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Evaluating effects of preventive actions to reduce wild boar damage in the agricultural landscape

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Abstract

The population of wild boar (*Sus scrofa*) is increasing dramatically in Sweden and all over Europe and cause an extensive amount of damage in agricultural landscapes. The economic losses for farmers due to damages are leading to intense conflicts between different stakeholders, particularly hunters and farmers. Several widely used management actions have the potential to limit wild boar damages. The aim of the study is to evaluate and test the effect of three different mitigation actions to limit the level of wild boar damages on three agricultural crops (wheat *Triticum aestivum*, mowing (grass and herb species) and other cereal (triticale *Triticale rimpaui* and barley *Hordeum vulgare*)). All fields were censused for damages at four different occasions from May to August 2018 using line transects. The study areas (Björkvik, Boo Egendom, Bornsjön and Ökna-Nynäs) are located in the southeast part of southern Sweden. Preventive actions included electric fencing, disturbance activities and divisionary feeding. Landowners and wildlife managers at the estates documented their disturbance activities and information about feeding. Fences were constructed by employed staff and volunteers within the research group, in the middle of July and removed 2 - 4 weeks later depending on the time of harvest. There was no significant effect of electric fencing to reduce damage in this study. However, the sample size was small, and the summer of 2018 was exceptionally dry and warm, thus, the results may somewhat be due to a failed experimental setting. Disturbance activities, distance to feeding stations and the density of these had a significant impact on the level of crop damage, even if the differences are relatively small. In conclusion, the prevention actions should be used in a combination of actions instead of separately to guarantee an efficient result.

Keywords: wild boar, *Sus scrofa*, wildlife damage, agricultural damage, crop damage, preventive actions, fencing, protective hunting, directed feeding

Sammanfattning

Vildsvinspopulationen i Sverige och övriga Europa ökar dramatiskt och orsakar omfattande skador i jordbrukslandskapet. De ekonomiska förlusterna till följd av skadorna leder till intensiva konflikter mellan olika intressegrupper, framför allt jägare och lantbrukare. Det finns många skyddsåtgärder som kan användas för att potentiellt minska mängden skador gjorda av vildsvin. Syftet med denna studie är att utvärdera effekten av tre olika skyddsåtgärder som används för att reducera skador på jordbruksgrödor. Studieområdena (Björkvik, Boo Egendom, Bornsjön och Ökna-Nynäs) ligger i sydöstra Sverige och fälten inventerades fyra gånger vardera, under Maj-Augusti. Endast fält sådda med vete, korn, rågvete och vall inventerades med linjetransekter. Störningsaktiviteter och information om utfodring samlades in från markägare och viltförvaltare på egendomarna. Stängslet sattes upp av anställda och volontärer inom vildsvinsprojektet på Grimsö i mitten av juli och plockades ner 2 – 4 veckor senare beroende på tiden för skörd på de olika egendomarna. Jag fann ingen statistiskt säkerställd effekt av stängsling på skadenivå, detta kan dels beror på en liten provstorlek och dels på mänskliga misstag och naturliga omständigheter (extremt varm och torr sommar). Överlag hade störning, avstånd till foderplatser och densiteten av dessa en signifikant effekt på skadenivån, även om skillnaderna var relativt små. Som slutsats anser jag att skyddsåtgärderna bör användas i kombination istället för som separata åtgärder för att garantera ett så effektivt resultat som möjligt.

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1. Introduction

The interaction between the presence and abundance of wildlife, and agricultural activities are complicated, and this interaction can be both negative and positive (Gren et al., 2018; van Wenum et al., 2004). The most widespread and common conflict between human and wild animals is damage made by animals on agricultural crops (Bleier et al., 2012; Hygnstrom et al., 1994; Schley and Roper, 2003). In Africa, elephants (*Loxodonta*) are a major problem as they raid crops (Walker, 2012), while on other continents, damage are typically caused by the ungulate species (Bleier et al., 2012; Gorynska, 1981; Trdan and Vidrih, 2008), such as grazing or lying damage by red deer (*Cervus elaphus*) (Trdan and Vidrih, 2008), browsing damage on safflower (*Carthamus tinctorius*) and sunflower (*Helianthus annus*) by roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*) and mule deer (*Odocoileus hemionus*) (Haney and Conover, 2013; Kamler et al., 2009) or rooting damage by wild boar (*Sus scrofa*) (Wilson, 2004).

In the management of wildlife, more than one kind of stakeholder (farmers, hunters, foresters, house owners and tourists) has an interest and thus, different aims with the management (Carpender et al., 2000). The impacts of wildlife can be both positive or negative at the same time, as different stakeholders have varied interests and are affected by the wildlife populations in several ways (Carpender et al., 2000; Gren et al., 2018; Messmer, 2000). Some stakeholders may benefit from a wildlife population while others are suffering from it (Carpender et al., 2000; Milner et al., 2014). Hunters in areas of high-density game populations can be called beneficiaries, as they are able to harvest more animals, while farmers are experiencing extensive damage and economic loss because of the same populations (Carpender et al., 2000; Gren et al., 2018). Economics and social conflicts play an important role in wildlife management and in limiting wildlife populations (Brown and Decker, 1979). In the case of wild boar, multiple interest groups and NGO's expresses opinions and argue that the population of wild boar has exceeded the acceptable size (SOU, 2014:54). A considerable amount of the hunters in wild boar populated areas expresses a wish to limit the population growth and the distribution of wild boars (SOU, 2014:54).

Wild boar cause a variety of damage, such as rooting, resulting in considerable destruction of crops, grasslands and gardens (Barrett and Birmingham, 1994). The level of crop damage has increased dramatically all over Europe because of the ever-growing population of wild boar and it is causing an increased amount of social conflicts (Amici et al., 2012; Geisser and Reyer, 2005; Schlageter and Haag-Wackernagel, 2012). The annual harvest of wild boar and the total amount of damage per year have steadily increased, suggesting that the amount of damage is related to the population density of wild boar (Schley et al., 2008; Thinley et al., 2017). In many regions, the situation is uncontrollable, and the management goal is because of this to reduce the wild boar population and minimize damages (Naturvårdsverket, 2013). Hunters in Sweden, and in the rest of Europe agree that a reduction of the wild boar population is necessary (Keuling et al., 2016).

The consequence of a growing population of wild boar is not only the extended amount of damage but also an increasing number of traffic collisions involving wild boar. The hunting bag has also increased quite rapidly during the last 9 years, which partly could be used to reflect the actual development of the population (Agetsuma, 2018; Keuling et al., 2016) (fig. 1).

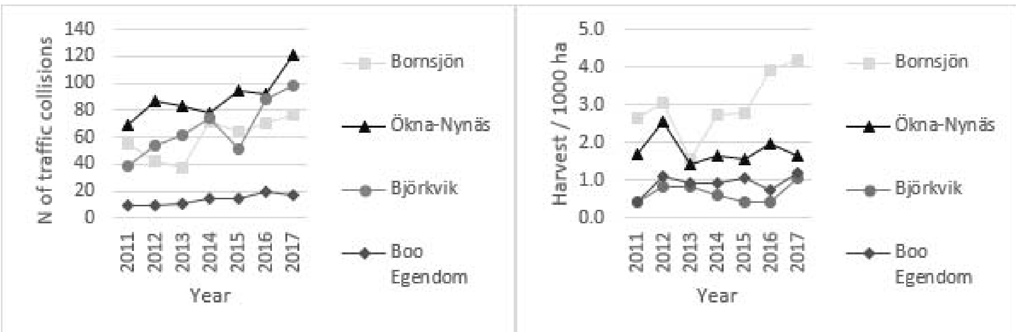

Figure 1. Development of traffic accidents (left) and harvest of wild boar per 1000 ha (right) during 2011 - 2017 in four game management areas in which the study areas are located (Viltdata 2018).

The damage to agricultural crops is the most significant problem related to wild boar and they cause damage for several million Euros every year (Amici et al., 2012; Frackowiak et al., 2013), and the costs of damage often show reginal dispersion (Gren et al., 2018). In the county of Södermanland in Sweden, economic losses due to damage by wild boar on crops was in 2009 estimated to about 17 million SEK (SOU, 2014:54). Thus, damages on farmland during the vegetation season (May to August), are of great economic importance (Andrzejewski and Jezierski, 1978; Frackowiak et al., 2013; Keuling et al., 2009; Mackin, 1970). The damage levels generally peak in July-August when the crops are ripe, and then decreases again before harvest (Frackowiak et al., 2013; Lemel, 1999; Lemel and Truvé, 2008; Mackin, 1970). On the other hand, damage to grassland occurs almost exclusively during the rest of the year, mostly during winter and early spring (Schley et al., 2008).

Damages on farmland cannot be avoided entirely, but it can be greatly reduced (Gorynska, 1981). The problem has different solutions and can normally be divided into three categories: (1) manage the animals or its habitat, (2) modify human activities in the concerned areas, and (3) increase human tolerance (Wagner et al., 1997).

Many prevention methods have been tried with the aim to lower damages on farmland (Lemel, 1999; Vidrih and Trdan, 2008). Generally, one or several of the following damage preventive actions are used on agricultural fields: (1) hunting, (2) scaring, (3) feeding (i.e. supplementary feeding used to mitigate damage to human activities) and (4) fencing (Lemel, 1999; Novosel et al., 2012). All of these have the potential to lower damages through different kinds of interventions that affect populations of wild boar in various ways.

The goal of protective hunting is to limit the amount and frequency of damage made on agricultural crops (Geisser and Reyer, 2004; Keuling et al., 2016; Lemel and Truvé, 2008). Protective hunting decreases the number of wild boar in the target area while the action also scare animals away (Lemel and Truvé, 2008). Animals tend to avoid habitats and make small changes in their activity pattern to adapt to where it is high risk of encountering humans (Lemel, 1999; Ohashi et al., 2014). Direct disturbance from humans, such as shooting and chasing, is known to change the behaviour and activity pattern of wild boar (Maillard and Fournier, 2014; Ohashi et al., 2014). This flexibility in behavioural traits might influence the result of efforts aimed at preventing their damage on agricultural crops as they are able to change their diurnal activity patterns, and quickly to get used to different scaring methods, making them inefficient and unusable for longer time periods (Ohashi et al., 2014).

A variation of repellents and deterrents are available but the efficiency of these vary (Lemel, 1999; Schlageter and Haag-Wackernagel, 2012). The fear of humans can keep wild boar away from a field through screaming and the usage of scent and placing it strategically in the target area (Lemel, 1999; Schlageter and Haag-Wackernagel, 2012). Wolf (*Canis lupus*) scent has also been used, although this may be inefficient in countries or in some parts of countries because of the wild boars inexperience with the scent of the predator (Lemel, 1999). Wild boar warning sounds is a very effective method that has been used, although, the efficiency usually do not last more than a few nights as the wild boar learns that there are no real danger or consequences in connection to the warning sound (Lemel, 1999).

Feeding can be used to protect the crop more permanently than scaring, and it can be executed in multiple ways: (1) as supplementary feeding with silage (2) in automated feeders that distribute peas or maize etc., and (3) fields sown with preferred crops to benefit game (Lemel, 1999). The ambition with diversionary feeding (also known as directed or dissuasive feeding) is to redirect the animals away from sensitive areas and occupy them for a long period of time (Cellina, 2008; Lemel, 1999; Novosel et al., 2012) and it could therefore be advantageous to distribute it more often or to spread the food over a larger area to increase the time spent foraging (SOU, 2014:54).

Feeding for wild animals is provided for different purposes, and the type of food provided depends on the target species (Cellina, 2008; Lemel, 1999). Mainly, maize, wheat and peas are used in automated feeders, which are supposed to attract wild boars and keeping them in the woodland (Cellina, 2008). Supplemental food constitutes an important part of the wild boar diet throughout the whole year (Cellina, 2008) and up to 69,6 % of the consumed food during the year comes from feeding stations (Lemel, 1999). Although, in Luxembourg during July-September, this part is replaced by an increased intake of agricultural crops (Cellina, 2008). Diversionary feeding is suggested as an efficient way to keep animals to stay in the forest, except when the fields offer a more attractive source of food (Lemel, 1999; Pascual-Rico et al., 2018). The efficiency of the diversionary feeding is related to the distance from feeding station to vulnerable vegetation, the type of food provided and during which parts of the year it is active (Milner et al., 2014). The distance to cover in the environment is a factor that are influence the spatial pattern of wild boar movement and therefore also damage in agricultural land (Calenge et al., 2004; Lemel, 1999; Thurfjell et al., 2009).

Electric fencing is recommended by many, as the only way to exclude wild boar during the more vulnerable "milk stage" of crop development, when it appears to be most attractive (Lemel, 1999). Fences are used to control movements of animals and to reduce damage and has been constructed in a variety of ways (Novosel et al., 2012; VerCauteren et al., 2006; Vidrih and Trdan, 2008). Some fences are more permanent and can, with regular maintenance, provide protection for over 30 years (VerCauteren et al., 2006). The most common practice is to use temporary fence designs, which are typically less expensive than permanent fences (VerCauteren et al., 2006; Vidrih and Trdan, 2008). Fencing is generally expensive and therefore a number of points should be considered before construction. It should be analysed if fencing is cost-beneficial and if crops has a high enough market value to be worth protecting (Craven and Hygnstrom, 1994). Temporary fences are easy to construct and more cost effective than permanent, but these require weekly inspection and maintenance (Craven and Hygnstrom, 1994).

The aim of this study is to evaluate and test the effect of three different mitigation actions (fencing, disturbance and directed feeding) to limit the level of wild boar damages on agricultural crops. Based on previous findings one can assume that when done right, all three actions should effectively deter wild boar from target fields, at least during a shorter period. I thus predict that (1) disturbance will decrease the damage on the target fields where it is performed, while it may result in an increased damage level on untreated fields as the wild boar try to avoid the other areas. Although, it is known that scaring and disturbance only has a temporary effect and is most effective when used together with another action (Lemel, 1999). An electric fence will be installed and according to precious research, I predict that (2) it will significantly lower the damage within fenced fields compared to unfenced control fields. Finally, I predict that (3) damages will decrease with greater distances to a feeding stations (4) higher densities of feeding stations leads to less crop damage.

2. Wild boar ecology

The wild boar is one of the most widely distributed mammals and are now present on all continents except Antarctica (fig. 2) (Long, 2003; Massei and Genov, 2004). The reproductive output of the wild boar is the highest known amongst all ungulate species (Geisser and Reyer, 2004; Massei and Genov, 2004) and female may start reproducing well under the age of 1 year (Bieber and Ruf, 2005). The reproduction is dependent on food availability and up to 90% of the females in a population can reproduce during a year with an overflow of food (Massei et al., 1996; Servanty et al., 2009). Like in other ungulates, the female wild boar have to reach a threshold body mass of 27 - 33 kg to be able to reproduce, which is a much lower weight than similar sized species (Servanty et al., 2009).

Figure 2. Distribution of S. scrofa. Native range marked in black and introduced range in grey. Circles indicate introduction of S. scrofa on islands (Long, 2003).

In Sweden, the species has been hunted to extinction at two separate occasions, in the seventeenth century and in 1940's (Thurfjell et al., 2009). The population has increased exponentially all over Europe since 1980s' (Geisser and Reyer, 2005), and the wild boar is now present in the south and middle of Sweden (fig. 3).

Wild boar is often considered one of the most important game species (Schley et al., 2008), but is also a species that often propose a problem for human activities all over the world (Schley et al., 2008). In Sweden, amongst other countries, wild boar can be hunted all year around (Jaktförordning, [SFS 1987:905]).

Figure 3. The dispersal of wild boar (S. scrofa) in Sweden, darker colour represent presence or establishment of wild boar in the area (SOU, 2014:54).

The wild boar is an omnivore and the diet consist primarily of plants and secondarily of animal material (Amici et al., 2012; Lemel, 1999; Massei and Genov, 2004; Schley and Roper, 2003). This flexibility in dietary patterns is partly responsible for the species ability to successfully colonize new habitats (Cellina, 2008; Schley and Roper, 2003). The diet is dependent on annual, seasonal and geographical variations and as the wild boar is opportunistic, the diet is also very influenced by availability (Schley and Roper, 2003). When available, agricultural crops can represent a major part of the animals' diet, which could cause a great deal of conflict (Herrero et al., 2006). The access to agricultural crops are also likely to affect the size of home range, which can vary a great deal between different wild boar groups (Lemel, 1999).

The Swedish Environmental Protection Agency (SEPA) is a committee that is responsible for the supervision of hunting, management and conservation of wild species. The population of wild boar is managed on a local level, where leisure hunters and hunting teams are responsible for keeping the population on a viable level while minimizing damage in the regarding areas.

3. Materials and method

3.1 Study area

The study area is located in south-eastern Sweden, at properties in Södermanland, Örebro- and Stockholm counties. The study areas comprise four estates with several land owners and tenants. The fields were censused for wildlife damages at four different occasions between the beginning of May until the end of August. The monitored fields were chosen in relation to crop type and location (logistics). Fenced field were chosen by a stratified random sampling but limited to wheat fields. Mean temperature during the four months of the study were 16.0 C°, 17.4 C°, 22.0 C° and 18.3 C° (SMHI-Klimatdata, 2018).

Bornsjön study area (59°14'N 17°40'E) is located in the county of Stockholm and is an estate managed by Stockholm Vatten AB and two tenants. The 4,600 ha estate is a water protection area and belongs to the Södertälje game management area (GMA) which has an area of 56,570 ha. Boo Egendom study area (58°53'N 15°26'E), in the county of Örebro, has one owner that hold both hunting- and farming rights. The estate covers an area of 15,000 ha, with 11,600 ha of productive forest and 700 ha of farmland. It belongs to Hallsberg GMA which has a total area of 124,000 ha. The county board of Södermanland possess the Ökna and Nynäs study area, 3742 ha, (58°48'N 17°22'E) and it is managed by the organisation "Sörmlands Naturbruk". Nynäs is a nature reserve in the eastern part of Södermanland and the hunting in both areas are managed by the students and teachers of the nearby practical boarding high school Öknaskolan. The two estates are situated in the Svärta-Trosa GMA, which has an area of 53,188 ha. The Björkvik study area (58°49'N 16°31'E) is located in the south-western part of Södermanland and the agricultural land covers 2300 ha. The area is part of Sydvästra Sörmlands GMA, which has a total area of 57,880 ha.

The landscape is varied with agricultural fields and forestland. These three counties, in which the estates are set in, cover a total area of 21,140 km^2. Forest covers most of the area (Stockholm: 56,9%, Södermanland: 63,4% and Örebro:

73,1%) while the area consists of 14,2% (Stockholm), 23,4% (Södermanland) and 13,3% (Örebro) of agricultural land, respectively (SCB, 2019). The counties hold all native wild ungulate species: moose (*Alces alces*), red deer, fallow deer, roe deer and wild boar.

3.2 Damage census

Four, six or eight, transects were monitored for damages in each field, depending on the size of the field. Transects were often placed in tractor tracks used when spraying or fertilizing the crops, and the total census transect width was 10 metres (5 metres on each side of the transect) (appendix 1). A damage was defined by rooting, lying grass, paths, chewed seeds and nests made by mainly wild boar. In total were 127 fields censused for wild boar damage, divided between the four different study areas (Boo Egendom, Björkvik, Bornsjön, Nynäs-Ökna). The crops on the monitored fields were limited to four species: wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), triticale (*Triticale rimpaui*) and mowing (combination of grass and herbs). The most important information extracted was: (1) the damaged area, (2) the crop type, (3) the type of damage and (4) the geographical location of the damage. The field form that was filled out can be seen in appendix 2.

We collected data at four different occasions at each field, with 3 - 4 weeks between sampling occasions. The 127 field contained either of four crops (wheat: 66, barley: 23, triticale: 7, mowing: 31). Barley and triticale were later in the process merged into one group called ‘Other cereal’.

3.3 Disturbance

The preventive actions, of hunting and scaring animals on fields started in the middle of May at two of the study areas (Bornsjön and Ökna-Nynäs), while in the third and fourth study areas (Björkvik and Boo Egendom) it started in the end of May or beginning of June. These were carried out during the whole summer and stopped around the time of harvest, in the first two weeks of August. Hunting and scaring activities at the estates were recorded by the game keepers and responsible hunters. The form at which hunters recorded their actions can be seen in appendix 3.

Disturbance was analytically used as the total number of scaring occasions, but also divided into 5 different categories: (1) Hunting, (2) Warning shot, (3) Walking/shouting, (4) Driving/Honking, and (5) Other. The category 'Hunting' includes all occasions a person was going out to a field with the purpose to hunt, and the boars were scared of the field for some reason, irrespective if a shot was fired or if a wild boar was shot. The category 'Warning shot' refers to all shots fired with the intention of scaring (not killing) wild boar from the field. 'Walking/shouting' includes all occasions when scaring wild boar from the field with the help of body movements and voice. 'Driving/honking' refers to the number of times a person was driving by a field or honking with the intention of scaring the wild boars of the field. The category 'Other' includes scaring the wild boars with other actions than previously described, such as releasing a dog, flying with a drone etc.

The Björkvik study area was excluded from the analysis as this information was missing or inconclusive.

3.4 Fenced fields and harvest statistics

In total, 12 wheat fields were fenced, and new damage survey transects were made for these. The fences were constructed and installed during a 2-week period in the middle of July (4/7-17/7). The areas of the fenced fields varied between 2.6 and 5.2 ha. We used 1.8 mm galvanized iron wire in 2 strands with 150 mm between. The lowest wire was placed 150 mm from the ground and the vegetation below were removed with a brush cutter. Impregnated wooden poles were placed in the corners of the fenced field and at the bottom of hollows and pits. In between the wooden poles was the two fence wires supported by plastic poles with double ground pegs.

Harvest statistics were collected from the farmers or through DataVäxt AB, a software created for documenting, tracing and monitoring the development of the agriculture. Information about ten fields were collected, five fenced and five unfenced control fields. The fields were located at Boo Egendom, Bornsjön and Björkvik. Information about harvest (kg/ha) from Ökna-Nynäs was not available as the fields were harvest as silage instead of grain. The fields were harvested during the last week of July and the first two weeks of August.

3.5 Diversionary feeding

The coordinates and type of feeding station were collected from each study area. In total there were 123 feeding stations divided between the estates (Boo Egendom: 54, Björkvik: 20, Bornsjön: 9 and Ökna-Nynäs: 39). These were inserted to Google Maps for an overview and analysed in QGIS 2.18.26 with GRASS 7.4.2 to measure distance from each field edge to the nearest feeding station and to estimate the number of feeding stations within 500 metres from each field. The distance to feeding stations were divided into intervals to correct for possible miscalculations when determining the distance to the feeding stations (Tab. 1).

Table 1. Dividing distances from field edge to feeding stations into 12 different interval groups to facilitate analyses of effect of distance to feeding stations.

Distance (m) to feeding station	Interval group
<50	25
≥50 and <100	50
≥100 and <200	100
≥200 and <300	200
≥300 and <400	300
≥400 and <500	400
≥500 and <600	500
≥600 and <700	600
≥700 and <800	700
≥800 and <900	800
≥900 and <1000	900
>1000	2000

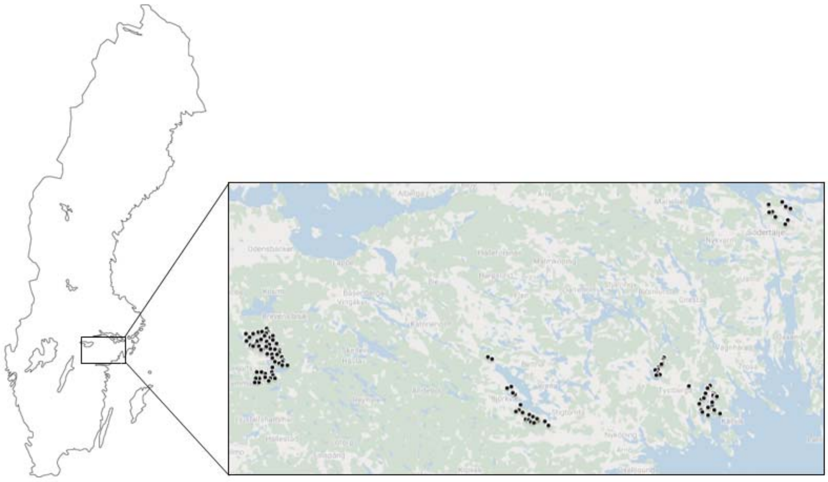

Figure 4. Geographical overview from Google Maps of the study region and a zoom-in on the known feeding stations (black dots) in the four study areas.

3.6 Statistical analysis

All processing and statistics were performed with RStudio® and Microsoft Excel. The analyses were performed twice, once with all data and once without the outlier and extreme value of 0.16 damage that was found on one wheat field in the Ökna-Nynäs study area on the third visit occasion. The high level of damage found on the concerned field was unique and not found on any of the other visits. The damage level also stands out from the nearby wheat fields and there appear to be no obvious reason to the extreme level (such as isolation or nearby forest etc.). The has been pointed out by the farmers that this field often produce less because of the soil composition, and that natural patches because of the soil may have been mistakenly registered as wild boar damage.

3.6.1 Fencing

Collected harvest statistics (kg/ha) from fenced and control fields were compared and investigated with a Wilcoxon rank-sum test, which was used because the dataset was not normally distributed and because of the limited sample size (10 fields). Also, the percentage of damage on the fields with different treatment, fenced or unfenced as explanatory variable, were compared with the tests mentioned above.

3.7.2 Disturbance

I used generalized linear models (GLMs) with Poisson regression to investigate how the number of disturbances on individual fields influenced the amount of wild boar damage. The different estates were corrected for in the models. Damage was used as response variable and the natural log of the transect length was used as offset. When constructing the graphs on the other hand, the proportion of damage was used, as it made it easier to interpret. Disturbance were divided into the subcategories 'Hunting', 'Warning shot', 'Walking/Shouting', 'Driving/Honking' and 'Other' and analysed separate to see if the kind of activity were affecting the response.

3.7.3 Diversionary feeding

Generalized linear models were used to investigate how feeding station density (within 500 metres of the field) affected damage level. Damage was used as response variable and the natural log of the transect length was used as offset. The distances from field edge to nearest feeding station was also used as parameter to investigate the effect of distance on damage level. Graphs were constructed using the proportion of damage instead, because they were easier to interpret.

4. Results

4.1 Fencing

Electric fencing was constructed on 12 wheat fields and next to them was 5 unfenced control fields. The total sample size was 10 fields, 5 fenced and 5 unfenced control fields, as many of the fields were harvested as silage instead of grain meaning that statistics (kg/ha) was missing. These 10 fields were compared in a Wilcoxon rank-sum test.

The mean harvest on the fenced fields (n = 5) were 3809.7 kg/ha (±SD 502.8) and slightly lower on the control fields (n = 5) (3263 kg/ha ±SD 1209.5) (fig. 5). The difference is illustrated (fig. 5) and may appear to be relatively large. However, I found no significant difference in harvest (kg/ha) between fenced and unfenced fields (Wilcoxon rank-sum test, p = 0.19). The mean damage on fenced fields were 49.2 m^2 (±SD 101.1) and 77.4 m^2 on control fields (±SD 97.3). Nor did the damage level differ significantly between the fenced and control fields (Wilcoxon rank-sum test, p = 0.86).

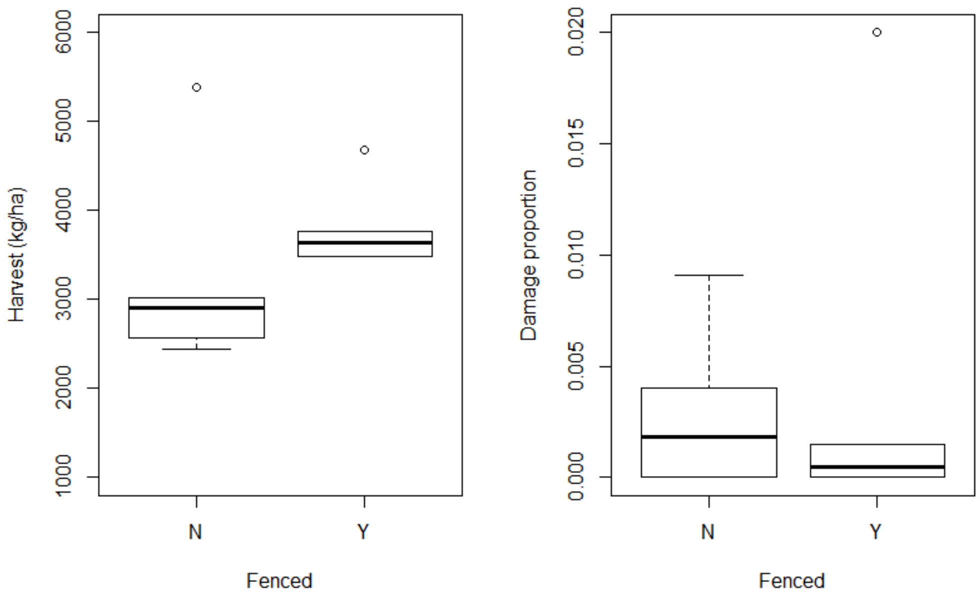

Figure 5. To the left: harvest (kg/ha) on fenced (Y) and unfenced (N) fields (n=10). To the right: proportion of damage on fenced (Y) and unfenced (N) fields (n=10). The thick vertical line dividing the box into two parts are indicating the median. The top end of the box represents the upper quartile, and the lower end of the box represents the lower quartile. The whiskers represent the maximum and minimum values in the dataset. Data from 10 fields monitored in South Eastern Sweden, during the vegetation season 2018.

4.2 Disturbance

Disturbances on fields were performed from May to August and had the purpose to scare the wild boar away from sensitive fields at the estates. These were analysed as overall disturbances, which were a total of 199 performed disturbances (tab. 2).

Table 2. The number of disturbance occasions divided into estate (Boo Egendom, Bornsjön and Ökna-Nynäs), type of crop (wheat, other cereal and mowing) and the type of disturbance (hunting, warning shot, walking/shouting, driving/honking and other).

Estate	Crop	Hunting	Warning shot	Walking/ shouting	Driving/ honking	Other
Boo Egendom	Wheat	8	6	6	3	7
Boo Egendom	Other cereal	0	0	0	0	0
Boo Egendom	Mowing	0	0	0	0	0
Bornsjön	Wheat	29	21	15	8	1
Bornsjön	Other Cereal	1	0	2	0	0
Bornsjön	Mowing	0	0	0	0	0
Ökna-Nynäs	Wheat	30	0	24	23	0
Ökna-Nynäs	Other Cereal	1	0	0	0	0
Ökna-Nynäs	Mowing	14	0	0	0	0

The total amount of disturbance significantly affected (tab. 3; tab. 4) the level of damage made on crops in both test rounds, with and without the outlier ($p < 0.0001$).

Table 3. Result of a GLM investigating the effect of overall disturbance and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage increases with an increasing number of disturbances on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 71 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E.	Z	P
Intercept	-3.16	0.027	-117.3	<0.0001
Bornsjön	0.02	0.036	0.5	>0.6
Ökna-Nynäs	1.29	0.029	44.1	<0.0001
Disturbance	0.03	0.001	21.6	<0.0001

Table 4. Result of a GLM investigating the effect of overall disturbance and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with increasing number of disturbances on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 70 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.06	0.027	-113.2	<0.0001
Bornsjön	0.16	0.03	4.60	<0.0001
Ökna-Nynäs	1.2	0.030	40.84	<0.0001
Disturbance	-0.0096	0.0020	-4.82	<0.0001

With all values included, the analysis indicates a positive relationship between number of disturbances and the amount of damage, while the result is reversed when excluding the outlier, indicating that an increased amount of disturbances leading to a higher amount of damage (fig. 6).

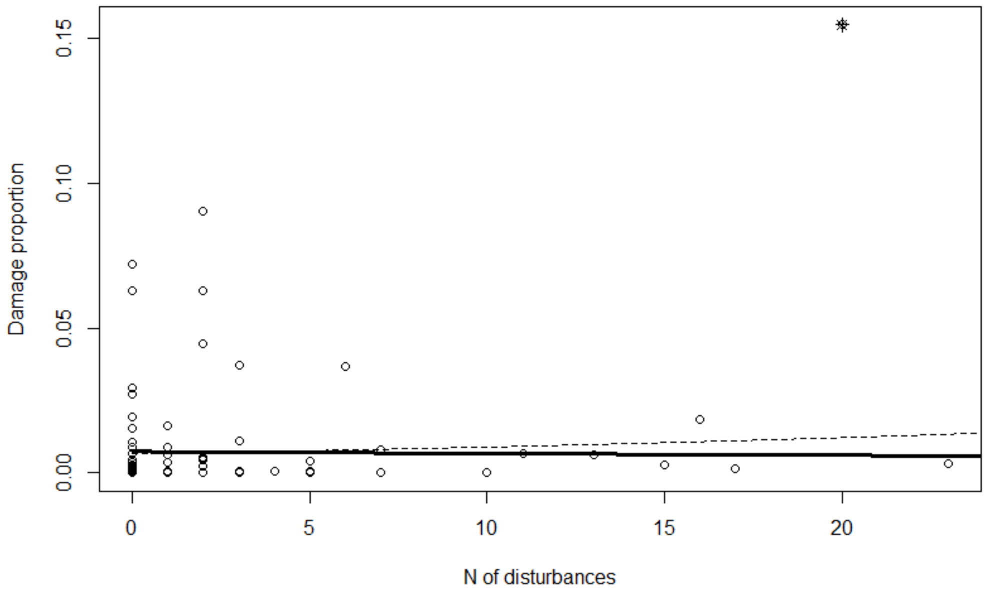

Figure 6. Relationship between the number of disturbances and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0.16) are marked with a black star, dotted line displays the effect of number of disturbances on damage with outlier and solid line on the effect without the outlier.

4.2.1 Hunting

In total, there was 83 hunting occasions that was used to analyse hunting disturbance and the effect on damage (tab. 2). I found evidence that hunting significantly affect the level of damage (tab. 5; tab. 6), both with ($p < 0.001$) and without the outlier (0.16) ($p = 0.009$).

Table 5. Result of a GLM investigating the effect of hunting and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage increases with an increasing number of hunting occasions performed on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 71 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.1	0.027	-117.3	<0.0001
Bornsjön	-0.020	0.036	-0.56	0.57
Ökna-Nynäs	1.28	0.029	43.6	<0.0001
Hunting	0.075	0.003	21.60	<0.0001

Table 6. Result of a GLM investigating the effect of hunting and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with an increasing number of hunting occasions performed on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 70 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.07	0.027	-113.8	<0.0001
Bornsjön	0.151	0.036	4.24	<0.0001
Ökna-Nynäs	1.21	0.030	40.76	<0.0001
Hunting	-0.012	0.0045	-2.61	0.009

With the completed data set (including the outlier) I found a positive relationship between the number of disturbances and the amount of damage (fig. 7). Without the outlier the results indicate a decrease of damage with a higher amount of hunting activities.

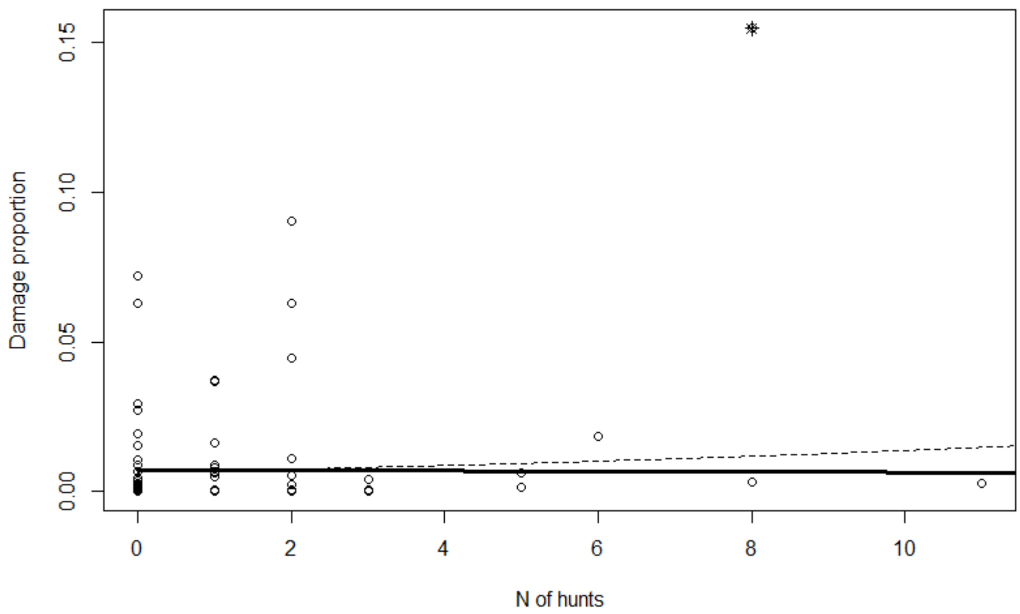

Figure 7. Relationship between the number of hunting occasions and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0.16) are marked with a black star, dotted line displays the effect of number of hunting occasions on damage with outlier and solid line on the effect without the outlier.

4.2.2 Warning shot

There was a total of 27 shots fired with the intention of scaring animals away without killing them, whereof 21 were fired at Bornsjön (tab. 2). There was a significant effect (tab. 7; tab. 8) of warning shots on the damage levels in both analyses (with and without the outlier) ($p < 0.001$).

Table 7. Result of a GLM investigating the effect of warning shots and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage increases with an increasing number of warning shots fired on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 71 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.28	0.028	-117.0	<0.0001
Bornsjön	-0.236	0.040	-5.90	<0.001
Ökna-Nynäs	1.542	0.030	50.63	<0.0001
Warningshot	0.289	0.011	25.84	<0.0001

Table 8. Result of a GLM investigating the effect of warning shots and study area on the estimated wild boar damages on fields with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage increases with an increasing number of shots fired on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 70 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.28	0.028	-117.0	<0.0001
Bornsjön	-0.236	0.040	-5.90	<0.0001
Ökna-Nynäs	1.404	0.031	45.54	<0.0001
Warningshot	0.289	0.011	25.84	<0.0001

There seems to be a slight increase in damage when a higher number of warning shots are fired. This is true for both the analyse with the whole dataset and without the outlier, as at the field containing the extreme damage value there were no warning shots fired (fig. 8).

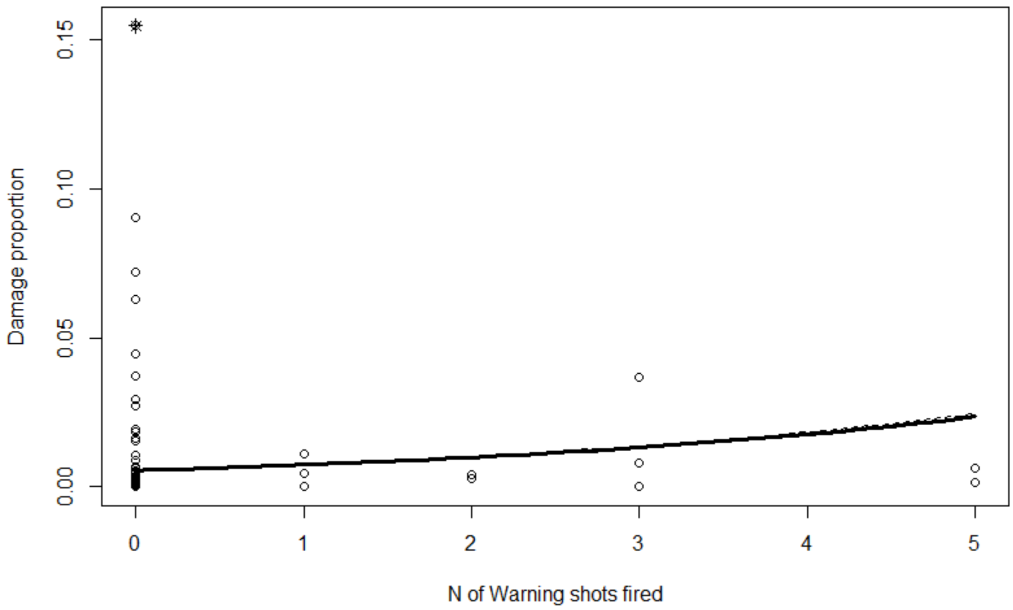

Figure 8. Relationship between the number of warning shots fired and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0.16) are marked with a black star, dotted line displays the effect of number of warning shots fired on damage with outlier and solid line on the effect without the outlier.

4.2.3 Walking and Shouting

Wild boars were disturbed using walking/shouting 47 times, the majority of times the action was performed at wheat fields (tab. 2). There was a significant effect of walking/shouting on the damage levels in both analyses (with (fig. 9) and without the outlier (fig. 10) ($p < 0.001$).

Table 9. Result of a GLM investigating the effect of walking/shouting and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage increases with an increasing number of times walking/shouting is performed on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 70 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.11	0.027	-116.3	<0.0001
Bornsjön	0.071	0.035	2.02	0.04
Ökna-Nynäs	1.28	0.029	43.5	<0.0001
Walking/Shouting	0.079	0.0045	17.5	<0.0001

Table 10. Result of a GLM investigating the effect of walking/shouting and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with an increasing number of times walking/shouting is performed on fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 70 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.07	0.027	-114.7	<0.0001
Bornsjön	0.178	0.035	5.03	<0.0001
Ökna-Nynas	1.23	0.030	41.4	<0.0001
Walking/Shouting	-0.058	0.0069	-8.37	<0.0001

With all data included there was a positive relationship between the number of occasions scaring wild boars away trough walking and shouting and the level of damage on fields (fig. 9). With the extreme value excluded from analysis, the relationship was negative, showing decreasing damage levels with an increasing number of scaring occasions through walking and shouting.

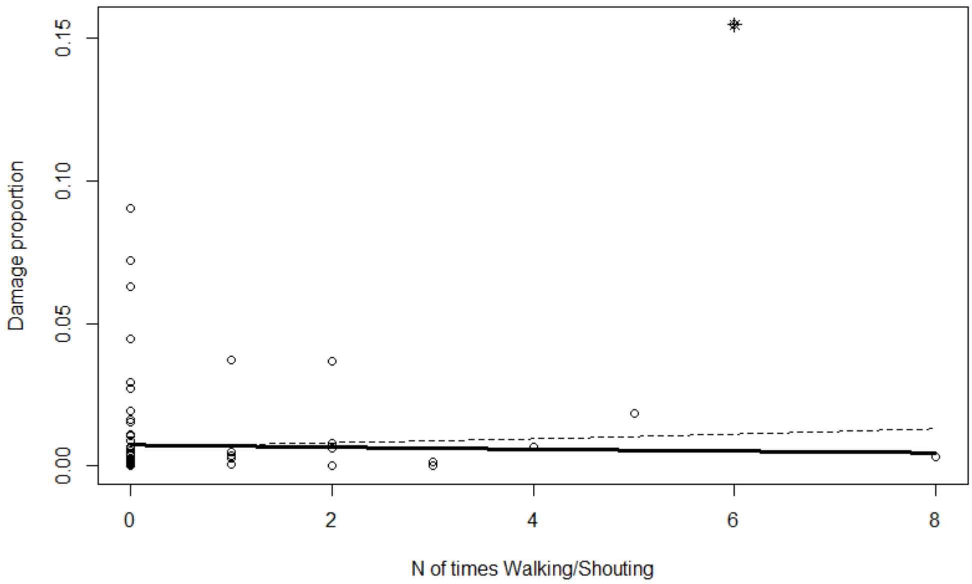

Figure 9. Relationship between the number of occasions scaring wild boar using walking/shouting and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0,16) are marked with a black star, dotted line displays the effect of number of times walking/shouting on damage with outlier and solid line on the effect without the outlier.

4.2.4 Driving and Honking

Driving/honking was performed exclusively on fields sown with wheat and the action were registered 34 times during the study period (tab. 2). There was a significant effect of driving/honking (tab. 11; tab. 12) on the damage levels in both analyses (with and without the outlier) ($p < 0.001$).

Table 11. Result of a GLM investigating the effect of driving/honking and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data). The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage increases with an increasing number of times driving/honking is performed at fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 71 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.09	0.027	-115.9	<0.0001
Bornsjön	0.115	0.035	3.29	0.001
Ökna-Nynäs	1.29	0.030	43.6	<0.0001
Driving/Honking	0.064	0.0052	12.3	<0.0001

Table 12. Result of a GLM investigating the effect of driving/honking and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with an increasing number of times driving/honking is performed at fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 70 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.06	0.027	-114.4	<0.0001
Bornsjön	0.173	0.035	4.93	<0.0001
Ökna-Nynäs	1.27	0.030	42.9	<0.0001
Driving/Honking	-0.183	0.010	-17.5	<0.0001

With all data included there was a positive relationship between the number of occasions scaring wild boars away trough driving and honking and the level of damage on fields (fig. 10). With the extreme value excluded from analysis, the relationship was negative, showing decreasing damage levels with an increasing number of scaring occasions through driving and honking.

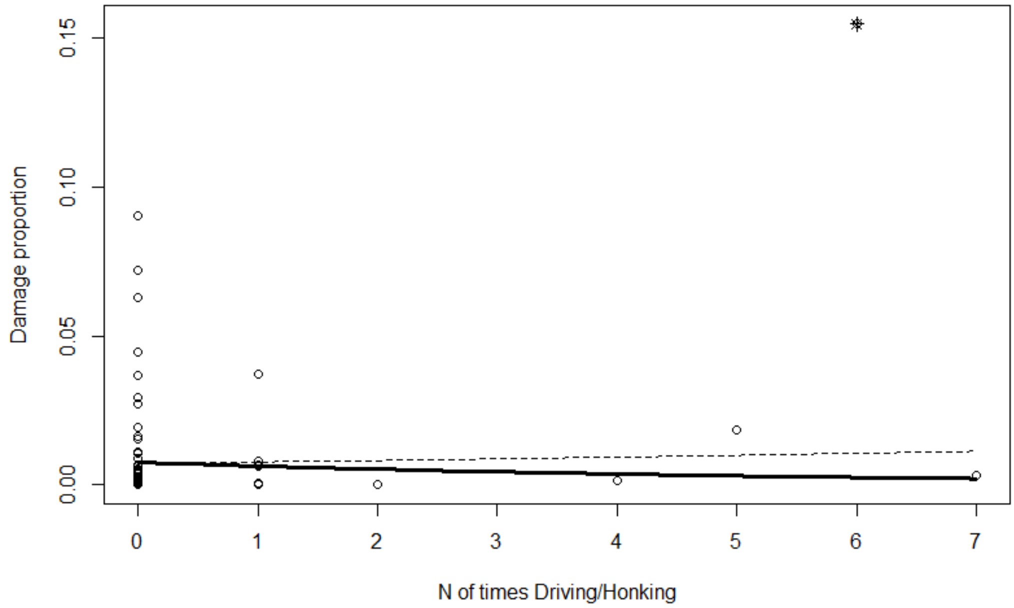

Figure 10. Relationship between the number of occasions scaring wild boar using driving/honking and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0.16) are marked with a black star, dotted line displays the effect of number of times driving/honking on damage with outlier and solid line on the effect without the outlier.

4.2.5 Other

The category 'other' includes scaring wild boar using dogs or drones etc. The samples were few, 8 in total, which led to a small dataset to use in analyses (tab. 2). These show that there was a significant effect of other disturbances (tab. 12 ;tab. 13). on the damage levels in both analyses (with and without the outlier) (p = 0.036).

Table 12. Result of a GLM investigating the effect of other disturbances and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with an increasing number of times other disturbances is performed at fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 71 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.07	0.028	-111.0	<0.0001
Bornsjön	0.12	0.035	3.50	0.0005
Ökna-Nynäs	1.32	0.030	44.1	<0.0001
Other	-0.05	0.027	-2.09	0.036

Table 13. Result of a GLM investigating the effect of other disturbances and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Boo Egendom", is used as the intercept to Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with an increasing number of times other disturbances is performed at fields. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 70 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.07	0.028	-111.0	<0.0001
Bornsjön	0.124	0.035	3.50	0.0005
Ökna-Nynäs	1.19	0.030	39.0	<0.0001
Other	-0.058	0.027	-2.09	0.036

Figure demonstrates a negative relationship between the amount of damage and the number of occasions scaring wild boar through actions counted as 'Other' (fig. 11). This is true for both the analyse with the whole dataset and without the outlier, as at the field containing the extreme damage value no other disturbances were performed.

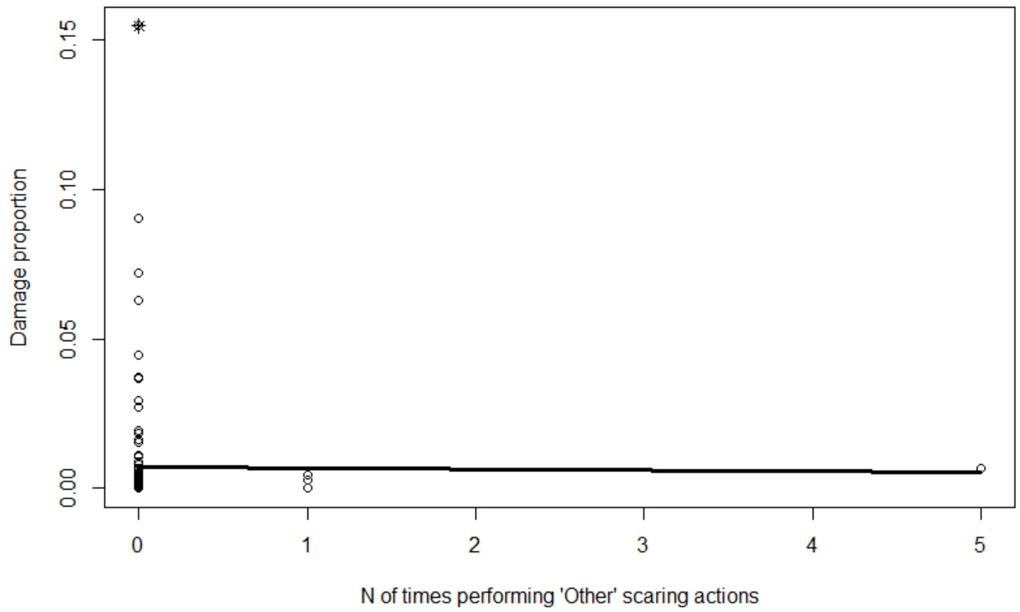

Figure 11. Relationship between the number of occasions scaring wild boar using other disturbances and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0.16) are marked with a black star, dotted line displays the effect of number of times disturbing using other actions than analysed in previous sections on damage with outlier and solid line on the effect without the outlier.

4.3 Diversionary feeding

In total 104 fields (103 when excluding the outlier) were used when analysing the effect of diversionary feeding on wild boar damage. The registered number of feeding stations on each estate were 54 (Boo Egendom), 20 (Björkvik), 39 (Ökna-Nynäs) and 9 (Bornsjön). I found a significant negative relationship between the amount of damage and the distance to the nearest feeding station ($p<0,001$) when analysing the whole dataset and without the outlier (0,16) (tab. 14; tab. 15).

Table 14. Result of a GLM investigating the distance to feeding stations and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. The study area "Björkvik", is used as the intercept to Boo Egendom, Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with distance to feeding station. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 104 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-2.62	0.023	-115.5	<0.0001
Boo Egendom	0.756	0.039	19.5	<0.0001
Bornsjön	0.434	0.031	14.2	<0.0001
Ökna-Nynäs	1.09	0.024	46.2	<0.0001
Distance to FS	-0.000674	0.0000193	-35.0	<0.0001

Table 15. Result of a GLM investigating the distance to feeding stations and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Björkvik", is used as the intercept to Boo Egendom, Bornsjön and Ökna-Nynäs. Estimate indicate that damage is decreasing with distance to feeding station. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 103 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-2.66	0.023	-116.2	<0.0001
Boo Egendom	0.690	0.039	17.9	<0.0001
Bornsjön	0.413	0.031	13.5	<0.0001
Ökna-Nynäs	0.972	0.024	40.4	<0.0001
Distance to FS	0.000612	0.0000192	-31.8	<0.0001

From interpretation (fig. 12) there is an effect of distance to the closest feeding station on the amount of damage found on field. This is true for analyses both with and without the outlier.

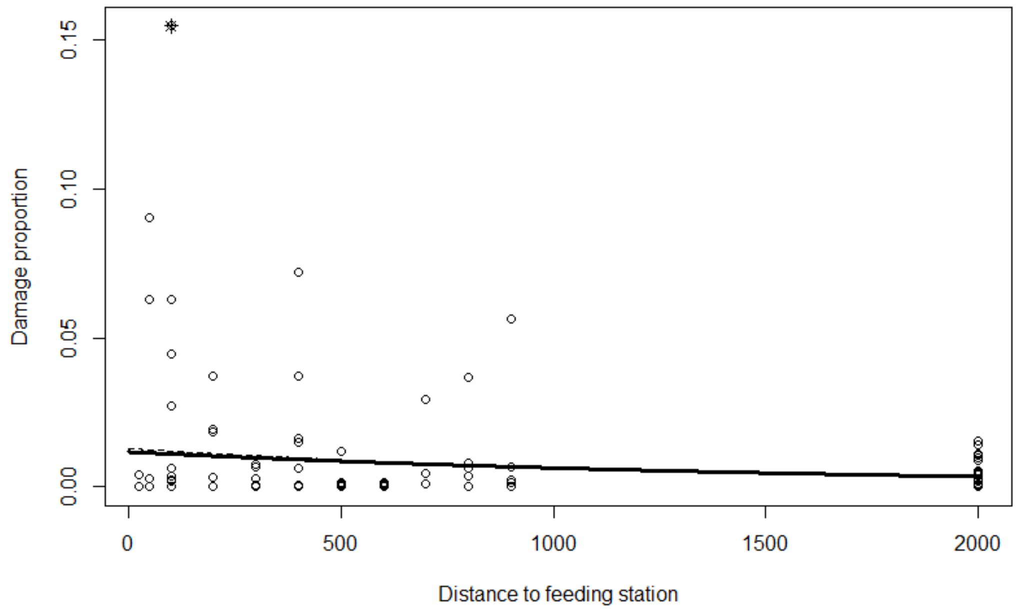

Figure 12. Relationship between the distance to the closest feeding station and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0,16) are marked with a black star, dotted line displays the effect of distance to feeding stations on damage with outlier and solid line on the effect without the outlier.

When analysing the whole dataset there was no significant relationship between the number of feeding stations within a range of 500 metres and the amount of damage on field (tab. 16).

Table 16. Result of a GLM investigating the number of feeding stations within 500 metres of the field and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. The study area "Björkvik", is used as the intercept to Boo Egendom, Bornsjön and Ökna-Nynäs. Estimate indicate that the number of feeding stations within 500 metres do not have a significant impact on wild boar damage. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 104 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.14	0.020	-157.8	<0.0001
Boo Egendom	0.087	0.033	2.61	0.009
Bornsjön	0.187	0.030	6.22	<0.0001
Ökna-Nynäs	1.39	0.025	56.1	<0.0001
FS within 500 m	0.003	0.010	0.315	0.75

Exclusion of the extreme value (0.16) when analysing produced a significant result, indicating that the number of feeding stations within 500 metres have an impact on wild boar damage (tab. 17).

Table 17. Result of a GLM investigating the number of feeding stations within 500 metres of the fields and study area on the estimated wild boar damages on fields sown with wheat, barley, triticale and mowing. Results produced from analysing data without the outlier (0.16). The study area "Björkvik", is used as the intercept to Boo Egendom, Bornsjön and Ökna-Nynäs. Estimate indicate that damage sightly increases with an increasing number of feeding stations within 500 metres. S.E. (Standard error), Z (z-test of the mean) and P (probability value). Data from 103 fields monitored in South Eastern Sweden, during the vegetation season 2018.

	Estimate	S.E	Z	P
(Intercept)	-3.16	0.020	-157.8	<0.0001
Boo Egendom	0.111	0.033	3.35	0.0008
Bornsjön	0.206	0.030	6.85	<0.0001
Ökna-Nynäs	1.20	0.026	46.9	<0.0001
FS within 500 m	0.0539	0.011	4.89	<0.0001

Illustration of the results (fig. 13) show the effect of number of feeding stations within 500 metres on the damage, where the outlier is marked with a star.

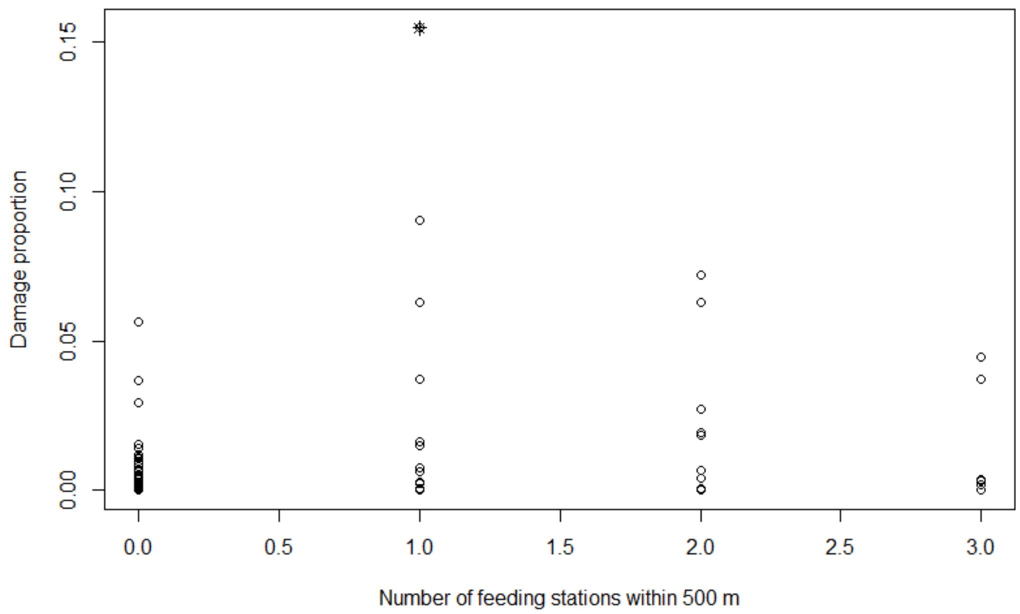

Figure 13. Relationship between the number of feeding stations within 500 metres of the fields and the amount of damage found on fields with wheat, barley, triticale and mowing. Outlier (0.16) are marked with a black star.

5. Discussion

Large populations of game are important as income and for recreational purposes, but these also cause extensive damage, leading to economic loss to farmers (Bleier et al., 2012). Understanding of the different interests and causes of conflicts are important for developing efficient strategies for wild boar management (Kansky and Knight, 2014). There is huge loss of income for the farmer when crop damages are extensive. To refrain any sort of preventive method, means that damage only will increase (Barrett and Birmingham, 1994). Lemel (1999) argues that to protect the agricultural crop more permanent, only three methods are efficient: fields sown for game with attractive crops, efficient feeding and electric fencing. However, my results suggest that also disturbance have the potential to locally reduce damage when it is performed regularly.

Depending on analysing with the whole dataset or excluding the extreme value (0.16), the results varied. In the majority of analyses, excluding the outlier gave an opposite result than analysing all data. This has made it complicated to express the result and comparing them to my hypothesis and predictions. Results from analyses are discussed in detail in each separate section below.

The reason I analysed each part twice, with and without oulier, was that the value of 0.16 differ a great deal from damage found on other fields. This amount of damage was also just registered during one of the census occasions, even though it was censused at four separate occasions in total, whereof three was performed before the time of harvest. The location of the field was discussed to determine if the differentiation could have been due to environmental factors. When comparing to the location of this field to other fields censused in this study, it was not especially exposed to wild boar damage as it was not completely surrounded by protective environment, such as forest. As the amount of damage on fields are positively related to the proportion of forest cover, fields surrounded by forest or other protective coverage are therefore more likely to be exploited by wild boar than when the surroundings consists of open spaces (Lemel, 1999). These are factors that are not analysed nor considered in this study but are highly relevant when investigating what may increase or decrease damage in the agricultural landscape. When constructing following studies, it would be of value to investigate the surrounding environment to be able to get a more correct analyse of the reason behind wild boar damage. The outlier was on a field with lower harvest in 2017 than other fields in Ökna-Nynäs and might have been left behind during the very warm and dry summer in 2018 (pers. com.). Thus, there might be a reason to exclude the outlier from the analyses. Due to all of these factors, I am basing the discussion on the results I got from analysing without the outlier.

Weather and environmental conditions may also affect the amount of damage on crops. Results from mean temperature during the summer of 2018 (May - August) when this study was performed were significantly higher (t-test; $p<0.0001$) than the normal "30 year mean" temperature (from calculations between 1961 – 1990 (SMHI-Klimatdata, 2018)), and are likely to have an impact on the results in this study. It does not only affect the damage, but also obstruct the monitoring, making it difficult to determine if crop losses are because of drought or a previous damage.

5.1 Fencing

Even though it is a visual difference (fig. 5) between the fenced and unfenced fields, results suggest that these difference was not significant. The damage levels and the harvest (kg/ha) did not significantly differ between the fenced and the unfenced fields even though the mean/median harvest was higher in the fenced fields. My results indicate that fencing is not a suitable method for preventing wild boar damages, although, there are multiple factors affecting the results. For example, the sample size was quite small (5 treatments and 5 controls). Futhermore, the mean temperature during these months were substantially higher than previous years (SMHI-Klimatdata, 2018), meaning that the crops became ripe much earlier than expected. The electric fences were constructed in the middle of July and the fields were harvested during the last week of July or in the first two weeks of August. Consequently, the fences were only up during 1 - 3 weeks before they had to be demounted and our study basically missed to protect the crops during the most attractive main ripe-period.

As studies previously shown, electric fencing should to be applied only during a short period, advantageously right after sowing, or as soon as the crops are in milk, and be kept until harvest (Schley et al., 2008). Our period was short, as recommended, but due to the unexpectedly warm and dry summer, the damages might already have happened before fences were in place. To get data that are more reliable from the fenced fields, it could be beneficial to put up the electric fences before starting the monitoring. By doing this, one can be sure that the damage on the field is not an old damage from before the fencing was installed.

Studies has shown that electric fencing is efficient when it is executed in the right way, and the fence is "just as strong as its weakest link" (Honda et al., 2009; Lemel, 1999; VerCauteren et al., 2006; Vidrih and Trdan, 2008). My result may also be affected by human bias, as the crew putting up the fence was not familiar with that kind of work. This could have led to construction flaws and missing important details, leading to weak spots where the wild boar could go through the fence as has been the case in numerous of studies showing that electric fencing had no effect (Lemel, 1999).

According to Lemel (1999), when two wires are used, the lower one should be placed 15 - 20 cm above the ground and the other one 30 - 40 cm over the other. It is also important that the electric tension are maintained and therefore the earth rods should be placed where the ground does not dry out and impairs the conductivity (Lemel, 1999). The voltage should be kept at a minimum of 3,000 volts to be able to maintain the protection of the field (Craven and Hygnstrom, 1994). Keeping the vegetation away from the electric wires and the wires as strained as possible is of importance as the voltage could decrease and the wild boar can go through the fence (Craven and Hygnstrom, 1994; Lemel, 1999). The construction and maintenance of the fences in this study was on some points lacking and there was a problem keeping voltage high due to the dryness in the soil. All of these could be used to explain potential intrusion by wild boar. Fencing are only effective if the construction and maintenance are done correct, but when it is, the electric fence have the ability to keep wild boars away from the field (Conover, 2001; Honda et al., 2009; Lemel, 1999).

5.2 Disturbance

The results I got indicate that most kinds of disturbance are affecting the amount of damage recorded on monitored fields. But despite of the analytical significance, the difference between the damage levels were relatively small. Disturbance are actions that scare the animals away from sensitive fields and the goal is that they in the future will avoid the area. Although, modifications in behavioural repertoire is not only shown during all kinds of hunting, but also before any shots has been fired, suggesting that animals that detect human activity are responding to these small disturbances (Thurfjell et al., 2013). When there is a lot of people performing disturbance actions, and when multiple shots fired, the disturbance is greater and thus leading to a more cautious behaviour (Thurfjell et al., 2013). My results suggest that the crop damage increase when an increasing number of warning shots are fired. I could argue that damage is not a reaction to the shots fired, but on the opposite that the number of actions performed are a reaction to an experienced higher amount of damage and to an increased number of wild boars observed on the field. This makes the results complicated to interpret, as we do not know which action led to which reaction.

Mostly the effect of hunting has been studied, and therefore it is a lack of research about how scaring with vehicles or voices are affecting the behaviour of wild boar. Of all disturbances performed, hunting was the superior action which may be interpret as a wish to lower the wild boar population in the areas. Results show that the number of hunts performed significantly affected the level of crop damage. The wild boar was likely scared away from the fields both because of human presence and the shots fired when an individual was killed. The lowered damage levels on the fields can consequently be explained both by avoidance of the hunted field and by the reduced population density which is a result of an increased hunting pressure (Geisser and Reyer, 2004). Geisser and Reyer (2004) support hunting as the ultimate damage preventive action and the main way to reduce wild boar damage because hunting is the only way regulate and lower the wild boar population.

As mentioned, increased hunting pressure may reduce damages, but can also have other (negative) consequences. Ohashi et al. (2014) suggests that unregulated hunting can cause undesired effects, such as spreading animals into other valuable areas. Maillard and Fournier (2014) also shows that even though shooting and disturbance results in spreading animals from the area, the effect is only temporary, and animals often return. To better investigate the time frame of the effectiveness of disturbance, it could be necessary to map the movement patterns of the wild boar while being exposed to these actions.

It may affect both behaviour and distribution, but also onset of reproduction (Servanty et al., 2009). In a French study by Servanty et al. (2009), when hunting pressure was high (once a week during regular hunting season), the threshold body mass for starting to breed was relatively low for female wild boar, and only 33 - 41% of adult body mass, compared to most other ungulate species, that need to reach about. This shows that the life-history tactics of wild boar females is more flexible than the tactic used by other similar-sized ungulate female (Servanty et al., 2009). When wild boar are exposed to high hunting pressure, Gamelon et al. (2011) found a selection for early birth dates in spring/winter. An adaptation that allows the female a longer growing period to manage to reach the threshold body mass for reproducing under the age of one (Gamelon et al., 2011). These are facts that are important to consider as it potentially will lead to higher population growth rates and probably also a higher wild boar density and therefore more damages.

Hunting of wild boar (yearlings <60 kg) in Sweden is allowed all year around, hence, there is no potential limitations in reducing population numbers. But not all authors support hunting as the only way to protect agricultural crops (Lemel, 1999). Extended hunting obviously lowers the number of wild boars in the area, and results in less amount of damage, but there will always be individuals that utilize crops as long as there are boars left in the area. It would probably take a lot of effort reduce the population to a level where the damage levels are distinctly reduced.

5.3 Diversionary feeding

Diversionary feeding includes sites feeding with silage, beats, spreading of peas, maize and wheat etc. A total of 122 feeding stations was registered and the effect on the selected fields at the estate was investigated. The results indicate that with greater distances to the nearest feeding station, the registered damage is lower. This relationship is confirmed by a study by Calenge et al. (2004), who spread maize in a 4.5 km trail to direct boars away from causing damage to vineyards in the Mediterranean. Situated 500 - 1000 m from the sensitive areas, it resulted in a slight decrease in intensity and proportion of damage (Calenge et al., 2004). Also Schlageter and Haag-Wackernagel (2012) argue that to successfully reduce damages the food should be supplied at a distance of 1 km from the edge of target fields. With feeding stations on average 300 m from agricultural land and with 1.05 feeding stations per 100 ha, the damage levels seem to increase (Geisser and Reyer, 2004). This could indicate that the distance between the feeding station and the crops is too short and the wild boar visit the field more frequently because of the closeness to it (Geisser and Reyer, 2004). This result indicates that to lower damage levels, feeding stations must be moved away from the fields and further into the forest, which could be difficult in some areas, as the sections of forest can be small, and they are often surrounded by fields.

The automatic feeding stations and their distribution can also affect the spatial behaviour of the animals and may attract them to sites they normally would not visit and cause damage in these areas (Geisser and Reyer, 2004; Milner et al., 2014). To counteract such effects, it is important to carefully plan the location and density of feeding stations (Geisser and Reyer, 2004). My results suggest that the density have an important effect on the level of damage. According to these data, damage is relatively low with no feeding station and then seem to peak when there is one feeding station within 500 metres of the field (fig. 13). The damage then reduces when two or three feeding stations are located within the area. This could indicate that when there is a feeding station within 500 metres, the food attracts the wild boars to the area, but the food is very limited, forcing some of the animals on to the fields nearby to forage instead. Damage seem to decrease when there were multiple feeding stations within the range, which may indicate that there was enough food distributed to occupy a higher number of individuals for a longer period.

Unfortunately, there was no information about which of these feeding stations that was active during the summer, which naturally would have an impact on the attractiveness. Nor did I have the opportunity to analyse the effect of type of forage supplied or the amount and time of day the food was distributed. Still, the artificial and often very attractive food that is supplied at the feeding stations is limited and force animals to disperse into small groups to search for "natural food" as it is usually not enough for all at the feeding stations, something that could result in increased damages to crops (Andrzejewski and Jezierski, 1978). Therefore, it may be more advantageous to spread the food over a larger area to attract more animals and to distract them from visiting the fields. This was not a method used in this study, but likely it would probably affect the damage levels if food was spread out instead of providing it all in one place, as it would allow more individuals to forage simultaneously. A more detailed study about preferred methods, optimal distribution area and number of times spreading food should be of interest to customize and have the most effective use of directed feeding.

The interest of feeding stations are perceived lower when crops are ripe (Lemel, 1999), hence, it can be hard to motivate the animals to keep away from the fields only with the help of diversionary feeding. Milner et al. (2014) concludes that to have maximum effect of diversionary feeding, it is vital that population densities are kept low, while food type is similar to natural forage and the sites are not near any vulnerable areas. Fields that has been sown only to benefit and lure game away from sensitive fields are an excellent example of this. Planning is key as it is vital that these fields provide the same, or an even more attractive crop at the same time as the other fields are ripe.

Although, some authors discuss that an unwanted effect of feeding may be an increased population size which might lead to increased damage in the long run (Andrzejewski and Jezierski, 1978), therefore it is advised that is used only during a short-time when crop damage is expected (Calenge et al., 2004). When used during a longer period and with more feeding sites per forest area, it may increase the carrying capacity, leading to a higher abundance of wild boar (Oja et al., 2014).

The effects of diversionary feeding are highly discussed, and its effectiveness to reduce crop damage is often very restricted (Pascual-Rico et al., 2018). It has the potential to reduce damage on crop, however seems to be only under some conditions: (1) when densities of wild boar are maximum 15 individuals per 1000 ha forest (Jullien et al., 1988), (2) the directed feeding is supplied only during a short, critical period (Vassant, 1994), (3) the food is spread over large areas and (4) minimum 1 km from the fields edge (Calenge et al., 2004).

5.4 Conclusion and recommendations

Based on my results, disturbance actions are significantly affecting the level of crop damage and supports the hypothesis that when wild boar are disturbed, they avoid the field. It usually works during short periods and therefore it is important that scaring is followed by consequences and making sure that wild boar learns that visiting the field to forage means real danger.

Regardless of the nonsignificant effect of electric fencing in this study, it is important to remember all the factors leading to this result and that multiple studies support fencing as an efficient damage preventive action (Honda et al., 2009; Lemel, 1999; VerCauteren et al., 2006; Vidrih and Trdan, 2008).

From my results and with support from previous findings (Calenge et al., 2004; Geisser and Reyer, 2004; Schlageter and Haag-Wackernagel, 2012) I conclude that fields close to feeding stations have a higher damage on the crop and that damage levels seem to peak when there is one feeding station within 500 metres. Recommendations are that the diversionary feeding only should be used during shorter periods to avoid the negative consequences (e.g. increased carrying capacity, higher wild boar densities) (Andrzejewski and Jezierski, 1978; Calenge et al., 2004; Oja et al., 2014).

To further investigate the effects of the feeding station in relation to damage levels in the agriculture landscape, more detailed and inclusive data must be collected. Analysing timing of spreading, type of forage together with the movement patterns and distances to attractive crops, could give a clearer indication about how diversionary feeding is affecting agricultural damage.

In conclusion, I want to emphasize the importance of using more than one preventive method to efficiently minimize wild boar damages on agricultural crops. Because even when fencing, and disturbance is effective on the fields where it is performed, it could lead to an extended amount of damage on other fields and because of this, the overall harvest and damage percent do not change remarkably (Lemel, 1999).

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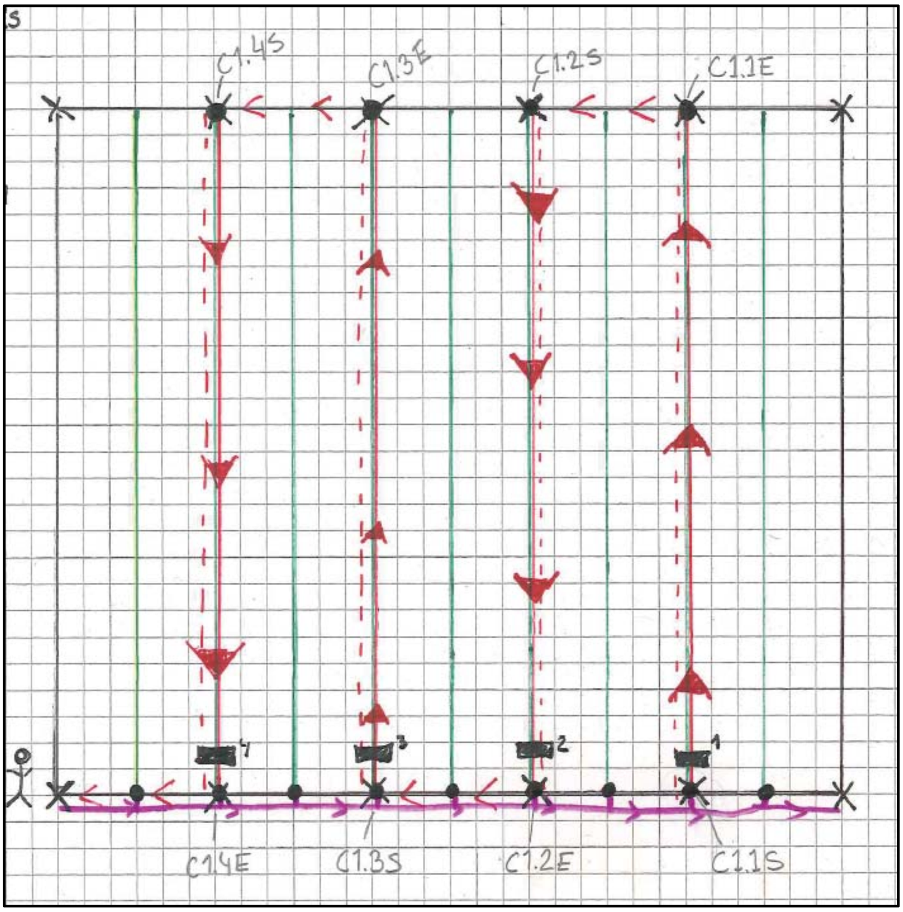
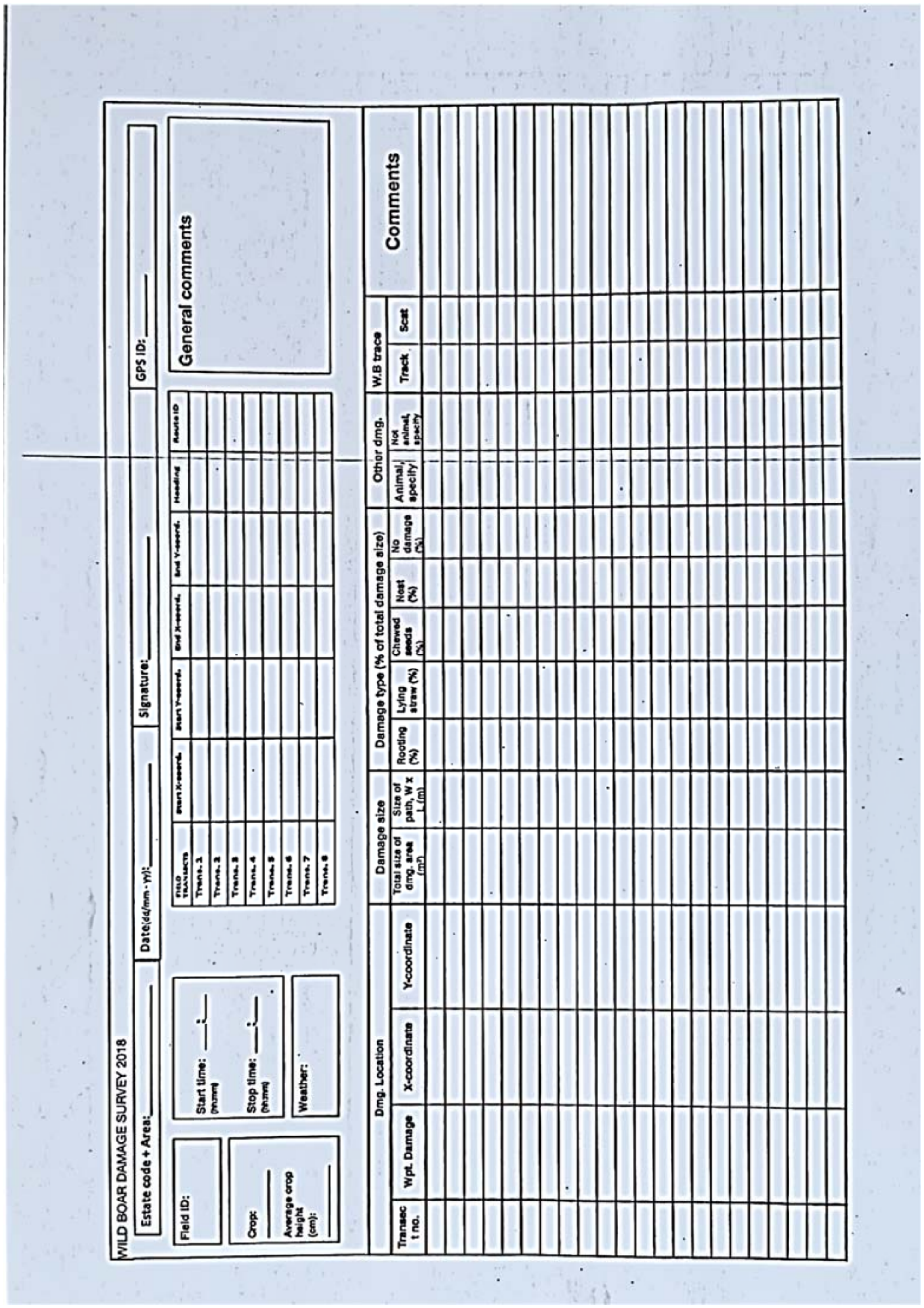
Appendix 1



Appendix 2



WILD BOAR DAMAGE SURVEY 2018

Estate code + Area: ____ Date(dd/mm - yy): ____ Signature: ____ GPS ID: ____

Field ID:

Crop: ____

Average crop height (cm): ____

Start time: (hh:mm) ___:___

Stop time: (hh:mm) ___:___

Weather:

FIELD TRANSECTS	Start X-coord.	Start Y-coord.	End X-coord.	End Y-coord.	Heading	Route ID
Trans. 1						
Trans. 2						
Trans. 3						
Trans. 4						
Trans. 5						
Trans. 6						
Trans. 7						
Trans. 8						

General comments

Transect no.	Wpt. Damage	Dmg. Location		Damage size		Damage type (% of total damage size)					Other dmg.		W.B trace		Comments
		X-coordinate	Y-coordinate	Total size of dmg. area (m²)	Size of path, W x L (m)	Rooting (%)	Lying straw (%)	Chewed seeds (%)	Nest (%)	No damage (%)	Animal, specify	Not animal, specify	Track	Scat	

Appendix 3

SKRÄMSEL/SKYDDSJAKT

Hagbyberga, Broby, Valinge

WB= Vildsvin, FD= Dovhjort, RD= Kronhjort, M= Älg

Datum *DD/MM*	Fält-id	J/S Jakt/ Skrämsel	Specificera åtgärd *Hund, bil, jakt m.m.*	Art **WB, FD m.m.*	Antal individer			Starttid	Stopptid	Observatör	Kommentar
						Adulta	Juvenila				

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