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African swine fever: Why the situation in Germany is not comparable to that in the Czech Republic or Belgium

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Abstract

After the first occurrence of African swine fever (ASF) in Germany in September 2020, control measures were implemented that resembled those taken in the Czech Republic and Belgium, the only two countries that succeeded in eliminating ASF from their territory so far in the current epidemic. In the present study, the epidemiological course of ASF in the first 6 months since introduction in these three countries is compared. Within 6 months, Germany experienced more cases than the Czech Republic and Belgium. The affected area in Germany, measured using minimal convex polygons, is much larger than the respective areas in the Czech Republic and in Belgium. All cases in the Czech Republic and in Belgium clustered in one single defined area, suggesting point-source introductions, whereas in Germany four distinct spatial clusters were observed, which indicates that multiple incursions had occurred along the border with Poland. While the overall course of the disease was comparable, when individual clusters were considered, the summarized data showed clear differences between the situation in Germany compared to that in the Czech Republic and Belgium. Germany experienced several independent introductions, caused by continuous infection pressure along the border to Poland, while the infection was only introduced on a single occasion each into the Czech Republic and Belgium. These differences may require appropriate adaptation of control measures, in particular concerning fencing along the border.

KEYWORDS
african swine fever, emerging, epidemiology, surveillance, wild boar

1 | INTRODUCTION

African swine fever (ASF) is a devastating disease of domestic pigs and wild boar with a tremendous socio-economic impact (Penrith et al., 2004). The occurrence of ASF in domestic pigs or wild boar in a country usually leads to substantial trade restrictions regarding pigs and porcine products.

The first case of ASF in a wild boar in Germany was confirmed on 10th September 2020 at a distance of approximately 6 km to the Polish border. Only 3 weeks later, an ASF-positive wild boar was found 60 km north of the first case, also close to the Polish-German border at a distance of less than 2 km. One month later (31 October 2020), an infected wild boar was detected approximately 60 km south of the first case less than 200 m away from the Polish-German border (Sauter-Louis et al., 2020). According to the estimated minimum post-mortem intervals (Probst et al., 2020), which were estimated based on the decomposition status of the wild boar carcasses at the time, when they were found, ASF virus (ASFV) was most likely introduced into Germany in the beginning of July 2020 at the latest. With the detection of the first cases, various control measures were applied with the aim of preventing further spread of the disease. Based on the successful elimination of ASF in the Czech Republic and in Belgium, the measures applied in these countries served as guideline for the German authorities. Thus, the first control measures focused on defining affected areas, intensifying the search for carcasses and fencing the areas at risks (Food & Agriculture Organization of the United Nations et al., 2019; Marcon et al., 2020).

In the Czech Republic, the first ASF cases in wild boar were detected in June 2017 and in Belgium in September 2018, respectively (Linden et al., 2019; Šatrán, 2019). Only wild boar were affected in both countries and no outbreaks in domestic pigs occurred. This has so far also been the case in Germany[1]. In addition, the first cases identified in the two countries emerged several hundred kilometres away from the closest reported ASF case, suggesting a human-mediated disease introduction over a long distance (Food & Agriculture Organization of the United Nations et al., 2019; Saegerman, 2018; Šatrán, 2019). Consequently, the control measures applied in these two countries were tailored to control and eliminate a focal introduction of ASF (point-source exposure). They were based on the establishment of various zones, which were defined around the respective index cases and regularly adapted, when new cases were detected outside the previously defined zones. The main aim was to minimize the risk of disease spread (Dellicour et al., 2020; Food & Agriculture Organization of the United Nations et al., 2019). Within 1 to 2 years, both countries had successfully eliminated ASF (World Organisation for Animal Health, 2020).

In Poland, where ASF has been circulating since 2014, only the eastern part of the country and the Warsaw region were affected until 2019. It has been hypothesized that the infection was originally introduced by infected wild boar that had crossed the border between Poland and Belarus (Frant et al., 2020; Pejsak et al., 2014, 2018; Smietanka et al., 2016). In November 2019, however, new ASF cases in wild boar were reported from Western Poland, about 270 km distant from the nearest ASF case in the country, suggesting a human-mediated virus spread (Mazur-Panasiuk et al., 2020). Since the detection of the first ASF-positive wild boar in Western Poland, surveillance measures resulted in the detection of 1683 ASF-positive wild boar in that area until mid-2020 (Mazur-Panasiuk et al., 2020). One of the cases was found only 10.4 km away from the Polish-German border (Sauter-Louis et al., 2020). According to Pejsak et al. (2018), the region bordering to Germany is the area with the highest wild boar density in Poland. It can be assumed that wild boar regularly cross the border between the two countries. It was, therefore, not surprising that the first German ASF case was detected only 6 km away from the German-Polish border (Sauter-Louis et al., 2020).

[1] First outbreaks of ASF in domestic pigs were detected in Brandenburg, Germany, on 15 July, 2021.

The successful ASF elimination strategies implemented in the Czech Republic and in Belgium were used as a template for designing control measures in Germany. However, in contrast to the Czech Republic and Belgium, where ASF was locally introduced in a single event in each country, Germany faces a constant infection pressure along the border with the affected region in Poland. Thus, the epidemiological situation in the three countries are different, resulting in the requirement to adapt measures to the actual situation in Germany and Western Poland to prevent further spread of ASF in the wild boar population.

To address these questions, we compared the course of the ASF epidemic in the first 6 months between the three countries.

2 | MATERIALS AND METHODS

ASF wild boar surveillance data from the Czech Republic, Belgium, and Western Poland were obtained from the European Animal Disease Information System (ADIS) or the former Animal Disease Notifications System. German ASF surveillance data were taken from the National Animal Disease Notification System (Tierseuchennachrichtensystem, TSN). These data are also used to inform ADIS. The extracted records contained information on the date and the location (coordinates) of ASF-infected wild boar (regardless of the diagnostic method) in each of the countries for the first 180 days after introduction, except for Western Poland, where data were extracted from the first occurrence in November 2019 to September 2020 (300 days).

The distances between the first occurrence in Germany to the cases of ASF in wild boar in Western Poland were calculated using the R (R Core Team, 2017) package sp (Pebesma et al., 2005) as previously described (Sauter-Louis et al., 2020). A moving average distance was calculated using a window size of 14 days, that is, a series of all cases of ASF occurring in Western Poland in the previous 14 days was created. The mean and the standard deviation of this average distance were calculated from day 50 to 200.

The cumulative numbers of cases detected in the first 6 months of the epidemics in the Czech Republic, Belgium, and Germany were separately calculated for each country. For data display, the date of the first occurrence was set as day 0 in each country.

Clusters in the geographical distribution of the cases were derived using a hierarchical clustering approach that defines clusters that occurred within a specified distance. The method of agglomerative clustering (agglomerative nesting, AGNES) has been used, employing complete linkage clustering, whereby pairwise distances between the elements in one cluster and elements in the other clusters are computed (Kassambara, 2017).

The size of the affected area was estimated using the minimum convex polygon (MCP) of cases of ASF. The MCP technique, often used in home-range analyses (Boyle et al., 2009; Kumbhojkar et al., 2020), is a nonparametric method using the locations of all observed positions by creating the smallest convex polygon (Anderson, 1982). The MCPs were calculated per day, including all cases that had occurred until that day. For the cases in each of the identified clusters, the MCPs were calculated and the sums of these MCPs calculated for each country. To

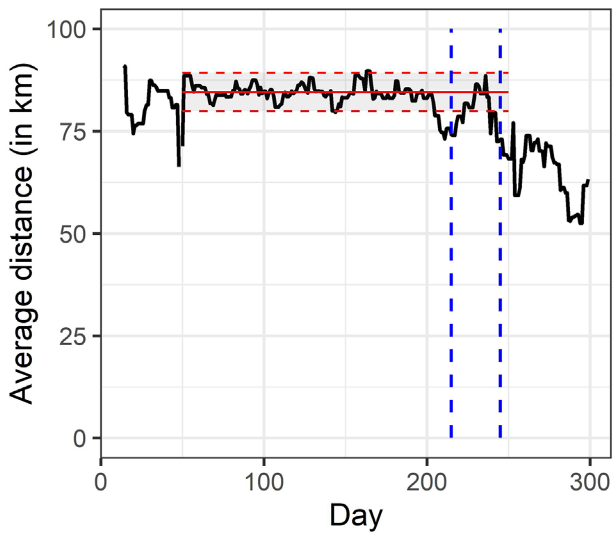

FIGURE 1 Average distance between the locations of the first ASF case in Germany and ASF cases in wild boar in Western Poland (using a moving window of 14 days prior to the day calculated). The red line represents the mean of the average distance between day 50 and 200 with the 95% confidence interval containing two standard deviations of this average distance (dashed red lines). The blue dashed lines represent the time of the presumed first introduction of ASF into Germany (mid-June to mid-July 2020)

compare the numbers of ASF-positive wild boar per kilometre square affected area, the cumulative sum of the ASF-positive wild boar cases was divided by the cumulative area of the MCPs. Data were stored and managed in Excel (Microsoft, version 2019). Calculations were performed and figures prepared using R Version 4.0.3 (R Core Team, 2017). Clusters were identified using the function hclust in R, after displaying the locations using the packages sp and rgdal (Keitt et al., 2010; Pebesma et al., 2005). Convex polygons were calculated using the R package geosphere (Hijmans et al., 2019).

The R package ggplot2 was used to prepare figures (Wickham, 2016) and a map produced with ArcMap (version 10.5.1., ESRI).

3 | RESULTS

The ASF case closest to the first ASF-infected wild boar detected in the Czech Republic in June 2017 was observed in a wild boar in the Ukraine at a distance of more than 300 km. The equivalent distance between the first ASF case in Belgium in September 2018 was more than 800 km from the nearest previous ASF cases in the Czech Republic. In Germany, the first ASF case in a wild boar was detected only 30 km away from the closest known case in Western Poland (detected in February 2020). The average distance of all cases reported from Western Poland before September 2020 ranged between 75 and 90 km from the location of the first ASF case in Germany (Figure 1). Especially from early-June 2020 onwards, the average distance decreased and reached 52 km shortly before the detection of the first case in Germany. During the presumed time of introduction, the average distance was partially below the lower 95 % confidence limit of the distance observed between day 0 and 200.

All cases in the Czech Republic and in Belgium clustered in a single defined area within the country. In Germany, four distinct spatial clusters of ASF cases were observed (Figure 2). The first case in cluster 1 was confirmed on 10th September 2020. By the end of September 2020, another area, approximately 60 km north of the first case, but also close to the border with Poland, was affected. In early March 2021, a case in the region between cluster 1 and 2 was detected, which was associated with cluster 2 in the hierarchical cluster analysis. This case was also located close to the border with Poland. In cluster 3, the first ASF-positive carcass was detected by the end of October 2020. At the same time, a first case was identified in cluster 4 in Saxony, approximately 60 km south of cluster 1 (Figure 2).

In the beginning, i. e. until day 50, the number of cumulative cases in cluster 1 increased in a similar way as the numbers in the Czech Republic and Belgium (Figure 3A). In contrast, the other German cluster areas showed slower increases. The numbers of the Czech cluster showed a flattening curve from day 50 onwards, while this is not the case for Belgium during the first 180 days. The cumulative number of cases in cluster area 4 (Saxony) remained low until day 90, when it started to rise.

The Czech Republic had the smallest affected area of only 46 kmš in the MCP at the end of the study period (Figure 3B). The sizes of the MCPs of the four individual cluster areas in Germany varied between the areas found in the Czech Republic and Belgium with similar increases over time. Cluster areas 1 and 2 showed a flattening in the curve from day 50 to day 110. For Belgium, such a flattening of the curve could not be observed during the study period.

When calculating the numbers of ASF-positive wild boar per affected area (Figure 3C), a wide range of values was obtained between the different areas. While the Czech Republic had the highest numbers with 4 to 6 ASF-positive wild boar per kilometre square affected area, the four cluster areas in Germany varied between 0.5 and 5 ASF-positive wild boar per kilometre square affected area. Both, cluster areas 2 and 4, showed a marked decrease in their curves, which were due to the increase in area, indicating that new cases had occurred outside the previously observed areas.

When the ASF case numbers in all four German cluster areas were accumulated and compared to those in the Czech Republic and Belgium, the numbers of the cumulative cases in the Czech Republic and Germany were very similar until day 45, while Belgium had a lower increase in the beginning (Figure 4A). However, from day 45 onwards, the numbers in Germany rose more rapidly than the numbers in the Czech Republic and Belgium.

When the sizes of the affected areas in each country were compared using the sums of the four individual cluster areas for Germany, the Czech Republic had the smallest area (46 kmš) affected at the end of the study period, while it was 463 kmš in Belgium and 628 kmš in Germany. Until day 60, the affected area in Belgium increased faster than that in Czech Republic and the summarized cluster areas in Germany (Figure 4B). Between days 60 and 133, the affected areas in Germany and Belgium were similar. On day 133, a new introduction

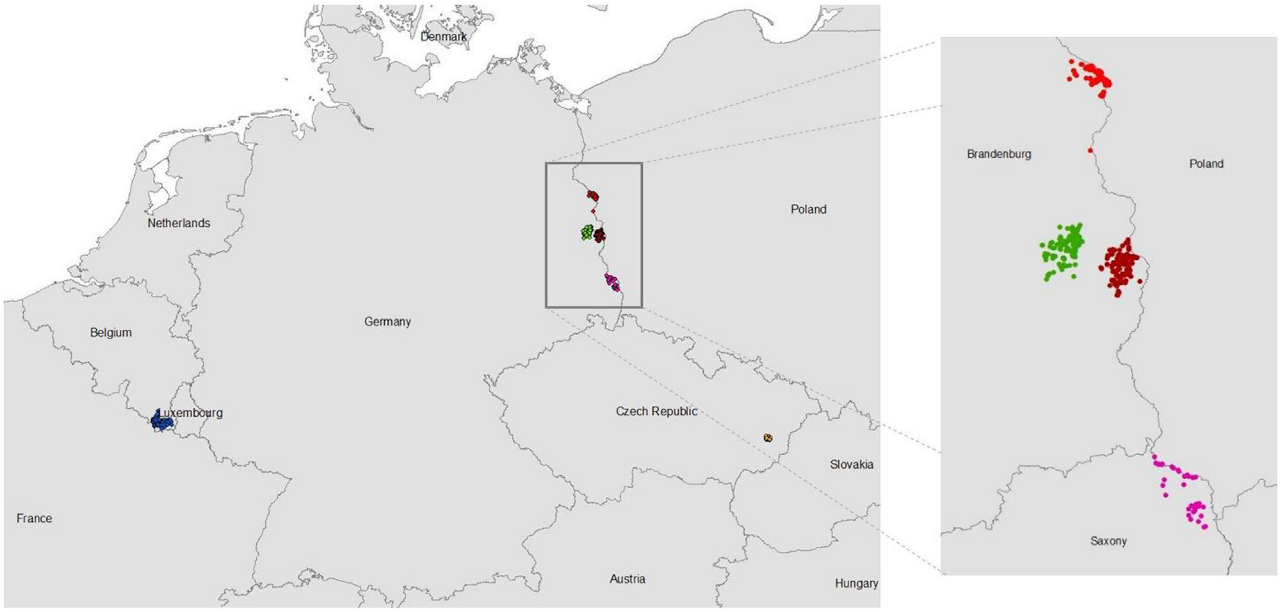

FIGURE 2 Spatial clusters of ASF cases in wild boar observed in the Czech Republic, Belgium and Germany for the first 6 months of the ASF epidemic in each country. Inset: distinct clusters in Germany (dark red: Cluster 1; red: Cluster 2; green: Cluster 3, all in Brandenburg; purple: Cluster 4 in Saxony)

into Germany was observed (cluster 4), and new cases occurred approximately 20 km westwards of the location of the first introduction (cluster 3), leading to an increase in the size of the affected cluster area. In Belgium, a similar increase was seen on day 156 (Figure 4B).

Differences in the numbers of ASF-positive wild boar per affected area between the three countries were also noted (Figure 4C). The respective number for Germany was in between the ones observed for the Czech Republic (4-6 ASF-positive wild boar per kmš) and Belgium (approx. 1.5 ASF positive animals per kmš) (Figure 4C).

4 | DISCUSSION

The aim of the present study was to compare the first 6 months of the ASF epidemic in wild boar in Germany with the equivalent period of ASF occurrence in the Czech Republic and Belgium. Due to the absence of any outbreaks in domestic pig holdings in all three countries, the applied control measures focused on minimizing spread of the infection between wild boar, and preventing disease transmission into domestic pig holdings. The rigorous measures implemented in the Czech Republic and in Belgium, such as enhanced passive surveillance, erecting fences to limit the movements of wild boar and drastic reduction of the wild boar population in the affected area, led to a successful elimination of the infection in both countries (Food & Agriculture Organization of the United Nations et al., 2019; World Organisation for Animal Health, 2020). This success, which in the current ASF epidemic that started in Georgia in 2007 (Rowlands et al., 2008), has so far been limited to these two countries. Thus, it seems reasonable that the effective control strategy applied in the two countries could serve as a blueprint for other ASF-affected countries including Germany. A direct comparison of the course of ASF between the three countries may help to evaluate the situation and the control measures.

Similarities in the ASF epidemics between the three studied countries were indeed observed. In Germany and Belgium, the first cases were detected in September (Linden et al., 2019; Sauter-Louis et al., 2020). This may have been by coincidence, but is seems also possible that the detection of the cases was facilitated by the harvest of agricultural fields, which usually occurs just before September in these regions. The harvested fields make it easier to detect wild boar carcasses, which may otherwise remain undetectable. This hypothesis is supported by the decomposition stage of the first carcasses found in both countries, which suggested that the disease had been introduced a few months ago (Federal Agency for the Safety of the Food Chain Belgium, 2018; Sauter-Louis et al., 2020). In contrast, in the Czech Republic, the first case was detected very shortly after the ASF-infected wild boar had died and there was no indication that the disease had been present in the area for months (Šatrán, 2019). Interestingly, the presumed introduction into Germany was around the same time of the year (June/July) (Sauter-Louis et al., 2020), when the first case was observed in the Czech Republic.

Evaluation and comparison of the areas affected may be performed by comparing the restriction zones defined by the European Commission (Commission Implementing Regulation 2021/605, formerly Commission Implementing Decision 2014/709/EU). However, several factors, such as the size, the territorial and geographical continuity with adjacent territories, the typology of biotope, the administrative divisions and the surveillance in place must be taken into consideration, when restriction zones are established. Thus, the sizes of the restriction zones do not allow an objective comparison between countries. We, therefore, used the MCP method to estimate the affected area. An

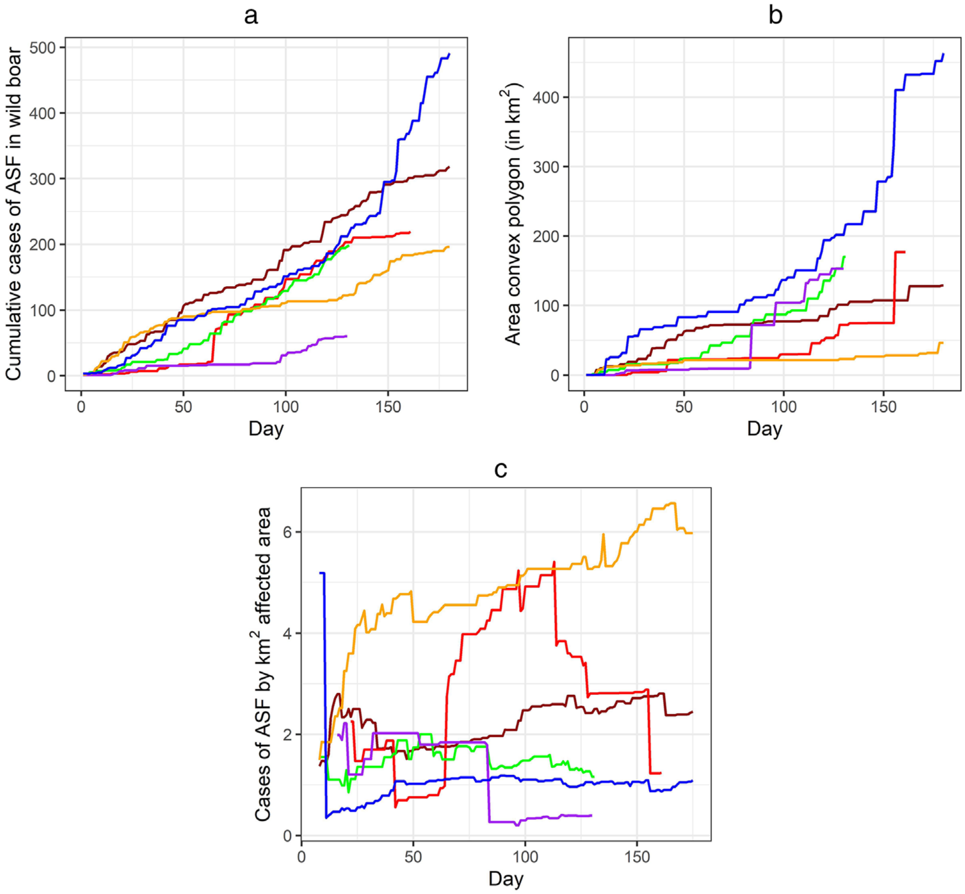

FIGURE 3 (a) Cumulative ASF cases in wild boar in the four cluster areas in Germany and in the Czech Republic and Belgium over the first 6 months after the first detection of ASF. (b) Cumulative area (minimum convex polygon) of ASF cases in wild boar for the four cluster areas in Germany and in the Czech Republic and Belgium over the first 6 months after the first detection of ASF. (c) Numbers of cases of ASF in wild boar by square kilometre affected area, as calculated in a minimum convex polygon for the four cluster areas in Germany and in the Czech Republic and Belgium over the first 6 months after the first detection of ASF (Orange: Czech Republic; blue: Belgium; dark red: cluster area 1, red: cluster area 2, green: cluster area 3, purple: cluster area 4 in Germany)

MCP describes only the area that encloses the detected cases. However, the area calculated in this way may not completely cover the truly affected area, as undetected ASF-positive wild boar might have been present outside the defined area.

In Germany, four different clusters were observed. Three weeks after the first introduction, further ASF cases emerged approximately 60 km north of the first cluster, which were also located close to the Polish border. Usually, the home range of wild boar does not exceed more than 20 km (Food & Agriculture Organization of the United Nations et al., 2019; Podgorski et al., 2013). It therefore seems unlikely that these new cases were directly related to the first cluster. This hypothesis is supported by the findings of the intensive carcass searches around the first case, which led to the detection of further ASF cases within a 6 km radius. No ASF-positive wild boar was found outside a radius of 12 km around the first case. In addition, the area between the two clusters has been monitored closely, and only in March 2021, that is, 6 months after the first detection of ASF, the first ASFV-positive carcasses were detected there. Likewise, cluster 4 emerged 60 km south of the first cluster. Despite intensive regular carcass search, no cases were found between the two clusters before March 2021. Consequently, a separate virus introduction may also be assumed in this case. Thus, there have been at least three separate introductions into Germany along the border with Poland, probably caused through wild boar migrating from Poland across the border. Despite intensive but negative carcass search immediately west of cluster 1, the emergence of cluster 3 might have been caused by migrating wild boar from cluster 1.

When comparing the cumulative numbers of infected animals, the cumulative affected area and the numbers of ASF-positive animals per kilometre square affected area for the four clusters in Germany with those in the Czech Republic and Belgium, similarities are noticeable. Our results suggest that the course of ASF in each individual German cluster area resembles those in the Czech Republic and in Belgium. This is not surprising, as the epidemics were caused by the same virus, affected the same species, that is, wild boar, and occurred under similar environmental conditions. However, when summarizing the data of the different cluster areas and comparing the cumulated area to those of the Czech Republic and Belgium, the results diverge, suggesting

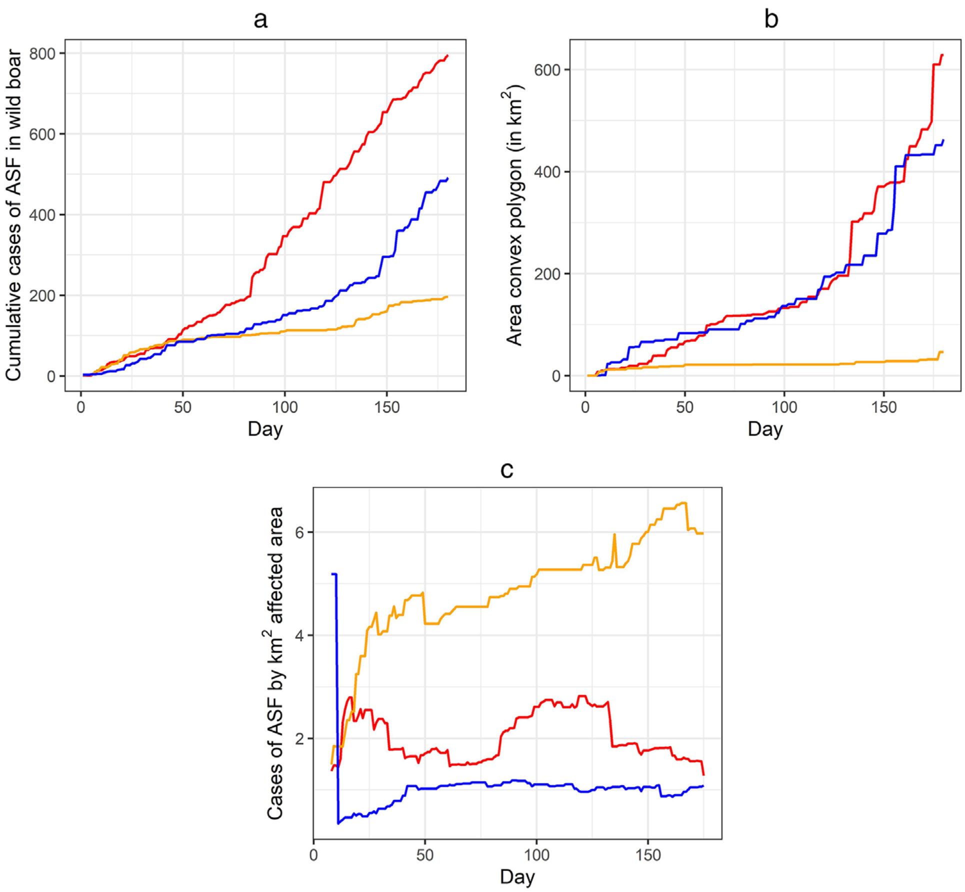

FIGURE 4 (a) Cumulative ASF cases in wild boar in Germany (red), the Czech Republic (orange) and Belgium (blue) over the first 6 months after the first detection of ASF. (b) Cumulative area (minimum convex polygon) of ASF cases in wild boar in Germany (red), the Czech Republic (orange) and Belgium (blue) over the first 6 months after the first detection of ASF. (c) Numbers of cases of ASF in wild boar by square kilometre affected area, as calculated in a minimum convex polygon, in Germany (red), the Czech Republic (orange) and Belgium (blue) over the first 6 months after the first detection of ASF.

differences. Despite all influencing factors, such as population density, search effort, landscape and other environmental factors like settlement structure and road network, the main and probably most influencing difference is the way of ASFV introduction. In the Czech Republic and Belgium, the virus had 'jumped' over several hundred kilometres. These introductions were most likely caused by human activities leading to a point-source exposure of wild boar at the site of introduction (Food & Agriculture Organization of the United Nations et al., 2019; Saegerman, 2018; Šatrán, 2019). Thus, the disease was only introduced at one single point in time and space, so that disease control measures could be implemented that focused on one defined area. The comparable course of the disease in each of the individual clusters demonstrates that a successful diseases elimination implementing the current control measures could also be possible, if the ASFV had been introduced only once at one point. In Germany, however, this was unfortunately not the case. Germany borders Poland over almost 400 km and a substantial proportion of this borderline extends over a region, where ASF occurs in Poland. In the western part of Poland, ASF has been present in the wild boar population since almost 2 years (Mazur-Panasiuk et al., 2020) and it does not seem to subside. Accordingly, the disease has not only been introduced at one point, but in several locations along the border with Germany and on several occasions.

The constant infection pressure, Germany is exposed to, is comparable to the one that resulted in the introduction of ASF into the Baltic States and Poland in 2014 and in the following years. These states border to ASF-affected countries, mostly in the East (European Food Safety Authority, 2015; Nurmoja et al., 2017; Oļševskis et al., 2016; Pejsak et al., 2014; Smietanka et al., 2016). However, at the time, when ASF reached these countries, knowledge about ASF in wild boar and possible control measures was scarce. Control measures, therefore, focused on hunting and the removal of carcasses, but did not include fencing measures to limit the movement of wild boar. The infection pressure along the southern part of the border between Poland and Germany is likely to persist for the foreseeable future. In addition to migrating wild boar, also travelling tourists or workers, who cross the German-Polish border regularly, might carry infectious material with them, for example, contaminated food. Consequently, control measures have to focus on the border area, while prevention and keeping disease awareness at a high level must be maintained in the entire country. Already in the beginning of 2020, only 2 months after the first cases had occurred in Western Poland, mobile fences were erected along the border on German territory. These fences had to be maintained, replaced by permanent fences and extended after the first ASF cases had emerged in Germany. It is obvious that controlling a disease in several locations needs approaches that differ, at least in part, from those required for controlling the disease in a single area. In the Czech Republic, the detected ASF cases were so far away from the border to Slovakia, that all control measures and zonings could be exclusively performed in the own country according to EU and national legislation. In Belgium, several cases were close to the border with France and Luxembourg. France established protection zones and thereby supported the control of ASF in Belgium. Regarding the situation in the border area between Poland and Germany, a joint effort of both countries is necessary to control and eventually eliminate the ASF epidemic in wild boar. If the infection pressure along the border continues, new introductions are likely and there is an increased risk of ASF spread in western direction.

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ETHICS STATEMENT

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. No ethical approval was required as no animal experiments were conducted.

CONFLICT OF INTEREST

The authors declare that there are no conflict of interest.

AUTHOR CONTRIBUTIONS

C.S.L. designed the study, performed the analysis and drafted the manuscript. K.S. supported the design of the study and drafted the manuscript. M.R. designed the study, provided data and reviewed the manuscript. C.S. supported the analysis and reviewed the manuscript. T.C.M. supported the design and carefully reviewed the manuscript. F.J.C. designed the study, provided epidemiological advice and carefully reviewed the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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