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REVIEW

The impact of environmental changes on the biology and ethology of wild boar in the agricultural landscape

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Abstract

Environmental changes significantly impact the populations of various game mammal species, altering their biology, behavior, feeding preferences, and the extent of damage they cause to agricultural crops. This study focused on the current status of the wild boar (*Sus scrofa* L.) — a species that has become a major agricultural pest in certain agricultural crops. In Greater Poland, which is an agricultural region of Poland, wild boars cause the greatest damage to rapeseed and maize crops. Both plant species are mainly damaged during the spring and summer growing seasons, as wild boars not only forage in these fields but also create shelter areas within them, which leads to significant yield losses. This analysis considered both the negative consequences of its presence and the positive role it plays in the ecosystem. A substantial part of the presented information is based on research and observations conducted at the Game Breeding Center of the Institute of Plant Protection – National Research Institute in Poznań (OHZ IOR-PIB), within hunting district no. 311 (Jarocin Forest District) near Winna Góra. This district covers areas within the Środa Wielkopolska and Miłosław municipalities.

Keywords: agriculture, environmental changes, ethology, game-related changes, wild boar

Introduction

In Poland, a rapid and continuous process of change is being observed both in the natural and anthropogenic environments, which significantly impacts the functioning of agriculture. Climate warming, which extends the plant growing season and alters both the biology and pressure of agricultural pests, along with changes in crop planting patterns, poses an ongoing challenge for plant protection. These phenomena result, among other things, in the need to limit the damage caused by certain species of wild mammals and birds. Despite the ongoing changes related to civilizational development, which lead to the transformation of animals' habitats, some species are successfully adapting, creating increasing difficulties for agriculture.

This study presents the current situation in Poland concerning a large game mammal species – the Eurasian wild boar (*Sus scrofa* L.), which, due to the aforementioned factors, has changed its behavior, feeding preferences, and biology in many environments. As a result, it has become an important pest in agroecosystems. The altered ontogenetic and paragenetic development of the wild boar, under the influence of environmental changes, currently poses a challenge for the biology and ethology of this species.

Most of the information provided in this text comes from many years of experience and observations of wild boars, conducted from the 1970s to the present day at the Game Breeding Center of the Institute of

Plant Protection – National Research Institute in Poznań (GBC IPP-NRI in Poznań). The central part of the hunting district, where the studies were conducted, consists of experimental fields of the Field Experimental Station and the Agricultural Experimental Facility of IPP – NRI in Winna Góra.

Most of the descriptions of wild boar behavior were based on direct observation methods and analysis of video recordings and photos from camera traps, recorded between 2014 and 2024.

Distribution

The Eurasian wild boar (*Sus scrofa scrofa* L.) belongs to the order Artiodactyla and the family Suidae. It occurs naturally throughout Europe, Asia, and North Africa and has also been introduced to Australia, North America, and South America (Fernandez-Llario and Mateos-Quesada 1998; Mayer 2009). It is the only wild ancestor of all domestic pig breeds, as confirmed by mitochondrial DNA (mtDNA) sequence analyses (Alves *et al.* 2003; Wu *et al.* 2007).

In 2015, the wild boar population in Poland was estimated at approximately 264,000 individuals. However, due to the emergence of African swine fever (ASF) in Poland in 2014 – a fatal disease for wild boars – along with intensified population reduction through sanitary culling, their numbers have significantly declined. According to data from the Central Statistical Office, the population dropped to 71,800 individuals in 2019, and by 2024, estimates from the national hunting reports collected in the Research Station of the Polish Hunting Association in Czempin placed it at around 51,000 (www.pzlow.pl).

Wild boars are found throughout Poland, with the highest population densities in the West Pomeranian, Greater Poland, Warmian-Masurian, and Lower Silesian Voivodeships. The smallest populations occur in the Lesser Poland and Świętokrzyskie Voivodeships. Until recently, the average population density of wild boars in Poland was around 15–20 individuals per 1,000 hectares of forest, with densities in northern and western Poland reaching up to 40 individuals per 1,000 hectares. Before the ASF outbreak, some forest habitats were known to support up to 100 wild boars per 1,000 hectares (www.lasy.gov.pl).

Biology

Wild boars typically live in family groups called sounders. Older, sexually mature males, starting from around 3–4 years of age, become solitary, although occasionally, two or even three older males may stay together. Sounders most commonly consist of a single family unit of 3–9 individuals. However, in areas with wolf (*Canis lupus* L.) predation pressure, larger groups of 20–30 individuals may form when several sows and their offspring from recent years band together. Socialization is a defense mechanism against predators, as animals living in larger groups can more effectively fend off attacks than solitary individuals or small groups. On the other hand, group living facilitates parasite transmission, which can increase the spread of infections. In the case of viral diseases such as African swine fever (ASF), this plays a significant role in population survival (Sweeney *et al.* 2003).

The wild boar is a highly prolific species. Females give birth annually to an average of 3–8 piglets, depending on age and environmental conditions, with a maximum of 12. The average annual population growth rate is around 100%, though locally it can reach up to 200%, depending on environmental conditions and population structure. Under favorable climatic and food conditions, young female wild boars reach reproductive maturity as early as 7–8 months of age. The availability and abundance of food from agricultural crops accelerate their sexual maturation, leading to earlier reproduction (within their first year) and larger litters in older sows (Fernández-Llario and Mateos-Quesada 1998; Fernández-Llario *et al.* 1999; Fernández-Llario and Carranza 2000; Fernández--Llario *et al.* 2003; Singer and Ackerman 1981).

Scientific studies have confirmed that zearalenone is a metabolite produced by *Fusarium* fungi that infect maize cobs. It is supposed to act as an estrogen at certain dose ranges, accelerating sexual maturity in young female wild boars (Pałubicki 2016).

Behavior

The behavior of wild boars varies significantly across different populations and is often influenced by their environment. It is primarily instinct-driven, meaning that internal motivation compels the animal to perform certain actions automatically. In recent years, increasing changes in boar behavior have been observed, which some biologists refer to as "cultural changes". These involve the transmission of information or behaviors from one individual to another through non-hereditary means, influenced by chemical changes that affect gene expression. Wild boars also exhibit cultural transfer, where new behaviors initially adopted by one animal are imitated and learned by others (Węgorek – personal observations at GBC IPP – NRI), even if they arose accidentally. The existence of cultural mechanisms in various animal species is widely observed and scientifically documented (Aplin *et al.* 2015).

Under current environmental conditions, wild boars are primarily nocturnal, resting in inaccessible refuges during the day (Erdtmann and Keuling 2020). However, synanthropic populations – those living near human settlements – are active during the daytime as well. In urban subpopulations, activity patterns differ significantly (Węgorek *et al.* personal observations; Briffa and Weiss 2010; Verhulst *et al.* 2016). These behavioral changes are likely linked to epigenetic phenomena, including the loss of fear of humans and the absence of natural predators such as wolves.

Wild boars are highly intelligent. According to researchers studying animal behavior, their IQ may be higher than that of dogs and even chimpanzees (Mayer 2009). This makes them one of the most cognitively advanced non-human animals. Numerous anecdotal reports and personal observations suggest that wild boars exhibit prosocial behaviors – certain emotional situations, such as an individual being trapped in a fence or enclosure, trigger empathy in others, prompting them to search for ways to assist the distressed animal (Bartal *et al.* 2011; Węgorek – personal observations at GBC IPP – NRI).

The wild boar is a species capable of migrating over very long distances, reaching hundreds of kilometers, as demonstrated by telemetry studies (Jerina *et al.* 2014). When forced to relocate due to disturbance or food scarcity, wild boars can travel 10–20 kilometers in a single night, at an average speed of approximately 5 km · h^{-1}. They are also capable of much faster movement; for example, during a hunt, boars can cover 5 kilometers in just 20 minutes and can gallop at speeds of 40–50 km · h^{-1} over shorter distances. They effortlessly jump barriers 1–1.5 meters high and are excellent swimmers, capable of crossing water bodies up to 6–7 kilometers wide. Rivers, canals, and lakes pose no significant obstacles to their migrations. However, harsh winters with extreme cold and food shortages lead to high mortality among piglets, which, due to their small size and high metabolic demands, have low resistance to freezing temperatures (Erdtmann and Keuling 2020).

Senses

The primary sense of the wild boar is its exceptional sense of smell. It can detect certain scents related to food, danger, or reproductive readiness from approximately 500–1000 meters. This keen olfactory ability plays a crucial role in environmental recognition, food searching, communication, and various other activities (Bear *et al.* 2007). Wild boars also have a well-developed Jacobson's organ (VNO – vomeronasal organ), which is highly sensitive to odorless, volatile chemical substances. These chemicals convey essential information, influencing mating behaviors and social interactions (Cooper Jr. and Burghardt 1990).

Wild boars possess excellent hearing, which is significantly more sensitive than that of humans. They can detect infrasound (below 20 Hz) as well as high-frequency sounds above 60 kHz, including those emitted by small forest and field rodents, which humans cannot hear. In contrast, vision is their third-most important sense for environmental awareness. Their sense of touch is primarily limited to their elongated snout, which consists of a highly sensitive nose, jaw, and upper jaw, used for exploring unfamiliar objects (Snethlage 1982).

Wild boars communicate through a variety of vocalizations to express mood, warn against threats, or maintain contact. These sounds are genetically encoded, and their repertoire does not change over an animal's lifetime. Unlike some animals, wild boars are unable to learn or mimic foreign sounds. Ethologists have identified at least 20–30 different vocal signals within the species' range of communication (20–20,000 Hz), which are also audible to humans (Klingholz *et al.* 1979; Garcia *et al.* 2016; Syrová *et al.* 2017; Maigrot *et al.* 2018).

Studies have shown that wild boars also use low-frequency sounds (infrasound below 20 Hz) for acoustic communication among themselves. These sounds can be heard by boars even from distances of several kilometers. Infrasound waves easily penetrate obstacles such as trees and even hills, allowing boars to communicate effectively, even in dense forests. This explains their ability to quickly reunite after being dispersed over large areas, for example, during hunting events (Saha and Mazumdar 2017; Spinka *et al.* 2019).

The most common sound made by wild boars is their characteristic grunting, which is similar to that of domestic pigs (Tallet *et al.* 2013; Linhart *et al.* 2015). Repetitive grunting during foraging helps maintain group cohesion, especially in dense vegetation such as rapeseed fields, maize fields, or thickets of brambles and raspberries, where visual contact is easily lost.

Feeding

The wild boar is an omnivorous, monogastric animal (Sweeney *et al.* 2003). From an ecological perspective, it is a dietary generalist, consuming hundreds of different plant and animal organisms. The wild boar's diet consists primarily of the most abundant species in its environment, while the smallest amount comes from the rarest species. Food selection is also influenced by its energy value and digestibility, which explains the increasing damage to agricultural crops. The stomach of an adult wild boar has a capacity of approximately 5–8 liters (Bodenchuk 2008). The animal consumes food daily, amounting to about 3–5% of its body weight, though some researchers have reported as much as 10% (Schley and Roper 2003; Węgorek – personal observations at GBC IPP – NRI). Plants make up about 90% of its diet, including green plant parts, leaves, roots, rhizomes, tubers, seeds, fruits, and grasses. Wild boars prefer easily digestible plant-based food with low fiber content. They cannot digest cellulose, hemicellulose, lignin, and certain other plant cell wall components. However, the high protein content in legume and cereal plants (20–42% in seeds) makes them particularly vulnerable to wild boar consumption when they reach maturity. In addition to fiber, wild boars cannot digest gluten and avoid grain varieties with husks or seeds covered in sharp awns and bristles (Bodenchuk 2008).

Diseases

A significant threat to wild boars, contributing to population declines, is viral diseases such as classical swine fever (CSFv - Classic Swine Fever virus) (Ganges *et al.* 2020) and pseudorabies (Aujeszky's Disease), which initially presents symptoms similar to rabies, including hypersalivation, nervous disorders, restlessness, wandering in search of water, seizures, and aggression. This is a serious disease affecting domestic pigs, caused by a herpesvirus. The virus can persist in the nervous tissue of pigs for an extended period in a latent state, reactivating periodically.

Another significant disease is parvovirus infection, which does not cause high mortality in juvenile and adult individuals but leads to embryo death and severe exhaustion in infected animals. Rabies is rarely observed in wild boars (Palinski *et al.* 2016).

In February 2014, African Swine Fever (ASF) was detected in Poland. This viral septicemic disease affects wild boars and domestic pigs, progressing acutely or chronically. A distinctive feature of ASF is severe hemorrhaging due to ruptured blood vessels in the mucous membranes. The incubation period of this dangerous virus lasts 5–9 days. The disease typically follows an acute course, though hyperacute and chronic cases are rare. Characteristic symptoms include loss of appetite, conjunctivitis, coughing, foamy nasal discharge, diarrhea, vomiting, and sometimes seizures. Mortality is almost always 100%, although some wild boars may survive the infection, remaining virus carriers. The ASF virus is excreted in feces, saliva, and urine of infected wild boars and can spread in the environment through nasal secretions or orally during foraging and rooting among infected animals (Ruiz-Fons *et al.* 2008).

Report on long-term (1994–2025) observations conducted at OHZ IPP – NRI - consequences of wild boar foraging in agricultural crops

Observations were carried out on hunting grounds using a variety of research methods. Data were collected through field and plot experiments, analysis of tracks and traces left by animals, as well as systematic field observations from hunting towers. Additionally, to improve monitoring accuracy, camera traps were used to record wild boar activity both during the day and at night.

The long-term studies allowed for the assessment of the wild boar population dynamics and their impact on agricultural crops over an extended period. At the same time, the analysis of animal behaviors in different seasons and under changing environmental conditions provided valuable insights into the factors that increase the risk of agricultural damage. The use of various research methods enabled the creation of a comprehensive picture of the scale of the problem and the effectiveness of preventive measures, which are described in the following subsection.

Maize

Wild boar foraging on maize plantations begins around April 21st, shortly after sowing. The swelling and germinating maize seeds are a delicacy for wild boars, prompting them to move from their shelters, sometimes covering many kilometers. The stages when maize crops are most at risk occur from the beginning of seed swelling to the five-leaf stage (BBCH 01–15). During this period, wild boars often inhabit flowering rape fields. In the evenings, they move from the rape fields to neighboring maize crops. It has been calculated that a wild boar of medium size, weighing around 40 kg, can consume about 5000 maize seeds in a single night. This results in the destruction of around 500 square meters of field (Węgorek – personal observations at GBC IPP – NRI). If a herd of several individuals visits the field, the extent of the damage can be dramatic. The period of wild boar foraging on emerging maize lasts, depending on weather conditions, for about 15–20 days. The damage caused by wild boars to maize crops can be significant, often requiring re-sowing or resulting in a much smaller yield. The only effective measure to limit damage during the emergence period is to treat the seeds with repellents to deter wild boars, use pyrotechnic devices, or fence the crop.

Another period of increasing damage caused by wild boars in maize occurs during the maturation of the cobs, which corresponds to August, September, October, and November – from phase BBCH "71" – development of kernels containing 16% dry matter, to phase BBCH "89" – full maturity of kernels containing 65% dry matter. During this period, wild boars, if they have access to bathing sites, remain in maize fields almost all day, treating them as resting places. It has been observed that female wild boars build nesting mounds made from maize plants, similar to beaver lodges, for their young in the first days after birth. Also, after the maize harvest, on stubble fields and even on ploughed land, wild boars cause damage by rooting in search of leftover maize, field rodents, and insect larvae.

Common maize, like other cereals, belongs to the grass family Poaceae. However, unlike most species in this family, it lacks the ability to branch due to grazing. Assimilatory leaves and the growth point (meristem) are the most sensitive to damage caused by herbivores during the early stages of the plant's phenological development. The lack of branching ability means that damage to the above-ground parts of maize plants during the growth phase BBCH 15 to 34, despite the plant's ability to compensate for damage, results in poorer yield and increased susceptibility to certain fungal diseases. In the case of maize plants, the phenomenon observed in other grass species, where defoliation caused by herbivores leads to increased photosynthesis in new tissues and branching, does not occur (Korbas *et al.* 2016).

Mechanical damage to plant tissues caused by herbivores is a well-known pathway for fungal, bacterial, and viral infections. Maize plants damaged by animals often suffer from smut and rust, as well as fusarium diseases. Many animals also mechanically transfer these pathogens and viruses, acting as vectors. One of the metabolites of the mold fungi genus *Fusarium* that attacks maize is the mycotoxin zearalenone, a natural estrogen. When consumed regularly by female wild boars, it is supposed to accelerate maturity and prolong the estrus period, which consequently leads to faster reproduction and an increase in population size (Korbas *et al.* 2016).

Damage estimation in maize usually concerns the period after sowing when wild boars consume the seeds and after the formation of cobs. Preliminary assessments determine the scale of the destruction and are expressed in terms of surface area and damage level. Final assessments should take place just before harvest and, depending on the intended use of the maize, involve conducting a yield trial on the crop. This involves identifying a representative number of sections in the rows, from which all plants are collected in their entirety if the crop is intended for silage or forage, or the formed cobs if the crop is intended for grain. The collected plants intended for silage or green mass are weighed, and from the collected cobs of plants intended for grain, the kernels are extracted, and their weight and moisture content are determined, along with the average weight per cob. By knowing the surface area and the level of its average damage by hunting animals, as well as the crop yield, further calculations are made, the results of which will determine the value of the compensation due.

Winter rapeseed

The damage caused by wild boars in rapeseed crops occurs throughout the entire vegetation period of this plant. Although wild boars do not eat the germinating rapeseed plants, they create deep "craters" in the fields while searching for mice and voles, if these animals are present in the crop, and trample young plants. This happens especially on fields where cereals or, as is often the case, rapeseed was the previous crop. Wild boars also frequently search for pests such as wireworms and grubs in rapeseed fields, digging shallowly in the soil but also damaging the plants in the process. Proper agronomy and well-thought-out plant protection, preventing mass occurrences of rodents and soil pests, play a very important role in preventing this type of damage. The most significant damage to rapeseed is caused by wild boars from the moment the plants start to branch in the autumn until harvest. Although wild boars cannot digest fibers, they eat the green shoots and flower heads, while chewing on the hard parts of the plants and spitting them out. The presence of these chewed plant parts indicates the presence and foraging of wild boars. These animals are keen to migrate from forests to rapeseed fields, which not only serve as a foraging site but also as a safe refuge. While staying in rapeseed fields, wild boars trample plants, create paths, and form bedding and a labyrinth of corridors. When the rapeseed plants begin to dry out, wild boars still consider the fields as safe places, but in the evening, they move on to forage in maize, wheat, and other cereal fields.

Preliminary damage assessment in rapeseed should be conducted early in the spring, when vegetation begins. The damaged area and the level of damage caused by game animals should be determined. Since rapeseed plants have excellent regenerative abilities, even after the growth tip is chewed off, the differences in yield compared to undamaged plants may be minimal (Węgorek *et al.* 2011). Yield trials should be conducted before harvesting rapeseed, calculating the average number of undamaged and game-damaged plants on control plots. Comparing the yields from these representative areas will reveal the differences, and the value of these differences will determine the compensation owed.

Wheat

Wheat is a cereal crop highly susceptible to damage caused by various species of game animals. The area cultivated with this cereal in Poland, which amounts to 2.4 million hectares (according to the Central Statistical Office), along with its popularity among farmers who grow this crop across the entire country, indicates a high risk of hunting damage. Game animals can damage wheat at all developmental stages of the plant, although different species tend to prefer different growth stages. Additionally, some wheat varieties differ in their susceptibility to grazing by game mammals, which is often related to the plant's morphology and the content of certain nutrients or anti-nutritional compounds. Wheat plants respond differently to chewing, trampling, and other types of damage, which subsequently leads to significant yield losses and an increased susceptibility to fungal diseases such as leaf fusariosis, wheat powdery mildew, and brown rust. However, in the case of slight grazing on winter wheat, for example due to foraging by wild geese or roe deer, plant development is stimulated. Wild boars damage wheat from the time of sowing until harvest. Damage includes uprooting seeds after sowing, trampling fields, and chewing spikes from the milk ripeness stage of the grains through to waxy, full, and even dead ripeness. Wild boars do not eat large amounts of spikes at once due to the high gluten content in wheat grains. Gluten, which is poorly tolerated by this species, thus limits the damage to wheat, although it does not prevent it. Damage to winter wheat often occurs on fields where potatoes or maize were the preceding crops. Wild boars, in search of leftover harvests from these crops, can damage wheat plants from sowing time, through the entire winter, and into later developmental stages by uprooting potato and maize cobs, even after they have been plowed deep into the soil. Neglected fields that have large amounts of mice or larvae of wireworms from the Elateridae family, grub larvae from the Scarabaeidae family, or cutworms (Agrotinae), provoke wild boars to forage for animal protein. In the spike ripening stages, wild boars prefer varieties of wheat without awns. Awned varieties may irritate the mucous membranes of the animals. Protection of wheat crops from wild boars should begin as soon as the first signs of damage are noticed, as animals quickly become accustomed to their feeding grounds, and the damage escalates rapidly.

Preliminary damage assessment for wheat and other winter cereals should take place once spring vegetation starts. The damaged area and the level of damage caused by game animals should be determined. Since wheat plants and other winter cereals have high regenerative capabilities during the tillering phase, differences in yield compared to undamaged plants may be minimal (Węgorek *et al.* 2011). Because damage can occur throughout the entire cereal crop period, yield trials should be conducted before harvest, calculating the average number of undamaged and damaged plants by game animals and their yields on control plots. Comparing the yields from these representative areas will reveal the differences, and after further technological treatments (drying, calculating the weight of 100 grains), the compensation amount will be determined.

Barley

Barley is cultivated in Poland on an area of approximately 1 million hectares. Barley crops are 85–90% spring barley, while 10-15% are winter varieties (according to the Central Statistical Office). Depending on the intended use (about 50 varieties) and sowing time (spring – mid-March or autumn – after September 21st), its vegetation period varies in different regions of the country (Platform for Agro-pest Signaling). Winter barley matures quickly (55–90 days), and its harvest takes place as early as July, alongside rapeseed. Like other cereals, including maize, barley is also susceptible to damage caused by wild boars.

The attractiveness of barley as food for wild boars is due to several reasons. During the grain development stage, barley contains 10–11% protein. The grain of many barley varieties, unlike wheat, does not contain gluten or contains only a small amount, which makes wild boars, which cannot digest gluten, consume much more of it than they would later in wheat, rye, or triticale, which contain large amounts of indigestible gluten. Barley contains 70–73% carbohydrates, mainly the plant polysaccharide starch, making it a high-energy food for animals (Platform for Agro-Pest Signaling).

The consequences of wild boar foraging on barley are very similar to those described for wheat. On fields prone to hunting damage, the minimum density of winter barley plants before the spring vegetation starts should be around 110–150 plants · m^{-2}. The optimal number is 400 plants · m^{-2}.

In the case of barley, when estimating damage, it is recommended to follow the same procedure as for wheat, based on yield trials of a representative sample of control plots.

Permanent grasslands

Permanent grasslands, whether natural or created by humans, are meadows or pastures where numerous species of grasses and dicotyledonous plants (annual, biennial, or perennial), as well as leguminous plants (such as clover, sainfoin, lucerne, etc.) grow. The area of meadows and pastures in Poland is significant, exceeding 3 million hectares (according to the Central Statistical Office). The long-term use of both meadows and pastures, especially those located near water sources, encourages the permanent inhabitation of these areas by various invertebrate species, mainly insects, snails, and earthworms. Among vertebrates, one can find rodents, amphibians, reptiles, birds, and mammals (mice, voles, rabbits, hares) in these grasslands. Due to their biodiversity, expressed by the large number of faunal and floral species, wild herbivorous game animals often visit these habitats, eagerly feeding on the protein-rich grasses, as well as various herbs containing health-promoting or antiseptic substances. Small soil-dwelling animals, primarily earthworms, insect larvae, and rodents, are a delicacy for wild boars, which can devastate a meadow or pasture in search of them. After rain, wild boars frequently visit grasslands, as many of these soil creatures surface and become easy prey for the boars. The resulting damage is characterized by deep ruts in the sod formed when searching for insect larvae, earthworms, small field rodents, and the roots of certain plant species. These ruts can be shallow or very deep, often reaching 0.5 meters in depth, making it difficult to perform mowing and harvesting of forage and hay, and significantly reducing the productivity of the grasslands.

Damage estimation for grasslands typically concerns wild boar rooting. This involves determining the damaged area, which is equivalent to the reduced area. At the appropriate moment in the vegetation cycle, the productivity of hay or forage must be assessed, as well as the cost of restoring the damaged area, including plowing or harrowing, raking or rolling, and sowing seeds, along with their associated costs.

Potatoes

The reason for damage caused by game animals in potato crops is the food attractiveness of the tubers. Other parts of the plant, such as aboveground stems, leaves, flowers, and berries (fruits), are not eaten, but they can be mechanically damaged when animals uproot or dig up the tubers or when herds of animals trample the area. The timing of planting and the progression of the potato crop's vegetation, depending on the variety and its intended use (early, mid-early, mid-late, late), also greatly affect the occurrence of damage. In spring, especially when other plant food is scarce, seed potatoes and the tubers of early varieties are particularly attractive to wild boars. The most significant damage caused by wild boars in potatoes occurs in May, and later, depending on the maturation time of the tubers and their starch content, in June, July, August, and September. These animals, using their sense of smell and instinct, can detect health-promoting substances in potatoes, such as phenolic compounds, thiamine, or ascorbic acid, which have antioxidant properties, as well as micro- and macro-elements. Additionally, potatoes contain about 2% high-quality protein rich in essential amino acids (methionine, threonine, phenylalanine, lysine, and leucine), which are necessary for lactating females and rapidly growing young individuals to build muscle [Bodenchuk 2008, Research Centre for Cultivar Testing (RCCT) variety list]. Wild boars show a wide variation in their preference for specific potato varieties. Often, within a mosaic of fields with different varieties, they focus on foraging only on a specific variety. This is likely related to the level of secondary metabolites in the tubers, mainly glycoalkaloids, such as solanine, chaconine, calystegine, and others, which can have toxic effects on the nervous and digestive systems when present in large quantities (Bodenchuk 2008). The fewer toxic compounds in the potato tubers, the more eagerly wild boars consume them.

Damage estimation in potato crops involves calculating the plant density per unit area (or representative row length) and then calculating the average yield of undamaged plants. The total length of rows with damaged plants over established measurement sections must be determined, and based on this, the value of the lost yield is calculated.

Methods of damage prevention

Due to the increasing threats from game animals, plant protection has relatively limited options, meaning that available methods in Poland do not always guarantee effective crop protection. Similar to other pests, different methods of preventing damage are recommended for game animals, and the best results are achieved through integration – combining available methods and strictly following recommendations. The main difference between methods of protection against game animals and birds compared to other agrofactors (such as insects or rodents) is that in Poland, limiting their numbers through the use of synthetic or natural biologically active substances with toxic properties, hormonal agents, or pheromones that inhibit reproduction is not allowed for game animals and birds.

In Poland, for herbivorous game mammals, including wild boars, mechanical, agronomic, and chemical methods are recommended.

Mechanical methods

Among mechanical methods, the most commonly used are visual, tactile, and sound devices (information from farmers, hunters, and foresters). Most often, agricultural and forest plant surfaces are secured with various types of fences adapted to the size of the animals that threaten the crops. Fencing has its advantages, but it is not a completely reliable method of protecting crops from damage caused by wild boars, which are capable of tearing down fences. An unfavorable consequence of this method, especially when protecting large areas, is increased damage in fields adjacent to protected areas. Moreover, it is an expensive method and, due to the unfavorable changes it introduces to biotopes, it is often considered "non-ecological" (Mayer 2009). It is commonly used in forests, especially in areas particularly vulnerable to crop destruction, mainly nurseries and young plantations.

Mechanical protection methods also include various visual, electrical, and acoustic devices. In recent years, noise ropes detonating explosive charges at specific time intervals have become popular. The effectiveness of these devices is high but short-lived, as animals quickly get accustomed to them. The period of effective operation in an unchanged location is 2–4 weeks, which is why these devices are best suited for protecting plants during the critical period when damage is most likely to occur – for example, protecting seeds and early sprouts (Przybylski 2011). Both farmers and hunters, as well as foresters, increasingly use camera traps, whose range and accuracy are growing year by year. These devices inform the owner of the presence of animals in the crop both during the day and at night, allowing for a quick response.

Agronomic methods

Agronomic methods include selecting the right variety of a given plant species. Among different varieties of a particular plant species, some are more preferred while others are less preferred by game animals, and wherever possible, these varieties should be sown and cultivated in areas particularly prone to game damage (Węgorek *et al*. 2009–2024).

An effective agronomic strategy involves careful selection of cultivation sites for specific plant species. Fields situated near forests, wetlands, water bodies, or shrubby areas – natural shelters for wildlife – are consistently more exposed to damage caused by mammals and birds.

Another good method is leaving parts of plants on fields. In the GBC IPP-NRI, long-term experiments showed that leaving unharvested areas of maize on large fields significantly reduces damage caused by wild boars on fields after maize. These leftover field fragments provide feeding bases and resting places for wild boars (Węgorek *et al*. 2009–2024). Leaving unharvested maize feeding strips should be recommended as a method in integrated protection programs for fields where maize was grown the previous year. Using this method allows for effective reduction of game damage without the use of chemical repellents. It also reduces the use of insecticides and fungicides, which limits the occurrence of diseases and pests.

Agronomic recommendations for reducing game damage include proper selection of sowing or planting locations for plants particularly attractive to animals. Whenever possible, crops with such vegetation should be established far from forests and other animal shelter areas (swamps, reedbeds, shrubs). Attention should also be paid to the necessity of thoroughly removing maize and root crop residues from fields, as plowing them in may provoke damage. It is also important to mechanically destroy wireworms, leatherjackets, grubs, and field rodents, which are favored food for wild boars, especially from autumn to spring (Węgorek *et al.* 2009–2024).

Chemical method

The chemical method provides plant protection products that typically work by repelling and discouraging herbivorous game mammals from protected crops. Chemical products include repellents, which deter animals from protected surfaces, and attractants, which lure them to unprotected surfaces (Przybylski 2011).

In Poland, the use of toxic and hormonal agents is prohibited, and they are only allowed in the case of controlling particularly harmful stored and field rodents. Active substances affect animals through short-term pain stimuli (irritation of mucous membranes) or fear. Both pain and fear serve as warning signals for organisms, playing a crucial role in the evolutionary history of every species. Some of these reactions are innate (phylogenesis), such as reflexes to specific stimuli, while others are learned during an individual's life (learning), forming conditional behavioral patterns (ontogenesis) (Bear *et al.* 2007). Some instincts in animals cannot develop without learned external inputs (specific stimuli from the environment), and many animal instincts exhibit a critical period during which new skills are acquired, which cannot be learned outside this period (Britta and Weiss 2010; Węgorek *et al.* 2014).

Signals that convey information about danger often lead animals to defensive reactions, often resulting in flight, avoidance, or less frequently, attack. Observations indicate that, in some cases, animals' instinctive reactions to incoming signals occur without analyzing the phenomenon and within very short intervals, measured in fractions of a second (Bear *et al.* 2007; Diegemans and Reale 2005).

Each species has an evolved basic neural network – so-called species memory – on which every individual develops, through learning processes, and its acquired memory throughout its life. This memory creates adaptive features that lead to behavioral changes as a result of experiences (Erdtmann and Keuling 2020).

Using knowledge about the role of senses and the ability to memorize and learn, plant protection aims to use this knowledge and influence animals' behavior in the environment through various types of stimuli.

Until recently, several odor-based repellents for deterring game animals and birds from agricultural or forest crops were registered in Poland. Several taste-based repellents for deterring game animals from forest crops were also available. Currently, many of these products have been withdrawn from use, leaving few chemical deterrents for game animals available to farmers and forest protection services. The withdrawal of these products, from the perspective of animals' increasing resistance to repellents, is not a favorable phenomenon, as it limits the ability to rotate products with different tastes and smells.

Monitoring the effectiveness of various repellents indicates that it may be limited by many factors (Bear *et al.* 2007; Węgorek *et al.* 2014). According to hunters and farmers, the effectiveness of repellents has been decreasing year by year, and currently, it is too low and often fails. Research conducted at GBC IPP-NRI in Poznań confirms that the effectiveness of repellents can be variable and often decreases with prolonged or improper use.

The positive role of wild boars in the ecosystem of fields and forests

The diet of wild boars consists mainly of animal food (about 10%), including insect larvae and pupae, small rodents, fish, frogs, snails, earthworms, and fresh carrion. During outbreaks of forest pests, wild boars significantly reduce their numbers. Fields inhabited by wireworms (Elateridae) and cutworms (Noctuidae) are often uprooted by wild boars, which feed on the larvae of these insects. Consuming animal food is essential for forest protection but also for other ecosystems, preventing mice populations (such as field mice, forest mice, and house mice) from exploding. These small rodents, which can produce 3–5 generations per season, breed from March to October (house mice, under favorable conditions, can breed year-round, producing up to 10 litters). These animals are found in various habitats, especially in moist areas at the forest edges, grasslands, marshes, crop fields, pastures, gardens in rural and suburban areas, and green spaces in cities. They feed on roots, grains, seeds, berries, and insects. Thanks to their excellent sense of smell, wild boars can easily detect and steal food from these rodents and eat them. Mice, which weigh between 25–50 g, provide wild boars with essential protein. In favorable periods, there can be up to 100,000 mice per square kilometer in the environment. Therefore, reducing the population of rodents through wild boars is crucial for many reasons. All species of mice are hosts for ticks, fleas, protozoa, and other parasites and, as such, are vectors for many bacterial (e.g., Lyme disease, brucellosis), viral (e.g., encephalitis, rabies), and fungal diseases. Their overpopulation is dangerous for forest ecosystems, livestock, humans, and the economy (Singer and Ackerman 1981; Sweenay *et al.* 2003; Ditchkoff and Mayer 2009).

Wild boars also consume various species of fungi, which play an essential ecological role in stabilizing ecosystems. Often the organisms consumed by wild boars compete with each other for the same environmental resources. Without these generalists in the ecosystem, it would become unstable, leading to the disappearance of many victim species and impoverishment of the ecosystem (Ditchkoff and Mayer 2009).

In recent years, in areas with a significant wolf population (a natural enemy of the wild boar), a clear decline in wild boar numbers has been observed, which has negatively affected natural forest regeneration processes, especially of beech forests. This is observed in the wild, mountainous region of the Bieszczady in Poland. It has been observed that wild boars, which cannot digest cellulose and hemicellulose, spread undigested seeds of many tree and shrub species across the forest floor, often in soils loosened by their rooting and fertilized by their droppings.

The current situation of wild boars in Poland is often viewed only through the lens of agricultural damage and the threat of ASF. However, like any species, wild boars play a variety of roles in the natural environment, some of which are beneficial to both humans and nature. Managing this species in the face of significant infrastructural changes and shifts in the biology and behavior of the wild boar must consider all aspects of its coexistence in the natural landscape of our country.

References

Alves E.C., Ovilo M., Rodriguez C., Silio L. 2003. Mitochondrial DNA sequence variation and phylogenetic relationships among Iberian pigs and other domestic and wild pigs populations. Animal Genetics 34 (5): 319–324. DOI: 10.1046/j.1365-2052.2003.01010.x

Aplin M.L., Farine D.R., Morand-Ferron J., Cockburn A., Thornton A., Sheldon B.C. 2015. Experimentally induced innovations lead to persistent culture via conformity in wild birds. Nature 518 (7540): 538–541. DOI: 10.1038/nature13998

Bartal I.B.A., Decety J., Mason P. 2011. Emphaty and prosocial behawior in rats. Science 334 (6061): 1427–1430. DOI: 10.1126/science.1210789

Bear M.F., Connors B.W., Paradiso M.A. (eds.). 2007. Neuroscience: Exploring the Brain. Williams and Wilkins, 857 pp.

Bodenchuk M.J. 2008. Feral hog management: Tying performance measures to resources protected. In: "National Conference on feral hogs" (Vantassel S.M. ed.), St. Louis, Missouri. DOI: http://digitalcommons.unl.edu/feralhog/8

Briffa M., Weiss A. 2010. Animal Personality. Current Biology 20: 912–914. DOI: 10.1016/j.cub.2010.09.019

Cooper Jr. W., Burghardt G.M.. 1990. Vomerolfaction and vomodor. Journal of Chemical Ecology 16 (1): 103–105. DOI: 10.1007/BF01021271

Diegemanse N.J., Reale D. 2005. Natural selection and animal personality. Behaviour 142 (9–10): 1159-1168.

Ditchkoff S.S., Mayer J.J. 2009. Wild pig food habits. p. 105–143. In: "Wild Pigs. Biology, Damage, Control Techniques and Management" (Mayer and Brisbin, eds.). Savannah River National Laboratory Aiken, South Carolina, 400 pp.

Erdtmann D., Keuling O. 2020. Behavioural patterns of free roaming wild boar in a spatiotemporal context. PeerJ. DOI: 10.7717/peerj.10409

Fernández-Llario P., Mateos-Quesada P. 1998. Body size and reproductive parameters in the wild boar. Acta Theriologica 43: 439–444.

Fernández-Llario P., Carranza J., Mateos-Quesada P. 1999. Sex allocation in a polygynous mammal with large litters: the wild boar. Animal Behaviour 58: 1079–1084.

Fernández-Llario P., Carranza J. 2000. Reproductive performance of the wild boar in a Mediterranean ecosystem under drought conditions. Ethology, Ecology and Evolution 12: 335–343.

Fernández-Llario P., Mateos-Quesada P., Silverio A., Santod P. 2003. Habitat effects and shooting techniques on two Wild boar (*Sus scrofa*) populations in Spain and Portugal. Zeitschrift für Jagdwissenschaft 49: 120–129.

Ganges L., Crooke H. R., Postel A., Sakoda Y., Becher P., Ruggli N. 2020. Classical swine fever virus: the past, present and future. Virus Research: 289. DOI: doi.org/10.1016/j.virusres.2020.198151

Garcia M., Gingras B., Bowling D.L., Herbst C.T., Boeckle M., Locatelli Y., Fitch W.T. 2016. Structural Classification of Wild Boar (*Sus scrofa*) Vocalizations. Ethology 122 (4): 329–342. DOI: 10.1111/eth.12472 Statistics Poland (GUS) https://www.stat.gov.pl

Jerina K., Pokorny B., Stergar M. 2014. First evidence of long-distance dispersal of adult female wild boar (*Sus scrofa*) with piglets. European Journal of Wildlife Research 60: 367–370. DOI: https://doi.org/10.1007/s10344-014-0796-1

Klingholz F., Siegert C., Meynhardt H. 1979. Die Akutische Kommunukation des Europaeischen Wildschweines (*Sus scrofa* L.). Der Zoologische Garten 49 (4–5): 277–303.

Korbas M., Węgorek P., Zamojska J., Danielewicz J., Jajor E., Dworzańska D., Bandyk A., Horoszkiewicz-Janka J. 2016. Influence of *Capreolus capreolus* L. and *Cervus elaphus* L. feeding simulation on disease incidence rate and maize yielding. Fresenius Environmental Bullettin 25 (10): 4269–4277. DOI: 10.1515/chem-2021-0074

Linhart P., Ratcliffe V.F., Reby D., Špinka M. 2015. Expression of Emotional Arousal in Two Different Piglet Call Types. Plos One 10 (8): 0135414. DOI: 10.1371/journal.pone.0135414 Research Centre for Cultivar Testing. Lista odmian roślin rolniczych COBORU. https://www.coboru.gov.pl (in Polish)

Maigrot A. L., Hillmann E., Briefer E.F. 2018. Encoding of Emotional Valence in Wild Boar (*Sus scrofa*) Calls. *Animals* 8: 85. DOI: https://doi.org/10.3390/ani8060085

Mayer J.J. 2009. Wild pig behaviour. p. 77–105. In: "Wild Pigs. Biology, Damage, Control Techniques and Management" (Mayer and Brisbin, eds.). Savannah River National Laboratory Aiken, South Carolina.

Palinski R.M., Mitra N., Hause B.M. 2016. Discovery of a novel Parvovirinae virus, porcine parvovirus 7, by metagenomic sequencing of porcine rectal swabs. Virus Genes 52: 564–567. DOI: 10.1007/s11262-016-1322-1

Pałubicki J. 2016. The impact of mycotoxins contained in maize on the reproduction of wild boar (Sus scrofa L.). Doctoral Dissertation, Poznań University of Life Sciences, Faculty of Forestry. (Wpływ mikotoksyn zawartych w kukurydzy na rozrodczość dzików (*Sus scrofa* L.). Praca Doktorska, Uniwersytet Przyrodniczy w Poznaniu, Wydział Leśny.

Ruiz-Fons F., Segales J., Gortazar Ch. 2008. A review of viral diseases of the European wild boar: Effects of population dynamics and reservoir role. The Veterinary Journal 176 (2): 158–169. DOI: 10.1016/j.tvjl.2007.02.017

Saha G.K., Mazumdar S. 2017. Wildlife Biology: An Indian Perspective. PHI Learning, 328 pp.

Schley L., Roper T. J. 2003. Diet of wild boar *Sus scrofa* in Western Europe, with particular reference to consumption of agricultural crops. Mammal Review 33 (1): 43–56. DOI: 10.1046/j.1365-2907.2003.00010.x

Singer F.J., Ackerman B.B. 1981. Food availability, reproduction and condition of European wild board in Great Smoky Mountains National Park. Research, Resource Management, and Reports 43: 1–52.

Snethlage K. 1982. Das Schwarzwild. 7th Edition. Verlag Paul Parey, Hamburg and Berlin, West Germany, 105 pp.

Spinka M., Syrova M., Policht R., Linhart P. 2019. Early vocal ontogeny in a polytocous mammal: no evidence of social learning among sibling piglets, *Sus scrofa*. Animal Behaviour 151: 9–19. https://doi.org/10.1016/j.anbehav.2019.02.018

Sweeney J.R., Sweeney J.M., Sweeney S.W. 2003. Feral hog, *Sus scrofa*. p. 1164–1180. In: "Wild Mammals od North America: Biology, Management and Conservation" (Feldhammed G.A., Thompson B.C., Chapman J.A., eds.). The Johns Hopkins University Press, Baltimore, Maryland, 385 pp.

Syrová M., Policht R., Linhart P., Špinka M. 2017. Ontogeny of individual and litter identity signaling in grunts of piglets. The Journal of the Acoustical Society of America 142 (5): 3116. DOI: 10.1121/1.5010330

Tallet C., Linhart P., Policht R., Hammerschmidt K., Šimeček P. 2013. Encoding of Situations in the Vocal Repertoire of Piglets (*Sus scrofa*): A Comparison of Discrete and Graded Classifications. Plos One 8 (8): 71841. DOI: https://doi.org/10.1371/journal.pone.0071841

Verhulst C.E., Mateman A.C., Zwier M.V., Caro S.P., Verhoeven K.J.F., van Oers K. 2016. Evidence from pyrosequencing indicates that natural variation in animal personality is associated with DRD4 DNA methylation. Molecular Ecology 25: 1801–1811. DOI: 10.1111/mec.13519

Węgorek P., Zamojska J., Dworzańska D. 2009-2024. Game (wildlife) damage. [In:] Integrated Pest Management Methodologies and Signalman's Guides of the Institute of Plant Protection – National Research Institute (IOR–PIB). (Szkody łowieckie. [W]: Metodyki Integrowanej Ochrony Roślin i Poradniki Sygnalizatora IOR – PIB)

Węgorek P., Korbas M., Zamojska J., Bandyk A. 2011. Wpływ wielkości i rodzaju uszkodzeń rzepaku ozimego przez zwierzęta łowne na plonowanie roślin. Progress in Plant Protection/Postępy w Ochronie Roślin 51 (1): 227–231.

Węgorek P., Zamojska J., Bandyk A., Olejarski P. 2014. Results of the monitoring of the effectiveness of repellents against wild boar in the fields. Progress in Plant Protection 54 (2). DOI: http://dx.doi.org/10.14199/ppp-2014-025

Węgorek – personal observations at Game Breeding Center, Institute of Plant Protection – National Research Institute (GBC IPP – NRI).

Wu G.S., Yao Y.G., Qu K.X., Ding Z.L., Li H., Palanichamy M.G., Duan Z.Y., Li N., Chen Y.S., Zhang Y.P. 2007. Population phylogenomic analysis of mitochondrial DNA in wild boars and domestic pigs revealed multiple domestication events in East Asia. Genome Biology 8: 245. DOI: https://doi.org/10.1186/gb-2007-8-11-r245

www.lasy.gov.pl

www.pzlow.pl