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REVIEW PAPER

Wild boar (*Sus scrofa* L. 1758), a problematic but also a useful species – A review*

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Abstract

The work analyzes the impact of the wild boar on the environment. Its useful role has been demonstrated, emphasizing its sanitary function and usefulness as a bioindicator in monitoring the natural environment. The problems posed by numerous wild boar populations were analyzed, including a sanitary threat to humans and animals, a real threat to soil and ecosystems, damage to the agricultural and forest environment, negative impact on local biodiversity in anthropogenic environments, nuisance to people in urban and suburban areas. *Sus scrofa* can be considered as a species capable of causing disturbances to biotic and abiotic elements of the environment. The work draws attention to the threats posed by *Sus scrofa* and/or the threats to the species. The focus is on the animal being the vector of infections for various species of animals and humans because wild boars are susceptible to various highly contagious diseases that sometimes decimate their populations. Wild boars should be seen as beneficial animals (a bioindicator of environmental contamination, sanitary function) and at the same time problematic ones, dangerous to other species, including domestic pigs and humans, and to the environment. Due to the significant damage caused to global agriculture, to agricultural and forest crops, the threat to biodiversity, the nuisance to humans in urbanized areas related to the wild boar, there is an increasing interest in the ecology of the species and the principles of wild boar population management.

Keywords: wild boar, environment, agriculture, bioindicator

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INTRODUCTION

Large ungulate populations and their high densities are now common throughout Europe. We can speak of their excess when their presence causes problems for humans, such as: loss of plant diversity, damage to crops and forestry, collisions between animals and vehicles, nuisance to humans, transmission of diseases to livestock or changes in habitats for other species. What level of density is acceptable depends on the ecological and socio-economic conditions in which a given population is located. Determining the population size and density is important for designing population management strategies and actions (Carpio et al. 2020). The cited researchers reviewed more than 300 published papers and identified six important areas associated with the overabundance of wild large ungulates in Europe; these are: protected areas, hunting areas, forestry, agriculture, animal husbandry, and suburban areas. They concluded that, in addition to the information related to a population size, four indicators of environmental change can be used to monitor the overabundance of animals of a given species, such as: impact on habitat, impact on animal performance, increase in disease and parasite burden, and increase in nuisance to humans. In the assessment by Carpio et al. (2020), nine ungulate species, including the wild boar, are found in excess in Europe. The wild boar (*S. scrofa*) was found to be the species with the highest probability of overabundance in relation to agriculture (60%), animal husbandry (29%) and in (sub)urban areas (38%).

ENVIRONMENTAL IMPACT

The wild boar responds very flexibly to changes in the abundance of the environment, which is subjected to heavy exploitation by man. This is linked to the ever-increasing human population and the need to satisfy its various needs, demands, and expectations (food, urban agglomerations, transport routes). Animals are changing their behaviour and habits as well as their food preferences in order to adapt to the new, man-made conditions. The forest has always been a refuge and natural biotope for the wild boar, but due to human activities, the forest foraging base has shrunk, forcing the animals to move to cultivated fields, which are used as feeding grounds. Even with a periodic lack of food typical of the species – oak acorns and beech nuts – agricultural crops (cereals, maize, potatoes) with which wild boar supplement or replace their natural forage remain fully available. The result is game damage to agricultural crops and products (Amici et al. 2012*b*, Piekarczyk et al. 2021, von Essen et al. 2023). In recent decades, crop damage in the EU countries has been increasing dramatically. The consequence is multi-million euro compensation paid to farmers. In France, in 1973, i.e. half a century ago, the amounts paid out in compensation amounted to €2.5 million, increasing to €21 and €32.5 million in 2005 and 2008, respectively (Cappa et al. 2021). In whole Europe, agricultural damage caused by the wild boar is estimated at €80 million per year (Cappa et al. 2021).

Damage to permanent grassland occurs more frequently and is more severe than damage to annual crops (Herrero, Fernandez de Luco 2002, Herrero et al. 2004, Schley et al. 2008, Amici et al. 2012*b*). Crops exposed to damage expressed in terms of reduced area of cultivation are maize, rye, oats, triticale, wheat and cereal mixtures and potatoes (Schley et al. 2008, Lombardini et al. 2017). The increase in the occurrence of game damage in field crops is largely dependent on the phenology of vegetative development of the plants (Frąckowiak 2012). Damage to maize crops occurs during the sowing and emergence period (May) and in autumn (October–November); after harvesting, ploughed crop residues again attract wild boar to the fields. During the period of potato planting and spring cereal sowing (April–June), wild boars destroy the crops; in addition, in spring, summer and autumn they root grassland and oilseed rape (Piekarczyk et al. 2021). In cultivated areas, wild boars not only eat crops but also, and above all, trample them (Schley, Roper 2003), which is due to their lifestyle. *Sus scrofa* move and rest in groups, always in contact with other individuals of their species (Sodeikat, Pohlmeyer 2003). Bobek et al. (2017) estimated that only 15-10% of crop damage is a consequence of the actual consumption and 85-90% is lost through trampling.

The size and spatial distribution and severity of damage in a given area depends on the size and type of forest complexes and the degree of fragmentation – the length of the forest-field boundary (Flis 2009, Orłowska and Nasiadka 2022). The high fragmentation of forest complexes favours the occurrence of wild boars (Virgós 2011).

The scale of damage to agricultural crops decreases when the species' numbers decline. Since 2005, hunters in Italy have killed around 295 000 wild boar per year, but the animals reproduce rapidly and each year the population can increase by up to 150 percent (Massei et al. 2015). In Spain, the cull is 400 000 animals per year, but the National Hunting Research Institute estimates a doubling of the population by 2025.

Until recently, the European wild boar was a seasonally reproducing species, with sows coming into heat in autumn and giving birth to 4-6 piglets in spring. Progressive climate and habitat change, including the availability of high-energy feedstuffs such as maize, have significantly accelerated the time at which females reach sexual and breeding maturity. As a result, young sows give birth to their first litter as early as the first year of life. Increasingly, they are giving birth to and rearing two litters a year. The consequence of this is a significant increase in the wild boar populations in some areas of our country and in other European countries. Precise determination of wild boar numbers across Europe is difficult, but it is recognized that the overall population of this species has shown a steady progression over the last three decades (Guerrasio et al. 2022). The European population is estimated to be around 10 million individuals (Massei et al. 2015). Wild boars have entered major European cities such as Barcelona and Rome. The Italian capital is home to five to six thousand wild boars. The Berlin area has a wild boar population of eight thousand, while Warsaw has about a thousand of these animals (Piana et al. 2024). The scavenging of scraps from rubbish bins in cities forms the basis of their good weight gain, with urban animals weighing about 35% more than individuals living in forests.

The most important factor in the biogeographical variation in the density of *S. scrofa* populations is temperature, less important being vegetation productivity and predator threat (Melis et al. 2006). The density of *S. scrofa* varies, in Europe being highest in oak-dominant forests. In Southeast Asia, *S. scrofa* is found in forests with mature stands, gardens and oil palm plantations. It reaches very high densities in tropical moist lowland forests, with predominantly tropical deciduous trees of the *Dipterocarpaceae* family, especially during their flowering period. In Malaysia, during periods of high food availability, the population density rate of *S. scrofa* was locally as high as 47 individuals per 1 km^2 (Ickes 2001). Diagnosis and monitoring of overabundant populations using indicators of ecological change and population management actions are, according to Carpio et al. (2020), strongly needed. It is recommended that the average density of this species in our country should be no more than 1 animal/1,000 ha.

The natural exploratory behaviour of wild boars, the need to forage and the innate rooting reflex promote soil loosening and mixing with litter in natural forest habitats. In recent years, attention has turned to the influence of wild boars on soil quality, particularly soil structure, nutrient availability and microbial activity, i.e. productivity. By analogy with ruminants, whose overgrazing alters natural soil processes and causes soil degradation (Macci et al. 2012), research in this area has been undertaken in southern Italy for wild animals, including the wild boar (Carpio et al. 2020). The actual threat of the wild boar to soils and ecosystems has been confirmed (Napoletano et al. 2023) and the species has been recognized as capable of causing disturbance to biotic and abiotic landscapes (Gray et al. 2020). A study in Sweden reported the impact of wild boars on the degree of plant damage and the disruption of saprophytic and symbiotic fungi and pathogenic fungi in soil (Carpio et al. 2022). The increase in wild boar populations and the invasion of animals of this species in anthropogenic environments negatively affects local biodiversity (Fulgione et al. 2016, Maselli et al. 2016, Fulgione, Buglione 2022). Animals rooting on the ground and to a depth of 40–50 cm have been shown to modify geomorphological processes (Mauri et al. 2019) and the stability of soil structure (Barrios-Garcia, Ballari 2012). Exploration and rooting alter nutrient cycling and decomposition rates, and modify nitrogen processes by accelerating mineralization (Singer et al. 1984, Siemann et al. 2009). Also according to Grey et al. (2020) rooting – turning the soil – accelerates the leaching of macronutrients, and alters the chemical processes, including nitrogen transformations, that take place in the soil. In contrast, Moody and Jones (2000), Wirthner et al. (2011) and Tierney and Cushman (2006) report that rooting has no effect on mineralization and its effect on soil texture, pH, moisture and organic matter is low. Mohr et al. (2005) indicated that rooting negatively affects soil biological properties – microbial activity, biomass, structure and bacterial diversity. The cited researchers noted an intense reduction in microbial activity and biomass and simplification of microbial composition. In relation to the adverse effects of wild boars on the soil environment shown in studies (Barrios-Garcia, Ballari 2012, Carpio et al. 2020, Grey et al. 2020, Napoletano et al. 2023), it is of interest to note the results of Pitta-Osses et al. (2022), which show that mitigating soil degradation can be more effective by reducing adverse abiotic processes than by controlling wild boar populations.

By digging into the soil, wild boars affect plants directly or indirectly by modifying soil properties. The intensity of this influence strictly depends on the plant species because the effort the animal puts into obtaining them is important. Most often, the action is directed towards an abundant food source, the acquisition of which involves minimal foraging effort (Welander 2000, Barrios-Garcia, Ballari 2012).

Damage caused by the wild boar can affect herbaceous plants and trees (Barrios-Garcia, Ballari 2012). Preferential food for wild boars are seeds and roots due to their high digestibility and high protein content. Rooting negatively affects plant regeneration, as animals either eat and digest seeds or damage them (Barrios-Garcia, Ballari 2012, Macci et al. 2012, Napoletano et al. 2023), although by excreting them undamaged they also spread them over a large area, thus contributing to biodiversity recovery and maintenance (Horčičková et al. 2019, Pedrosa et al. 2019). The behaviour of farrowing females involving the natural nest-building reflex before parturition is locally destructive. When preparing the lair, sows tear off fragments of woody plant seedlings or uproot them, thus destroying forest nurseries.

The destructive impact of the wild boar has been confirmed in areas of Australia, New Zealand, Tasmania, the Pacific Islands, North and South America. The destruction caused by wild boars has affected both the plant and animal world, including endemic species, especially ground-nesting birds and reptiles and small mammals. In these areas, wild boar is considered a conflict animal and even a pest (Risch et al. 2018). In North America and Australia, the wild boar devastates local ecosystems, therefore it is seen as an invasive species.

Rooting can also disrupt plant communities. Wild boars eat whole plants or their vegetative parts – bulbs, tubers, fruits, which leads to a reduction in the species diversity of herbaceous plants and sometimes at high densities of wild boars to the local extinction of some plant species (Howe et al. 1981). By exploring the environment to find food, the wild boar destroys scrub, which promotes soil erosion. In areas accessed by animals of this species, reduced survival and seed success has been found (Howe et al. 1981, Singer et al. 1984) as well as reduced diversity of native herbaceous plants (Gray et al. 2020).

The omnivorousness of animals means that, in addition to plant foraging, they need to acquire animal food. Wild boars eat carrion, rodents, sick birds and mammals, thereby reducing the transmission of diseases – they perform a sanitary function in forest complexes; they also eat the larvae and pupae of insects, including forest pests. Reducing the abundance of pest insects protects the forest stand and is beneficial for forest management (Lee, Lee 2019, Tobajas et al. 2022).

RISKS

The threat issue can be considered in two ways – as a threat from *Sus scrofa* and/or a threat directed at *Sus scrofa*. For *S. scrofa*, the biggest threat is man (shooting, trapping). The natural causes of wild boar mortality are mainly infectious diseases and food scarcity in adverse weather conditions. However, hunters and their hunting as well as traffic accidents involving wild boars play a major role in reducing wild boar populations (Keuling et al. 2021). In most EU countries, no statistics are kept on the scale of road accidents involving wild boars. However, the costs of accidents involving them have been estimated in Sweden. They amounted to about PLN 130 million in 2011 in Polish currency terms, and after about seven years they increased more than fivefold to an amount of about PLN 736 million; this confirms the size of the losses and the scale of the problem.

At the global level, there are no major threats to the species as populations are abundant in many places. At a local level, however, such threats do exist, due to habitat destruction and hunting pressure. Hunting can be for sport and recreation, sometimes for food, sometimes as a form of crop protection. Hybridization can also be a problem, through the interbreeding of the wild boar with domestic pigs or feral pigs (Laliotis and Avdi 2018, von Essen 2020).

INFECTION VECTOR

Sus scrofa is a vector of infection for various animal species and humans as it is itself susceptible to various highly contagious diseases that sometimes decimate its populations. Swine cholera was reported on the island of Honsiu in Japan (1877), severe skin disease occurred on Iriomote Island (Riukiu Archipelago) in Okinawa Prefecture, Japan, between 1976 and 1980, while swine fever was reported in Sri Lanka in 1989 (Kameyama et al. 2019).

Wild boars are reservoirs for many epidemiologically and economically important pathogens. They can be the source of diseases dangerous to humans, such as hepatitis E, tuberculosis, leptospirosis and trichinosis, as well as diseases dangerous to livestock, such as brucellosis, classical swine fever (CSF) and African swine fever (ASF) – Ruiz-Fons et al. (2008), Meng et al. (2009), Carpio et al. (2020), Frederiksson-Ahomaa et al. (2020).

African swine fever virus (ASFV) is the only known representative of the *Asfarviridae* family. The virus causes a highly fatal hemorrhagic disease that affects domestic pigs, wild boars and African wild pigs (O'Neill et al. 2020). ASF is particularly dangerous to populations of wild pigs at risk of extinction, e.g. the pygmy hog (*Porcula salvania*), found in West Bengal and north-west Assam, India (Manas National Park) – Luskin et al. (2021). ASF, commonly found in members of the family *Suidae*, including *S. scrofa*, is an incurable, highly infectious and contagious disease, listed by the World Organization for Animal Health as a notifiable disease subject to compulsory control (Costard et al. 2013, EFSA et al. 2021).

The high virulence of African swine fever virus (ASFV) limits the spread of infection to the closest animals in the herd, infectivity is relatively low and prevalence is about 10%. The morbidity is around 9%, but mortality is high, with up to 100% in domestic pigs, up to 95% in wild boars (O'Neill et al. 2020). In Europe, ASFV is transmitted by direct contact between an infected host (wild boar or domestic pig) and a susceptible animal; in Africa transmission is by ticks belonging to the genus *Ornithodoros* (EFSA, 2018). Indirect transmission of the virus through contaminated materials – carcasses, feed, soil, food, objects, vehicles – is also possible. Careless human action is often the route of introduction of ASFV into pig herds. The incubation period for ASF in diseased animals is typically 4-19 days (3-4 days for the acute form) (O'Neill et al. 2020). The virus shows high stability in the environment due to its resistance to extreme conditions – pH and temperature – which favours its transmission (Cisek et al. 2016). The disease can present in various forms, with the acute form presenting with high fever, respiratory and gastrointestinal symptoms, cyanosis and ataxia leading to death.

African swine fever is endemic and spreads slowly. The persistence of ASFV in the environment (epidemic time) is proportional to the size of the wild boar population and the forest cover of the area, hence correct population management is important to limit the spread of the virus. Wild boars that died due to ASF can be the vector of the virus for quite a long time, depending on sunlight, temperature, pH, humidity, provided healthy animals come into contact with the fallen ones (Frant et al. 2021). In the EU countries, the ASF control strategy includes a ban on feeding and the use of bait, increased passive monitoring, culling and biosecurity during hunting.

Since 2014, the year in which ASF appeared on the territory of our country, wild boars have been considered the biggest enemy of pig farmers in Poland, as the occurrence of ASF on a pig farm means their slaughter, disposal and huge financial losses (Szymańska, Dziwulaki 2022). State institutions undertake costly preventive and corrective measures to combat

ASF (diagnostics, outbreak extinction, bio-assurance, sanitary shooting, search for and disposal of fallen wild boars) but incidents of new infections, deaths of wild boars and the presence of ASF on pig farms are constantly confirmed (Frant et al. 2021).

Wild boars are hosts to a variety of parasites: nematodes (*Nematoda*) – *Trichinella*, e.g. *Trichinella spiralis* and *Gongylonema,* protozoa (*Toxoplasma gondii*), worms (helminths): lungworms (*Metastrongylus elongatus*), kidney worms (*Stephanurus dentatus*), stomach worms (*Physocephalus sexalatus*) and roundworms (*Ascaris lumbricoides*), whipworms (*Trichuris suis*), American dog ticks (*Dermacentor variabilis*), pig lice (*Haematopinus suis*). Some of these can be transmitted to humans and other animals, which is definitely unfavourable, often dangerous and harmful. They most often cause deterioration of animal health, but can also lead to death (Nosal et al. 2020, Petersen et al. 2020).

In Malaysia and Singapore in 1999, wild boars and domestic pigs were the main vectors for Nipah virus between forest bats and humans (Chua 2003, Skowron et al. 2022); the problem of Nipah virus infection of wild pigs and the human population is an ongoing one.

BIOINDICATOR

Organic pollutants (OPs) are a complex group of substances considered toxic or potentially toxic to living organisms. Most are characterised by their persistence and ability to disrupt biological systems, and are detected in human and animal tissues (Strobel et al. 2018). Organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polybromodiphenyl ethers (PBDEs) or organophosphate pesticides (OPPs) and pyrethroids (PYRs) used in pest control have been found in the tissues of wild animals, including wild boars (Tomza-Marciniak et al. 2014, Holma-Suutari et al. 2016). They can cause short- or long-term damage to living organisms, including humans and animals (Pagliuca et al. 2005, Van der Veen, de Boer 2012). These substances disrupt the endocrine system by interfering with the synthesis and mechanism of action of certain hormones, causing carcinogenesis, neurotoxicity, hepatotoxicity or reproductive disorders (González-Gómez et al. 2021).

The wild boar is sensitive to pollutants in the environment and acts as an indicator of environmental condition (Wren 1986). It can thus be seen as a beneficial animal for both the environment and humans. *Sus scrofa* is easy to identify, the animals live quite long and their populations are numerous. The wild boar has a narrow range of tolerance to certain environmental conditions and is a good bioindicator of environmental contamination by xenobiotics due to its diet. It is widespread, which allows it to be harvested on a large scale – this guarantees the availability of numerous samples for research. Animals scavenge for food in the environment of forests, fields, meadows and pastures, and take up a variety of harmful compounds present with their food and soil, including polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs). These compounds are released into the environment during incineration processes in industrial plants and households. Accumulated waste in landfills is also a source of them. Absorption and bioaccumulation processes of contaminants occur in the body of wild boars, and toxic compounds accumulated in animal tissues indicate the degree of pollution of the environment in which wild boars live (Warenik-Bany et al. 2016).

The toxicity of fluorine and its continuous circulation in the trophic chain (water, air, soil, living organisms – plant and animal, including humans) is important in terms of environmental contamination (Han et al. 2021). In order to determine the impact of fluorine compounds on the environment, Telesiński and Śnioszek (2009) made a comparison of bristles obtained from wild boars (the animals were found in areas affected or unaffected by fluorine compound emissions) using domestic pig bristles as a control. The cited authors showed an increase in the fluorine content of more than 67% in the bristles of wild boars living in areas affected by fluorine emissions.

There is a confirmed high likelihood of immunotoxicity, thyroid disease, liver damage, kidney and testicular cancer, elevated cholesterol levels, developmental toxicity and adverse reproductive and fertility effects in humans when exposed to perfluoroalkyl and polyfluoroalkyl compounds (PFAS), including perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) – Uhl et al. (2023). PFOA and PFOS are persistent organic pollutants detected in the environment (flora, fauna, water, soil) and in living organisms (animals, humans), and wild boars are also exposed to them. Animals take these acids with their food and accumulate them in the liver – this makes it possible to use animals as bioindicators of environmental pollution. The results of studies carried out in various areas of Germany between 2007 and 2013 confirm the accumulation of PFOA and PFOS in wild boar livers, while also indicating a particular risk in those areas with large human populations (Kowalczyk et al. 2018).

The suitability of liver and hair samples to assess exposure and bioaccumulation of polychlorinated biphenyls (PCBs), including dioxins and non-dioxin-like PCBs (DLPCBs and NDLPCBs) – González-Gómez et al. (2021), was determined on a sample of 60 wild boars from north-western Spain. The presence of organochlorine and organophosphorus pesticides (OCPs and OPPs, respectively), as well as polybromodiphenyl ethers (PBDEs), pyrethroids (PYRs) and polycyclic aromatic hydrocarbons (PAHs) were also investigated in the biological material. Significant to moderate correlations were found between socio-demographic characteristics (gender, age and place of residence) and concentrations of the compounds studied. The results confirmed their bioaccumulation in liver and bristle samples and the suitability of the wild boar as indicator animals for environmental contamination.

The results of studies carried out in Poland, Croatia, Italy and Slovakia indicate that meat (muscle tissue) and internal organs (kidneys and liver) of the wild boar are characterized by an increased content of toxic elements such as lead, cadmium, arsenic, mercury (Piskorová et al. 2003, Amici et al. 2012*a*, Danieli et al. 2012, Lazarus et al. 2014, Durkalec et al. 2015, Florijančić et al. 2015). Therefore, it is necessary to regularly monitor the quality of the harvested raw material and to select organs for consumption (Rudy et al. 2019).

CONCLUSIONS

Wild boars can be described as 'beneficial pests'. On the one hand, their sanitary function should be appreciated, as well as their usefulness as bioindicators in environmental monitoring. On the other hand, they are a sanitary threat to humans and animals, a real threat to soil and ecosystems, they cause damage to agricultural and forest environments, have a negative impact in anthropogenic environments on local biodiversity, and are a nuisance to humans in urban areas. *Sus scrofa* can be considered a species capable of causing disturbance to biotic and abiotic elements of the environment. Due to the significant damage caused to global agriculture, there is growing interest in the ecology of this species and the principles of managing their populations.

Author contributions

A.R., J.W. and M.S. wrote the paper. All authors have read and agreed to the published version of the manuscript.

Conflicts 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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