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The ability to detect wild boars with increased body temperature in the natural environment with the use of unmanned aerial vehicles equipped with thermovision in two provinces in Poland

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Abstract

African swine fever (ASF) is a highly contagious disease affecting both free-living wild boars (*Sus* scrofa) and domestic pigs (*Sus scrofa domesticus*). In accordance with EU regulations, an ASF outbreak in pig farms necessitates immediate herd culling, leading to severe economic losses and restrictions on pork exports. Therefore, effective epidemiological surveillance of wild boar populations is crucial for monitoring the spread of the disease in the natural environment and preventing transmission to domestic pig farms. This study assessed the effectiveness of an ASF surveillance system consisting of the AtraxASF (unmanned aerial vehicle) and the NeoxASF (fixed-wing aircraft), both equipped with thermal imaging cameras. The study was conducted in Mielec County, Subcarpathian Province, an area with confirmed ASF outbreaks. The proposed surveillance system was used to observe wild boars and identify individuals exhibiting elevated body temperature, which is the earliest detectable symptom of ASF infection. The thermal imaging technology allowed for real-time detection and mapping of potentially infected animals. The system successfully detected wild boars with increased body temperature, demonstrating its potential utility for early detection of ASF in wildlife populations. The application of drone- and aircraft-based monitoring significantly enhanced surveillance efficiency by providing a rapid, non-invasive approach to assessing the health status of wild boar populations in affected areas. The implementation of drone-based surveillance systems and thermal imaging technologies offers a highly effective alternative to traditional epidemiological monitoring methods. The system enhances early detection capabilities, enabling quicker response measures to prevent the spread of ASF to pig farms. Integrating such technologies into existing biosecurity strategies could play a key role in controlling ASF outbreaks and minimizing economic losses in the pig farming sector.

Keywords: African Swine Fever, drone, thermovision

Introduction

African Swine Fever (ASF) is a disease first described in 1921, endemic to Africa. The aetiological agent is the African Swine Fever virus (Asfivirus, ASFV), belonging to the family *Asfarviridae*. It is a DNA virus with a genome of up to 192 kb (Gallardo et al. 2014). The natural reservoirs of the virus are domestic pigs of all breeds and wild boars, and the vector are soft ticks of the genus *Ornithodoros*. It is not infectious for humans. Infection with ASF can occur through the ingestion through the contact with excreta and secretions of infected animals, or infected feed, through the respiratory system and injuries to the animal's skin (Pershin et al. 2019). Infection with ASFV is primarily characterized by hemorrhagic fever, bloody spots on the body, and enlarged spleen, and the course of the disease can be from asymptomatic to acute with mortality of ~ 95%, and even 100% in farm animals. The incubation period is from 1 to 13 days, while the duration of the disease is up to 18 days. The duration of incubation, as well as the occurrence of symptoms, depends on the genotype of the virus and the virus inoculation dose (Woźniakowski et al. 2021). ASF is one of the officially controlled diseases and those reported to the World Organization for Animal Health (OIE).

ASF genotype II has been present in the European Union since 2014. The first case of ASF in Poland was diagnosed in a dead boar, which was found frozen under ice near the Belarusian border in the village of Grzybowszczyzna in the Podlaskie Province. From February 2014 to 2021, over 10,017 cases of ASF in wild boar were recorded in Poland. In 2019, 48 ASF outbreaks in pigs were detected in Poland, 104 in 2020, and 2021 cases in 2021. In 2021, 1,874 outbreaks were registered across Europe, representing approximately half the number of cases recorded in the previous year (Inspectorate 2020, Inspectorate 2021, 2022). African swine fever demonstrates seasonal patterns, which is confirmed by the increase in the number of outbreaks observed since 2014 in the period from spring to summer. Currently, disease outbreaks are being observed in the following Polish provinces: Lubelskie, Podlaskie, Masovian, Warmian-Masurian, Greater Poland, Subcarpathian, Lesser Poland, Lubuskie, Lower Silesian and West Pomeranian, and their number is increasing (Woźniakowski et al. 2021). ASF constitutes a major threat to the pork production sector, causing substantial economic losses. Due to the absence of an effective vaccine and treatment, disease control relies exclusively on rigorous epidemiological surveillance and biosecurity measures (Pershin et al. 2019). In the Subcarpathian Province, as of December 28, 2021, a total of 196 ASF outbreaks were recorded in 223 wild boars, including 32 outbreaks involving 41 wild boars in Mielec County, specifically in the communes of Przecław, Mielec, Wadowice Górne, and Czermin. It is an area where, at the beginning of 2021, the number of outbreaks in Mielec was 51, and due to preventive measures or symptoms of infection 3.5 thousand pigs died or were slaughtered on 77 farms.

The procedure for suspecting ASF is regulated by national and EU legislation. Due to the prohibition of treating infected animals and the absence of effective vaccines against ASF, the disease is combated only by administrative methods, by killing the infected herds and animals located within designated restriction zones. Consequently, the occurrence of ASF cases is the cause of extremely serious economic losses, related to the mass deaths of animals, eradication costs, payments of compensation, and above all to the suspension of the circulation and export of live pigs, pork, and pork-derived products (Kononow et al. 2020).

Various methods are used to control ASF in wild boars populations, starting with the information campaigns aimed directly at interested parties to communicate the current epidemiological situation. Another method used in combating ASF that has been introduced in many countries is an attempt to limit animal movement through the construction of fences and other physical barriers. Another attempt to limit the migration of wild boars was to feed them. Furthermore, there are also activities aimed at reducing the population of wild boar through intensified hunting and numerous culls (Jori et al. 2020).

In the case of ASF-infected animals, protection and surveillance zones are introduced. Wild boars within these areas are subject to culling, which must be conducted in accordance with strict biosecurity principles. In addition, in the designated area, searches of the area should be carried out to eliminate the carcasses of the animals that died as a result of ASF infection from the environment. These activities are mainly based on the monitoring of the virus infection cycle, which covers the entire wild boar population, their carcasses, and habitats. This is due to the features of the envelope virus, which makes it highly resistant to environmental conditions, allowing infected material to remain infectious for a very long period (Jori et al. 2020).

Unmanned aerial vehicles (UAVs) equipped with thermal imaging cameras can also be used as a tool for monitoring wild boars populations (Burke et al. 2019). Currently, drones have proven effective in monitoring the populations of chimpanzees (*Pan troglodytes*), orangutans (*Pogo abelli*), goats (*Capra aegafrus hircus*), roe deer (*Capreolus capreolus*), and various marine animals. The use of UAVs offers numerous advantages for wildlife monitoring (Linchant et al. 2015). These are devices that, thanks to their high mobility, can be used to observe large areas and access to locations that are difficult or inaccessible for ground-based observers.. The application of thermal imaging cameras in monitoring of wild boars population makes it possible to observe animals with increased body temperature, which may suggest symptoms of ASF infection (Hodgson et al. 2016, Witczuk et al. 2018, Kim et al. 2021).

The aim of this study was to assess the feasibility of detecting wild boars with increased body temperature in their natural habitat using unmanned aerial vehicles equipped with thermal imaging sensors.

Materials and Methods

Equipment used

The "ASFochrona" system consists of two components: NeoxASF fixed-wing aircraft with a four-wheel-drive command vehicle, and the AtraxASF UAV drone with an all-terrain intervention vehicle. The vehicles in both NeoxASF and AtraxASF are equipped with communication systems. The NeoxASF is a fixed-wing unmanned aircraft (NeO3, MSP manufacturer), that takes off from a pneumatic launcher. To fulfill its purpose, the basic equipment of NeoxASF, has been expanded with additional elements, such as a retractable optoelectronic head, and a camera stabilizing head. The length of flights is up to 100 minutes. Flights may be conducted at a maximum altitude of 120 meters and a speed ranging from 65 to 130 km/ h. The system is equipped with a cooled KTCH thermal imaging module. The resolution of the obtained image is 640 x 512 pixels with a frame rate of 60 frames per second. The maximum search efficiency is up to 150 km^2 per flight. Sound pressure generated during the flight of the NeoxASF unmanned observation aircraft is 53 dB.

The AtraxASF is a multirotor UAV equipped with a precise, high-resolution thermal imaging module. Used for targeted flights, in areas where animals were detected by NeoxASF. Equipped with a KTX bolometer camera (Electronika), offering a module resolution of 1024 x 768 pixels and a frame rate of 30 frames per second. The operational range is 4.5 km, and it is capable of conducting beyond visual line-of-sight (BVLOS) night flights. Search efficiency up to 10 km^2 per flight, with real-time H.264video streaming. Flight duration up to 50 minutes, with operational altitude of 5 to 350 meters and a speed of 50 km/ h. At least two operators are required to operate the system. The sound pressure level of the AtraxASF multirotor during the observation shall not exceed 54 dB. The system is equipped with a program for automatic analysis of data collected during operations.

Observation method

NeoxASF is used for large area flight tests. After the operator observes the heat points, targeted observations were conducted using the AtraxASF. When the presence of animals was confirmed, the AtraxASF system was used for detailed inspection.

The observation is carried out from a height of 70-80 meters above the ground level, the head of camera is set at an angle of 40-45°, and then the so-called "warm spots" are searched for. After detecting "warm spots", the operator approached the target to conduct a closer observation and to identify the animal and assess relevant details.

Place of searches

The searches were conducted in the Subcarpathian and Świętokrzyskie Provinces in Poland. Site searches were carried out in July and September 2021. The coordinates of the research sites and detected wild boars were as follows: 50°23′N 21°33′E, 50°25′N 21°47′E, 50°19′N 21°55′E.

Results

The area of high quality and efficiency of searches is 15 km^2/ flight. The searches were made from an altitude of 70-80 meters. Two objects with increased body temperature were observed in each province. The area that was subjected to searches was 67.9 km^2. The searches were conducted for four days in the Subcarpathian Province (Fig. 1) and two days in the Świętokrzyskie Province (Fig. 2).

Application for data analysis and report generation

The algorithm for the automatic detection of wild boars and the study of temperature anomalies and wild boar behaviorism is based on the analysis of the geometric features of the object and the analysis of the distribution of the relative thermal energy differences on the surface of the object (Hodgson et al. 2016). After reading the image of the detected object, the image parameters are determined, and then the background of the object is determined, which is used to obtain a normative image. By using appropriate filters, the object is extracted from the background. Then the geometrical features of the object are determined, i.e. its size, orientation and dynamics. Next, the distribution of the energy difference on the surface

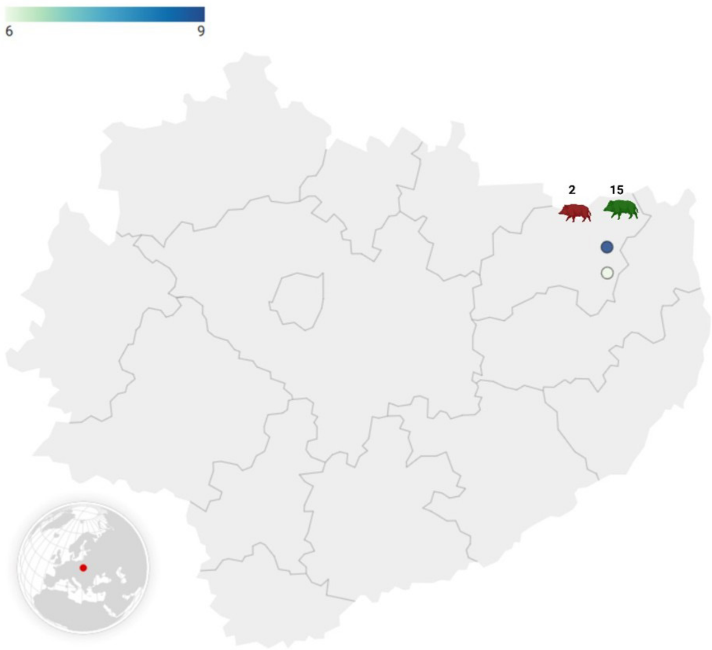

Fig. 1. During observations conducted in the Subcarpathian Province, 11 wild boars with normal body temperature and 2 individuals exhibiting elevated body temperature were recorded. Created with https://www.datawrapper.de/ and BioRender.

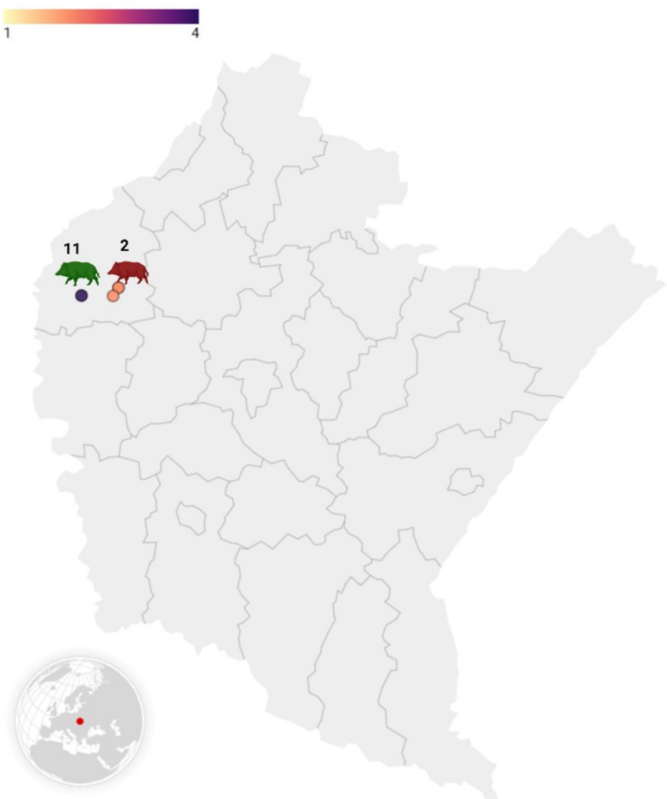

Fig. 2. During observations conducted in the Świętokrzyskie Province, 15 wild boars with normal body temperature and 2 individuals exhibiting elevated body temperature were recorded. Created with https://www.datawrapper.de/ and BioRender.

of the object is analyzed. The following data are analyzed: the maximum value of the relative energy difference on the object's surface, the size of the object's surface with the relative energy difference, and the value of the relative difference in thermal energy on the object's surface. These data are integrated which allows to characterize the observed object. The analysis of the obtained images is carried out automatically, the result of which is a report containing such data as: the location of the observed object, the number of objects, and the

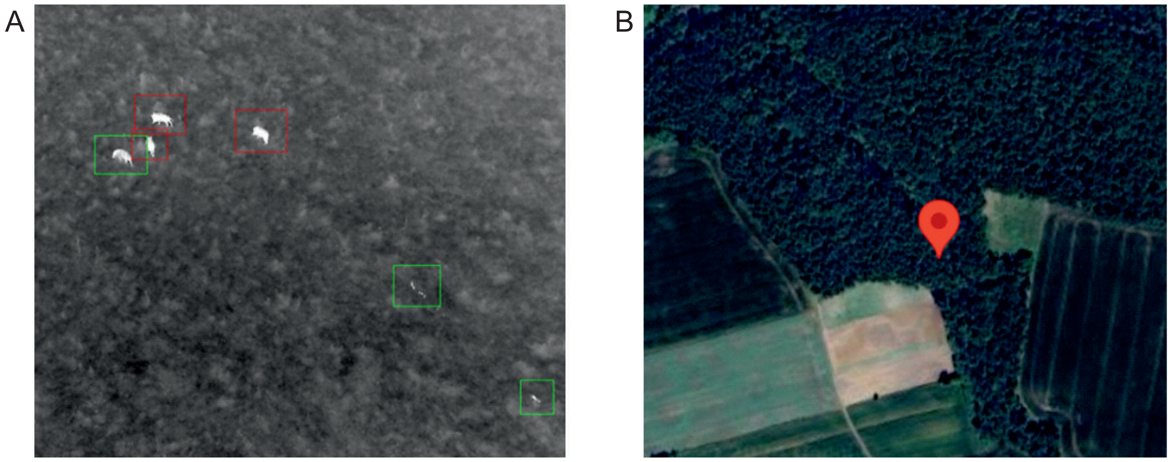

Fig. 3. A. Detection of individuals with normal and elevated body temperature. B. Topography of the study site.

results of detection of temperature anomalies indicating suspected ASF infection. System tuning was performed during the observations carried out on a total area of 152 km^2, on 130 observed objects. The observations were carried out in the Kraśnik County (Lubelskie Province) on the area of 42 km^2, Piaseczno County (West Pomeranian Province) on the area of 65 km^2, Ostróda and Iława County (Warmian-Masurian Province) on the area of 27.1 km^2, Zielona Góra County (Lubuskie Province) on the area of 32.1 km^2. The observations were conducted from December 2020 to April 2021. During the searches in the Zielona Góra administration district, nine objects were found, two of which, according to the “ASFochrona” system, were suspected of being infected with ASF. Samples from suspected individuals were collected, and tested for the presence of the ASF virus in accordance with national law regulations. The obtained results confirmed the presence of the ASF virus.

In this research 30 boars were detected, four of them were suspected of infection based on higher body temperature. Figures 1-3 present reports from researches, which were conducted in forest areas. In these cases, ASF infection could not be confirmed by laboratory testing due to the inability to cull the animals and collect diagnostic samples. However, based on previous system validation tests in the Lubuskie Province, the likelihood of infection was considered high.

Discussion

The use of fences to combat and reduce ASF infection is not only society controversial but may also have negative political implications. An additional argument against building the fences is the very high costs of their construction and subsequent maintenance (Kononow et al. 2020). Fences can disrupt the migration of other free-living animals and cause stress. It is necessary to focus on conducting passive protection, which require close cooperation between selected professional groups, particularly foresters and veterinarians, to ensure effective and efficient epidemiological surveillance in the control of ASF. The use of drones equipped with very precise thermal imaging cameras seems to be a promising tool offering many benefits, including reduction of costs and working time (not all detected cases will need to be laboratory confirmed), searching large areas in the shortest possible time, and increasing the safety of employees. Drones, thanks to their relatively quiet operation, are well tolerated by free-living animals, which has a positive effect on animal welfare and reduces the level of stress associated with the presence of humans (Witczuk et al. 2018). However, it should be noted that the animals are adapted to the noise of the forest with a height of about 20 dB, whereas drones noise levels of 70-80 dB. The low population of the forest increases the skittishness of animals, and any new, unidentified sounds can disrupt their normal activity, causing them to run away (Witczuk et al. 2018). The behavior of animals can be influenced by various factors: the size, color, and shape of the drone (multirotor or fixed-wing aircraft), type of propulsion (internal combustion engine or electric engine), method and type of flight, flight altitude, speed and angle of inclination. Flight altitudes should be from 40 to 70 m, especially in wooded areas as to avoid collision. Such a height allows to recognize the silhouette of animals using a double magnification, and does not lead to scaring animals (Jori et al. 2020). Higher altitudes of drones allow a wider area of observation, whereas lower provide higher image resolution. In addition, the mobility of vehicles should be taken into account. Due to the height of the pneumatic mast required to maintain communication with the drone and the fixed-wing aircraft may significantly limits vehicle deployment in places with dense vegetation. Another danger can be also the fall down of the drone to the ground and causing injury to animals or people, due to battery depletion or a collision with an obstacle (e.g. trees), loss of the control over the device, or change in weather conditions (strong wind, rainfall). These risks are foreseeable, therefore, measures should be taken to prevent such an event by controlling the telemetry data of the device and environmental conditions. If a threat is detected, the drone can be brought to the ground in an emergency. Another potential threat may be the loss of control over the drone due to the loss of communication or visual contact with the drone. In such a situation, an autopilot should be used, which will assist in automatic navigation and stabilize the flight along the previously designated route.

When monitoring, the behaviorism of the species under observation should be taken into account. In the case of wild boars, observation should be made at night, due to their nocturnal lifestyle, which does not exclude daytime activity. The wild boars live mainly in forested areas. Monitoring may be more effective at night due to the drop in temperature, which is particularly important during summer months, when the temperature difference between the ground and the animal's body is the biggest, which supports the identification of animals with increased body temperature. Other challenges that are posed before the use of drones in monitoring the population of wild animals are restrictions in the law, as well as high dependence on the weather (Kardasz et al. 2017, Burke et al. 2019). Drones with high-resolution devices and sensors can be an alternative to labor-intensive field researches, moreover they can constitute a reduction of costs of monitoring animals suffering from ASF (Linchant et al. 2015). Compared to the traditionally used methods of monitoring the population of free-living wild boars, the method with the use of drones is the one that ensures the performance of reliable research in a manner that is safe and involves a smaller number of people. As the technology of thermal imaging sensors progresses, the measurements will become increasingly accurate, and the increase in the frequency of observations using unmanned aerial crews will increase the precision of the observations, which will increase the statistical value of the measurements (Zbyryt, 2018).

Recent research by Rietz et al. (2023) has demonstrated great potential in the use of infrared technology in locating wild boar carcasses that contribute to the spread of African swine fever (ASF). For this purpose, infrared sensors are used to detect animal carcasses in the environment. Research confirm the usefulness of thermal imaging in searching for dead wild boars in a specific environment and its useful in supporting ground searches (Rietz et al. 2023). However, other studies have drawn attention to the capabilities of commercially available thermal imaging cameras, including testing of a multi-rotor unmanned aerial vehicle (UAV) equipped with a thermal sensors from open market which was used to detect large game species such as Eurasian moose, red deer, European roe deer or Eurasian wild boar. In the research work carried out in the Czarna Białostocka Forest District (Podlaskie Province), an E20Tvx Yuneec thermal imaging camera with a viewing angle of 33° 26.6° and a thermal sensor resolution of 640 x 512 pixels was selected. This system was used to estimate the population size and sex structure of animals. It was relatively new issue, particularly in Poland, where thermal imaging is not yet an officially recognized method for monitoring large game species (Frąckowiak and Goraj 2023). In the study by Kim et al. (2021) described techniques for monitoring wild boars in mountain forests using a UAV equipped with an infrared camera. In contrast to lowland areas, in mountain forests the monitoring area is difficult due to the variable terrain elevation and observation height, which is associated with a high risk of collision. Therefore, the WAYPOINT method used in such difficult areas is the most effective because it requires fewer unmanned aerial vehicle (UAV) flights and the monitoring is adapted to altitude changes. For reconnaissance UAV operations, equipment compatible with monitoring UAVs should be selected. Since the monitoring route can be established at any time of the year with reconnaissance UAVs, even when the thermal imaging performance is suboptimal, the monitoring survey can be effectively conducted along predefined routes during winter and nighttime with less risk of collision. Thanks to the WAYPOINT function, multiple monitoring is possible in the area with differences in terrain height, which are perfectly captured by this function. Once created, the route can be used many times in the future to track habitat movement and wild boar population dynamics by monitoring the same place each time. To minimize the risk of collision during monitoring, it is recommended to use manipulation options such as the rotation speed of the UAV and camera tilt angle (Kim et al. 2021). The increasing availability of high-precision thermal cameras and technologically advanced drones with greater payload and flight time, allows for their wider use in carrying out inventory activities of wild animals. The use of drones equipped with a thermal imaging camera allows the inventory to be carried out by practically two people in a very short time, eliminating the need for large teams of observers and traverse often inaccessible areas. From both technical and organizational perspectives, this technology can be used by entities such as hunting clubs and forest districts to conduct an annual animal inventory using drones equipped with a thermal imaging camera (Boczkowski et al. 2021).

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Author Declarations

Ethics approval

Ethical approval was not required for this study, as no direct intervention involving the animal or its natural habitat was performed.

Use of generative artificial intelligence

No artificial intelligence tools were used at any stage of the research process or during the preparation of the manuscript.

Conflicts of interest

The authors declare no conflict of interest "The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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