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Article

Development of African Swine Fever in Poland

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Abstract: African swine fever (ASF) is a major problem in the production of live pigs in many EU countries. The aim of this research is to identify the causes and effects of this disease in Poland. The study used data from various institutions in Poland and from the EU Animal Diseases Information System (ADIS). Within the range of causes for ASF development, we considered the transmission of the ASF virus by wild boars and human activity. The article presents the number and distribution of ASF cases in wild boars, and the outbreaks of ASF in domestic pigs, in the years 2014–2020. The relationship between these variables was determined with a rectilinear regression analysis. The analysis of data for poviats where ASF cases in wild boards and ASF outbreaks in domestic pigs have been reported shows a certain periodicity of ASF occurrence in the country. This research shows that, despite the actions taken by veterinary services, hunting associations and the involvement of state administration bodies, the disease spreads rapidly. The occurrence of ASF outbreaks in domestic pigs concerns both small and large scale farms. However, due to the fragmented nature of pig farming in Poland, ASF is more prevalent in smaller holdings. Among the main reasons for the development of this disease in the country are the insufficient bio-insurance coverage of pig holdings, and the presence of the virus in the wild boar population. The process of ridding the country of the ASF virus is long and costly.

Keywords: holdings; pigs; African swine fever; reasons; economic effects; Poland

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1. Introduction

African swine fever (ASF) is an important disease, mainly because of its significant sanitary and socioeconomic consequences [1]. ASF is caused by the African swine fever virus (ASFV) which is a member of the Asfarviridae family. This virus is non-infectious for humans but lethal for both wild boars and domestic pigs. The ASFV infection may progress in an acute, chronic or persistent form [2]. The disease shows variable clinical signs, with high cases of fatality rates, up to 100%, in the acute forms [3]. ASF epidemiology varies significantly between countries, regions and continents, since it depends on the characteristics of the virus in circulation, the presence of wild hosts and reservoirs, environmental conditions, and human social behavior. Unlike most livestock diseases, no vaccine or specific treatment is currently available for ASF. Developing an effective vaccine against ASF is difficult due to the complex structure of the virus and its mutations. Therefore, disease control is mainly based on early detection and the application of strict sanitary and biosecurity measures [4]. ASF was first found and described by R.E. Montgomery as a highly fatal and contagious disease that caused severe outbreaks among settlers' pigs in British East Africa [5]. Subsequently, a similar scenario was also described in South Africa [6,7]. The various transmission routes of ASF contributed to a fast spread of ASFV across the African continent, and the subsequent introduction of ASFV in Europe [8].

In Europe, ASF genotype I first appeared near Lisbon in 1957, causing almost 100% mortality of pigs. After that, there was a three-year epidemiological silence, only for the virus to attack domestic pigs again in 1960 (Portugal). During these epidemic waves, the virus reached Portugal, Spain, France, Italy, Malta, the USSR, Belgium and the Netherlands [9,10]. The outbreaks of ASF occurred mainly in domestic swine populations. However, by utilizing rigorous disease control programs (e.g., eradication, improved biosecurity measures, and education), countries in Europe successfully eradicated the disease. Since 1999, continental Europe has been ASF-free (although the virus remained present in Sardinia, Italy) [11–13].

The second introduction of ASFV to Europe, but this time of the genotype II, was through the Caucasus region. In 2007, ASFV entered Georgia through the port of Poti, potentially via contaminated food used to feed pigs. From this region, ASFV spread rapidly through the country and affected neighbouring countries including Armenia, Azerbaijan and the Russian Federation. In this geographical region, ASFV affects domestic and wild boar and has spread to the north and to the west. In 2012, the first outbreaks were declared in Ukraine, followed by Belarus in 2013 [10,14]. In 2014, the virus reached Estonia, Latvia, Poland and Lithuania [15,16]. Currently, ASF in Europe, Russia and Asia is an epidemic disease, except in Sardinia, where the disease has been endemic since 1978 in wild boar and unregistered free-living pigs called brado [4,17,18]. According to the system data, from 2014 to 2020, there were 14,548 ASF cases in wild boars and 599 outbreaks in domestic pigs in Poland, Lithuania, Estonia and Latvia (Table 1). In June 2017, ASF cases in wild boars also occurred in the Czech Republic [19]; however, as a result of very radical actions (electric and scent fencing of high-risk agricultural areas, wild boar shooting by trained snipers, and biosecurity), the spread of the disease was very limited. To date, not a single case of transmission of the ASF virus to pigs has been reported in the Czech Republic [20].

Table 1. ASF cases in wild boars and ASF outbreaks in domestic pigs in EU countries in 2014–2020.

Countries	2014		2015		2016		2017		2018		2019		2020	
	DP	WB	DP	WB	DP	WB	DP	WB	DP	WB	DP	WB	DP	WB
Poland	2	24	1	52	20	80	81	741	109	2443	48	2477	103	4156
Latvia	32	148	10	752	3	864	8	947	10	685	1	369	3	320
Lithuania	6	45	13	111	19	303	30	1328	51	1446	19	464	3	230
Estonia	0	41	18	723	6	1.052	3	637	0	231	0	80	0	68
Czech Republic	0	0	0	0	0	0	0	202	0	28	0	0	0	0
Romania	0	0	0	0	0	0	2	0	1164	182	1728	693	1060	906
Hungary	0	0	0	0	0	0	0	0	0	138	0	1605	0	4052
Bulgaria	0	0	0	0	0	0	0	0	1	5	44	165	19	533
Belgium	0	0	0	0	0	0	0	0	0	163	0	482	0	3
Italy (Sardynia)	40	9	16	13	23	39	17	24	8	4	1	63	0	41
Slovakia	0	0	0	0	0	0	0	0	0	0	11	27	17	388
Greece	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Germany	0	0	0	0	0	0	0	0	0	0	0	0	0	403

Designation: DP—ASF outbreaks in domestic pigs, WP—ASF cases in wild boars. Source: https://www.3trzy3.pl/wiadomosci_z_branzy/ile-ognisk-asf-odnotowano-w-ue_3349/ (accessed date: 10 July 2021).

In 2017, ASF spread to Romania, initially resulting in a small number of outbreaks in domestic pig farms. In July 2018, 334 outbreaks were detected, mostly in domestic farms and predominantly in the Southeast. From then on, ASF spread widely in Romania with outbreaks in more than 1100 domestic pig farms in 2017 and about 1730 in 2018 [21].

On 14 September 2018, several cases of the disease in wild boars were reported in Belgium. Within a few days, a potentially affected area of 63,000 ha was designated there. All the pigs located there were slaughtered, and the transport of further animals was banned in the area. Moreover, a periodic ban on tourist traffic, and on all activities of hunters and forest workers, was introduced there. In addition, the area was fenced. Thanks to these measures, not a single outbreak of the disease in domestic pigs has been detected in Belgium [22].

The disease is currently present in large parts of Europe where it continues to spread, particularly among wild boar populations, and despite the extensive disease control measures implemented [23,24]. In 2020, ASF cases in wild boars and ASF outbreaks in domestic pigs occurred in: Poland, Romania, Bulgaria, Hungary, Slovakia, Estonia, Lithuania, Latvia, Greece, Italy (Sardynia), Belgium and Germany. The causative virus strains are of genotype II and showed high virulence for both domestic pigs and European wild boars [25].

In August 2018, ASFV genotype II emerged for the first time in China, which is the largest pig producer in the world, accounting for almost half of the world's pork production. ASF outbreaks have since been reported in large parts of the country [26]. By the end of March 2019, the ASF virus was already present in all Chinese provinces except for the island of Hainan. For this reason, more than 1,000,000 animals were slaughtered [27]. Recently, a new genotype I ASFV variant has been detected in China; it shows low virulence and efficient portability in pigs, and causes a mild onset of infection and chronic disease. The emergence of genotype I ASFVs will present more problems and challenges for the control and prevention of ASF in China [28].

Wild boars play an important role in the spread of ASF and potentially in its maintenance. It is difficult to eliminate ASF from wild boar populations once it has become endemic. Contact between infected wild boar and domestic pigs on outdoor farms poses a risk of transmission. Although large pig farms in Europe are better protected by strict biosecurity and hygiene practices, ASF-infected wild boar contaminating the surrounding environment could pose a threat. Expanding wild boar populations in many parts of Europe compound these risks [23]. Poland has been combating the disease since 2014. Over the period of several years of struggling to contain ASF, Poland has introduced many legal and institutional regulations. Since the vaccine is a distant promise, producers, government officials and hunters are trying to contain the epidemic by implementing biosecurity measures and shooting wild boar. The alarming fact is that the number of ASF cases in wild boar is still increasing despite the relatively low wild boar density in the country [29].

In connection with the development of ASF in Poland, the aim of this research is to identify the causes and effects of this disease in Poland. Based on observations, two hypotheses were formulated:

1. There is a causal relationship between the intensity of ASF cases expressed in wild boars and the number of ASF outbreaks in domestic pigs.
2. The development of ASF outbreaks in domestic pigs and ASF cases in wild boars in Poland is cyclical.

2. Materials and Methods

The study used data from the Ministry of Rural Development and Agriculture, the Chief Veterinary Inspectorate (CVI), the Central Statistical Office (CSO), the Agency for Restructuring and Modernization of Agriculture (ARMA), PKO Bank Polski S.A., Animal Disease Information System (ADIS) and information from the literature on the subject. The article presents selected characteristics of the development of ASF in the country, its causes and effects. Within the range of causes for ASF development, we considered the transmission of the ASF virus by wild boars and human activity. In order to verify the first hypothesis, an attempt was made to determine the dependence between the number of ASF cases in wild boar and the number of ASF outbreaks in domestic pigs. Moreover, changes in the number of ASF cases in wild boar and outbreaks in domestic pigs in subsequent years are presented. To show the changes in individual regions of Poland, the administrative division of the country into voivodships and poviats was taken into account. To verify the second hypothesis for changes in the number of ASF cases in wild boar and the number of outbreaks in pigs in the following years, a polynomial trend line was determined. The analyses took into account the share of outbreaks in the structure of farms with pigs, as well as the share of pigs in ASF outbreaks.

Within the range of the economic effects of ASF in Poland, the limitations resulting from the occurrence of ASF cases in wild boar and/or ASF outbreaks in pigs in certain areas of the country, and restrictions related to the trade in pigs, were taken into account. Moreover, changes in the number of pigs and the costs of combating ASF in the country are presented. In this respect, account was taken of the number and distribution of ASF cases in wild boars, and the number and distribution of ASF outbreaks in domestic pigs. The analysis covered the period of development of ASF in Poland, i.e., the years 2014–2020. In order to verify the hypotheses, the analysis was based on the relationship between the number of ASF casas in wild boars and the number of ASF outbreaks in domestic pigs, and their changes over time.

The relationship between the intensity of ASF cases expressed in wild boars and the number of ASF outbreaks in domestic pigs was determined with a linear regression analysis. The ASF outbreaks in domestic pigs (y) was adopted as the dependent variable, and the number of ASF cases in wild boars was adopted as the independent variable (x). The following formula was used (1):

$$y = bx + a \quad (1)$$

where:

y—dependent variable,
x—independent variable,
b—regression coefficient,
a—constant value.

The regression equation allows the prediction of the value of the dependent variable y from the observed values of the independent variable x.

The analysis did not include urban or agglomeration areas (poviats) (e.g., the city of Elblag, or Warsaw poviats), which were characterised by a high number of ASF cases in wild boars but a low intensity of pig production. To verify the second hypothesis, the data from 2014 to 2020 were used. The analysis included the number of ASF outbreaks in domestic pigs and the number of cases in wild boars in poviats.

3. Results

3.1. Selected Features of ASF Development in Poland

The first case of ASF was detected on 17 February 2014, in a dead boar, a few kilometers from the border with Belarus. A day later, another case of the virus was reported. The likely source of this disease on the territory of the country was the cross-border movement of wild boars [20]. Another wave of ASF cases in 28 wild boars occurred between May and December 2014. This was probably the result of the limited circulation of the virus on the Polish territory. The first outbreak in pigs was reported on 23 July and the second on 8 August 2014. In total, in 2014 there were 31 ASF cases in wild boars and 2 ASF outbreaks in domestic pigs [30]. The dynamics of ASF spread in Poland in the first three years was considerably lower than in Latvia, Lithuania or Estonia [31,32]. Unfortunately, in 2017 (the third quarter), and during the first and the second quarter of 2018, the rate of ASF spread in the wild boar population had significantly increased [33]. By the end of December 2019, there were 5824 ASF cases in wild boars and 261 ASF outbreaks in domestic pigs in Poland.

Based on the regression analysis presented in Equation (2), it was confirmed that there is a causal relationship between the intensity of ASF cases (expressed in wild boars in a given poviat) and the number of ASF outbreaks in domestic pigs (Figure 1).

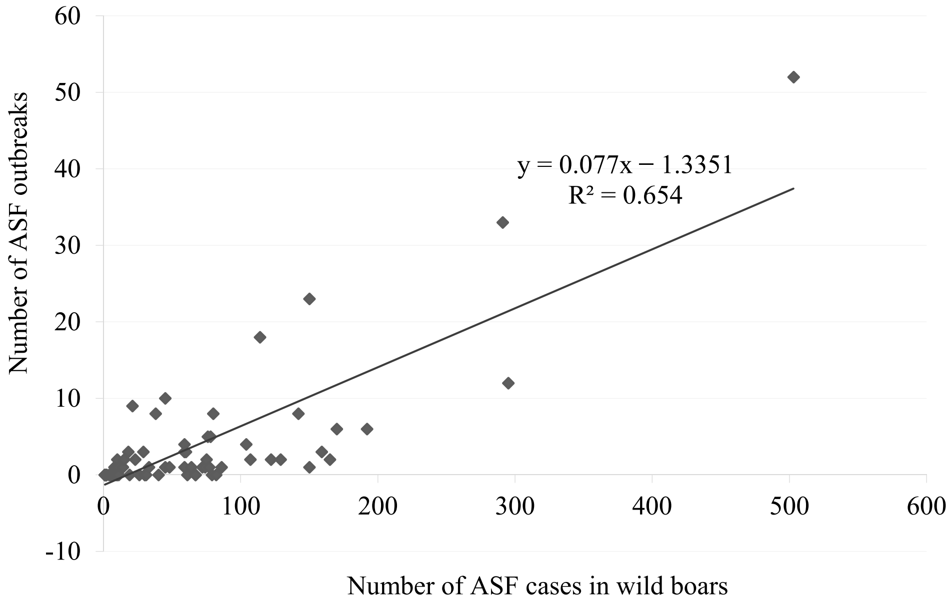


Figure 1. Regression analysis between ASF outbreaks in domestic pigs and ASF cases in wild boars in Poland according to poviats. Source: own study based on CVIF and PKO BP data.

This predicted relationship is as follows:

$$y = 0.077x - 1.3351, R^2 = 0.65 \quad (2)$$

The resulting relationship shows that an increase in the number of cases in wild boars in a given poviat by 1 unit contributes to an increase in the number of outbreaks of swine by 0.08. In this way, the first hypothesis has been positively verified. The developed model explained 65% of the variation in the number of ASF outbreaks in domestic pigs. This result implies that the spread of the ASF virus in pig herds, in addition to cases of ASF in wild boars, might also be explained by other factors which were not directly captured in the regression analysis presented above.

The ASF problem in 2014–2020 mainly affected four voivodeships in the eastern part of Poland. In Podlaskie Voivodeship, the number of cases in the period 2015–2017 ranged initially from 31 to 61 (Figure 2).

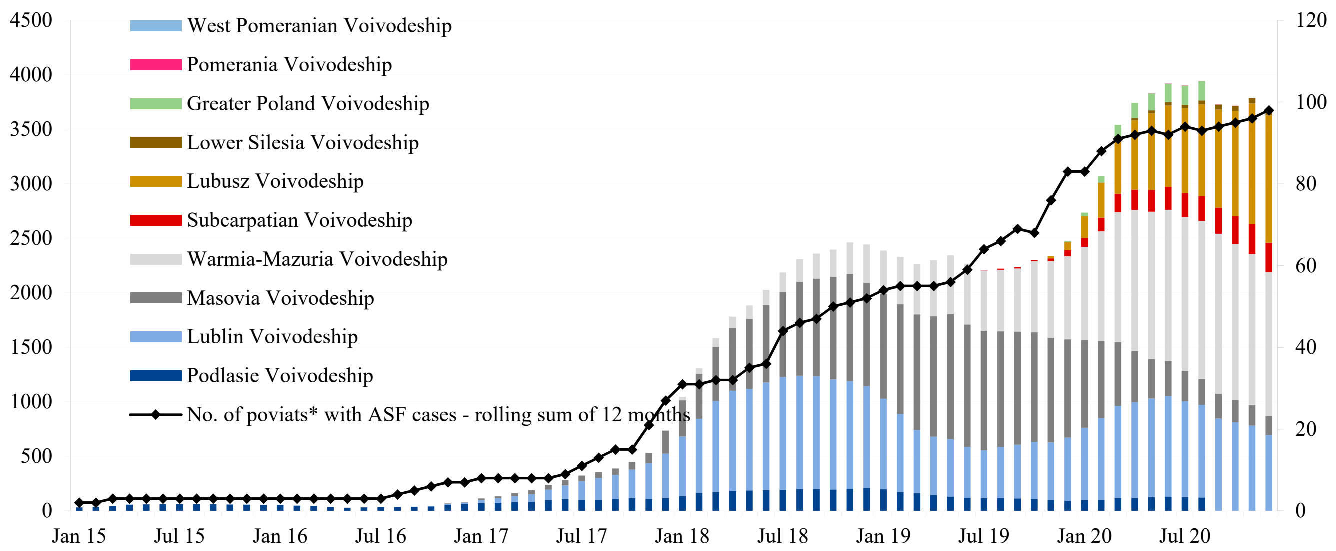
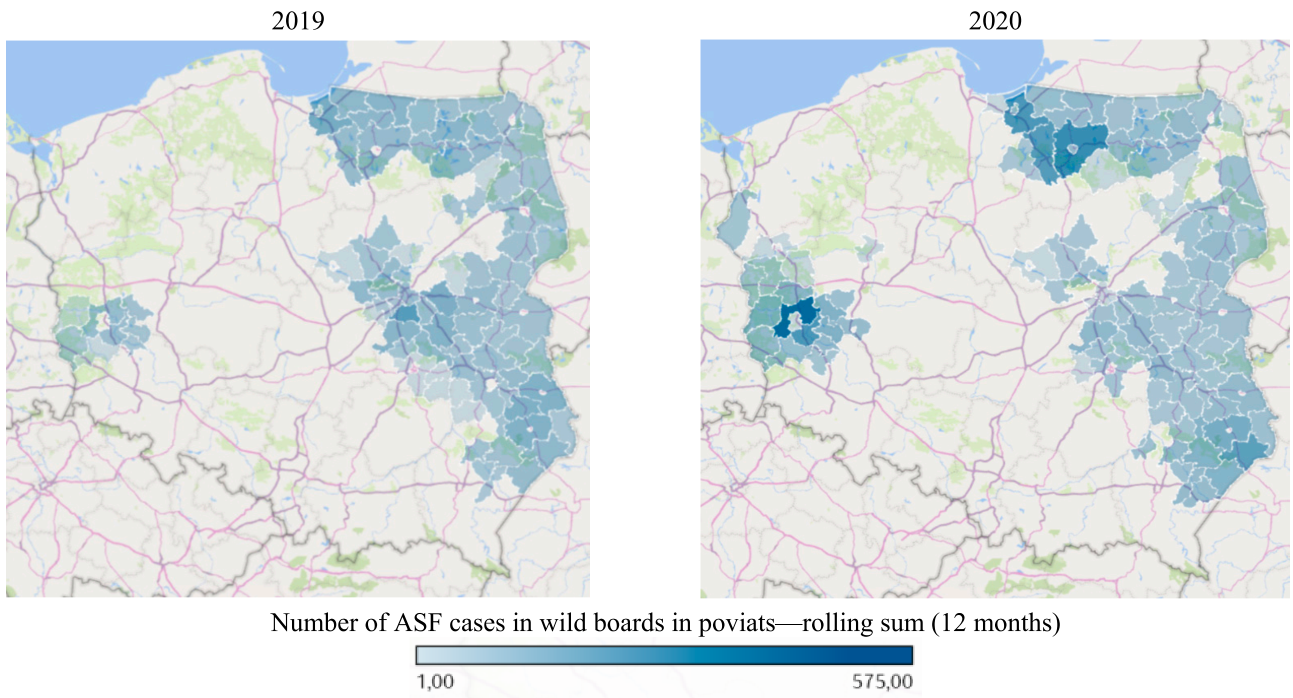


Figure 2. Cumulative number of ASF cases in voivodeships in 2015–2020. Source: own study based on CVI and PKO BP data.

The highest severity of this virus in wild boars in this voivodeship was recorded in December 2018, when the Veterinary Institute confirmed 210 cases in wild boars. The following year, the number of ASF cases in wild boars in Podlaskie Voivodeship decreased and in October it was 109. A more intense rate of development of ASF in wild boars occurred in Lublin Voivodeship, where the first cases of this disease were reported in October 2016. By August 2018, their numbers had increased to 1039. In the following months, there was a reduction in ASF cases in wild boars in this voivodeship to 438 in July 2019, and then, there was a further increase in those cases until October 2019. In Masovia Voivodeship, the largest number of ASF cases in wild boars was recorded in May 2019 (1147). In the following months, the number of cases in wild boars decreased to 1006 in October 2019. In Warmia-Masuria Voivodeship, the first case of ASF in wild boars only appeared in July 2017. Since then, their numbers have increased to 649 in October 2019. In July 2019, the first cases of this disease were also detected in wild boars in Subcarathia Voivodeship.

On 15 November 2019 the Chief Veterinary Officer announced the detection of the first case of ASF in wild boars in Lubusz Voivodeship, in a place 300 km away from the existing ASF area. On 26 November 2019, the first case of ASF was also confirmed in the Lower Silesia region and on 5 December the same year, in the Greater Poland Voivodeship. In total, by 20 December 2019, 64 cases of ASF in wild boars in the western part of Poland were confirmed, including 57 cases of ASF in wild boars in Lubusz Voivodeship, two in the Lower Silesia Voivodeship and five in the Greater Poland Voivodeship. This means that cases of ASF in wild boars in Western Poland have already spread over a large area. According to the General Veterinary Inspectorate (CVI) data, 2477 cases of ASF in wild boars were detected in Poland in 2019, i.e., 1.4% more than in 2018. On the other hand, the ASF area in Poland has increased (Scheme 1). However, attention must be drawn to the reduced number of ASF outbreaks in domestic pigs in 2019, which was 48 according to CVI, which is a yearly decrease of 54%. This may indicate the effectiveness of the measures taken to improve the biosecurity of farms in the country.



Scheme 1. ASF movement in Poland in 2019–2020—the number of ASF cases in wild boars in individual poviats. Source: own study based on CVI and PKO BP data.

The data analysis of ASF outbreaks in domestic pigs in Polish poviats reveals a certain periodicity in the virus development (Figure 3). Over 7 years of the presence of ASF in Poland, it has been observed that the occurrence of ASF outbreaks in domestic pigs intensifies from the late spring to the end of summer, whereas from October to May, the new ASF outbreaks in domestic pigs take place.

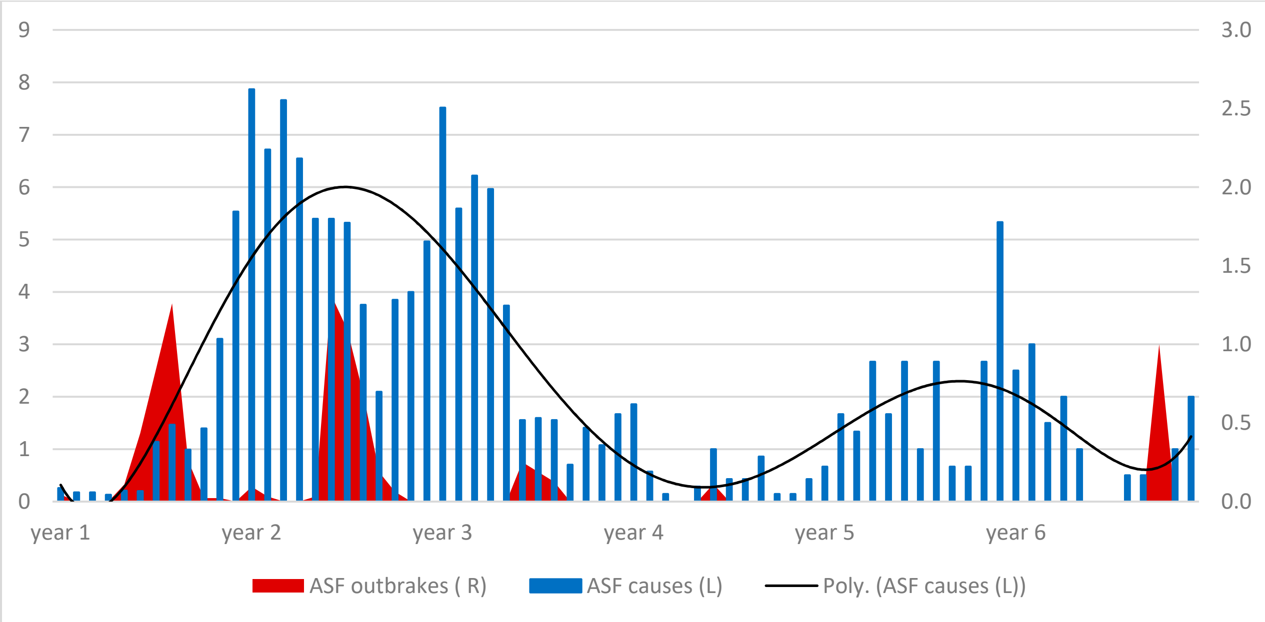


Figure 3. ASF life cycle based on the average of 1-year onset of disease. Source: own study based on CVI and PKO BP data. Explanation: the figures in the graph are the arithmetic means for ASF outbreaks in domestic pigs and for ASF outbreaks in wild boars in the following months.

One exception was the turn of 2014 and 2015. Less regular periodicity occurs in cases of ASF in wild boars. In the first years of the development of ASF in Poland the severity of ASF in wild boars occurred from November to April. Based on the data, it is possible to largely indicate two cycles of development of this disease in the wild boar population, but with a different amplitude of growth. The first cycle falls in the 2nd and 3rd year of ASF occurrence in the country, and the second one occurs in the 5th and 6th year, respectively. The lower amplitude of the second cycle may have been due to greater experience in fighting this disease. In this way, the second hypothesis has been positively verified. Therefore, the research indicates that the elimination of the virus from the environment is very difficult in view of the ease with which it spreads, its high resistance to environmental conditions, and the many obstacles related to the introduction of effective specific immunoprophylaxis [34]. Therefore, it is important to emphasise the increased quality of biosecurity in domestic pig farms. The cyclic distribution of ASF development in Poland indicates that pig herds should be particularly protected from the ASF virus later in spring and summer, while the development of ASF cases in wild boars should be expected especially during winter. This ASF seasonality in pigs may be related to the intensification of fieldwork during spring and summer; this increases the possibility of contact in the field with the virus in the remains of fallen wild boars or their excrements. On the other hand, the increase in ASF cases in wild boars during the winter may result from difficulties in obtaining food and more frequent contact with the infected remains of dead animals. Significant importance can bring the feeding of wild boars, which can lead to an unnatural concentration of wild boars in certain places and increase the likelihood of contact between healthy and infected animals. In total, in the years 2014–2020, ASF outbreaks in domestic pigs included 123,625 pigs (Figure 4). The largest increase in the number of pigs infected during the outbreaks was recorded in the last three years of the analyzed period. In 2018, the ASF outbreaks in domestic pig ASF included 25,395 pigs, in 2019 it included 35,360 pigs, and in 2020 it included 56,210 pigs.

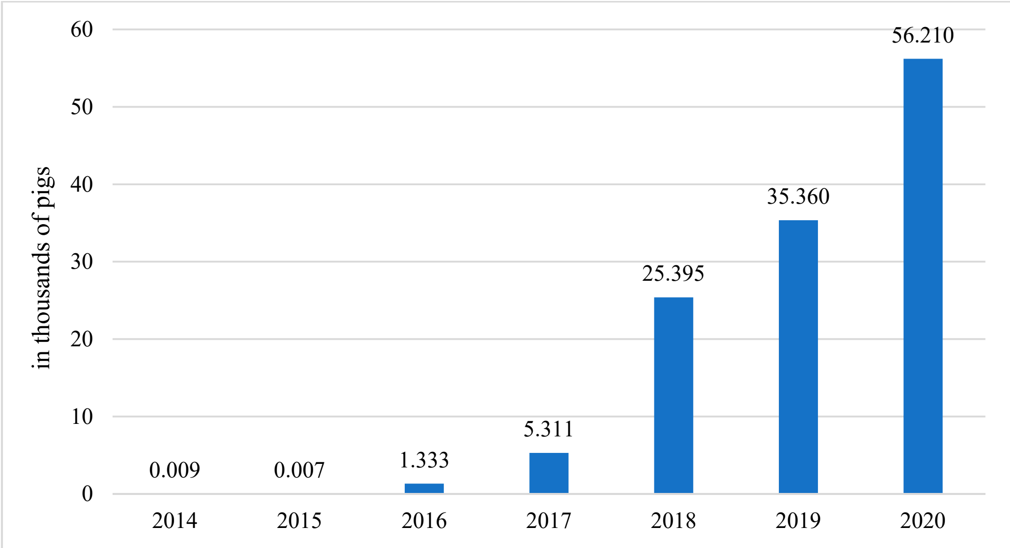


Figure 4. The number of pigs in ASF outbreaks in Poland. Source: Chief Veterinary Inspectorate.

The occurrence of ASF outbreaks in domestic swine concerns both small and large scale farms. The fact is that the production of live pigs in Poland is very fragmented. Many farms are characterised by a small scale of production. The structure of pig farms is dominated by farms with a production scale of up to 50 pigs, whose share is about 75.1%. On the other hand, the share of farms with over 1000 pigs is only 2.0%. Due to this structure of pig farms, the largest number of ASF outbreaks in domestic pigs was recorded within the group of farms ranging from 10 to 49 pigs (41.75%) (Table 2). A smaller percentage of ASF outbreaks in domestic pigs concerns holdings with up to 9 pigs (27.9%). In the group of entities keeping from 50 to 99 pigs, ASF outbreaks in domestic pigs occurred in every 10 farms. A similar situation was observed in farms with 100 to 399 pigs where ASF outbreaks in domestic pigs occurred in 8.6% of farms. On the other hand, in farms with 499 to 1000 pigs, the outbreaks were recorded in 4.1% of farms, and in farms with herds of over 1000 pigs their share was 7.7%.

Table 2. Structure of outbreaks according to the pig rearing scale in Poland.

Pig Herd Size	Number of ASF Outbreaks in Domestic Pigs	Number of Pigs in Herds with ASF	Share of ASF Outbreaks in Domestic Pigs on Farms	Share of Pigs on Farms with ASF
0–9	101	454	27.9	0.4
10–49	151	3489	41.7	2.8
50–99	36	2560	9.9	2.1
100–399	31	5829	8.6	4.7
400–999	15	9309	4.1	7.5
≥1000	28	102,741	7.7	82.6
Total	362	124,382	100	100

Source: own study based on ARMA, CVI and PKO BP data.

However, taking into account the scale of pig breeding in farms, 82.6% of ASF outbreaks in domestic pigs were recorded in farms with more than 1000 pigs. In farms keeping 100 to 399 animals, and 400 to 999 pigs, the percentage of ASF outbreaks in domestic pigs covered 4.7 and 7.5% of pigs, respectively. In smaller farms, the share of ASF outbreaks covered 2–3% of pigs. On the other hand, on farms with only a few pigs, the share was less than 1%.

3.2. Reasons for Developing ASF in the Country

In the years from 2014 to 2015 in Poland, the most highlighted factors that contributed to the occurrence of ASF outbreaks were the insufficient biosecurity protection of pig farms and the occurrence of this virus in the wild boar population in a limited area of Bialystok, Sokoł and Hajnowka poviats. On the other hand, in 2016, the most probable sources of the ASF virus that spread in pigs in Podlaskie, Lublin and Masovia Voivodeships, were the human activities; this is because only a few cases of this disease were detected in wild boars in areas around new ASF outbreaks in domestic pigs, despite intensive monitoring of these animals [35]. The pathogenic agent had been getting into the piggery in the first years of the ASF epizootic, usually through: introduction of infected animals into the facility during the incubation period of the disease, illegal feeding with beakers, and indirectly through equipment, vehicles, or the clothing of people contaminated with ASF virus. In 2015–2016, there were also events in ASF outbreaks indicating direct contact of pigs with virus-contaminated tissues of fallen wild boars. Later, in 2017–2020, green forage, hay, or straw contaminated with ASFV were the likely vectors of the disease [36].

Evidence of the unpredictable role of humans in dragging ASFV over long distances was the occurrence of ASF cases in wild boars at the end of 2017 near Warsaw, more than 100 km from the zones connected with restrictions in eastern Poland [16,33]. In the summer of 2018, eight ASF outbreaks were also confirmed in the Podkarpackie Province, in the Cieszanów commune, without the presence of infected wild boars at a distance of approximately 90 km [37]. In November 2019, the virus was first detected in a boar killed in a traffic accident in the west of the country, in the Sława commune, Lubuskie Voivodeship. The mentioned case was discovered at a distance of over 300 km from the nearest ASF outbreaks, or cases of the disease [38]. Human participation in the spread of the ASF virus has also been confirmed by the conducted research. The data in Figure 5 show that in 10 poviats, the ASF outbreaks in domestic pigs occurred earlier than those of the virus in wild boars. Moreover, in two poviats (Zambrow and Wysokomazowieckie) where there were ASF outbreaks in domestic pigs, no cases of this virus were reported in wild boars; it was probably related to the illegal sale of ASF-infected pigs. In Central and Eastern Europe, wild boars are the main reservoir of ASFV in all affected EU countries [39]. The rate of ASF spread among wild boars is essentially determined by the wild boar population density [3]. Its limitation by intensive culling results in a proportional reduction in the number of cases of the disease. Nevertheless, according to other experts [4], even when the population density is very low (less than 0.1 wild boar/km^2), the long-term circulation of the virus in the environment is kept by wild boars killed by ASF.

The vast majority of ASF cases in wild boars have previously occurred in the immediately adjacent poviats. The exception is the poviat of Lubaczow, where the first ASF outbreak in domestic pigs occurred earlier than the case of the virus in wild boars in this poviat and their neighbouring poviats; however, due to its border location, the ASF virus could have been transmitted from Ukraine. Therefore, human error is a significant cause of ASF virus transmission.

However, the analysis is somewhat limited, because it is not possible to precisely determine the moment of the first appearance of ASF in wild boars in a given poviat. In some circumstances, their detection is decided by chance (e.g., a road accident in Lubusz Voivodeship) and the presence of the virus in a given area precedes the date of its official confirmation. This especially applies to areas that are very distant from the places where cases of diagnosed ASF occur in wild boars and where there is an ASF outbreak in pigs.

However, it is worth noting that there are poviats in the country where ASF cases in wild boards occur and there are no ASF outbreaks in diseased pigs on the farms. In general, ASF cases in wild boars were recorded in urban and suburban areas. Moreover, their scale was often small and, due to the seasonality of the ASF outbreaks in domestic pigs, their impact on ASF on farms has not yet been identified.

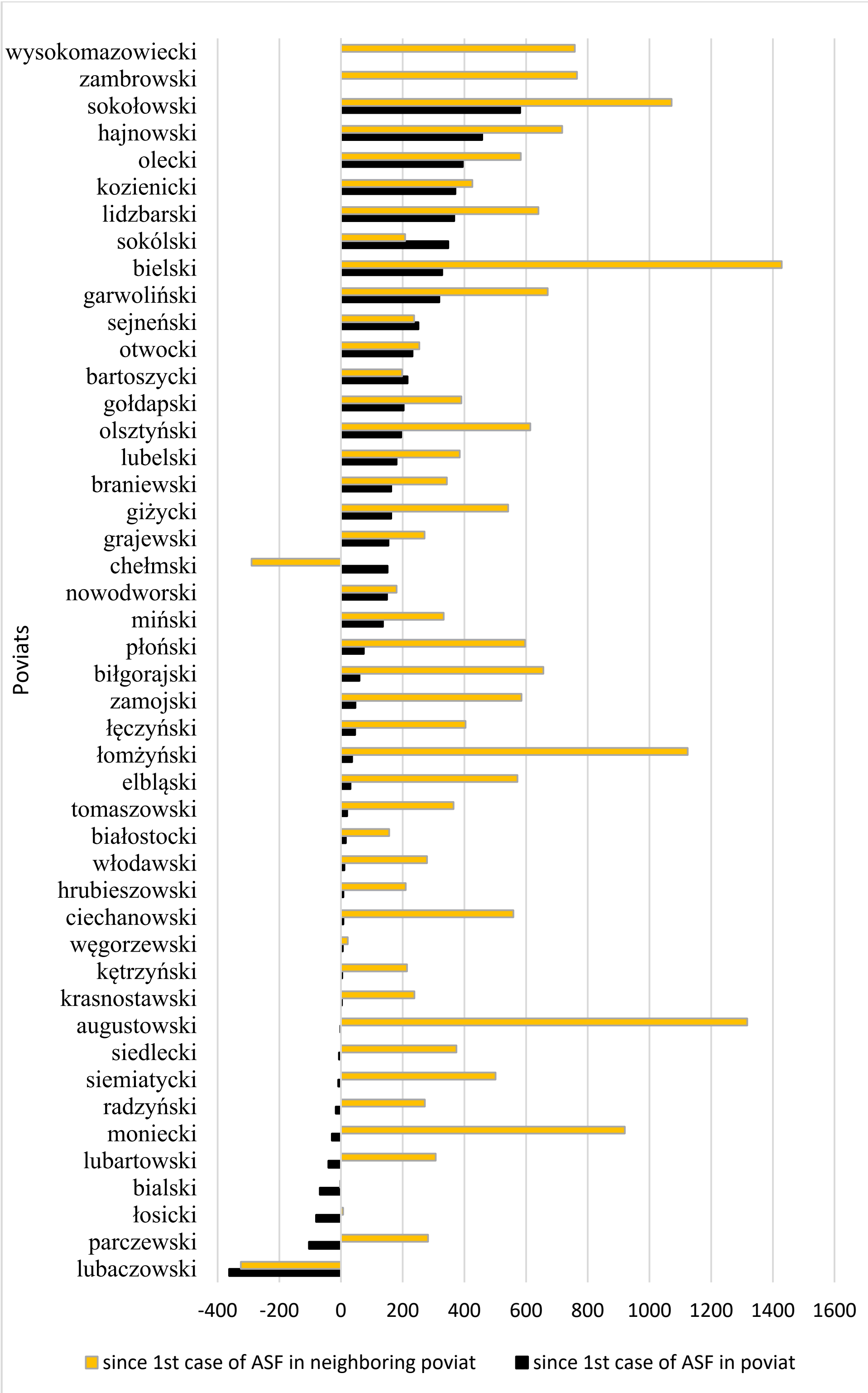


Figure 5. Number of days from the appearance of ASF to the first outbreak in a given poviat. Explanations: 0—date of the first case. Source: own study based on CVI and PKO BP data.

Despite the belief that there are human mistakes in ASF entering the farms, the question arises as to whether the ASF outbreaks in domestic pigs can be fully eliminated. The occurrence of ASF outbreaks in domestic pigs in large farms (to a greater extent than in other farms), where the level of biosecurity is certainly relatively high, may indicate other, unknown factors of virus transmission to farms, e.g., through insects. However, the existence of even the smallest number of ASF outbreaks in domestic pigs in a country does not protect against negative economic effects of ASF. They may include suspension of imports by some Asian countries (Japan, South Korea, Taiwan, Malaysia, China) which generally do not recognise regionalisation. These countries prohibit exports of pigs from ASF-affected countries, even if they come from their ASF-free regions.

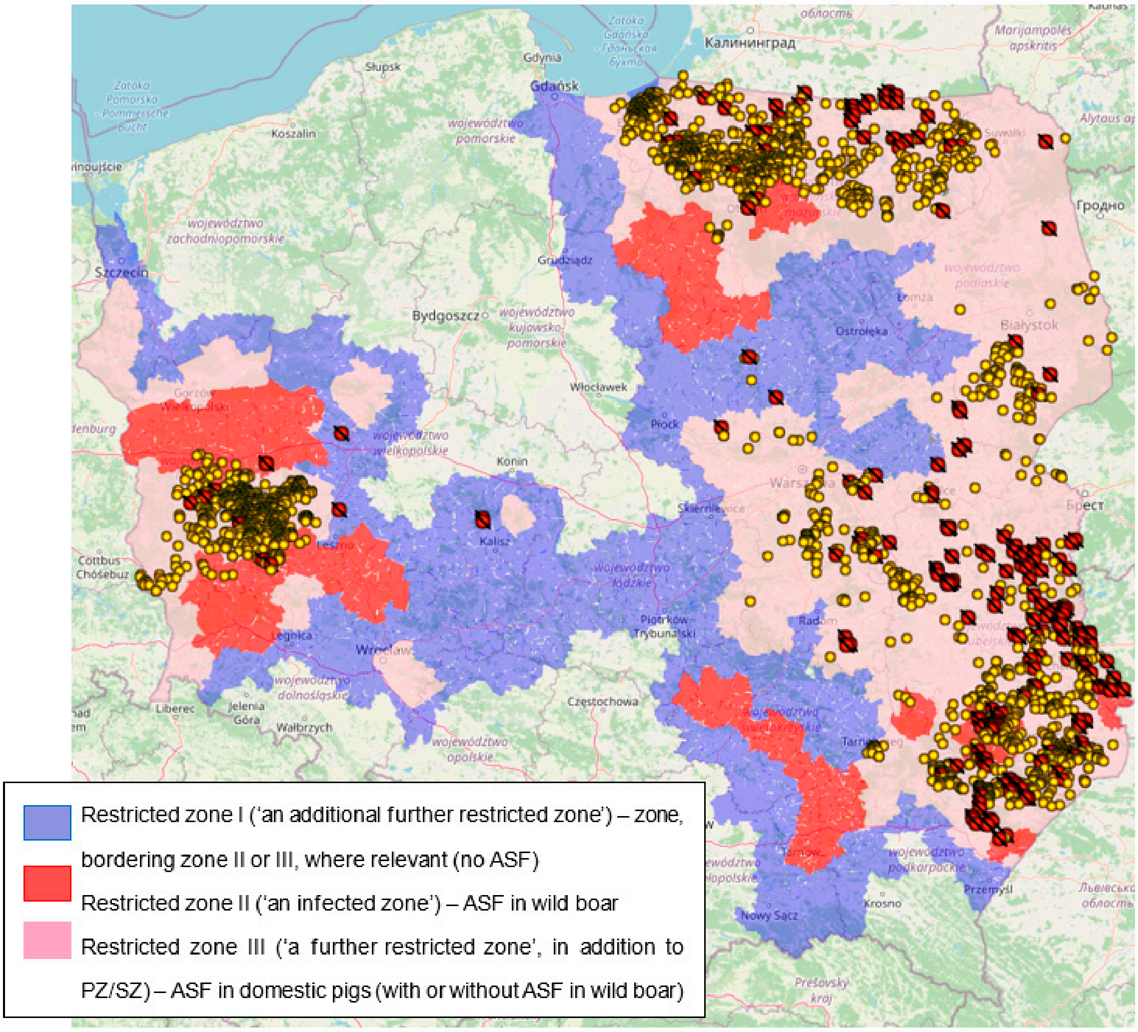
The probability of human error in ASF transmission from the environment to farms increases with the intensity of ASF cases in wild boars. Therefore—in addition to improving biosecurity—it appears to be appropriate to effectively reduce the risk of ASF outbreaks in domestic pigs, inter alia, by reducing the wild boar population, and by adequately protecting against virus transmission from other countries, in particular from Russia, Belarus and Ukraine.

3.3. Economic Effects of African Swine Fever

With the spread of ASF cases in wild boards, larger and larger areas of the country are covered by restrictions resulting from the application of regionalisation principles in Poland. It consists of demarcating ASF risk areas and subjecting them to appropriate restrictions depending on their disease risk. The restrictions mainly concern: the movement of pigs from and to holdings, slaughterhouses, veterinary supervision, appropriate transport conditions, and appropriate documentation. There are three types of ASF-related areas [29]. Their boundaries at the end of December 2020 are shown on Scheme 2.

To reduce the presence of ASF in the country, specific biosecurity measures were applied. The control of their implementation on the farms was entrusted to the staff of the Veterinary Inspection. To meet the biosecurity requirements on farms, financial support has been launched for pig producers for the purchase of disinfection mats, equipment for disinfection, disinfestation or deratisation procedures, as well as biocidal products, disinfectant or deratisation products, protective clothing and footwear. Financial support has also been launched for covering the expenses incurred to secure buildings in which pigs are kept in order to prevent other domestic animals from intrusion. If the farmers gave up the breeding of pigs or received an administrative decision from a poviat veterinary surgeon to ban the breeding of pigs, on account of not meeting the biosecurity conditions, they could apply for compensation on account of the discontinuation of production in the Agency for Restructuring and Modernisation of Agriculture. Moreover, farmers who were in a difficult financial situation due to ASF could apply for loans for settling their obligations.

As a result of the decommissioning of stocks in which ASF outbreaks in domestic pigs occurred, and the abandonment of rearing this animal species by some farmers, there followed a significant reduction in the number of pig farms in Poland from more than 260 thousand in 2012 to about 124.5 thousand at the end of 2019. The reduction in the number of herds was also associated with low profitability in live pig production, difficulties in the sale of animals and the precarious situation related to the spread of ASF on the European and global markets. Thus, in June 2019, the pig population in the country amounted to 10.8 million units and it decreased from the previous year by 1 million 47 thousand, i.e., by 8.9% (Figure 6). The number of all age groups of the population, including the covered sows, has also decreased by 9.1%. As a result of the reduction in the pig population, self-sufficiency in pork production in Poland fell to 88% [40]. The situation did not improve until 2020 when, due to the higher profitability of production, the pig population increased to 11.7 million units.



Scheme 2. Areas of ASF outbreaks in domestic pigs and cases in wild boars in Poland on 28 December 2021. Source: https://www.wetgiw.gov.pl/nadzor-weterynaryjny/asf-w-polsce (accessed date: 30 December 2021).

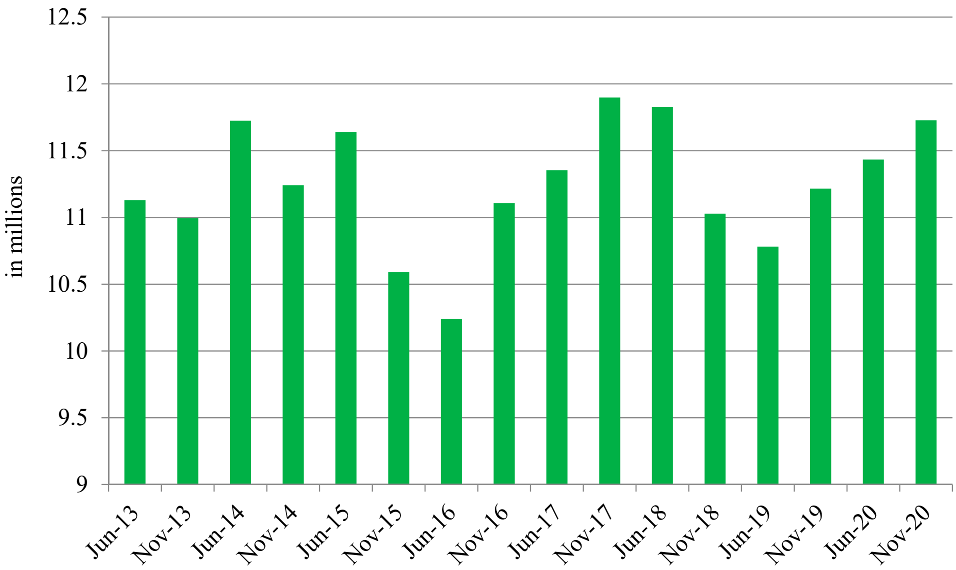


Figure 6. Pig population in Poland in 2013–2020. Source: Central Statistical Office.

As for the pork trade, the confirmation of the ASF virus in Poland has resulted in many non-EU countries (Russia, Belarus, Ukraine, Kazakhstan, China, Japan, South Korea, Taiwan, Singapore, Azerbaijan and Georgia) banning the import of pork products from Poland. This has caused difficulties in exports and the need to diversify outlets. The year 2014 was particularly difficult in this respect, as the exports dropped to 383.3 thousand tonnes, with export to non-EU countries accounting for only 26.5%. In this situation, Polish exporters have been forced to search for new outlets in EU countries. In 2015, pork exports to other countries of the European Community increased to 337.2 thousand tonnes, and to non-EU countries, only 70.7 thousand tonnes. In the subsequent years, pork exports were on an upward trend, and the main recipient of pork from Poland was the United States of America [40].

The occurrence of ASF results in high costs associated with the eradication of the disease, as well as a drastic reduction in the possibility of selling and exporting pigs or pig meat both at home and abroad. Where an outbreak of ASF is detected, the following actions are taken under the supervision of the Veterinary Inspection:

- All pigs on the holding where ASF was found must be killed immediately and their corpses transported to rendering plants, where they are destroyed;
- All products obtained from pigs, and any objects and substances (including feed) present on the farm, which may have been contaminated with the ASF virus and cannot be disinfected, are also destroyed;
- The holding where ASF is found must be cleansed and disinfected using appropriate biocidal preparations which have a disposal effect on the ASF virus;
- Once all the necessary measures have been completed, a sufficiently long period must elapse before the first pigs can be placed in the farm again (at least 40 days after the completion of last cleansing and disinfection);
- A protection zone (with a radius of at least 3 km) and a surveillance zone (extending at least 7 km beyond the protection zone) are defined around the ASF outbreak; in these areas, appropriate orders, prohibitions and restrictions (in particular, as regards the possibility to transfer pigs) are applied, combined with the supervision of the health status of the pigs concerned.

All of these activities generate costs. Their size is shown in Table 3. In the years 2014–2020, almost 93.2 million EUR were allocated to the early ASF detection programme. Moreover, in the period 2015–2018, the high costs for the biosecurity programme were also incurred, for which more than 4.4 million EUR were allocated. In total, in the years from 2014 to 2020, the costs of ASF virus control in Poland amounted to over 97.6 million EUR.

Table 3. Costs incurred for ASF eradication in Poland in 2014–2020 (in EUR).

Years	Biosecurity Programme	ASF Early Detection Programme
2014	-	2,185,362.17
2015	649,267.95	1,928,719.84
2016	294,820.35	5,478,797.93
2017	3,279,286.99	7,402,863.43
2018	182,381.54	16,905,045.52
2019	-	20,246,838.82
2020	-	39,087,298.13
Total	4,405,756.83	93,234,925.84

Source: Chief Veterinary Inspectorate.

The costs of combating ASF in pigs in Poland depend on the number of ASF outbreaks in domestic pigs, the number of animals subjected to liquidation (including the quality of the genetic material of the herd), the market price of pigs, and in particular the prices of services provided by external entities (private practice doctors, rendering companies, and diagnostic laboratories). The costs of eliminating an outbreak are dominated by the costs of the laboratory tests and compensation for the slaughtered pigs.

To limit the spread of ASF outbreaks in domestic pigs in Poland, in December 2019, parliament passed a special law on wild boar hunting. It assumes, among other things, the possibility of the sanitary shooting of wild boars by soldiers or policemen, prohibition of blocking hunting by ecologists, and facilitation of biosecurity for farmers. A large number of wild boars is conducive to the development of ASF. By the end of 2020, almost 4.1 thousand units of dead boars were found in Poland, including 2.5 thousand in the western part of the country. However, many researchers have stressed that mass hunting of wild boars, carried out in groups, without a selection of specimens and in unfenced areas, may lead to further spread of the virus in Poland. This is because infected animals can move over long distances and the virus may be present in the wild boars' remains in the environment. Thus, it might be spread further by hunting dogs or be transmitted on the boots and cars of hunters.

4. Discussion

ASFV does not cause disease in humans, but it is highly contagious and causes high mortality in domestic pigs and wild boar; furthermore, it has a significant economic impact on the global swine industry [41]. Important progress has been made over the past few years regarding the understanding of the important sources of ASFV transmission in the Caucasus, Eastern Europe and the Baltic countries [42]. With the development of the disease, various epidemiological scenarios were observed [43]:

- In the Caucasus, in the Russian Federation, Ukraine and Romania, the disease mainly affects domestic pigs, with fewer ASF cases in wild boars;
- In the European Union (excluding Romania), more than 90% of ASF cases concern wild boars, and ASF outbreaks in domestic pigs are less common on pig farms;
- In China, the disease spreads rapidly within the domestic pig population.

The first years of the epidemic in the EU were characterised by slow geographical expansion of the disease within the affected member countries, dominated by cases in wild boars, and only sporadic outbreaks in domestic pig farms. In contrast to what was initially predicted, the epidemic thus seemed to be driven by wild boar, and ASFV circulation could be maintained within the affected wild boar population, independently from outbreaks in domestic pigs [24]. In this new epidemiological scenario, described as the wild boar–habitat cycle, infected wild boar carcasses and the virus-contaminated environment are believed to constitute the long-term source of the virus needed to maintain the virus circulation over time [44]. Whereas local disease expansion occurred through natural movements of infected wild boar, longer distance translocations of the virus—locally or regionally within affected countries, or to more distant and previously unaffected parts of the EU—were most likely related to human activities [19].

In this way, within Europe, two different epidemiological scenarios have been observed depending on the predominant type of host affected. On the one hand, there are the affected countries of the European Union (with the exception of Romania, Bulgaria, Slovakia and Greece), where more than 90% of the notified cases are attributed to wild boars, with sporadic outbreaks in domestic pig farms. However, in Eastern Europe, including countries such as Russia, Ukraine, Belarus, Moldova and Romania, ASF mostly affects domestic pig farms and, to a lesser extent, wild boar. This difference can be explained by the fact that these latter countries have a greater number of family or backyard farms. This type of production system has low levels of biosecurity and is usually located in areas where wild boars live, which increases the risk of transmission of the virus to domestic pigs.

The continued spread of ASFV in Africa and Europe demonstrates a potential for further spread in other regions of the world. There are still many gaps in the knowledge of the biology of ASFV, its interaction with hosts, immune responses correlating with protection and how these immune responses can be activated. Vaccine development against ASF is hampered by large gaps in the knowledge concerning ASFV infection and immunity. Current studies indicate that ASFV isolates circulating in Eastern Europe and the Russian Federation are highly virulent and kill most of the infected domestic pigs and wild boars. There is a need for continued monitoring in the field, along with experimental infections, to identify the ASFV isolates of altered virulence [45]. ASFV can be transmitted directly during: (i) contact between infected and susceptible pigs; (ii) consumption of the meat from infected pigs; (iii) the bites of infected soft ticks (Ornithodoros species); and indirectly, (iv) by contact with fomites contaminated by virus-containing matter such as blood, faeces, urine, or saliva from infected pigs [46].

Bergman et al. reviewed the currently known environmental risk factors that can influence the occurrence of ASF virus infection in wild boars compared to disease occurrence in wild boars of a non-exposed reference scenario. They identified the following ASF risk factors [47]:

- Climate factors, such as temperature, precipitation, humidity, wind, cloud coverage, ultraviolet light conditions, climate changes or season;
- Land cover and geomorphology factors, such as vegetation type, coverage, distribution pattern, altitude, soil type and water availability or type;
- Human activity factors, such as human population density, traffic, pollution, artificial structures, housing, roads, farm density, livestock density as well as human outdoor activity types and levels;
- Wild boar host-related factors, such as wild boar presence in terms of density, distribution, or measurable effects as a result of their activity (e.g., crop damage);
- ASF disease factors, such as disease presence, disease type (e.g., a high proportion of ASFV seropositive wild boars present), distribution, distance in space and time from susceptible animals and the viral load, infectious pressure, or contamination level.

Bellini et al. analyzed ASF risk factors in pig farms in the European Union scenario; they defined seven categories: biosecurity; swill feeding and slaughtering on-farm; trading of pigs and products; human activity factors and farm management; sociocultural risk factors; ASF in wild boars, as a risk for neighbouring farms; and ticks and other blood-feeding arthropods. Based on a literature review, they concluded that different types of risks affect different types of farming systems, and they need to be specifically considered when preparing a biosecurity program [48].

Sources of infection in Europe include infectious domestic pigs and wild boar, contaminated carcasses, food waste, and contaminated vehicles or equipment. The soft ticks of Ornithodoros spp. are not involved in the transmission of ASFV in Eastern Europe, Russia or the Trans-Caucasus region. In turn, wild boars are not present in Africa, but wild suids, including warthogs and bush pigs, can be persistently infected and act as a source of infection. Ornithodoros spp. ticks inhabiting warthog burrows or pig housing can also be involved in transmission in East Africa [45].

Pig production in the EU is highly heterogeneous regarding farm type (industrialised, outdoor, or backyard), biosecurity standards, and purpose (commercial or own consumption), and the risk of exposure to ASF depends on the country, area and farm location, and the epidemiological situation of the territory [48].

The European Food Safety Authority (EFSA), assessing the risk of spread of ASF in Eouth-Eastern Europe in 2019, considered the following as the main risk factors for ASF spread in domestic pig populations: swill feeding, the presence of free-ranging pigs in some areas of a country, the presence of a substantially high number of smallholders in the country, and home-slaughtering [49].

The conducted research confirms that in Poland, most cases of ASF concern wild boars, and outbreaks of the disease are less common on pig farms. Despite actions taken by veterinary services, hunting associations and the involvement of state administration bodies in combating ASF in Poland, the disease spreads rapidly. Initially, the ASF problem mainly concerned the voivodeships in the eastern part of Poland, but at the end of 2019 ASF cases in wild boards were also reported in the western voivodeships of the country.

The most common causes of this disease in Poland were classified by Rzymski [20] as follows:

- Feeding pigs with fresh, green fodder, collected from wild boar areas where ASF cases in wild boars have been found;
- Insufficient compliance with the biosecurity rules for the maintenance and handling of different livestock species;
- Carrying out other farming activities, e.g., tree felling in the forests of the ASF areas;
- Human activity, such as illegal pig trafficking.

The analyses carried out by M. Flis and J. Nestorowicz [50] show that there are two potential vectors for the spread of the ASF virus in Poland. In border poviats, the main vector of ASF virus transmission is migrating wild boars that move from neighbouring countries. In contrast, in the case of poviats located in the central and western part of the country, the main spread vector is the human factor. Negative human activities include feeding animals with refuse, buying piglets from unknown sources, burying dead pigs in the area of the pigsty, and sluggishness in implementing the biosecurity programme. This is indicated by the conducted research. The data show that there are poviats in Poland where ASF outbreaks in domestic pigs occurred earlier than ASF in wild boars; however, they occurred much earlier in the neighbouring poviats. In two poviats with ASF outbreaks in domestic pigs, however, no ASF cases in wild boars were reported.

The results of De la Torre et al. [51] agree with our conjecture that the sources of transmission of ASF in the Baltic States and Poland are related to the wild boars' habitat suitability, and to the neighbouring distance from infected wild boars and domestic pigs. Apart from the wild boar population and the habitat, the current ASF epidemic recognises humans as the main responsible source for both long-distance transmission and virus introduction in domestic pig farms [24]. The most important measures which are crucial to limit ASF spread are based on control and prevention methods, including administrative regulations, stamping out the infected pigs, implementation of sufficient biosecurity conditions, as well as a reduction in the wild boar population, supported by the disposal of wild boar carcasses [18]. In this regard, J. Bosch et al. have developed a useful tool to control affected areas and prevent disease in still-unaffected areas. Based on such a map, decisions can be made regarding wild boar hunting and the location of pig farms [52]. The country in which ASF occurs is exposed to very high economic losses in the meat and farming industry, caused by the deaths of pigs, the cost of eradicating the ASF outbreaks in domestic pigs, as well as the restrictions on trade and export of pigs, pork and other related products obtained from pigs. The impact is often greatest for resource-poor livestock farmers in developing countries, who rely on pigs as an additional source of income and a relatively cheap source of protein [45].

ASF is an increasing threat for the European Union, which is the world's second-biggest pork producer after China. Poland is one of many EU member states from the former Eastern Bloc that was hit hard by this virus. The appearance of the ASF virus has harmed the pork market in Poland, resulting in restrictions on the export of this meat, costs of eradication of ASF outbreaks, and biosecurity [53]. The scale of the costs of combating ASF and eliminating disease outbreaks is primarily related to the density of pig population in a given area, including the number of piggeries and their size [54].

According to A. Stancu, ASF harms the livestock industry because all of the animals in an infected herd must be slaughtered. The need for feed is reduced as a result of the decline in the number of domestic pigs, and feed is an indirect transmission vector of ASF from infected to healthy pigs. The companies from the food industry have to find new suppliers for pork meat if the consumers' demand for pork products remains unchanged. The export of pork meat and pork products decreases because every importing country wants to avoid the introduction of ASF to their food chain [55].

Further recommendations to eradicate ASF in Poland, or at least to minimise the economic loss caused by ASF in pig production, include effective wild boar population management strategies, along with the implementation of strict biosecurity measures in domestic pigs farms and in the management of populations of wild boars.

5. Conclusions

The occurrence of ASF outbreaks in domestic pigs concerns both small and large scale farms. ASF is more prevalent in smaller holdings, but taking into account the scale of pig farming, the ASF virus brings more losses to large farms with herds of more than 1000 pigs.

Among the main reasons for the development of ASF in the country are the insufficient bio-insurance coverage of pig holdings, and the presence of that virus in the wild boar population, particularly as there is a strict correlation between the number of ASF cases in wild boars and the number of ASF outbreaks in domestic pigs of that virus in domestic pigs. The cause of the spread of the ASF virus is also due to humans and their activities. The likelihood of human error increases with the number of ASF cases in wild boars in areas close to pig farms.

The analysis of data for poviats where ASF cases in wild boars and ASF outbreaks in domestic pigs have been reported shows a certain periodicity of ASF occurrence in the country. The incidence of ASF outbreaks in domestic pigs is increasing from late spring to the late summer. In turn, from October to May, a slowing-down of new ASF outbreaks in domestic swine can be observed. Less regular periodicity occurs in ASF cases in wild boars.

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