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Effect of Wild Boar (*Sus scrofa* L.) on Forests, Agricultural Lands and Population Management in Lithuania

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Abstract: The wild boar (*Sus scrofa* L., 1758) is one of the most common and widespread game species not only in the Baltic Sea region but also throughout its entire range. However, quantitative population management is required due to the danger of contagious diseases; the census is imprecise, and integrated management and monitoring are still missing in Lithuania. This study focused on the current condition of the wild boar population at the country level, species activity in forests and adjacent agricultural lands, the problem of damage to agriculture and forestry caused by wild boar, and methods for the management of the wild boar population. A methodology for the assessment of the effect of wild boar will help in reducing their impact. For the successful management of wild boar, an increase in the carrying capacity in conformity with animal density should be accomplished.

Keywords: wild boar; habitats; effect; damage; assessment; management

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1. Introduction

The wild boar (*Sus scrofa* L. 1758) is one of the most common and widespread game species not only in the Baltic Sea region but also throughout its entire range. It is native to forests ranging from Western and Northern Europe and North Africa to India, the Andaman Islands, and China and has been introduced to New Zealand and the United States [1,2]. Wild boars are an important and inherent component of the forest ecosystem in Lithuania.

The Lithuanian wild boar belongs to the central European subspecies *Sus scrofa*. In Lithuania, the spread of wild boars occurred no later than at the end of the early Holocene (i.e., 8–6 millennium B.C.), especially in the third to second millennium B.C [3]. The species was not rare: its bones make up 20–50% of ungulates' bones found at archaeological sites. In the period after World War II, the number of wild boars decreased because of an abundant population of predators (e.g., the wolf, *Canis lupus* L.), poaching, and other human disturbances (e.g., landscape conversion, forest operations, hunting, recreation, etc.). Historical sources indicate that [3] severe winters in the past negatively affected the annual increment of the population and caused the loss of at least a quarter of adults. Nevertheless, abundant supplementary feeding in winter, protection from poaching, a reduction in the predator numbers, and the improvement of habitat conditions (e.g., agricultural land mosaic; increase in the area under oak stands, and other measures to provide food and shelter) were suitable measures that allowed the species to recover and further increase in number. The behavioural plasticity of wild boars has allowed them to adapt to the feeding conditions of the anthropogenic landscape [4–6]. Consequently, the animals have gathered in the most suitable localities [4,6], causing a clumped distribution and inducing changes in their territorial and feeding behaviour while also becoming a prime risk factor for the spread of contagious diseases in a short time [7–16]. The distribution, movement, grouping, and abundance of wild boars depend on several key drivers, such as the available food supply, safety, and assurance of reproduction. When the animals' needs are unsatisfied [5,17–19], their adaptation to changes in their environment is disordered, and feeding requirements prevail [5,19,20]. Simultaneously, the damage caused to agricultural crops and forestry increases [19–31]. Despite their omnivorous and highly opportunistic diet, wild boars mostly consume vegetative food, and a better food supply is found in deciduous and mixed forests [19,31,32]. Although wild boars are inseparable from forests, their effect on forests is not exceedingly significant, and their rooted area comprises only 0.9–2.9%, regardless of the high density of wild boar (e.g., density ranges from 15 to 82 individuals per 1000 ha) [33]. Wild boar rooting facilitates the sprouting and growth of tree seeds; moreover, the animals consume insects and rodents [32–35] and stimulate the decomposition of organic matter and the mobilization of soil nutrients [35]. Therefore, they have an important function in assisting nutrient transfer in native forest habitats [36–38]. Although wild boar rooting in forests reduces carbon (C) stocks in the forest soil, they have a negligible effect on large-scale emissions [37,38]. Wild boar mainly roots in older forests, and their rooting has little effect on the germination of seeds via the scarification of the topsoil layer [39]. One study found that rooting occurred in <1% of the area and caused negligible damage to the roots of trees with commercial value [39]. However, other authors have emphasized the considerable risk of damage to seedlings, especially during the first week after planting, with most damage occurring during the first four weeks [40,41]. Wild boars can be described as ecosystem engineers because they mechanically change their environment [42]. It has been found that the most damaged tree species are pine (*Pinus* spp.) or spruce (*Picea* spp.) [39–41] and hardwood species [41–46]. The damage caused by wild boar to seedlings in young forest plantations is site dependent and likely influenced by a combination of food availability, seedling accessibility, animal density, land cover, hunting pressure, and soil moisture [43]. Wild boar can also negatively affect forest litter (losses reaching 80–95%) [32]. Moreover, they contribute to the disappearance of rare plant species and damage tree roots, which cause slope erosion [44,45].

Wild boars cause hundreds of thousands of euros worth of damage [47–53] to almost all agricultural crops [20,21,28,45–47,54,55]. In Luxembourg, the damage caused by wild boar increased by 1600% from 1971 to 2004 [22]. The damage to crops differs in both space and time and is dependent on specific plant growth stages [22,47,48,54,56]. Wild boars spend less time in cultivated fields in March, April, and May than in the summer [48]. In mixed agricultural–forest landscapes, wild boars mostly use fields adjacent to forests [48,49,54]. Many authors have emphasized the severity of crop damage not only due to consumption but also due to trampling (e.g., [22,28,47]). Conflicts among landowners, hunters, and other stakeholders regarding wild boar have also increased. Damage assessment is one of the foremost objectives when addressing human/wildlife conflicts [25,46,50,53,57–60]. A methodology for the assessment of damage to agricultural crops, livestock, and forests caused by game animals, including wild boar, was approved in Lithuania in 2002, and a consolidated version has been valid since 20 October 2018 [59]. This methodology helps to mitigate the above-mentioned conflicts. It regulates the calculation of the monetary expression of the damage caused by wildlife to agricultural crops, livestock, forests, and hydraulic equipment for the owners, users, and managers of agricultural and forest lands and water bodies and lays out measures to protect crops against damage. Wild boar management techniques have been suggested in many countries, including the USA and Australia [61,62]. Problems caused by wild boar and the need for an assessment methodology and compensation have also been emphasized in different countries [40,59,63,64]. In eastern Germany, the needs of stakeholders were identified, and an integrated framework that leverages the individual strengths of previously isolated methodologies was proposed [65]. To assess the damage to agricultural crops caused by wild boar, unmanned aerial systems (drones) [66–68] are commonly used, or the assessments are based on surveys and questionnaires [40,69].

The overabundance of wild boar is a global issue of growing interest. To manage their numbers properly, knowledge of the density of local populations and any changes is needed. Density is an important indicator of animal living conditions and can be used as a tool for their monitoring, risk assessment, and management [19,28,54,70–78]. Various methods and models have been used to estimate density [70,71], including snow tracking, hunting-bag data, drive hunts, pellet group counts, camera trapping, etc. A common practice with a long history is the counting of wild boar tracks in snow. Briefly, straight-line transects are located using a random or systematic sampling design and the location of each track or trail that crosses a transect is recorded [28,79–81]. However, snow tracking is available only for a short time, and snow conditions are often unsuitable for tracking [19,28,70,79]. Moreover, climate warming and drastic fluctuations in wild boar numbers due to contagious diseases [8–11] have encouraged the utilization of proper methods to estimate the density of wild boar populations. For example, in Lithuania, the wild boar population declined by 2–2.5 times from 1967 to 1990 due to outbreaks of classic swine fever (CSF) [82]; however, it recovered rapidly. The permissible quotas of wild boar densities were approved in 1995 [83] on the grounds of damage caused to agricultural crops and forests and the susceptibility of wild boar to contagious viral diseases. However, the quotas were cancelled in 2005 by the Ministry of Environment [84]. This shows that attention to wild board management was abated in the absence of the direct emergency associated with zoonotic diseases. The abundance of wild boar has again exceeded permissible levels, and their environmental impact and the spread of contagious diseases [19,82,85] have become a challenge at the global level.

This situation causes great concern and questions about the further management of local populations of wild boar. Although the damage to landowners caused by wild boar is less visible today, the current situation encouraged us to present a long-term study on the effect of wild boar on agricultural crops and forests. We aimed to determine the occurrence of wild boar and assess the damage caused to forests and agricultural crops in different natural regions.

2. Materials and Methods

The study was conducted from 2010 to 2020 in different natural regions, including the model territory (MMMPV), with a total area of 5646 ha in the north-western part of Lithuania (Figure 1).

We employed an integrated method to assess the effect of wild boar on agricultural crops and forests as well as to determine animal distribution and habitat preferences. We estimate densities from indirect signs combining indirect snow-track surveys in the winter (in the presence of snow cover, considering the number of the ingoing and outgoing tracks both ways from the transect line within the grid of six parallel transects; the grid covered all forest stand) and counts of faeces taken within belt transects [31,70] in the early spring that was performed during the count of ungulates (belt transect unit 100 m $\times$ 2 m; each transect crosses all habitats and is established in parallel with the forest compartment line; habitat is characterized every 100 m) by pellet group counting (PGC + FGP) [6,28,31,85–90]. All counts were performed during the daytime. The density was calculated using the standard population density formula Dp = N/A, where N is the total number of individuals and A is the land area unit (1000 ha), considering the average defecation rate of the wild boar 4.95 for Lithuania [6]). The total number of counters was 7–12. The number of wild boars in the entire area of Lithuania was obtained from each hunting ground unit (HGU) (n = 911). Considering the delineation of territory for game animals [6,19,85,91], forests were divided into four categories as follows: (1) pure pine forests, including the maritime zone (western and southern Lithuania; other species comprise less than 10%; the study area 2 736 ha and 5519 ha, respectively); (2) pine/spruce mixed forests (eastern and central Lithuania; deciduous species comprise 11–25%; the study area, 7505 ha); (3) mixed spruce/deciduous forests (deciduous species comprise 11–50%; the study area 3234 ha); and (4) deciduous forests with a mixture of spruce species (coniferous species comprise less than 10%; the study area 1043 ha), which were distributed in almost all natural regions. The data collected from the field studies and official statistics sets were stored in a database.

Figure 1. Location of Lithuania on a map of Europe (dark green colour) (55°10′24.96″ N; 23°53′41.29″ E) and the model territory (56°01′54.9″ N 21°53′20.4″ E (MMMPV) (red—borders of model territory and HGU names).

To estimate the number and age/sex structure of the local wild boar populations, we have used direct counting at baiting points reported during stand hunting, and camera traps, in the model territory. The camera traps were placed at the baiting points (n = 10). This method was combined with the tracking of wild boar herds, which stay outside of the attractive zone, using thermal imaging monoculars. To assess the age/sex structure of local wild boar populations, we distinguished three animal categories: (a) males older than 1 year; (b) females older than 1 year; and (c) juveniles aged up to 1 year. The total number of detected wild boar herds was 211. The herd index was defined on the grounds of the annual mean long-term recruitment, which reached 60%, considering species-specific susceptibility to diseases and mortality, differences in the age-related reproduction of females, and long-term observations [19,31]. To calculate herd indices for practical use, the summation of all observed animals in herds is divided by the number of herd observations in a certain territory.

The occurrence of wild boar and the damage caused to agricultural crops depending on animal density were studied during the summer–autumn period within a radius of 1 km from the forest edge. Belt transects were established every 100 metres from the forest edge for the whole agricultural crop area. The size of each belt transect unit was 0.1 ha (100 m × 10 m). The number of transects depended on the length of the area. The total length of the transects was 920 km of the total area (921 ha). The intensity of the damage (i.e., "trampled", "consumed", etc.) to agricultural crops in the belt transects was estimated visually using a five-point scale as follows [85,92]:

0—no damage (intact);

1—sporadic damage, 5%;

2—less than half of all areas damaged, 30%;

3—more than half of all areas damaged, 75%;

4—all areas damaged, 100%.

The abundance of each agricultural crop (A) in their rotation was calculated using the formula below:

$$A = n \times 100/N\%$$

where n is the number of sample belt transects where each crop was found, and N is the total number of sample belt transects in all agricultural crops.

The average intensity (I) of the damage to each agricultural crop was calculated using the following formula:

$$I = i/N\%,$$

where i is the sum of the percentage of damage to each agricultural crop, and N is the total number of sample belt transects where each agricultural crop was found.

The index of the consumption (i.e., direct effects to plant tissues including mechanical damage) of each agricultural crop (trampled, eaten up, etc.) was calculated using the formula below:

$$C = A \times I\%,$$

The share of each agricultural crop consumed by animals was calculated using the following formula:

$$S = C \times 100/\Sigma c$$

where C is the consumption index of each agricultural crop in% and Σc is the sum of the percentage of the consumption indices of all agricultural crops.

The percentage (i.e., 5%, 30%, or 75%) of differently damaged agricultural crop area (D) was calculated using the following formula:

$$D = n \times 100/N\%,$$

where n is the number of belt transects, where the damage was 5%, 30%, or 75%, and N is the total number of sample belt transects.

The differently damaged (i.e., 5%, 30%, or 75%) agricultural crop area in hectares was calculated using the formula below:

$$D_{ha} = D_t \times D/100\%,$$

where D_t refers to the total area of each agricultural crop in hectares and D is the area of each agricultural crop differently damaged (5%, 30%, or 75%) by animals in hectares.

To study the wild boar diet, we analysed the stomach contents of 200 harvested wild boars. We collected 500 mL samples from the stomach and stored them in 5% formalin. The contents were washed with water in 1.7 mm and 5 mm mesh sieves. The food content of the samples was analysed using the standard volumetric method. We calculated and recorded the percentage by volume of each food item by displacing water in a volumetric beaker [91–93].

We assessed the effect of wild boar on the yield of different agricultural crops using a plot sampling method. The size of each sample plot unit was 1 m^2. The sample plots were established directly within the belt transects where crops were differently damaged (i.e., 5%, 30%, 75%, or 100%). Simultaneously, the control plots were established in areas with undamaged agricultural crops. The difference between the cereal mass of the control and sample plots allowed us to calculate the amount of trampled and consumed yield separately. This method enabled us to correctly ascertain the extent of the losses and predict certain preventive and precautionary means for the restoration and maintenance of the balance between animal numbers and the carrying capacity of their habitats.

Research outputs are the ground for population management. The quantitative method for the management of wild boar populations is based on the loss of agricultural crops, population size, and annual recruitment. The ratio of population use is calculated using the following formula [47,60,85,94]:

$$N = IN + (RN - PN)/y,$$

where N refers to the ratio of use; IN is the wild boar annual recruitment in animal units; RN is the actual number of animals in the territory; PN is the permissible number of animals in the territory (the number of animals approved for the territory based on the category of the forests and their corresponding carrying capacity); and y is the number of years needed to recover the balance between the animal number and carrying capacity of the territory.

Data Analysis

All of the analyses were performed using MS Excel spreadsheets and the Statistica 8.0 software packages [95]. The relationships between variables (damage–density of wild boar, density–herd index, etc.) were determined using linear regression analysis. The significant differences between the means were determined using one-way ANOVA. The significance of the difference between the means of the obtained data was evaluated using Student's *t*-test, where $p < 0.05$ was considered significant.

3. Results

3.1. Wild Boar Distribution and Foraging in the Different Habitats

The distribution of wild boar depends on food availability; human disturbances, e.g., hunting intensity; and seasonal changes ([11], et al.). Wild boars are most abundant in areas with high soil fertility [6,19] in the northern, southwestern, and northern central parts of the territory of Lithuania.

Although wild boars are omnivorous animals, plant fodder predominates their diet, comprising almost 97%. In forest rooting sites, the ratio of plant food to animal food was 3:1, showing the dominance of plant food. The average shares of the rooting sites (% of the total study area) and foraging supply of different origins (plant or animal) for the different categories of forests are shown in Table 1. The total share of forest food was only 4% while agricultural crops were available. The analysis of the rooting sites showed that the rooting character depended on the forest stand parameters and forest sites (r = 0.589, $p \leq 0.05$).

Table 1. Average seasonal food supply of different origin (plant or animal) and the share of rooting sites in different forest categories in Lithuania.

Forest	Spring			Summer			Winter		
Category	Rooting	Food Supply		Rooting	Food Supply		Rooting	Food Supply	
	Site	g/1 m^2		Site	g/1 m^2		Site	g/1 m^2	
	%	Plant	Animal	%	Plant	Animal	%	Plant	Animal
Pure pine	0.1	0.1	27	0.3	0.2	2.3	0.003	2	2.8
Pine with spruce	2.1	144	7	0.8	22	15.2	0.01	237	0.4
Mixed spruce deciduous	0.5	144	14	0.3	155	15.6	0.09	303	0.3
Deciduous with spruce	1.0	320	31	1.3	204	28.5	0.09	299	-
Natural meadow	3.6	475	37	x	x	x	0.2	128	0.5

In pure pine forests, there was a low food supply, except for *Alnetum filipendulosum* black alder stands, where earthworm stores of up to 100 g per 1 square meter could be found. In spring, the rooted sites most often occurred in *Betuletum vaccinio-myrtillosum*, *Tremuletum vaccinio-myrtillosum*, and *Alnetum filipendulosum* birch and aspen stands in territories belonging to the pure pine forest category, while the area of rooted sites was the largest in the forest sites containing *Pinetum vacciniosum* and *Pinetum vaccinio-myrtillosum*.

In summer, when mushrooms start growing, the rooted sites were predominant in *Pinetum vacciniosum* and *Pinetum cladoniosum* pine stands. These were the largest rooted sites. In winter, the largest rooting area was found in *Alnetum filipendulosum* black alder stands, where food consumption fluctuated from 65% to 100% (Table 1).

The stands belonging to the pine with spruce forest category provided more plant food for the wild boar. The plant forage store amounted to 500–700 g per 1 m^2 of the rooted sites in *Pinetum myrtillo-oxalidosum* and *Piceetum myrtillo-oxalidosum* pine and spruce stands and in *Alnetum urticosum* and *Alnetum caricosum* black alder stands. Food consumption ranged from 57% to 100%. (Table 1). In spring, the greatest rooting was observed in *Alnetum caricosum* and *Alnetum urticosum* black alder stands and *Pinetum vaccinio-oxalidosum* and *Pinetum oxalidosum* pine stands, while the largest rooted sites occurred in *Pinetum oxalidosum*, *Pinetum vaccinio-myrtillosum*, and *Pinetum myrtillo-oxalidosum* pine stands and *Piceetum oxalidosum*, *Piceetum myrtillo-oxalidosum*, and *Piceetum vaccinio-myrtillosum* spruce stands. In summer, the most rooting occurred in *Alnetum urticosum, Piceetum oxalidosum,* and *Pinetum oxalidosum* black alder, spruce, and pine stands, whereas the largest rooted sites were found in *Pinetum oxalidosum* and *Piceetum oxalidosum* pine and spruce stands. In winter, more rooted sites occurred in the *Alnetum caricosum* black alder stands of pine with spruce forests, whilst the largest rooted sites were found in the *Alnetum caricosum, Pinetum myrtillosum, Pinetum myrtillo-oxalidosum, Piceetum myrtillosum,* and *Piceetum myrtillo-oxalidosum* black alder, pine, and spruce stands of the pine with spruce forests.

In the stands of mixed spruce/deciduous forests, the food supply was similar to that of the stands of the pine with spruce forest category, with the exception of *Myrtillo-oxalidosa*, *Urticosa*, and *Caricosa* forest sites with deciduous stands, where the foraging supply ranged from 230 to 930 g/m^2. Food consumption reached 32–100% (Table 1). In spring, the rooted sites were mostly found in *Alnetum caricosum* black alder stands and *Piceetum oxalidosum* spruce stands, and natural meadows. The largest rooting areas were found in *Piceetum oxalidosum* spruce stands and *Aegopodiosa* and *Oxalidosa* forest sites with deciduous stands. In summer, the wild boars mostly rooted in *Piceetum oxalidosum* spruce and *Alnetum urticosum* black alder stands, while the largest rooting area occurred in *Piceetum oxalidosum* spruce and deciduous stands. In winter, rooting was observed mostly in the natural meadows and in *Oxalidosa-myrtillosa* and *Oxalidosa nemorosa* forest sites with deciduous stands. The largest rooting areas were found in *Piceetum aegopodiosum* spruce stands, natural meadows, and *Myrtillo-oxalidosa* and *Caricosa* forest sites with deciduous stands.

In the deciduous spruce forests, the food supply was the greatest (Table 1), and food consumption comprised 50–90% [3,28]. In spring, the most rooting occurred in natural meadows, *Carico-nemorosa* forest sites with deciduous stands, and *Alnetum urticosum* and *Alnetum filipendulosum* black alder stands, while the largest rooted sites were found in *Carico-mixtoherbosa* forest sites with deciduous and mixed stands. In summer, rooting mostly occurred in *Alnetum urticosum* and *Alnetum filipendulosum* black alder stands and in *Carico-mixtoherbosa* forest sites with deciduous spruce stands, while the largest rooted sites were found in *Carico-mixtoherbosa* forest sites with deciduous stands, *Alnetum urticosum* and *Alnetum filipendulosum* black alder stands, and *Piceetum carico-mixtoherbosum* spruce stands. In winter, wild boar mostly rooted in *Alnetum urticosum* black alder stands, while the largest rooting areas were found in *Alnetum urticosum* black alder stands and *Piceetum nemorosa-oxalidosum* spruce stands.

Agricultural crops comprised a major part of the plant food consumed by wild boar (ca. 81%). The largest shares of agricultural crops were consumed in the summer (ca. 90%) and autumn (83%). The available residues of crops in fields were found to attract animals and still prevailed in their diet during the winter (ca. 79%) and winter–spring (ca. 66%) periods. Natural plant fodder comprised, on average, 17% of the animals' diet. This food was important in the spring–summer period, but its importance decreased in winter and autumn [2,6,96]. Above-ground food predominated in the animals' diet, comprising ca. 57% of their diet, and was particularly prevalent in the summer (more than two-thirds). The share of the underground food reached 40%. Cereal comprised 47% and potatoes 53%

of their annual diet. The third most preferable food after cereal and potatoes was beets (ca. 12%). Beets were rarely found in the stomach samples from the summer period, but their importance as supplemental fodder increased during autumn and winter. Green plants were found in 85% of wild boar stomachs; however, the share of this food was only found to be nearly 6% of the diet. A frequently observed food was different roots and bulbs, the share of which was 5%, while the frequency of occurrence was approximately 77%. Wild boar preferred the roots of plants such as *Pteridium aquilinum*, *Urtica dioca, Asarum europaeum, Oxalis acetosella, Anemone nemorosa, Ficaria verna*, *Caltha* sp., *Phragmites* sp., *Typha* sp., *Ranunculus* sp., and small shrubs, among others. Berries and fruits accounted for 1.5–2% of their annual diet. Another important food was acorns. This kind of food comprised 10–40% of their diet during the productive time of year and about 1.5% of their annual diet. Needles, leaves, and moss were observed less frequently. These types of food comprised 2.5% of the animals' diet in the winter and up to 0.2–0.4% during other seasons. Other plant foods, such as the roots and shoots of trees and shrubs and mushrooms, were rarer in the wild boar diet (0.4–0.7%). Foods of animal origin comprised only 3–4% of their diet; this share was negligibly more during the winter (5%), when small rodents and different carrion predominated than in the spring–summer period (3%). Earthworms were the main contributor to foods of animal origin. Different insects, including the larvae of the cockchafer (*Melolontha hippocastani* L.), flea-beetles (Elateridae), the chrysalides of sawflies (*Lyda nemoralis* Thoms., *Diprion pini* L., *Neodiprion sertifer* Geoffr., *Gilpinia polytoma*), and others, comprised a lower share of the wild boar diet. In spring and autumn, the share of food of animal origin was similar (ca. 2%).

As mentioned above, wild boars inhabit all forests; however, coniferous forests and spruce stands were found to be preferred in this study. Deciduous forests are more important during the summer, not only for foraging but also for bathing—there are a number of suitable bathing points in these forests. Coniferous forests protect wild boar against precipitation (i.e., snow and rain). Many wild boar dens were found under older spruces. Dens were rarely established in the undergrowth of spruce, under pine, or in the pine plantations, while several dens were found in the cuttings and under the roots of fallen trees. The dens were usually found in the southern, southeastern, or southwestern parts of trees (41%) and were exceedingly rare in the western part of trees (6.3%) because of the predominating western winds. In winter, most dens (60%) were covered by spruce twigs or sometimes by juniper, pine, and moss (14.5%) or herbs (1.4%). The dens without any bedding were considered temporary (ca. 23% of cases) [3]. During the warmer weather, the dens had no bedding except those of the females with sucking piglets.

In Lithuania, the largest herds of wild boar occurred in the spring. The average herd size was ca. six individuals; however, there could be up to twenty-two animals at the maximum. Generally, the females stayed with the juveniles, and separate herds sometimes joined. During summer and the beginning of autumn, the average herd size decreased to up to five animals. Simultaneously, more abundant herds of up to thirty-five individuals were also found. After the weather became cooler, the animals gathered into larger herds. The largest herds were observed in the winter, with up to twenty-seven animals, while their average size was 5.5 animals.

Although the wild boars were settled when the food supply was sufficient and the animals were not disturbed, they could move about 10–20 km per day because of human disturbances (e.g., four-wheel motor vehicles). Longer movements were characteristic of males. The average movement distance of wild boar is from 0.3 km to 10.5 km depending on the local conditions, such as the season, animal age, and sex [6,31,96,97]. The average herd of wild boar moves about 1–2 km in the wintertime and up to 10–12 km during the summer [96,97].

3.2. Effect of Wild Boar on Forests and Agricultural Crops and Management Issues

Wild boars visit the agricultural lands surrounded by forests depending on crop rotation and animal density. One individual can root 1 ha in the forest, ravage 0.3–0.4 ha of crops from milky ripeness to harvest, and damage other crops yearly. The damage to agriculture caused by wild boar comprises 70–75% of total damage to agriculture; in comparison, damage by deer amounts to 25–30%. Wild boar trample, root, and consume winter and summer cereals, root crops, potatoes, damaged caraway, and other available species depending on their occurrence.

The total annual (excepting autumn) area of forest litter rooted by wild boar was, on average, 0.4% in pine forests, 2.9% in spruce/pine forests, 0.9% in mixed spruce/deciduous forests, and 2.4% in deciduous forests. The damage caused by wild boars was strongly and positively related to animal density ($r = 0.59$, $y = -0.140 + 0.120x$; $p < 0.001$), and stronger damage was observed in winter while less was found during summer ($r = 0.88$, $p < 0.05$).

The intensity of damage to rye and wheat was weakly but positively related to the distance from the forest. Animals are safer away from the forest in comparison to its edges because of possible disturbance factors (hunting, recreational activities, etc.). Wild boar can settle there for a long time. Similar but negative relationships were found between the damage caused by wild boar and potato and beet fields. The intensity of damage to oats was the greatest and was negatively related to the distance from the forest edge ($r = -0.80$, $p < 0.04$). The damage to potatoes and sugar beets was negatively related to the distance from the forest edge ($r = -0.48$ and $r = -0.41$, respectively; $p \leq 0.05$). The animals damaged more plants in smaller oat, potato, and beet fields. The principal factor of damage intensity was animal density (number of individuals per 1000 ha; $r = 0.59$; $p \leq 0.05$). The animals mostly trampled crops (ca. 80%), and less damage was due to the consumption of cereals and root crops (ca. 20%). Therefore, the damage caused by wild boar considerably changed the structure of the agricultural crops considered.

When the density of wild boar exceeds 100 animals per 1000 hectares (i.e., up to 115/1000 ha), the animals visit 23–52% of the agricultural crops within a radius of 1 km. At a density of 12 animals per 1000 ha, wild boars attend 6% of the agricultural crops, and when the density is only 6/1000 ha, this value is decreased to 3% [3,6,28].

4. Discussion

4.1. Effect of Wild Boar on Forests and Agricultural Crops

In Lithuania, foresters and game managers have long dealt with the problem of restraining and reducing the damage caused by wild boars, despite the considerable decline in the wild boar population since the first detection of African swine fever (ASF) in 2014. Today, ASF continues to expand its range in Lithuania, despite efforts to eradicate it and implement national disease control measures, including intensive hunting at the national level and in the model territory (MMMPV) (Figure 2).

Effective protection and a decrease in losses are possible if the reasons for wild boar damage and the factors necessary to improve methods for damage prediction and assessment are perfectly understood. Nevertheless, the assessment of the damage caused by wild boar and management strategies for practical application have not been sufficiently presented [40,50,51,59,63,64,98,99]. A methodology for the assessment of the damage caused by wild boar to agricultural crops and forests was included in the Wild Boar Management Programme, a legal act on the damage caused by wildlife to agricultural crops, facilities, and forests [19,100] in Lithuania, and is currently used to estimate crop losses.

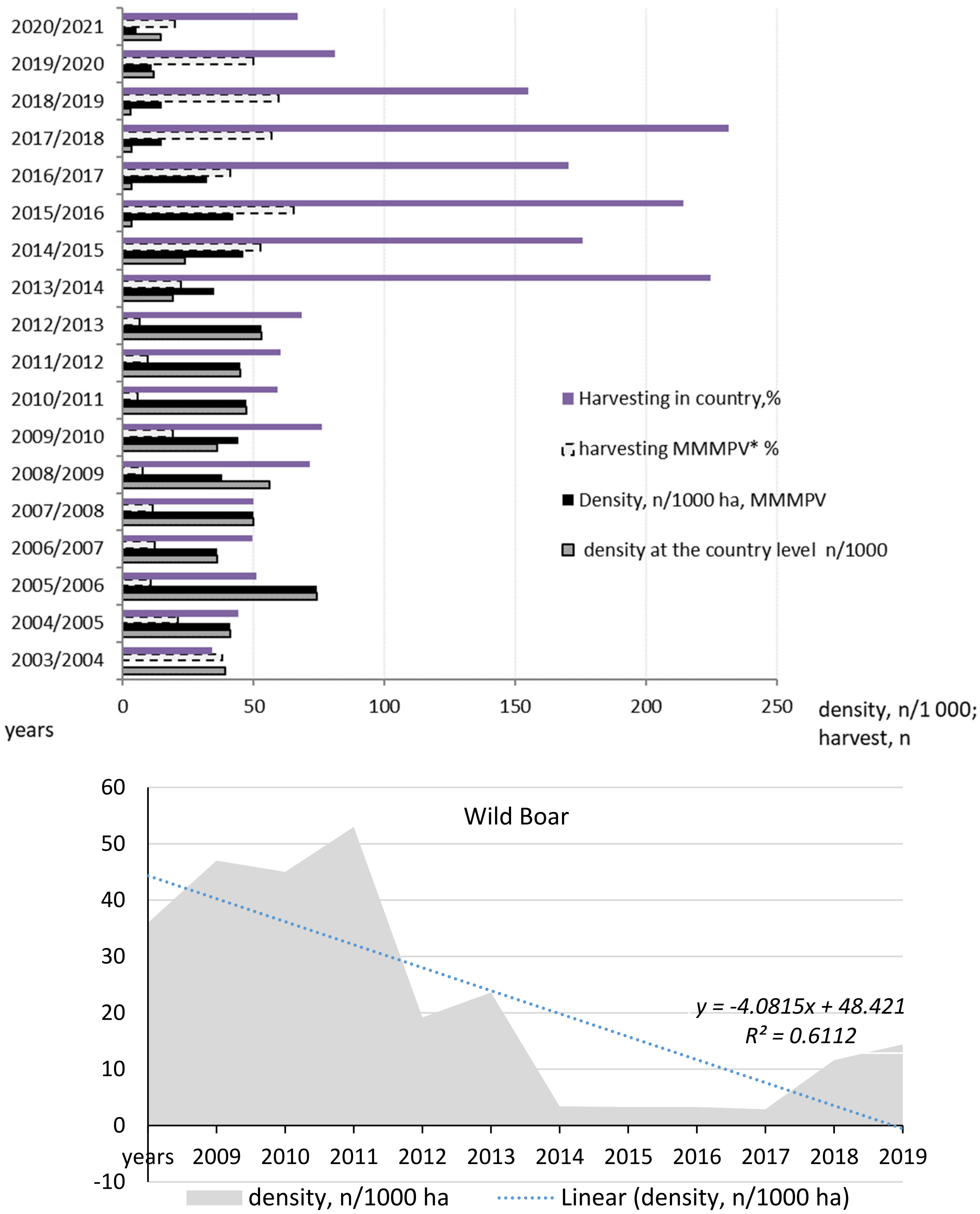

Figure 2. Changes in wild boar harvesting and density in the model territory and entire country. *Note:* MMMPV is the abbreviation of the model area.

4.2. Management of the Wild Boar Population

The management of local wild boar populations depends on wild boar numbers and their effect on agriculture and forestry. There are different management plans for wild boar populations [101–112]. Wild boar populations are managed territorially, quantitatively, and qualitatively [6,19,28,85]. The essence of territorial management is harvest planning and the regulation of numbers in the local wild boar populations despite any administrative borders, such as a region, forest enterprise, or single forest. The local wild boar population should be the object of management. This approach provides scientific ground for the use of the population when considering the carrying capacity of a certain territory and maintaining an optimal population density. Territorial management is performed in forest stand complexes with an area from 5 to 10 thousand hectares when considering the size of the home range and seasonal migration of wild boars [27,30,84].

Direct observations are important measures for the qualitative management of wild boar. This method is suitable when considering the age/sex structure of the population. The scientifically grounded count method is necessary for the successful management of wild boar populations. The combination of several count methods can be used, for example, the count of animals during drive hunting; at baiting points; by faecal group (FPG), which can be combined with the usual deer count by pellet groups at the beginning of the growing season; or via the camera trapping method [68,71,72,113]. To manage local populations properly, an increase in the carrying capacity of the habitat and its conformity to animal density should be accomplished. In this respect, three categories of wild boar densities were distinguished in Lithuania [28,31,85]:

- Minimum density, when animal distribution is random, forage consumption is low, and the negative impact on the habitat is intangible. At this density, infection by parasitic diseases is not intensive, and the population size increases; immigration is common, while emigration is negligible;
- Permissible density, when the distribution of wild boar is spaced, forage consumption does not exceed the permissible limits, and the negative impact is insignificant;
- Ecological density, when animal distribution is clumped in favourable habitats. Here, the forage demand conforms to forage resources.

The permissible quotas for wild boar and other ungulates in the different forests were already legally approved (Table 2)). The group of food supply is officially approved according to the forest category in Lithuania [114] (hunters pay taxes for the use of wildlife resources in each hunting ground unit HGU based on the group of food resources of their HGU).

Table 2. Permissible quotas for the local wild boar population density in the different forests [85,99,114].

Forest Category	Group of Food Supply	Density in All Forests		Wild Boar Density, *n*/1000 ha		
		Permissible	Ecological	Protective Forests	Managed, Recreational	Commercial Hunting
				Agroforests	Forests	Grounds
Pure pine (dominant forest sites: *Cladoniosa*, *Vacciniosa*)	IV	4–7	5–10	4	7	≥15
Pine with spruce (dominant forest sites: *Vacciniosa-myrtillosa*, *Myrtillosa*)-	III	6–11	10–15	6	11	≥20
Mixed spruce/deciduous (dominant forest sites: *Oxalidosa*, *Oxalido-myrtillosa*)	II	8–14	10–15	8	14	≥30
Deciduous with spruce (dominant forest sites: *Aegopodiosa*, *Carico-mixtoherbosa*)	I	10–15	15–20	10	15	≥30

Note: Variations in soil conditions were observed in Piceetum myrtillo-sphagnosum, Piceetum oxalido-myrtillosum, and Piceetum asperulo-tiliosum (+ = to).

The density quotas must correspond to the local conditions and consider the limiting ecological factors. In addition, the damage caused by wild boars to agricultural crops may not exceed 3–5%. The differences between the density of wild boar and harvesting in the model territory and the whole country are shown in Figure 2. The permissible density of wild boar should be kept in protected areas, forests used for recreational purposes, and agroforests. Ecological density would be suitable for commercial hunting ground units.

In these forests, wild boar density could exceed the ecological density depending on the foraging supply.

The qualitative management of the wild boar population is based on population structure, as shown in Table 3. The local wild boar population structure in Lithuania also depends on the feeding conditions during winter.

Table 3. Age and sex structure of the wild boar population in different forest stand categories.

Stand	Population Structure					
	Herd Index, av	Males Older than 1 Year, %	Females Older than 1 Year, %	Sex Ratio	Piglets below 1 Year of Age, %	Recruitment Coefficient
Pure pine	3.9	28.3 ± 3.8	27.6 ± 2.7	1:1.2	48.6 ± 4.1	0.9
Pine with spruce	4.9	18.7 ± 1.9	30.8 ± 1.2	1:1.6	50.5 ± 1.8	1.0
Mixed spruce/deciduous	5.5	16.4 ± 2.2	28.6 ± 1.9	1:1.7	55.0 ± 3.3	1.2
Deciduous with spruce	4.9	18.1 ± 1.3	33.7 ± 2.7	1:1.9	48.2 ± 3.1	0.9

If baiting during the winter was insufficient, the recruitment coefficient was only 0.9, while under the conditions of sufficient abundant feeding in the winter, it reached 1.7.

Until now, the herd index was not discussed in scientific publications, while it was emphasized several decades ago in Lithuania. However, its importance has emerged during the last decade in the context of the spread of ASF. As the herd index was not considered, the number of harvested animals exceeded 200–400%. A model of the relation between wild boar density and herd index can be expressed as follows: $y = -30.4 + 12.1x - 0.3x^2 - 0.03x^3$, where x is the herd index ($r = 0.89$, t = 6.12, $p \leq 0.05$). We recommend considering this useful parameter for wild boar management. The herd index for the different natural regions was determined as follows: 2–3 for pure pine forests in southern Lithuania and 3–4 for the same forests in western Lithuania; 3–4 for mixed coniferous forests in eastern Lithuania and 4–5 for the same forests in central Lithuania; 5–5.5 for mixed spruce/deciduous forests; and 5 for deciduous forests with spruce admixture, including a herd index of 4–5 for the same type of forests in northern Lithuania [19].

In pure pine forests, the herd index was 2–3, and the actual density of wild boar reached 27/1000 ha in 2013; however, because of ASF, it was reduced to 7/1000 ha in 2016, and long-term density stands at only 5/1000 ha.

In stands belonging to the pine with spruce forest category, the herd index was 3–4 in eastern Lithuania and 4–5 in the central part of the country.

In the stands of mixed spruce/deciduous forests, the herd index reached 5–5.5. Wild boar density was reduced to 14–22/1000 ha (2–4 times) because of the general measures against ASF. However, it should be less—around 8–12/1000 ha—considering the carrying capacity of these territories, the herd index, and the risk of ASF.

In the stands of deciduous forests with spruce, the average herd index was 5; however, it was less (4–5) in northern Lithuania.

To ascertain the carrying capacity of territories, game managers should consider the following criteria:

1. Forest species composition and forest habitats in the whole territory settled by local wild boar populations.
2. The distribution of the food supply.
3. The volume of losses to the agricultural crops and forests caused by wild boars.

The long-term annual recruitment of the local wild boar population in Lithuania is 50–60%, while the annual recruitment coefficient is 1.0–1.5. If animal foraging in winter is insufficient, a harvest volume of 80–100% is allowed. Following variable winters with severe and warm periods, harvesting should be reduced by up to 60–70%, which will allow the annual recruitment coefficient to decrease to 0.6–0.7 despite the high reproductive potential of wild boar [115]. To avoid sudden changes in animal numbers, the sex ratio of males to females should be 1.5:1.0. With respect to hunting, the share of juveniles below

1 year should be 70–80%, 15–20% for sub-adults, and 5–10% for adult animals. We must consider not only the high reproductive potential of wild boar but also their biological plasticity [116,117], sociality [4,118], and adaptability; damage to agriculture and forestry; habitat suitability; and other ecological features.

Traditional methods for wild boar hunting include drive hunting, excluding localities of ASF outbreaks, and stand hunting; stalking and chase are also popular, depending on the season. In Lithuania, before the detection of ASF in 2014, the hunting of males and second-year juveniles was allowed from 1 May to 1 March, and the hunting season for females was from 1 October to 1 March. The number of harvested animals was similar over 5 years (Figure 2). A total of 10.3 thousand animals were harvested in 1998/1999, while 10.84 thousand animals were harvested in the 2003 hunting season. However, this number reached 35.56 in the 2017/2018 season, representing an increase of 231.5%. It would be unrealistic to hunt more than 200 percent of the population. What is the reason for such an increase? All harvested animals and their number during the last hunting season must be reported until 5 April annually [114]. However, we recognized that hunters do not consider recruitment of the local population and the region-specific herd index. Since 2015, wild boar hunting has been allowed year-round. Maintaining the minimum permissible density depends on the category of the forest under consideration, i.e., pure pine, pine with spruce, mixed spruce/deciduous, or deciduous with spruce forests, and its functional purposes; its value can fluctuate from 4 to more than 30.

Wild boars are not welcome in agroforests of less than 300–500 ha. Near the forest edges, less preferable agricultural crops are sowed, and cultural pastures are established. In addition, in regions with the most damaged agricultural crops, hunter lookout towers have been established for hunting and frightening away wild boar. Moreover, electric fencing is also used to frighten away wild boar. These means are most notably used by landowners.

5. Conclusions

There is marked evidence of the importance of wild boar in Lithuanian game management, forestry, and agriculture. Considering the damage caused by wild boar, it is necessary to maintain the permissible density of the local wild boar population. This density depends on the local conditions of the forests and surrounding areas, in addition to the functional purposes of the land.

The wild boar population should be managed territorially, quantitatively, and qualitatively considering the density of the local population; the carrying capacity of the territory under consideration and the possibility of it increasing; the age-sex structure of the wild boar population; the annual recruitment of the population; and agricultural crop losses in the territory. In particular, we should seek to maintain the permissible density of the local population. Herd index could be a useful parameter to manage populations. The omission of this index causes incompatibility between the actual number of wild boars and the number of harvested animals (i.e., harvest can reach 120% or more, even reaching 400–550% in some localities). The herd index in the different natural regions was determined as follows: 2–3 for pure pine forests in southern Lithuania and 3–4 for the same forests in western Lithuania; 3–4 for mixed coniferous forests in eastern Lithuania and 4–5 for the same forests in central Lithuania; 5–5.5 for mixed spruce/deciduous forests; and 5 for deciduous forests with spruce admixture, including a herd index of 4–5 for the same type of forests in northern Lithuania.

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References

1. Anon. *Sus scrofa* [ISC] (feral pig). In *Invasive Species Compendium. Detailed Coverage of Invasive Species Threatening Livelihoods and the Environment Worldwide*; CAB International Wallingford: Oxon, UK, 2010. Available online: https://www.cabi.org/isc/datasheet/119688#tosummaryOfInvasiveness (accessed on 23 August 2022).
2. Spencer, P.B.S.; Hampton, J.O. Illegal translocation and genetic structure of feral pigs in Western Australia. *J. Wildl. Manag.* **2005**, *69*, 377–384.
3. Prūsaitė, J. *Fauna of Lithuania. Mammals*; Mokslas: Vilnius, Lithuania, 1988; p. 293. ISBN 5420000547, 9785420000540. (In Lithuanian)
4. Belova, O. *Ethology of Game Animals*; Lututė: Kaunas, Lithuania, 2001; p. 280. ISBN 9955-452-48-X. (In Lithuanian with English Summary).
5. Bieber, C.; Ruf, T. Population dynamics in wild boar *Sus scrofa*: Ecology, elasticity of growth rate and implications for the management of pulsed resource consumers. *J. Appl. Ecol.* **2005**, *42*, 1203–1213.
6. Belova, O. Guidelines on Wild Boar (*Sus scrofa* L.) Population Qualitative, Quantitative and Territorial Management to Reduce Damage Caused to Agriculture and Forestry and to Prevent Contagious Diseases. In *Newest Recommendations for Agriculture and Forestry*; Semaškienė, R., Mikšys, V., Feiza, V., Kadžiulienė, Ž., Lazauskas, S., Ruzgas, V., Samuolienė, G., Eds.; LAMMC: Akademija, Lithuania, 2015; pp. 60–62.
7. Alіešiūnienė, A. Wild Boar (*Sus scrofa*) Feeding and Metastrongylus spp. Infection in the Feeding Points and the Main Epizootic Aspects. Master's Thesis, Lithuanian Veterinary Academy, Kaunas, Lithuania, 2010; p. 39.
8. Lange, M. *Alternative Control Strategies against ASF in Wild Boar Populations*; External Scientific Report; EFSA Supporting Publication: Parma, Italy, 2015; p. 29.
9. EFSA. Evaluation of possible mitigation measures to prevent introduction and spread of African swine fever virus through wild boar. Mitigation measures for African swine fever virus in wild boar. *EFSA J.* **2014**, *12*, 3616.
10. EFSA. African swine fever. EFSA Panel on Animal Health and Welfare (AHAW). *EFSA J.* **2015**, *13*, 4163. [CrossRef]
11. EFSA; SIGMA. *A Comprehensive Animal Disease Data Collection Approach. Harmonized Data Model for Domestic and Wild Animal Populations*; EFSA Supporting Publication: Parma, Italy, 2018; pp. 1–7. [CrossRef]
12. Risco, D.; Serrano, E.; Fernández-Llario, P.; Cuesta, J.M.; Gonçalves, P.; García Jiménez, W.L.; Martínez, R.; Cerrato, R.; Velarde, R.; Gómez, L.; et al. Severity of bovine tuberculosis is associated with co-infection with common pathogens in wild boar. *PLoS ONE* **2014**, *9*, e110123. [CrossRef]
13. Sorensen, A.; van Beest, F.M.; Brook, R.K. Impacts of wildlife baiting and supplemental feeding on infectious disease transmission risk—A synthesis of knowledge. *Prev. Vet. Med.* **2014**, *113*, 356–363.
14. Śmietanka, K.; Woźniakowski, G.; Kozak, E.; Niemczuk, K.; Frączyk, M.; Bocian, Ł.; Kowalczyk, A.; Pejsak, Z. African swine fever epidemic, Poland, 2014–2015. *Emerg. Infect. Dis.* **2016**, *22*, 1201–1207.
15. Oja, R.; Velström, K.; Moks, E.; Jokelainen, P.; Lassen, B. How does supplementary feeding affect endoparasite infection in wild boar? *Parasitol. Res.* **2017**, *116*, 2131–2137. [CrossRef]
16. Maslow, A.H. A Theory of Human Motivation. *Psychol. Rev.* **1943**, *50*, 370–396.
17. Maslow, A.H. *Motivation and Personality*; Harper and Row: New York, NY, USA, 1954.
18. Belova, O. The Main Behavioural Changes in the Herbivorous Game Animals in Managed Forests. *Balt. For.* **1999**, *5*, 64–68.
19. Belova, O.; Tarvydas, A.; Urbaitis, G. Wild boar distribution and habitat preference in Lithuania. In Proceedings of the 12th Intern. Symposium On Wild Boar and Other Suids, Lázně Bělohrad, Czech Republic, 4–7 September 2018; Kramer, J., Drimaj, J., Eds.; pp. 94–108.
20. Grodziński, W.; Maycock, L.; Weiner, J. (Eds.) *Forest Ecosystems in Industrial Regions*; Springer: Berlin/Heidelberg, Germany, 1984; pp. 241–268.
21. Schley, L.; Roper, T.J. Diet of wild boar *Sus scrofa* in Western Europe, with particular reference to consumption of agricultural crops. *Mammal. Rev.* **2003**, *33*, 43–56.
22. Schley, L.; Dufrêne, M.; Krier, A.; Frantz, A.C. Patterns of crop damage by wild boar (*Sus scrofa*) in Luxembourg over a 10-year period. *Eur. J. Wildl. Res.* **2008**, *54*, 589–599.
23. Baubet, E.; Bonenfant, C.; Brandt, S. Diet of the wild boar in the French Alps. *Galemys* **2004**, *16*, 99–111.
24. Cervo, I.B.; Guadagnin, D.L. Wild boar diet and its implications on agriculture and biodiversity in Brazilian forest–grassland ecoregions. *Anim. Biodivers. Conserv.* **2020**, *43*, 123–136. [CrossRef]

25. Amici, A.; Serrani, F.; Rossi, C.M.; Primi, R. Increase in crop damage caused by wild boar (*Sus scrofa* L.): The "refuge effect". *Agron. Sustain. Dev.* **2012**, *32*, 683–692. [CrossRef]
26. Hegel, C.G.Z.; Marini, M.Â. Impact of the wild boar, *Sus scrofa*, on a fragment of Brazilian Atlantic Forest. *Neotrop. Biol. Conserv.* **2013**, *8*, 17–24. [CrossRef]
27. Honda, T.; Sugita, M. Environmental factors affecting damage by wild boar (*Sus scrofa*) to rice fields in Yamanashi Prefecture, central Japan. *Mammal. Study* **2007**, *32*, 173–176.
28. Padaiga, V. *Biological Essentials of the Game Management*; Žiburio leidykla: Vilnius, Lithuania, 1996; p. 212. (In Lithuanian)
29. Ficetola, G.F.; Bonardi, A.; Mairota, P.; Leronni, V.; Padoa-Schioppa, E. Predicting wild boar damages to croplands in a mosaic of agricultural and natural areas. *Curr. Zool.* **2014**, *60*, 170–179. [CrossRef]
30. Fonseca, C. Winter habitat selection by wild boar *Sus scrofa* in south-eastern Poland. *Eur. J. Wildl. Res.* **2008**, *54*, 361–366. [CrossRef]
31. Belova, O. Long-term changes in the wild boar and population control. In *Newest Recommendations for Agriculture and Forestry*; LAMMC: Akademija, Lithuania, 2018; pp. 52–54.
32. Janulaitis, Z.; Padaiga, V. Effect of wild boar on the forest biogeocoenosis. In Proceedings of the Scientific Conference Wildlife Management in Problem-Oriented Forestry, Kaunas-Girionys, Lithuania, November 1983; pp. 45–46. (In Russian).
33. Mori, E.; Ferretti, F.; Lagrotteria, A.; La Greca, L.; Solano, E.; Fattorini, N. Impact of wild boar rooting on small forest-dwelling rodents. *Ecol. Res.* **2020**, *35*, 675–681. [CrossRef]
34. Torre, I.; Cahill, S.; Grajera, J.; Raspall, A.; Vilella, M. Small mammal sampling incidents related to wild boar (*Sus scrofa*) in natural peri–urban areas. *Anim. Biodivers. Conserv.* **2022**, *45*, 33–42. [CrossRef]
35. Lacki, M.J.; Lancia, R.A. Changes in Soil Properties of Forests Rooted by Wild Boar. *Proc. Annu. Cont. Southeast. Assoc. Fish Wildl. Agencies* **1983**, *37*, 228–236.
36. Wirthner, S. The Role of Wild Boar (*Sus scrofa* L.) Rooting in Forest Ecosystems in Switzerland. Ph.D. Thesis, ETH Zurich, Zurich, Switzerland, 2011. [CrossRef]
37. Wirthner, S.; Schütz, M.; Page-Dumroese, D.S.; Busse, M.D.; Kirchner, J.W.; Risch, A.C. Do changes in soil properties after rooting by wild boars (*Sus scrofa*) affect understory vegetation in Swiss hardwood forests? *Can. J. For. Res.* **2021**, *42*, 585–592. [CrossRef]
38. Risch, A.C.; Wirthner, S.; Busse, M.D.; Page-Dumroese, D.S.; Schütz, M. Grubbing by wild boars (*Sus scrofa* L.) and its impact on hardwood forest soil carbon dioxide emissions in Switzerland. *Oecologia* **2010**, *164*, 773–784. [CrossRef]
39. Haaverstad, O.; Hjeljord, O.; Wam, H.K. Wild boar rooting in a northern coniferous forest—Minor silviculture impact. *Scand. J. For. Res.* **2014**, *29*, 90–95. [CrossRef]
40. Skoták, V.; Drimaj, J.; Kamler, J. Evaluation of damage to forest tree plantations by wild boar in the Czech Republic. *Hum.-Wildl. Interact.* **2021**, *15*, 66–73. [CrossRef]
41. Zeman, J.; Hrbek, J.; Drimaj, J.; Plhal, R.; Kamler, J.; Adamec, Z.; Heroldova, M. Wild Boar Impact to the Natural Regeneration of Oak and Acorn Importance in its Diet. *Acta Univ. Agric. Et Silvic. Mendel. Brun.* **2016**, *64*, 579–585.
42. Sims, N.K.E. The ecological impacts of wild boar rooting in East Sussex. Ph.D. Thesis, School of Biological Sciences University of Sussex, Falmer, UK, 2005; p. 276. Available online: http://www.britishwildboar.org.uk/The%20ecological%20impacts%20of%20wild%20boar%20rooting%20in%20East%20Sussex.pdf (accessed on 16 March 2022).
43. Fern, M.P.; Armstrong, J.B.; Barlow, R.J.; Kush, J.S. Ecological factors influencing wild pig damage to planted pine and hardwood seedlings. *Hum.-Wildl. Interact.* **2020**, *14*, 228–238.
44. Bratton, S. The effect of the European wild boar (*Sus scrofa*) on the high-elevation vernal flora in Great Smoky Mountains National Park. *Bull. Torrey Bot. Club* **1974**, *101*, 198–206. [CrossRef]
45. Howe, T.; Singer, F.J.; Ackerman, B.B. Forage relationships of European wild boar invading northern hardwood forest. *J. Wildl. Manag.* **1981**, *45*, 748–754. [CrossRef]
46. Massei, G.; Genov, P.V. The environmental impact of wild boar. *Galemys* **2004**, *16*, 135–145.
47. Janulaitis, Z.; Padaiga, V. Some fundamentals of the damage caused by wild boar to agricultural crops. In Proceedings of the Scientific Conference Wildlife Management in the Problem-Oriented Forestry, Kaunas-Girionys, Lithuania, November 1983; pp. 43–44.
48. Gerard, J.F.; Cargnelutti, B.; Spitz, F.; Valet, G.; Sardin, T. Habitat use of wild boar in a French agroecosystem from late winter to early summer. *Acta Theriol.* **1991**, *36*, 119–129.
49. Genov, P. Significance of natural biocenoses and agrocenoses as the source of food for the wild boar (*Sus scrofa* L.). *Ekol. Pol.* **1981**, *29*, 117–136.
50. Schön, T. The cost of having wild boar: Damage to agriculture in South-Southeast Sweden. Master's Thesis, Swedish University of Agricultural Sciences, Umeå, Sweden, 2013; p. 40.
51. Engeman, R.M. Economic Considerations of Damage Assessment. In *Human Conflicts with Wildlife: Economic Considerations*; Volume 4, pp. 36–41. Available online: https://digitalcommons.unl.edu/nwrchumanconflicts/4 (accessed on 14 June 2021).
52. Fern, M.; Barlow, R.; Slootmaker, C.; Kush, J.; Shwiff, S.; Teeter, L.; Armstrong, J. Economic Estimates of Wild Hog (*Sus scrofa*) Damage and Control Among Young Forest Plantations in Alabama. *Small-Scale For.* **2021**, *20*, 503–516. [CrossRef]
53. Kotulski, Y.; König, A. Conflicts, crises and challenges: Wild boar in the Berlin city—A social empirical and statistical survey. *Nat. Croat. Zagreb* **2008**, *17*, 233–246.

54. Fattorini, N.; Ferretti, F. Estimating wild boar density and rooting activity in a Mediterranean protected area. *Mamm. Biol.* **2020**, *100*, 241–251. [CrossRef]
55. Statistical Database SBS. 2021. Available online: https://www.statistikdatabasen.scb.se/pxweb/en/ssd/ (accessed on 20 April 2021).
56. Boyce, C.M.; VerCauteren, K.C.; Beasley, J.C. Timing and extent of crop damage by wild pigs (*Sus scrofa* Linnaeus) to corn and peanut fields. *Crop Prot.* **2020**, *133*, 105–131. [CrossRef]
57. Lombardini, M.; Meriggi, A.; Fozzi, A. Factors influencing wild boar damage to agricultural crops in Sardinia (Italy). *Curr. Zool.* **2017**, *63*, 507–514. [CrossRef]
58. Schlageter, A. Preventing Wild Boar *Sus scrofa* Damage–Considerations for Wild Boar Management in Highly Fragmented Agroecosystems. Ph.D. Thesis, University of Basel, Basel, Switzerland, 2015; p. 97.
59. Bergman, T.E. *An Investigation of Human-Wild Boar Conflict—The Perceived Need for Economical Compensation among Farmers Due to Crop Damage Caused by Wild Boars—A Case Study in Arboga, Sweden*; Department of Social and Economic Geography, Arbetsrapporter, Uppsala University: Uppsala, Sweden, 2014; p. 30.
60. Anon. *On the Methodology for Assessment of Damage Caused by Game Animals to Agricultural Crops, Livestock and Forest*; Consolidated Version from 28-09-2021. Code Posted: Official Gazette, 2002, No. 97-4303, id 102301MISAK0486/359; New Edition: Since 2015-01-24: No. D1-69/3D-36, 2015-01-22, publ. TAR 2015-01-23, id 2015-01000; The Ministry of Environment and The Ministry of Agriculture of the Republic of Lithuania: Vilnius, Lithuania, 2018. Available online: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.187999/PqnIxigXak (accessed on 23 August 2022).
61. West, B.C.; Cooper, A.L.; Armstrong, J.B. Managing wild pigs: A technical guide. *Hum. -Wildl. Interact. Monogr.* **2009**, *1*, 55.
62. Mitchell, B.; Balogh, S. *Monitoring Techniques for Vertebrate Pests. Feral Pigs*; NSW Department of Primary Industries, Bureau of Rural Sciences: Canberra, Australia; Natural Heritage Trust: Canberra, Australia, 2007; p. 32.
63. Wilson, C.J. *Feral Wild Boar in England. Status, Impact and Management*; A Report on behalf of Defra European Wildlife Division; Defra, RDS National Wildlife Management Team: Exeter, UK, 2005; p. 56.
64. Putman, R.; Apollonio, M. *Behaviour and Management of European Ungulates*; Whittles Publishing: Scotland, UK, 2014; p. 304.
65. König, H.J.; Ceauşu, S.; Reed, M.; Kendall, H.; Hemminger, K.; Reinke, H.; Ostermann-Miyashita, E.-F.; Wenz, E.; Eufemia, L.; Hermanns, T.; et al. Integrated framework for stakeholder participation: Methods and tools for identifying and addressing human–wildlife conflicts. *Conserv. Sci. Pract.* **2021**, *3*, e399. [CrossRef]
66. Michez, A.; Morelle, K.; Lehaire, F.; Widar, J.; Authelet, M.; Vermeulen, C.; Lejeune, P. Use of unmanned aerial system to assess wildlife (*Sus scrofa*) damage to crops (*Zea mays*). *J. Unmanned Veh. Syst.* **2016**, *4*, 266–275. [CrossRef]
67. Rutten, A.; Casaer, J.; Vogels, M.; Addink, E.A.; Borre, J.V.; Leirs, H. Assessing agricultural damage by wild boar using drones: Wild Boar Damage Assessment. *Wildl. Soc. Bull.* **2018**, *42*, 568–576. [CrossRef]
68. Kim, M.; Chung, O.-S.; Lee, J.-K.A. Manual for Monitoring Wild Boars (*Sus scrofa*) Using Thermal Infrared Cameras Mounted on an Unmanned Aerial Vehicle (UAV). *Remote Sens.* **2021**, *13*, 4141. [CrossRef]
69. Rutten, A.; Casaer, J.; Onkelinx, T.; De Smet, L.; Witters, N.; Huysentruyt, H.L. Using an online survey to assess the spatial distribution of wild boar (*Sus scrofa* L.) crop damage and factors influencing this distribution and severity in Limburg province, Belgium. *Belg. J. Zool.* **2019**, *149*, 1–13. [CrossRef]
70. Belova, O. Wildlife Census Methods: Reliability and Application. In *Wildlife Census Methods: Reliability and Application*; Žemaitija National Park: Plateliai, Lithuania, 2010; pp. 21–25.
71. ENETWILD Consortium; Grignolio, S.; Apollonio, M.; Brivio, F.; Vicente, J.; Acevedo, P.; Palencia, P.; Petrovic, K.; Keuling, O. *Guidance on Estimation of Abundance and Density Data of Wild Ruminant Population: Methods, Challenges, possibilities*; EFSA Supporting Publication: Parma, Italy, 2020; p. 54. [CrossRef]
72. ENETWILD-Consortium; Acevedo, P.; Aleksovski, V.; Apollonio, M.; Berdión, O.; Blanco-Aguiar, J.A.; del Rio, L.; Ertürk, A.; Fajdiga, L.; Escribano, F.; et al. *Wild Boar Density Data Generated by Camera Trapping in Nineteen European Areas*; EFSA Supporting Publication: Parma, Italy, 2022; p. 21. [CrossRef]
73. Keeping, D.; Pelletier, R. Animal Density and Track Counts: Understanding the Nature of Observations Based on Animal Movements. *PLoS ONE* **2014**, *9*, e96598. [CrossRef]
74. Kie, J.G. *Performance in Wild Ungulates: Measuring Population Density and Condition of Individuals*; Gen. Tech. Rep. PSW-106; Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture: Berkeley, CA, USA, 1988; p. 17.
75. Gilbert, S.L.; Hundertmark, K.J.; Lindberg, M.; Person, D.; Boyce, M.S. The Importance of Environmental Variability and Transient Population Dynamics for a Northern Ungulate. *Front. Ecol. Evol.* **2020**, *8*, 531027. [CrossRef]
76. Chauvenet, A.L.M.; Gill, R.M.A.; Smith, G.C.; Ward, A.I.; Massei, G. Quantifying the bias in density estimated from distance sampling and camera trapping of unmarked individuals. *Ecol. Model.* **2017**, *350*, 79–86. [CrossRef]
77. Santini, L.; Benítez-López, A.; Dormann, C.F.; Huijbregts, M.A.J. Population density estimates for terrestrial mammal species. *Glob. Ecol. Biogeogr.* **2022**, *3*, 978–994. [CrossRef]
78. Focardi, S.; La Morgia, V.; Montanaro, P.; Riga, F.; Calabrese, A.; Ronchi, F.; Aragno, P.; Scacco, M.; Calmanti, R.; Franzetti, B. Reliable estimates of wild boar populations by nocturnal distance sampling. *Wildlife Biol.* **2020**, *2020*, 1–15. [CrossRef]
79. D'Eon, R.G.; Wilson, S.F.; Hamilton, D. *Ground-Based Inventory Methods for Ungulate Snow-Track Surveys. Standards for Components of British Columbia's Biodiversity*; No. 33a; Resources Information Standards Committee: Victoria, BC, Canada, 2006.

80. Bobek, B.; Merta, D.; Furtek, J. Use of a Line Intercept Snow Track Index and Plot Sampling for Estimating Densities of Wild Boar (*Sus scrofa*) in Southwestern Poland. *Wildl. Biol. Pract.* **2014**, *10*, 7–16. [CrossRef]
81. Dzięciolowski, R. Estimating ungulate numbers in a forest by track counts. *Acta Teriol.* **1976**, *21*, 217–222.
82. Malakauskas, A.; Karvelienė, B. Dangerous pig diseases: Classical and African swine fever. *Mano Ūkis* **2010**, *4*, 77–79.
83. Anon. *On the Approval of Permissible Quotas of Ungulate Density in Forests of the Republic of Lithuania*; The Order No. 86 15/05/1995; TAR; Parliament of the Republic of Lithuania: Vilnius, Lithuania. (In Lithuanian)
84. Anon. *On the Approval of the Preparation, Submission, and Approval of the Schedule of Procedures of Wildlife Management Plans*; The Order No. D1-162 21/03/2005. Available online: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.252979?jfwid=-11tbwd089g (accessed on 23 August 2022). (In Lithuanian)
85. Padaiga, V. Project of the Programme for the Integration and Reasoned Management of the Forest and Game Management. Vilnius, Lithuania, 1994; p. 84. (In Lithuanian)
86. Bennett, L.J.; English, P.F.; McCain, R. A study of deer populations by use of pellet-group counts. *J. Wildl. Manag.* **1940**, *4*, 398–403.
87. Eberhardt, L.; van Etten, R.C. Evaluation of the pellet group count as a deer census method. *J. Wildl. Manag.* **1956**, *20*, 70–74.
88. Neff, D.J. The pellet-group count technique for big game trend, census, and distribution: A review. *J. Wildl. Manag.* **1968**, *32*, 597–614.
89. Acevedo, P.; Vicente, J.; Höfle, U.; Cassinello, J.; Ruiz-Fons, F.; Gortazar, C. Estimation of European wild boar relative abundance and aggregation: A novel method in epidemiological risk assessment. *Epidemiol. Infect.* **2007**, *135*, 519–527. [CrossRef]
90. Plhal, R.; Kamler, J.; Homolka, M. Faecal pellet group counting as a promising method of wild boar population density estimation. *Acta Theriol.* **2014**, *59*, 561–569. [CrossRef]
91. Belova, O. Delineation of the Territory of Lithuania for the Hares Leporidae: Estimation of the Habitat Suitability. *Balt For.* **1999**, *5*, 49–59.
92. Janulaitis, Z. Wild boar foraging in the agricultural landscape of Lithuanian SSR. In Proceedings of the Scientific Conference Wildlife Management in the Problem-Oriented Forestry, Kaunas-Girionys, Lithuania, November 1983; pp. 41–42.
93. Merta, D.; Mocała, P.; Pomykacz, M.; Frąckowiak, W. Autumn-winter diet and fat reserves of wild boars (*Sus scrofa*) inhabiting forest and forest-farmland environment in south-western Poland. *Folia Zool.* **2014**, *63*, 95–102. [CrossRef]
94. Janulaitis, Z.; Padaiga, V. Control of wild boar population in Lithuanian SSR. In *LMŪMTI Mokslo Darbai*; LMŪMTI: Vilnius, Lithuania, 1987; Volume 23, pp. 163–178. (In Lithuanian)
95. StatSoft. *Statistica 8.0, an Advanced Analytics Software Package*, StatSoft Inc.: Tulsa, OK, USA, 2008. Available online: www.statsoft.com(accessed on 27 March 2018).
96. Belova, O. ASF management strategy in wild boar population. In *Newest Recommendations for Agriculture and Forestry*; Semaškienė, R., Mikšys, V., Feiza, V., Kadžiulienė, Ž., Lazauskas, S., Ruzgas, V., Samuolienė, G., Eds.; LAMMC: Akademija, Lithuania, 2020; Volume 10, pp. 59–60.
97. Belova, O.; Gedminas, A.; Urbaitis, G. GPS technology to track wild boars in Lithuania: The tool for research and management. In Proceedings of the 34 IUGB Congress, Kaunas, Lithuania, 26–30 August 2019; pp. 37–38.
98. Piekarczyk, P.; Tajchman, K.; Belova, O.; Wójcik, M. Crop damage by wild boar (*Sus scrofa* L.) depending on the crop composition in Central-Eastern Poland. *Balt* **2021**, *27*, 86–96. [CrossRef]
99. Vercauteren, K.C.; Dolbeer, R.A.; Gese, E.M. Identification and Management of Wildlife Damage. In *The Wildlife Techniques Manual*; Silvy, N.J., Ed.; Paper 1204; Johns Hopkins University Press: Baltimore, MD, USA; USDA National Wildlife Research Center–Staff Publications: Fort Collins, CO, USA, 2010; pp. 232–269.
100. Anon. *On the Approval of the Methodology on Estimation of Damage Caused by Wildlife to Crops, Facilities, and Forests*; The Order No. 486/359, No. D1-69/3D-36, 2015-01-2; The Parliament of the Republic of Lithuania: Vilnius, Lithuania, 2002. Available online: https://www.e-tar.lt/portal/legalAct.html?documentId=73ea58b0a2f611e4a82d9548fb36f682 (accessed on 23 August 2022)
101. Baleišis, R.; Bluzma, P.; Balčiauskas, L. *Ungulates of Lithuania*; Mokslas: Vilnius, Lithuania, 1987; p. 200. (In Lithuanian)
102. Kairiūkštis, L.; Padaiga, V. Peculiarities of wildlife management in the problem-oriented forestry. In Proceedings of the Scientific Conference Wildlife Management in the Problem-Oriented Forestry, Kaunas-Girionys, Lithuania, November 1983; pp. 45–46.
103. Reimoser, F.; Reimoser, S. Ungulates and their management in Austria. In *European Ungulates and their Management in the 21st Century*, 1st ed.; Apollonio, M., Andersen, R., Putman, R., Eds.; Cambridge University Press: Cambridge, UK, 2010; Volume 16, pp. 338–356. ISBN 10 0521760615.
104. Magnusson, M. Population and management models for the Swedish wild boar (*Sus scrofa*). Master's Thesis, Swedish University of Agricultural Sciences Grimsö Wildlife Research Station, Uppsala, Sweden, 2010; p. 26.
105. Keuling, O. Managing Wild Boar–Considerations for Wild Boar Management Based on Game Biology Data. Ph.D. Thesis, Dresden University of Technology, Dresden, Germany, 2009; p. 91.
106. Boitani, L.; Mattei, L.; Nonis, D.; Corsi, F. Spatial and activity patterns of wild boar in Tuscany, Italy. *J. Mammal.* **1994**, *75*, 600–612.
107. Lemel, J.; Truvé, J.; Söderberg, B. Variation in ranging and activity behaviour of European wild boar *Sus scrofa* in Sweden. *Wildl. Biol.* **2003**, *9*, 29–36.
108. Vild, O.; Hédl, R.; Kopecký, M.; Szabó, P.; Suchánková, S.; Zouha, V. The paradox of long-term ungulate impact: Increase of plant species richness in a temperate forest. *Appl. Veg. Sci.* **2017**, *20*, 282–292. [CrossRef]

109. Schmidt, R.H.; Timm, R.M. Vertebrate impacts on oak regeneration in California: A review of management options. In Proceedings of the 10th Great Plains Wildlife Damage Conference, Lincoln, Nebraska, 15–18 April 1991; Hygnstrom, S.E., Case, R.M., Johnson, R.J., Eds.; University of Nebraska: Lincoln, Nebraska, 1991; pp. 134–144.
110. Rutten, A.; Casaer, J.; Strubbe, D.; Leirs, H. Agricultural and landscape factors related to increasing wild boar agricultural damage in a highly anthropogenic landscape. *Wildlife Biol.* **2020**, *2020*, 1–11. [CrossRef]
111. Cappa, F.; Bani, L.; Meriggi, A. Factors affecting the crop damage by wild boar (*Sus scrofa*) and effects of population control in the Ticino and Lake Maggiore Park (North-western Italy). *Mamm Biol.* **2021**, *101*, 451–463. [CrossRef]
112. Ballari, S.A.; Barrios-García, M.N. A review of wild boar *Sus scrofa* diet and factors affecting food selection in native and introduced ranges. *Mamm. Rev.* **2013**, *44*, 124–134. [CrossRef]
113. Rowcliffe, J.M.; Field, J.; Turvey, T.; Carbone, C. Estimating animal density using camera traps without the need for individual recognition. *J. Appl. Ecol.* **2008**, *45*, 1228–1236. [CrossRef]
114. Anon. *On the Confirmation of the Rules of Hunting in the Republic of Lithuania*, The Order No. 258; Consolidated version No. D1-610 Official Gazette Valstybės žinios; TAR: Vilnius, Lithuania, 2019; p. 16390. Available online: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.104124/asr (accessed on 23 August 2022).
115. Servanty, S.; Gaillard, J.-M.; Ronchi, F.; Focardi, S.; Baubet, E.; Gimenez, O. Influence of harvesting pressure on demographic tactics: Implications for wildlife management. *J. Appl. Ecol.* **2011**, *48*, 835–843. [CrossRef]
116. Podgórski, T.; Baś, G.; Jędrzejewska, B.; Sönnichsen, L.; Śnieżko, S.; Jędrzejewski, W.; Okarma, H. Spatiotemporal behavioral plasticity of wild boar (*Sus scrofa*) under contrasting conditions of human pressure: Primeval forest and metropolitan area. *J. Mammal.* **2013**, *94*, 109–119. [CrossRef]
117. Gordigiani, L.; Viviano, A.; Brivio, F.; Grignolio, S.; Lazzeri, L.; Marcon, A.; Mori, E. Carried away by a moonlight shadow: Activity of wild boar in relation to nocturnal light intensity. *Mamm. Res.* **2022**, *67*, 39–49. [CrossRef]
118. Maselli, V.; Rippa, D.; Russo, G.; Ligrone, R.; Soppelsa, O.; D'Aniello, B.; Raia, P.; Fulgione, D. Wild boars' social structure in the Mediterranean habitat. *Ital. J. Zool.* **2014**, *81*, 610–617. [CrossRef]