA, published in 2018 (EFSA, 2018). These narrative sections focus on:

- the evolution of the epidemic in the MS since the last reporting period;
- a short description of specific prevention and control measures (in addition to measures described by EU legislation);
- field evidence of indirect and direct sources of introduction in domestic pig holdings;
- field evidence of human-mediated spread in wild boar populations.

3.1.2. Time profiles of proportions of positive samples tested with Ab-ELISA or PCR in wild boar hunted and found dead

The proportion of positive samples reported through the DCF (either tested by PCR or Ab-ELISA) were calculated as the number of positive animals divided by the total number of tested animals (either hunted or found dead) per month, in the affected MSs. Local regression or local fitting (LOESS) smoothing (Cleveland et al., 1988) was used to estimate the average profiles describing the global trends of the PCR- or Ab-ELISA-positive samples. Confidence bands are also presented to show uncertainties in the estimation of the smoothing curves.

Two time profiles were provided per country: the first showing the proportion of positive samples in all LAU 2 areas (affected and non-affected) of the MSs where animals were sampled from the first introduction of the disease in the MS; the second displays the proportion of positive samples from only the affected areas where at least one positive case has been found, from the first positive detection in that area onwards. Data were available on LAU 2 level from year 2016 onwards. The regions affected contributed to the estimation of proportion of positive only in the months after the first infection was found.

3.1.3. Seasonality of proportions of positive samples in wild boar hunted and found dead

A visual inspection was carried out to compare the number of cases in wild boar and the number of outbreaks in domestic pigs notified to the ADNS by season in the Baltic countries combined with Poland as well as in Romania.

Subsequently, the seasonal patterns of the numbers of cases reported through EFSA's DCF were analysed. Therefore, the data were aligned according geographical location (sampling region), the sampling date and the final test result (for this analysis, a sample was considered an ASF case in a wild boar if it tested PCR positive). ELISA-positive results were not considered as the focus for this analysis was on incidence. Each LAU 2 region was included from the date on which the first positive sample was reported for that LAU 2 region, e.g. starting date. Previous negative reports for that region were excluded from the analysis. A local regression or local fitting (LOESS) smoothing (Cleveland et al., 1988) was used to estimate the average profiles describing the global trends of the PCR- or Ab-ELISA-positive samples. Confidence bands are also presented to show uncertainties in the estimation of the smoothing curves.

In addition, Tukey's test was used to compare the different seasons. Winter was defined as December, January and February, spring as March, April and May, summer as June, July and August and autumn as September, October and November. A significance level of 0.05 was used for pairwise comparison.

3.1.4. Speed of propagation of ASF in wild boar population

A network analysis was performed for all the affected countries based on the cases reported to the ADNS database. Two scenarios were evaluated based on the following assumptions:

- Scenario 1: a case is caused by any of the previous cases in time and the network pairs are created based on the minimum distance and time elapsed between two cases.
- Scenario 2: a case is caused by any of the previous cases in time, if at least 7 days have elapsed, and network pairs are created based on minimum distance between two cases.

The outcomes of the different methods were compared.

3.1.5. Human-mediated spread of ASF in wild boar

To evaluate the possible human-mediated spread of ASF, the cases reported to the ADNS were used to calculate between-case distances and between-case velocity as a function of the time delays between these cases. Here, two values were assigned to the individual cases reported to the ADNS, i.e. first, the distance to the closest case reported older than 7 days (assumed to be the average incubation period, REF) and second, the report older than 7 days that required the minimum velocity to bridge the distance between the two cases. Then, for each notification, the velocity and the distance values were ranked. The resulting rank sum was noted for each case report. Finally, the geographical mapping of all notifications was produced, highlighting the upper percentile (99–100th percentile) of the distribution of the rank sum values of all notifications.

3.2. Risk factor analysis – TOR2 and TOR6

3.2.1. Risk factors for the occurrence of ASF in wild boar in Estonia (TOR2)

A Besag, York and Mollié (BYM) model was fitted to identify risk factors for ASF occurrence in wild boar in Estonia. The BYM is a lognormal Poisson model that includes both an intrinsic conditional autoregression for spatial smoothing and an ordinary random effects component for non-spatial heterogeneity. A generalised additive model was also performed with the purpose of comparing results. Details about the models used can be found in EFSA (2017) and in the Zenodo repository (Varewyck et al., 2017).

First, the model was fitted with all risk factors available. Using a backward elimination procedure, risk factors were reduced one by one when their significance level was $p > 0.05$, given their lack of significant contribution to model.

All risk factors considered were aggregated spatially on the LAU 2 level. Table 4 lists all the risk factors considered in the model. Only data from Estonia were provided with detailed enough spatial and temporal resolution to perform the analysis and the data did not allow a risk factor analysis for determining the persistence of the disease, but only the probability of occurrence of an ASF case in wild boar. Because there were not enough regions that were affected persistently (e.g. more than a year) to be compared with regions that were not persistently affected. In addition, monthly samples for each LAU 2 region would be needed to perform this analysis. The analysis incorporated data from 2014 to 2019.

Table 4: Potential risk factors based on the available data used in the analysis

Acronyms	Description	Explanation
Potential risk factors related to wild boar habitat		
QAH	Quality of available habitat of wild boar (average)	Habitat quality could drive wild boar density
WBDNS	Wild boar density (estimated number/km^2)	Wild boar density could have an effect on the occurrence of the disease
SNOWDEPTH	Average yearly snow depth	Climatic conditions could have an effect on the presence of the virus
TEMPERATURE_MIN	Average yearly minimum temperature	
Potential risk factors related to hunting activity and wild boar management		
huntersDNS	Density of hunters/km^2	Describe hunting and managerial activities
dogDNS	Density of hunting dogs/km^2	
feedsDNS	Density of feeding/baiting places/km^2	
huntedDNS	Density of hunted wild boar/km^2	
Potential risk factors related to the pig farming system		
PgFrmDNS	Density of pig farms (in total)	Pig density could have an effect on the occurrence of the disease (assuming circulation in domestic pigs)
PgDNS	Density of pigs (in total)	
PgFrmSDNS	Density of small pig farms (pig holding with up to 10 heads)	Small pig farms are assumed to have lower biosecurity measures in place, and lower reporting rate, which could have an effect on the occurrence of the disease
PgSDNS	Density of pigs in small holdings (pig holding with up to 10 heads)	
Potential anthropogenic risk factors		
StlmDNS	Human settlements density/km^2	A higher human activity in an area could have an effect on the occurrence of the disease
RdDNS	Total road length (km)/km^2 of admin unit area	
HumPopDNS	Human population density (ind./km^2)	

3.2.2. Risk factors for the occurrence of ASF in domestic pig herds in Romania (TOR6)

The risk factor study was carried out between 15 May 2019 and 15 September 2019. All domestic pig farms on which ASF was diagnosed during this period were included as eligible for being selected as case farms in the study, if they were located in the following counties: Brăila (BR), Constanţa (CT), Călăraşi (CL), Bihor (BH), Buzău (BZ), Vrancea (VN), Tulcea (TL), Galaţi (GL), Arad (AR), Timiş (TM) Satu Mare (SM), Sălaj (SJ), Teleorman (TR), Covasna (CV), Ialomiţa (IL), Giurgiu (GR), Botoşani (BT), Bacău (BC), Dâmboviţa (DB), Olt (OT), Argeş (AG), Ilfov (IF), Dolj (DJ). Therefore, during each week of the period, a list of all outbreaks was updated until the end of the study and all new outbreaks were selected as case farms from 15 May onwards. From 3 July onwards, due to an overwhelming number of outbreaks in some regions, a maximum of nine case non-commercial farms, were selected from each county.

In general, the selected control farms were matched according herd type, county and time of selection (same week as case farm detection). In Romania, three farm types were described: non-commercial farms, Type A farms and commercial farms (see Section 2.2.2.1 for description of different farm types). For non-commercial farms and Type A farms, for each case, two controls were randomly selected each week from a list of 10 farms matched by herd type and county. For commercial farms, four controls were randomly selected, and no matching on county was carried out. This was carried out because of the limited number of this herd type in Romania.

All farm visits were performed by the National Sanitary Veterinary and Food Safety Authority. The designated team of official veterinarians informed the farmers about their visit and the purpose of the questionnaire beforehand. Strict biosecurity rules were followed when entering the farms. When interviews had to be completed in different farms (case or control farms) on the same day different interview teams were sent out for the surveys.

During each visit, the infrastructure was inspected and the presence of insect nets and the state of the sewage systems were inspected for leakages. The documents on the registration of all transports and visitors were requested and inspected. The farmer was interviewed on the activity of the employees and the remaining questions of the questionnaire were completed.

The sample size for the case–control study was calculated using the epi.ccsize function of the epiR package v1.04 in R (R Core Team, 2018), which made it possible to calculate the sample size taking into account the power or minimum detectable odds ratio (OR), for a matched case–control the following parameters were used: OR = 2.5, p0 = 0.1, n = NA, power = 0.9, r = 2, rho = 0.1, design = 1, sided.test = 2, conf.level = 0.95, method = 'matched', fleiss = TRUE. Based on the following parameters: OR: the odds ratio that is expected to be detected by the study of 2.5; p0: the prevalence of exposure among the controls of 0.1; power: the required study power of 0.9; r: the number of subjects in the control group divided by the number of subjects in the case group of 2; rho: the correlation between case and control exposures for matched pairs.

An EU Survey/questionnaire was created to collect the data related to the features of the farm, i.e. type of holding, GPS coordinates, date of confirmation of the outbreak in case farms, number of pigs, other species present in the holding, place of slaughter, biosecurity-related questions, wild boar presence in the proximity of the premises, feed and water and questions related to the arthropods or rodents observed on the farms. Some questions were related to the high-risk period (HRP), interpreted as the time period in which disease introduction could have occurred. For non-commercial farms, this period was defined as the 2 weeks before detection of disease, while for 'Type A' holdings this was 4 weeks and for commercial holding 6 weeks. It was assumed that, in large herds, a few dead pigs would have limited influence on the overall mortality rates, and therefore that longer HRP could be observed in Type A holdings, and even longer in large commercial farms.

From the ADNS, coordinates on all outbreaks and cases of ASF in Romania and neighbouring countries were extracted and used to calculate distances between outbreaks or cases and farms included in the study. The distance to the nearest outbreak in domestic farms, as well as cases in wild boar and the number of outbreaks or cases within 1, 2, 5 and 10 km were calculated and used in the analyses. A detailed table with all the covariates that were included at the start of the model building in the analysis is provided in Appendix B.

A logistic regression analysis was performed on the data received from the survey combined with data on distances to outbreaks and densities, as described above. A matched design was used. Stepwise backward elimination was used, combined with forward selection and meaningful pairwise interactions were tested. Covariates were considered statistically significant if $p < 0.05$, and for those that were correlated with each other (multicollinearity) the one with the smallest confidence interval was retained. The model was run in R, v.3.5.2 'Eggshell Igloo' (R Core Team, 2018).

3.3. Review wild boar management measures for controlling the spread of ASF – TOR3

3.3.1. Model

To review the control measures applied by the affected MSs for controlling the spread of the disease a spatiotemporally explicit individual-based model approach was used in the previous reporting period (EFSA, 2018). This model process was not repeated for this reporting period.

3.3.2. Extensive literature review

Also, in the previous report (EFSA, 2018) an extensive literature review was carried out to study the efficacy of different methods to reduce wild boar population densities to control ASF spread. The review was updated in this reporting period.

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

Review questions:

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

Furthermore, the population studied, the type of interventions and outcome measures studies were as follows:

Population:

Wild boar *Sus scrofa* populations

Type of interventions:

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

Type of outcome measures:

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

Search methods:

Search strategies were undertaken to identify studies that report methods for wild boar population density reduction or control, and separation methods available for wild boar (Table 5).

Table 5: Databases consulted to retrieve studies pertaining wild boar population reduction measures and separation methods

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

The searches were executed on 29 July 2019.

The search strategy was adapted according to the configuration of each resource of information. The search identified 1,499 records retrieved in the Web of Science platform and 85 in Scopus. The results were imported into EndNote x8 bibliographic management software (Clarivate Analytics).

Duplicated records were removed to keep a final number of 173 records. The screening of the titles and abstracts was performed by two independent reviewers using DistillerSR systematic review software. Out of these 173 studies, 19 were included for further screening of the full texts. From these 19 studies, 13 were found relevant by one independent reviewer.

3.4. Review natural/artificial borders – TOR4 for the determination/demarcation of the restricted areas

3.4.1. Natural borders

See EFSA (2018) for model description.

3.4.2. Artificial borders

See Section 3.3.2.

4. Assessment

4.1. Descriptive epidemiology – TOR1

4.1.1. Update of the ASF situation

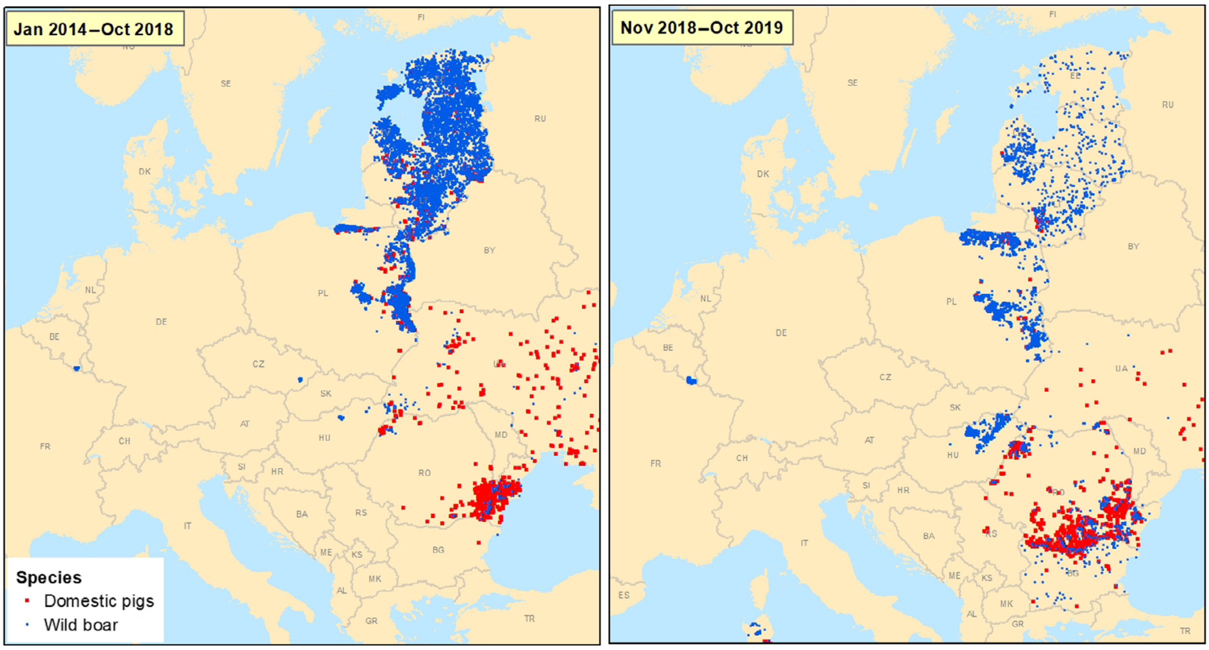
During the last 12 months, there has been a further increase in the number of ASF-affected EU MSs. Nine MSs (BE, BG, EE, HU, LV, LT, PO, PL and SK) are currently infected with ASFV Genotype II, whereas Czechia was recognised as officially ASF-free in March 2019 (Commission Implementing Decision (EU) 2019/404). ASF is present in each of the non-member countries on the eastern border of the EU, except Turkey. Of the Balkan countries, ASF was confirmed in Serbia in July 2019 (Figure 1). In broad terms, ASF continues to spread slowly towards the south-west. All ASF-affected areas are essentially contiguous, except for the isolated introductions of ASF in Czechia (now resolved), in western Poland and Belgium.

Within the EU, all phases of the ASF epidemic are now represented, including non-affected areas (i.e. most MSs), affected areas following geographic expansion of affected areas (areas in Poland and Romania), affected areas where prevalence has reached a plateau (areas of Poland), areas of reducing prevalence/endemic infection (for example, LV, EE) and non-affected areas with a recent history of ASF infection (CZ).

The current situation in Estonia, Latvia and Lithuania provides more insight into the epidemiological evolution following the initial epidemic in 2014. In these countries, there has been an interval of approximately 5 years from initial infection. The number of hunted wild boar short per hunting ground is now very low (e.g. in Estonia the range goes from 0 to 0.1 wild boar per km^2 in 2019 with an average of 0.02 wild boar/km^2 based on the data provided by the Estonian Environment Agency; see Section 2.2.1). Less than 2.4% of the hunted animals were seropositive in the areas where ASF has incurred (Table 7), and PCR-positive hunted wild boar are relatively rare (i.e. 10 PCR-positive animals in the last reporting period in Estonia (Figure 6). In some areas in the Baltic countries, it is unclear whether ASFV is still circulating. To date there is no evidence that seropositive survivors play any significant role of in the epidemiology of the disease, and also the significance of single, PCR-positive wild boar in areas with no further evidence of infection is uncertain (EFSA, 2015; Ståhl et al., 2019). However, recovery of the wild boar population is likely to increase the risk of ASF maintenance in the area, especially if this is combined with regular re-introductions of ASFV from affected neighbouring countries.

The presentation of the ASF situation varies substantially between EU MSs, due to multiple influences including the nature of domestic pig production (in particular, the proportion of backyard holdings), geographic considerations (including topography, natural barriers), characteristics of the wild boar population (density, etc.). In HU to date, ASF has been confined to wild boar and no outbreaks in domestic pigs has been reported. Furthermore, a corridor of wild boar cases has occurred along the Tizla river. In Romania, the epidemic is dominated by outbreaks in domestic pigs, primarily non-commercial holdings, with proportionally few cases found in wild boar compared to other MSs'.

ASF eradication has been achieved on several occasions following an isolated introduction. Czechia was declared ASF-free in March 2019 (European Commission, 2019a), and potentially also Belgium will be. Belgium and Czechia (examples of isolated ASF introductions far from previous affected areas within the EU) each mounted an aggressive and sustained response, underpinned by the best available science. A range of measures were implemented specific to each of the countries and are detailed in the following sections.



Left: notifications from January 2014 to October 2018 (DP: n = 1,824; wild boar (WB): n = 13,007). Right: notifications from November 2018 to 31st October 2019 (DP: n = 1,853; WB: n = 6,066).

Figure 1: ASF notifications to the ADNS

Below follows an update of the ASF situation in all affected EU MSs and Serbia for the last reporting period (November 2018 to October 2019). The countries are listed according to the chronological order of ASF introduction in the countries since 2014.

4.1.1.1. Lithuania

- **Evolution of ASF epidemic in this reporting period**

From November 2018, ASF was abundantly detected in the wild boar population in most parts of Lithuania. A cluster of ASF-infected wild boar was identified in south-west of Lithuania, where the first 532 positive wild boar were detected in 2018 in Mažeikiai, near the Latvian border. In total, over 17,900 samples from hunted and found-dead wild boar were collected and analysed by PCR, indirect fluorescent assay (IFA) and immunoperoxidase test (IPT), resulting in 532 samples positive for ASFV. From June to August, new cases of ASF in wild boar were unexpectedly detected in many regions of Lithuania that belonged to the Part I zone, according to Decision 2014/709/EU. All these cases were detected in hunted wild boar and were confirmed only by antibody detection methods IFA and IPT method. During the summer season, most of the ASF cases were detected in hunted wild boar, while the cases identified in spring and winter were mainly found in wild boar carcasses.

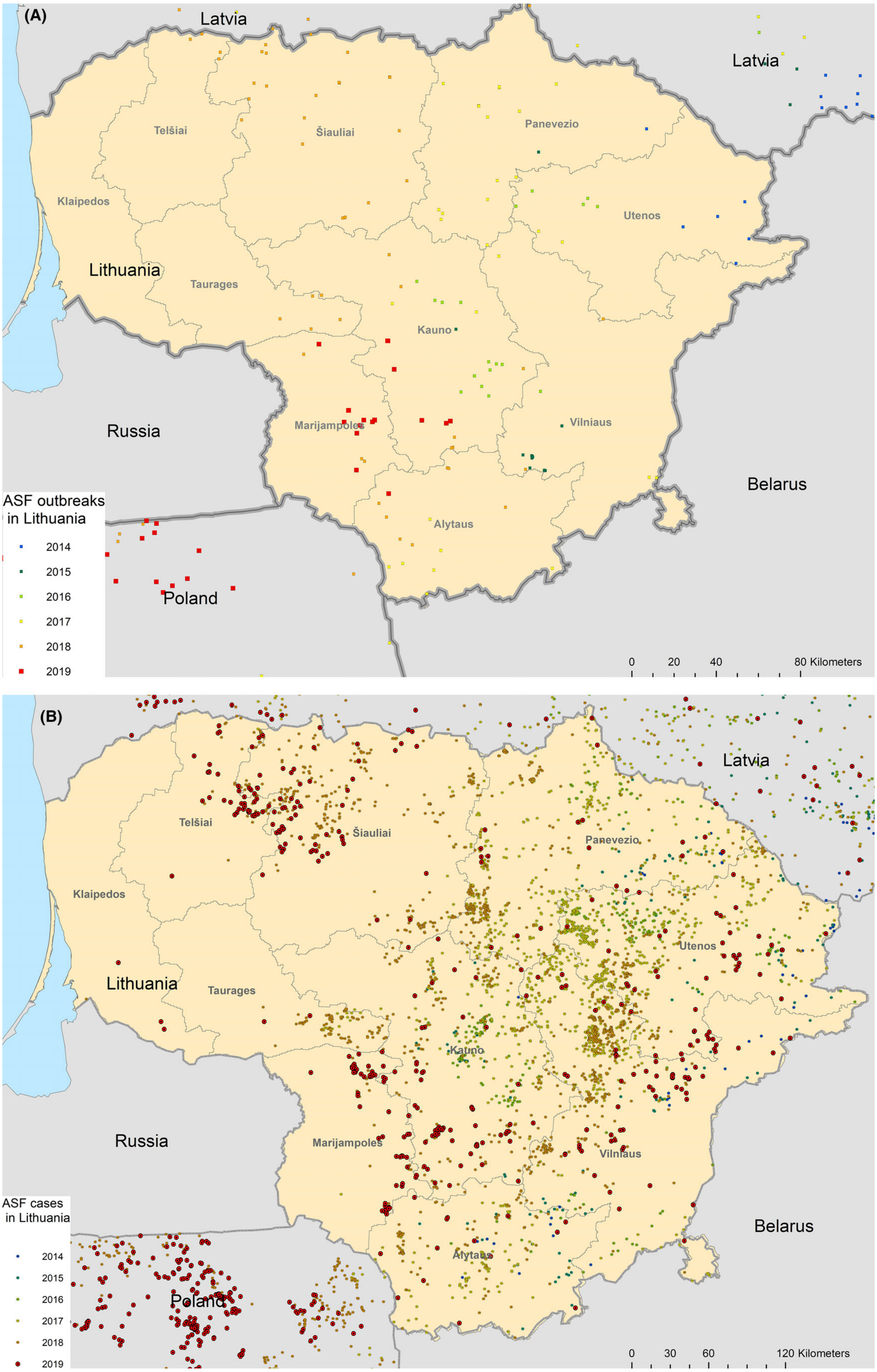


Figure 2: ASF outbreaks and cases in domestic pigs (A) and cases in wild boar (B), respectively, reported to ADNS in Lithuania 24 January 2014 to 31 October 2019

According to the data of the Lithuanian Ministry of Environment, between 15 April 2018 and 15 April 2019, 18,016 wild boar were hunted, i.e. 17,561 wild boar less than in the previous hunting season of 2017–2018, which shows a decreasing tendency of wild boar being shot and a decreasing amount of wild boar in the forests (Figure 2B). Based on recent observations made in 2019, the current density in most regions of Lithuania is less than 0.5 wild boar/km^2.

In 2019, ASF in domestic pigs in Lithuania was detected during the summer: the first outbreak was detected on 6 June (in Šakiai district, Plokščiai subdistrict, a small farm where pigs were kept for own consumption). In addition, three outbreaks of ASF were confirmed in Marijampolė municipality, four outbreaks in Prienai district municipality, five outbreaks in Kazlų Rūda (pig holdings) and one outbreak in each of Alytus and Kaunas district municipalities. In total, 12 outbreaks of ASF in non-commercial pig holdings with up to 10 fattening pigs kept for own consumption and three outbreaks of ASF in commercial pig holdings with more than 10 pigs kept for the commercial purposes (in total, 52, 42 and 24 pigs in ASF outbreak locations) were detected during the summer season.

The number of ASF outbreaks in domestic pigs in this reporting period has decreased dramatically (2.8-fold, namely 15 outbreaks in this period compared with 42 outbreaks in the previous period). The outbreaks of 2019 were concentrated in a relatively limited area in south-western Lithuania, whereas in 2018 they were spread widely from the north to the south of Lithuania. In 2019, most of the outbreaks of ASF were detected in the area of Kazlų Rūda municipality.

- **Specific prevention and control measures (besides those laid down in the EU legislation and the strategic approach to the management of ASF for the EU)**

It is forbidden to include any animals susceptible to ASF in public events (circus, exhibitions, shows). Trade with live pigs is allowed only directly between farms but not at the market.

- **Proven sources of introduction in domestic pig (direct/indirect contact)**

None.

- **Proven human-mediated ASF spread in wild boar population**

None.

4.1.1.2. Poland

- **Evolution of ASF epidemic in this reporting period**

A section on this reporting period (up to the end of October 2019) and an update of the human-mediated introduction of ASFV in November in 2019 in the territory of western Poland (Lubuskie, Dolnoslaskie and Wielkopolskie voivodship) will be provided in the next report.

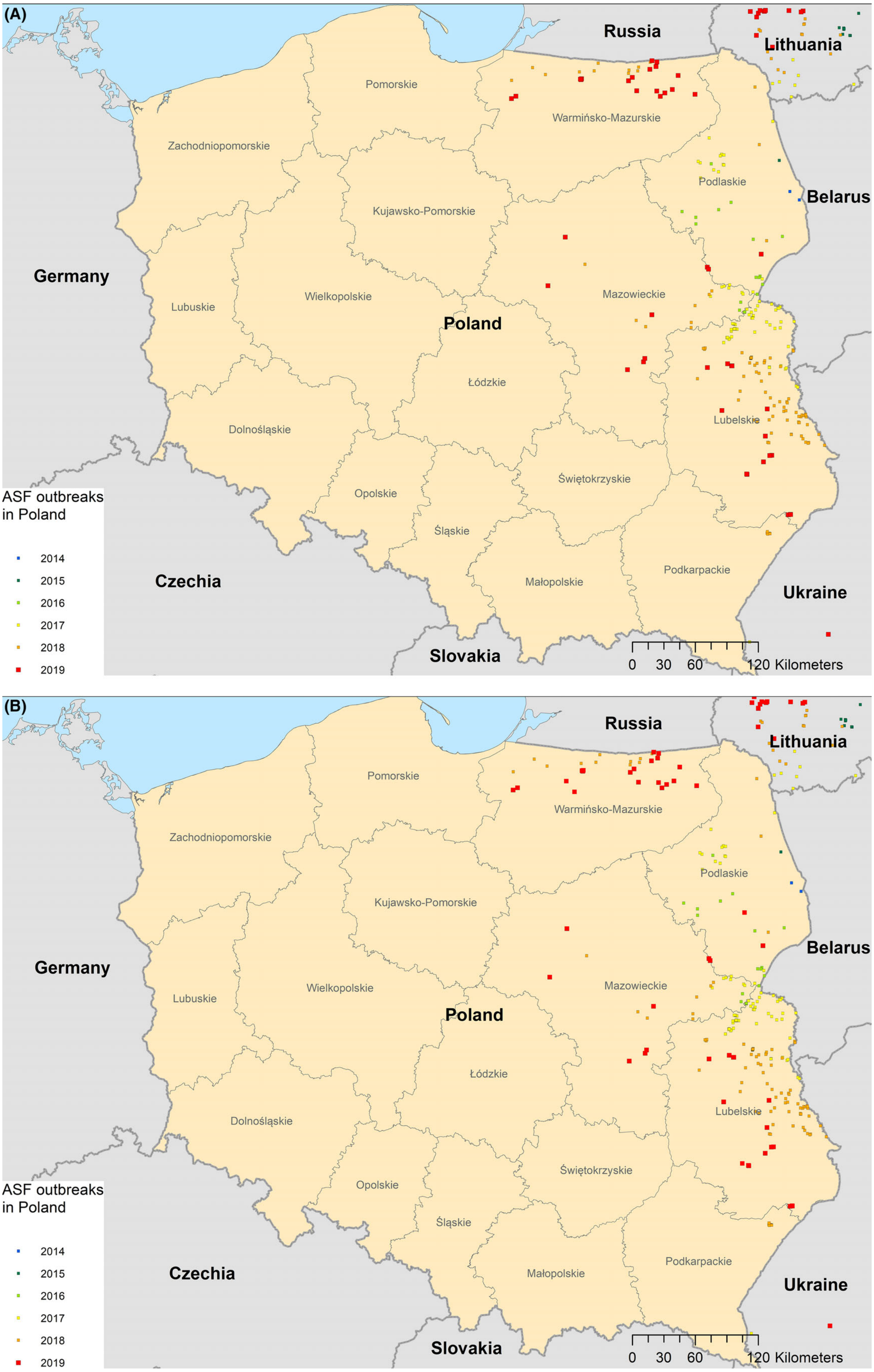


Figure 3: ASF outbreaks in domestic pigs (A) and cases in wild boar (B), respectively, reported to the ADNS in Poland (17 February 2014 to 31 October 2019)

In 2019, ASF has spread continuously in the wild boar population, especially in central Poland (Mazowieckie voivodship – 813 cases) and in the north of the country (Warmińsko-Mazurskie voivodeship – 417 cases) but also in eastern Poland (Lubelskie voivodeship – 336 cases and Podlaskie voivodeship – 55 cases). Unfortunately, ASF has also reached new regions of southern Poland in the Podkarpackie voivodeship (9) (Figure 3).

According to recent observations the current density in most region in Poland is below 0.5 wild boar per square km. During the hunting season, which lasted the whole year 2017/2018 (except the protective time span for sows from 16 January to 14 August), in total, 341,411 wild boar were hunted.

The current prevalence (PCR-positive samples) in wild boar found dead within Part II and Part III according to the appendix of the 2014/709/EU Commission Decision reached 72.7%; this was 58.4% when the samples from the whole country were included. Among the wild boar involved in car accidents, the prevalence reached 7.5% within Part II and Part III and 0.86% in the whole country, respectively. In hunted wild boar, the ASF prevalence within Part II and Part III reached 0.84%. The seroprevalence in hunted wild boar did not reach 0.46% of the overall number of tested wild boar from affected areas (Pejsak et al., 2018).

In 2019, there was a geographic overlap between cases in wild boar and in domestic pigs. During the year, in total, 47 ASF outbreaks were reported in Mazowieckie (9), Warmińsko-Mazurskie (19), Lubelskie (16) and Podlskie (1) voivodeships (Figure 1).

- **Specific prevention and control measures (besides those laid down in the EU legislation and the strategic approach to the management of ASF for the EU)**

None.

- **Proven human-mediated spread in wild boar population**

A new case was notified, detected in November 2019 in wild boars as positive in Lubuskie voivodeship, located 360 km away from the previously confirmed ASF cases in western and central Poland. This will be explained in detail in the next report.

4.1.1.3. Latvia

- **Evolution of ASF epidemic in this reporting period**

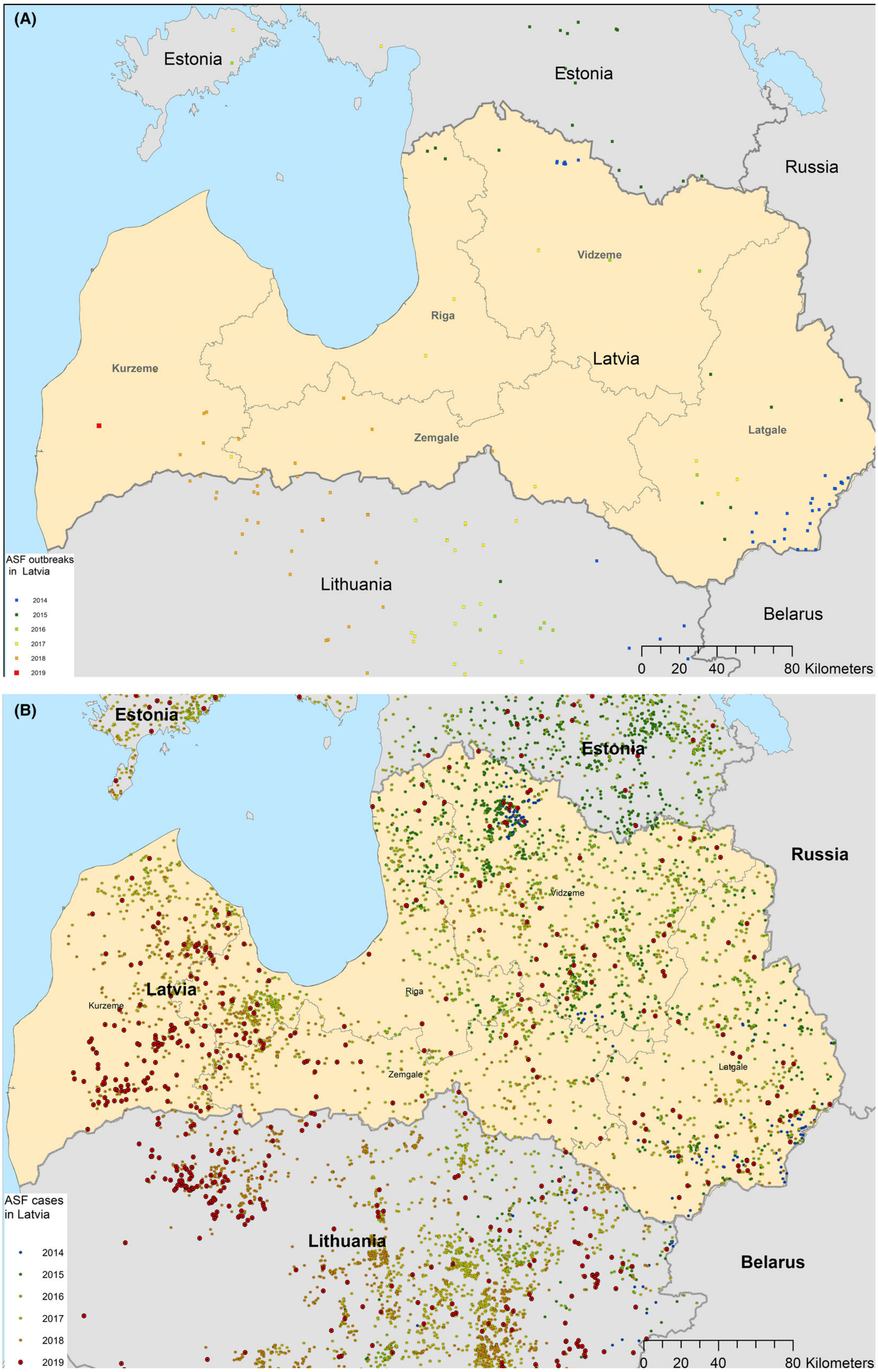


Figure 4: ASF outbreaks and cases in domestic pigs (A) and wild boar (B), respectively, reported to the ADNS in Latvia (26 June 2014 to 31 October 2019)

In November and December 2018, 113 ASF cases in wild boar were registered (17.7% in young and 82.3% in adult animals). Most cases (108) were detected in hunted animals and only five cases in dead animals. Markedly, most of the 113 ASF cases were animals with only seropositive results (Figure 4).

A cluster of PCR-positive wild boar was observed in the south-western part of Latvia near the border with Lithuania. This cluster is considered as the frontline of the epidemic wave that is still moving very slowly towards the Baltic Sea (westwards).

In 2019, by the end of September, 8,452 hunted wild boar and 63 dead wild boar were tested for the presence of ASFV. In total, 247 ASF cases (226 in hunted animals and 21 in dead animals) in wild boar had been confirmed. Only 26% of ASF cases were confirmed as PCR positive and 86% of them were located in the south-west of Latvia close to the epicentre of the epidemic front. Out of 226 cases in hunted wild boar, 74% were detected in animals with seropositive results only. Most cases with seropositive results (62.8%) originated from western Latvia, where ASF was introduced in the summer of 2016 and spread locally afterwards. However, cases with seropositive results in hunted wild boar were also detected in the areas where ASF was introduced and has been spreading since June 2014 (i.e. in the eastern part of Latvia) (Figure 4). However, in this area, the proportion of seropositive samples was much lower (37.2%) than in the western part (Table 6).

Table 6: Seroprevalence in hunted wild boar in Latvia January to September 2019

Region	Young (< 1 year)		Adult (> 1 year)		Total (%)
	Tested	Positive (%)	Tested	Positive (%)	
East	795	0,3	3,252	2,0	1,7
West	318	1,9	4,053	2,7	2,6

In this reporting period, only one outbreak has been confirmed and, between January and September 2019, 1,664 domestic pigs were tested under enhanced passive surveillance according to the ASF strategy. In July 2019, the first ASF outbreak in a small commercial pig farm with 52 pigs was confirmed. The location of the outbreak was in south-west Latvia close to the cluster of active infection in wild boar.

A non-haemadsorbing ASF virus genotype II was isolated from a hunted wild boar in Latvia in 2017 (Gallardo et al., 2019). This strain is considered as a good candidate for vaccine development against ASF (Barasona et al., 2019). Since then, similar isolates have not been found in Latvia, however, not all ASF virus isolates are sequenced.

- **Specific prevention and control measures (besides those laid down in the EU legislation and the Strategic approach to the management of ASF for the EU)**

Nothing specific in addition to EU Strategy.

- **Proven human-mediated spread in wild boar population**

Not observed since 2016.

4.1.1.4. Estonia

- **Evolution of ASF epidemic in this reporting period**

Figure 5: ASF outbreaks and cases in domestic pigs (A) and wild boar (B), respectively, reported to the ADNS in Estonia (8 September 2014 to 31 October 2019)

The epidemic of ASF in Estonia has been in a descending phase since the beginning of 2018. The last outbreaks in domestic pig herds occurred in summer 2017 and the number of cases detected among wild boar has been gradually decreasing. Most cases detected in wild boar have been antibody positive but virus (PCR) negative. The last PCR-positive wild boar in 2019 was detected in February.

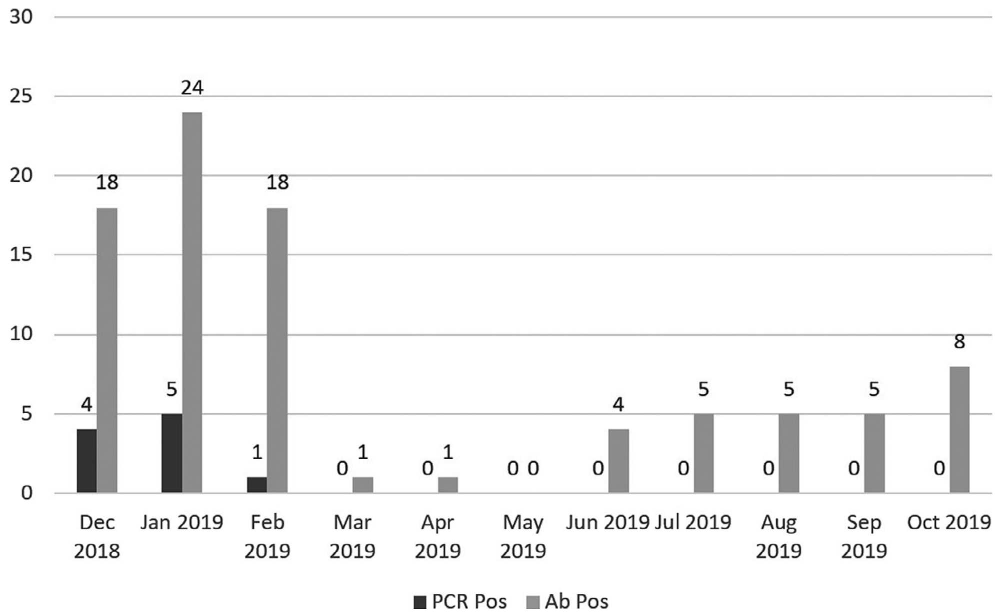


Figure 6: Numbers of ASF virus (PCR)-positive and antibody (Ab)-positive wild boar detected in Estonia in the period 1 December 2018 to 31 October 2019

In this reporting period, the first cluster of four cases was detected in December 2018. Between December 2018 and January 2019, four PCR-positive wild boar (four cases) were detected at Narva river, on the north-eastern border with the Russian Federation (previous PCR-positive cases from that county dated back to January 2017). The infected animals were hunted from an area with a radius of *c.* 5 km (the first cases *c.* 1.5 km from the border). In January 2019, additionally two PCR-positive carcasses and one hunted wild boar were detected within and adjacent to the same area. Since autumn 2018, there has been an ongoing epidemic of ASF among wild boar on the other side of the border (OIE, WAHIS, 2019) and it may therefore be hypothesised that the cases observed on the Estonian side might have been a spillover from that epidemic. However, in January 2019 one virus positive animal (a less than 1-year-old male) was hunted c. 45 km to the west from the cluster at Narva river. From the same area, an antibody-positive piglet was detected 1 month earlier. This situation may indicate that these cases in the north-east of Estonia still reflected local spread (Figure 6). However, there is no evidence to date that the virus has spread further from these two foci in the north-east. No specific action has been taken to restrict the spread. This may indicate that the wild boar density in this area is currently too low to enable transmission between the groups of wild boar (i.e. the number of wild boar shot in the hunting grounds in Ida-Viru was on average 0.04 wild boar per km^2).

During the same period, there were two PCR-positive cases detected in the western part of the country, one in Saaremaa in January and one in Läänemaa (in February). The cases of antibody-positive wild boar were detected in all 14 affected counties. However, most of these animals were older than 1 year (n = 75; 83%). Young (< 1-year-old) seropositive animals have been detected in seven counties (Table 7). The seroprevalence among hunted adult wild boar was 3.2%, whereas among younger animals it was 0.9%. As expected, most young seropositive wild boar were detected in the western part of the country and in Ida-Virumaa, where the latest PCR-positive animals had been detected in January and February 2019. Nevertheless, one case was detected in Lääne-Virumaa county (north-east) and two cases in Viljandimaa (south-west), where the last PCR-positive wild boar were found in summer 2017. So, a low level (undetected) virus circulation among wild boar can still not be excluded in these areas.

- **Specific prevention and control measures (besides those laid down in the EU legislation and the strategic approach to the management of ASF for the EU)**

The Board of Environment has assigned to hunting clubs the compulsory number of wild boars to be hunted to keep the population density at ~ 0.1 adults per km^2 of hunting ground.

Equal biosecurity requirements for all categories of pig farms.

Outdoor keeping of pigs prohibited.

- **Proven sources of introduction in domestic pig (direct/indirect contact)**

Not applicable.

- **Proven human-mediated ASF spread in the wild boar population**

None.

Table 7: Number of detected ASFV antibody-positive hunted wild boar in Estonia by counties and age groups from 1 December 2018 to 30 October 2019

Geographical region	County	Age category of wild boar								Total		
		Young			Adults			Unknown				
		n	positive	% positive	n	positive	% positive	n	positive	n	positive	% positive
North-West	**Harju**	135	1	0.7	162	12	7.4	4	0	301	13	4.3
	Lääne	44	1	2.3	90	7	7.8	0	0	134	8	6.0
	Rapla	47	4	8.5	43	4	9.3	1	0	91	8	8.8
	Hiiumaa	275	0	0.0	439	0	0.0	4	0	718	0	0.0
South-West	**Viljandi**	189	2	1.1	112	3	2.7	1	0	302	5	1.7
	Pärnu	108	0	0.0	179	10	5.6	5	0	292	10	3.4
	Saaremaa	212	1	0.5	429	12	2.8	2	0	643	13	2.0
North-East	**Ida-Viru**	80	3	3.8	154	4	2.6	2	1	236	8	3.4
	Lääne-Viru	44	1	2.3	95	2	2.1	2	0	141	3	2.1
	Jõgeva	17	0	0.0	54	2	3.7	4	0	75	2	2.7
	Järva	51	0	0.0	74	4	5.4	0	0	125	4	3.2
South-East	**Tartu**	101	0	0.0	179	7	3.9	11	3	291	10	3.4
	Põlva	35	0	0.0	52	4	7.7	3	0	90	4	4.4
	Valga	40	0	0.0	115	1	0.9	1	0	156	1	0.6
	Võru	122	0	0.0	152	3	2.0	4	0	278	3	1.1
Total		1,500	13	0.9	2,329	75	3.2	44	4	3,873	92	2.4

Young = below 1 year old; n = number tested; positive = number positive.

4.1.1.5. Czechia

In March 2019, Czechia was officially recognised to be free of ASF (European Commission, 2019a) (Figure 7). Table 8 shows the tested samples from wild boar that were found dead in Czechia as assessed by ELISA and PCR. All test results were negative

Table 8: Passive surveillance of ASF in wild boar found dead in the period 1 January 2019 to 15 November 2019 in Czechia

Number	Region	Number of samples submitted	Samples tested by PCR	Samples tested by ELISA	Positive
1	Capital city of Prague	53	53	46	0
2	Jihočeský region	174	174	106	0
3	Jihomoravský region	137	137	3	0
4	Karlovarský region	47	47	15	0
5	Královéhradecký region	22	22	15	0

Number	Region	Number of samples submitted	Samples tested by PCR	Samples tested by ELISA	Positive
6	Liberecký region	29	29	8	0
7	Moravian-Silesian region	28	28	26	0
8	Olomouc region	43	43	7	0
9	Pardubice region	59	59	44	0
10	Plzeň region	176	176	95	0
11	Central bohemian region	164	164	41	0
12	Ústí nad Labem region	269	269	98	0
13	Vysočina region	46	46	22	0
15	Zlín region	71	71	58	0
Total	Czechia	1,318	1,318	562	0

Testing period: From 1 January 2019 to 15 November 2019.

Figure 7: ASF cases in and wild boar reported to the ADNS in Czechia (26 June 2017 to 31 October 2019)

4.1.1.6. Romania

- **Evolution of ASF epidemic in this reporting period**

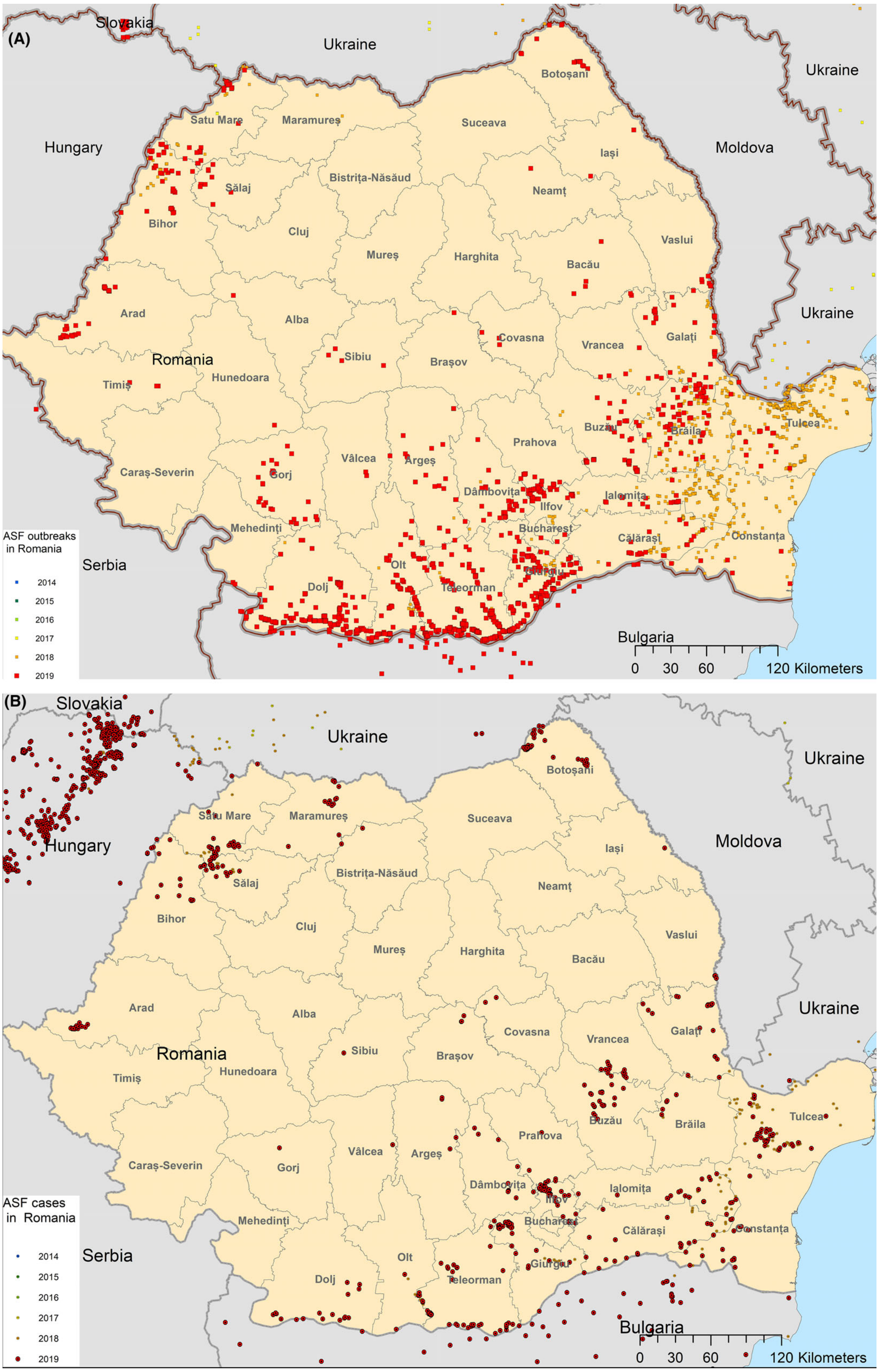


Figure 8: ASF outbreaks in domestic pigs (A) and cases in wild boar (B), respectively, reported to the ADNS in Romania (31 July 2017 to 31 October 2019)

The first half of this reporting period was characterised by many new cases in wild boar, detected both in found-dead and hunted animals. Regarding the ASF situation in domestic pigs, outbreaks were confirmed both in already affected areas and also in areas far away from the previous outbreaks (Figure 8). All the necessary resources have been allocated to ensure that there is no circulating virus in the restricted areas and so the vast majority of ASF outbreaks have been closed. By the 10 July 2019, there were 52 outbreaks.

In the second half of this reporting period ASFV had spread aggressively in the area of the Danube Delta, and several cases in wild boar were detected in the Dobrogea region. Human-mediated spread, however, is still considered as the main risk factor. The low level of biosecurity in backyard farms and the traditional particularities of pig keeping in Romania have facilitated the introduction of ASF in many backyard farms over a short period of time.

It is assumed that due to the high infection pressure of the environment, combined with possible breaches in biosecurity, ASF was also introduced in commercial farms (e.g. the outbreaks in commercial farms in Olt and Vrancea).

- **Specific prevention and control measures (besides those laid down in the EU legislation and the Strategic approach to the management of ASF for the EU)**

Preventive culling: after performing of a risk assessment, the Local Centre for Disease Control can decide to preventively cull pigs in a certain locality/area to stop the spreading of the disease.

Portable disinfection devices (for vehicles) and foot disinfectors (for pedestrians) are installed at the entrance and exits of markets and at vegetable and fruit fairs. Vehicles used in forests and farmlands are being disinfected at the sanitary check points on the roads.

Pig raising is prohibited when not registered in the National Data Base.

Romanian eradication plan of ASF in wild boar, the affected area of 8 km radius is surrounded by a buffer zone of another 5 km. The measures in this area are focused on culling all wild boar.

The official veterinarians together with the police officers perform checks on animal fairs and traffic to verify if the restrictions are being complied with.

- **Proven sources of introduction in domestic pig (direct/indirect contact)**

There are currently no proofs of the exact sources of introduction of ASF in domestic pig holdings. However, the risk factors for occurrence of ASF in domestic pig farms in Romania were investigated in a specific case–control study and described in Section 4.2.2.

- **Proven human-mediated spread in wild boar population**

There are currently no proofs of the exact sources of human-mediated spread of ASF in wild boar.

4.1.1.7. Hungary

- **Evolution of ASF epidemic in this reporting period**

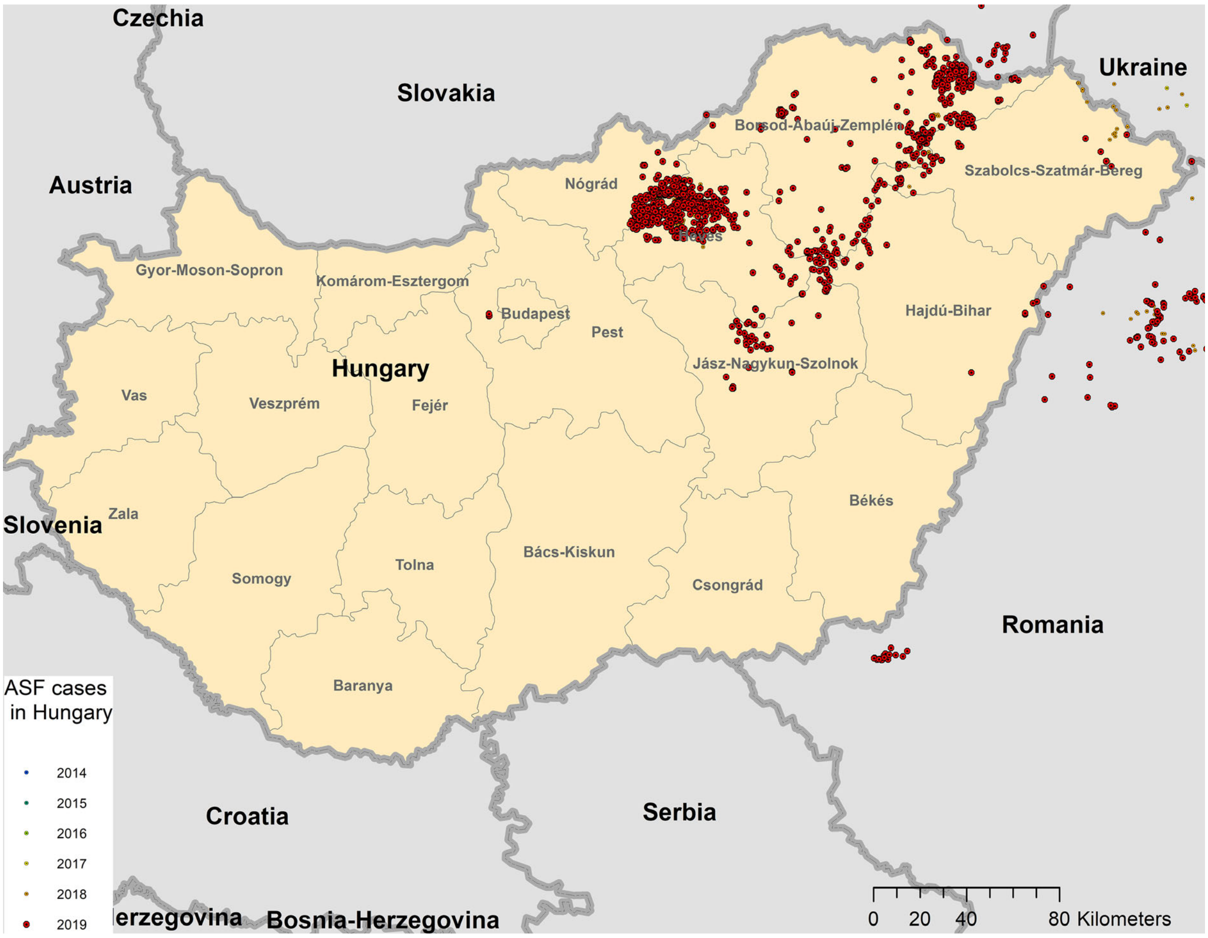


Figure 9: ASF cases in wild boar reported to the ADNS in Hungary (31 July 2019 to 31 October 2019)

The first wild boar ASF case was confirmed in Heves county in Hungary on the 21 April 2018. ASF was confirmed by the National Reference Laboratory (NRL) (Veterinary Diagnostic Directorate of the National Food Chain Safety Office, Budapest) via PCR test (Figure 9).

Subsequently, the disease appeared in wild boar also in Szabolcs-Szatmár-Bereg county in May 2018 and Borsod-Abaúj-Zemplén and Nógrád county in October 2018.

In the first half of 2019, the disease spread further and the first cases in Hajdú-Bihar county were found. A dead wild boar was found in the locality of Álmosd and two dead wild boar were found in the locality of Nyírábrány on 28 April 2019. ASF was confirmed in the NRL on 29 April 2019 by PCR test.

On 21 August 2019, three dead wild boar were found in Heves county of the locality of Poroszló, and on 26 August 2019, two dead wild boar were found in Borsod-Abaúj-Zemplén county around the locality of Tiszakeszi. Samples were taken and sent to the NRL, and ASF was confirmed on the 28 August 2019 by PCR. Table 9 shows all tested samples in 2019 taken from wild boar up to 31 August 2019.

Table 9: Tested wild boar samples in 2019 in Hungary by PCR

County	Found dead			Hunted			Grand total
	Negative	Positive	Total	Negative	Positive	Total	
Pest	50	0	50	2,498	0	2,498	2,548
Fejér megyei	7	0	7	2	0	2	9

County	Found dead			Hunted			Grand total
	Negative	Positive	Total	Negative	Positive	Total	
Komárom-Esztergom megyei	12	0	12	3	0	3	15
Veszprém	27	0	27	13	0	13	40
Gyor-Moson-Sopron	14	0	14	2	0	2	16
Vas	20	0	20	117	0	117	137
Zala	2	0	2	2	0	2	4
Baranya	11	0	11	13	0	13	24
Somogy	8	0	8	7	0	7	15
Tolna	73	0	73	21	0	21	94
Borsod-Abaéj-Zemplén	257	337	594	10,540	37	10,577	11,171
Heves	240	737	977	5,200	78	5,278	6,255
Nógrád	228	177	405	6,595	26	6,621	7,026
Hajdé-Bihar	32	8	40	2,332	0	2,332	2,372
Jász-Nagykun-Szolnok	12	4	16	191	0	191	207
Szabolcs-Szatmár-Bereg	59	43	102	1,943	9	1,952	2,054
Bács-Kiskun	16	0	16	131	0	131	147
Békés megyei	1	0	1	67	0	67	68
Csongrád	2	0	2	3	0	3	5
	1,071	1,306	2,377	29,680	150	29,830	32,207

No new positive cases have been found near the Ukrainian border (Szabolcs-Szatmár-Bereg county) since March 2019.

- **Specific prevention and control measures (besides those laid down in the EU legislation and the Strategic approach to the management of ASF for the EU)**

Decision 3/2018 of the Chief Veterinary Officer of Hungary categorises all Game Management Units (GMUs) into different categories in the whole territory of Hungary: affected, high-risk, medium-risk or low-risk area. The affected area is the Part II and the high-risk area is the Part I in EU regionalisation. The medium-risk and the low-risk areas are beyond the EU regionalisation, these areas are only in Hungary. The medium-risk area is a buffer zone surrounding Part I areas, where many measures of the area listed for Part I are in force. Extension of the affected, high-risk and medium-risk areas in GMUs could occur.

All wild boar shot within Part II areas have to be sampled and immediately disposed of, regardless of ASF results.

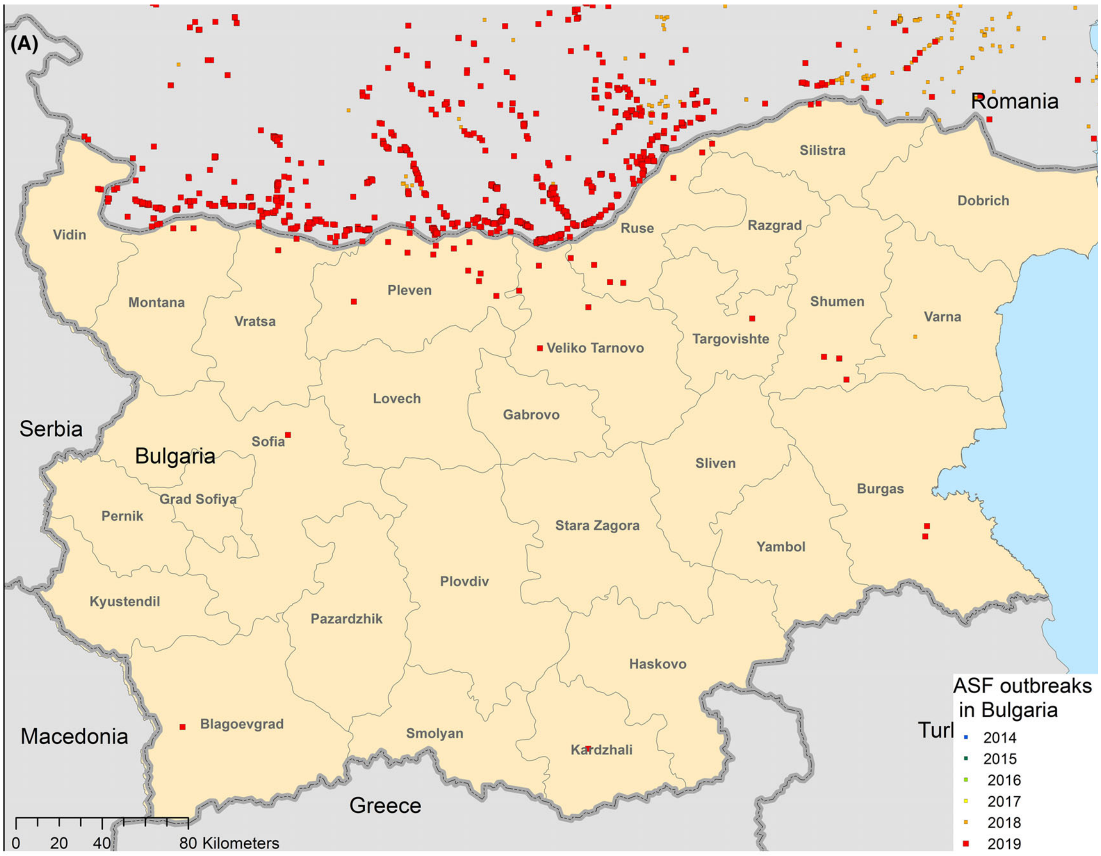
- **Proven human-mediated spread in wild boar population**

There is no direct proof of human-mediated spread.

4.1.1.8. Bulgaria

- **Evolution of ASF epidemic in this reporting period**

Since the beginning of 2019, 41 outbreaks of ASF have been notified in 14 out of 28 regions of Bulgaria (Figure 10).



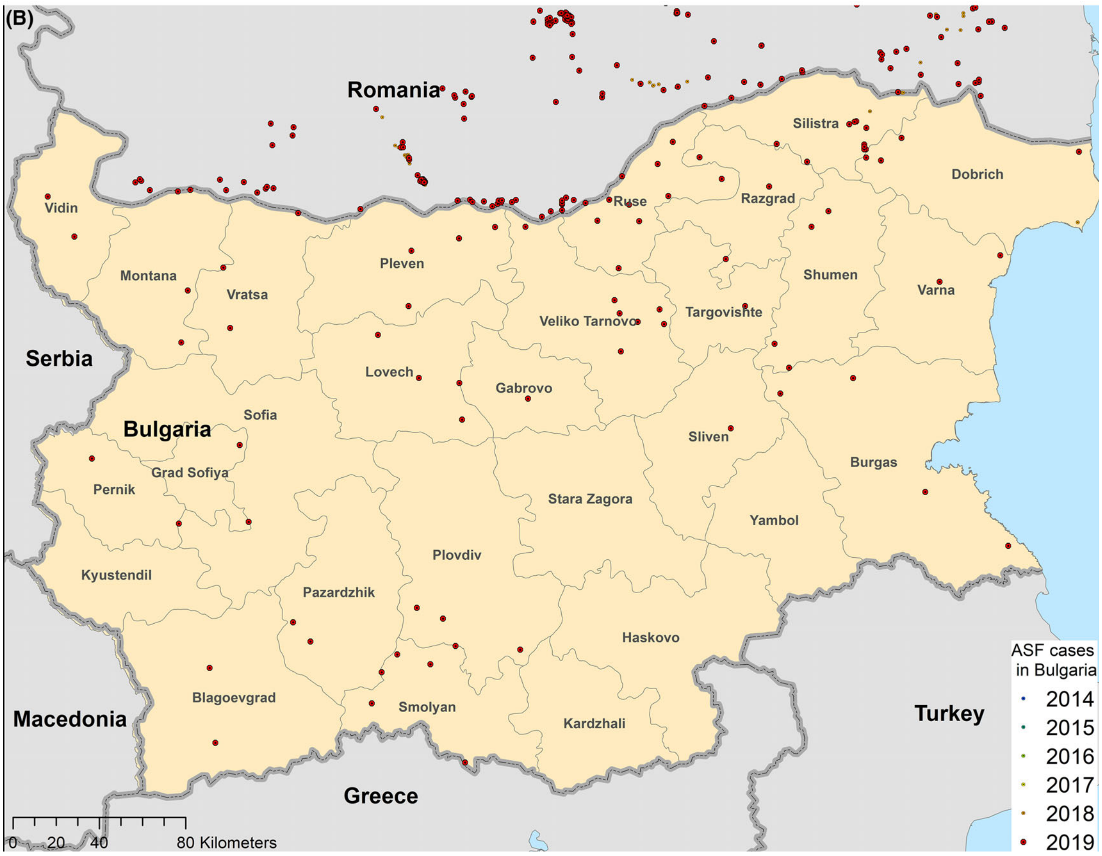


Figure 10: African swine fever outbreaks and cases in domestic pigs (A) and wild boar (B), respectively, reported to the ADNS in Bulgaria (31 August 2018 to 31 October 2019)

In total, eight industrial pig farms, three family farms (small commercial farms with level of biosecurity) and 25 backyard farms and five East Balkan pig farms were affected and almost 1,420,000 pigs were culled and destroyed.

The first outbreak was confirmed on the 3 July 2019 in the Pleven region, central-north Bulgaria, an area considered as a high-risk area close to the border with Romania. The outbreak was confirmed in Zhernov village, in an unregistered backyard holding following notification of increased mortality of the pigs. In total, 12 outbreaks in backyard farms were reported as a result of suspicion of ASF notified by the owner, and 10 were detected during the implementation of the surveillance activities within 10 km surveillance zones around outbreaks.

Following an epidemiological inquiry carried out in these backyard holdings where the outbreak was first confirmed, a few hypotheses were considered for the introduction of the virus:

- People (high probability):
  - the holding owner was identified travelling abroad to affected countries;
  - visits of a hunter and a veterinary assistant (including to other villages of the same and the neighbouring municipality outbreaks that were also confirmed later).
- Contaminated vehicles (high probability):
  - the holding was located on a transit road with Romania with a considerable number of vehicles and trucks passing daily;
  - contaminated equipment and vehicles of the owner who is an agricultural producer and information was provided to the competent authority about the frequent movements of the vehicles, including abroad. In addition, no biosecurity procedures were in place at the entrance of the holding.
- Feed (moderate probability):
  - the pigs were fed with own-produced crops, no swill feeding was indicated, however, information was gathered that owner fed the dogs in the yard (in close proximity to the premises for the pigs) with kitchen leftovers (including pork products brought from abroad).
- Direct contact with wild boar (low probability):
  - the pigs were kept in well fenced concrete premises, the outside yard of the holding was not entirely fenced, as the back of the yard bordered a field.
- Illegal animal movement to the holding (ruled out):
  - no new animals were introduced in the months preceding the outbreak confirmation.

ASF in industrial farms was detected under passive surveillance (weekly sampling of dead animals per each production unit, according to the strategic approach to the management of ASF for the EU).

In total, 162 cases have been confirmed in wild boar in 14 regions of the country (48 in hunted and 114 found-dead wild boars) since September 2019.

The national strategy to control ASF in wild boar has been amended since July 2019. An affected area is set up with a size of more than 200 km^2 in case positive wild boar are found in the area. The affected area is set up in collaboration with the Veterinary Service and the Forestry Agency. The measures in affected area are described Table 10.

Table 10: Measures implemented in ASF-affected area of Bulgaria

Within the 2 months since the latest ASF case ascertained	2–4 months since the latest ASF case ascertained	4–6 months since the latest ASF case ascertained	More than 6 months since the latest ASF case ascertained
Restricted access and placing tables Ban on hunting Total ban on feeding wild boar Biosecurity Searching Entering data into the Hunting Module	Biosecurity Individual hunting Traps Searching Ban on feeding Entering data into the Hunting Module The wild boar shot should be ASFV tested and buried Testifying document signed by an official veterinarian	Biosecurity Individual hunting Traps Team hunting without dogs Increased vigilance Entering data into the Hunting Module The wild boar shot should be ASFV tested Refrigerators	Biosecurity Individual hunting Traps Team hunting Increased vigilance Entering data into the Hunting Module The wild boar shot should be ASFV tested

The domestic pigs within the affected areas are also included into surveillance system. No other activities, such as tree cutting, cultivation of agricultural land, picking herbs, or mushrooms, are allowed.

Additional measures and activities:

- regular meetings with stakeholders (Executive Agency for Forestry (EAF), hunting organisations and associations, pig industry) on regional and central levels;
- training on biosecurity measures during hunting, epidemiology, sampling and for ASF control. brochures, leaflets, awareness campaigns;
- requirements for dedicated pits for wild boar carcasses and animal by-product disposal in each hunting ground;
- fence along the land border with Romania;
- **proven sources of introduction in domestic pig (direct/indirect contact);**
- **proven human-mediated spread in wild boar population.**

4.1.1.9. Slovakia

- **Evolution of ASF epidemic in this reporting period**

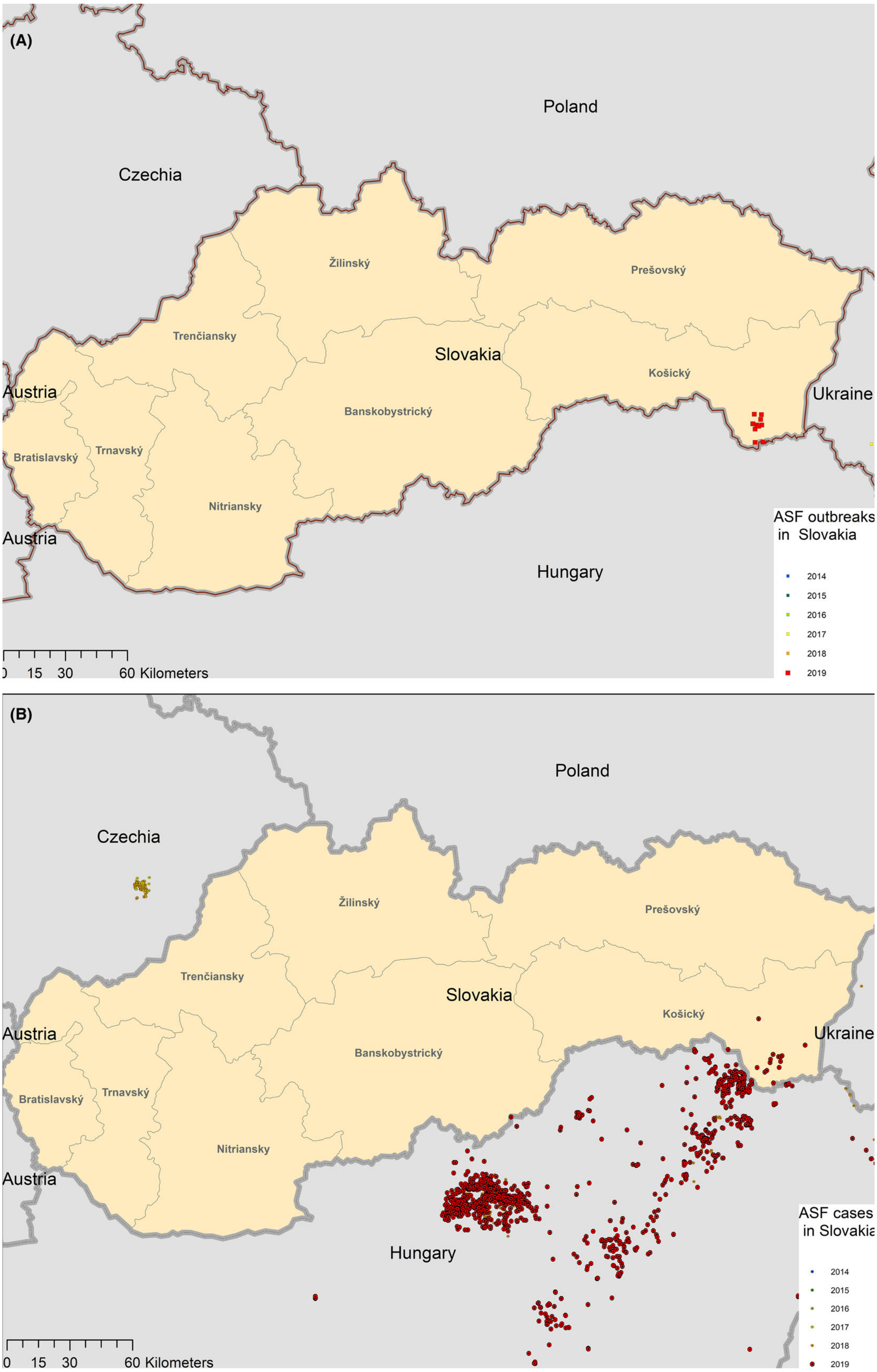


Figure 11: ASF outbreaks and cases in domestic pigs (A) and wild boar (B), respectively, reported to the ADNS in Slovakia (24 July 2019 to 31 October 2019)

When ASF approached the Slovakian border, Slovakia set up the so-called buffer zones in the border areas. These zones have been set up to provide an overview of the situation and to raise awareness of the threat of the disease and its impact on the wild boar population and it is devastating effect on the whole pig sector (Figure 11). Slovakia introduced both an active and passive systematic surveillance in these buffer zones, ordered measures related to hunting management and set up a surveillance system in domestic pigs.

The first ASF case in Slovakia was confirmed on 24 July 2019 in a domestic pig that clinical signs and was from a backyard holding in the south-east part of Slovakia in the Trebišov district, very close (450 m) to the Hungarian border where ASF was present. All four pigs in the backyard holding either died from the disease or were culled and safely rendered in the rendering plant. After the census of pig farms was carried out, all pigs in the village were culled. Up to the end of September, 11 outbreaks in total were confirmed. All outbreaks were in backyard holdings with low levels of biosecurity, located in the same area. The source of infection in the backyard holdings was probably the wild boar population because, in August 2019, positive wild boar cases were also found. The EUVET team of experts that visited Slovakia in August 2019 concluded that the connected wild boar populations between the Hungarian and Slovakian border facilitated the natural spread of ASF (EUVET, 2018).

In Slovakia, in affected areas and buffer zones, active surveillance (all hunted wild boar were investigated) and passive surveillance (all perished/sick animals have to be investigated mandatory) was performed. In the zones outside these two determined areas, only passive surveillance was carried out.

During the first 7 months of 2019, 15,066 wild boar were tested virologically for the presence of ASFV, with negative results. However, on the 8 August 2019, the first positive wild boar case was confirmed in the south-east part of Slovakia, again in the Trebišov district close to the Hungarian border. The wild boar was shot because behavioural changes were observed. Seven days later, a second positive case in wild boar was confirmed in the same district. During August and September, 6,760 wild boar (6,382 hunted and 378 dead wild boar including road accidents) were tested virologically. In total, 16 positive wild boar were confirmed. All ASF cases were detected in the same area, in the south-east part of Slovakia close to the border to Hungary.

- **Specific prevention and control measures (besides those laid down in EU legislation)**

All hunting grounds in Slovakia have been ordered to reduce their wild boar population as a preventive measure to avoid spreading of ASF. Selective hunting is promoted by financial incentives of 30 EUR – selective hunting of females and last year’s wild boar, 10 EUR/piece of wild boar. Feeding of wild boar is prohibited in the whole territory of Slovakia. According to the hunter’s database more than 56,000 wild boar are expected to be hunted in the hunting season.

4.1.1.10. Belgium

- **Evolution of ASF epidemic in this reporting period**

Figure 12: ASF cases in wild boar reported to the ADNS in Belgium (13 September 2018 to 31 October 2019)

Outbreak

On September 13, 2018, the presence of ASF was confirmed in Belgium for the first time since 1985 (Figure 12). The two first positive cases, one found-dead adult and one sanitary-shot young wild boar, were detected in the Bois de Buzenol (latitude 49.6833°N and longitude 5.6°E) near the village of Etalle (province of Luxembourg, south-east Wallonia). The outbreak was about 12 and 17 km, respectively, from the borders of France and Grand-Duchy of Luxembourg. Within the first 4 weeks, 89 ASF-positive dead wild boar were detected in the zone. The origin of the outbreak in Belgium is still unknown. Considering the nearest affected country in 2018 (Czechia), the ASFV jumped at least 1,000 km. This isolated introduction was probably linked to human activities, a judicial investigation is ongoing. After confirmation of the outbreak, preventive and control measures were immediately implemented. In Belgium, federal (Federal Agency for the Safety of the Food Chain – FASFC) and regional (Public Service of Wallonia – SPW) authorities are responsible for management measures in domestic and wild animals, respectively.

Control measures in domestic pigs

About 1 year after the emergence, there have been still no cases among domestic pigs. The self-declaration of 'free status of ASF for domestic and wild pigs kept in captivity' submitted by Belgium to the OIE was approved in April 2019. Immediately after the confirmation of ASF in wild boar, preventive measures were implemented in domestic pigs by federal authorities. The first one-off measure was the preventive culling of all domestic pigs and captive wild pigs present in the provisional 'infected zone' (see below) with prohibited repopulation. In total, 5,222 pigs were culled (Source: FASFC). Other measures, including enhanced passive surveillance in all pig holdings, training of veterinarians, increased biosecurity measures and prohibition of assembly of pigs, were carried out by the FASFC over the whole Belgian territory.

Control measures in wild boar

1) Zoning – As soon as the first cases were confirmed and according to the Directive 2002/60/EC, federal and regional authorities delimited a provisional 'infected zone' extending over 630 km^2. In November 2018, the provisional infected zone was replaced by the two official zones corresponding to the European legislation: zone II (in which ASF has only been detected in wild boar) and zone I (surrounding zone II and in which no cases of ASF had been recorded). From that time on, these zones were continuously adapted according to the spatial coordinates where new cases were confirmed. In each zone, specific measures were imposed by the European legislation both in domestic pigs and in wild boar. Simultaneously, a regional operational zoning was implemented to facilitate implementation of control measures in wild boar: (i) an infected area (roughly corresponding to European zone II); and (ii) two concentric peripheral zones (called 'reinforced observation area' and 'vigilance area') corresponding to European zone I. The specific measures imposed by the regional authorities in each of these three operational zones were/are more stringent than those imposed by EU in zones II and I. Feeding wild boar is strictly prohibited in the three areas and a total ban of hunting (until July 2019) as well as a partial ban of circulation and logging were imposed in the infected area.
2) Carcass search – Active and systematic searches for dead wild boar with immediate carcass removal and soil disinfection were organised in the three zones by regional authorities since the beginning of the outbreak. Each found-dead wild boar is packed according to strict biosecurity procedures and transported to the principal collection centre by professionals of the Civil Protection, after which they are sent to the rendering plant.
3) Fencing – A network of concentric fences was built on the border and within the three aforementioned areas (about 300 km until November 2019). Belgian fences were connected to those built in France and the Grand-Duchy of Luxembourg wherever pertinent. The goal was/is two-fold: (i) slowing down the centrifugal geo-diffusion of the disease; and (ii) creating tight corridors in which depopulation can be carried out without taking the risk of causing movement of animals over long distances.
4) Depopulation – Many tools were implemented (trapping, night shooting, single hunting on baiting points, driven hunts with/without dogs) with specific restrictions according to the area. All these measures were carried out under the supervision of the regional authorities with the objective to depopulate the three areas. The hunters were involved in the depopulation operations. Compensations (50 EUR or 100 EUR per wild boar, depending of the area) were provided to agreed hunters who had received specific training on biosecurity procedures, including packaging and transport of culled wild boar to the collect/diagnostic centres.

Diagnosis

Three centres were created (the principal in the infected area, the second in the reinforced observation area and the third in the vigilance area) to collect wild boar (found dead or culled) from the ASF-affected zone. Drastic biosecurity measures are met by veterinarians for carcasses handling and sampling. Targeted organs are sent to the NRL for qPCR analysis and carcasses are removed to the rendering plant. Only one truck is specifically dedicated to wild boar carcass transport to the rendering plant.

Current situation

From the ASF-wild boar outbreak day in September 2018 to 30 September 2019, 3,864 wild boar (found dead, culled or hunted) were analysed. Among these, 3,667 were sampled inside the ASF zone (1,106.62 km^2 area) including infected, reinforced observation and vigilance areas. All of the 827 ASFV-positive animals were from the infected zone. Most of the positive cases were found dead (96.1%), the remaining were killed for sanitary reasons (1.9%), culled (1.6%) or road killed (0.4%). In the infected zone, the disease moved from east to west within large and continuous forests.

Two types of epidemiological studies were implemented. First, a stochastic spatiotemporal individual-based model was applied on Belgian land cover data (province of Luxembourg) to simulate

ASFV spread in a time varying wild boar population, with a specified index case localisation. As a first step, the virus spread was assessed without any control measure: 1 year after virus introduction, the modelled infected zone extends beyond the present infected zone in more than 80% of the iterations. New developments in the R codes will soon make it possibly to specifically model the impact of each of the control measures such as: (i) animal confinement in fenced areas; (ii) animal trapping; (iii) targeted hunting; and (iv) carcasses removal on wild boar population and ASFV spread (Simons X. and Dispas M., personal communication).

Second, spatial modelling techniques that were developed in invasion ecology to quantify and map the local rate of spread during the course of the epidemics were implemented. In addition, a new method derived from previous studies in landscape genetics is being used to quantify how the land cover (forest versus unforested areas) may influence the local rate of spread. The role of fences that were installed in reaction to the development of the epidemic in reducing the spread rate is more complicated to set up because, in several cases, the invasion simply did not cross the fence. So, the present pattern of spread needs to be contrasted with a null model with reactive installation of fences, and this is not easy to implement. New analytical methods that are currently being evaluated will be considered.

The control strategy, including the combination of the aforementioned different measures, has so far proved effective to maintain ASFV inside the affected area. Since March 2019, the date of the last zoning adaptation, no infected wild boar has been detected outside this zone. The network of fencing limited wild boar movements and facilitated depopulation measures in the ASF zone. Within each zone, the number of hunted wild boar before the outbreak (previous hunting season) was compared with the number of found dead, culled and/or hunted wild boar after the outbreak (September 2018 to March 2019). In the infected zone, the number of wild boar found dead was double the number of those hunted during the previous year. In the reinforced observation and vigilance areas, depopulation measures (trapping, night shooting, culling and hunting) yielded numbers of retrieved carcasses that were, respectively, 159% and 187% those retrieved the preceding year from hunting (Licoppe A., personal communication). In the ASF zone, active (analysis of culled or hunted wild boar) and passive (active search of dead wild boar, carcass removal and analysis) surveillances are maintained. Passive surveillance is a key point in the control strategy, this activity is ongoing with strict respect to biosecurity procedures. For our objective of near-total depopulation in the ASF zone, destruction activities must be maintained with strong motivation of hunters and forest rangers. Outside the ASF zone (the rest of Wallonia), passive surveillance is also carried out. From the outbreak until the end of September 2019, 197 found-dead wild boar were analysed, all were ASFV negative. Communication networks with EU authorities, neighbouring countries as well as several Belgian stakeholders (hunters, forest rangers, farmers, veterinarians, tourists, forestry workers, etc.) are essential. They have continuously been implemented by both regional and federal authorities since the first day of the emergence.

The regional and federal authorities were determined to keep pressure on all players to manage a second possible epidemic wave in the affected area after the dispersal of piglets born in 2019 and/or accidental spillovers of infected animals across fences.

4.1.1.11. Serbia

- **Evolution of ASF epidemic in this reporting period**

Figure 13: ASF outbreaks in domestic pigs reported to the ADNS in Serbia (31 July 2019 to 31 October 2019)

The presence of ASF was officially confirmed on the 30 July 2019 in a backyard holding in the central part of the country (in the Mladenovac municipality, district of Belgrade), where one sow was found dead and confirmed to be ASF positive by the NRL (Figure 13). This first outbreak was discovered by a routine passive surveillance check, far from the expected regions of introduction bordering the affected neighbouring countries of Hungary, Romania and Bulgaria.

According to the results of the epidemiological survey carried out in the affected area, the possible time for virus entry and the origin of the virus on the infected holding, the 17 contact holdings were identified in terms of the parameters related to the movement of humans and pigs within the last 30 days, as well as the location of these holdings, which were isolated by geographical barriers from the other holdings in the village at a distance of approximately 2 km. Depopulation was conducted immediately in these holdings as a preventive measure. Clinical signs on pigs in these holdings were non-specific but sampling was performed during the culling with positive results, this action justified the suspicion that the virus could be present on these holdings. Clinical examination was carried out in all the other holdings in the rest of the village, but no clinical signs were detected.

Tracing back the activity of the veterinary technician operating in the area, the second outbreak was confirmed in the neighbouring village Velika Krsna, where eight pigs were destroyed in the affected holding. In the next 2 days, 75 pigs were culled in eight nearby holdings and 246 holdings with 2,550 pigs were checked for clinical signs in the same village. In the second outbreak holding, ASFV was detected in deep frozen meat in the holding. This was in a pig that had been reared in the farms and slaughtered for personal consumption at the beginning of May 2019. According to the owner, this frozen meat originated from one of his own pigs. It can therefore be concluded that ASF had been present in that region since April 2019.

The third outbreak was confirmed in the neighbouring municipality of Smederevska Palanka. On 5 August, three pigs died and 60 were destroyed in the identified holding in the village of Kusadak. An additional investigation was conducted in 28 surrounding holdings with no positive findings. Finally, by 19 August, two more outbreaks were identified in the village that had the second outbreak, Velika Krsna.

Furthermore, another outbreak of ASF in Serbia was confirmed on the 10 September in a backyard holding near the border with Romania (in the village Srpski Itebej, municipality of Žitište). In this area, 260 holdings with a total of 2,180 pigs were examined. No other affected holdings were found in that region. So far, no large commercial farm nor wild boar has been found to be infected.

Overall, from 30 July to 10 September, there has been 18 confirmed outbreaks in three districts and four settlements. The 24 samples taken during stamping out were positive (Figure 13). In total, 622 animals were destroyed (283 in 18 positive backyard holdings and 339 in the contact backyards holdings).

- A short description of specific prevention and control measures (besides those laid down in the EU legislation and the Strategic approach to the management of ASF for the EU)

Due to the appearance of the disease in the neighbouring countries of Romania, Hungary and Bulgaria, three risk-based zones were established. High-risk areas were set up within the north-eastern territory, where controlling measures were enforced, including custom and traffic control.

All identified outbreaks were connected and discovered according to the findings of the epidemiological enquiry. The limited movement of humans and animals in this area was a mitigating circumstance in the investigation and collection of relevant data.

Within the last 2 weeks of August, 106 samples were collected under official suspicion in passive surveillance all over the country, but no other case was confirmed. As the general survey in the country for the screening purpose is planned to be conducted by the end of November, the restrictive measures in the protection and surveillance zones remain in force until the final results are obtained.

On 9 September 2019, the Veterinary Directorate adopted a special programme for the control and surveillance of ASF in domestic pigs. ASF surveillance was carried out in all holdings where pigs were kept and raised and included:

- Visiting and examination of the pigs' health status and completing the epidemiological questionnaire.
- Sampling all the susceptible animals with clinical signs or dead.
- Diagnostic examination for the presence of the African swine fever virus (ASFV) genome.

- **Field evidence of indirect and direct sources of introduction in domestic pig holdings**

The risk factors linked to the spread of ASF in Serbia are generally represented by free-ranging pigs, the geographic vicinity of affected areas, illegal movement of pigs, swill feeding of pigs, low biosecurity levels in pig farms, undetected virus circulation, the large number of small holdings, illegal trading of pigmeat/products, human-mediated spread, wild boar and hunting. Infected frozen meat has also proven to be a source of infection in pig farms.

- **Field evidence of human-mediated spread in wild boar populations**

Human-mediated spread is considered as the certain cause of introduction of the virus into Serbia. Also, iatrogenic spread, through veterinary treatments and vaccination campaigns might have contributed to the virus spread.

On 9 September 2019, the Veterinary Directorate adopted a special screening programme for the control and surveillance of ASF in domestic pigs with the aim of early detection of ASFV and, in particular, to gather relevant data to improve knowledge of the epidemiological situation of ASF in Serbia. A surveillance plan has been applied throughout the entire territory of Serbia. A passive surveillance programme is planned do be conducted for at least 2 months, or until all holdings keeping pigs in the territory of the Republic of Serbia have been tested (all animals clinical, dead or sick by PCR). The surveillance programme officially ended on 30 November. In total, more than 16,000 samples from dead or sick animals have been collected (blood or spleen) without positive findings.

The infection status of the wild boar population in Serbia is currently unclear. An enhanced passive surveillance programme in wild boar has been implemented based on epidemiological principles.

4.1.2. Spatiotemporal patterns observed in the affected Member States

4.1.2.1. Proportions of positive samples tested either by PCR or antibody-ELISA since first detection

Figures 14(A)–17(A) show the observed proportions of positive samples of hunted wild boar tested by PCR (dashed blue line) and by Ab-ELISA (dotted red line) in the LAU 2 areas in the affected areas in Lithuania, Poland, Latvia and Estonia, respectively. Only samples tested since 2016 are shown. Figures 14(B)–17(B) show the same proportions, but only from the wild boar found dead,

The following conclusions can be drawn:

- Throughout the observation period, the proportion of ASF-positive wild boar has always been higher among found dead compared with hunted animals, regardless of the testing method.
- In affected areas, the proportion of wild boar testing positive with PCR has always been much higher than the proportions testing positive to Ab-ELISA.
- During the observation period (1 January 2016 to 31 August 2019), there has been no increase in the proportion of seropositive samples in hunted wild boar nor in wild boar found dead.
- In hunted animals, the proportion of wild boar testing PCR and Ab-ELISA positive has remained low (i.e. < 5%), however some minor seasonal differences were observed. Seasonality is studied in more detail in Section 4.1.2.2.
- The proportions of PCR-positive samples in the wild boar found dead in Lithuania, Latvia and Estonia declined in the last reporting period.

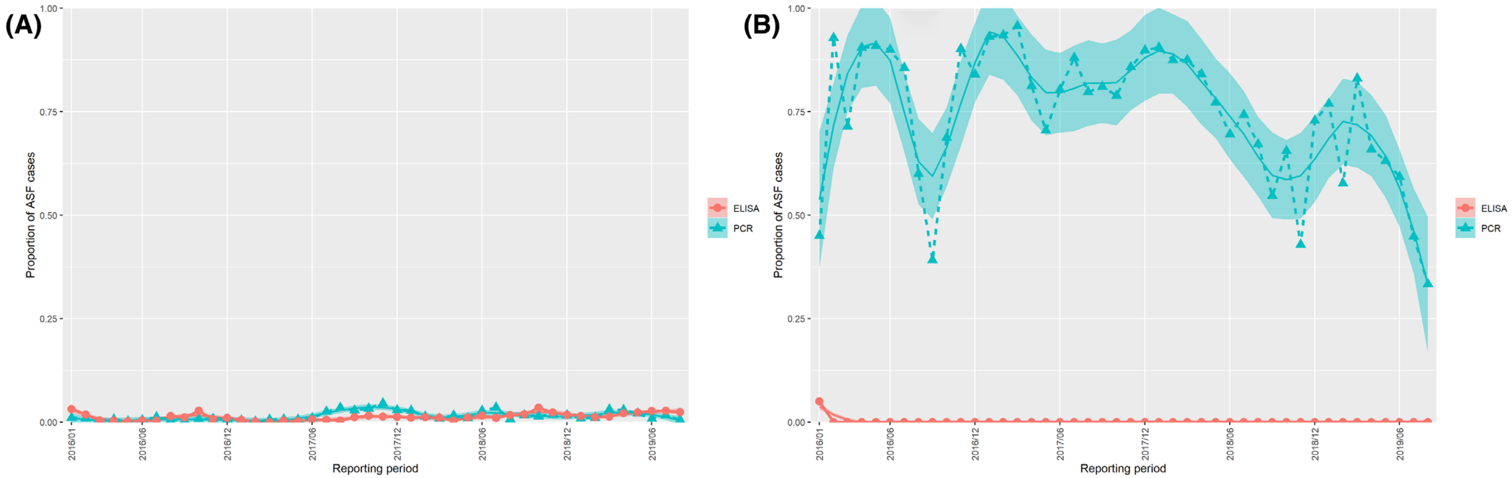


Figure 14: Proportion of ASFV-positive samples (by AB-ELISA and PCR) over the tested samples from all hunted wild boar (A) and from wild boar found dead (B) in the ASF-affected areas of Lithuania (1 January 2016 to 31 August 2019)

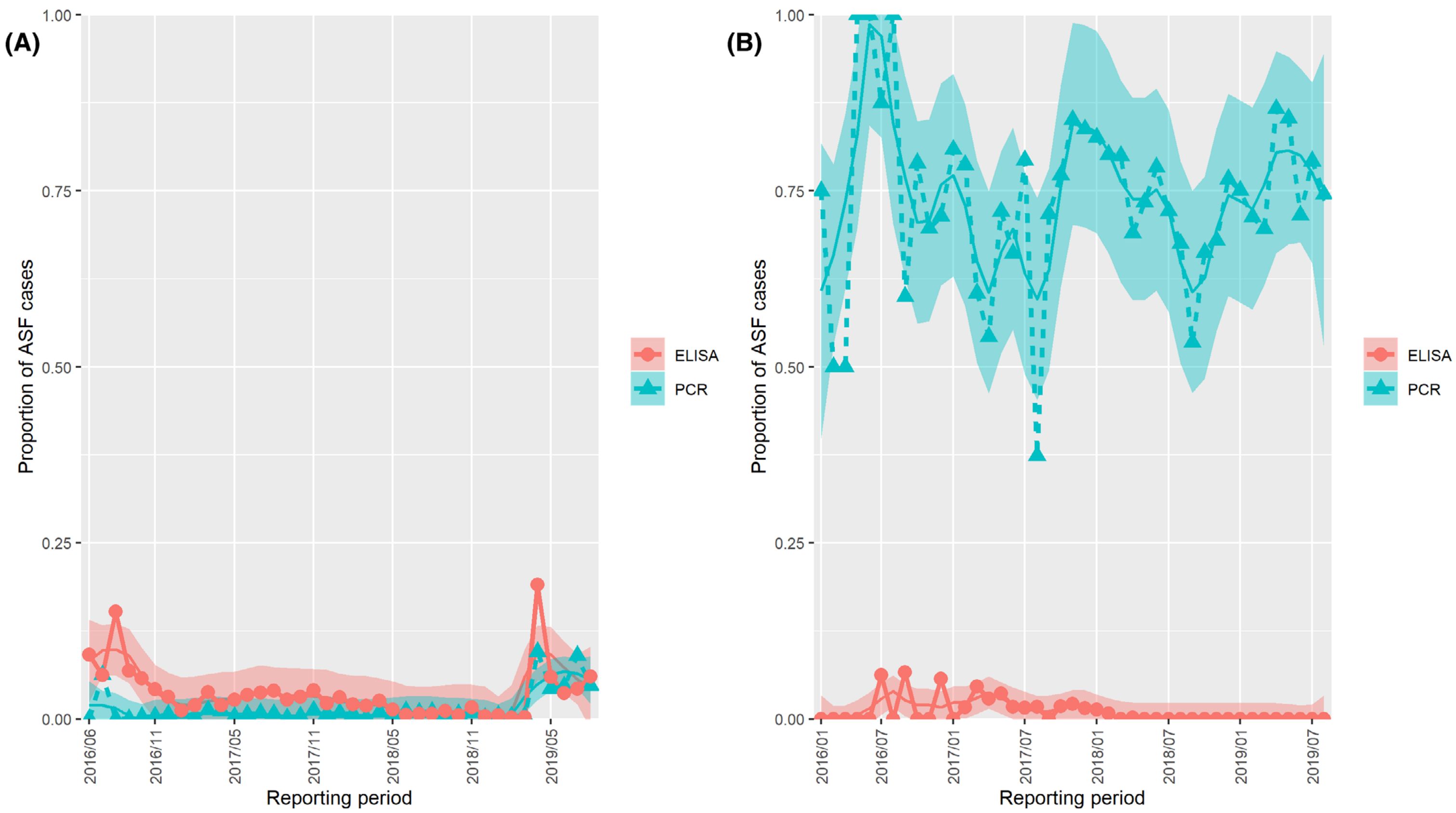


Figure 15: Proportion of ASFV-positive samples (by Ab-ELISA and PCR) over the tested samples from all hunted wild boar (A) and from wild boar found dead (B) in the ASF-affected areas of Poland (1 January 2016 to 31 August 2019)

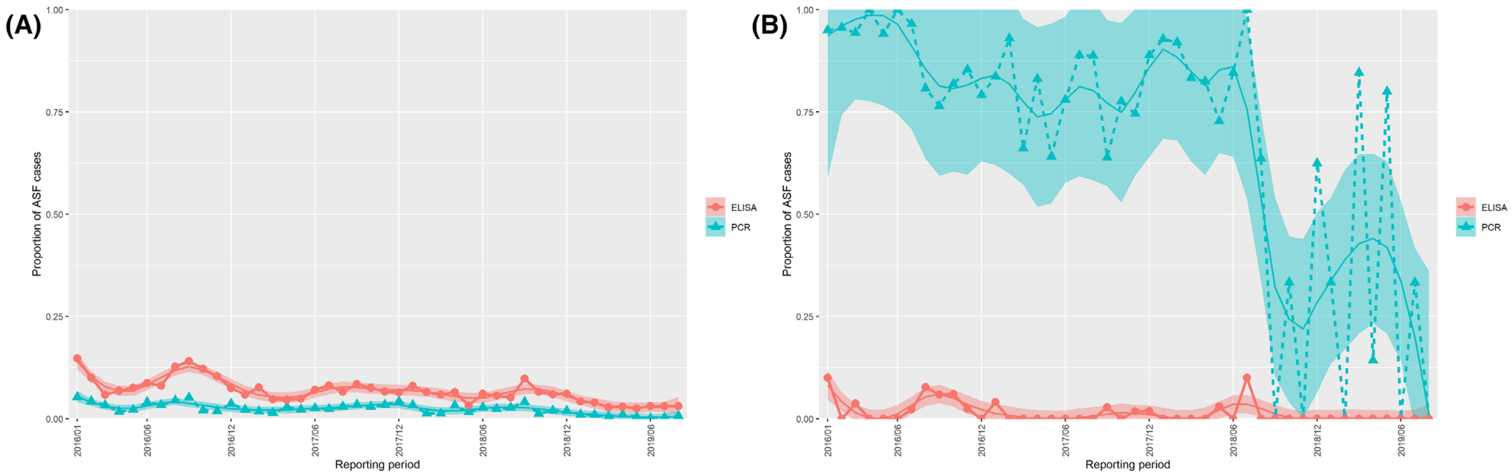


Figure 16: Proportion of ASFV-positive samples (by Ab-ELISA and PCR) over the tested samples from all hunted wild boar (A) and from wild boar found dead (B) in the ASF-affected areas of Latvia (1 January 2016 to 31 August 2019)

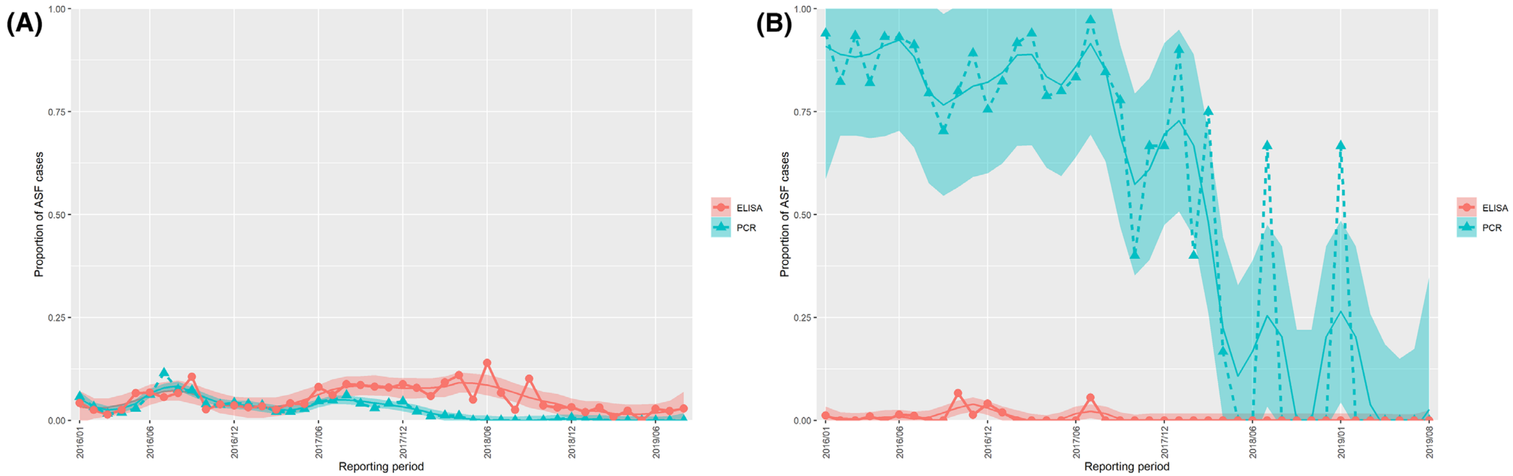
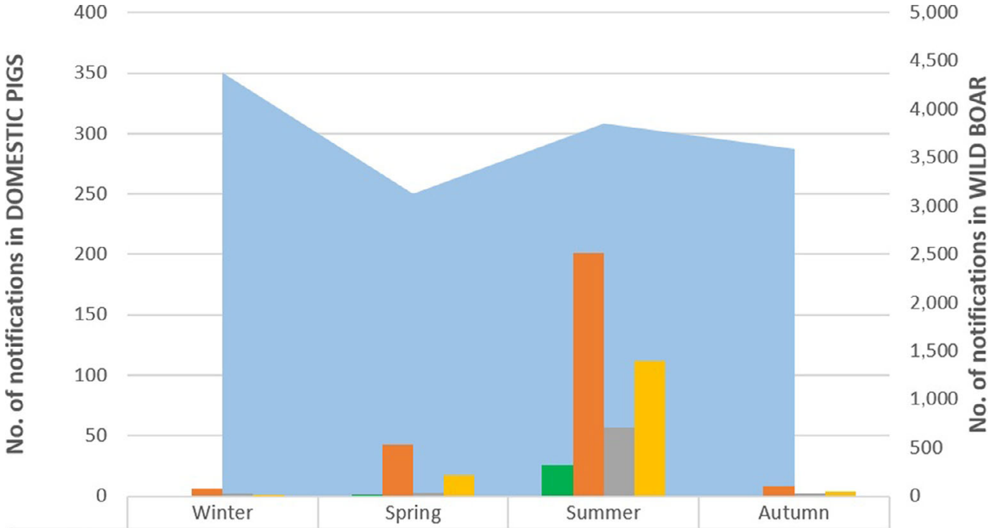


Figure 17: Proportion of ASFV-positive samples (by Ab-ELISA and PCR) over the tested samples from all hunted wild boar (A) and from wild boar found dead (B) in the ASF-affected areas of Estonia (1 January 2016 to 31 August 2019)

4.1.2.2. Seasonality

Figure 18 shows the seasonal distribution of ADNS notifications from the Baltic countries and Poland from the first introduction in 2014 through to 31 August 2019. In wild boar, incidence is highest in winter, with a peak also in summer, and lowest in spring. In domestic pigs, only a summer peak is evident from the notified outbreaks in these countries.



	Winter	Spring	Summer	Autumn
Wild boar	4,379	3,130	3,851	3,590
Estonia	0	1	26	0
Poland	6	43	201	8
Latvia	2	3	57	2
Lithuania	1	17	112	4

Figure 18: Seasonal distribution of ADNS notifications in domestic pigs from the Baltic countries and Poland from 2014 to 2019 and the accumulative outbreaks in wild boar for the same period of time

Figure 19 illustrates the same information for the last 2 years in Romania. Similar patterns were observed: a peak in summer for both wild boar cases and domestic pigs outbreaks, although different epidemiological processes are assumed due to the comparatively high proportion of notifications in wild boar in the Baltic States and Poland and, inversely, a high proportion of notifications in domestic pigs in Romania.

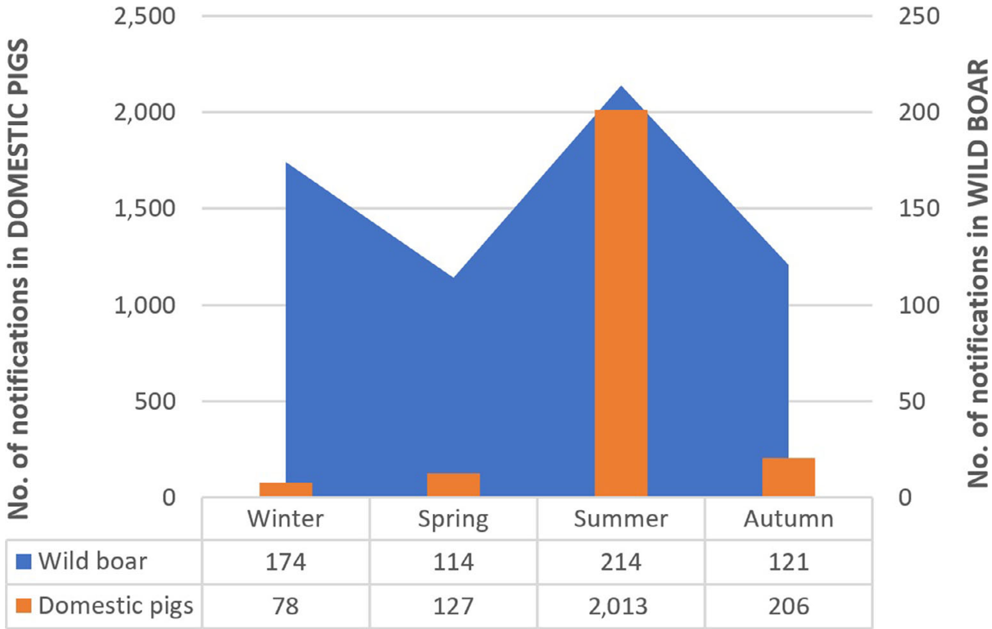


Figure 19: Seasonal distribution of ADNS notifications in wild boar and domestic pigs from Romania since introduction in July 2017 to August 2019

Figures 20–26 shows the proportion of wild boar found dead or hunted in the Baltic countries, Poland, Czechia, Hungary and Belgium that were positive compared with those tested for ASFV. Seasonal patterns were not consistent across these countries. An apparent summer peak in the proportion of positive samples among wild boar found dead was observed in Latvia and Estonia, but not in the other countries. Belgium and Hungary appeared to show a drop in wild boars found dead in summer. For hunted wild boar, seasonal fluctuations in the proportion of animals found positive were less pronounced over the year but appeared to be lower during spring in the Baltic countries, and higher in late summer and winter. In the other countries, this pattern is not visible. Broader confidence intervals for Belgium, Czechia and Hungary can be explained by the shorter period that wild boar have been infected, and so there are less data behind the analysis.

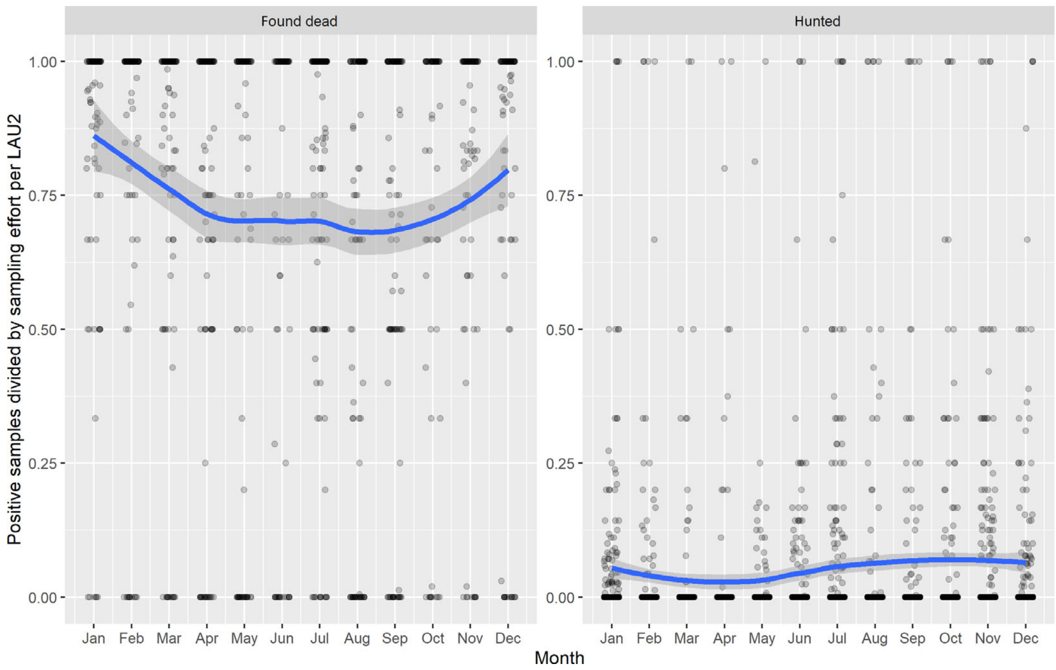


Figure 20: Proportion of wild boar testing positive for ASF (PCR) in Lithuania by calendar month, for animals found dead (left) or hunted (right) in Lithuania

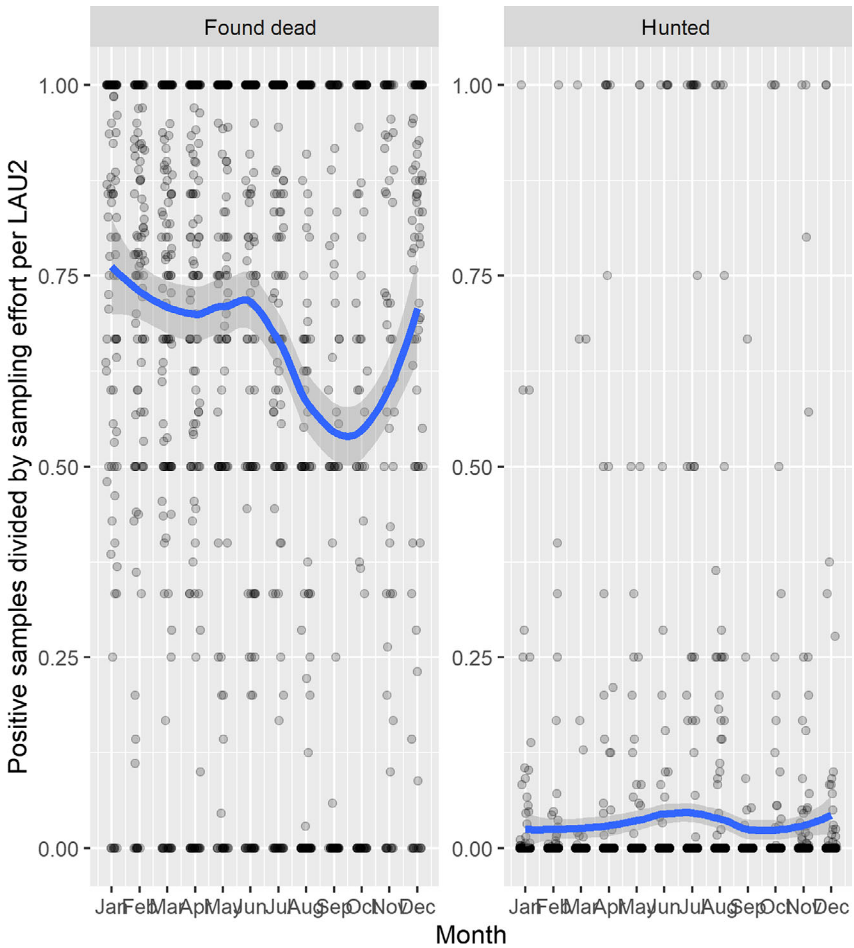


Figure 21: Proportion of wild boar testing positive for ASF (PCR) in Poland by calendar month for animals found dead (left) or hunted (right) in Poland

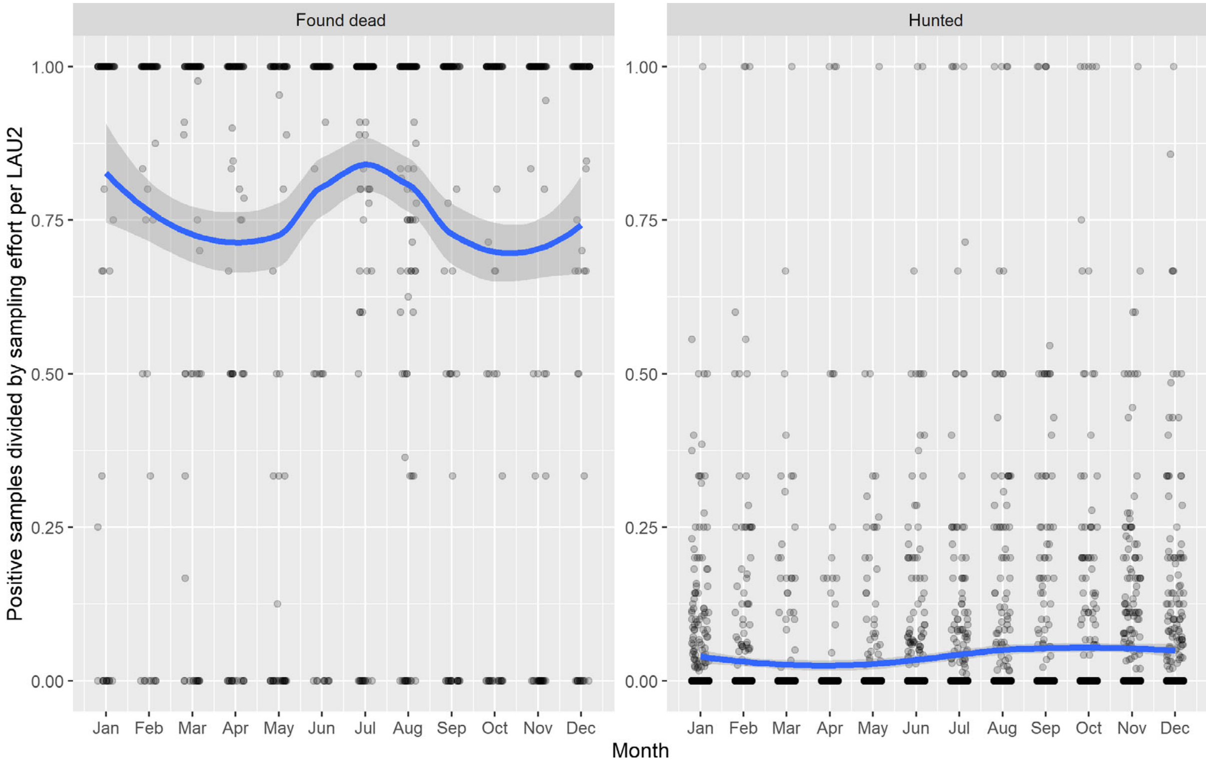


Figure 22: Proportion of wild boar testing positive for ASF (PCR) in Latvia by calendar month for animals found dead (left) or hunted (right) in Latvia

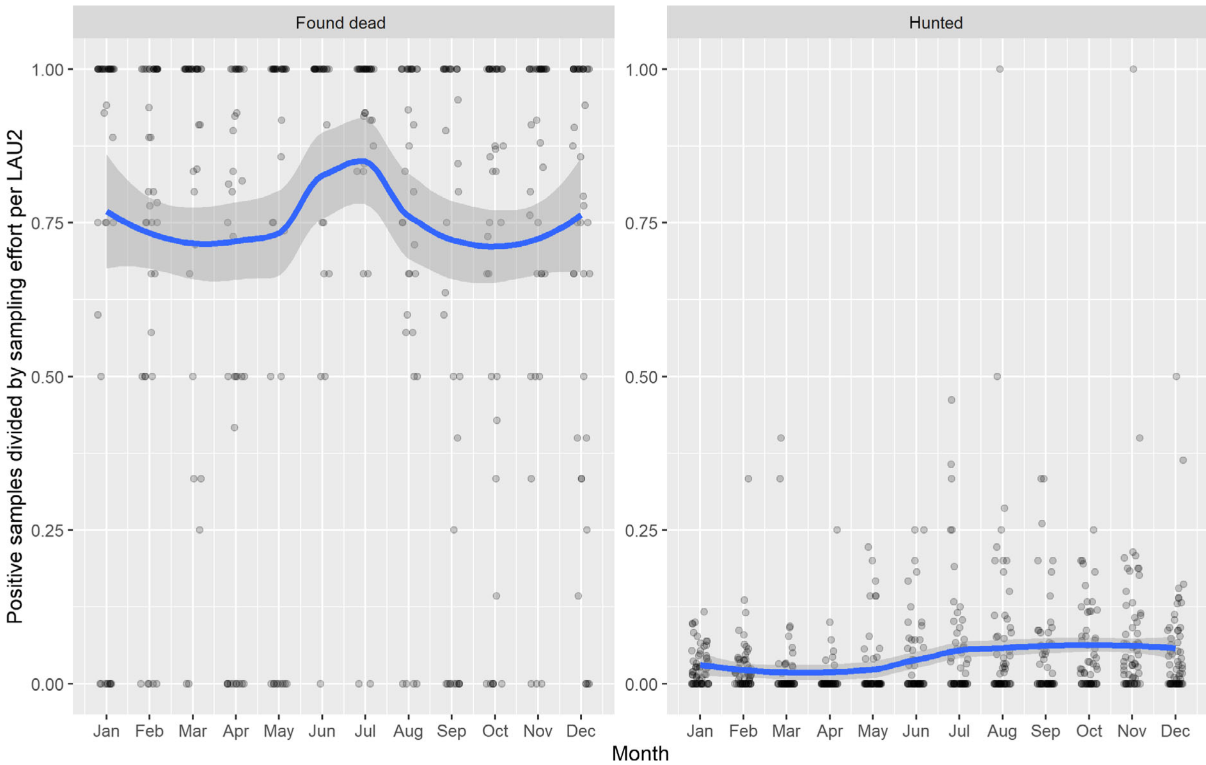


Figure 23: Proportion of wild boar testing positive for ASF (PCR) in Estonia by calendar month, for animals found dead (left) or hunted (right) in Estonia

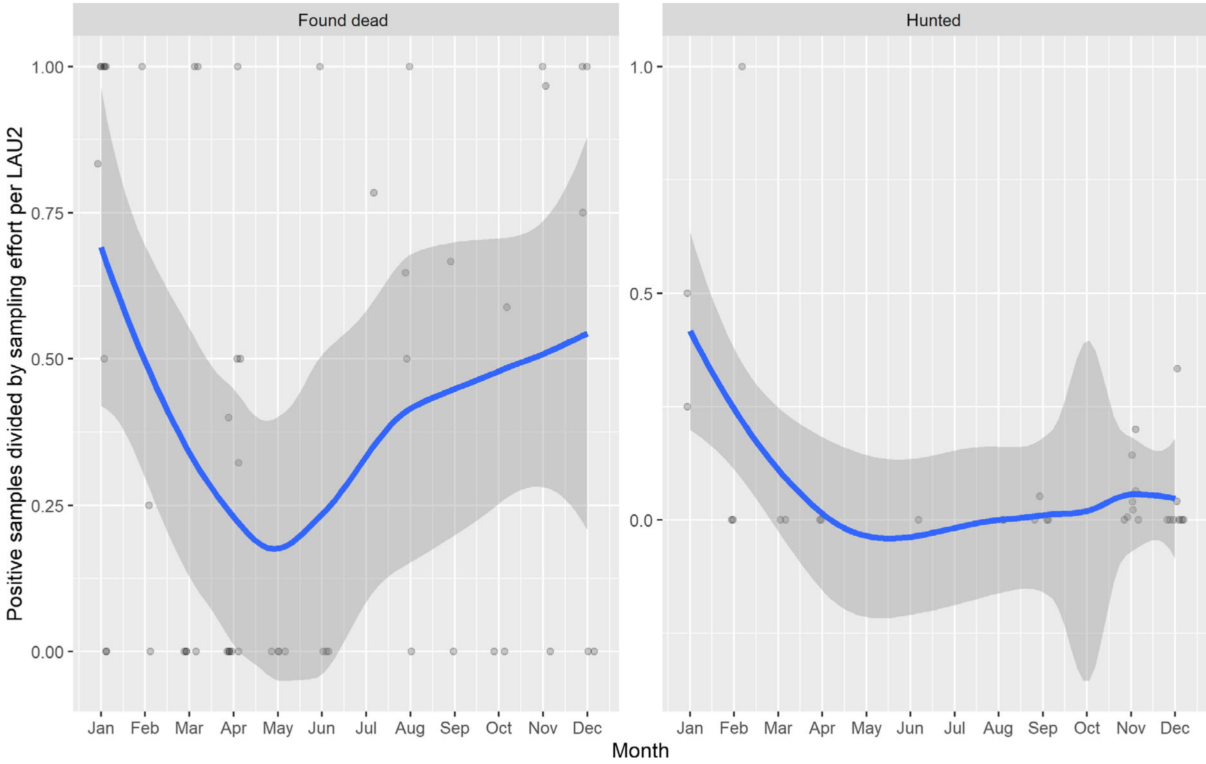


Figure 24: Proportion of wild boar testing positive for ASF (PCR) Czechia by calendar month, for animals found dead (left) or hunted (right) in Czechia

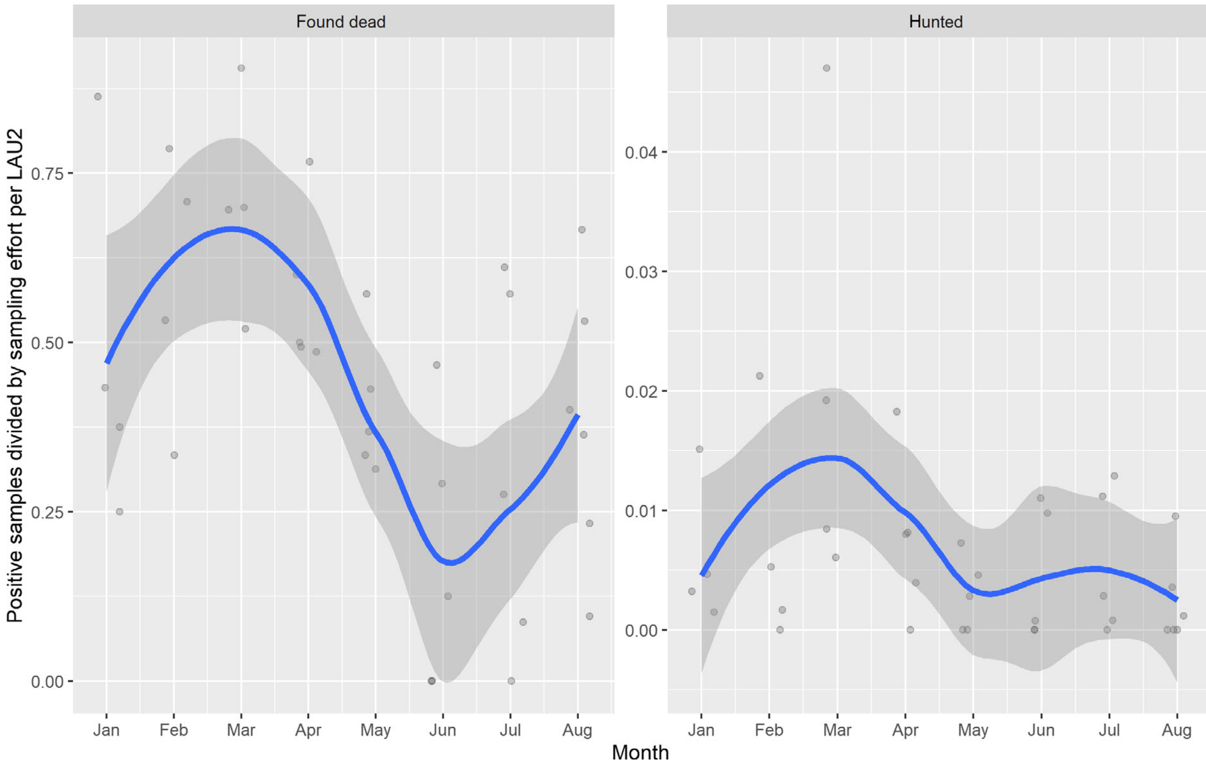


Figure 25: Proportion of wild boar testing positive for ASF (PCR) in Hungary by calendar month, for animals found dead (left) or hunted (right) in Hungary

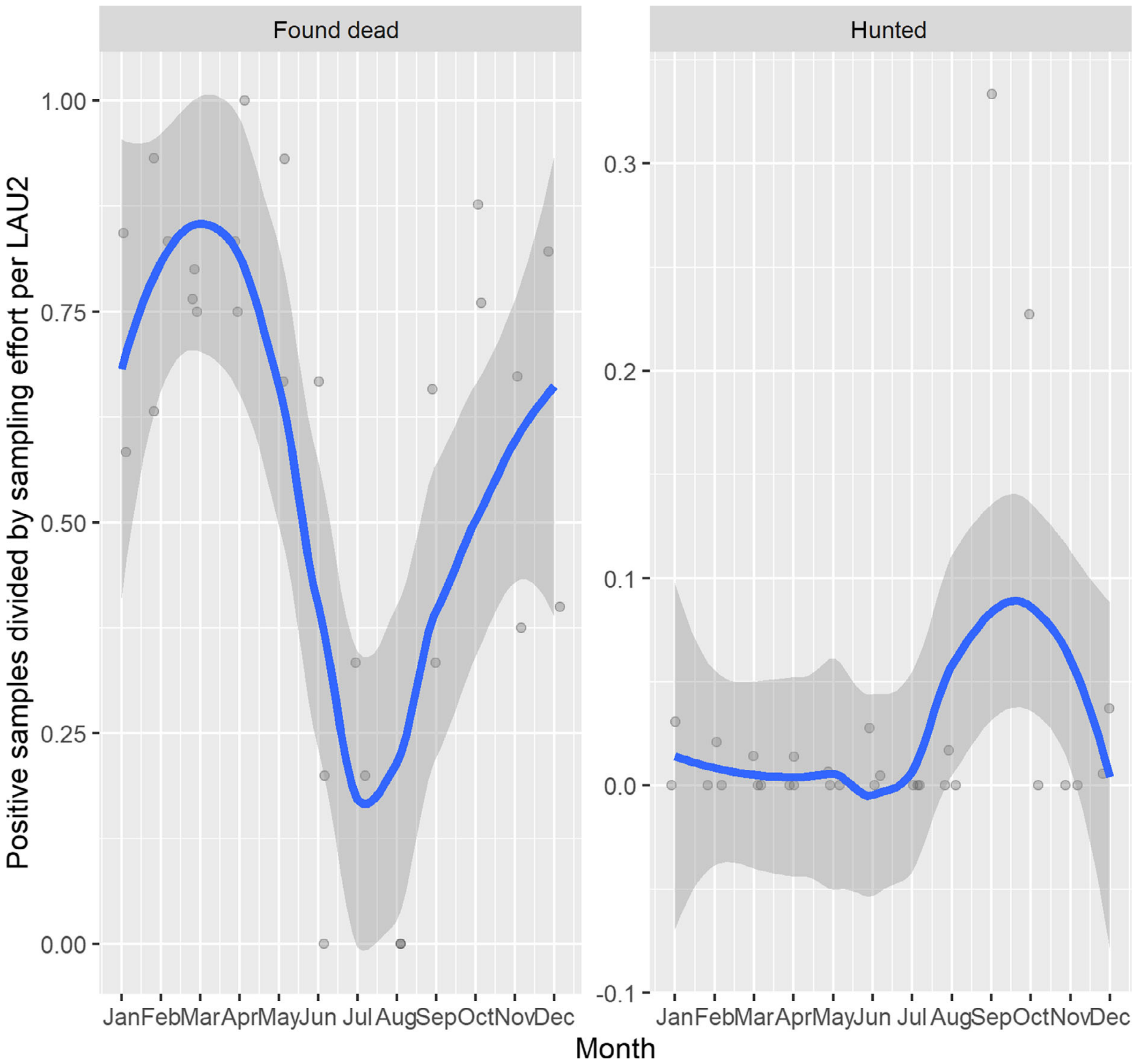


Figure 26: Proportion of wild boar testing positive for ASF (PCR) in Belgium by calendar month, for animals found dead (left) or hunted (right) in Belgium

Figures 27–33 show the results of the Tukey's pairwise comparison of incidence between each pair of seasons using a generalised linear mixed model. Winter is defined as December, January and February, spring as March, April and May, summer as June, July and August and autumn as September, October and November. Seasonal differences were observed in each country, indicating that the probability of ASF occurrence in wild boar, either found dead or hunted, is not equally observed across the year.

There could be several explanations for the seasonal fluctuations of ASF incidence in wild boar.

This could be potentially be related to several driving forces, related to the virus, the wild boar ecology, hunting practices, carcass search intensity, climatic conditions, the pig farming husbandry, to the possible involvement of arthropod vectors or to human behaviour.

In addition, it should be cautioned that the results could change according to the choice of monthly grouping that comprise each season. Furthermore, although there were no major differences of the hunting efforts within and across the years for the different countries (EFSA, 2018) and there was no change in hunting policy reported this period, the intensity of the search of carcasses could vary across the seasons in different countries. In Belgium, for instance, carcass search intensity was slowed down in summer and detection was more difficult due to high vegetation.

Taking this into consideration, the different carcass search intensity over the year could have influenced the seasonality observed in the total numbers of wild boar cases found dead (Figures 18 and 19) and the comparison of seasonal incidence in wild boar found dead (Figures 28A–33A). However, Figures 20–26 illustrate the proportions of positive samples that should not be influenced by the sampling effort.

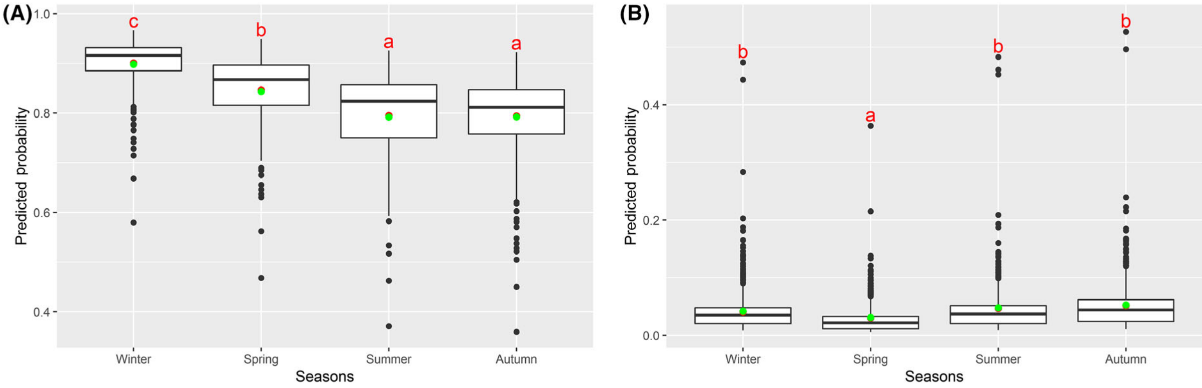


Figure 27: Seasonal incidence of ASF cases (PCR positive) reported in Lithuania using a generalised linear mixed model for (A) wild boar found dead and (B) hunted wild boar. Seasons with different letters (a, b, etc.) were significantly different

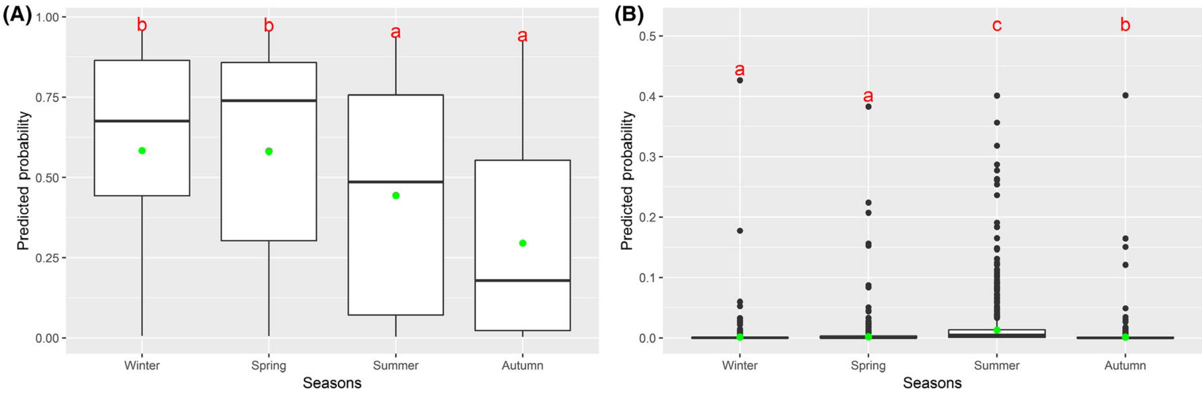


Figure 28: Seasonal incidence of ASF cases (PCR positive) reported in Poland using a generalised linear mixed model for (A) wild boar found dead and (B) hunted wild boar. Seasons with different letters (a, b, etc.) were significantly different

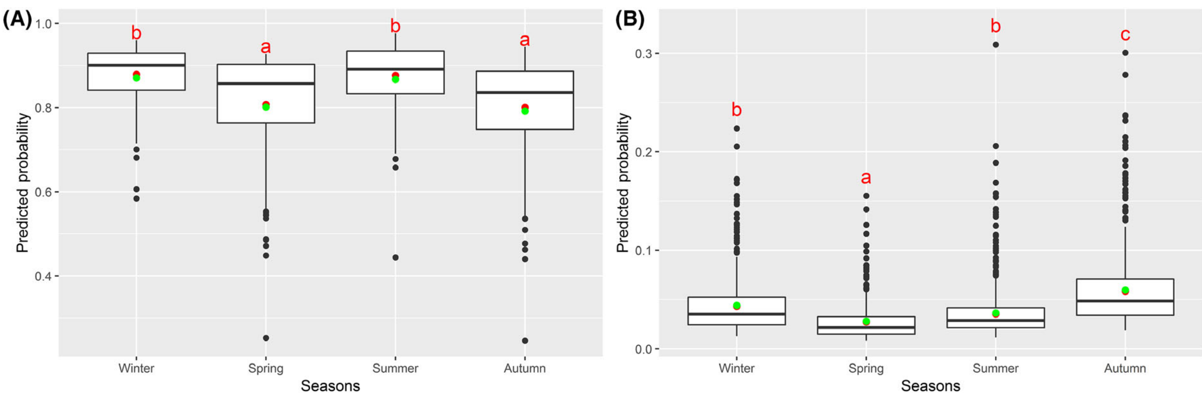


Figure 29: Seasonal incidence of ASF cases (PCR positive) reported in Latvia using a generalised linear mixed model for (A) wild boar found dead and (B) hunted wild boar. Seasons with different letters (a, b, etc.) were significantly different

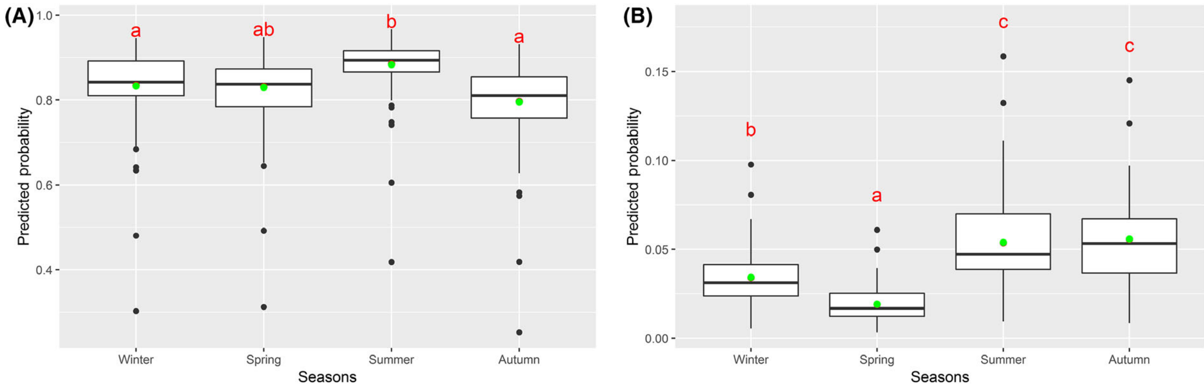


Figure 30: Seasonal incidence of ASF cases (PCR positive) reported in Estonia using a generalised linear mixed model for (A) wild boar found dead and (B) hunted wild boar. Seasons with different letters (a, b, etc.) were significantly different

Hungary and Belgium did not report the days of detection in the DCF and, to produce the analysis, all samples were assumed to have been taken on the first day of the month for which they were tested. In addition, as the lowest administrative units of the areas where the samples were collected did not report, the sample area at the NUTS 3 level was used instead to aggregate the information at spatial level.

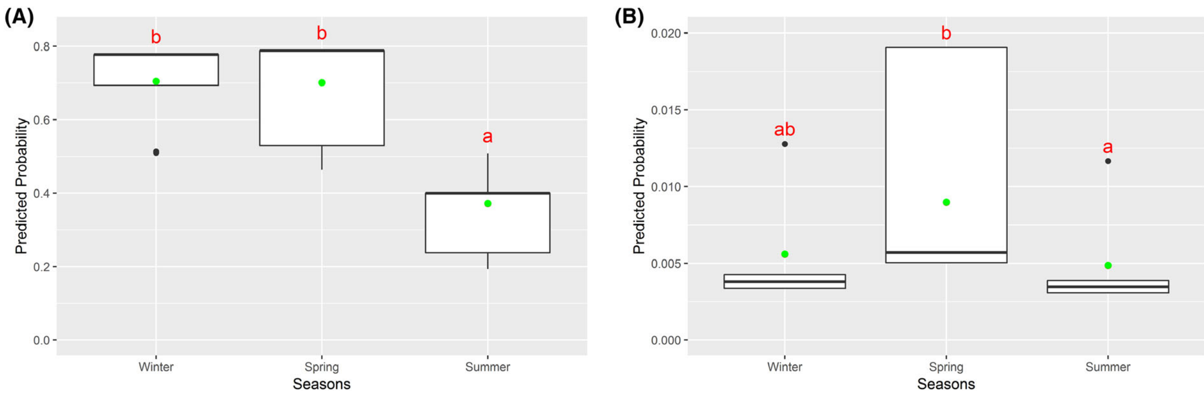


Figure 31: Seasonal incidence of ASF cases (PCR positive) reported in Hungary using a generalised linear mixed model for (A) wild boar found dead and (B) hunted wild boar. Seasons with different letters (a, b, etc.) indicate significant ($p < 0.05$) differences by Tukey's comparison test

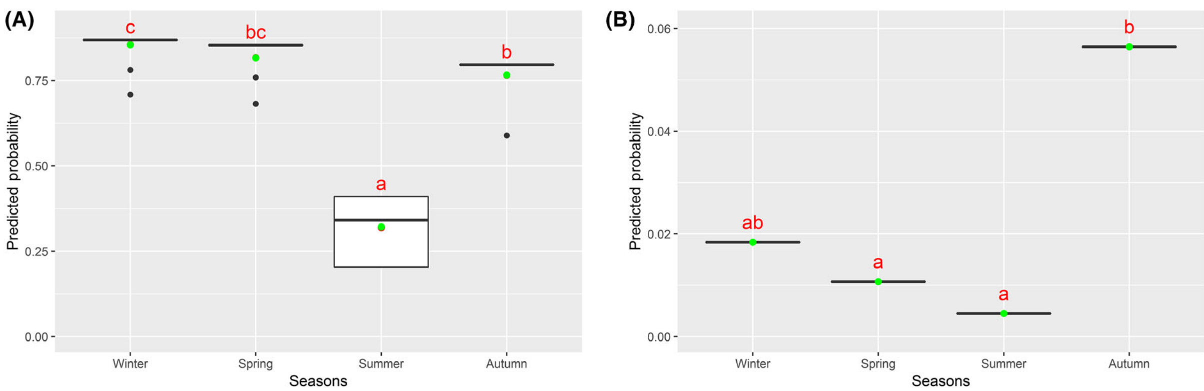


Figure 32: Seasonal incidence of ASF cases reported in Belgium using a generalised linear mixed model for (A) wild boar found dead and (B) hunted wild boar. Seasons with different letters (a, b, etc.) were significantly different

Slovakia and Czechia only reported three and 18 findings for hunted wild boar in the DCF, respectively, and Slovakia reported only one finding of wild boar found dead in the DCF. Therefore the analysis of seasonality of the ASF incidence was not meaningful for these countries for these findings. However, the results of wild boar found dead in Czechia are shown in Figure 33.

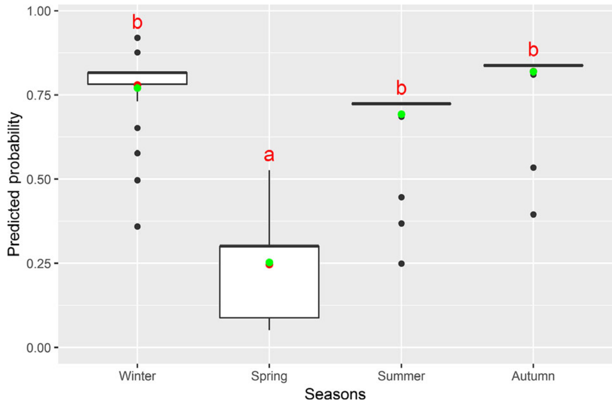


Figure 33: Seasonal incidence of ASF cases reported in Czechia using a generalised linear mixed model and Tukey's pairwise comparison for wild boar found dead. Seasons with different letters (a, b, etc.) were significantly different

4.1.2.3. Speed of natural propagation estimated with network analysis

Figure 34 presents an example of a network linking ASF cases in wild boar in Estonia, using ADNS notification data and based on a minimum distance between consecutive cases. This network assumes that one case is causing the next case in time that is closest in distance to it. This network approach was used to approximate the range of velocity of natural spread of the infection in wild boar in the affected region. This approach results in a distribution of the observed speed of propagation. The interquartile range is presented along with the median and the mean excluding extreme events. However, larger distances between outbreaks are possible.

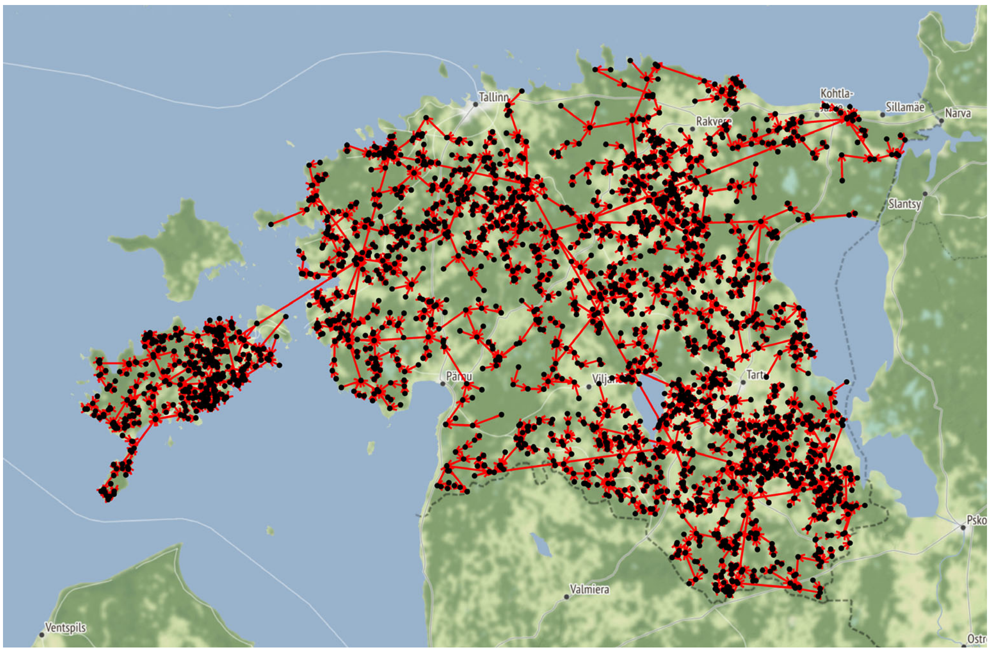


Figure 34: Network representation of ASF outbreaks in Estonia based on nearest distance

A further network was constructed (not displayed by figures) based on the assumption of at least 7 days elapsing between cases. Furthermore, network pairs were also created based on minimum distance between the cases. The outcomes of the different methods were compared and are shown in

Table 11. The 25, 50 and 75 percentiles of the speed of propagation are provided, as well as the mean speed after excluding the most extreme 10% of the speed (which could be considered as spread through human intervention). The median velocity of the infection in Belgium, Czechia, Estonia, Hungary, Latvia, Lithuania and Poland, as estimated with network analysis, was between 2.9 and 11.7 km/year.

The number of ASF cases in Bulgaria, Slovakia and Ukraine has been limited compared with other affected countries. Therefore, available estimates of the speed of propagation in these countries were not reliable.

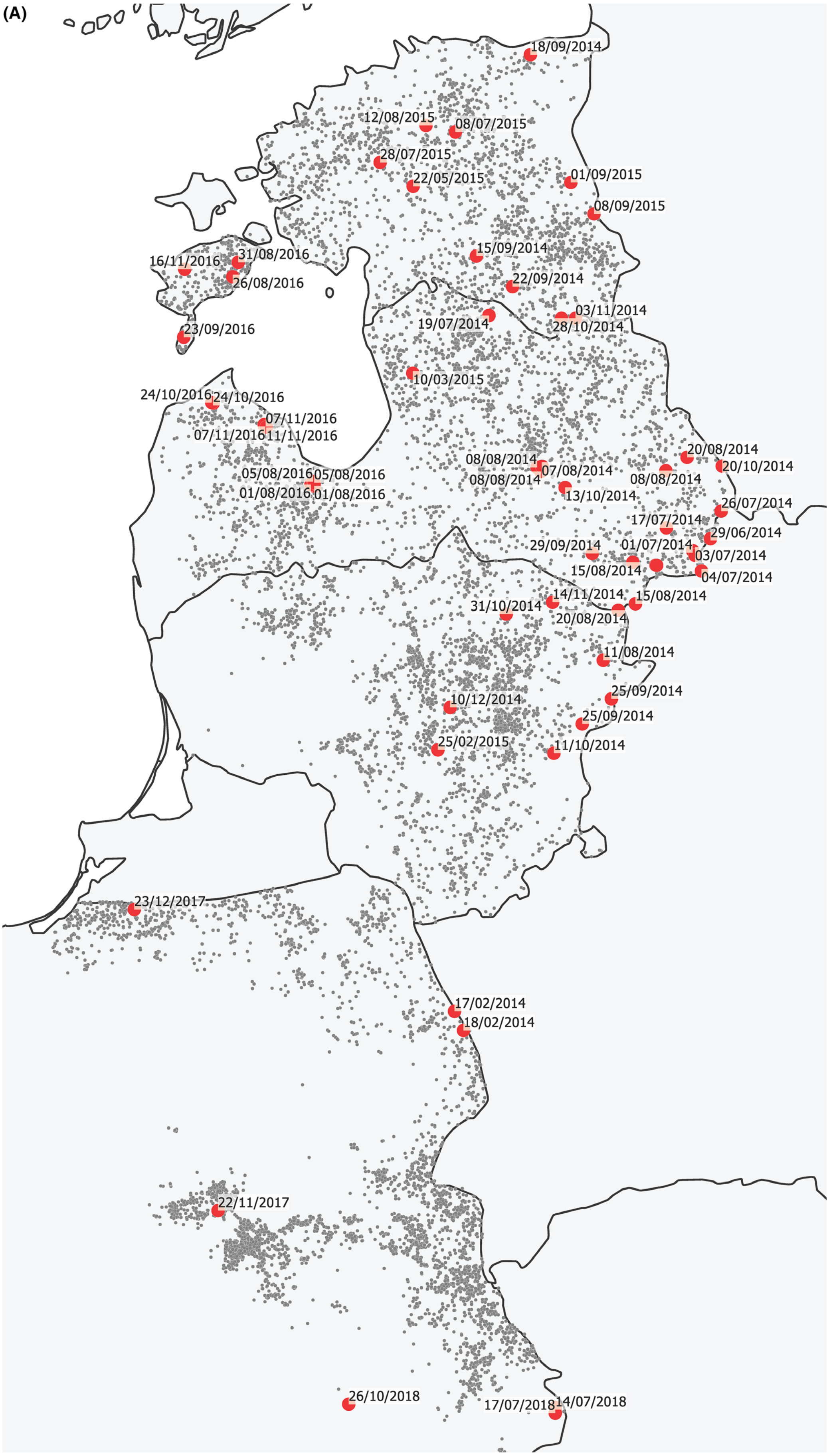
Table 11: Speed of propagation (km/year) of ASF infection in wild boar population assuming a different time–distance combination between the paired cases in network analysis

Country	Numbers of cases reported to ADNS	Time	Speed of propagation (km/year)			Mean(excluding extreme)
			P25	Median	P75	
Belgium	642	Closest	2.4	7.8	25.1	12.1
		> 7 days	2.3	5.7	15	8
Czechia	230	Closest	1.3	5	11.7	6.6
		> 7 days	0.7	2.9	6.6	3.4
Estonia	2,745	Closest	2.3	7.1	25.4	13.2
		> 7 days	2.2	6.3	19.1	9.9
Hungary	1,174	Closest	3.5	11.7	38.4	21.1
		> 7 days	3.2	8.6	24.1	13.1
Latvia	3,639	Closest	1.7	5	19.4	9.9
		> 7 days	1.6	4.5	15.3	7.8
Poland	5,080	Closest	2.9	9.1	31.1	16.1
		> 7 days	2.6	7.7	22.9	11.5
Lithuania	3,596	Closest	2.5	8.1	26.7	14.2
		> 7 days	2.3	6.9	19.9	10.5
Romania	671	Closest	9.3	31.4	120.3	64
		> 7 days	7.6	25	87.8	43.6

4.1.2.4. Human-mediated spread

ADNS notifications are ordered according to the distance and velocity to possible parent notification. Exceptional notifications (1%) are coloured in Figure 36, whereas all other notifications are plotted in grey. The highlighted notifications are related to presumably human-mediated translocation of the virus beyond the biological capacity of wild boar movement velocity. Interestingly, the procedure identifies a substantial number of confirmed human-mediated translocations.

(A)


18/09/2014
12/08/2015
08/07/2015
28/07/2015
22/05/2015
01/09/2015
08/09/2015
15/09/2014
22/09/2014
16/11/2016
31/08/2016
26/08/2016
03/11/2014
28/10/2014
19/07/2014
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10/12/2014
25/09/2014
25/02/2015
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17/07/2018
14/07/2018

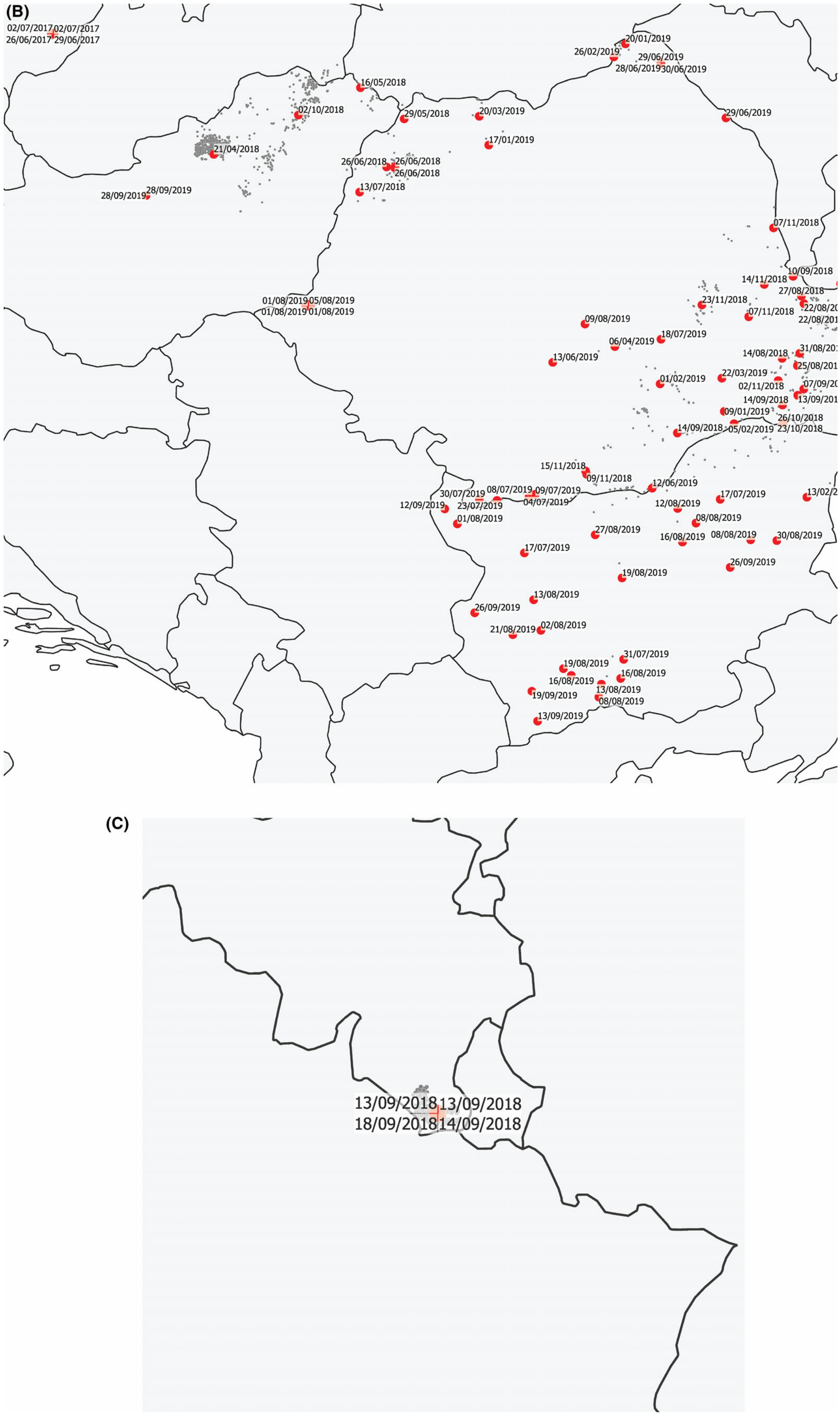


Figure 35: Presumably human-made translocations of ASF across the EU

The red dots highlight the notifications for which distance and/or velocity to older notifications is beyond the 99 percentiles of the distribution of this value for all notifications. The map is shown by three segments to support readability; however, calculations did consider all 17.922 notifications for the entire area altogether. The red dots indicate notifications incompatible with direct transmission between wild boar or indirect transmission between wild boars and infected carcasses and these cases are presumably are caused by human-mediated translocation of the infection. Whether the highlighted notifications itself represent the translocated infection, or one which was secondary to an unreported translocation nearby, cannot be derived from the map.

In combination with the per se human-mediated spread of ASFV into wild boar of CZ Figure 35A; (controlled since 2019), Belgium (Figure 35C) and western Poland (November 2019 not yet on the map), the red dots underpin why human-mediated translocations appears to be the most important factor contributing to the spread of ASF into and within wild boar populations. The distribution of red dots, i.e. presumably human-mediated dislocations of the virus, differ between regions of Figure 35A and 35B. In the Baltic States (Figure 35A), red dots form an irregular pattern across the map. Contrary, the map of southern MS (Figure 35B) shows more regularly spaced and well distributed pattern of red dots. The latter implies that, repeatedly, wild boar notifications due to distant human-mediated translocations are followed by local perpetuation in wildlife. Hypothetic under-reporting does not explain the observation due to the clear separation between the wild boar notifications before those depicted by red dots.

4.2. Risk factor analysis – TOR2 and TOR6

4.2.1. Risk factors of ASF occurrence in wild boar in Estonia (TOR 2)

A risk factor analysis of ASF in wild boar was performed using the Bayesian hierarchical model described in Section 2.2.2. Several non-significant (α = 0.05) risk factors that did not contribute to the model were eliminated from the model, such as average quality of available habitat of wild boar, average yearly snow depth, average yearly minimum temperature, the number of wild boar hunted per hunting ground); and risk factors related to hunting activity and wild boar management (i.e. density of hunters/km^2, density of hunting dogs/km^2, density of feeding/baiting places/km^2, density of hunted wild boar/km^2).

The Bayesian hierarchical model determined the density of pigs in small holdings (Pg SDNS) per LAU 2 as the only significant risk factor (Table 12). The results indicate that the probability of observing an ASFV-positive wild boar increases by 18.17 for each unit increased in the density of pigs in small holdings per LAU 2 (animals in small holdings/km^2). This could be because higher densities of pigs in small farms were located in the regions for which the estimated probability to be affected by ASF was higher, indicating a potential relationship. This does not imply a direct link between infections observed in wild boar populations and infections in small farms. Furthermore, the analysis was based on data from pig holdings in Estonia over the years 2014–2019 and is highly influenced by the conditions of the domestic pig sector in 2014.

Table 12: Parameter estimates and 95% confidence intervals, median and mode of the posterior distributions in the Bayesian hierarchical model

Parameters	Mean	Standard deviation	Lower 95% CI	Median	Upper 95% CI	Mode	Significant
(Intercept, baseline year 2014)	–3.05	0.63	–4.37	–3.02	–1.91	–2.96	Yes
2015	2.86	0.58	1.74	2.79	4.03	2.74	Yes
2016	4.97	0.72	3.65	4.94	6.46	4.88	Yes
2017	2.83	0.65	1.62	2.80	4.21	2.75	Yes
2018	1.76	0.67	0.51	1.73	3.15	1.68	Yes
2019	0.24	0.81	–1.34	0.24	1.84	0.23	No
PgSDNS	18.17	5.54	7.68	18.04	29.42	17.78	Yes

Figure 36 demonstrates an increased probability of ASF occurrence in wild boar during the first 2 years (2014–2016) followed by a progressive drop up to 2019 in Estonia.

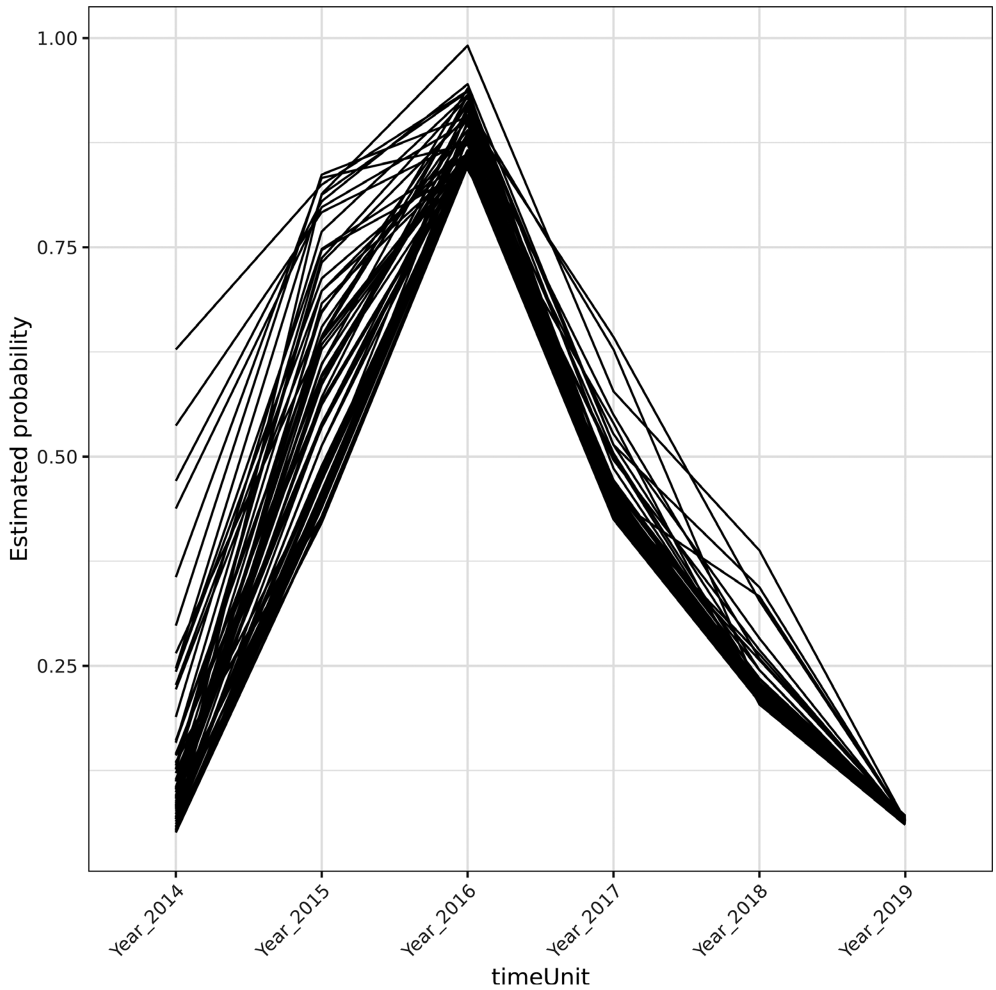


Figure 36: Temporal estimated probabilities for each LAU 2 region showing the probability of observing African swine fever cases in Estonia for each year since introduction.

The spatial predictions (Figure 37) indicate the same increase over time in the probability of ASF detection in Estonian wild boar for all LAU 2 regions up to 2016, followed by a progressive decrease from 2018 to a non-existence in 2019.

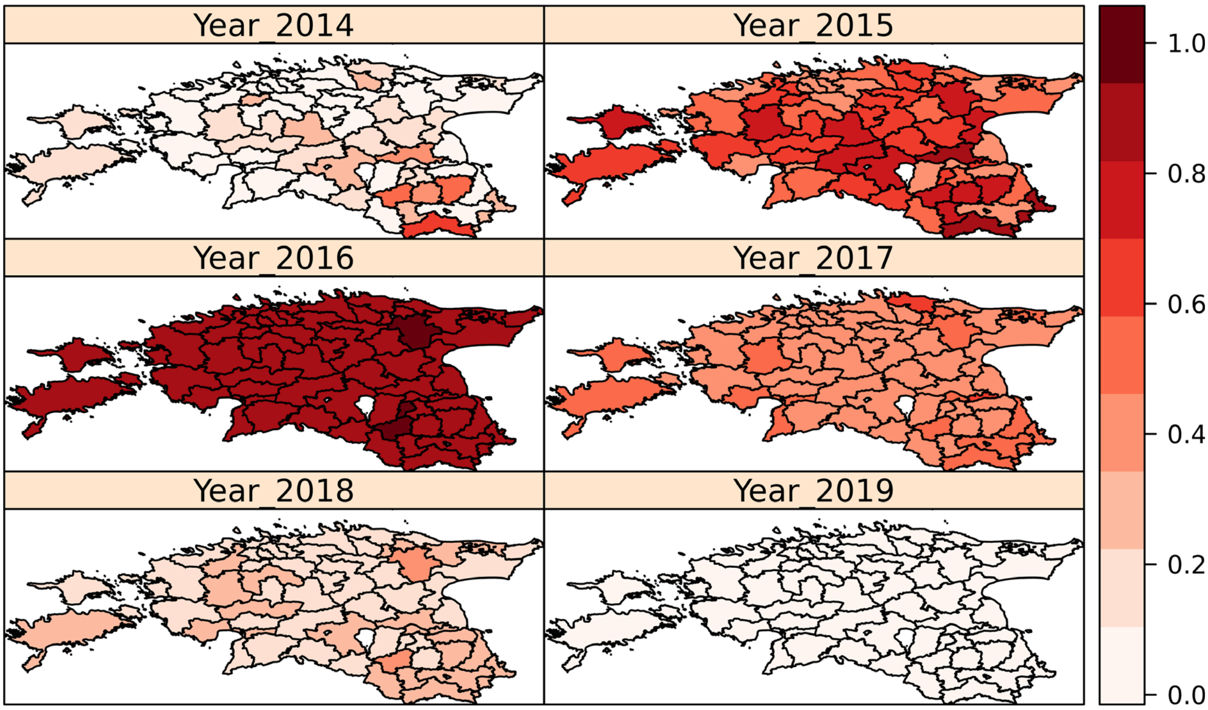


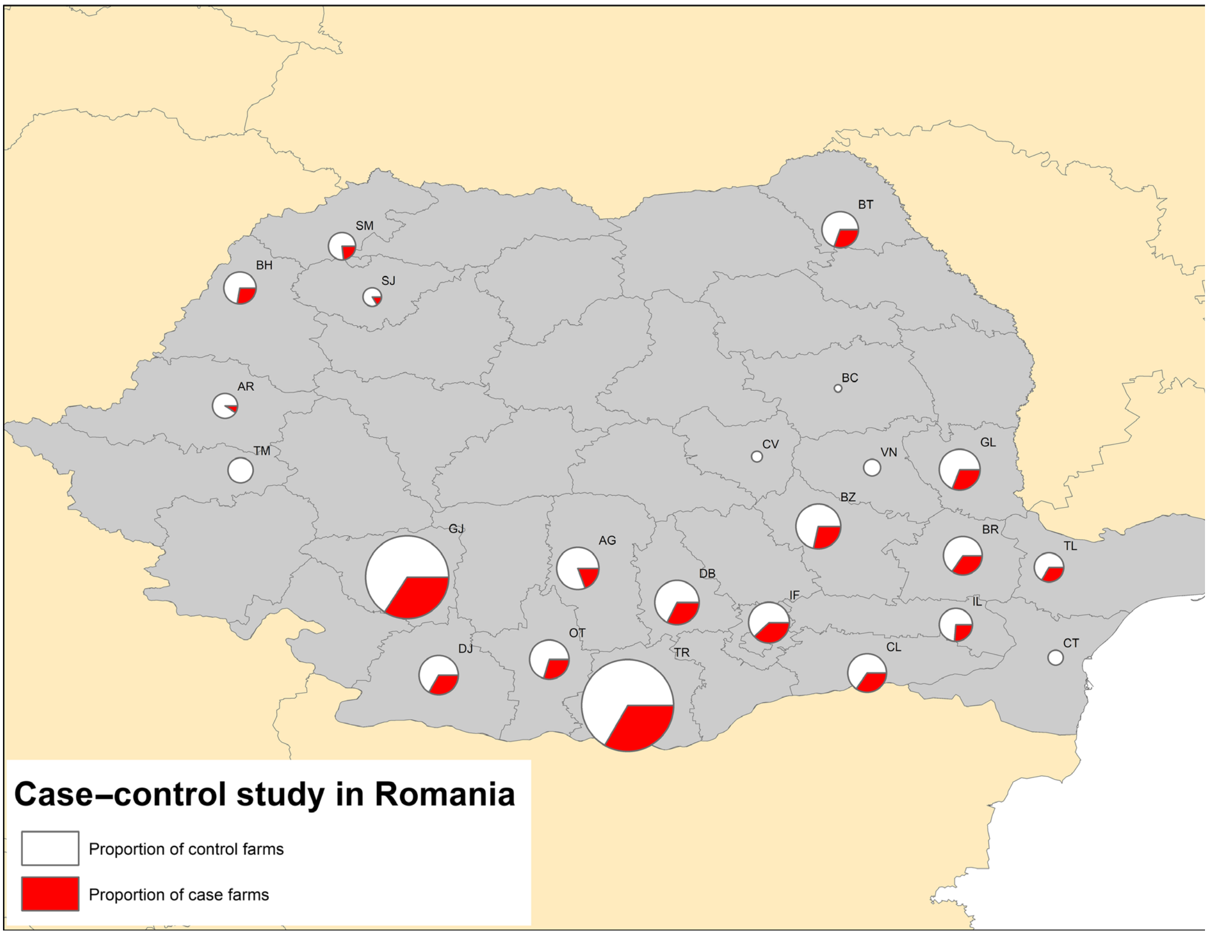
Figure 37: Spatial predictions for each LAU 2 region in Estonia of probabilities of observing African swine fever for each year since introduction

The same results and temporal trends confirming existence of significant relationships in time and space between wild boar with positive test result and small holding pig densities were observed after backward eliminations of non-significant potential risk factors in the General Additive Model (GAM) statistical model.

4.2.2. Risk factors of ASF occurrence domestic pigs (TOR6)

4.2.2.1. Case–control study Romania

In total, 199 cases were included in the study, including nine Type A and 13 commercial farms. Additionally, 460 farms were included as controls, including 32 Type A farms and 74 commercials. Control farms were located in all 23 included counties (Figure 38), while some counties (AR, BC, CT, CV, TM and VN) did not have any outbreaks in the period and were therefore not included with cases in the study.



TR = Teleorman, CL = Călăraşi, DJ = Dolj, CT = Constanţa, TL = Tulcea, BR = Brăila, IL = Ialomiţa, IF = Ilfov, VN = Vrancea, GL = Galaţi, BR = Brăila, BZ = Buzău, CV = Covasna, BC = Bacău, BT = Botoşani, SM = Satu Mare, SJ = Sălaj, AR = Arad, TM = Timiş, DB = Dâmboviţa, GJ = Gorj, OT = Olt, AG = Argeş.

Figure 38: The proportions between outbreak and control in a case–control study in Romania. The size of the pie chart indicates the number of farms included in the study

The number of cases in each county varied from 3 to 49, with a median of eight. Especially Giurgiu (GR) and Teleorman (TR) had many outbreaks, and had therefore 31 and 49 cases included, respectively. In all other counties, the maximum number of included cases was 10. Six control farms were diagnosed with ASF less than 28 days after being interviewed as controls. These farms were therefore interviewed (again) as case farms, and excluded as controls, as it could not be excluded that the farms might have already been infected at the time of the first interview.

Table 13 presents the results of the final logistic regression model in non-commercial farms. The logarithm of the number of pigs on the farm (herd size), the wild boar density in the hunting ground in which the farm was located and the numbers of professional visitors in the HRP were included as a significant risk factors, while the distance to the nearest case detected in wild boar and in domestic farms were protective factors, i.e. the longer distance to the nearest outbreak, the lower the risk of ASF occurrence.

Furthermore, the numbers of outbreaks in domestic pigs within a radius of 2 km of the holding was a significant risk factor. Also, the number of visits by professionals (e.g. by private veterinarians, consultants, workers for infrastructural maintenance) in the HRP visits was significantly related to the ASF occurrence. Finally, if forage from areas affected by ASF was used on the farm, or if attractive crops were cultivated around the farms, the risk of ASF occurrence in the farm was higher. The use of straw as bedding material, in contrast, had apparently a protective effect. Table B.1 in Appendix B shows all the covariates that were included in the analysis at the start of the model building, and their definitions. Table 14 shows the distribution of the categorical covariates that stayed in the final logistic regression model in non-commercial farms, for both farm types.

Table 13: Odds ratios with 95% confidence intervals and p values obtained from logistic regression analysis for Romanian non-commercial farms (n = 531)

	Baseline	OR	CI	p value	
Ln(HerdSize)		28.18	7.21–110.2	1.58e-06	***
WBdensity		5.036	1.36–18.6	0.0153	*
Ln(nearWB)		0.222	0.079–0.629	0.00459	**
Ln(nearDB)		0.613	0.379–0.992	0.0464	*
DB2		4.601	1–34–15.8	0.0155	*
Professional visits in HRP		6.93	3.08–15.6	2.8e-06	***
Attractive crops	Yes	9.092	1.85–44.8	0.00665	**
	No	1	–	–	
Origin of forage	ASF+	19.1	3.52–103.7	0.00063	***
	ASF–	0.627	0.195–2.02	0.455	
	No forage	1	–	–	
Bedding	Straw	0.135	0.0378–0.485	0.00212	**
	NoStraw	1	–	–	

For the commercial farms in Romania there was only one significant risk factor (p = 0.0004) in the final logistic regression model, namely the distance to the nearest outbreak, with an OR of 0.18 (0.07–0.47). ASF occurrence decreases with increased distance to the nearest outbreak in a commercial domestic pig farm. It should be noted that for the analysis of risk factors for ASF occurrence in commercial farms most, but not all, of the 53 variables tested for non-commercial farms were tested, as some variables had the same replies for all surveys in commercial farms. This implies that there will be no effect on the risk for ASF occurrence in the farm (see Appendix A).

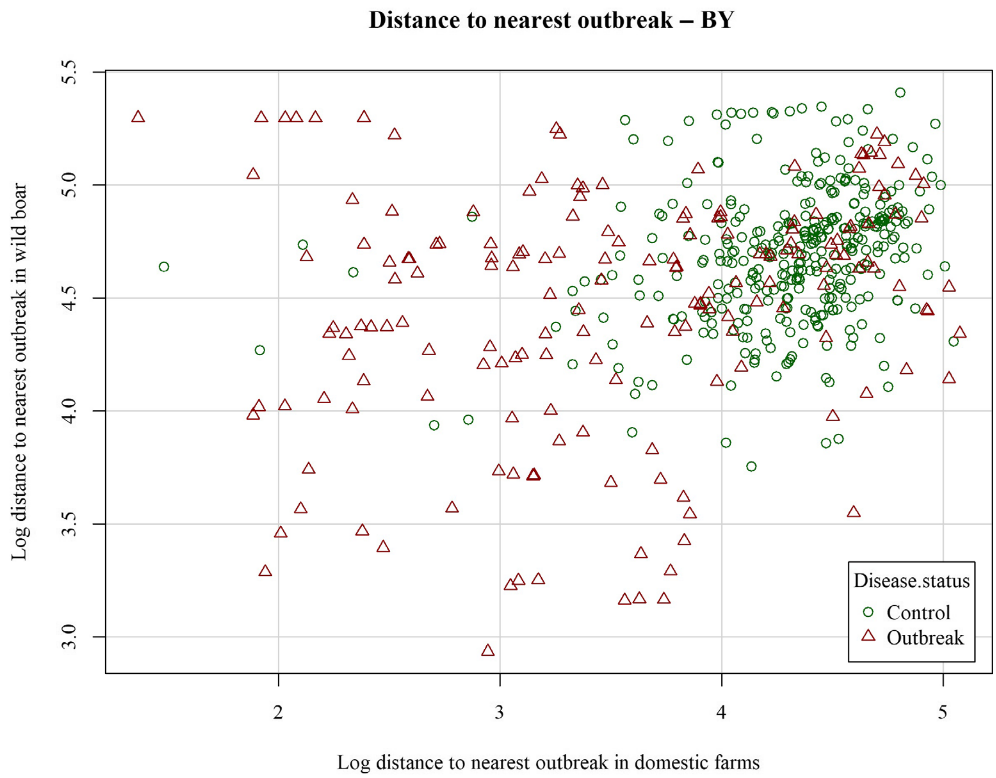


Figure 39: Distance (log_{10} in metres) to the nearest outbreak in domestic farms, as a function of distance to nearest outbreak in wild boar for non-commercial farms that were enrolled in the Romanian study

Generally, control farms were located at longer distances from outbreaks in domestic farms as well as in wild boar, as can be seen by the location of the green circles in the upper right corner of

Figure 39. In contrast, the distance between case farms and outbreaks in domestic pigs or wild boar were often, but not always, shorter, as can be seen by the even spread of the red triangles in Figure 39.

Table 14: Descriptive statistics for those covariates that were statistically significant in the logistic regression model for ASF risk in non-commercial farms

		Commercial farms		Non-commercial farms	
		Case	**Control**	**Case**	**Control**
Pigs introduced in HRP	Yes	4	29	4	1
	No	19	73	173	352
Attractive crops around the farm	Yes	8	55	21	13
	No	15	47	156	340
Origin of forage	From ASF+	0	0	47	23
	From ASF–	5	6	46	142
	No	18	96	84	188
Bedding	Straw	2	10	47	137
	No straw*	21	92	130	216
Total		22	103	177	353

4.3. Review wild boar management measures for controlling the spread of ASF – TOR3

4.3.1. Model

See EFSA (2018, chapter 3.3) for model outputs reviewing wild boar management options controlling the spread of ASF. No contradicting evidence has subsequently emerged and, therefore, the conclusions and recommendations are still valid.

4.3.2. Literature review

In 2018, EFSA carried out an extensive literature review to study the efficacy of different methods to reduce wild boar population densities to control ASF spread. The detailed outcomes of that review can be found in the Scientific Opinion (EFSA AHAW Panel, 2018, Chapter 3.3.2)

In the literature, *Sus scrofa* are called 'wild boar' in the areas where they are native and 'feral pigs' in the areas where they are invasive. Generally, control efforts to reduce feral pigs have been more rigorously implemented than those to control wild boar, often with a differing legal background and differing public attitude.

4.3.2.1. Hunting

- Recreational hunting

The extensive literature review in 2018 (EFSA, 2018) concluded that recreational hunting of wild boar and feral pigs can be effective as a mean to maintain population stability, however biased hunting preferences towards large males and feeding of wild boar should be avoided. Hunting efforts should be increased in intensity (harvest rate > 67% per year) to stabilise wild boar populations (Bonet-Arboli et al., 2000; Monzon and Bento, 2004).

In this update of the 2018 review, two additional primary studies were found. The first one (Giacomelli et al., 2018) suggested that delegating the responsibility for wild boar management to the local community contributes to wild boar control. The second one, Vajas and coauthors (2020), modelled the effect of different hunting procedures on wild boar hunting efficiency. They concluded that the proportion of wild boar hunted of those present could be improved by changing the characteristics of the hunting effort. In particular, they found that more posted hunters, larger hunted areas and hunts carried out in the early season would increase hunting efficiency and found that more posted hunters, larger hunted areas and hunts carried out in the early season would increase hunting efficiency.

- Hunting to depopulate

Urgent interventions for disease control (i.e. locally implemented emergency measures) are different from, and should not be confused with, long-term management at a larger scale associated with sustainable population management. In the context of disease control, the extensive literature review in 2018 (EFSA, 2018) concluded that depopulation of wild boar has been achieved in small, fenced estates. In larger areas, however, not more than 50% of population reduction was reported. In areas of high habitat quality, the maintenance over a prolonged period of time of intense measures for wild boar population control is expensive and possibly not sustainable in the long term (Leranoz and Castien, 1996; Boadella et al., 2012a; Garcia-Jimenez et al., 2013).

In addition, a large group of experts made the point that large-scale culling strategies should include population monitoring that could evaluate its effectiveness and should be combined with feeding bans and limiting wild boar access to agricultural crops (Vicente et al., 2019). An intensive reduction of the wild boar population density before ASF emergence might help to control the disease in case of an introduction (Schulz et al., 2019b).

Eradication of isolated feral pig populations has occasionally been achieved through intense drive hunting with dogs conducted over a number of years, with or without the use of other methods such as trapping or shooting from helicopters (Katahira et al., 1993). This was confirmed in the recent review by Engeman et al. (2019).

Drastic reduction (up to 80%) of feral pigs populations has been reported with control programmes in which pig hunting is conducted from a helicopter or through a combination of trapping and intense drive hunting with dogs (Saunders, 1993b; Davis et al., 2018). Rapid recovery of the population has been reported, up to 77% the year following these interventions (Saunders, 1993a). Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however, was not prevented (Barron et al., 2011).

These conclusions from primary studies found in the extensive reviews in 2018 and 2019 are in line with previous comments from Bengsen et al. (2014) who stated that when populations are reduced below local environmental carrying capacity, compensatory population growth can be expected through increased fecundity or reduced mortality in survivors and their progeny. When densities are held well below carrying capacity, compensatory growth is unrestricted and therefore likely to reach the maximum rate of annual increase (e.g. 0.6–0.78 in Australia).

4.3.2.2. Traps

The review in 2018 (EFSA AHAW Panel, 2018) concluded that the use of traps resulted in a harvest of up to 79% of the wild boar population (Hafeez et al., 2007; Alexandrov et al., 2011), offering potential in areas where hunting is not recommended. The update of the review in 2019 found one additional study looking at the efficiency of trapping wild boar to reduce population density (Gaskamp et al., 2018). Removal and intensive trapping were suggested as effective measures to decrease the wild boar population. Intensive control, however, would be needed to achieve long-term reduction in wild pig numbers because wild pigs have high reproductive rates, high survival and can recolonise areas rapidly.

4.3.2.3. Immune contraceptive

The review in 2018 (EFSA AHAW Panel, 2018) concluded that the parenteral use of a GnRH immunocontraceptive vaccine has been demonstrated to reduce the fertility of feral pigs kept under experimental conditions (Killian et al., 2006). Research is needed, however, to investigate the presence of potential residues of GnRH in meat, and the potential of oral vaccine delivery in a selective manner to avoid non-target species. No new studies were found related to this topic in the update of the review in 2019.

4.3.2.4. Culling with toxic substances

The review in 2018 (EFSA AHAW Panel, 2018) noted that poisoning of wild boar is forbidden in the EU under biodiversity conservation legislation. However, poisoning of feral pigs has been shown to be a highly efficient method to reduce local populations (Anderson and Stone, 1993; Cowled et al., 2006; Snow et al., 2017). Two additional studies confirmed these results during the update of the review in 2019 (Poche et al., 2018; Snow et al., 2019).

The potential undesirable effects of poisoning have not been sufficiently investigated in the European context, including welfare concerns on the administration of the poison and the possible effects of residues on the health of humans and animals through direct or indirect exposure.

4.4. Robustness and effectiveness of the different types of geographical artificial or natural boundaries used for the determination/ demarcation of the restricted areas – TOR4

4.4.1. Model

In 2018, a spatiotemporally explicit individual-based model approach was used (see http://ecoepi.eu/ASFWB; Lange et al., 2018) to improve the conceptual understanding of the impact of natural barriers on the spread of ASF in wild boar populations (EFSA, 2018, chapter 3.4). The model simulated the continental spread of ASF in wild boar habitat in the Baltic countries. Based on the comparison of model outputs and the present ADNS data with the reported cases in wild boar, it was not possible to demonstrate an effect of natural barriers (e.g. roads, rivers) on ASF spread. However, there was anecdotal evidence from the field (e.g. Estonian islands remaining free of infection, due to the straits separating mainland and the islands), demonstrating the temporarily hampering effect of rivers or straits, suggesting that these can be used for demarcation for restricted areas as they have shown to reduce, but not completely impede, the movements of wild boar.

4.4.2. Literature review

In 2018, EFSA carried out an extensive literature review to study the efficacy of different methods to separate wild boar and feral pig populations. The detailed outcomes of that review can be found in the Scientific Opinion (EFSA AHAW Panel, 2018, chapter 3.3.2).

4.4.2.1. Fencing

EFSA's Scientific Opinion (EFSA, 2018) concluded that some fences were found to temporarily protect crops from damage caused by wild boar or feral pigs, but with different levels of efficiency. The fence type, size of the fenced areas, as well as the duration of the experiments were important factors influencing the efficiency. For instance, an efficiency of 100% crop protection was reported for small test sites (Schmidt, 1986; Vidrih and Trdan, 2008) but, controversially, also 0% efficiency was reported for large fenced areas to reduce crop damage (Jeyasingh and Davidar, 2003). Most studies, however, reported a positive protective effect on crops of fences, somewhere between these two extremes. It was concluded that no electrical fence design can be considered to be 100% wild boar proof on a large scale for a prolonged period of time.

In this update of the review, carried out up to September 2019, three additional studies reported a positive effect of fences to keep out wild boar (Sreeja and Mani, 2017; Kopler and Malkinson, 2018) or feral pigs (Negus et al., 2019) from fenced areas. The latter study shows that fence efficacy for the intended purpose (wild boar exclusion) requires ongoing and effective fence monitoring and maintenance regimes.

4.4.2.2. Odour repellents

The extensive review carried out in 2018 investigated the use of odour repellents for wild boar control (EFSA AHAW Panel, 2018, Chapter 3.3.2). The Scientific Opinion in 2018 reported on several studies looking into odour repellents to exclude wild boar and feral pigs from crops, but with divergent results. Some studies reported a positive effect of odour repellents to exclude wild boar (Wegorek and Giebel, 2008; Sakthivel Rao et al., 2013; Bil et al., 2018) and others showed no, or a very weak, effect of odour repellents (Piechowski, 1996; Schlageter and Haag-Wackernagel, 2012a; Wegorek et al., 2014).

During this update (to September 2019), only two additional relevant published papers were found. One paper (Vasudeva Rao et al., 2017) reported the positive effect of castor crops as an odour repellent to protect crops from wild boar. However, the odour study tested two commercial odour repellents, one of these allegedly wild boar specific, that failed to protect simulated tortoise nests against wild boar predation (Vilardell et al., 2008).

4.4.2.3. Light and sound repellents

During the review carried out in 2018 (EFSA AHAW Panel, 2018, chapter 3.3.2), light and sound repellents were included in the review to evaluate their possible effectiveness for separating wild boar. The use of light repellents did not show any significant effect on the probability of wild boar visiting luring sites according to two studies (Dakpa et al., 2009; Schlageter and Haag-Wackernagel, 2011), whereas sound repellents were reported to reduce 67% of crop damage caused by wild boar according to one study (Dakpa et al., 2009). No new papers were retrieved during this update of the review.

4.4.3. Field experience

4.4.3.1. Field experience with fencing in Czechia

No update, but refer to EFSA (2018) for model outputs to evaluate control measures related to fencing in Czechia

4.4.3.2. Field experience with fencing in Belgium

Three types of measures have been taken to slow or even stop the centrifugal spread of the virus. The first was to ban, over the entire affected area, activities likely to cause the movement of wild boar: hunting, feeding, logging and forest circulation of tourists and youth organisations. The second consisted in implementing measures to cull wild boar on the periphery of the infected zone (reinforced observation area and vigilance area) with the aim of creating a stamping out area. The third was to build, as the disease extended centrifugally, a network of concentric fences, always trying to have a fence-in-advance on the virus.

Approximately 300 km of fences have been installed since the first incursion of ASF in Belgium (September 2018). Whenever possible, the fences were installed along national roads to facilitate regular inspection. It is an unburied fence, metallic, 120 cm high and whose mesh size is about 15 cm × 20 cm. The fences are not fixed into the ground. The posts are spaced 3–4 m apart and are lined with reinforcements and barbed wire. If the posts were not robustly buried enough were consolidated with additional posts spaced less 3–4 m apart.

Source: M Herman and A Licoppe, by permission.

Figure 40: A typical fence section

The fence is regularly interrupted at the level of villages and hamlets crossings (Figure 40). A major challenge was to equip all private and logging roads with barriers that were both solid and easily mobilised and to urge the population to keep them closed as much as possible (Figure 41). Sometimes, when it was not possible to build a fence, repellents were put in place.

The white poster on the tree in the background recalls the instructions to follow when entering the affected area.
Source: M Herman and A Licoppe, by permission.

Figure 41: Example of closing a logging road by a barrier

The network of fences built in Belgium was directly connected to fences set up by France and the Grand-Duchy of Luxembourg to complete the initiative on their side of the border. Soon after the first fences were put in place, it became clear that regular inspections and repairs were crucial. On average, fences were inspected/repaired once a week, except near the densest infected boar areas where they were inspected/repaired daily.

The following zones were defined:

- The **core area,** as the polygon that encompassed all locations where an ASFV-positive wild boar had been found. It thus corresponded to the present 'infected area'. This polygon was gradually enlarged each time a positive animal was detected outside the perimeter. Within this core area, the goal was twofold: (i) to avoid incoming and outgoing movements of wild boars as much as possible; and (ii) to proceed to their total destruction. To minimise animal movements, the area was fenced as completely as possible, if necessary facilitating its centrifugal extension. Logging, feeding and recreational hunting were prohibited. Quasi-complete depopulation was achieved first by letting the virus circulate for a few months, then by implementing a series of, culling methods (traps, night-shots, single hunting on baiting points) with as little disturbance as possible. Over the whole period, the search and removal of dead animals was constant, intensive and risk oriented. All found-dead and culled animals were tested for the presence of the ASFV virus before being transported to a rendering plant. Control measures in the core area were carried out under the supervision of the regional authorities.
- The **reinforced observation area** (called buffer zone in Czechia) was roughly ring-shaped; it surrounded the core area and its width is approximately equivalent to the wild boar home range over a year. The animals that lived there were presumed to be vironegative but the risk of them being infected is high, as only an (imperfectly tight) fence separated these from the infected animals. Here, the goal is to mitigate the centrifugal spread of the virus by totally eliminating wild boars and avoid a recolonisation of the area from the peripheral territories (stamping out). The destruction policy consisted of combining the action of hunters and forest rangers. Quantitative destruction objectives were assigned to hunters. Driven hunts were allowed, including the use of small dogs. All other means were simultaneously implemented by forest rangers: traps, night shooting and hunting from hides. Logging and recreational activities were allowed, but not wild boar feeding. The search and removal of dead animals was carried out by random, repeated surveys. All found-dead and culled animals were packed, tested and rendered. In this zone, concentric fences were built to anticipate a possible spatial extension of the infected polygon, the objective being to have at least a fence ahead of the virus.

- The **vigilance area** was roughly ring-shaped too, it was the most eccentric area in which anti-ASFV operations are conducted. Here, the usual forestry activities were allowed, including recreational hunting. Feeding wild boar remained prohibited. The goal was to move towards a total depopulation. The same control measures were implemented as in the previous zone. The aforementioned fencing policy was implemented here too. All found-dead and about 20% of the hunted wild boars were tested for the presence of the virus. No hunted animals were marketed.

After a year of experience, it was clear that the fences installed played a key role: (i) in curbing/stopping the spread of the virus; and (ii) in promoting the destruction of wild boar. When one examines visually the spatial distribution of the density of the viro-positive cadavers collected during the first 11 months of the crisis and although a specialised statistical analysis is still in progress, one perceives very clearly the mitigating effect exercised by fences on the spread of the virus, especially in the south-west of the infected zone (see video https://youtu.be/z-yORL1k7xw). Conversely, the installation of fences facilitated the mobilisation of hunters for the destruction of wild boar in the reinforced observation area and vigilance area. The presence of the fences was perceived as a guarantee against spontaneous repopulation after the efforts of destruction. As the human factor is essential to manage a crisis of this nature, this unexpected effect of the fences on the perception of the merits of the efforts required has proven to be very favourable for the management of the crisis.

5. Conclusions

5.1. Update of ASF situation in the EU – TOR1

During the last 12 months, Slovakia was added to the list of affected countries, whereas Czechia was recognised as officially ASF free in March 2019. ASF is present in each of the non-member countries on the eastern border of the EU, except Turkey. New introductions from these non-MSs can be suspected.

ASF was confirmed in Serbia in July 2019.

During the last 12 months, there has been further progressive geographical expansion of the ASF-affected area. All ASF-affected areas are essentially contiguous, except for isolated introductions in Czechia (now resolved), western Poland and Belgium.

Within the EU, all phases of the ASF epidemic are now represented, including non-affected areas, areas recently affected either following an isolated introduction or following geographic expansion of infected areas, affected areas that are progressively expanding, and areas where ASF infection has been present in most/all of the territory for a relatively short or for a longer period of time.

In Estonia, Latvia and Lithuania, there has been an interval of approximately 5 years from initial infection through to endemicity. Wild boar density is now very low (e.g. estimated between 0 and 0.1 wild boar/km^2 in Estonia, see Section 2.2.1), an estimated 3.2% of hunted animals are seropositive, and PCR-positive animals are relatively rare. In some areas in the Baltic countries, it is unclear whether ASFV is still present.

The extent of the ASF situation varies substantially between EU MSs, due to multiple influences including the nature of domestic pig production (in particular, the proportion of backyard holdings), geographic considerations (including topography, natural barriers), characteristics of the wild boar population (density etc.).

ASF eradication has been achieved on several occasions following isolated introduction, successfully in Czechia and potentially also in Belgium.

Backyard farms present particular challenges in an ASF eradication programme, including uncontrolled movement, poor biosecurity and the identification of holdings. Human-mediated spread, for example between local villages, has been a feature of the ASF epidemic in areas where backyard farms are particularly common.

5.2. Descriptive epidemiology – TOR1

5.2.1. Spatiotemporal patterns

5.2.1.1. Proportions of samples testing positive either by PCR or antibody-ELISA since first detection

- The proportion of ASF-positive wild boar has always been higher among found-dead compared with hunted animals, regardless of the testing method.

- In affected areas, the proportion of wild boar testing positive by PCR has always been much higher than the proportions testing positive by ELISA.
- During the observation period (1 January 2016 to 31 August 2019), there has been no increase in the proportion of seropositive (i.e. ELISA positive) samples in hunted wild boar.
- In hunted animals, the proportions of wild boar testing both PCR and ELISA positive has remained low, however some minor seasonal peaks were observed.

5.2.1.2. Seasonality of ASF occurrence

- In wild boar, ASF incidence is highest in winter and summer and lowest in autumn, based on ADNS notifications from the Baltic countries and Poland. In domestic pigs, only a summer peak is evident from the notified outbreaks in these countries.
- An apparent summer peak in the proportion of positive among wild boar found dead was observed in Latvia and Estonia, but not in other countries.
- For hunted wild boar, seasonal fluctuations in the proportion of animals found positive were less pronounced over the year but appeared to be lower during spring in the Baltic countries, and higher in late summer and winter. In other countries, this pattern is not visible.
- The probability of notifying ASF in wild boar, either found dead or hunted, is not equally observed across the year. Although the pattern of seasonal differences was not consistent between countries, ASF occurrence was generally lower in summer and often also autumn, compared with winter and spring.

5.2.1.3. Speed of propagation

- The median velocity of the infection in Belgium, Czechia, Estonia, Hungary, Latvia, Lithuania and Poland, as estimated using the network analysis, was between 2.9 and 11.7 km/year.
- The number of ASF cases in Bulgaria, Slovakia and Ukraine has been limited, therefore available estimates of the speed of propagation need to be interpreted with care.

5.2.1.4. Human-mediated translocations of ASFV

- There is evidence in all affected MSs of human-mediated translocation of ASFV. The most obvious examples of this include the introduction of ASF into Belgium, Czechia and western Poland. Additional human-mediated translocations of ASFV are likely to have been based on the appearance of cases that could not plausibly be associated with transmission between wild boar.
- Based on available evidence, human-mediated translocation of ASFV remains a very important factor contributing to the spread of ASF both into and within wild boar populations.

5.3. Risk factor analysis – TOR2 and TOR6

5.3.1. Risk factors of ASF occurrence in wild boar in Estonia (TOR 2)

- Based on an analysis of data from pig holdings in Estonia during 2014–2019, there was an 18-fold increase in the probability of observing an ASF-positive wild boar for each unit increase in the density of pigs in small holdings per LAU 2 (animals in small holdings/km^2). Similar results were obtained using two different statistical methods. These results were particularly influenced by the conditions of the domestic pig sector in 2014.

5.3.2. Risk factors of ASF occurrence domestic pigs in Romania (case–control (TOR6))

- ASF occurrence in the area around the farm was identified as an important risk factor of ASF occurrence in backyard farms in Romania, based on the results of a case–control study conducted during 2019.
- Key risk factors for ASF occurrence in non-commercial farms included the number of outbreaks within a radius of 2 km of the farm and the distance to the nearest outbreak in domestic herds or the nearest case in wild boar. Herd size, local wild boar density, the numbers of professional visits on the farm, growing attractive crops around the farm, and the feeding of forage harvested in areas with ASF were also identified as significant risk factors. The only significant risk factor for ASF occurrence in commercial herds was distance to nearest domestic pig outbreak.

5.4. Review wild boar management measures for controlling the spread of ASF – TOR3

5.4.1. Model

Conclusions from EFSA et al. (2018) are still valid (not copied here).

5.4.2. Extensive literature review

Conclusions from EFSA (2018) are still valid and copied below, as the extensive review was updated in this reporting period.

In the literature, *Sus scrofa* are called 'wild boar' in areas where they are endemic and 'feral pigs' in areas where they are invasive. Generally, control efforts to reduce feral pigs have been more rigorously implemented than those to control wild boar, often with a differing legal background and differing public attitude.

In non-infected populations, recreational hunting of wild boar and feral pigs can be effective as a means to maintain population stability, however, biased hunting preferences towards large males and feeding of wild boar should be avoided. Hunting efforts should be increased in intensity (harvest rate > 67% per year) to stabilise wild boar populations.

Urgent interventions for disease control (i.e. locally implemented emergency measures) are different from, and should not be confused with, long-term management on a larger scale associated with sustainable population management.

In the context of disease control, depopulation of wild boar has been achieved in small, fenced estates but, in larger areas, not more than 50% of population reduction was reported.

In areas of high habitat quality, the maintenance over a prolonged period of time of intense measures for wild boar population control is expensive and possibly not sustainable over the long term.

Eradication of isolated feral pig populations has occasionally been achieved through intense drive hunting with dogs conducted over a number of years, with or without the use of other methods such as trapping or shooting from helicopters.

Drastic reduction (up to 80%) in the feral pig populations has been reported with control programmes in which pig hunting is conducted from a helicopter or through a combination of trapping and intense drive hunting with dogs. Rapid recovery of the population has been reported, up to 77% the year following these interventions.

The use of traps has resulted in a harvest of up to 79% of the wild boar population, offering potential in areas where hunting is not recommended.

The parenteral use of a GnRH immunocontraceptive vaccine has been demonstrated to reduce the fertility of feral pigs kept under experimental conditions. Research is needed, however, to investigate the presence of potential residues of GnRH in meat, and the potential of oral vaccine delivery in a selective manner to avoid non-target species.

Poisoning of feral pigs has been shown to be a highly efficient method to reduce local populations. In the EU, however, poisoning of wild boar is forbidden under biodiversity conservation legislation. The potential undesirable effects of poisoning have not been sufficiently investigated in the European context, including welfare concerns on the administration of the poison and the possible effects of residues on the health of humans and animals through direct or indirect exposure.

5.5. Review natural/artificial borders – TOR4 for the determination/ demarcation of the restricted areas

5.5.1. Model

Conclusions from EFSA (2018) are still valid (not copied here).

5.5.2. Extensive literature review

Conclusions from EFSA (2018) are still valid and are copied below, as the extensive review was updated in this reporting period.

- Some electrical fences have been demonstrated to temporarily protect crops from damage caused by wild boar or feral pigs with different levels of efficiency, but no electrical fence design can be considered 100% wild boar proof on a large scale for a prolonged period of time. Fences have been shown to be more effective if wild boar are not disturbed by drastic hunting such as drive hunts with dogs, which increase the movement of wild boar and their urge to escape.
- Odour repellents have been tested to keep away wild boar and feral pigs from crops with divergent results.
- Light repellent did not show any significant effect on the probability of wild boar visiting luring sites according to two studies.
- Sound repellents have been reported to reduce 67% of crop damage caused by wild boar according to one study.

5.5.3. Field experience

- So far, the control strategy deployed in the Belgian focal outbreak of ASF in wild boar has proven effective to keep ASFV inside the affected area, avoiding further spread. This strategy included a combination of different measures, namely zoning, carcass removal, a complete feeding ban, specific hunting regulations and depopulation actions depending on the zone, a partial ban of circulation and logging, and setting up a network of concentric fences.
- Fencing (120 cm high, mesh size 15 × 20 cm, unburied and not fixed into the ground) contributed to slowing down ASF spread and allowed the creation of compartments in which depopulation could be carried out, without taking the risk of causing long distance wild boar movements.

6. Recommendations

6.1. Recommendations for managing wild boar populations in four geographic areas with different stage of ASF epidemiology – TOR5

6.1.1. PREVENTION: Recommendations for non-affected areas, far from any ASF occurrence, but at risk of human-mediated ASF introduction

Evidence in support

- Passive surveillance is the most important tool for early detection in the current ASF epidemic, both for domestic pigs and wild boar (see EFSA, 2018):
  - With respect to wild boar, the July 2018 EFSA report provides details of methodology to assess the effectiveness of passive surveillance. As a rough guide, the number of carcasses detectable each year is approximately 1% of the total adult population (assuming 10% annual mortality and 10% of carcasses detectable). This provides a 'baseline' for effective passive surveillance (the number of carcasses that should be detected on an ongoing basis) in the absence of ASF.
- High levels of biosecurity are needed to prevent the introduction of ASF into non-affected areas (both domestic pig farms and wild boar populations). With respect to this, the following aspects are important:
  - The long-term virus survival of ASFV in a range of matrices, including pork products.
  - Experiences during the current epidemic with evidence of human-assisted movement of virus on multiple occasions and often over long distances.
- There is an observed year-on-year increase in the density of wild boar populations in many parts of Europe (Massei et al., 2014).
- There are several successful examples of substantial reduction in the size of wild boar populations (up to 65% reduction compared with the initial total population) through culling in defined local areas (e.g. Boadella et al., 2012a; Quiros-Fernandez et al., 2017). However, population reduction over large areas and over long time periods is very difficult to achieve. This is because wild boar are extremely adaptable to different environmental circumstances and will respond to increased mortality through a compensatory increase in reproductive success (Gethöffer et al., 2007; Hanson et al., 2009; Fonseca et al., 2011).

Recommendations for non-affected areas, far from any ASF occurrence, but at risk of human-mediated ASF introduction:

- Set up, maintain and periodically evaluate systems of passive surveillance for early detection of ASF in wild boar and domestic pigs.
- Continue implementation and control of the ban on cross-border trade of wild boar.
- Complete and periodically evaluate contingency plans, clearly outlining protocols, roles and responsibilities, etc., in the event of an ASF incursion.
- Improve biosecurity and biosecurity awareness in all relevant sectors and among all relevant stakeholders on domestic pigs and wild boar:
  - Collect discarded rubbish material on roads/in parks, etc., noting the potential ASF risk for both urban and sylvatic wild boar.
  - Increase awareness and understanding among hunters, and others who visit or work in the forest, of the importance of passive surveillance for early detection of ASF and efficient hunting strategies, respecting a high level of biosecurity.
  - Set up a call centre to report carcasses of wild boar.
  - Increase the awareness of international travellers (i.e. tourists, foreign workers, transporters, etc.) coming from ASF-affected countries about the risks associated with meat, including the potential for inappropriate disposal of such foods to domestic pigs or in areas accessible to wild boar (e.g. picnic sites, by the road, etc.).
- Increase understanding of local wild boar ecology.
- Implement preventive measures to reduce wild boar density, as this will be beneficial in reducing both the probability of establishment of ASF following introduction and the efforts needed for potential emergency actions (such as carcass removal) if an ASF incursion were to occur. These measures should focus on:
  - Habitat carrying capacity. Key measures are needed to limit the carrying capacity of local habitats for wild boar including a complete ban on feeding wild boar and strategies to improve crop protection. Baiting should be avoided and alternatives used when possible.
  - Culling of wild boar. Hunting yields should be substantially increased to reduce wild boar density and achieve sustainable management of these populations. Given the temporal trend of increasing wild boar population density that has been observed in Europe, these hunting efforts should include harvesting animals of reproductive age (sows and boar), not excluding piglets. Hunting regulations and limitations should be made as flexible as possible to maximise opportunities for population reduction in the wild boar. Once accurate estimates of wild boar density become available, it will be possible to refine the size of the hunting ban that will be required, consistent with sustainable population management in each region.
- In specific areas, fencing could be considered, in combination with other measures, to reduce movement of wild boar between different areas.

6.1.2. PREVENTION: Non-affected areas near affected areas, or restricted areas at higher risk of ASF introduction primarily via natural spread mediated by wild boar

Evidence in support

- As above, in Section 6.1.1.

Recommendations for non-affected areas near affected areas, or restricted areas at higher risk of ASF introduction primarily via natural spread mediated by wild boar

The recommendations are equivalent to those in Section 6.1.1, with the following adjustments:

- Preventive measures to reduce wild boar density, focusing both on habitat carrying capacity and culling of wild boar, will be even more urgent. In non-affected areas in close proximity to affected areas, hunting of wild boar should be conducted at the highest levels achievable in that area. Furthermore, it is recommended that hunting of wild boar is conducted throughout this area, including in protected areas (such as national parks).
- There is a need for a planned, active and systematic approach to passive surveillance, to maximise the probability of early detection in domestic pigs or wild boar following introduction.

Following introduction, passive surveillance of wild boar will further assist in defining the geographic extent of the infected wild boar population.

- Forage and bedding from affected areas should not be used, unless it is treated to inactivate the ASFV; or stored for at least 30 days for fresh grass or grains and 90 days for straw used for beddings (European Commission, 2019b).
- As a precaution, it is suggested that fresh forage from affected areas should not be used.

6.1.3. CONTROL: ASF presence following an isolated introduction (e.g. Czechia, Belgium) far from affected areas

Evidence in support

- In large part, these recommendations are based on field experiences gained during the situation in Czechia and Belgium. The ASF outbreak in the Zlín area is, as yet, the only example during the current epidemic in which ASF has been both contained and locally eradicated. The management in the Belgian affected area is similar to the Czech approach, with a key difference being flexible reorganisation of fence structures in response to spatial expansion over time. Key items of the zonal approach in these MSs are described below:
  - In the core area, there is as little disturbance of the wild boar population as possible, and both incoming and outgoing wild boar movements are prevented, preferably using fencing. Logging, feeding and recreational hunting are prohibited. The epidemic is allowed to proceed, leading to the death of most wild boar in this area. After several months, remaining animals are culled using methods that also limit disturbance, including traps, night-shots, hunting from hide. Throughout this period, there is intensive, risk-based searching and removal of dead animals. All found-dead and culled animals are tested for the presence of the ASFV virus before being transported to a rendering plant.
  - In the reinforced observation area (known as the buffer zone in Czechia), all wild boar are assumed at high risk of infection given the imperfect barrier(s) (such as fencing) between this and the core area. Here, the goal is to mitigate the centrifugal spread of the virus from the core area and to avoid recolonisation from the vigilance area (see below). Multiple hunting strategies are used including driven hunts, traps, night shooting and hunting from hide. Logging and recreational activities are allowed, however feeding of wild boar is not allowed. Searching and removal of dead animals is conducted through random, repeated surveys and all found-dead and culled animals are removed, tested and rendered.
  - In the vigilance area, the primary goal is a dramatic reduction in the density of the wild boar population. Multiple hunting strategies are used, as in the reinforced observation area, and feeding is prohibited. Approximately 20% of the hunted wild boars are tested for the presence of the virus.

The conclusions from modelling have been presented previously.

Recommendations for areas with recent, isolated introduction of ASF into wild boar populations

- Following the initial isolated ASF introduction, the affected area should be defined based on passive surveillance and if possible demarcated based on natural and artificial barriers:
  - Within the central core area, the wild boar populations should be kept undisturbed throughout the period of active ASF transmission (e.g. a complete hunting ban on all species should be imposed and a strategy to ensure that the needs of the wild boar are met should be developed and implemented to limit animal movement); fencing should be considered to prevent inward and outward wild boar movement. Carcass removal should be undertaken to limit infection in the environment, but under conditions of high biosecurity. Following a decline in the epidemic, as demonstrated through passive surveillance, active population management under strict biosecurity, including rapid population destruction (culling) and carcass removal, should be reconsidered.
  - In the core zone, domestic pigs should be culled if possible, unless extremely high levels of biosecurity can be guaranteed together with an intensive ongoing passive surveillance for ASF in these farms.

- In the areas around the core zone, intensive measures should be introduced to drastically and sustainably reduce the wild boar population. The measures include trapping, hunting from hide, but no drives or dog hunts. Recent evidence suggests that additional fencings to enclose these areas of intensive hunting is recommended.
- To adapt measures in response to a potentially expanding infected polygon, a dynamic expansion of fenced perimeter should be considered.

- Surveillance activities are area specific. Carcass search should be in place in all areas, however in the core area it is recommended that a structured and risk-based carcass search is organised. Hunted or culled animals should be investigated more intensively the closer to the infected polygon they were caught.

6.1.4. CONTROL: ASF presence in previously non-affected areas as a consequence of geographic expansion of known affected areas (a moving front of infection)

Evidence in support

- In the epidemic to date, geographic spread mainly presents in the form of a small-scale epidemic. However, there have been multiple examples of human-mediated spread.
- The estimated median speed of propagation in wild boar populations is between 2.9 and 11.7 km/year. In affected countries, there is evidence that the velocity of local spread increases during summer.
- With the exception of the Czech and the Belgian situations (which occurred as a result of an isolated introduction), no strategies have yet proved effective in the current epidemic in preventing the geographic expansion of known affected areas.
- These recommendations are drawn from the experiences of affected MSs.

Recommendations following geographic expansion of the ASF-affected areas

- In theory, the strategies recommended in response to isolated ASF introduction are also suited to ASF introduction following geographic expansion of known ASF-affected areas. In practice, however, some changes will be needed, as the latter will generally result in a much larger affected area. At these larger scales, culling can be more difficult to implement, fencing is likely to be impractical and broader societal and political issues need to be considered.
- Given this background, the following strategies are recommended:

  - Passive surveillance is particularly important, both for early detection in domestic pigs and wild boar and to delineate the geographic extent of the infected wild boar population.
  - Larger reinforced observation areas should be considered, to account for expected wild boar movement. Preventive culling of wild boar is likely to be beneficial. Incentives should be considered to increase the biosecurity level in backyard farms.
  - Biosecurity and biosecurity awareness are particularly important, to minimise the risk of human-mediated spread.
  - Forage and bedding coming from affected areas should not be used, unless it is treated to inactivate the ASFV; or stored for at least 30 days for fresh grass or grains and 90 days for straw used for beddings (Document SANTE/7113/2015).

6.1.5. CONTROL: Areas where ASF has been present in the wild boar population for more than 1 year

Evidence in support

- Based on experience to date, particularly in the Baltic countries, infected wild boar have been detected in affected areas for some years after initial introduction, suggesting as yet poorly understood pathways to facilitate persistence of the virus. The re-emergence could be also caused by new introductions of the virus from adjacent affected country(ies).
- Active and passive surveillance are both useful during the period following the initial epidemic. As outlined previously, (EFSA, 2018), the surveillance objectives will change during different phases following ASF introduction:

- In affected areas that are progressively expanding, surveillance objectives include determining the extent of affected areas and identifying potentially useful interventions.
- In countries/areas where ASF infection has been present in most/all of the territory for a relatively short period of time, surveillance objectives include determining the extent of affected areas, identifying potentially useful interventions and monitoring the impact of interventions on ASF prevalence.
- In countries/areas where ASF infection has been present in most/all of the territory for a longer period of time, surveillance objectives include monitoring the effect of interventions on the prevalence of infected animals and building evidence to regain ASF-free status.

- Active surveillance is generally the most suited approach for most of the above-mentioned surveillance objectives. However, passive surveillance remains the most effective and efficient method of surveillance for early detection of ASF in wild boar (for example, into new areas or areas where ASF has not been detected in wild boar for some time) (EFSA, 2018).
- The modelling results highlight the key role of carcass removal in limiting infection in affected wild boar populations in combination with wild boar hunting (EFSA, 2018).

Recommendations in areas where ASF has been present in the wild boar population for more than 1 year

- There should be continuous and intensive hunting of wild boar to maintain low population densities, both to slow down the speed of infection spread and to monitor progress through active surveillance.
- There is an ongoing need for passive surveillance and carcass removal, both to identify hot spot areas and to limit ASF presence in carcasses/the environment.
- The age and sex profiles of found dead animals as well as 'carcass age' (time since death) should also be monitored to allow a more comprehensive assessment of the evolution of infection in wild boar populations. Application of molecular methods to estimate carcass age (time since death) should be considered.
- Incentives should be considered to maintain high levels of biosecurity level in all remaining domestic pig farms.
- There should be an ongoing feeding ban. Baiting should be kept to a minimum, and alternatives used when possible.
- Awareness campaigns should be continuous to maintain high levels of awareness among hunters and farmers.
- Further research is needed:
  - to clarify the pathways that facilitate ASF persistence in affected areas over a number of years
  - to clarify the interpretation of seropositivity in the context of ASF infection, including whether animals that test both PCR negative and Ab positive should be notified as an ASF case or not
  - to clarify the ability of survivor animals to excrete or harbour the virus
  - to clarify the epidemiological significance of a single, PCR-positive wild boar in areas with no current evidence of infection
  - to clarify the duration of colostral antibodies in piglets
  - to validate methods to estimate carcass age (time since death) in found-dead wild boar
  - to define a pathway to ASF freedom following detection of the last known infected animal/carcass.

6.2. Other recommendations

- There are significant gaps in knowledge on the epidemiology of ASF in Europe, including the contact rate between wild boar and carcasses, the contact rate between groups, and potential role of vectors in ASF spread (including insects) or mechanical vectors. Further research in each of these areas is recommended.
- Regulations should be developed for home slaughtering and appropriate controls enacted, to limit the circulation of infected meat.

References

Alexandrov T, Kamenov P, Stefanov D and Depner K, 2011. Trapping as an alternative method of eradicating classical swine fever in a wild boar population in Bulgaria. Revue Scientifique Et Technique-Office International Des Epizooties, 30, 911–916.

Anderson SJ and Stone CP, 1993. Snaring to control feral pigs *Sus scrofa* in a remote Hawaiian rain-forest. Biological Conservation, 63, 195–201.

Barasona JA, Gallardo C, Cadenas-Fernández E, Jurado C, Rivera B, Rodriguez-Bertos A, Arias M and Sánchez-Vizcaíno JM, 2019. First oral vaccination of Eurasian wild boar against African swine fever virus genotype II. Frontiers in Veterinary Science, 6, 137. https://doi.org/10.3389/fvets.2019.00137

Barron MC, Anderson DP, Parkes JP and Ohukaniohia Gon SM, 2011. Evaluation of feral pig control in Hawaiian protected areas using Bayesian catch-effort models. New Zealand Journal of Ecology, 35, 182–188.

Bengsen AJ, Gentle MN, Mitchell JL, Pearson HE and Saunders GR, 2014. Impacts and management of wild pigs *Sus scrofa* in Australia. Mammal Review, 44, 135–147. https://doi.org/10.1111/mam.12011

Bil M, Andrasik R, Bartonicka T, Krivankova Z and Sedonik J, 2018. An evaluation of odor repellent effectiveness in prevention of wildlife–vehicle collisions. Journal of Environmental Management, 205, 209–214.

Boadella M, Vicente J, Ruiz-Fons F, de la Fuente J and Gortázar C, 2012a. Effects of culling Eurasian wild boar on the prevalence of *Mycobacterium bovis* and Aujeszky's disease virus. Preventive Veterinary Medicine, 107, 214–221. https://doi.org/10.1016/j.prevetmed.2012.06.001

Boadella M, Barasona JA, Pozio E, Montoro V, Vicente J, Gortazar C and Acevedo P, 2012b. Spatio-temporal trends and risk factors for *Trichinella* species infection in wild boar (*Sus scrofa*) populations of central Spain: a long-term study. International Journal for Parasitology, 42, 739–745.

Bonet-Arboli V, Llimona F,Pla A, Rafart-Plaza E, Padros J and Rodriguez-Teijeiro JD, 2000. Evolution of wild boar (*Sus scrofa*) hunting in Collserola Park. [First meeting on research on the natural systems of Collserola: applications to the management of the park.]. #volume#:225-232.

Bosch J, Iglesias I, Muñoz MJ and Torre A, 2016. A cartographic tool for managing african swine fever in Eurasia: mapping wild boar distribution based on the quality of available habitats. Transboundary and Emerging Diseases, 64, 1720–1733. https://doi.org/10.1111/tbed.12559

Burt MD, Miller C and Souza D, 2011. The use of volunteer hunting as a control method for feral pig populations on O'ahu. Hawaii. Occasional Papers of the IUCN Species Survival Commission, 42, 402– 406.

Cleveland WS, Devlin SJ and Grosse E, 1988. Regression by local fitting. Journal of Econometrics, 37, 87–114.

Correia-Gomes C, Henry MK, Auty HK and Gunn GJ, 2017. Exploring the role of small-scale livestock keepers for national biosecurity – the pig case. Preventative Veterinary Medicine, 145, 7–15.

Cowled BD, Gifford E, Smith M, Staples L and Lapidge SJ, 2006. Efficacy of manufactured PIGOUT® baits for localised control of feral pigs in the semi-arid Queensland rangelands. Wildlife Research, 33, 427–437.

Dakpa P, Penjore U and Dorji T, 2009. Design, fabrication and performance evaluation of wild pig repellent device. Journal of Renewable Natural Resources Bhutan, 5, 116–126.

Davis AJ, Leland B, Bodenchuk M, VerCauteren KC and Pepin KM, 2018. Costs and effectiveness of damage management of an overabundant species (Sus scrofa) using aerial gunning. Wildlife Research, 45, 696–705.

Ditchkoff SS, Holtfreter RW and Williams BL, 2017. Effectiveness of a bounty programme for reducing wild pig densities. Wildlife Society Bulletin, 41, 548–555.

EFSA (European Food Safety Authority), 2017. Data dictionaries—guidelines for reporting data on zoonoses, antimicrobial resistance and food-borne outbreaks using the EFSA data models for the Data Collection Framework (DCF) to be used in 2017, for 2016 data. EFSA supporting publication 2017:EN-1178. 106 pp. https://doi.org/10.2903/sp.efsa.2017.en-1178

EFSA (European Food Safety Authority), Boklund A, Cay B, Depner K, Foldi Z, Guberti V, Masiulis M, Miteva A, More S, Olsevskis E, Satran P, Spiridon M, Stahl K, Thulke H-H, Viltrop A, Wozniakowski G, Broglia A, Cortinas Abrahantes J, Dhollander S, Gogin A, Verdonck F, Amato L, Papanikolaou A and Gortazar C, 2018. Scientific report on the epidemiological analyses of African swine fever in the European Union (November 2017 until November 2018). EFSA Journal 2018;16(11):5494, 106 pp. https://doi.org/10.2903/j.efsa.2018.5494

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. https://doi.org/10.2903/j.efsa.2015.4163

EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare), More S, Miranda MA, Bicout D, Bøtner A, Butterworth A, Calistri P, Edwards S, Garin-Bastuji B, Good M, Michel V, Raj M, Saxmose Nielsen S, Sihvonen L, Spoolder H, Stegeman JA, Velarde A, Willeberg P, Winckler C, Depner K, Guberti V, Masiulis M, Olsevskis E, Satran P, Spiridon M, Thulke H-H, Vilrop A, Wozniakowski G, Bau A, Broglia A, Cortinas Abrahantes J, Dhollander S, Gogin A, Munoz Gajardo I, Verdonck F, Amato L and Schmidt CG, 2018. Scientific Opinion on the African swine fever in wild boar. EFSA Journal 2018;16(7):5344, 78 pp. https://doi.org/10.2903/j.efsa.2018.5344

Engeman R, Hershberger T, Orzell S, Felix R, Killian G, Woolard J, Cornman J, Romano D, Huddleston C, Zimmerman P, Barre C, Tillman E and Avery M, 2014. Impacts from control operations on a recreationally hunted feral swine population at a large military installation in Florida. Environmental Science and Pollution Research, 21, 7689–7697.

Engeman RM, Wilson BE, Beckerman SF, Fischer JW, Dufford D and Cobban JB, 2019. Locating and eliminating feral swine from a large area of fragmented mixed forest and agriculture habitats in north-central USA. Environmental Science and Pollution Research, 26, 1654–1660.

European Commission, 2019a. Commission Implementing Decision (EU) 2019/404 of 12 March 2019 amending the Annex to Implementing Decision 2014/709/EU concerning animal health control measures relating to African swine fever in certain Member States. C/2019/1833. OJ L 72, 14.3.2019, pp. 50–80.

European Commission, 2019b. Directorate G – Crisis management in food, animals and plants Unit G3 – Official controls and eradication of diseases in animals Brussels SANCO G3/FB (25.11.2019) SANTE/7113/2015 – Rev 11 WORKING DOCUMENT Strategic approach to the management of African Swine Fever for the EU. Available online: https://ec.europa.eu/food/sites/food/files/animals/docs/ad_control-measures_asf_wrk-doc-sante-2015-7113.pdf

EUVET, 2018. Mission of the Veterinary Emergency Team (EUVET) to Slovakia. Available online: https://ec.europa.eu/food/sites/food/files/animals/docs/reg-com_ahw_20190924_asf_svk_euvet.pdf

Flis M, 2019. Biology, reproduction and demography of wild boars affected by increased shooting due to the occurrence of the African swine fever virus. Zycie Weterynaryjne, 94, 149–153.

Fonseca C, da Silva AA, Alves J, Vingada J and Soares AMVM, 2011. Reproductive performance of wild boar females in Portugal. European Journal of Wildlife Research, 57, 363–371. https://doi.org/10.1007/s10344-010-0441-6

Gallardo C, Soler A, Rodze I, Nieto R, Cano-Gómez C, Fernández-Pinero J and Arias M, 2019. Attenuated and non-haemadsorbing (non-HAD) genotype II African swine fever virus (ASFV) isolated in Europe, Latvia 2017. Transboundary and Emerging Diseases, 66, https://doi.org/10.1111/tbed.13132

Garcia-Jimenez WL, Fernandez-Llario P, Benitez-Medina JM, Cerrato R, Cuesta J, Garcia-Sanchez A, Goncalves P, Martinez R, Risco D, Salguero FJ, Serrano E, Gomez L and Hermoso-de-Mendoza J, 2013. Reducing Eurasian wild boar (*Sus scrofa*) population density as a measure for bovine tuberculosis control: Effects in wild boar and a sympatric fallow deer (*Dama dama*) population in Central Spain. Preventive Veterinary Medicine, 110, 435–446.

Gaskamp JA, Gee KL, Campbell TA, Silvy NJ and Webb SL, 2018. Damage caused to rangelands by wild pig rooting activity is mitigated with intensive trapping. Cogent Environmental Science, 4, 1.

Geisser H and Reyer HU, 2004. Efficacy of hunting, feeding and fencing to reduce crop damage by wild boar. Journal of Wildlife Management, 68, 939–946.

Gethöffer F, Sodeikat G and Pohlmeyer K, 2007. Reproductive parameters of wild boar (Sus Scrofa) in three different parts of Germany. European Journal of Wildlife Research, 53, 287–297.

Giacomelli S, Gibbert M and Vigano R, 2018. Community empowerment for managing wild boar: a longitudinal case study of northern Italy 2001–2018. Ecology and Society, 23, 12.

Gioeli KT, Munyan S, Adams L, Huffman J, Russakis E and Vachon E, 2015. 4-H southern swines feral hog challenge. Journal of Extension, 53, 4IAW7.

Hafeez S, Khan ZH, Khan RA, Qadir I and Rashid F, 2007. Comparative efficacy of some trap for controlling porcupines, wild boars and other vertebrate pests. Pakistan Journal of Agricultural Sciences, 44, 150–153.

Hanson LB, Mitchell MS, Grand JB, Jolley DB, Sparklin BD and Ditchkoff SS, 2009. Effect of experimental manipulation on survival and recruitment of feral pigs. Wildlife Research, 36, 185–191.

Hone J and Stone CP, 1989. A comparison and evaluation of feral pig management in two national-parks. Wildlife Society Bulletin, 17, 419–425.

Jeyasingh PD and Davidar P, 2003. Crop depredation by wildlife along the eastern boundary of the Kalakad-Mundanthurai Tiger Reserve, southern India. Journal of the Bombay Natural History Society, 100, 38–45.

Katahira LK, Finnegan P and Stone CP, 1993. Eradicating feral pigs in montane mesic habitat at Hawaii Volcanos National Park. Wildlife Society Bulletin, 21, 269–274.

Killian G, Miller L, Rhyan J and Doten H, 2006. Immunocontraception of Florida feral swine with a single-dose GnRH vaccine. American Journal of Reproductive Immunology, 55, 378–384.

Kopler I and Malkinson D, 2018. Differential response of mammals to agricultural fences – the effects of species vagility and body size. Basic and Applied Ecology, 33, 79–88.

Lange M, Guberti V and Thulke H-H, 2018. Understanding ASF spread and emergency control concepts in wild boar populations using individual-based modelling and spatio-temporal surveillance data. EFSA supporting publication 2018:EN-1521, 46 pp. Available online: https://doi.org/10.2903/sp.efsa.2018.en-1521

Lavelle MJ, Vercauteren KC, Hefley TJ, Phillips GE, Hygnstrom SE, Long DB, Fischer JW, Swafford SR and Campbell TA, 2011. Evaluation of fences for containing feral swine under simulated depopulation conditions. Journal of Wildlife Management, 75, 1200–1208.

Leranoz I and Castien E, 1996. Evolution of wild boar (*Sus scrofa* L., 1758) in Navarra (N Iberian peninsula). Miscellania Zoologica (Barcelona), 19, 133–139.

Massei G, Kindberg J, Licoppe A, Gačić D, Šprem N, Kamler J, Baubet E, Hohmann U, Monaco A, Ozoliņš J and Cellina S, 2014. Wild boar populations up, numbers of hunters down? A review of trends and implications for Europe. Pest Management Science, 71, 492–500.

Mihalik B, Stéger V, Frank K, Szendrei L and Kusza S, 2018. Barrier effect of the M3 highway in Hungary on the genetic diversity of wild boar (Sus scrofa) population. Research Journal of Biotechnology, 13, 32–38.

McCann BE and Garcelon DK, 2008. Eradication of feral pigs from Pinnacles National Monument. Journal of Wildlife Management, 72, 1287–1295.

McIlroy JC and Gifford EJ, 1997. The 'Judas' pig technique: a method that could enhance control programmes against feral pigs, *Sus scrofa*. Wildlife Research, 24, 483–491.

McIlroy JC and Saillard RJ, 1989. The effect of hunting with dogs on the numbers and movements of feral pigs, Sus scrofa, and the subsequent success of poisoning exercises in Namadgi National Park, A.C.T. Australian Wildlife Research, 16, 353–363.

Monzon A and Bento P, 2004. An analysis of the hunting pressure on wild boar (*Sus scrofa*) in the Tras-os-Montes region of northern Portugal. Galemys, 16, 253–272.

Negus PM, Marshall JC, Clifford SE, Blessing JJ and Steward AL, 2019. No sitting on the fence: protecting wetlands from feral pig damage by exclusion fences requires effective fence maintenance. Wetlands Ecology and Management, 2019, 1–5.

Nurmoja I, Motus K, Kristian M, Niine T, Schulz K, Depner K and Viltrop A, 2018. Epidemiological analysis of the 2015–2017 African swine fever outbreaks in Estonia. Preventative Veterinary Medicine, https://doi.org/10.1016/j.prevetmed.2018.10.001

Pejsak Z, Niemczuk K, Frant M, Mazur M, Pomorska-Mól M, Ziętek-Barszcz A, Bocian Ł, Łyjak M, Borowska D and Woźniakowski G, 2018. Four years of African swine fever in Poland. New insights into epidemiology and prognosis of future disease spread. Polish Journal of Veterinary Science, 21, 835–841. https://doi.org/10.24425/pjvs.2018.125598

Piechowski D, 1996. Field trials on efficiency of odour repellent – Duftzaun in game deterring. Sylwan, 140, 49–60.

Poche RM, Poche D, Franckowiak G, Somers DJ, Briley LN, Tseveenjav B and Polyakova L, 2018. Field evaluation of low-dose warfarin baits to control wild pigs (*Sus scrofa*) in North Texas. PLoS ONE, 13, e0206070.

Quiros-Fernandez F, Marcos J, Acevedo P and Gortazar C, 2017. Hunters serving the ecosystem: the contribution of recreational hunting to wild boar population control. European Journal of Wildlife Research, 63, 57.

R Core Team, 2018.R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available online: https://www.R-project.org/

Reidy MM, Campbell TA and Hewitt DG, 2008. Evaluation of electric fencing to inhibit feral pig movements. Journal of Wildlife Management, 72, 1012–1018.

Reidy MM, Campbell TA and Hewitt DG, 2011. A mark-recapture technique for monitoring feral swine populations. Rangeland Ecology and Management, 64, 316–318.

Ribbens S, Dewulf J, Koenen F, Mintiens K, De Sadeleer L, de Kruif A and Maes D, 2008. A survey on biosecurity and management practices in Belgian pig herds. Preventative Veterinary Medicine, 83, 228–241.

Sakthivel Rao AMKM, Rao NS and Reddy P, 2013. Efficacy of non poisonous castor based repellent against wild boar (Sus scrofa) in maize crop around Hyderabad. Pestology, 37, 26–29.

Santilli F and Stella RMD, 2006. Electrical fencing of large farmland area to reduce crops damages by wild boar Sus scrofa. Agricoltura Mediterranea, 136, 79–84.

Sapkota S, Aryal A, Baral SR, Hayward MW and Raubenheimer D, 2014. Economic analysis of electric fencing for mitigating human-wildlife conflict in Nepal. Journal of Resources and Ecology, 5, 237–243.

Saunders G, 1993a. The demography of feral pigs (*Sus scrofa*) in Kosciusko National Park, New South Wales. Wildlife Research, 20, 559–569.

Saunders G, 1993b. Observations on the effectiveness of shooting feral pigs from helicopters. Wildlife Research, 20, 771–776.

Schlageter A and Haag-Wackernagel D, 2011. Effectiveness of solar blinkers as a means of crop protection from wild boar damage. Crop Protection, 30, 1216–1222.

Schlageter A and Haag-Wackernagel D, 2012a. Evaluation of an odor repellent for protecting crops from wild boar damage. Journal of Pest Science, 85, 209–215.

Schlageter A and Haag-Wackernagel D, 2012b. A gustatory repellent for protection of agricultural land from wild boar damage: an investigation on effectiveness. Journal of Agricultural Science (Toronto), 4, 61–68.

Schmidt A, 1986. Wild boar control with electric fences – experiences of an effective method for the protection of young coconut plantations. Oleagineux, 41, 557–559.

Schulz K, Staubach C, Blome S, Viltrop A, Nurmoja I, Conraths FJ and Sauter-Louis C, 2019b. Analysis of Estonian surveillance in wild boar suggests a decline in the incidence of African swine fever. Scientific Reports, 9, 8490.

Snow NP, Foster JA, Kinsey JC, Humphrys ST, Staples LD, Hewitt DG and VerCauteren KC, 2017. Development of toxic bait to control invasive wild pigs and reduce damage. Wildlife Society Bulletin, 41, 256–263.

Snow NP, Lavelle MJ, Halseth JM, Glow MP, VanNatta EH, Davis AJ, Pepin KM, Tabor RT, Leland BR, Staples LD and VerCauteren KC, 2019. Exposure of a population of invasive wild pigs to simulated toxic bait containing biomarker: implications for population reduction. Pest Management Science, 75, 1140–1149.

Sreeja P and Mani C, 2017. Evaluation of crop protection measures against wild boar (*Sus scrofa*) damage on Chinese potato *Solonostemonrotun difolius* (Poir) Morton in Kerala. Pest Management in Horticultural Ecosystems, 23, 133–137.

Ståhl K, Sternberg-Lewerin S, Blome S, Viltrop A, Penrith M-L and Chenais E, 2019. Lack of evidence for long term carriers of African swine fever virus – a systematic review. Virus Research, 272, 197725.

Twigg LE, Lowe T, Martin G and Everett M, 2005. Feral pigs in north-western Australia: basic biology, bait consumption and the efficacy of 1080 baits. Wildlife Research, 32, 281–296.
Ueckermann E, 1972. Zur jagdlichen Nutzungsfähigkeit von Rot-, Dam- und Schwarzwildbeständen nach Beobachtungen in einem Jagdgatter. Zeitschrift für Jagdwissenschaft, 18, 24–31.
Vajas P, Calenge C, Richard E, Fattebert J, Rousett C, Saïd S and Baubet E, 2020. Many, large and early: hunting pressure on wild boar relates to simple metrics of hunting effort. Science of the Total Environment, 698, 134251.
Varewyck M, Verbeke T and Cortinas Abrahantes J, 2017. Exploratory analysis for spatio-temporal epidemiological data WEB app (spatial). Zenodo, https://doi.org/10.5281/zenodo.889551
Vasudeva Rao V, Naresh B, Tripathi RS, Sudhakar C and Reddy Ravinder V, 2017. Reduction of wild boar (Sus scrofa L.) damage in maize (Zea mays L.) by using castor (Ricinus communis L.) as barrier. Journal of Entomology and Zoology Studies, 5, 426–428.
Vicente J, Apollonio M, Blanco-Aguiar JA, Borowik T, Brivio F, Casaer C, Croft S, Ericsson G, Ferroglio E, Gavier-Widen D, Gortázar C, 2019. Science-based wildlife disease response. Science, 364, 943–944.
Vidrih M and Trdan S, 2008. Evaluation of different designs of temporary electric fence systems for the protection of maize against wild boar (*Sus scrofa* L., Mammalia, Suidae). Acta Agriculturae Slovenica, 91, 343–349.
Vilardell A, Capalleras X, Budó J, Molist F and Pons P, 2008. Test of the efficacy of two chemical repellents in the control of Hermann's tortoise nest predation. European Journal of Wildlife Research. https://doi.org/10.1007/s10344-008-0176-9. https://www.bing.com/search?q=eur+j+wildl+res&form=EDGTCT&qs=AS&cvid=de806008c287406fac9cc60498b112e7&refig=8e44641351154b3ddd4b9675666f9128&cc=GB&setlang=en-US&plvar=0
Vilardell A, Capalleras X, Budó J, Molist F and Pons P, 2008. Test of the efficacy of two chemical repellents in the control of Hermann's tortoise nest predation. European Journal of Wildlife Research, 54, 745–748.
WAHIS (World Animal Health Information and Analysis Department, OIE). 2019. African Swine Fever (ASF) Report N° 31: November 8-21. Available online: https://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/ASF/Report_31_Current_situation_of_ASF.pdf
Wegorek P and Giebel J, 2008. The effectiveness of selected active substances in keeping away wild boar (*Sus scrofa* L.) from feeding on maize crops. Progress in Plant Protection, 48, 1002–1006.
Wegorek P, Zamojska J, Bandyk A and Olejarski P, 2014. Results of the monitoring of the effectiveness of repellents against wild boar in the fields. Progress in Plant Protection, 54, 159–162.

Abbreviations

ADNS	Animal Disease Notification System
ASF	African swine fever
ASFV	African swine fever virus
BYM	Besag, York and Mollié
DCF	Data Collection Framework
EAF	Executive Agency for Forestry
FASFC	Federal Agency for the Safety of the Food Chain
GAM	general additive model
GIS	geographic information systems
GMU	Game Management Unit
GnRH	gonadotrophin-releasing hormone
HRP	high-risk period
IFA	indirect fluorescent assay
IPT	immunoperoxidase test
LAU	local administrative unit
LIMS	Laboratory Information Management System
MS	Member State
NRL	National Reference Laboratory
NUTS	Nomenclature of Territorial Units for Statistics
OR	odds ratio
PCR	polymerase chain reaction
QAH	quality of available habitat
SNIIA	National System of Identification and Registration of Animals
SPW	Public Service of Wallonia
TOR	Terms of Reference
WB	wild boar
WVC	wildlife-vehicle collisions

Appendix A – Proportions of positive samples in wild boar in the whole country

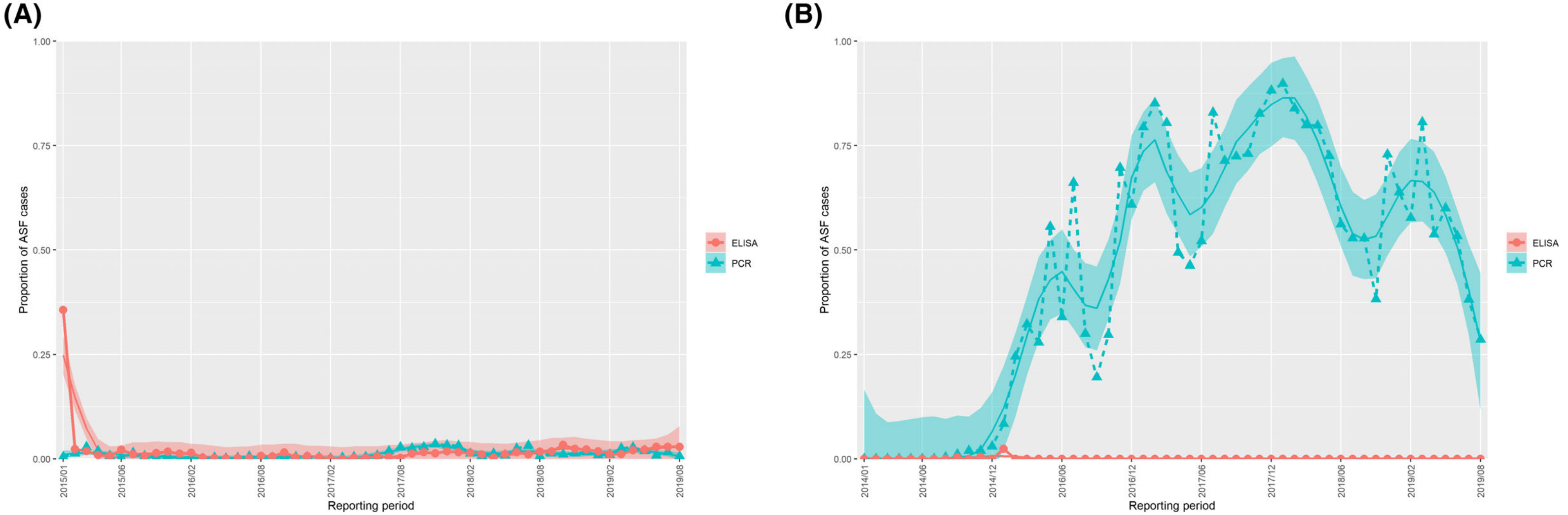


Figure A.1: Proportion of ASFV-positive samples (tested by antibody-ELISA and PCR) over the tested samples, from all hunted wild boar (A) and from wild boar found dead (B) in all the sampled areas in Lithuania

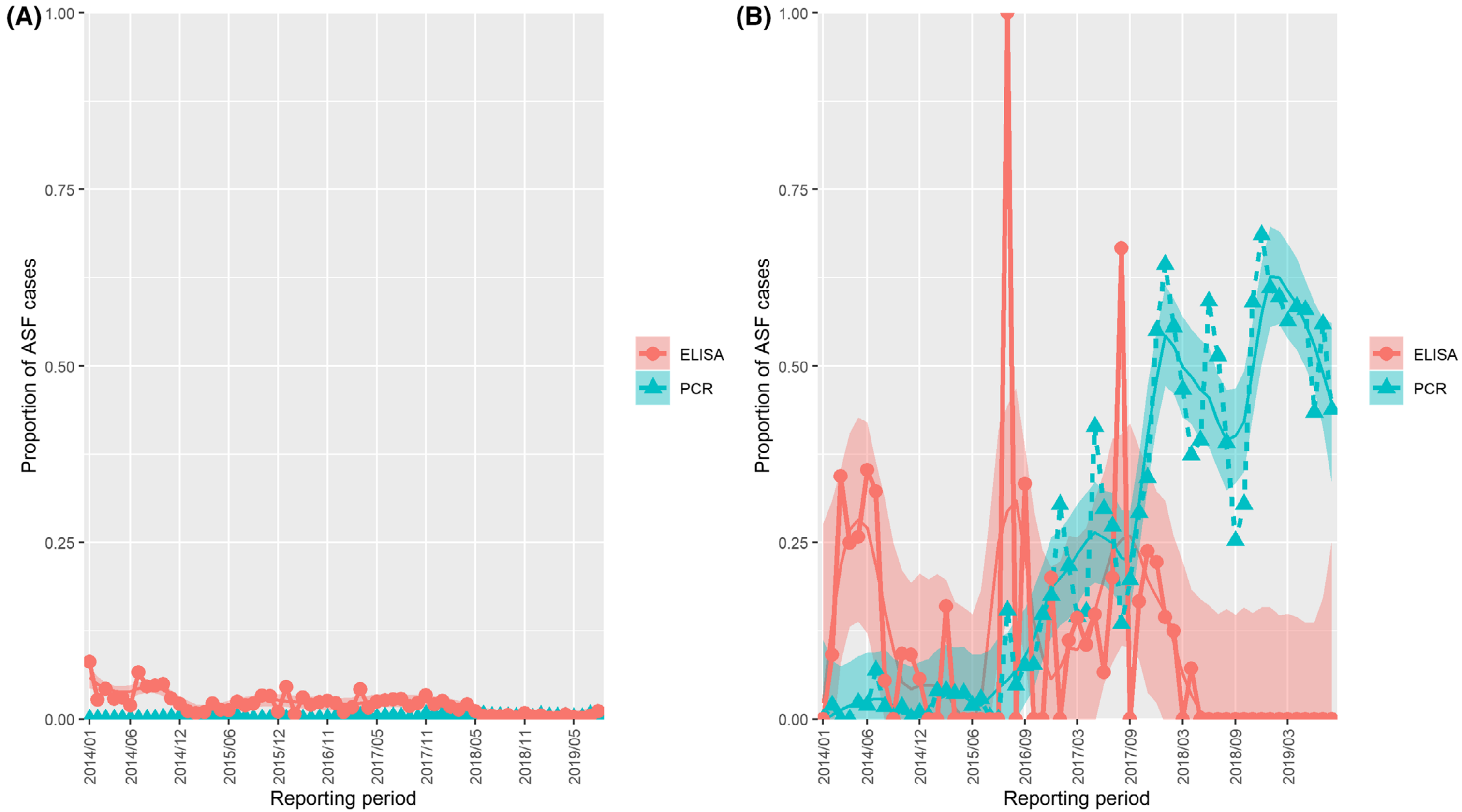


Figure A.2: Proportion of ASFV-positive samples (tested by antibody-ELISA and PCR) over the tested samples, from all hunted wild boar (A) and from wild boar found dead (B) in all the sampled areas in Poland

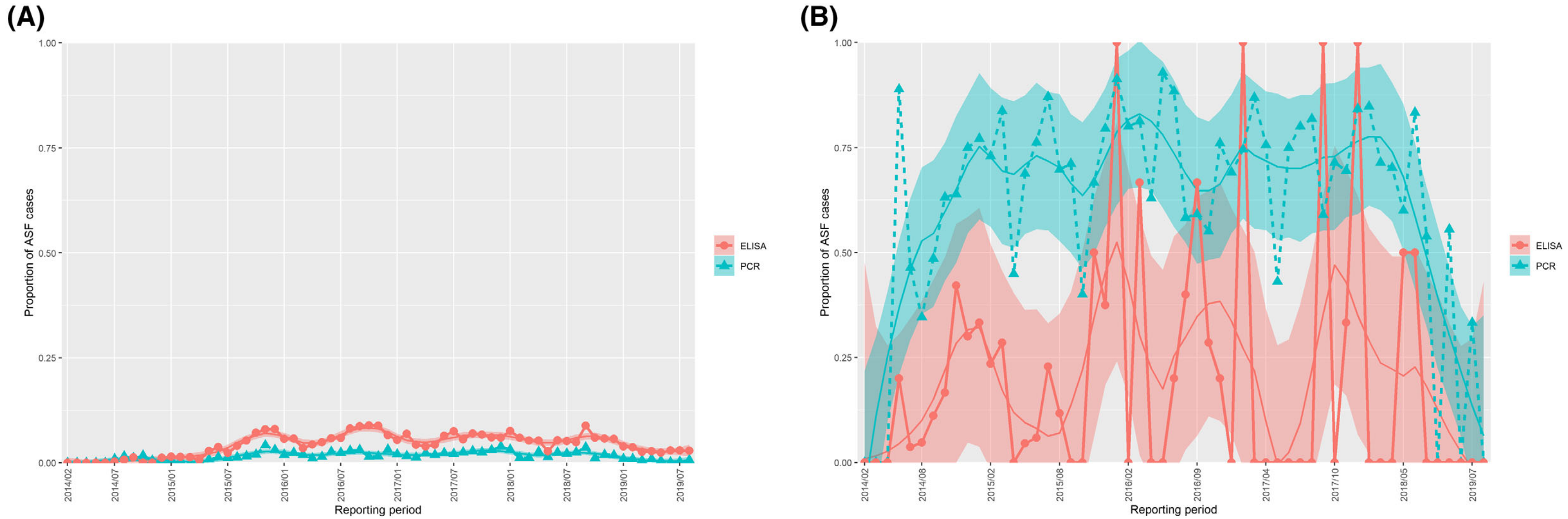


Figure A.3: Proportion of ASFV-positive samples (tested by antibody-ELISA and PCR) over the tested samples, from all hunted wild boar (A) and from wild boar found dead (B) in all the sampled areas in Latvia

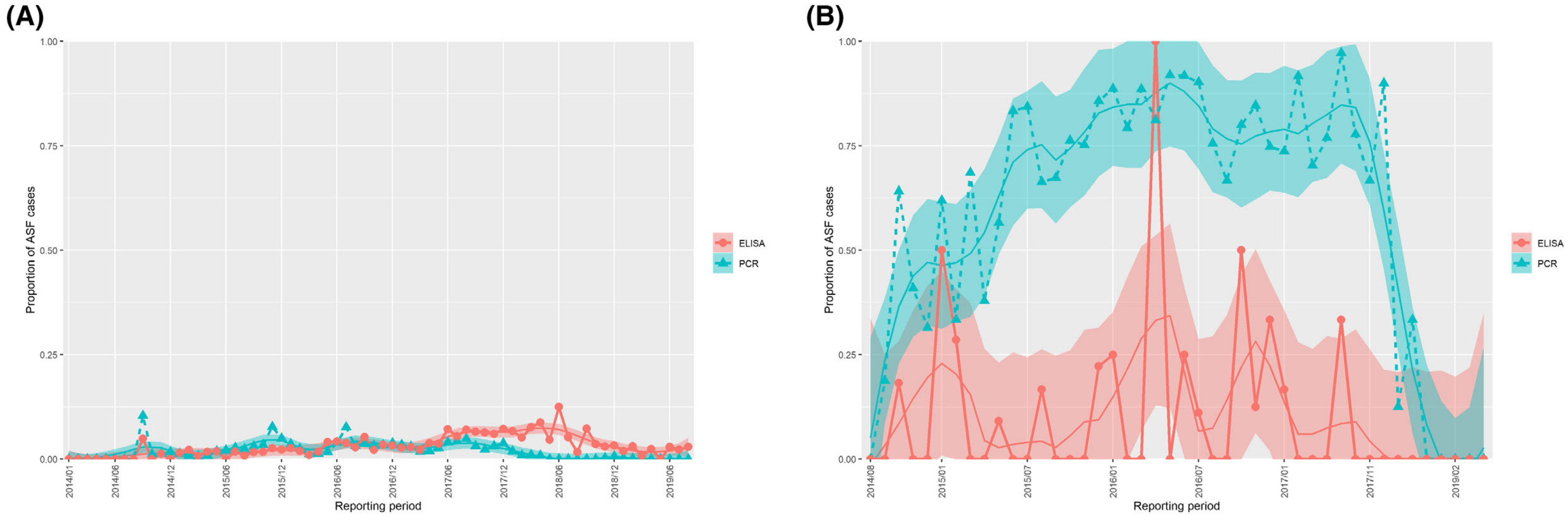


Figure A.4: Proportion of ASFV-positive samples (tested by antibody-ELISA and PCR) over the tested samples, from all hunted wild boar (A) and from wild boar found dead (B) in all the sampled areas in Estonia

Appendix B – Risk factor analysis for ASF incursion in Romanian farms

Table B.1: Covariates included in the analyses of risk factors

Covariate	Type	Description
Total.pigs	Numeric, discrete	Total numbers of pigs on the farm. For Case farms, data from ADNS was used
Piglets	Numeric, discrete	Total numbers of piglets on the farm. For Case farms, data from ADNS was used
Sows	Numeric, discrete	Total numbers of sows on the farm. For Case farms, data from ADNS was used
Seen.WB	Dichotom, y/n	Does the farm owner see sign of wild boar around the farm
Crossbred.pigs[(a),*]	Dichotom, y/n	Does the farmer observe crossbred piglets, as result of wild boar visits
Carcass[(a),*]	Dichotom, y/n	Does the farmer observe wild boar carcasses around the farm
WB.access.to.feed. storage[(a),*]	Dichotom, y/n	Does wild boar have access to the feed storage
WB.access.to.bedding. storage*	Dichotom, y/n	Does wild boar have access to the bedding storage
Attractive.crops	Dichotom, y/n	Are there crops around the farm, which would be attractive to wild boar
Origin.of.the.forrage*	Categorical, no/from ASF area/ from non-ASF area	From where does the forage used for pigs origin
Origin.of.the.cereals*	Categorical, no/from ASF area/ from non-ASF area	From where does the cereals used for pigs origin
Origin.of.the.on.farm. milling.and.mixture*	Categorical, no/from ASF area/ from non-ASF area	From where do the ingredients for home mixing for pigs origin
Vehicles.visits.HRP	Numeric, discrete	Numbers of vehicles entering the farm area in the high-risk period
Professionals.visits.HRP	Numeric, discrete	Numbers of professional visits in high-risk period
Nonprof.visitors.HRP	Numeric, discrete	Numbers of non-professional visits in high-risk period
Bedding	Categorical, straw/no straw	Originally, the type of bedding was registered as no/straw/wood chips/other
Fenced.holding*	Dichotom, y/n	
Manure.from.other. holdings*	Dichotom, y/n	Are manure from other holdings used on the fields around the farm
Pigs.introduced.in.HRP	Dichotom, y/n	Were pigs introduced in high-risk period
Soft.ticks*	Categorical, 0/0–4/5–9	Are soft ticks observed on the farm
Hard.ticks[(a),*]	Categorical, 0/0–4/5–9	Are hard ticks observed on the pigs
Ticks	Dichotom, y/n	Combined from the two above
Mosquitoes	Dichotom, y/n	Combined from 0/0–9/10–10/> 100
Biting.midges	Dichotom, y/n	Combined from 0/0–9/10–10/> 100
Fatteners	Numeric, discrete	Total numbers of fatteners on the farm. For Case farms, data from ADNS was used
Bovine	Dichotom, y/n	Cattle on the farm
Ovine	Dichotom, y/n	Sheep on the farm
Caprine*	Dichotom, y/n	Goats on the farm
Poultry	Dichotom, y/n	Poultry on the farm
Equine*	Dichotom, y/n	Horses on the farm
Pets	Dichotom, y/n	Pets on the farm
Swill	Dichotom, y/n	Are there sign of swill feeding at the farm visit

Covariate	Type	Description
Compound	Dichotom, y/n	Is compound feed used
Fountain	Dichotom, y/n	Drinking water supply for pigs fully or partly from fountain
Tap	Dichotom, y/n	Drinking water supply for pigs fully or partly from the tap
Tank[(b)]	Dichotom, y/n	Drinking water supply for pigs fully or partly from a tank
Surface[(b),*]	Dichotom, y/n	Drinking water supply for pigs fully or partly from surface water
Water[(b)]	Dichotom, y/n	This one takes the lowest level from above assuming tap > fountain > tank > surface (as several farms had > 1 type of supply)
nearWB	Numeric, continuous	Distance (m) to nearest outbreak in wild boar in the HRP
lnnearWB	Numeric, continuous	Ln distance (m) to nearest outbreak in wild boar in the HRP
WB1	Numeric, discrete	Number of wild boar outbreaks within a distance of 1 km from the farm
WB2	Numeric, discrete	Number of wild boar outbreaks within a distance of 2 km from the farm
WB5	Numeric, discrete	Number of wild boar outbreaks within a distance of 5 km from the farm
WB10	Numeric, discrete	Number of wild boar outbreaks within a distance of 10 km from the farm
nearDB	Numeric, continuous	Distance (m) to nearest outbreak in domestic pigs in the HRP
lnnearDB	Numeric, continuous	Ln distance (m) to nearest outbreak in domestic pigs in the HRP
DB1	Numeric, discrete	Number of domestic pigs outbreaks within a distance of 1 km from the farm
DB2	Numeric, discrete	Number of domestic pigs outbreaks within a distance of 2 km from the farm
DB5	Numeric, discrete	Number of domestic pigs outbreaks within a distance of 5 km from the farm
DB10	Numeric, discrete	Number of domestic pigs outbreaks within a distance of 10 km from the farm
WBdens	Numeric, continuous	Wild boar density around the farm
Farmdens	Numeric, continuous	Farm density around the farm
Pigdens	Numeric, continuous	Pig density around the farm

*: Marks covariates, which could not be tested for commercial farms, as there were none or too few commercial farms with this management to include it in the model.
(a): Strongly correlated to other covariates, and were therefore left out of the model.
(b): No control farms used surface water and the covariate was therefore left out of the model.

Table B.2: Outcomes of literature review on measure to reduce wild boar population density

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Wild boar																			
Monzon and Bento, 2004	X							Drive hunts	Portugal, Nord, Trás-os-Montes region	12,864	Forest and agricultural land	1996	nr	2001	nr	Not reported	Hunting bag	202	The increase in corn production was the main factor involved in the increase in wild boar hunting bags
Quiros-Fernandez et al., 2017	X							Recreational hunting	Spain, Asturias,	124.46	Atlantic ecosystem	2000	9	2014	2	Hunting bag	Population growth rate	0.056	Hunters are able to contribute to reduce wild boar abundance, as shown by reduced growth rate compared with period before hunting ban (but still increasing growth rate of 5.6% per year after hunting ban, despite intensive hunting)
Bonet-Arboli et al., 2000	X							Recreational hunting	Spain, Catalonia, Collserola	1	Forest and grassland	1978	nr	1999	nr	Hunting bag	Harvest rate	0.85	No calculation of population density but increasing hunting bag over the last years
Giacomelli et al., 2018	X							Hunting	Italy, Piedmont	2,5402 km	Forest land	2001		2008		Expert opinion			A regulation allowing hunting (especially hunting with dogs) actually increased the overall population via incentivising illegal releases. Delegation of responsibility to the local community proved most effective in reducing illegally releasing wild boar
Flis, 2019		x						Population dynamics simulations								Direct observation	Spring counting (less individuals)	Simulations with differed sex ratio and % hunted of population per hunting seasons	Hunting has a significant impact on reproduction rate, and thus on the demography of wild boar and population dynamics
Garcia-Jimenez et al., 2013		X						Drive hunts with dogs	Spain, Central Spain, fenced estate near Madrid	30	Mediterranean ecosystem	2007		2012		Hunting bag	nr	nr	bTB prevalence remained high in the remnant wild boar population, despites increased hunting efforts. Absolute density measures were not provided

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Leranoz and Castien, 1996		X						Drive hunts	Spain, Navarra	100	Forest, grassland and marshland	1987	nr	1988	nr	Hunting bag	Harvest rate	0.37	Although there has been a gradual increase in hunting bag, the proportion of the population taken by hunting was small and insufficient to keep the population at a stable number
Leranoz and Castien, 1996		X						Drive hunts	Spain, Navarra	100	Forest, grassland and marshland	1991	nr	1992	nr	Hunting bag	Harvest rate	0.25	Although there has been a gradual increase in hunting bag, the proportion of the population taken by hunting was small and insufficient to keep the population at a stable number
Boadella et al., 2012b		X						Drive hunts (intense and year round culling strategy)	Spain, South-Central	542.52	Mediterranean ecosystem	2008	nr	2008	nr	direct observation	Proportion removed	0.5 approximately	Culling effectively reduced tuberculosis prevalence in wild boar, while Aujezky's disease prevalence remained unaffected. No density estimates before and after intervention were available
Boadella et al., 2012b		X						Drive hunts and stand hunting	Spain, South-Central	7.23	Mediterranean ecosystem	2005	nr	2011	nr	Transect	Proportion removed	0.5 approximately	Culling effectively reduced tuberculosis prevalence in wild boar, while Aujesky's disease prevalence remained unaffected. No density estimates before and after intervention were available
Boadella et al., 2012b			X					Capture and moving of females and juveniles	Spain, South-Central	26.9	Mediterranean ecosystem	2005	nr	2011	nr	Not available	Proportion removed	0.5 approximately	Animal removal effectively reduced. Tuberculosis prevalence in wild boar, while Aujezky's disease prevalence remained unaffected No density estimates before and after intervention were available and trapping technique was not described
Alexandrov et al., 2011			X					Wooden traps with wire fencing and maize baiting	Bulgaria, river Danube in the north-eastern part	25	Forest and agricultural land (maize)	2009	8	2010	1	Not reported	Harvest rate	79.00	Very efficient. Up to seven wild boar could be trapped in one trap. Feasible in areas where hunting is not recommended (viraemic animals that should not spread)

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Hafeez et al., 2007			X					Panel trap, Fahad trap and Loop trap were tested	Pakistan, Faisalabad Division	nr	Forest, Grassland and Marshland	2002	nr	2002	nr		Trap efficacy	0.49–0.71	Panel trap 70.83% efficacy; Fahad trap 48.57%; Loop trap 53.84%
Gaskamp et al., 2018			x					Trapping and removal of wild boar			Agricultural land					Number of removed animals/ number of estimated animals			The removal and intensive trapping are a solution to decrease the wild boar population. Intensive control will be needed for the long-term effective reduction in wild pig numbers because wild pigs have high reproductive rates, high survival and can recolonise areas rapidly
Ueckermann et al., 1972						x		Wild boar : maintenance of age structure, maximum age of 10 years	Germany, Ittenbach, Laagshof	100 ha		1953		1970					Even when animals under 1 year of age constituted 72.5–74.2% of the annual harvest, a population increase could not be prevented. Mean annual increase was 4 to 5 young per female
Feral swine																			
Gentle and Pople, 2013	X							Commercial hunting	Australia, South-western Queensland,	246–6,000	Mainly grassland with some Forest	2007	10	2010	4	Aerial surveys	Harvest rate	0.20	Commercial harvesting is inefficient for population reduction. Harvest rates of > 50% are needed over several years to reduce populations
Saunders, 1993a,b		X						Helicopter shooting	Australia, New South Wales, Oxley station	120	Forest, grassland and marshland	1985	4	1985	4	Aerial surveys	Percentage population reduction	0.8	Recovery of 77% of the population after 1 year. More than one control programme should be carried out to obtain sustainable reduction
Saunders, 1993a,b		X						Helicopter shooting	Australia, New South Wales, Oxley station	120	Forest, grassland and marshland	1986	4	1986	4	Aerial surveys	Percentage population reduction	0.65	Recovery of 77% of the population after 1 year. More than one control programme should be carried out to obtain sustainable reduction
Davis et al., 2018		x						Hunting, aerial gunning			Agricultural land								Populations were reduced by 31% for the first flight, by 56% after two flights and 67% after three flights. Removal rates varied by habitat (0.05 per hour in open habitats compared with 0.03 in shrubby habitats) and by gunning team (0.03 versus 0.05)

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Katahira et al., 1993		X	X		X			Drive hunts with dogs, followed by helicopter hunting, trapping and snaring	United States, Hawaii, Volcanoes National Park	78	Rainforest, Mixed	1983	11	1989	2	Transect	Proportion removed	1	Pigs were controlled primarily by drive hunts with dogs, followed by other method for remnant pigs. The mean effort needed to eradicate 175 pigs was 20 worker hours/ animal. Eradication occurred in 3 years. Transect useful for monitoring population
Burt et al., 2011		X						Drive hunts with dogs	United States, California, National park	249	Mediterranean ecosystem	1990	11	2000	3	Transect			Model based on hunting data showed that strategy of intense harvest for 5 years will likely achieve eradication of many insular feral pig populations
Barron et al., 2011		X						Drive hunts with dogs	United States, Hawaii, Honomanu Makai	3	Forest	2007	10	2008	2	Capture–recapture	Proportion removed	1	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however was not prevented
Barron et al., 2011		X						Drive hunts with dogs	United States, Hawaii, Waikamoi Preserve	8	Forest	2007	10	2008	2	Capture–recapture	Proportion removed	1	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however was not prevented
Barron et al., 2011		X						Drive hunts with dogs	United States, Hawaii, Kamakou Preserve	4	Forest	2008	3	2008	7	Capture–recapture	Proportion removed	97.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however was not prevented
Barron et al., 2011		X						Drive hunts with dogs	United States, Hawaii, Moloka'i South Slope	10	Forest	2008	3	2008	7	Capture–recapture	Proportion removed	53.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however was not prevented
Barron et al., 2011		X						Drive hunts with dogs	United States, Hawaii, Waikamoi Preserve	2	Forest	2008	3	2009	7	Capture–recapture	Proportion removed	89.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however was not prevented

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Barron et al., 2011		X						Drive hunts with dogs	United States, Hawaii, Kapunakea Preserve	5	Forest	2008	2	2008	3	Capture–recapture	Proportion removed	65.00	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however was not prevented
Barron et al., 2011		X						Drive hunts with dogs	United States, Hawaii, Waikamoi Preserve	6	Forest	2007	10	2008	2	Capture–recapture	Proportion removed	nr	Intensive hunting reduced pig abundance to zero or near-zero in most of the control zones. Reinvasion, however was not prevented
Ditchkoff et al., 2017		X						Not specified	United States, West-Central Georgia, Fort Benning conservation branch	36	Coastal vegetation	2007	9	2008	2	Camera trapping	% increase density	1.1	Pig population increased during the bounty programme, mainly due to baiting and biased shooting of trophy males
Ditchkoff et al., 2017		X	X					Night hunting, trapping and bait usage allowed	United States, West-Central Georgia, Fort Benning conservation branch	36	Coastal vegetation	2007	7	2008	2	Camera trapping	% increase density	1.52	Pig population increased during the bounty programme, mainly due to baiting and biased shooting of trophy males
Engeman et al., 2014		X						Not reported	United States, Florida, Avon Park air force range	400	Forest, grassland and marshland	2009		2012		Passive tracking index	Reduction estimated with passive tracking index	1.00	
Gioeli et al., 2015		X						Drive hunts	United States, Florida,		Nr	2013	10	2014		Hunting bag		123 removed	
McIlroy and Saillard, 1989		X	X					Trapping, hunting with dogs	Australia, Capital Territory, Orroral Valley, Namadgi National Park	11	Forest and Grassland	1986	9	1986	12	Direct observation	Culling efficiency (number of animals killed per animals seen during battues)	27	The cost of hunting was *c.* US$312 per pig

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
McIlroy and Gifford, 1997		X	X					Trapping, hunting with dogs	Australia, Capital Territory, Orroral Valley area, Namadgi National Park, ACT	11	Forest and grassland	1989	6	1990		Radio-tracking	Contact rate with Judas pigs	80.00	Expensive equipment and special skills needed to precisely locate collared individuals. However, high efficacy to reduce population
McCann and Garcelon, 2008		X	X					Trapping, hunting with dogs	United States, California, Pinnacles National Monument	57	Forest, Mixed	2003	10	2006	3	Transect	Proportion removed	100	Trapping techniques removed most pigs, but a combination of techniques was required for eradication
Reidy et al., 2011		X	X					Box traps and helicopter hunting	United States, Texas, Fort Hood	10	Marshland	nr	nr	nr	nr	Direct observation	Proportion removed	31	2–3 weeks of trapping and 1 day of shooting swine from a helicopter resulted in removal of 31–43% of the estimated feral swine population
Reidy et al., 2011		X	X					Box traps and helicopter hunting	United States, Texas, Rob and Bessie Welder Wildlife Refuge	32	Marshland	Nr	Nr	Nr	Nr	Direct observation	Proportion removed	43	2–3 weeks of trapping and 1 day of shooting swine from a helicopter resulted in removal of 31–43% of the estimated feral swine population
Hone and Stone, 1989		X	X					Exclusion fencing, drive hunts with dogs, trapping, snaring and baiting	United States, Hawaii, Volcanoes National Park	929	Mixed	1980	nr	1983	nr	Dung counts	Nr		Pigs were eliminated from 3 of 9 management unit. Cost of removing the last animals is high
Saunders, 1993a,b			X					16 portable traps over 63 bait stations	Australia, New South Wales, Kosciusko National Park	300	Forest and grassland	1988	nr	1988	nr	Capture–recapture	Proportion removed	0.28	Local characteristics and the time of year had significant effects on trapping rate. Higher rates observed when traps placed in baiting area

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Hone and Stone, 1989			X				X	2% sodium hydroxide	Australia, Namadgi National Park	910	Mixed	1985	6	1987	11	Dung counts	nr		Significant reduction of pig abundance. No poisoning effects were observed on non-targeted species
Anderson and Stone, 1993				X	X			Cable snares 3–96 m in length and 0.3 cm in diameter	United States, Hawaii, Kipahulu Valley, lower unit	6	Forest	1979	11	1980	3	Transect	% reduction of wild boar per km^2	0.97	A mean of seven worker hours–pig to remove 175 animals from the more densely populated lower unit. We recommend that transects be used in the early stages of an eradication programme to determine population density
Anderson and Stone, 1993				X	X			Cable snares 3–96 m in length and 0.3 cm in diameter	United States, Hawaii, Kipahulu Valley, Upper unit	8	Forest	1979	11	1980	3	Transect	% reduction of wild boar per km^2	0.99	A mean effort of 43 worker hours–pig was used to remove 53 pigs from the upper management unit. We recommend that transects be used in the early stages of an eradication program to determine population density
Killian et al., 2006						X		GnRH immune-contraceptive vaccine	United States, Florida, (controlled trial)		Captive	2002	1	2002	12	Fertility reduction	% pregnant. % weight testis		Single injection effective in reducing fertility. Future research needed on residues in meat and oral form
McIlroy and Saillard, 1989							X	2% sodium hydroxide	Australia, Capital Territory, Namadgi National Park, Gudgenby area	225	Forest, grassland and marshland	1986	5	1986	5	Radio-tracking	Proportion removed	0.91	12/14 pigs carrying transmitters died. Foxes died that fed on the corpses of the poisoned pigs
McIlroy and Saillard, 1989							X	2% sodium hydroxide	Australia, Capital Territory, Namadgi National Park, Boboyan Valley	140	Forest, grassland and marshland	1986	5	1986	5	Radio-tracking	Proportion removed	1	All pigs carrying transmitters died. Foxes died that fed on the corpses of the poisoned pigs

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
McIlroy and Gifford, 1997							X	2% sodium hydroxide	Australia, Capital Territory, Orroral Valley area, Namadgi National Park	11	Forest and grassland	1990	10	1990	12	Radio-tracking	Proportion removed	1	All pigs followed up died of poisoning
Twigg et al., 2005							X	Sodium fluoroacetate	Australia, Western Australia	150	Riverland and grassland	2004	8	2004	8	Direct observation	Daily sighting index	89.00	Pig activity/abundance was reduced by 89% (81–100%) and no bait uptake by non-target species
Twigg et al., 2005							X	Sodium fluoroacetate	Australia, North-western Australia	150	Riverland and grassland	2005	8	2005	8	Direct observation	Daily sighting index	90.00	Pig numbers had been reduced by ~ 90% within four days. Population recovery of 20–23% of the 2004 pre-baiting level
McIlroy and Saillard, 1989							X	2% sodium hydroxide	Australia, Western Australia, Namadgi National Park, Orroral Valley	19	Forest, grassland and marshland	1986	5	1986	5	Radio-tracking	Proportion removed	0	None of the pigs with transmitters died
McIlroy and Saillard, 1989							X	2% sodium hydroxide	Australia, Western Australia, Honeysuckle Creek area, Namadgi National Park	5	Forest and grassland	1986	9	1986	12	Radio-tracking	Proportion removed	0.14	The cost of poisoning was *c.* US$237 per pig
McIlroy and Saillard, 1989							X	2% sodium hydroxide	Australia, Western Australia, Orroral Valley, Namadgi National Park	11	Forest and grassland	1986	9	1986	12	Radio-tracking	Proportion removed	0.19	The cost of poisoning was *c.* US$237 per pig

Reference	Methods							Methodshort description	Location	Area size (km2)	Landscape	Period				Method estimation density	Reduction measure	Reported reduction statistic	Short comment
	Recreational hunting	Depopulation Hunting	Trapping	Fencing	Snaring	Fertility control	Poisoning					Start_year	Start_month	End_year	End_month				
Snow et al., 2017							X	HOGGONE	United States, Texas, Kerr Wildlife Management Area (controlled trial)	0	nr	2015	10	2016	6	Camera trapping	Bait efficacy (%)	0.98	The bait proved lethal, acutely acting and stable in experimental conditions. Field studies needed to investigate any potential non-target risks posed by carcasses of wild pigs that have succumbed to sodium nitrite
Cowled et al., 2006							X	Sodium fluoroacetate	Australia, Welford National Park	nr	Mixed	2005	1	2005	1	nr	% reduction of wild boar per km^2	0.73	Almost all feral pigs (34 of 36) died less than 17 h after bait consumption but of non-target poisoning of other free-ranging wildlife in areas where feral pigs are baited possible not excluded
Snow et al., 2019							x	The population of wild pigs are exposed to a simulated toxic bait to gain insight on potential population reductions	nr	16.8 km		nr		nr		Radio-tracking	% reduction of wild boar per km^2	91	Toxic baits may be an effective tool for reducing wild pig populations. Bait sites spaced in 0.75 km have the maximal response, in 0.75–1.5 km they obtain a optimal response and the wild pigs ranging ≥ 3 km away were susceptible. Toxic baits may be an effective tool for reducing wild pig populations especially if used as part of an integrated pest management strategy
Poche et al., 2018							x	Use of bait containing low doses of warfarin 0.001–0.005%	United States, Texas, Amarillo			nr		nr			Bait efficacy (%)	97.8%-96.2%	The study suggest low-dose warfarin bait, presented in species-specific feeders, can effectively reduce wild pig numbers and pose minimal risk to non-target wildlife and domestic animals. A product containing warfarin may provide another management tool in reducing wild pig problems

nr: not reported.
YELLOW ROWS: new updates found in extensive review update in 2019.

Reference	Method					Method description	Location	Area size (km^2 if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Wild boar																	
Santilli and Stella, 2006	X					Electric fence	Italy, Tuscany	20	Agricultural land	1999	5	2003	11	Crop damage	% crop damage reduction	93	Damage decreased of 93% during the 5 years following the fence installation
Vidrih and Trdan, 2008	X					Electric fence	Slovenia, Postojna, Western High Karst hunting territory	0.12	Agricultural land	2005	7	2005	10	Crop damage	% crop damage reduction	100	Fences were 100% successful in keeping wild boar from entering the field
Boadella et al., 2012a	X					Fenced hunting grounds	Spain, Central Spain, Ciudad Real	19,813	Mediterranean ecosystem	1998	nr	2010	nr	Hunting bag	Effect on disease prevalence	−0.709	Risk factor analysis highlighted that the presence of the disease (*Trichinella* spp.) was lower in fenced areas ($\beta = -0.709$)
Geisser and Reyer, 2004	X					Electric fence	Switzerland, Thurgau	860	Forestland and agricultural land	1994	nr	1996	nr	Crop damage	% crop damage reduction	0	Fences did not decrease the total damage rather they caused the animals to shift their activities to less protected regions in the area (+27% in total damage)
Sapkota et al., 2014	X					Electric fence	Nepal, Chitwan National Park	23	Forestland and agricultural land	nr	nr	nr	nr	Crop damage	% crop damage reduction	78	Crop damage caused by wild boar and other wildlife were significantly reduced after the installation of the fence
Mihalik et al., 2018	x					Fence highway. Set up the genetic profile of the wild boar	Hungary M3 Highway	nr	nr	nr	nr	nr	nr	40 samples (blood, meat, fur and hide)			The two groups are only slightly separated and still belong to the same population. This situation may be due to the recent building of M3, or to the functioning wildlife underpasses and the good mobility of wild boar

Reference	Method					Method description	Location	Area size (km² if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Kopler and Malkinson, 2018	x					Welded wire mesh fence with horizontal and vertical pitch of 15 cm and overall height of 1.6 m to 2.0 m	Israel, north-eastern region	6 enclosures of min. 40 ha		1990		1991		Transect walks	Mountain gazelle and wild boar faeces pellet counts and mean abundance were greater outside fenced enclosures		Protective fences affect landscape functionality by altering wildlife abundance patterns. Mammal species response to presence of the protective fence is species-specific and related to vagility and body size
Negus et al., 2019	x					Use a typical cattle exclusion fence , a specific pig exclusion fence and no fence	Australia, Archer River and Northern Australia		Marshland					Pig damage scores per transect	Mean pig damage score	Significant differences between mean pig damage score p = 0,0001 (only for sites with intact fences)	Wetlands with functioning pig exclusion fences had no physical pig damage. Wetlands with compromised pig exclusion fences had damage that was statistically equivalent to sites without fences or with cattle exclusion fences, or even worst damage
Vilardel et al., 2014		x				Commercial aluminium devices containing wild boar repellent Stop and in addition to new devices containing the Schwegler© carnivore repellent Jabalí© Hagopur GmbH		8 rectangular 625-m^2 plots	Grassland	6	2006	9	2006			The only noticeable effect of the combination of repellents was to delay predation, although after 4 days almost all protected nests had been depredated	98.8% of the nests in the four control plots and 97.5% in the four treatment plots were depredated after 4 days

Reference	Method					Method description	Location	Area size (km^2 if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Sreeja and Mani, 2017	x	x				Olfactory repellent (Bo Rep) and physical barrier with nylon net	India, Kerala		Agricultural land	2013		2015				Increased yield of crop of 22.96% to 29.9%	Using repellent and physical barriers increased crop yield
Schlageter and Haag-Wackernagel, 2012b		X				Predator odour repellent	Switzerland, Basel-Land	518	Forestland and agricultural land	2007	7	2008	12	Direct observation	% effectiveness of the barrier	0.4	The odour repellent reduced the probability of wild boar visits at the luring sites by 0.4%, but the effect was not significant
Schlageter and Haag-Wackernagel, 2012a		X			X	Pellets with phosphorous acid	Switzerland, Basel-Land	518	Forestland and agricultural land	nr	nr	nr	nr	Crop damage	% crop damage reduction	0	The repellent did not have a significant effect on the frequency of damages events, nor it prolonged the interval between two consecutive events
Piechowski, 1996		X				Predator odour repellent	Poland, Masovian voivodship	0.0188	Forestland	1995	4	1995	5	Animal traces	% effectiveness of the barrier	0	A weak response of the product was reported
Piechowski, 1996		X				Predator odour repellent	Poland, Lodz voivodship	0.01	Forestland	1994	10	1995	5	Crop damage	% crop damage reduction	0	Different wildlife species were observed sporadically over the barrier
Piechowski, 1996		X				Predator odour repellent	Poland, Upper Silesia	3.2 km	Forestland	1994	12	1995	3	Animal traces	% effectiveness of the barrier	0	Wild boar specifically feeding signs were reported all over the barrier
Piechowski, 1996		X				Predator odour repellent	Poland, Upper Silesia	0.4 km	Forestland	1994	12	1995	3	Animal traces	% effectiveness of the barrier	0	Wild boar were observed all over the barrier
Piechowski, 1996		X				Predator odour repellent	Poland, Warmian-Masurian	0.01	Forestland	1994	10	1995	5	Crop damage	% crop damage reduction	1.6	Reported damage were caused by different wildlife species

Reference	Method					Method description	Location	Area size (km^2 if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Wegorek and Giebel, 2008		X				Human odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	5	2007	5	Crop damage	% crop damage reduction	55	The repellent was effective in keeping the animals away from the crops, even if a certain grade of accustomisation was recorded
Wegorek and Giebel, 2008		X				Human odour repellent	Poland, voivodship	0.01	Agricultural land	2007	8	2007	9	Crop damage	% crop damage reduction	65	The repellent was effective in keeping the animals away from the crops, even if a certain grade of accustomisation was recorded
Wegorek and Giebel, 2008		X				Human odour repellent	Poland, voivodship	0.002	Forestland	2007	3	2007	4	Crop damage	% crop damage reduction	55	The repellent was effective in keeping the animals away from the crops, even if a certain grade of accustomisation was recorded
Wegorek and Giebel, 2008		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	8	2007	9	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel, 2008		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	5	2007	5	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel, 2008		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	5	2007	5	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel, 2008		X				Predator odour repellent	Poland, Wielkopolskie	0.002	Forestland	2007	3	2007	4	Crop damage	% crop damage reduction	85	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel, 2008		X				Predator odour repellent	Poland, Wielkopolskie	0.01	Agricultural land	2007	8	2007	9	Crop damage	% crop damage reduction	100	The repellent was effective in keeping the animals away from the crops
Wegorek and Giebel, 2008		X				Predator odour repellent	Poland, Wielkopolskie	0.002	Forestland	2007	3	2007	4	Crop damage	% crop damage reduction	90	The repellent was effective in keeping the animals away from the crops

Reference	Method					Method description	Location	Area size (km^2 if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Wegorek et al., 2014		X				Human odour repellent	Poland, Wielkopolskie	nr	Forestland and agricultural land	2012	3	2013	8	Direct observation/ animal traces	% effectiveness of the barrier	0	The product has proven to be not effective
Wegorek et al., 2014		X				Odour repellent	Poland, Wielkopolskie	nr	Forestland and agricultural land	2012	3	2013	8	Transect	% effectiveness of the barrier	0	The product was effective only for a 2–3 days period, then the animals get used to it
Wegorek et al., 2014		X				Human odour repellent	Poland, Zachodniopo morskie	nr	Forestland and agricultural land	2012	3	2013	8	Direct observation/ transect	% effectiveness of the barrier	0	The product has proven to be not effective
Wegorek et al., 2014		X				Odour repellent	Poland, Zachodniopo morskie	nr	Agricultural land	2012	3	2013	8	Transect	% effectiveness of the barrier	0	The product was effective only for a 2–3 days period, then the animals get used to it
Bil et al., 2018		X				Isovaleric acid odour repellent	Czechia	1936 m	Road section	2014	9	2016	10	Carcasses/ crash reported	% crop damage reduction	26–43	The reduction of WVC was 26–43%, therefore the odour repellent helps to mitigate the number of accidents
Sakthivel Rao et al., 2013		X				Ricinoleic acid odour repellent	India, Telangana, Hyderabad	0.000016	Agricultural land	nr	nr	nr	nr	Crop damage	% crop damage reduction	100	After the repellent treatment, no damage was recorded despite the presence of the animals around the crops
Rao et al., 2017		x				Castor crops odour repellent	India , Tandur		Agricultural land						% crop damage reduction	74%	Strong odour emitted by castor crop as border/barrier resulted in increase of yield and minimised wild boar entry in to the maize fields
Schlageter and Haag-Wackernagel, 2011			X			Solar blinkers near luring sites	Switzerland, Basel-Land	518	Forestland and agricultural land	2007	1	2005	1	Camera trapping	% effectiveness of the barrier	8.1	Blinkers reduced the probability of wild boar visits at the luring sites by 8.1% but the effect was not significant

Reference	Method					Method description	Location	Area size (km^2 if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Dakpa et al., 2009			X	X		Shrill electrical sound and bright light	Bhutan	nr	Agricultural land	2008	5	2009	2	Crop damage	% crop damage reduction	67	The device is effective when functioning smoothly. It is recommended as short-time measure
FERAL PIGS																	
Lavelle et al., 2011	X					Hog panel mesh	United States, Texas, Kingsville	0.0038	Grassland	2009	7	2009	9	Direct observation	% effectiveness of the barrier	96.7/83/100	Hog panel fences were estimated to be 96.7 effective if humans entering the enclosures, 83% if humans walking discharging paintball projectors and 100% effective when the animals were pursued by gunners in a helicopter
Reidy et al., 2008	X					Electric fence, agriculture trial	United States, Texas, King Ranch	24.35	Agricultural land	2006	5	2006	6	Crop damage	% crop damage reduction	64	The mean percentage of crop damage at harvest was 64% less for electric fence treatments than controls
Reidy et al., 2008	X					Electric fence, rangeland trial	United States, Texas, San Patricio County, Sinton	31.57	Marshland	2006	3	2006	4	Camera trapping	% intrusion reduction	49/26	Mean number of daily intrusions by pigs during the period with electrified fence were 49% less than during period without electric fence, and 26% less than during period after electrification (non-electrified fence)

Reference	Method					Method description	Location	Area size (km² if not specified)	Landscape	Period				Method estimation effectiveness	Separation measure	Results	Short comment
	Fencing	Odour	Light	Sound	Gustatory					Start year	Start month	Stop year	Stop month				
Reidy et al., 2008	X					Electric fence, captive trial	United States, Texas, Kleberg County, Kingsville	0.0051	Artificial environment	2005	10	2005	11	Camera trapping	% effectiveness of the barrier	65/69	The mean number of crosses during the period without electric fencing was 65% greater than the period with electrified fence and 69% greater than the period after electrification (non-electrified fence)
Schmidt, 1986	X					Electric fence	Indonesia, West Sumatra	0.32	Agricultural land	nr	nr	nr	nr	Farmer surveys/direct observation	% effectiveness of the barrier	100	After the fencing installation, no feral pigs entered the protected area, despite their presence around the crops
Jeyasingh and Davidar, 2003	X					Electric fence	India, Tamil Nadu, Kalakad-Mundanthurai Tiger Reserve	26 km	Forestland and agricultural land	1998	12	1999	3	farmer surveys	% crop damage reduction	0	No significant difference in the loss estimates, raiding frequency and wild boar group size between the fenced and unfenced villages

YELLOW ROWS: new updates found in extensive review update in 2019; nr: not reported; WVC: wildlife-vehicle collisions.