African Swine Fever Survey in a European Context

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African swine fever (ASF) is currently the most threatening disease for domestic and wild pigs worldwide. Wild boar has been the main affected species in all EU countries except for Romania, where most notifications occur in domestic pigs. The spread of ASF in wild boar is challenging to control; risk factors are harder to identify and establish than in domestic pigs, which, together with an underestimation of the disease and the lack of treatment or an effective vaccine, are hindering control and eradication efforts. We distributed two online questionnaires, one for domestic pigs and one for wild boar, to experts of different background and countries in Europe, to explore risk factors in relation to ASF control connected to farming, hunting, trade, the environment, and domestic pig and wild boar populations.

pigs wild boar expert opinion questionnaire stakeholders epidemiology

1. Introduction

The unprecedented worldwide spread of ASF since it reached Europe in 2007, Asia in 2018, and now the Americas in 2021 turns ASF in the worst livestock pandemic of this century. The European Union (EU) was free from African swine fever (ASF), except for the Italian island of Sardinia, until 2014, when it entered through the Baltic countries and Poland [1][2]. Excluding Sardinia, from 2014 up to December 2020, there have been 6037 ASF outbreaks in domestic pigs in the EU and 39,970 ASF notifications in wild boar across 12 EU countries (Belgium, Bulgaria, Czech Republic, Estonia, Germany, Greece, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia) [3]. Only Belgium and the Czech Republic, both with only wild boar affected, have regained an ASF-free status [4][5].

Wild boar has therefore been the main affected species in all EU countries except for Romania, where most notifications occur in domestic pigs (**Figure 1**). Romania is also the EU country with the largest number of pig farms, more than 2 million in 2015, but up to 99% of these farms held 10 pigs or fewer [6]. Other affected countries such as Lithuania, Slovakia, or Bulgaria also have a similar average farm size. These figures are reflected in the number of outbreaks per country by farm size (**Figure 2**).

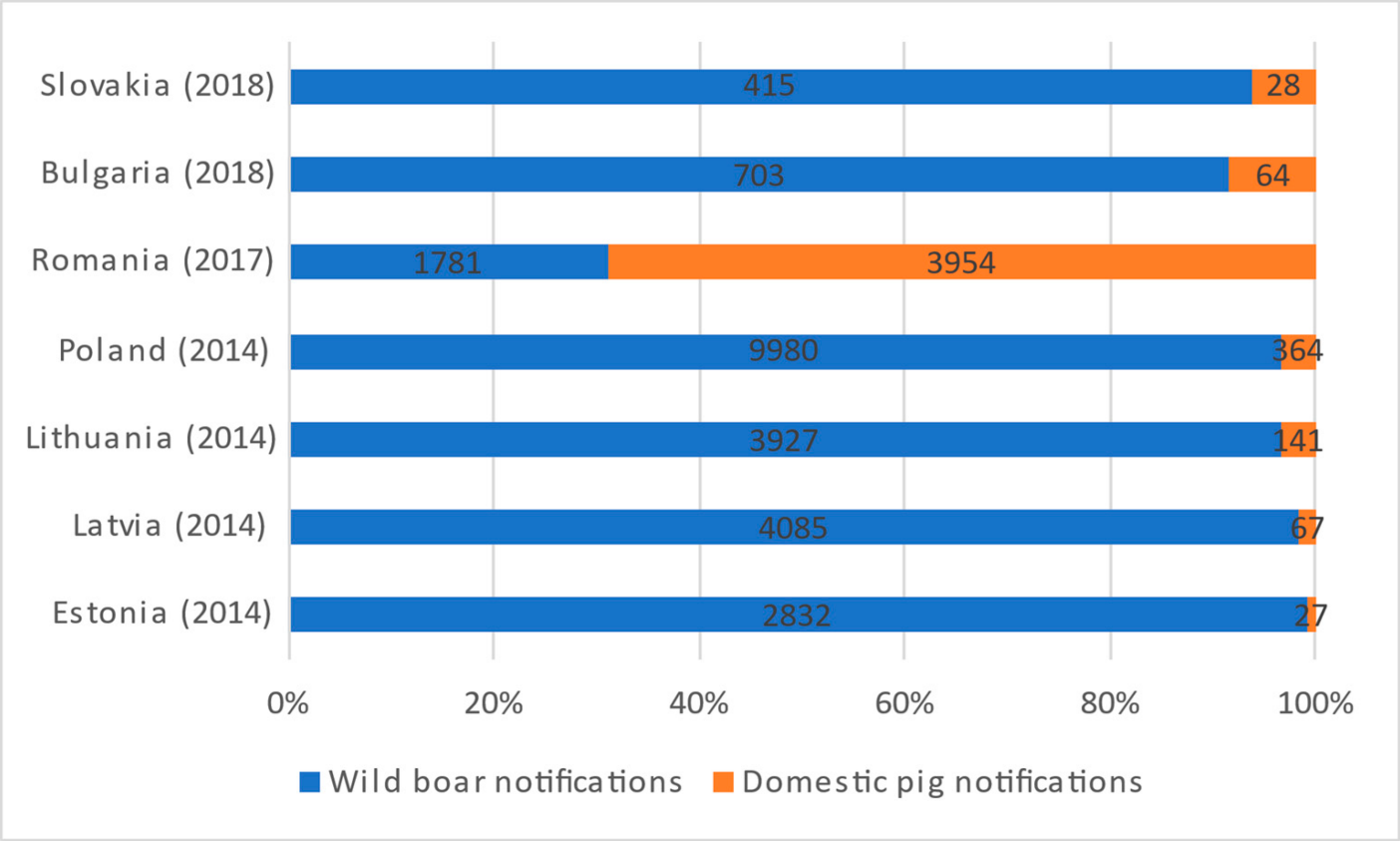

Figure 1. ASF notifications from 2014 to 2020 in countries with domestic pigs affected in the EU (except Sardinia), based on ADIS data. Year of first notification in brackets after country name.

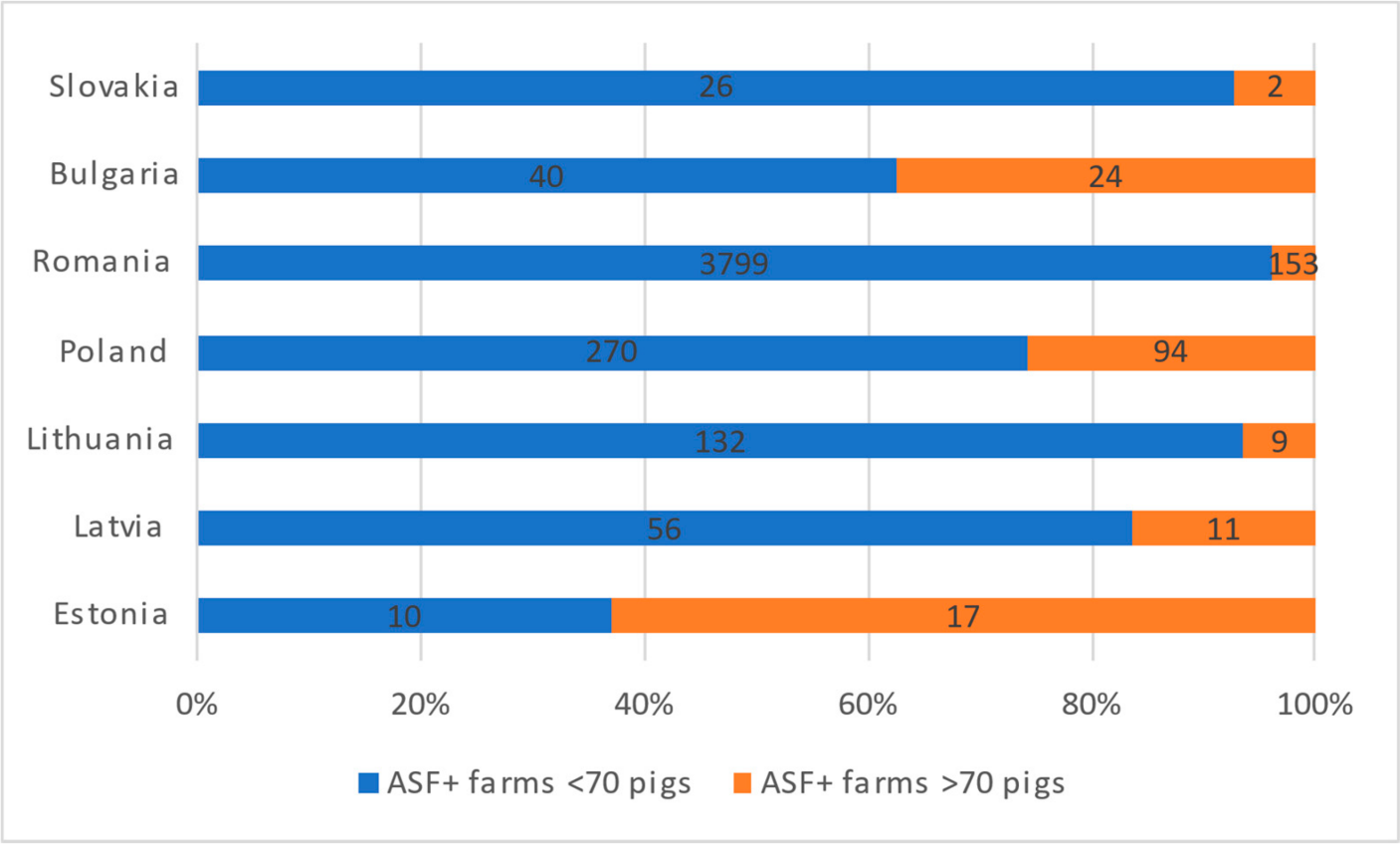

Figure 2. ASF notifications by farm size from 2014 to 2020 in countries with domestic pigs affected in the EU (except Sardinia), based on ADIS data.

The risk factors for ASF spread in domestic pigs are well-known and have been reviewed within the EU recently [7][8]. Risk factors associated with ASF spread and persistence in wild boar are harder to identify and control. Through epidemiological analyses and modelling approaches, potential explanations of probable disease distribution have been explored [9][10]. As a wildlife species, exposure to disease depends on environmental risk factors (season, climate, land cover, connectivity between landscapes), human activities related with wild boar (population management, hunting, and gaps in biosecurity), human activities related with the environment (land use, farming, leisure, waste control), and wild boar ecology and behavior [11][12][13][14][15][16][17]. Given the high ASF incidence in wild boar, the domestic–wildlife interactions remain poorly assessed [18], and ASF remains underestimated. ASF virus has been circulating in wild boar in Europe for more than a decade, during which there has been an increase in the detection of asymptomatic wild boar positive for antibodies against ASF but negative for virus detection, thus immune to infection [19]. However, the number of immune wild boar remains low, and the infection keeps spreading.

So far, the main tools to control and eradicate ASF remain early detection; depopulation; contact tracing; and the establishment of movement restrictions, disinfection, and active surveillance within a protection and surveillance zone around each outbreak [20]. Depopulation, active carcass search and removal, the definition of an infected zone and surrounding surveillance zones, and the use of fences have also been recommended within the EU for wild boar [21]. The continuous spread of and difficulty in controlling ASF with the current tools have boosted the need to develop effective vaccines against ASF. The most promising protective vaccines against heterologous ASF

strains are naturally attenuated virus [22], but to avoid infection with circulating virus, biosecurity measures should be taken. Furthermore, for effective control against ASF, it is essential that stakeholders involved in it are aware and have good knowledge and understanding about risk factors for ASF spread.

2. African Swine Fever Survey in a European Context

The objective of this expert elicitation was to obtain information and increase awareness on risk factors for ASF spread and control in Europe. The experts were mainly veterinarians and ecologists from administration and research involved in disease control, as well as from the swine and hunting industry. The researchers aimed at reaching those already involved or that could potentially be involved in ASF control. Some experts replied to both the domestic pig and the wild boar questionnaires, but the majority of experts replied to just one of them. The researchers also aimed at having representation from infected and non-infected countries. However, the number of respondents per country was not homogeneous, with Italy, Latvia, Portugal, and Spain being the countries with the highest number of respondents. By background, only private industry (wild boar hunting/domestic pig) was less represented in the wild boar questionnaire, particularly in the risk assessment questions. The perception by hunters of ASF control has been assessed in Estonia, Latvia, Lithuania, Bulgaria, Germany, and Russia [23][24][25][26]. The researchers study complements the perception of ASF risk factors and control by other stakeholders, such as people engaged in wildlife management and research as well as those familiar with both domestic pigs and hunting, and increases the study area to other parts of Europe as well.

The starting point to recruit experts was contacting partners from the EU project on ASF vaccines and vaccination, VACDIVA. While this ensured a relevant expertise in ASF, it may have also influenced the higher number of experts from the countries mentioned, all of which are represented in the project. The main limitation of the questionnaire design was it was too lengthy, taking at least 30 min to complete. The researchers did aim to reduce as much as possible the content and split the original questionnaire in two, aiming to gather opinions from both domestic pig and wild boar experts. Experts were warned in advance of the time of completion, but around 5 experts out of 28 were lost towards the last questions. This time could have also discouraged experts and influenced the final number of respondents. While the response rate seems low (30%), 91% of the experts who replied were either from the VACDIVA Consortium or recommended by a partner from VACDIVA. Therefore, the opinions, while not a comprehensive sample that represents a whole sector or country, allow for analyzing perceptions and information about important factors in ASF control, and given the variability of cultures, environmental conditions, and even domestic pigs and wild boar exploitation within the EU, the authors considered it appropriate to summarize and compare results per country or group of countries as well as per background.

This study has provided an updated assessment of the main perceived risk pathways of ASF entry and spread in infected and historically or never-infected countries. In this way, the main risk perceived for both the entry and spread of ASF is associated with wild boar. This was particularly evident for recently infected countries, which are clearly very aware of the continuous risk of re-introduction of infected wild boar from neighboring countries with ASF. Several authors [27][28] already indicated that the existence of suitable wild boar habitats at the borders increased the risk of ASF entry in these countries. The entry pathway with the second-highest risk of introduction

for recently infected countries and highest for historically or never-infected countries was estimated to be the illegal movement of products and the introduction of contaminated products for own consumption. The pathways ranked with lowest risk were the legal movement of pigs, pig products, and fomites. Assuming that the EU is in a “high-risk period” because of the high threat of ASF at the moment, the researchers results align with Mur al. [29], who considered wild boar movements as one of the main entry pathways. The low-risk estimation of legal movement of pigs could similarly be attributed to the increased awareness because of the “high-risk period” situation. However, illegal movements are today ranked with a higher risk.

Swine production across the EU is diverse, and several pig farming systems coexist, with industrialized farming, traditional small-scale farming, and specialized farming (local breeds or organic) being the most common [30]. In many countries of Eastern Europe, the traditional small-scale or backyard farming is predominant, but in Western Europe, the predominant form is industrialized farming, including specialized extensive production such as in the Iberian Peninsula that should not be compared with non-commercial outdoor pig farming. Swill feeding is banned across the EU [31] but was admitted to still happen, although not frequently, by the respondents of the domestic pig questionnaire. In fact, the biosecurity measures against ASF that are estimated to be complied with by a smaller number of non-commercial establishments according to the results of the domestic pig questionnaire included feed and water control, cleaning and disinfection of structure and equipment, animal health education, measures for visitors and farm workers, and pest control. Animal health education or limited farm visits with proper register and protective equipment had also been assessed as very important in Jurado et al. [8]. However, even if most of the ASF notifications in domestic pigs have occurred in the backyard sector, the risk of ASF occurrence can also affect the rest of pig farming systems.

Given the high apparent incidence of ASF in wild boar in Europe, direct and indirect contact with wild boar appear as important risk factors for ASF spread to domestic pigs. Some important risk factors identified through the questionnaires were the location of farms in habitats highly favorable for wild boar, the existence of hybrid pigs, domestic pig farmers who also practice wild boar hunting, and the access of wild boar to crops around domestic pig farms. Despite these interactions, contact between domestic pigs and wild boar was ranked as medium to low risk by both domestic pigs and wild boar experts. However, when compared with other exposure pathways, the indirect contact between domestic pigs and wild boar was ranked the highest for domestic pig experts. The indirect interaction between wild boar and domestic pigs has been suggested as the most likely source of ASF transmission in several field studies [32][33][34][35]. For wild boar experts, the most likely interaction between domestic pigs and wild boar would also be through indirect contact, but the highest risk exposure pathways were attributed to wild boar–wild boar interactions. The practices that could spread the virus from domestic pig establishments to the surrounding environment were estimated to happen less frequently than access of potentially infected wild boar to the surroundings of a pig establishment. However, recycling manure as an organic fertilizer in crops is a common practice in the EU. A survey of farmers in France on manure management indicated that 36.5% of manure is spread on grassland, 39.6% on maize ground, 12.9% on cereal land, and 7.9% on oilseed/protein crops [36].

The practices that could spread the virus from wild boar to domestic pig establishments include gathering bedding and other materials from the environment. Access of wild boar to crops around farms was estimated to happen frequently, particularly in summer but also in autumn and spring, with winter being the season with lowest probability of crop damage by wild boar. For reasons yet to be elucidated, ASF in Europe seems to peak in autumn in wild boar and in summer in domestic pigs [12][37]. Crops mentioned by experts in this questionnaire, which grow in summer and are accessed by wild boar, included cereals (mainly maize and oat), protein crops (sunflower), and potato, which offer food and shelter to the animals. Indeed, the highest percentage of ASF notifications have occurred in Europe in agroforestry landscape (including monoculture areas). Agriculture accounts for around 35% of the total land within the EU [38] and is estimated to expand because of the projected increase in the demand for agricultural commodities (70–100% by 2050) [39]. Specifically, the use of land for cereals, protein crops, and fodder for animal feed, human consumption, and industrial purposes is expected to grow in the EU. The European Commission has estimated a significant growth for total EU cereal production (mainly wheat and maize) (up to 319 million t by 2030) and feed crops such as oat (260 million t in the medium term) [40]. The relationship between virus spread and the seasonal ASF summer peak in domestic pigs, where high environmental contamination in the surroundings of pig establishments seems to exist due to the available feed and shelter offered by crops to potentially infected wild boar, should be further studied. In addition, flying insects carrying potentially infectious blood are also present in larger amounts in the warmest months, having a potential impact particularly on local short-distance spread. Interestingly, ASF notifications in the EU in agroforestry landscape have increased by 30% in wild boar and by 80% in domestic pigs since 2016 (based on notifications to the Animal Disease Information System of the EU). Between 2007 and 2016, ASF wild boar notifications were more prevalent in natural areas in the EU (78.5%), followed by agroforestry areas (21.3%) and agro-urban areas (0.5%). In contrast, in non-EU countries (Russian Federation, Belarus, Ukraine, and Caucasus region), the distribution of ASF notifications was 57.5% in natural areas, 40.9% in agroforestry areas, and 1.6% in agro-urban areas (1.6%). In domestic pigs, ASF occurred mainly in natural areas in the EU (63.6%), in contrast with 20.5% of notifications in natural areas in non-EU countries. Oppositely, in non-EU countries, the main landscapes for ASF notifications in domestic pigs were agroforestry areas (42.3%) while in the EU, they accounted for 16.4% of notifications. In any case, wild boar movement was the entry pathway ranked with the highest risk by experts of both domestic pig and wild boar groups. The introduction of ASF through infected pork or pork products for own consumption and through illegal trade was also ranked with a high-to-very-high risk. However, it was surprising to find the introduction pathway through catering waste being ranked with a low risk, considering that this has been a major suspected pathway of introduction of transcontinental ASF spread as well as origin of recent outbreaks [41][42].

A few questions obtained contradictory responses, such as the role of scavengers and predators in the spread of ASF. The existing scientific literature also reveals inconclusive evidence. On one hand, scavengers reduce the time a carcass remains in the environment, decreasing environmental persistence, but on the other hand, not all carcass remains are removed, and bones in particular will remain [17][43]. ASF virus genome can remain preserved in bones and the remnants of bone marrow of buried carcasses for more than two years [44]. Furthermore, some mammals and birds can transport pieces of meat in their mouths or beaks, contributing to local ASF spread [43]. For the moment, the researchers can only hypothesize that scavengers could contribute both to an increase and a

decrease in ASF local spread and persistence risk. One should also bear in mind that wild boar could scavenge its own species' remains [45], which is considered a high-risk factor for the spread of ASF that is minimized through effective carcass search and removal [21]. Scavenger species that were mentioned other than wild boar and pigs (domestic and feral) included foxes, small and large carnivores (martens, badgers, water vole, polecat, raccoon, dogs, golden jackal, and bear), birds (corvids and birds of prey), and insects. Depending on landscape, season, and time of the day, there will be different species scavenging on carcasses [46]. In open habitats of the European temperate woodland, ravens, common buzzards, white-tailed eagles, and domestic dogs were found to be the most common scavengers. In the forest, pine martens, jays, and wild boar predominated. When temperature decreased, scavenging increased, except for raccoon dogs. In the Mediterranean ecosystem, the most common scavenger in open habitats was the griffon vulture (during the day), while in vegetation-covered habitats, the most frequently mammal scavengers were red fox and, in the evenings and nights, wild boar. As for predators, there was a high agreement among the questionnaires' respondents that the main predator animal species of wild boar is the wolf, although other species such as foxes and jackals can also predate on wild boar. Studies on food habits of wolves indicate that wild boar is their main prey, reaching up to 50% of wolves' diet [47][48]. All experts indicated that predation occurred mainly on piglets or juveniles, being more frequently in spring, although they can also predate during the whole year, as 48% of experts agreed and in line with other studies [43][44]. Two new concerns expressed by experts were the possibility of wild boar increasing movements and range, leading to ASF dispersal because of wolf activities, and the potential overlapping of wolves and other potential predators with wild boar in natural and agroforestry areas. Therefore, even if the direct effect on ASF spread by wild boar predators is inconclusive, one could attribute an indirect risk of ASF dispersal by wild boar to the presence of predators in an area.

Regarding control measures, from the questionnaire replies the researchers found that the existence of a shared surveillance program for ASF across neighboring countries of different geopolitical scope is more than necessary to focus control efforts in a coordinated manner. Evidently, vaccination in wild boar would also help control efforts, and there seems to be acceptation among those surveyed to support such a plan. However, despite vaccination, biosecurity measures would still be necessary to achieve an effective ASF control.

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