Scientific Papers. Series D. Animal Science. Vol. LXVI, No. 1, 2023
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

WILD BOAR SURVEILLANCE THROUGH ELECTRONIC MODULE "HUNT" MOBILE APPLICATION IN BULGARIA

Dimitar TANCHEV, Gergana BALIEVA

Trakia University, Stara Zagora, Bulgaria

Corresponding author email: dimitar.tanchev@trakia-uni.bg

Abstract

African swine fever is a disease that affects representatives from Suidae family and leads to serious economic losses and ecological damage to swine population. A major role in the etiology of the disease is played by wild boars, both as a vector and as a reservoir. Due to this fact, monitoring the spread of the disease among feral pigs is one of the main factors for the prevention of the disease. For this reason, in 2019, the Bulgarian Food Safety Agency launched `Module "Hunt" application. The application allows hunters both easy and quick sending of data on the sample taken from a shot or found dead animal, as well as checking the result just by writing the sample number, while location, date and time of taking the sample are obtained automatically by the application. The current study analyzed both application performance (input, output of data) and data on number of samples taken from hunted feral pigs, percentage positive results from shot animals, proportion of samples taken from wild boars found dead with ratio of positive samples from them.

Key words: *African swine fever, surveillance, wild boars.*

INTRODUCTION

Due to the huge economic importance of the African swine fever disease, the fight for prevention or eradication of the disease is a priority in the agricultural policies of the countries. Wild boars play a major role in the spread of the disease. They are involved both directly, through contact, in low biosecurity of pig farms, and indirectly, e.g. through contaminated feed or food waste (Yoo et al., 2019; Schulz et al., 2021). In addition, wild boars play the role of a reservoir for the disease (Gervasi et al., 2019; Dixon et al., 2020). This makes it impossible to control ASF without controlling the infection in feral pigs. Disease surveillance is one of the main methods of control. Countries affected by the disease or those at risk of its introduction take different measures to control the disease as far as feral pigs are concerned.

In Italy, where the disease is already present, regarding passive surveillance in wild boars, everyone is required to report discoveries of carcasses found in the field, and the local veterinary service collects samples from these animals (including wild boars killed in motor vehicle accidents). Wild boar sampling was planned in order to rule out ASF virus infection in the general wild boar population. The ASF plan includes sampling of all wild boars found dead (Iscaro et al., 2022).

To prevent the disease from entering its territory, following an outbreak of the disease in Belgium near to the border, France is introducing three new protocols for the active search for dead wild boars in the border area, which complement the standard surveillance in level III risk areas: patrols by volunteer hunters, professional systematic search of the area and use of dogs. These protocols complement each other in terms of location and time. The main objectives of the designed surveillance system are to ensure early detection in the event of disease introduction and to support the area's continued free status (Desvaux et al., 2021).

On the other hand, as mentioned above, one of the main routes for the spread of the disease in both wild and domestic animals is the remains of contaminated food. For this reason, it is vitally important that meat from infected animals is not allowed for consumption or food preparation. This applies to the greatest extent to the meat obtained from wild pigs, and the timely detection of infected meat from the shot animals is of great importance to prevent the spread of the disease (Guberti et al., 2022; Dixon et al., 2020; Mazur-Panasiuk et al., 2019).

In order to performs qualitative and timely control, it is important that the information on the found carcasses of wild pigs, the data on animals shot, the patho-anatomical findings and data on the samples taken reach the competent authorities and laboratories as quickly and easily as possible. Getting a result quickly also plays an important role in the disease surveillance process. The use of database-related mobile applications, in addition to fast and easy data transfer, provide a volume of information that can be used both for various analyses and for visualization of the received data (Beyene et al., 2018; Moses et al., 2021).

For thousands of years, maps have been used for display and analysis of geographic information. We can use the visualization of sample results on a map for visualization, retrieval and analysis of spatial data. Geographic information systems (GIS) in animal control are mainly used for outbreaks of notifiable animal diseases. They support the veterinary officer in defining restriction areas, assessing the number of animal holdings and animals and planning control measures. GIS makes routine tasks easier, e.g. by enabling the establishment of sampling plans or herd statistics for a specified area.

Geographic analytical methods help to investigate the spatial and temporal spread of animal diseases and to describe the risks. The results of such studies can be used as a basis for spatial simulation models which describe the spatial spread of the disease (GIS: Friedrich-Loeffler-Institut, n.d.; Norstrom et al., 2001; Tadesse & Amare, 2021). GIS have been widely used by researchers during the Covid-19 pandemic (Elsheikh, 2022; Kabir et al., 2021).

In September 2002, the Institute of Epidemiology (Friedrich-Loeffler-Institut) started the development of an animal based database system on the epidemiological situation of swine fever in wild boar in Belgium, France, Germany (federal states of North Rhine-Westphalia, Rhineland-Palatinate, and Saarland), Luxembourg and the Netherlands. This project was carried out in close cooperation with the working group for swine fever in wild boar of the European Commission. The database was realised as an internet based project and permits data entry and analysis via an internet browser (EURL CSF/ASF Database: Friedrich-Loeffler-Institut, n.d.).

After the entry of ASF in Bulgaria in 2018 and the sharp increase of cases in 2019, by order of the executive director of the Bulgarian Food Safety Agency the mobile application Module “Hunt” was launched on 10.07.2019.

MATERIALS AND METHODS

Mobile application. Module "Hunt" is an application for mobile phones that aims to facilitate the process of registering and sending samples from game, allowing the registration of a sample directly through the application, eliminating the paper copies of a letter to the laboratory. The application automatically reports the GPS coordinates of the place where the sample was taken, or where the animal was shot. The date and time of sampling are automatically recorded. The data are saved on a server. ASF testing laboratories can access these data and the result is re-entered electronically and can be accessed through both the mobile application and web-based application.

Data. In the application, in addition to the automatically generated data, data on the type of animals are entered (due to the fact that additional functionalities have been added to the application to control of a different wild animal diseases). After choosing the type of animal - wild boar, the data that must be entered are:

Sex of the animal

Shot or found dead. If the animal was shot, information is filled in, whether the animal was visibly healthy or with atypical behaviour. If an animal carcass is found, information is provided as to whether the carcass is fresh or in the process of decomposition.

Information on the age of the animal. Offspring - up to one year, one to two years, young animal - 2-3 years, and animal over 3 years.

Weight - up to 50 kg, 50 to 100 kg, over 100 kg.

For which disease the sample will be tested. There have to be selected for which disease the sent material should be examined, as well as the type of material.

Unique sample number - barcode.

Attached photos. The application also allows the introduction of photographs, in the case of patho-anatomical changes that would be important in establishing the diagnosis.

Samples. Data can be entered into the application for both shot and found dead animals. According to the sampling instruction, samples are taken from every wild boar shot or found dead. An organ sample from the spleen and a blood sample are taken from the shot animals. The same samples are taken from an open fresh carcass. A tubular bone is taken from corpses in stages of decomposition or from the remaining skeleton of an animal and sent for examination.

Organization for sending the samples: Each hunting group or every hunter who would send samples has barcodes, two by two with the same unique number provided by the hunting association of which he is a member. The samples taken from the shot wild boar are placed in a vial on which one of the barcodes is affixed, the second is affixed to the carcass, which is not allowed to be used until a negative result is obtained. The samples are sent to the laboratory by the hunting company, and the laboratory accesses the available data related to the sample by dialling the corresponding barcode in the application. A study protocol is re-entered into the application, and for the result, database can be accessed through both a mobile and a web-based application.

Data. In addition to the specific results for a given sample, the application creates a database of collected samples from its inception to the present date. The application has a public part where anyone interested can choose data on the type of game and disease for which he/she wants to receive data, the period of sending the samples (start and end date), the territory where the sample was taken (the whole country, a specific area, or municipality from the district). The data is received in tabular form and visualized on a map. When the mouse pointer is placed on the point visualizing a certain sample, the data for the corresponding sample is loaded on the screen. The differences in the colour with which the sampling locations are marked (negative - green, positive - red) enables quick orientation.

The official veterinarians' individual access, which is protected by a username and password, enables a more detailed review of the information.

RESULTS AND DISCUSSIONS

For the period from its commissioning to 31.12.2022, 64,175 samples have been entered into the application for 42 months. From all these, 2,676 were positive, 61,347 were negative, and unfit and blocked were 152 pcs. For comparison, in Estonia, 62,944 data records were available for 84 months of study, of which 60,238 originated from active surveillance (from a hunted wild boar) and 2,706 from passive surveillance (from a wild boar found dead, shot, sick or involved in a traffic accident accident). For Latvia, 102,321 data records were analysed over 83 study months. Of the samples analysed, 99,665 were from active and 2,656 from passive surveillance. Lithuanian data are available for 72 months of study. A total of 87,307 data records were analysed, of which 83,566 data came from active and 3741 from passive surveillance. The data for all three countries originate from the European Union wild boar CSF/ASF surveillance database (https://surv-wildboar.eu) (Schulz et al., 2022).

The data required to enter a sample in the Module "Hunt" correspond to a large extent to the data described in the Data collection chapter in African swine fever in wild boar ecology and biosecurity - second edition FAO Animal Production and Health Manual No. 28 (Guberti et al., 2022). According to this manual, the aim of data collection is to improve understanding of animal diseases and the capacity to control and eradicate them. Data collection and analyses are an essential part of any animal disease surveillance programme, acting as a useful tool to measure the efficacy of control and eradication strategies, and eventually to highlight weak points. A sample collection form has been created that includes the basic data to be collected. In addition to the basic data, it is important to include the latitude and longitude of the location where the animal was shot or found dead. According to the cited guide, geographic data are suitable for studying the spatial and temporal evolution of infection. Latitude and longitude are easy to register using a basic smartphone. In affected hunting grounds may have hunting lodges with specific coordinates and thus used as a proxy for the location. A dedicated mobile application can be a very useful solution, facilitating the reporting process by hunters when it comes to collecting samples from hunted animals or carcass finds (Guberti et al., 2022).

Similar data collection was obtained in many surveillance programs. The relevant authorities approved the use of the data. Each data record corresponds to the surveillance data for a single wild boar and contains information about place (county, municipality and the smallest administrative unit, where the animal was found or shot), the time (day/month/year) of sampling, age, sex of the wild boar and the origin of sample. The "origin" refers to how it was recorded: whether the sample was taken from an apparently healthy hunted wild boar (active surveillance) or from a wild boar found dead, shot because it was sick or killed in a road traffic accident (passive surveillance). Furthermore, the data of the laboratory test results were recorded (Schulz et al., 2021; Dellicour et al., 2020).

Data entry into The European Union Wild Boar Surveillance Database (https://surv-wildboar.eu), includes characteristics of the individual wild boar (sex, age, cause of death and location) as well as the results of laboratory diagnostic tests (virology and/or serology) (EURL CSF/ASF Database: Friedrich-Loeffler-Institut, n.d.).

Data entry in the Module "Hunt" application enables any interested person to enter data, the only required access information being a mobile phone number. The data can also be obtained through the application downloaded to a mobile device or through a web browser. The publicity of the data at the Module "Hunt" is of a great importance so that the citizens and mainly interested parties can get a clear idea of the extent of the spread of the disease. The individual account provides detailed information on each criteria set when entering the sample as well as the results entered by the laboratory. Access to EU CSF/ASF database is restricted by safety mechanisms. The users must authenticate themselves by user names and passwords (EURL CSF/ASF Database: Friedrich-Loeffler-Institut, n.d.).

Recording the automatic receipt of the coordinates where the sample was taken and the time and date of collection, allows the veterinary authorities to take immediate measures in case of a positive result of the sample. Zones can easily be defined, additional measures can be taken if necessary. The intensity of distribution in a relevant area can be estimated. The visualization of the map enables a clearer idea of the distribution and intensity of the disease in a specific area, creating geographic models, detailed information for disease forecasting, epidemic forecasting, identification of disease clusters or hotspots, creation of buffer zones, and for evaluating various strategies to prevent the spread of infectious diseases (Tadesse & Amare, 2021; Forth et al., 2023).

The Module "Hunt" visualizes the test results of the samples with different colours, which clearly shows the results by region. The results of all samples can be visualized (Figure 1), or specific results - positive (Figure 2), negative, unsuitable, blocked. The application provides the possibility to filter the samples by administrative region - district or municipality, as well as introducing a filter for the time period of sending the samples. These options are valid for both the public version of the application and the one accessible by veterinary authorities with authorization.

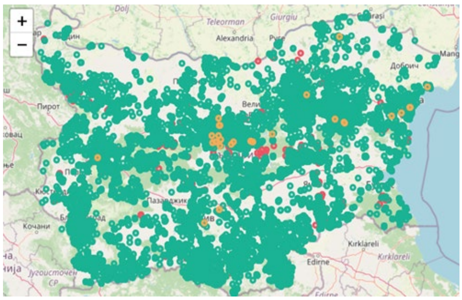

Figure 1. Visualisation of all samples recorded in Module "Hunt" for the period 2019-2022 (public account access)

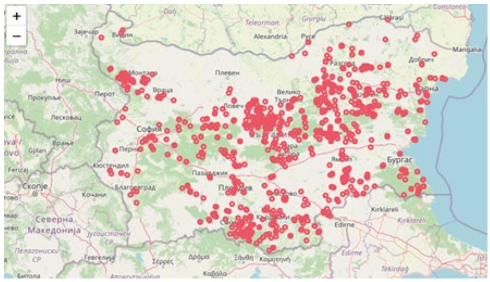

Figure 2. Visualisation of all positive samples recorded in Module "Hunt" for the period 2019-2022 (public account access)

The European Union database also shows in addition to the analysis in the form of a table that can be filtered by time period, administrative units (e.g. Member State, Federal State, Region), age classes and results, the Internet map server also allows to display of the results in the form of a map according to administrative boundaries and topographic features (hunting module does not provide topographic features). Map Explorer connects the laboratory results with the corresponding areas of restriction and vaccination and facilitates the coloring and display of the maps. (EURL CSF/ASF Database: Friedrich-Loeffler-Institute, n.d.).
The possibility of obtaining data through active and passive surveillance leads to obtaining the most accurate information about the spread of the disease, as well as increases the percentage of found positive cases. In the Module "Hunt" the results can be obtained not only for the whole country but also for individual regions. Figure 3 shows the distribution of positive results in the 28 administrative regions of the country, for the period from the entry into operation of the application until the end of 2022. The diagram confirms the data, that although unevenly distributed due to the geographical and natural features of the regions, wild boar disease occurs in all regions of the country.

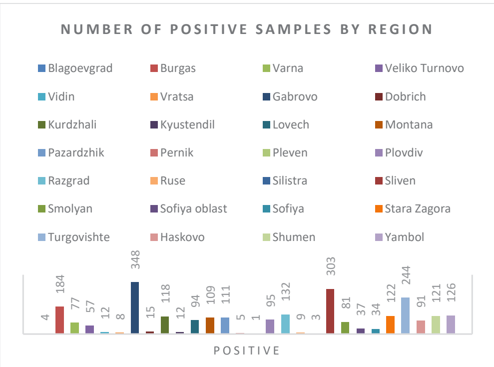

Figure 3. Number of positive samples by administrative region in Bulgaria

The ability to visualize the results allows a visual model of the spread of the disease to be created. (Depner et al., 2017; Dellicour et al., 2020).

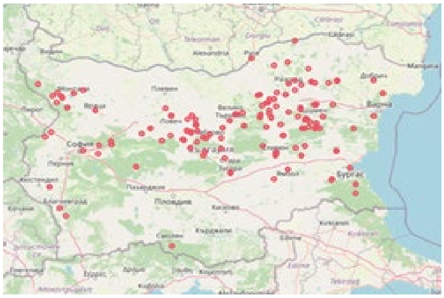

Figure 4. Visualization of positive samples of ASF in Wild boar – 2019

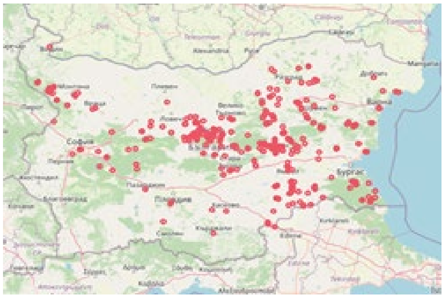

Figure 5. Visualization of positive samples of ASF in Wild boar – 2020

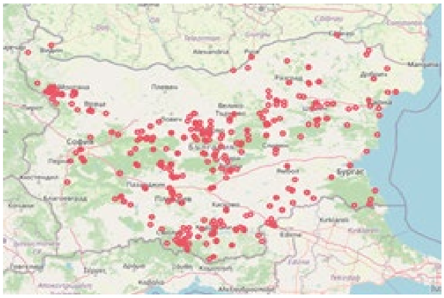

Figure 6. Visualization of positive samples of ASF in Wild boar – 2021

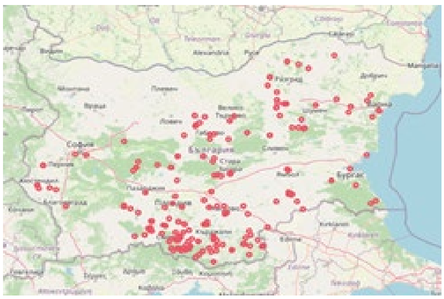

Figure 7. Visualization of positive samples of ASF in Wild boar - 2022

From the images above, we can get a clear idea of the territorial distribution of ASF in Wild boar for the research period 2019-2022. The number of positive samples had increased in territories unaffected or slightly affected by the disease, and decreased in territories where the incidence was high. The long-term retention of the amount of positive samples in the central part of the country is due to a huge mountain massif in terms of territory - Stara Planina mountain, creating conditions, on the one hand, for maintaining a high population of wild boars, and on the other hand, hindering the movement of animals over such large distances as it is possible to pass in the plains and foothills. All this makes the dynamics of the disease smoother, by keeping a relatively high percentage of morbidity for a longer time.
From the analysis of the data obtained by the application (Figure 8), it is possible to track the dynamics and intensity of the spread of the disease. From the data below it is clear that the percentage of positive, out of the total number of examined suitable samples among the population of wild boars, increased sharply and reached its peak in the year after the disease entered the territory of the country. The number of samples also increased, over the next two years the percentage of positive samples to all sent gradually decreased.

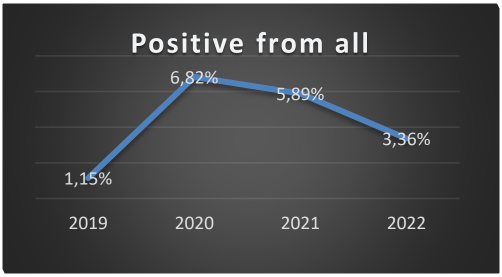

Figure 8. Percentage positive from all samples - 2019-2022 period

Similar trends are observed in other studies. The larger number of samples tested at the beginning of the outbreak is likely due to several factors. It can be assumed that the motivation and hope of successfully eliminating the disease led to increased efforts to hunt or find and sample wild boar. In addition, animal population density was significantly higher shortly after the introduction of ASF than in subsequent years, so more wild boar were available for sampling. A decrease in the number of samples obtained from dead wild boar has been described as an indication of a late phase of the epidemic (Schulz et al., 2022).
The same dynamics are observed in the percentage of samples of dead animals found, out of the total number of samples sent (Figure 9). From this it can be concluded that, following the peak of the disease and the peak of mortality from ASF in wild boars, it was also normal in the second year of the disease, after which it gradually decreased. We consider that the data analyzed do not give 100% credibility, due to the influence of other factors - the downturn from Covid 19, etc.

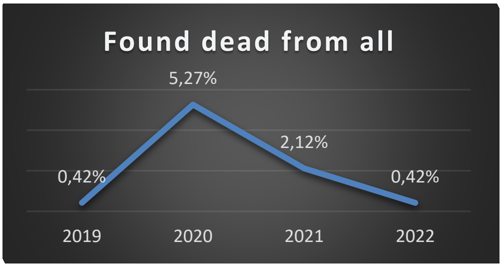

Figure 9. Percentage samples of found dead animals, from all samples - 2019-2022 period

Knowledge of this percentage is important because wild boars found dead represent a main sign of alert, especially when they are found in clusters (Ho et al., 2022).
An indicator of the intensity of the disease can also be the percentage of positive results from samples of dead animals found. According to the analysis of application data, the trends in positive results from dead animals found were the same as for the total number of results and mortality. A sharp increase in the number of positives in the second year after the infection entered the territory of the country and a gradual decrease in the following two years were detected. Unlike positive reactions from all animals which reach close to 7% at their peak, here it reaches 94% positive reactions from the sent samples (Figure 10). This can be considered as an indicator of the intensity of disease in feral pigs.

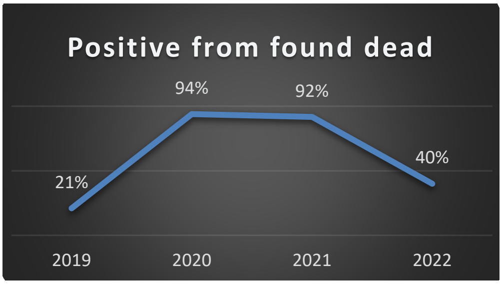

Figure 10. Percentage samples of found dead animals, from all samples - 2019-2022 period

In Lithuania, the average prevalence of ASFV-positive wild boar found dead, as determined by PCR, was 65.7%, while the serological prevalence in hunted animals (active surveillance) was only 0.45%.(Sauter-Louis et al., 2021).

When presenting the analysis results of the Module "Hunt" application, we cannot fail to mention one of its main functions - easy and quick sending of samples and receiving a result. Working with the application in its part of sending sample data and receiving the result is easy and intuitive. Sending samples from shot animals not only constitutes surveillance of the disease and tracks its spread, but by marking the sample and the carcass of the killed animal with barcodes with an identical number, it plays an important role in measures to prevent the spread of disease through animal products. The meat is released for consumption only after receiving a negative result through the application. In the case of a positive result, the carcass of the animal, according to EU legislation Regulation (EC) No. 1069/2009 of the European Parliament and of the Council of October 21, 2009, art. 8 point a(v), whole bodies and all parts of the body, including treated and untreated skins of wild animals suspected of being infected with a disease that is communicable to humans or animals are Category 1 material and are buried under biosecurity measures preventing the spread of the disease.

The advantages of working with the application described above are also applicable when working with found carcasses of dead animals. It not only makes it easier for hunters to send the samples, but because the data can be sent quickly and easily, it increases the percentage of sent samples from dead animals found. The effective and safe disposal of infected carcasses of dead animals plays a crucial part the disease control, because of their role in disease epidemiology (Guberti et al., 2022; Schulz et al., 2021).

CONCLUSIONS

Incorporating the data recommended by the FAO Manual to unify the information needed for disease screening application facilitates the analysis and sharing of data with other countries. The possibility of territorial and temporal filtering of the data allows the preparation of detailed analyses.

The geographic model allows easy tracking of the dynamics of the disease, its spatial movement and intensity. It facilitates delineation of areas and creation of geographic distribution models and simulations.

Making the data public allows the wide public and stakeholders to gain insight into the intensity and geographic distribution of the disease.

ACKNOWLEDGEMENTS

The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

Beyene, T. J., Asfaw, F., Getachew, Y., Tufa, T. B., Collins, I., Beyi, A. F., & Revie, C. W. (2018). A Smartphone-Based Application Improves the Accuracy, Completeness, and Timeliness of Cattle Disease Reporting and Surveillance in Ethiopia. *Frontiers in veterinary science*, *5*, 2. https://doi.org/10.3389/fvets.2018.00002

Dellicour, S., Desmecht, D., Paternostre, J., Malengreaux, C., Licoppe, A., Gilbert, M., & Linden, A. (2020). Unravelling the dispersal dynamics and ecological drivers of the African swine fever outbreak in Belgium. *Journal of Applied Ecology*, *57*(8), 1619–1629. https://doi.org/10.1111/1365-2664.13649

Depner, K., Gortazar, C., Guberti, V., Masiulis, M., More, S., Oļševskis, E., Thulke, H., Viltrop, A., Woźniakowski, G., Cortiñas Abrahantes, J., Gogin, A., Verdonck, F., &

Dhollander, S. (2017). Epidemiological analyses of African swine fever in the Baltic States and Poland. *EFSA Journal*, *15*(11). https://doi.org/10.2903/j.efsa.2017.5068

Desvaux, S., Urbaniak, C., Petit, T., Chaigneau, P., Gerbier, G., Decors, A., Reveillaud, E., Chollet, J. Y., Petit, G., Faure, E., & Rossi, S. (2021). How to Strengthen Wildlife Surveillance to Support Freedom From Disease: Example of ASF Surveillance in France, at the Border With an Infected Area. *Frontiers in veterinary science*, *8*, 647439. https://doi.org/10.3389/fvets.2021.647439

Dixon, L. K., Stahl, K., Jori, F., Vial, L., & Pfeiffer, D. U. (2020). African Swine Fever Epidemiology and Control. *Annual review of animal biosciences*, *8*, 221–246. https://doi.org/10.1146/annurev-animal-021419-083741

EURL CSF/ASF Database: Friedrich-Loeffler-Institut. (n.d.). EURL CSF/ASF Database: Friedrich-Loeffler-Institut. https://www.fli.de/en/services/information-systems-and-databases/eurl-csf-asf-database/

Fadlalla Elsheikh, R. (2022). Covid-19's Pandemic Relationship to Saudi Arabia's Weather Using Statistical Analysis and GIS. *Computer Systems Science and Engineering*, *42*(2), 813–823. https://doi.org/10.32604/csse.2022.021645

Forth, J. H., Calvelage, S., Fischer, M., Hellert, J., Sehl-Ewert, J., Roszyk, H., Deutschmann, P., Reichold, A., Lange, M., Thulke, H. H., Sauter-Louis, C., Höper, D., Mandyhra, S., Sapachova, M., Beer, M., & Blome, S. (2023). African swine fever virus - variants on the rise. *Emerging microbes & infections*, 12(1), 2146537. https://doi.org/10.1080/22221751.2022.2146537

Gervasi, V., Marcon, A., Bellini, S., & Guberti, V. (2019). Evaluation of the Efficiency of Active and Passive Surveillance in the Detection of African Swine Fever in Wild Boar. *Veterinary sciences*, *7*(1), 5. https://doi.org/10.3390/vetsci7010005

GIS: Friedrich-Loeffler-Institut. (n.d.). GIS: Friedrich-Loeffler-Institut. https://www.fli.de/en/services/information-systems-and-databases/gis/

Guberti, V., Khomenko, S., Masiulis, M. & Kerba S. (2022). African swine fever in wild boar ecology and biosecurity – second edition . *FAO Animal Production and Health Manual No. 28. Rome,* FAO, WOAH and EC.

Ho, H.P.J., Bremang, A., Conan, A., Tang, H., Oh, Y. & Pfeiffer, D.U. 2022. *Guidelines for African swine fever (ASF) prevention and control in smallholder pig farming in Asia: Monitoring and surveillance of African swine fever.* Bangkok, FAO.

Iscaro, C., Cambiotti, V., Bessi, O., Pacelli, F., Ruocco, L., & Feliziani, F. (2022). Analysis of surveillance and prevention plan for African Swine Fever in Italy in 2020. *Veterinary medicine and science*, *8*(4), 1502–1508. https://doi.org/10.1002/vms3.824

Kabir, K., Taherinia, A., Ashourloo, D., Khosravi, A., Karim, H., Salehi Shahrabi, H., Hedayat Yaghoobi, M., Soleimani, A., Siami, Z., Noorisepehr, M., Tajbakhsh, R., Maghsoudi, M. R., Lak, M., Mardi, P., Nouri, B., Mohammadzadeh, M., Azimzadeh, M., & Bakhtiyari, M. (2021). Epidemic size, trend and spatiotemporal mapping of SARS-CoV-2 using geographical information system in Alborz Province, Iran. *BMC infectious diseases*, *21*(1), 1185. https://doi.org/10.1186/s12879-021-06870-6

Mazur-Panasiuk, N., Żmudzki, J., & Woźniakowski, G. (2019). African Swine Fever Virus - Persistence in Different Environmental Conditions and the Possibility of its Indirect Transmission. *Journal of veterinary research*, *63*(3), 303–310. https://doi.org/10.2478/jvetres-2019-0058

Moses, J. C., Adibi, S., Shariful Islam, S. M., Wickramasinghe, N., & Nguyen, L. (2021). Application of Smartphone Technologies in Disease Monitoring: A Systematic Review. *Healthcare (Basel, Switzerland)*, *9*(7), 889. https://doi.org/10.3390/healthcare9070889

Norstrom M. (2001). Geographical Information System (GIS) as a tool in surveillance and monitoring of animal diseases. *Acta veterinaria Scandinavica. Supplementum*, *94*(Suppl 1), 79–85. https://doi.org/10.1186/1751-0147-42-s1-s79

Sauter-Louis, C., Conraths, F. J., Probst, C., Blohm, U., Schulz, K., Sehl, J., Fischer, M., Forth, J. H., Zani, L., Depner, K., Mettenleiter, T. C., Beer, M., & Blome, S. (2021). African Swine Fever in Wild Boar in

Europe-A Review. *Viruses*, *13*(9), 1717. https://doi.org/10.3390/v13091717

Schulz, K., Masiulis, M., Staubach, C., Malakauskas, A., Pridotkas, G., Conraths, F. J., & Sauter-Louis, C. (2021). African Swine Fever and Its Epidemiological Course in Lithuanian Wild Boar. *Viruses*, *13*(7), 1276. https://doi.org/10.3390/v13071276

Schulz, K., Oļševskis, E., Viltrop, A., Masiulis, M., Staubach, C., Nurmoja, I., Lamberga, K., Seržants, M., Malakauskas, A., Conraths, F. J., & Sauter-Louis, C. (2022). Eight Years of African Swine Fever in the Baltic States: Epidemiological Reflections. *Pathogens (Basel, Switzerland)*, *11*(6), 711. https://doi.org/10.3390/pathogens11060711

Schulz, K., Schulz, J., Staubach, C., Blome, S., Nurmoja, I., Conraths, F. J., Sauter-Louis, C., & Viltrop, A. (2021). African Swine Fever Re-Emerging in Estonia: The Role of Seropositive Wild Boar from an Epidemiological Perspective. *Viruses*, *13*(11), 2121. https://doi.org/10.3390/v13112121

Schulz, K., Staubach, C., Blome, S., Viltrop, A., Nurmoja, I., Conraths, F. J., & Sauter-Louis, C. (2019). Analysis of Estonian surveillance in wild boar suggests a decline in the incidence of African swine fever. *Scientific reports*, *9*(1), 8490. https://doi.org/10.1038/s41598-019-44890-0

Tadesse, B., & Amare, A. (2021). Application of Geographical Information System in Animal Disease Surveillance and Control: A Review. *Ethiopian Veterinary Journal*, *25*(1), 128–143. https://doi.org/10.4314/evj.v25i1.8

Yoo, D. S., Kim, Y., Lee, E. S., Lim, J. S., Hong, S. K., Lee, I. S., Jung, C. S., Yoon, H. C., Wee, S. H., Pfeiffer, D. U., & Fournié, G. (2021). Transmission Dynamics of African Swine Fever Virus, South Korea, 2019. *Emerging infectious diseases*, *27*(7), 1909–1918. https://doi.org/10.3201/eid2707.204230