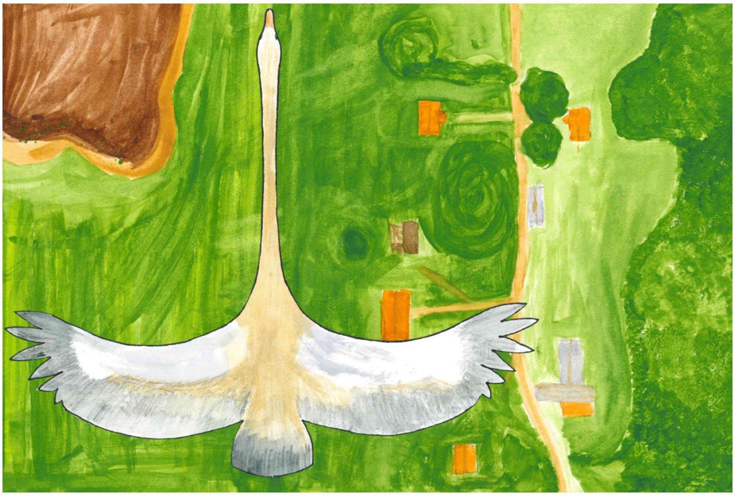
Push and pull strategies

Behaviour of geese in relation to scaring and set-aside fields

MALIN TERÄVÄINEN



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in relation to scaring and set-aside fields

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Abstract

Geese have been increasing in numbers in Europe during the last decades. They forage in agricultural landscapes and may cause damage to sensitive crops. Scaring and set-aside fields are two commonly used methods to alleviate damage by "pushing" geese from sensitive fields and "pulling" them to areas where they don't cause damage. I investigated field selection and the utilization of a set-aside field, as well as the effect of two scaring measures on behaviour of greylag geese (*Anser anser*) in two areas in south central Sweden. I concluded that the set-aside field was generally selected more than other fields during spring and summer, but not during fall. In addition, an increased field selection with a decreasing distance to roost was found. GPS data from tagged greylag geese were compared before and after scaring. After one hour scared geese were on average 1146 meters (95% C.I. 843 - 1449) away from the scaring location. The number of positions in close vicinity to the scaring location ("return rate") decreased significantly during at least 48 hours after scaring. Geese scared by walking had a slightly higher probability of returning than if scared by a drone. Geese also showed a significant shift in habitat use, from cropland to wetland the first four hours after scaring, but then returned to arable land. I conclude that scaring can work as a "push strategy". However, scaring is not a full solution at the landscape level, as geese continue to forage in other fields soon after a scaring event. A combination of scaring and areas such as set-aside fields, where geese can graze undisturbed without causing damage, are therefore important to avoid just "moving the problem around".

Keywords: *Anser anser*, behaviour, conservation conflicts, crop protection, sacrificial crop, wildlife damage management

Skadeförebyggande åtgärder - beteende hos gäss i förhållande till skrämsel och avledningsåkrar

Sammanfattning

Gäss har ökat i antal i Europa under de senaste decennierna. De söker föda i jordbrukslandskap och kan orsaka skador på känsliga grödor. Skrämsel och avledningsåkrar är två vanliga metoder för att minska skador genom att skrämma ("push") gäss från känsliga åkrar och locka ("pull") dem till områden där de inte orsakar skada. I den här avhandlingen har jag studerat fältval och nyttjande av en avledningsåker i relation till andra konventionellt odlade fält samt hur skrämsel påverkar beteendet hos grågäss (*Anser anser*). Studierna utfördes i två områden i Mellansverige. Avledningsåkern användes generellt sett mer än andra fält och sannolikheten att ett fält skulle besökas av gäss minskade med avståndet till övernattningsplatsen. GPS-data från märkta grågäss jämfördes före och efter skrämsel visade att gäss en timme efter skrämsel i genomsnitt befann sig 1175m 1146 m (95% C.I. 843 -1449), från platsen där de skrämdes. Antalet positioner nära skrämselplatsen ("return rate") minskade upp till 48 timmar efter skrämsel. Gäss som skrämdes av en människa hade en högre sannolikhet att återvända än om de skrämdes med en drönare. Gäss visade också en betydande preferens för våtmark direkt efter skrämseln. Jag drar slutsatsen att skrämsel fungerar men är i sig inte en lösning på landskapsnivå, då de fortsätter att söka föda på åkermark. Därför behövs avledningsåkrar där gässen inte gör skada. I min avhandling visar jag att om man tar hänsyn till viktiga faktorer kan avledningsåkrar vara attraktiva och avlasta känslig gröda. Tillsammans kan dessa två åtgärder vara en framgångsrik förvaltningsstrategi.

Nyckelord: *Anser anser*, beteende, naturvårdskonflikter, förebyggande åtgärder, grödoskador, viltförvaltning,

Dedication

Till mig.
Till Rasmus, katten,
mamma och pappa

Vi lever våra dagar så som vi lever våra liv.

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Teräväinen, M., Elmberg, J., Tennfors, C., Devineau, O., Mathisen, K-M., Månsson, J. (2022). Field selection of greylag geese (*Anser anser*) - implications for management of set aside fields to alleviate crop damage. Ornis Fennica, (submitted manuscript)

II. Teräväinen, M, Elmberg, J., Million, W., Andrén, H., Månsson, J. Return or not return – scaring geese off crops, how efficient is it? (manuscript)

1. Introduction

Competition and interactions between humans and wildlife have existed for as long as we have shared space. With the expansion of human land use these interactions are increasing and causing more and more conservation conflicts as natural habitats for wildlife turn into for example agricultural land or cities. We need to combine and consider the interests of multiple stakeholders and listen to many voices while speaking for the interests of wildlife. This is not an easy task. To gain a better understanding it is important to gather as much knowledge from as many angles as possible. The voice of wildlife is according to me one of the most important, since they cannot speak for themselves. Attempting to understand the language of geese is challenging and needs methods like the ones used in this licentiate thesis. We cannot simply ask, so we need to observe and interpret what we see. Combining observations with previous knowledge is our best chance to understand and manage geese.

This thesis focuses on interactions between humans and greylag geese in the agricultural landscape of Sweden. I wanted to gain more knowledge about the behaviour of geese, and to manage situations where interactions are not positive for all as when large flocks of geese are causing damage by grazing on agricultural crops. The two studies consider field selection of greylag geese and their use of a set-aside field, and the reactions of greylag geese when scared by two measures in areas agricultural fields. The results can be used to prevent crop damage.

1.1 Human-wildlife interactions and conservation conflicts

As a response to a rapid increase of the human population during the last century interactions between wildlife and humans have increased remarkably (Decker and Chase, 2016; Michalski et al., 2006). Humans and wildlife more often share land now than in the past and one of the challenges is to maintain a balance between human land use and conservation (Conover, 2001; Messmer, 2009; Soulsbury and White, 2015). Wildlife provides both ecosystem services such as food and recreation e.g., birdwatching or hunting (Soulsbury and White, 2015), but also disservices in terms of damage to human livelihoods, vehicle collisions, injuries or even death (Choudhury, 2004; Treves and Naughton-Treves, 1999). Such disservices can cause conservation conflicts i.e., conflicts between societal interests such as conservation and land use (e.g., forestry and agriculture) (Redpath et al., 2013).

As early as in ancient cave paintings there is proof of attempts to reduce damage caused by wildlife, e.g. people guarding crops and livestock (Conover, 2001) and native Americans using traps to kill wolves competing for prey. To scare away birds from crop, native Americans constructed platforms from which it was easier to throw stones at birds (Conover, 2001). Trapping and poisoning of wildlife, then considered pest species, were frequently occurring in the US up until the 1970´s when a number of large carnivores became protected by law (Conover, 2001; Linnell et al., 2001).

Today mitigations involve several different measures to reduce conservation conflicts and they are often both a way to increase public acceptance and reduce negative attitudes towards wildlife, as well as reducing impacts and damage (Conover, 2001). Examples of measures are barriers, sounds, repellents, scaring, lethal measures, and translocation (Fox et al., 2017; Linnell et al., 1997; Widén et al., 2022). Another strategy is to compensate for damage or provide means for preventive measures (Fox et al., 2017; Hake et al., 2010).

Scaring, is a measure commonly used for many different species (Conover, 2001) to "push" wildlife from damage prone areas. For example, human presence in combination with shouting, drumbeating, noisemaking, use of firecrackers, lights, and torches are used to keep crop raiding mammals and birds out of fields (Fernando et al., 2008; Knight, 2000; Tombre et al., 2005). Dogs are used to chase off problem bears and to keep birds from airports (Beckmann et al., 2004; Carter, 2000). Auditory scaring such as distress calls from crows has been used to keep conspecifics away from corn fields (Naef-Daenzer, 1983) and recorded predatory sounds to successfully reduce crop damage by ungulates (Widén et al., 2022). Loud bangs, predator sounds, human or sounds played to mimic the sound of an angry beehive are other examples (Goodrich and Buskirk, 1995; Hoare, 2012; Treves et al., 2009). Scarecrows, flags, and predator effigies are used to scare birds (Bishop et al., 2003; Parrott and Watola, 2008).

However, only focusing on removing wildlife by scaring will just move the problem around if no areas where they can feed undisturbed are available (Hake et al., 2010). Potentially this also results in reduced welfare in wildlife with no space to be undisturbed. Creating areas attracting ("pull") wildlife and where they don't cause damage and are left undisturbed, for example nature reserves or managed set-aside fields, is another strategy to reduce damage and conflict (Hake et al., 2010; Koffijberg et al., 2017; McKay et al., 2001; Nilsson et al., 2016; Tombre et al., 2013). Lethal control or fertility control are often used as a last resort to problems that are hard to solve in another economical and efficient non-lethal way (Conover, 2001; Månsson, 2017).

1.2 Geese and agriculture

A group of wildlife increasing in numbers and creating conflicts are geese (*Anserinae*). Intensive modern farming with large areas of monoculture grassland and fall sown crops is creating high availability of quality food all year around and seems to be one of the reasons why some goose populations have expanded and increased in the last centuries (Fox et al., 2010, 2017; Fox and Madsen, 2017; Nilsson, 2016). This in combination with decreased hunting and restoration of wetlands used by geese as roost sites has led to superabundant populations in certain areas (Fox et al., 2010). When foraging in agricultural fields, geese can cause severe damage and conflicts between different societal interests (Fox et al., 2017). In Sweden, damage on agricultural crops due to geese has increased during the last 20 years (Frank et al., 2021; Montràs-Janer et al., 2019).

1.3 Measures used to prevent damage

To mitigate crop damage and conflicts caused by geese several measures are used, such as barriers (fences), repellents, scaring, lethal control and refuge areas (Fox et al., 2017). According to some, a combination of different scaring measures that are varied over time to reduce the risk of habituation and scaring in proximity to refugee areas or set-aside fields are most efficient (Bishop et al., 2003). Several studies point out the importance of protected and undisturbed areas, for example as set-aside fields, in proximity to areas where scaring is taking place to reduce the risk of just pushing the birds around (Simonsen et al., 2016; Vickery and Summers, 1992). To scare geese away from sensitive crop and use set-aside areas to attract them could be compared with the terminology used in insect pest management, where attraction, i.e., “pull”, and a component of repellent, i.e., “push” (Cook et al., 2007).

1.3.1 Scaring

Several measures to scare geese from sensitive crop are used, such as human presence, silhouettes and acoustic scaring such as gas cannons, distress calls and screamer shells (Fox et al., 2017; Smith et al., 1999). Laser and dogs have been used to keep Canada geese off airports (Blackwell et al., 2012; Carter, 2000). Measures such as flags, ribbons or kites in the fields are used and considered cost efficient and require little effort (Mason et al., 1993; Mason and Clark, 1994; Parrott and Watola, 2008).

Understanding the mechanism behind behaviours as well as acknowledging ecological theories such as optimal foraging (that animals strive to maximize their nutritional benefits while foraging), is of help when trying to understand behavioural responses to scaring (Conover, 2001; Greenberg, 1989). If the landscape available to a goose includes fear and danger, there is a threshold when the nutritional benefits do not overcome the energy spent avoiding the danger (Sinervo, 2013). The individual goose in the agricultural landscape needs to make decisions based on predation risk and the maximum benefits of foraging. Geese perceive scaring as an attempt of predation that should be avoided (Boissy, 1995). Fear might be experienced because of the physical characteristics of the fear-producing stimuli's presentation, with the aim to mimic predators or human shapes such as scarecrows or painted eyes. It might also be due to the movement, proximity, intensity and duration (Boissy, 1995). Avoiding predation and reacting to movements or silhouettes related to predators is an innate behaviour with adaptive differences depending on which predators are present in the area (Gould and Marler, 1987). When it comes to predators such as large birds of prey, canids or humans, which are common threats to geese, they probably learn to react to different types of predators by observing their conspecifics (Gould and Marler, 1987). The combination of terrestrial and airborne predators makes it necessary for geese to be vigilant both towards the surrounding ground and the sky. Like most animals, geese are neophobic, reacting with fear through a cognitive assessment to novel stimuli, and making decisions based on their surrounding being novel or dissimilar to their previous experiences (Greenberg, 1990; Greggor et al., 2015).

1.3.2 Set-aside fields

Many studies point out the importance of protected and undisturbed areas near where scaring is taking place to reduce the risk of just pushing the birds around in the landscape, creating problems in neighbouring areas (Simonsen et al., 2016; Vickery and Summers, 1992). Set-aside fields (also referred to as lure crops, alternative feeding areas, sacrificial crops, diversionary, or accommodation fields in the literature) are an example of a measure that is used and recommended (Hake et al., 2010; Koffijberg et al., 2017; Tombre et al., 2013; Vickery and Gill, 1999). In some cases farmers receive governmental subsidies to actively lure geese to selected fields by cultivating attractive crops (Koffijberg et al., 2017; MacMillan et al., 2004). When cultivating sacrificial crops for geese it is important to keep in mind that their field selection may also change between seasons. The nutritional demands of geese change over the year, as does the availability of different food types (Fox et al., 2017; Jensen et al., 2008; Newton and Campbell, 1973). Hence, focusing on crops that are attractive to staging migratory birds at different times of the year will add to the success of set-aside fields (Fox et al., 2017).

1.4 The greylag goose

The greylag goose (*Anser anser*) is one of the most common geese in Europe and Sweden, and it is known to cause crop damage (Montràs-Janer et al., 2020). Some of the most utilized crops are ley and pasture (Strong et al., 2021). In recent time the species has shifted from being largely migratory, wintering in the southern parts of Europe and breeding in the northern parts, to now migrating shorter distances or staying in southern Sweden all year around (Månsson et al., 2022). Breeding takes place in spring; greylag geese lay 5 – 8 eggs in large nests near water (Scheiber and Weiß, Brigitte M. Hemetsberger, Josef Kotrschal, 2013; Young, 1972). The goose family remains together for much of the first year and migrate as a group within a larger flock. Yearlings stay with their parents until the next breeding season (Scheiber and Weiß, Brigitte M. Hemetsberger, Josef Kotrschal, 2013).

Greylag geese are obligate herbivore grazers and prefer short grass such as pasture or meadows even though they also eat grain, root crops, and leafy vegetation (Nilsson and Kampe-Persson, 2013; Olsson et al., 2017; Scheiber and Weiß, Brigitte M. Hemetsberger, Josef Kotrschal, 2013). The high daily energy requirements of geese are met by feeding on agricultural crops, which are plentiful and nutritious. This reduces their foraging time compared to foraging on natural vegetation (Fox et al., 2017). They seem to prefer cultivated crops more than natural vegetation and are not site specific, rather selecting specific crops (Scheiber and Weiß, Brigitte M. Hemetsberger, Josef Kotrschal, 2013). According to studies in the south of Sweden greylag geese feed mainly on grassland in the summer period and stubble and newly sown cereals and sugar beets in fall and winter (Nilsson and Kampe-Persson, 2013; Nilsson and Persson, 1992; Strong et al., 2021). Feeding takes place mainly in the morning and in the afternoon and daily feeding time increases before migration (Nilsson and Persson, 1992). The low nutrient content of grass and the simple inefficient digestive system of geese force them to maximize their feeding intake and they can spend up to 80 % of the day foraging (Scheiber and Weiß, Brigitte M. Hemetsberger, Josef Kotrschal, 2013). Greylag geese can live until 20 years of age (Lorenz, 1991). Known airborne predators are raptors (*Accipitridae*) but also corvids (*Corvidae*) on eggs and goslings and terrestrial predators are dogs (*Canis familairis*), foxes (*Vulpes*), wild boar (*Sus scrofa*), and humans (*Homo sapiens*) (Lorenz 1991).

1.5 Objectives

The aim of the studies in this thesis was to investigate how greylag geese respond to measures to decrease damage on agricultural fields. More specifically:

Paper I

Aimed to provide insights about 1) field selection of greylag fields in relation to crop types, distance to roost site and season and 2) whether a can a well-managed and "goose-friendly" field attract geese to a higher extent than vulnerable conventional crops?

Paper II

Aimed to study how scaring by approaching geese with a drone or walking affects the behaviour of individual geese in terms of return rate and habitat use.

2. Material and Methods

2.1 Study areas

The field work and data collection for this thesis were carried out in the south-central parts of Sweden (Fig 1). The goose counts in paper I were performed in Sörfjärden and the scaring trials in paper II were performed in Kvismaren. Both areas are protected by the Ramsar Convention (SPA) and the Habitat Directives (Nilsson, 2016; Ödman et al., 2013).

2.1.1 Sörfjärden

The fieldwork of paper I was carried out 2010-2012 in the surroundings of lake Sörfjärden (59°25´N/16°46´E; Fig 1). The protected area is 209 hectares and the surrounding landscape consists of agricultural land and forests. The agricultural land is used for intensive farming of mainly cereals such as wheat, oats, barley, and rye, but also grass for hay and silage, potatoes, and oil rapeseed. Crops are sown in both fall and spring.

The growing season lasts from April to September. Harvest takes place from late June (ley fields) to September (ley, cereals, potatoes, and rapeseed). Fall sown growing crop in spring, such as wheat and ley fields are most sensitive to damage by geese. The area hosts a generally rich birdlife and many breeding species. The number of greylag geese at Sörfjärden in September varied between 1200 and 5000 in 2007-2012 (mean 4060 individuals, mainly non-local staging birds) according to local counts (Ödman et al., 2013). The number of breeding greylag geese at Sörfjärden was estimated at an average of 175 pairs in 2007-2009. A total of 21 573 greylag geese were counted in the surveyed fields during the three years of study, with peaks in April and

September. In most cases (92%) there were not any geese on the surveyed fields.

2.1.2 Kvismaren

In Paper II the fieldwork took place in Kvismaren (59°10′N/15°22′E; Fig 1). The area encompasses two shallow, eutrophic lakes (2.5 kilometres apart) surrounded by narrow belts of grazed wetlands (Nilsson, 2016). The protected area is 732 hectares. The surrounding landscape is flat and mainly farmland (~66%) that produces mostly cereals, grass, and potatoes. Most crops are harvested from August to October, depending on weather conditions and crop type (Nilsson, 2016). Each year approximately 200 bird species are recorded in the area. Among them several species of geese such as bean goose (*Anser fabalis*), Canada goose (*Branta candensis*), barnacle goose (*Branta leucopsis*), greater white-fronted goose (*Anser albifrons*), and pink-footed goose (*Anser brachyrhynchu*s). Greylag goose is the only goose species breeding in large numbers. They arrive in the area in March and leave in early October. The GPS tagged greylag geese scared in this study were local breeders, but the flocks of which they were part most likely also included moulting and staging visitors.

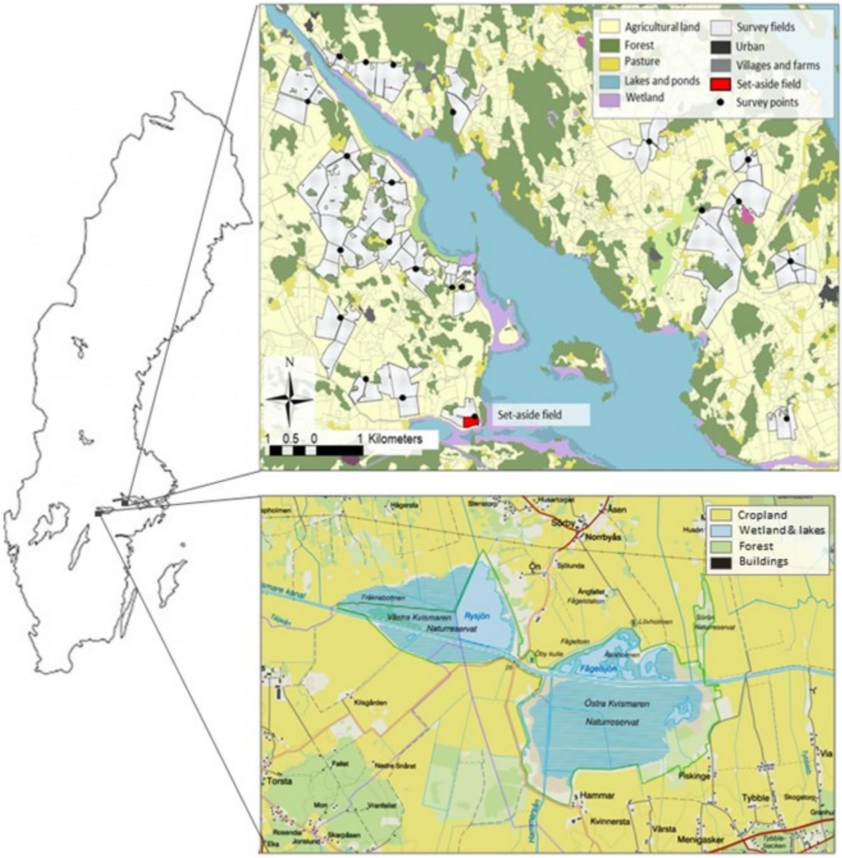

Figure 1. Map of the study areas. In the top map (Sörfjärden - paper I) white polygons shows the surveyed fields and the red polygon is the set-aside field. Black circles show the survey points from which geese were counted. The bottom map shows Kvismaren Nature Reserve (paper II). Adopted from Topografisk webbkarta Visning © Lantmäteriet 2020.

2.2 Data on crops and habitats

Data on field size in paper I and on crop type for both paper I and II were obtained from the database "SAM" provided by the County Administrative boards (Södermanland and Örebro), and the Swedish Board of Agriculture. This database builds on farmers´ annual reports of used crop type for obtaining EU and government subsidies (in accordance with the European Common Agriculture Policy (CAP)). For paper I, I pooled crop types to obtain eight categories for my analyses (wheat, barley, rye, rapeseed, oats, set-aside, grass, and other). Potatoes, linseed, fallow land, and mixed cereal were merged into the category 'other' and pasture, ley, meadows, and mowed pasture into the 'grass' category. For paper II land cover types were classified into two habitat categories: cropland and wetland habitat (inland water and open wetland). In paper II I linked the GPS positions of tagged geese with land cover data (Swedish Environmental Protection Agency) for the analysis of habitat use. Two habitat classes were used, cropland and wetland. GPS positions in other types of habitat types such as roads, built-up areas, and forest were rare (6648, i.e. 0.03% of all positions) and they were removed.

2.3 Paper I

2.3.1 Management of the set-aside field

The set-aside field was established in March 2010 with the aim to attract greylag geese and reduce crop damage, particularly during spring when most damage occurs to fall-sown cereals in the area. The location of the set-aside field was based on previous observations, indicating that this specific field was used by many foraging geese. The size of the field is 5.7 ha, and it was sown with a seed mix containing 25% alfalfa (*Medicago sativa*), 23% timothy (*Phleum pratense*), 15% bird's-foot trefoil (*Lotus corniculatus*), 12% meadow fescue (*Festuca pratensis*), 10% white clover (*Trifolium repens*), 10% chicory (*Cichorium intybus*), and 5% caraway (*Carum carv*i). Manure fertilizer was applied in spring every year. The field was managed by harvesting to keep the grass sward low, i.e. in accordance with preference by geese (0-10 cm, Strong et al., 2021). In 2010, the set-aside field was harvested in August. In 2011 it was harvested in June, July, and August, and in 2012 once in June (Ödman et al., 2013, 2012, 2011).

2.3.2 Data analysis

My aim was to relate the probability of goose presence to the explanatory variables field size, crop type, and distance to roost. I measured distance to water from the center point of each field to the nearest water edge by using

the function “Near” in ArcGIS version 10.5. The distance from surveyed fields to the surrounding roost sites varied from 150 to 3100 meters.
Presence (1) or absence (0) of greylag geese was used as a binary response variable, whilst field and landscape characteristics were explanatory variables (see Paper I). To estimate relationships between the presence of geese and field characteristics (crop type, distance to roost, and field size) I used multiple regression analysis, with season added as covariate. I also grouped data into three seasons: spring, summer, and fall.

Field id was set as a random factor to account for dependency of repeated observations within individual fields (Zuur et al., 2010). The response variable was over-dispersed with an excess of zeroes, so I used a zero-inflated binomial model with a logit link function, in the glmmTMB package (Bolker, 2019) in program R (R Core Team, 2021). I used the Akaike Information Criterion (AICc) for small sample size for model selection. ΔAICc values were used to compare the relative support of candidate models with a cut-off at <2. I also used the conditional R-square (Nakagawa et al., 2017) as a measure of the overall model fit. To explore the relative importance of variables I used model averaging (Symonds and Moussalli, 2011).

2.4 Paper II

2.4.1 Goose tagging and GPS data

In June 2017—2019 breeding and moulting greylag geese (N=32) were caught on meadows and pastures near water. In addition to classical tarsal metal rings, geese were provided neckbands fitted with solar powered GPS tracking devices: Ornitela (OT-N35 and OT-N44). Out of the 32 individuals, 4 were juveniles and 28 adults, 13 were females and 19 males. All catching, and handling was done according to permits from the Animal Ethics Committee of Central Sweden (permission # 5.8.18-03584/2017).

For the present study I used GPS positions from 48 hours before to 48 hours after each scaring event of an individual. The default positioning rate was set to one every 30 minutes (i.e., in total 192 positions per scaring event). In addition, I tracked the geese more intensively (one position every 5 minutes) from four hours before to four hours after each scaring event (i.e., 128 positions per scaring event). This intensive and real-time positioning allowed us to find a certain goose individual targeted for a scaring trial and to follow its movements before and after scaring.

I calculated the distance from the scaring position to each GPS position before and after scaring but excluded positions > 7000 meters away to avoid those where geese were outside the Kvismaren study area. Return rate was calculated in ArcGIS version 10.5 as the number of positions inside a radius of 300 meters from the scaring position. Field size in the study area ranges from <1 to 72 hectares and the 300 meter radius is assumed to mirror the size of most of the fields (average field size is 5 hectares i.e. 200*250m) (Nilsson, 2016).

2.4.2 Scaring events

In total 299 scaring events were performed from March to September: 76 in 2018, 75 in 2019, and 148 in 2020. A specific goose was not targeted for scaring more than once every fifth day, so that I could study its behaviour 48 hours before and after scaring. On average geese were scared 9 times (min 1, max 15). Scaring took place between 03:30 AM and 20:00 PM and targeted only geese actively feeding in an agricultural field and outside the boundaries of any protected area.

The OrniTrack Control Panel portal provided by (https://www.ornitela.com/) was used to find the last recorded GPS location of a target goose on a given field before a scaring event took place. This defined the 'scaring position' and it was used as the starting point for subsequent spatial analysis. The targeted goose was found by car. Before starting a scaring event we randomly selected measure (drone or walking human) and counted the number of conspecifics and other goose species in the flock (flock size averaged 508 birds; range min 1 - max ~10,000).

When using the drone, it was flown in a straight line towards the target goose, at a speed of 50 km/h and an altitude of 10 m. The top speed of the drone used in slow mode is 50 km/h and it was used to standardize the speed for all trials. The altitude was based on an estimation of vegetation height and probable maximal visibility for the geese to see the drone. Scaring by

walking was conducted by approaching the flock of geese in a straight line, by keeping a normal walking pace.
In my analysis I compared presence of geese (if and when they returned and what habitat they used) before and after a scaring event. The number of positions before and after scaring for the different time periods = -1 to 0-48 hours) were in general 50 % for each period (min 49 % max 51%) and therefore data from the period before was used as a control to compare with the positions after a scaring event.

2.4.3 Data analysis

I used logistic regression to test the effect of scaring on return rate and habitat use. For this, I classified all GPS positions before scaring as 0 and all GPS positions after scaring as 1. As I have more or less the same number of positions before and after scaring, a value of 0.5 indicates similar probability of use of either habitat type before and after scaring. A probability value higher than 0.5 indicates higher use after scaring, whereas a value less than 0.5 indicates lower probability of use after scaring. Therefore, I compared probabilities of use in the same habitat before and after scaring, and not the probability of use between different habitats. I compared the number of positions before and after scaring and variables possibly affecting the probability of finding positions (scaring measure, season, and time of the day, season and time of the day were interacted with habitat).

I grouped data by season into spring (March and April, 23 098 positions), summer (July and August, 118 916 positions), and fall (September, 49 600 positions). I divided the GPS positions into six gradually larger sub-sets (time spans) of different duration: 0-1, 0-2, 0-3, 0-4, 0-24, and 0-48 hours before and after scaring. These time periods were nested inside one another; e.g., the data from the 1-hour period was included in the 2-hour period, and so on. However, only a subsample (every 30 min) from the shorter time periods was included in the 24_{before}+24_{after} and 48_{before}+48_{after} hour periods.

Distance

I estimated the average distance to the scaring position using time before and after scaring as a response variable in generalized additive models (GAMs, package gmvc in R (Hastie and Tibshirani, 1986), with the ID of unique events as random factor and time as a smoothed variable.

Return rate

I used generalized linear mixed models in the glmmTMB package (Bolker, 2019) in program R (R Core Team, 2021), the ID of unique scaring events, and ID of individual geese as random factors to account for variation among events for both the return rate and habitat analyses.

To assess the probability of geese returning to inside the 300-meter radius from the scaring position, I used GPS positions before (coded as 0) and after (coded as 1) the scaring event as a binomial predictor variable. I compared the probability of finding GPS positions outside (reference) and within 300 meters from the scaring position, respectively, in relation to scaring measure used (drone (reference) versus walking), season (fall (reference) versus spring or summer), and time of day when the scaring event took place (morning < 11 AM (reference) versus afternoon > 11 AM).

Habitat

I analysed the probability of finding geese in different habitats before and after scaring in the same way as return rate, using GPS positions before (coded as 0) and after (coded as 1) scaring as predictor variable (binomial) in relation to habitat (cropland (reference) versus wetland habitat), scaring measure, season, and time of day as response variables.

3. Results

3.1 Paper I

3.1.1 Factors influencing presence or absence of geese

Several factors influenced presence of geese in the surveyed fields. The best model to explain probability of goose presence included crop type, season, and distance to roost (conditional $R^2 = 0.42$). Field size was not included in the top ranked model. The probability of goose presence in the set-aside field was higher than for the rest of the crop types, but it also had a larger error with a higher uncertainty. There was a negative relationship between probability of goose presence and distance to nearest roost site. The top model showed that geese were more likely to be present in surveyed fields in spring than in summer and fall (Fig 2).

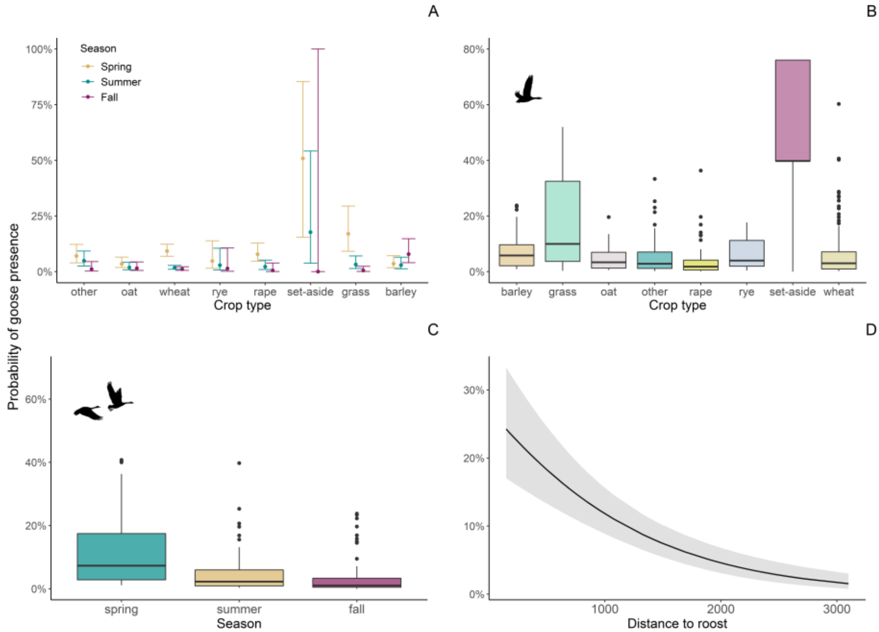

Figure 2. Predicted mean probability of greylag goose presence (y axis) in study fields based on the top-ranked model estimates, relative to crop type and season (A), crop type for all seasons (B), seasons (C), and distance to roost site (D). The error bars in the A, B, and C graphs and the grey area in D show confidence intervals (CI). Distance to roost site is held constant in the predictions to its mean (127.7 meters) in plot A, B and C, and for plot C barley is the crop type held constant.

3.1.2 Predicted probability of goose presence

To provide some relative results for comparison I here list//give//present some predicted probabilities of goose presences given different distances to roost site (150m i.e. representing fields close to roost and 1400m i.e. representing the mean distance). According to the top ranked model, the probability of goose presence on the set-aside field 150 meter from the roost site was predicted to be 0.68 (CI: 0.31-0.91) in spring. Grass fields had the second highest probability of 0.34 (0.21-0.49) and the category of other the third highest with 0.25 (0.15-0.37). At 1400 meters from the roost site in spring the probability of goose presence was highest at the set-aside field at 0.37 (0.11-0.74), second highest for grass at 0.13 (0.07-0.22) and third was wheat at 0.8 (0.06-0.10) together with other at 0.8 (0.5-0.16).

In fall, 150 meters from the nearest roost site, the predicted probability of goose presence on the set-aside field was 0.22 (0.6-0.58) and in summer for the same distance 0.35 (0.10-0.72). Grass fields were ranked second in fall at the same distance from the roost site and had a predicted probability of 0.07 (0.03-0.12) to host geese and 0.12 (0.07-0.20) in summer. At 1400 meters from the roost site in fall the set-aside was more likely to host geese at 0.07 (0.02-0,09), and grass was second at 0.02 (0.01-0.04). In summer at 1400 meter from the roost, set-aside had a predicted probability of goose presence of 0.13 (0.03-0.043) compared to the second highest probability for grass 0.04 (0.02-0.07).

3.2 Paper II

3.2.1 Distance

Geese were on average 557 meters (95% C.I. 269- 846) from the scaring position 10 minutes after scaring. After one hour they were on average 1176 meters (95% C.I. 863-1489) from it. After 1 - 2 hours' geese were at about the same distance from the scaring position as 3 – 4 hours before scaring (Fig 3). The predicted mean distance from the scaring position increased significantly with time after the scaring event (Fig 3, all $p < 0.05$).

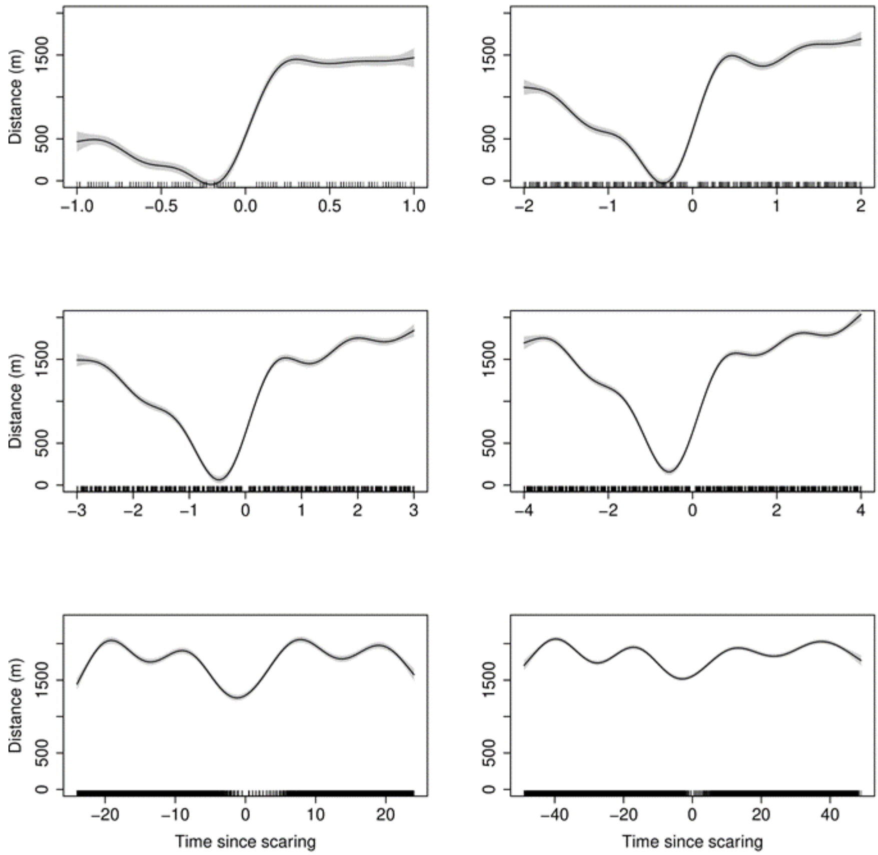

Figure 3. Mean distance (m) from scaring position (0). -1 to 1, -2 to 2, -3 to 3, -4 to 4, -24 to 24, and -48 to 48 hours before (-) and after scaring. Vertical lines along the abscissa show data points of individual geese. The different time periods are nested inside one another; e.g. data from the 1-hour period are included in the 4-hour period. However, only a subsample (every 30 min) from the shorter time periods was included in the 24 and 48 hour periods.

3.2.2 Return rate

The raw data show that the proportion GPS positions within the 300 m radius from the scaring position increased from 13% to 86% from 48 hours to 1 hour before scaring. After scaring only about 1% of the GPS positions were inside the 300 m radius and the effect lasted at least 48 hours after scaring.

Geese were significantly less likely to be found in the vicinity of the scaring position (<300 m) after scaring as compared to before scaring (i.e., all predicted probabilities were less than the expected 0.5, all $p < 0.001$). For a short period (0-1 to 0-4 hours after scaring), the return rate was significantly higher in scaring events where walking was used compared to drone events (i.e., positive coefficients for the effect of 'walking' compared with the reference 'drone', Fig 4, all $p < 0.05$). Time of day when scaring was conducted (morning versus afternoon) did not affect return probability in any of the time periods (all $p > 0.05$). In spring, the return rate after scaring was significantly higher than in summer and fall for the 24 and 48 hours' periods (i.e., positive coefficients for the effect of 'spring' compared with the reference 'fall', both $p < 0.05$, Fig 5).

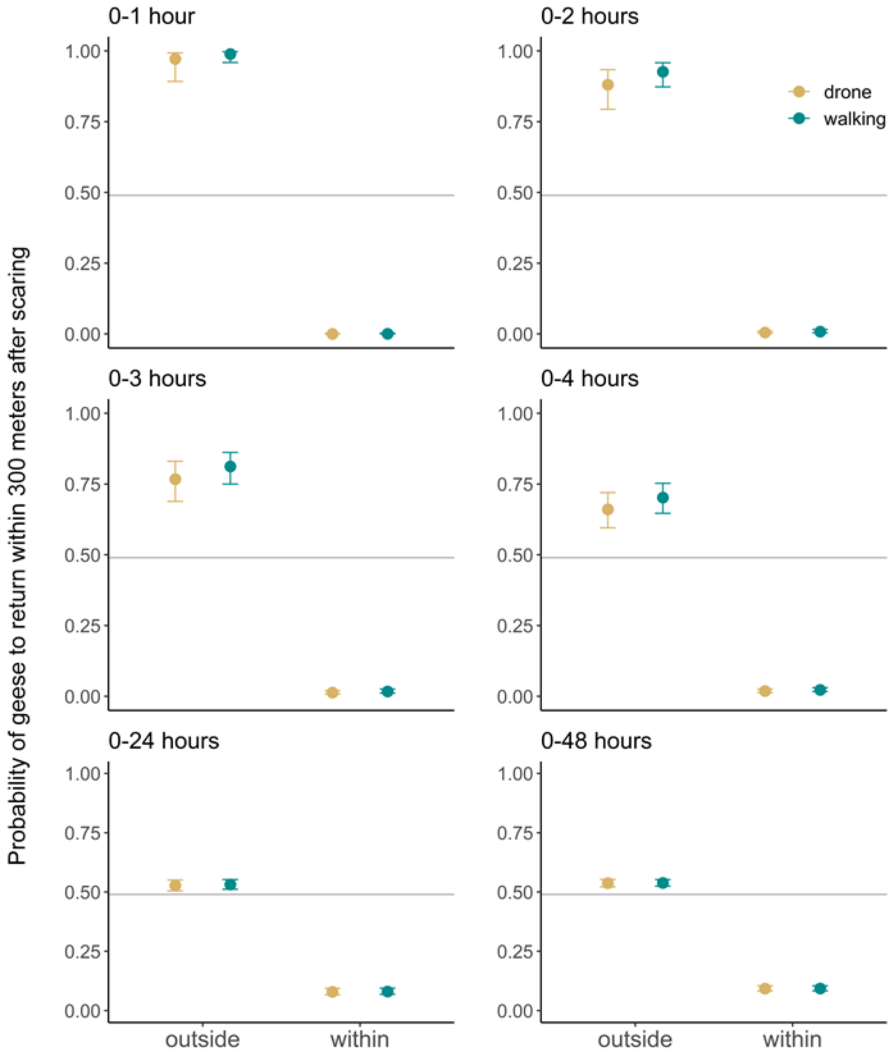

Figure 4. Predicted presence probability and confidence interval (95%) of geese being within or outside a radius of 300 meters from the scaring point, when scared by walking (blue) or by drone (yellow). Plots are shown for the time periods 0-1, 0-2, 0-3, 0-4, 0-24 and 0-48 hours after scaring. A probability of 0.5 (grey line) indicates a similar probability of use before and after scaring.

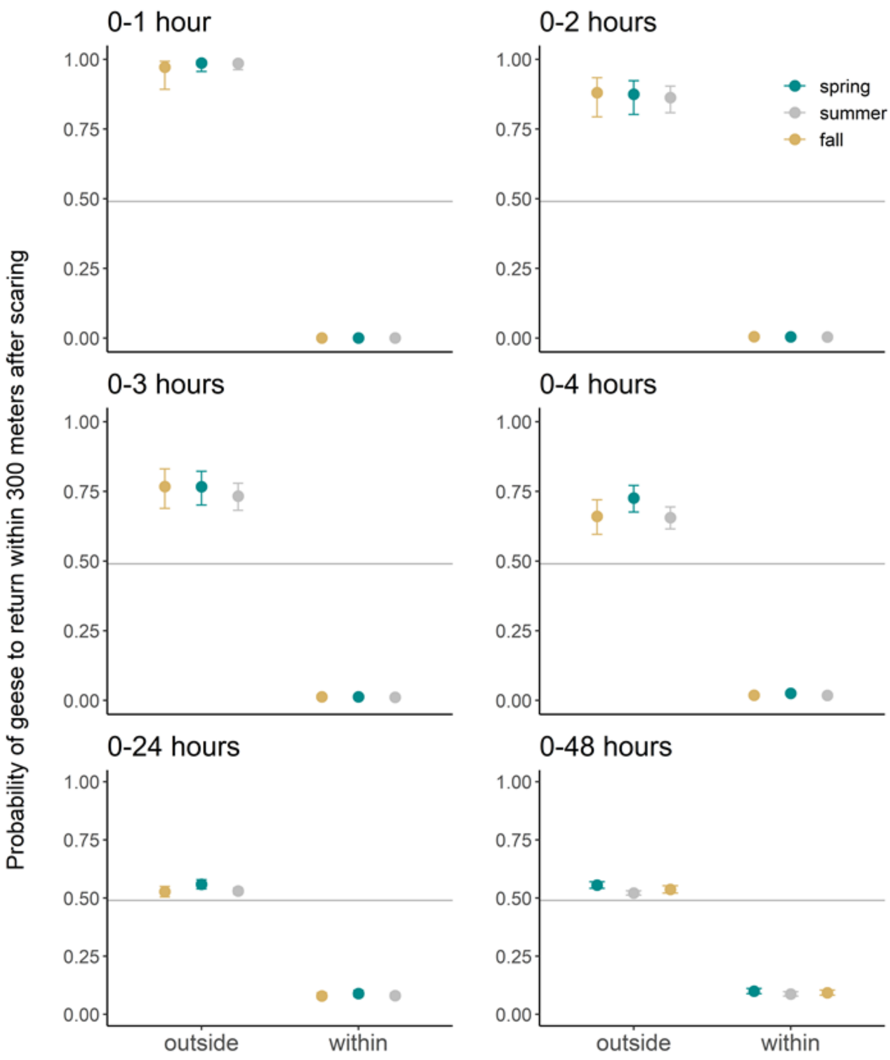

Figure 5. Predicted presence probability and confidence interval (95%) of geese being within 300 meters from the scaring point in different seasons: spring (blue), summer (grey), and fall (yellow). Plots show data for the time periods 0-1, 0-2, 0-3, 0-4, 0-24, and 0-48 hours before and after scaring. A predicted probability of 0.5 (grey line) indicates a similar probability of use outside the 300 m radius before and after scaring, as well as inside it before

and after scaring. The different time periods were nested inside one another; e.g., data from the 1-hour period were included in the 4-hour period.

3.2.3 Habitat

For a short time period after the scaring event (1- 4hours), there was a higher predicted probability that geese were in wetland habitat (probabilities higher than the expected 0.5) compared to cropland (probabilities lower than the expected 0.5). Also, there was a predicted long-term effect of scaring on habitat use for the opposite, cropland use over wetland (probabilities about 0.5 for the time periods 0-48). Scaring measure (‘walking’ versus ‘drone’) did not significantly affect habitat use after scaring for any of the time periods (all $p > 0.05$).

Geese were more likely to use wetland after being scared in the morning as compared to the afternoon for the time periods 0-2 to 0-4 hours (Fig 6, all p < or = 0.05). The difference between being scared in the afternoon versus in the morning was significant in spring, but not in summer and fall for the first hour, meaning that in spring geese scared in the morning were more likely to use wetlands after scaring than geese scared in the afternoon, compared to in fall and summer (Fig 6, all p < or = 0.05). The probability of using wetlands after being scared in the morning was significantly higher in fall than in spring for the periods 0-2 to 0-4 hours (Fig 6, all $p < 0.001$). There was not any effect on habitat use before versus after scaring for the longer periods, as indicated by probabilities close to 0.5 for 0-24 and 0-48 hours (Fig 6).

Being scared in the afternoon did not have an effect on habitat use compared to before scaring in spring for the periods 0-2 – 0-48 hours and in summer for the periods 0-3 – 0-48 hours (Fig 6). However, if scared in the afternoon the probability to use wetland rather than cropland after scaring was significantly higher in spring and summer 0-1 hour after scaring than before scaring (Fig 6, all $p < 0.05$).

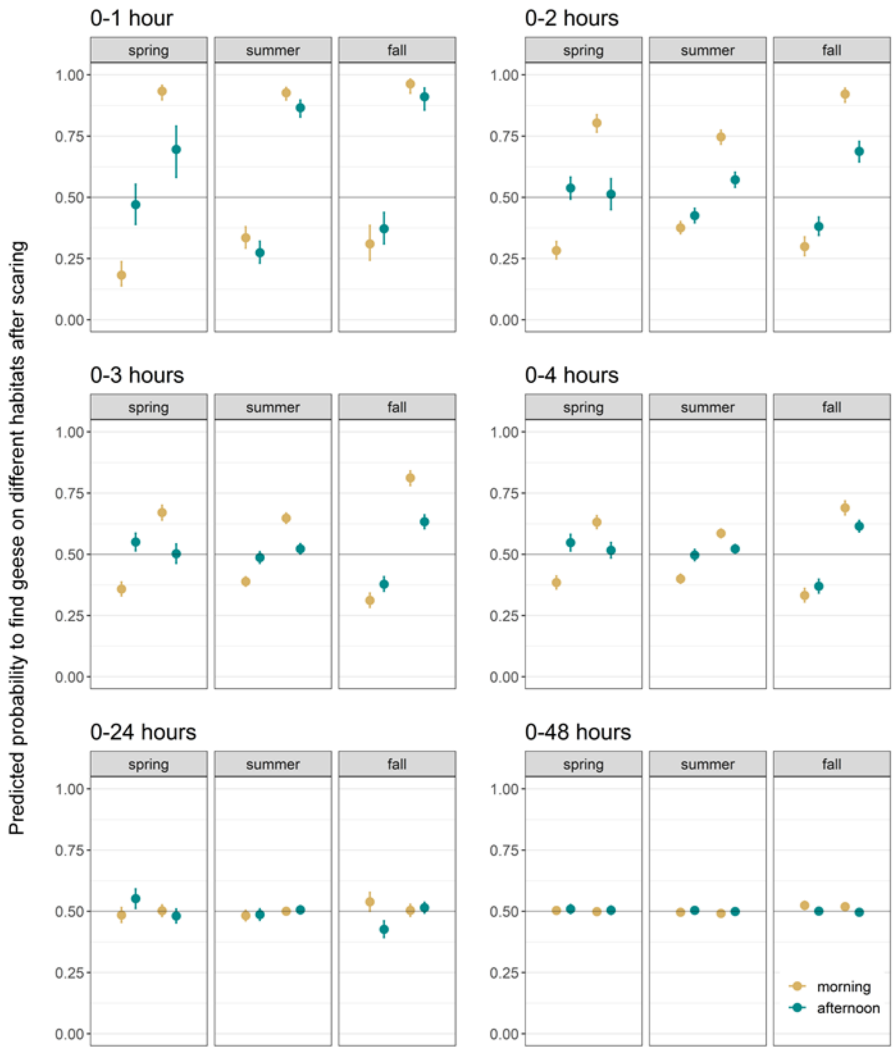

Figure 6. Predicted probability of GPS positions being on cropland versus wetland habitat 0-1, 0-2, 0-3, 0-4, 0-24, and 0-48 hours before and after scaring depending on whether scaring took place in the morning (<11 AM (yellow)) or in the afternoon (>11 AM (blue)) and in different seasons (spring, summer, and fall). A predicted probability of 0.5 (grey line) indicates a similar probability of use of cropland before and after scaring, as well as of wetland habitat before and after scaring.

4. Discussion

Goose numbers and their damage to crops continue to increase (Montràs-Janer et al., 2019), highlighting the need to find efficient preventive measures. However, there are few studies of the effect of measures for preventing crop damage. In my thesis I have considered two: scaring and set-aside fields, so called "push and pull" strategies.

My results show that the set-aside field in general was used more than other fields in the area during spring and summer but not during fall. Even though the set-aside was preferred compared to other available fields, it attracted only 28% of the total number of counted geese in the surveyed area during spring. Moreover, I show that experimental scaring by a drone or a walking person both caused a spatial displacement of greylag geese from the original agricultural fields, but only a short-term (1-4 hours) change in habitat use.
In other words, geese can be successfully pushed from specific fields but will soon use other cropland in the landscape after scaring. These results imply that areas such as set-aside field to pull geese from sensitive cropland are needed for successful scaring also on a landscape perspective.

Below I discuss these results further, how this knowledge is important to the understanding of geese, and to guidance of management.

4.1 Set-aside fields

My results show that field selection of foraging greylag geese in Sörfjärden is influenced by a combination of factors such as crop type, season, and distance from the roost site. This implies that all these variables need to be considered when deciding where to place and what agricultural practices to use when establishing set-aside fields. Though my study concerned only one set-aside field it still indicates that its management made it more attractive to geese than the adjacent conventional fields.

Undisturbed sites in the agricultural landscape where geese can forage have been pointed out as important for conservation purposes, but also to reduce damage and thereby manage possible conflict between conservation and agriculture (Bishop et al., 2003; Fox and Madsen, 2017; McKenzie, 2014). Previous studies have shown that set-aside fields can attract geese if managed in the right way; e.g. by ensuring short sward height, using a preferred crop, and by applying fertilizer (Aerts et al., 1996; Fox et al., 2017; Merkens et al., 2012).

In my study area, most damage from geese occurs in spring and early summer, during the early growth phase of many crops. Later in summer and in fall more stubble fields are available, where geese can feed without affecting unharvested fields. To make sure set-aside fields are as efficient as possible it is important to adapt crop type/forage to seasonal preferences by geese (Amano et al., 2004). The aim with the set-aside field in my study was to divert greylag geese from conventional fields in spring and early summer by using a seed mix of grass and herbs known, from practical experience, to attract geese. According to my results and in line with my prediction, the probability of goose presence was higher on the set-aside field in spring compared to the other seasons. This indicates that the management of this field was appropriate.

My study found a low predicted probability for greylag goose presence on grass crops, but higher than for barley and wheat. I also found a decreasing probability of goose presence with increasing distance to the roost site. In accordance with my result, McKay et al., (1996) and Amano et al., (2007) point out that the set-aside should be placed close to the roost and where disturbance from people is minimal. My field was managed to suit the foraging preferences of geese in spring. The type of crop, nutritional content, and crop stage are according to Fox et al., (2017) beneficial to consider, and Hassall and Lane, (2001) recommend fertilizing set-aside fields before arrival of geese.

Even though the set-aside was preferred compared to other available fields, it attracted only 28% of the total number of geese counted in the surveyed area during spring, and 12% for the whole period. One reason could be that food availability on the set-aside field was limited in relation to the number of geese present in the area, so that they needed to forage elsewhere. Additional set-aside fields evenly distributed within the study area may therefore be needed to attract a larger proportion of geese. Increasing the size of the existing set-aside field might be another way to divert a higher proportion of geese from conventional fields. The size of the set-aside field in relation to the overall number of geese in the area should therefore be considered Vickery and Gill, (1999). Scaring efforts to reduce goose presence in surrounding fields could decrease their attractiveness in relation to the set-aside field.

My study was based one set-aside field and one species. This might limit the generality of the results. However, I am confident that my findings still may be useful in terms of crop protection because: a) there are very few previous studies evaluating the effect of established set-aside fields and b) my results are largely in line with previous studies on field selection patterns by geese in general. I did not assess the actual damage level caused by goose grazing but is reasonable to assume that when geese are foraging in a field, they damage crops. Estimating and comparing damage levels could be an important next step to evaluate the effectiveness of preventive measures such as set-aside fields.

4.2 Scaring

To my knowledge this is the first study of the behaviour of individual geese to evaluate the effects of scaring them off cropland. I find that walking humans as well as drones approaching greylag geese can be used to displace them from a certain field. However, the scared geese continue to use cropland in the neighbourhood to the same extent 24 hours after scaring. I conclude that the two tested scaring measures are effective tools to displace targeted individuals at the field level, and for the individual farmer, but not at the landscape level. Several earlier studies conclude that scaring may decrease the number of geese in certain specific fields and sites, but that it is time-consuming and in most cases not a final solution for displacing them and mitigating crop damage, because the targeted fields soon are visited by geese again (Clausen et al., 2019; Jensen et al., 2016; Månsson, 2017).

Even though there were some differences between the effect of drones versus a walking person, the difference only lasted for less than 4 hours. There are still few studies on scaring birds using drones, but Wang et al., (2020) conclude that they can be efficient to scare birds from fruit crops. Moreover, Mulero-Pázmány et al., (2017) found that birds in general react stronger to drones compared to mammal carnivores, primates, and ungulates. On the other hand, Grémillet et al., (2015) found that wild flamingos (*Phoenicopterus roseus*) and common greenshanks (*Tringa nebularia*) in a wetland area were not disturbed by drones. I used a less advanced drone than Wang et al., (2017), but one that is affordable also to smaller farms. Even though the drone used by me had an effect comparable to an approaching person it may still be a time saving tool, as it quickly can reach geese far away and operate in places where it is not advisable to walk due to sensitive growing crops.

This study was conducted in a study area where several factors could affect the generality of the results. For example, the efficiency of scaring probably depends on the spatial composition of crops and crop stages in the landscape. When the availability of high-quality food is high, geese most likely are more prone to fly and find food elsewhere after being scared, compared to when good food is scarce and they might be more reluctant to leave the area. A similar scenario may apply in areas where available fields are fewer and smaller, that is, scaring may be less efficient because geese have no alternative foraging sites nearby. However, even though my study was limited to one area, the generality of my results is high in the sense that different seasons and many individuals were included. Studies covering other landscape types and species could be an important next step to evaluate the effectiveness of scaring.

4.3 Combined push and pull strategies and future perspectives.

I demonstrate that scaring local geese off agricultural fields by drones or walking are efficient measures at the field level. However, the measures used in our study did not have a lasting effect on habitat use. In other words, the scaring tends to just "move the problem" around' rather than solve it.
Therefore set-aside fields permitting undisturbed grazing are important to attract geese and pull them away from sensitive crop, particularly in areas where scaring is occurring (Jensen et al., 2008). Then it is important to make the fields as attractive as possible for geese by using crops suitable for seasonal energy demands, applying fertilizer, keeping the crop at a low sward height, and placing the set-aside as close to roost as possible.

In my case, the set-aside field was managed to attract geese, and scaring occurred on conventional fields, but still only 28 % of the geese were pulled in to the set-aside field during spring (when the set-aside field was most attractive). This indicates that even more effort is needed for a successful "push and pull" strategy and more studies are therefore needed to find efficient preventive measures. For example, in my studies a fairly simple drone model was used, and geese were approached at standardized speed and height. Future studies should investigate how drones can be developed and how geese should be approached to increase the effect. Furthermore, in my thesis I studied scaring and set-aside fields separately. To learn more and possibly increase the efficiency of the combined push and pull strategy, replicated scaring experiments with several set-asides in several study areas are needed. However, if goose populations continue to increase even more set-aside fields will be needed and more scaring effort. As long as we have geese within the agricultural landscape preventive measures will be needed, but a more long term solution as population control might also be important to consider to alleviate the conservation conflict.

5. Management implications

My thesis shows that both drones and walking can displace geese from a specific field. Scaring by drone is more time efficient and affects growing crops less than walking. My results and experience from previous studies imply that developing the drone scaring measure bears promise of making it even more efficient, especially if scaring events are repeated. Recent studies propose to increase the effect of scaring by equipping drones with fearful sounds or visual deterrents mimicking birds of prey (Wang et al. 2017). With the continued advancement of technology, drones encompass possibly limitless capacity for variation of disturbance patterns as a fully automated scaring device. Several studies have attempted to develop adaptive scaring devices (i.e., altering the timing and frequency of disruptive bioacoustics stimuli) using machine learning algorithms to recognize behaviour of specific bird species with video and audio-based detection systems (Steen et al. 2012b, 2012a, 2015). While still in the early stages of development, these systems offer a glimpse of promise of being combined with drone systems. Hypothetically, drones could perform automated 'patrol missions' around a field after strategically placed sensors have triggered detection algorithms for specific foraging species.

My results further show that geese seem to change foraging sites regularly. This means that even if we did not see a general return to the same field by the scared geese, other geese are likely to "fill the void" after them and repeated scaring can still be needed to prevent new geese from visiting the targeted field.

Field selection by greylag geese was influenced by several factors such as distance to the roost site, season, and crop type. This knowledge is important for both agriculture and management of geese. More specifically I show that ley during spring located in a field close to roost can help pulling geese from other crop in spring. The information can be used for informed decisions about where to place the set-aside field and when to grow what type of crop to attract geese. It can also be used as a strategy to reduce the number of geese on growing crop, e.g., placing sensitive crop far from roost sites. The combination of push (scaring) and pull (set-aside fields) is important as scaring alone just tend to “move the problem around”.

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Popular science summary

The number of geese has increased dramatically in Europe over the last 50 years. This is partly due to conservation efforts (reduced hunting, restoration of wetlands and creation of protected areas), but also to the development of agriculture since the 1950s and today's warmer climate. More intensive agriculture has resulted in an availability of quality food throughout the year. Geese are opportunists which move readily in the landscape. They have changed the way they seek forage, from natural areas to growing crop. With warmer climate, many geese tend to stay all year round in the southern parts of Sweden. Wetlands in the agricultural landscape are used by geese for roosting then they graze in nearby fields during the day. As increasing numbers of geese graze and cause damage to agricultural crops, the conflict between interests such as nature conservation and agriculture increase. Moreover, restoration of wetlands to reduce the leakage of nutrients and promote biodiversity can lead to more geese being present on surrounding agricultural land and cause more conflicts. To reduce the damage and to manage conflicts several different types of damage preventive measures are used. So called set-aside fields is one of the measures used. A set-aside field is a piece of land that is adapted so that the geese can graze there undisturbed instead of on sensitive crops on conventional fields. Scaring is another measure. Gas cannons, flags, bangers, and inflatable scarecrows are examples scaring techniques being used. However, the geese habituate after a while and the effect is often short.

The greylag goose is one of the species of geese that in recent years has received a boost in numbers and that causes the most damage and financial losses for Swedish farmers. The greylag goose moves in large groups parts of the year, it is herbivorous and prefers ley fields and cereals of low sward height. Greylag geese also eat harvest residues such as root vegetables and spilled grains.

In this thesis I used counts of greylag geese and data from GPS tagged greylag geese to study how set-aside fields and scaring affect their field selection and movement patterns.

I looked at:

1) how field selection by geese is affected by crop, distance to roost sites and season. One of the fields in one of the study areas was a set-aside field and therefore I was able to compare how much it was used in comparison with other fields.

2) how scaring affects goose movement patterns and habitat use in the agricultural landscape. I did this through three different analyses where I measured how far geese moved before scaring compared to after, if they came back to the same place as they were previously scared from, and what habitat they used before compared to after being scared. The results can be used for an increased understanding of the effect of scaring on geese, which in turn can help to develop and improve scaring measures. More effective scaring measures in combination with well-planned set-aside fields can hopefully reduce damage to growing crops.

My results showed that:

1) The set-aside field is more selected than other crops, especially in the spring. When geese select fields, several factors such as crop and distance to roost are taken into account. In the case of crops, ley (both the set-aside field and conventional) were more selected than wheat, barley, and rye. The distance to the roost site is another important factor; the closer to the roost a field is located, the more attractive it becomes. This can be explained by the fact that geese, like other animals, have a built-in threshold for how much energy must be supplied via food versus how much is spent to fly to the fields. If a goose flies too far, there is a risk that the energy they gain through forage will not provide a surplus. My results show that in spring when growing crops are most sensitive, a set-aside field with well-fertilized ley placed close to roost is a winning concept to attract geese. In fall, stubble fields with spilled grain can also pull geese away from sensitive crops.

2) Through the GPS collars we were able to follow exactly how individual geese moved. A scaring event, which is probably perceived by the goose as a predation attempt, was expected to prevent them from returning to a field. The results show that the geese were to be found on average about 1 km from the site where scared one hour after the scaring. The geese did not return to the same area for the next 48 hours after scaring. When geese are scared by drones, the probability is slightly lower that they return to the same area in the first four hours after they have been scared compared to if they were scared by a human. The geese preferred wetland habitat after scaring to a greater extent than fields, but just short-term i.e. less than 4hrs. Even before scaring few GPS positions (geese) were within 300 meters of the scaring point//place//site, 50% of the positions 3 hours before scaring was further away than 300 meters, which also indicates that the individual goose moves a lot in the landscape. Time of day and season, on the other hand, have no effect on whether they returned. The study area is dominated by agricultural land and the availability of alternative foraging places is high, which was expected to reduce the motivation to return to the place where they were scared. Greylag geese need to spend many hours a day searching for food. It is therefore likely that geese in the morning would be more motivated to remain on agricultural land to meet that need. It turned out, however, that geese scared in the morning visited wetlands more often than those scared in the evening. One explanation for this may be that they simply take a break in the middle of the day, but it is a speculation based on our observations in the field.

How can my results be used for management?
Both managers and farmers can benefit from evaluated knowledge about set-aside fields and scaring measures. My results show that scaring by drones and humans works on a small scale (field level). Geese fly away and do not return for at least 48 hours. Drones also have the advantage that you can reach geese on agricultural land that is sensitive and easily damaged. Even though the GPS tagged geese didn´t return other geese may still come to forage in the targeted fields. Scaring frequently e.g., every one to two hours can be an option to remove or prevent new geese from landing.

Scaring without having set-aside areas might move the geese to other fields in the area. Set-aside fields should therefore be considered in combination with scaring in areas where damage is high. Crop that is preferred, e.g. grass can be used in set-aside fields to attract geese, but should be avoided in places near roost sites where the geese like to forage. In my study, the set-aside field (well-fertilized and mowed to keep sward height low, and located near water) attracted more geese than other fields, especially in the spring.

To reduce the risk of moving around the problem in the landscape, priority should be given to areas where geese can graze without being disturbed. Implementing//Establishing a set-aside field close to the night roost site and adapting it to seasonal needs, reduces the risk of geese continuing to graze on agricultural land even after a scaring attempt. Areas where geese can graze undisturbed also benefit the welfare of geese.

In the future, research focusing on which types of crops are most attractive during which season of the year and evaluations of set-aside fields in several areas can contribute to improved knowledge. Research that combines both scaring and set-aside fields in the same area could also give further knowledge on how to reduce damage.

Finally, hopefully efficient management leading to reduced damage can contribute to a greater tolerance for geese but also for wetlands, which are essential for the survival and well-being of many other species.

Populärvetenskaplig sammanfattning

Antalet gäss har ökat dramatiskt i Europa under de senaste 50 åren. Det beror dels på åtgärder inom naturvården (artskydd, restaurering av våtmarker och skapande av skyddade områden), men också på jordbrukets utveckling sedan 1950-talet och dagens varmare klimat. Ett intensivare jordbruk har medfört god tillgång till föda av god kvalitet under i hela året. Gäss är opportunister som lätt flyttar sig i landskapet. De har ändrat sitt sätt att söka föda från naturliga områden till odlade fält. I takt med de ökande klimatförändringarna stannar nu även många gäss året runt främst i Sveriges södra delar. I jordbrukslandskapets våtmarker samlas grågässen på kvällarna för att övernatta medans de på dagarna betar på åkrarna i närheten. Eftersom gässen betar och orsakar skador på jordbruksgrödor så ökar motsättningarna mellan naturvård och jordbruk när gässen blir fler. T. ex. kan restaurering av våtmarker för att minska läckaget av växtnäringsämnen och gynna biologisk mångfald leda till fler gäss på omkringliggande jordbruksmark. För att minska skadorna och motsättningarna används flera olika typer av åtgärder. Att använda så kallade avledningsåkrar är en av åtgärderna som används. En avledningsåker är en bit mark som avsätts och anpassas för att gässen ska kunna beta där ostört i stället för på känslig gröda. Skrämsel är en annan åtgärd. Man har tidigare använt bland annat gasolkanoner, flaggor och vimplar och uppblåsbara fågelskrämmor för att få bukt med skadorna. Dock vänjer sig gässen efter en tid vid det mesta och effekten är ofta kortvarig.

Grågåsen är den av de arterna av gäss som på senare år ökat i antal och som orsakar mycket skada och ekonomiska förluster för svenska lantbrukare. Grågåsen är flocklevande och rör sig i stora flockar under delar av året. De är växtätare och föredrar framför allt låg vall och spannmål. Men de äter gärna spill av både rotfrukter och spannmål efter skörd.

I den här avhandlingen använde jag räkningar av grågäss och data från GPS märkta grågäss för att studera hur avledningsåkrar och skrämsel påverkar deras fältval och rörelsemönster.

Jag tittade dels på; 1) hur gässens val av fält påverkas av gröda, avstånd till övernattningsplats och säsong. En av åkrarna i studieområdet var en avledningsåker och därför kunde jag jämföra hur mycket den nyttjades i jämförelse med andra konventionellt odlade fält, och 2) hur skrämsel påverkar gässens rörelsemönster och habitatval i jordbrukslandskapet. Detta gjorde jag genom tre olika analyser för att studera i) hur långt gässen rörde sig före respektive efter skrämsel, ii) om gässen kom tillbaka till samma plats de tidigare skrämdes ifrån, och iii) vilket habitat de använder före jämfört med efter skrämsel. Resultaten kan användas för en ökad förståelse för skrämselns påverkan på gäss, som i sin tur kan hjälpa till att utveckla och förbättra skrämselåtgärder. Effektivare skrämselåtgärder i kombination med välplanerade avledningsåkrar kan förhoppningsvis minska skador på växande gröda.

Mina resultat visade att:

1) Avledningsåkern är mer vald än andra grödor speciellt på våren. När gäss väljer vart de ska födosöka spelar flera faktorer såsom gröda och avstånd till övernattningsplats in. När det gäller gröda var vall mer vald än vete, korn och råg. Avståndet till övernattningsplatsen är en faktor som spelar roll, ju närmre övernattningsplatsen ett fält är beläget desto mer omtyckt blir det. Det kan förklaras med att gäss, som andra djur, har en inbyggd tröskel för hur mycket energi som måste tillföras via föda kontra hur mycket som spenderas för att flyga till fälten. Flyger en gås för långt finns det risk att den energin som de hinner tillgodose sig via föda inte ger ett överskott.

Mina resultat visar att under våren när växande gröda är som känsligast är en avledningsåker med välgödslad vall placerad nära övernattningsplats ett vinnande koncept om man vill avleda gäss från att göra skada på annan jordbruksmark. På hösten kan spillrester från skörd fungera för att locka gäss bort från känslig gröda.

2) Genom GPS halsbanden kunde vi följa hur den individuella gåsen rörde sig. Ett skrämselförsök, som förmodligen upplevs av gässen som ett predationsförsök, borde avskräcka gässen och hindra dem från att återvända. Resultaten visar att gässen har rört sig i genomsnitt ca 1 km bort från punkten där de skrämdes en timme efter skrämseln. Gässen återvände inte till samma område under de närmaste 48 timmarna efter ett skrämselförsök. När gässen skräms med drönare är sannolikheten något lägre att de återvänder till skrämselområdet de fyra första timmarna efter att de skrämts i jämförelse med om de skrämdes av en människa. Tid på dygnet och säsong har däremot ingen påverkan på huruvida de återvände i större eller mindre utsträckning. Gässen föredrog våtmarkshabitat efter ett skrämselförsök i större utsträckning än åkrar men bara en kort tid efter skrämsel (mindre än fyra timmar).

Få av gässens positioner befann sig inom 300 meter från skrämsel positionen även före skrämsel, vilket pekar på att gässen förflyttar sig mycket i landskapet. Studieområdet domineras av jordbruksmark och tillgången till alternativa födosöksplatser är riklig vilket förväntades minska motivationen att återvända till platsen där de skrämdes.

Energibehovet hos en grågås är högt och den behöver ägna många timmar per dag åt att födosöka. Man kan därför tänka sig att gäss på morgonen skulle vara mera benägna att stanna kvar på jordbruksmark för att tillgodose behovet. Det visade sig dock att gäss som skräms på morgonen uppsöker våtmark oftare än gäss som skräms på kvällen. En förklaring till att så inte verkar vara fallet kan vara att de helt enkelt tar en vilopaus mitt på dagen, men det är en spekulation baserad på våra observationer i fält och som inte är bekräftad i tidigare litteratur.

Hur kan mina resultat användas i förvaltningen?

Både förvaltare och lantbrukare kan ha användning av hur effektiva avledningsåkrar och skrämselmetoder är. Mina resultat visar att skrämsel med drönare och människa fungerar för att hålla en gåsindivid borta på en liten skala (fältnivå). Gässen flyr fältet och kommer inte tillbaka på åtminstone 48 timmar. Drönare har även fördelen att man kommer åt gäss på jordbruksmark som är känslig och där man inte vill gå. För att ytterligare kunna förbättra ska man ha i åtanke att jag visar att gässen rör sig en hel del i landskapet inom rätt så korta tidsintervaller. Det som man tidigare trott varit samma gäss som kommit tillbaka till ett fält efter skrämsel är förmodligen ett nytt gäng gäss som anländer. Fler skrämselinsatser kan således behövas för att hålla även andra gäss borta. Att skrämma utan avledningsåkrar kan resultera i att flytta gässen till andra närliggande fält. Avledningsåkrar bör därför övervägas i kombination med skrämsel i områden där skadorna är stora.

Gröda som föredras t.ex. vall kan användas på avledningsåkrar för att locka gäss men bör undvikas på platser nära övernattningsplatser där gässen gärna födosöker. I min studie lockade avledningsåkern (välgödslad och putsad vall nära vatten) mer gäss än övriga konventionella fält under framförallt våren. För att minska risken för att flytta runt problemet i landskapet bör man prioritera områden där gässen kan beta utan att bli störda. Att anlägga en avledningsåker, nära övernattningsplatsen och anpassa det efter säsongsbehov, i ett skadebenäget område minskar risken att gäss fortsätter att beta på jordbruksmark även efter ett skrämselförsök. Att tillgodose områden där gässen kan beta ostört gagnar även gässens välfärd.

I framtiden kan forskning med fokus på vilka typer av grödor som är mest attraktiva under vilken säsong på året och utvärdering av avledningsåkrar inom flera områden bidra till mer kunskap. Forskning som kombinerar både skrämmande och avledningsåkrar i samma område skulle också kunna ge ytterligare kunskap om hur man kan minska skadorna.

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The number of geese have increased in Europe, causing increased crop damage and conservation conflicts. This thesis investigates two measures to alleviate damage by greylag geese (Anser anser). The results show that 1) set-aside fields can work to “pull” geese from conventional fields and 2) scaring works to “push” goose individuals from specific fields but scaring alone does not solve the problem at a landscape level. Combining the measures may reinforce the effects of scaring also at a landscape level.

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