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PREVENTING CROP DAMAGE BY GEESE: EFFECTIVENESS OF DIFFERENT SCARING TECHNIQUES IN SWEDEN

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

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DEDICATION

I dedicate this thesis work to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. I also dedicate this thesis to my mom Everlyne Wasike and dad Wilfred Injendi whose prayers, words of encouragement and support saw me through this academic journey. Special gratitude to my mentor Michael Fredricksen and the entire Canadian Education Society (Kenya and Canada) family for their consistent source of support and great inspiration during research work. To my spiritual parents Euphraith Ngari and Jacob Gititi am grateful for moral and spiritual support throughout this journey God bless you. I sincerely thank my friend Geoffrey Oduor who greatly encouraged and gave me full support throughout the research journey.

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LIST OF ACRONYMS AND ABBREVIATIONS

BACI	Before-After Control-Impact
CI	Confidence Interval
GLMM	General Linear Mixed Model
LGBs	Large Grazing Birds
SLU	Swedish University of Agricultural Science
USD	United States Dollar

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ABSTRACT

Several goose species have increased in numbers in Europe and North America for more than five decades. This has posed conflict between agriculture and conservation. Scaring is a widely used damage mitigation tool to make agricultural fields less attractive to wildlife and to reduce crop damage. This study sought to investigate the effectiveness of different scaring techniques in preventing crop damages caused by geese in Sweden. For objective one, the effect of three different scaring devices (kite, scarecrow, inflatable man) on the number of geese in fields with cereals, ley, rapeseed, potatoes, and carrots were tested in south-central Sweden. Geese were counted by camera traps. Two approaches were used; in a first (model 1) only geese within 50–150m of the scaring devices were counted, and in a second (model 2) all geese in the field were included. A total of 42,281 geese were counted: Greylag goose (*Anser anser*) was the most common species (87%), followed by bean goose (*Anser fabalis*) (6%), greater white-fronted goose (*Anser albifrons*) (3%), barnacle goose (*Branta leucopsis*) (2%), and Canada goose (*Branta canadensis*) (2%). The inflatable man decreased goose numbers by 90.0 %, scarecrow 64.6%, and kite 60.5%. A similar pattern was found in model 1, but the decrease was not significant. General Linear Mixed Models (GLMM) were used to evaluate the effect of the treatments on the number of geese in each trial. All analyses for this objective were performed in the statistical software R version 3.6.6. For objective two, literature review on ScienceDirect using the search terms "Geese" and "scaring was conducted." These terms were searched anywhere in the articles except in the references. The initial search yielded 223 results. However, 22 articles were inaccessible due to unavailability of authors, leaving us with 201 articles for further examination. To determine relevance, abstracts were scanned for indications of effectiveness and cost efficiency. Examination of full text was done for articles with relevant findings in the abstracts to extract data pertaining to the type of crop, season, methods employed, geographical region, the comparative efficacy of various scaring techniques, and the associated costs. Human bird scarers had 100% and inflatable man 90% scaring effect, but the cost of scaring was high when using inflatable man (364 USD) while kites had 60.5% and scarecrow had 64.5% scaring effect but were less costly (18.2 and 36.4 USD respectively). All analyses for this objective were performed in Microsoft excel. For objective three, scaring consultants employed by county administrative boards to help farmers deter geese from farms in 15 counties in Sweden (Dalarna, Gotland, Jämtland, Jönköping, Kalmar, Norrbotten, Örebro, Östergötland, Skåne, Södermanland, Uppsala, Värmland, Västerbotten, Västmanland, and Västra Götaland) were interviewed. Farmers were asked to rate the perceived effectiveness of commonly used scaring techniques for geese on a scale from 1 to 10. They provided assessments of the perceived duration of the scaring effect in terms of the number of days and the perceived cost efficiency of these techniques on a scale from 1 to 10. Fire crackers (4.6) and Lethal scaring (4.5) had the highest perceived effect, Exclosure river (3.7) and Inflatable man (3.2) had moderate effect and Rotating mirror pyramid (2.6) and Rotating mirror (2.4) had the lowest effect. All analyses for this objective were performed in Microsoft excel. This study showed that the scaring devices examined can reduce goose grazing pressure locally for some time. However, since geese continued to graze during scaring, its concluded that scaring alone is not enough to mitigate crop damage from geese. Future work to develop more effective control measures should address the efficiency of other management tools and scaring techniques, and in combination.

CHAPTER ONE

INTRODUCTION

1.1 Background information

There are 15 species of geese in the world, out of which eight species are considered to occur naturally in the Western Palearctic region (Madsen et al., 1999). Geese, swans and cranes (hereafter 'Large Grazing Birds' - LGBs) are mobile and widely distributed species, migrating over large areas during their annual cycle. Geographically, their occurrence and abundance vary seasonally according to consistent migratory routes and regular phenology patterns (Montràs-Janer et al., 2020). In Sweden and other parts of Europe, geese have drastically increased over the past decade, which has become a problem to the surrounding community (Madsen et al, 2017). According to Abraham et al., (2005a, 2005b), the increasing population of geese can have a detrimental effect on vegetation and ecosystems and bring geese into conflict with farmers as they cause crop damage (Fox et al., 2017). Between the year 2000 and 2015, Sweden reported a huge number of crop damage by geese, when common crane *(Grus grus*), barnacle goose (*Branta leucopsis*) and greylag goose (*Anser anser*) caused 90 % of the reported damage, yield loss and costs for compensation, while bean goose *(Anser fabalis*) and whooper swan (*Cygnus cygnus*) combined represented 8 % of the reported damage (Montràs-Janer et al., 2019). This has led to increase in areas of conflict, especially in instances where the wild bird is protected and where non-lethal preventive tools do not have the intended effect (Hake et al., 2010). The conflicts are evident especially for protected species, that is species that cannot be hunted during the damaging periods. According to Hake et al., 2010, the conflicts result in financial losses for the affected farmers. Consequently, landowners may be more reluctant to agree on setting off their land as reserves to protect vulnerable birds and other organisms (Gordon, 2009). Therefore, there is need to manage the conflict to avoid detrimental effects on the economy and possibly suggest measures of conserving them. In Sweden different tools have been used to divert geese from crops that are economically sensitive to other alternative fields where they do not cause harm (Conover, 2001, Fox et al., 2017). Non-lethal scaring devices have been used to minimize crop damage by geese. These tools are used to induce fear by mimicking hunting, and they include use of propane cannons, camouflage nets and firecrackers (Conover, 2001). Shooting is also a tool of reducing damage by geese (Månsson 2017), but has been questioned as behavioral shifts may lead to increased damage. For example, it has been noted that non-targeted geese species can be scared by hunting from areas where they do not cause damage to more sensitive areas hence increasing risk of damage (Bechet et al., 2004, Duriez et al., 2009, Mooij, 1991, Nolet et al., 2016). Furthermore, lethal scaring is currently permitted in Sweden and is performed during variety of times, including controversial periods (e.g., breeding season). According to (Månsson, 2017), lethal scaring technique minimizes the number of geese (greater than 60%) for at least three consecutive days. It's unfortunate that the data doesn't allow one to make conclusion beyond three days. It's imaginable that the birds will go back to the field slowly day by day. Thus, lethal scaring may need to be repeated until the crop reaches an insensitive stage. Therefore, there is need to evaluate the persistence of the scaring technique to reinforce its effectiveness. This study aims to increase knowledge about the effectiveness of various scaring techniques aimed at decreasing the number of foraging geese in the fields, and to mitigate the impact and harvest losses. It will also increase the understanding of appropriate scaring methods and may provide important and urgent guidelines for decision makers and stakeholders involved in the complex issue of goose management and crop protection.

1.2 Problem statement

Geese populations have drastically increased in Sweden in the past decades. This has resulted to increased crop damage causing low agricultural production. The increasing number of geese can have devastating effects on vegetation and ecosystems. It can also result to increased conflict between geese and farmers. The rapid increase in geese numbers present a serious management challenge. Several scaring techniques have been used to keep geese from agricultural farms in an effort to mitigate crop damage. However, knowledge about the effectiveness is poor and further research is required. There are different geese species that have been reported to cause crop damage, yield loss and costs for compensation in Sweden. These species include barnacle goose (*Branta leucopsis*), greylag goose (*Anser anser*), and bean goose (*Anser fabalis*).

Conflict between societal interests such as conservation and farming are particularly evident in cases where birds are protected and where non-lethal preventive tools do not have the intended effect. Moreover, farmers often claim that these preventive measures are ineffective. This study aims to disentangle the perceived and real effect of non-lethal preventive tools by increasing knowledge about use of scaring techniques to reduce the number of foraging geese in the fields. The tools are also aimed to divert geese attention from economically sensitive crops to alternative feeding areas. These techniques include scaring ‘‘pushing’’ birds away, sacrificial crops-“pulling” the birds to certain fields, use of passive scaring –placing devices such as propane cannons, kites, scarecrows and flags in damage-prone fields and use of active scaring e.g. fire-cracks, green-laser, dogs, walking, shooting, drones. From previous studies it is predicted that the scaring methods will reduce the number of geese at a local spatial level and therefore decrease damage risk, and the birds will increase escape distance to an approaching man after scaring. This study will increase understanding of appropriate scaring methods and may provide important and urgent guidelines for decision makers and stakeholders involved in the complex issue of goose management and crop protection.

1.3 Justification

The dramatic increase in the number of European geese populations in Sweden over the past decade has resulted into conflict between farming and conservation. This is because of their high reproduction and survival rates, even in the harsh environmental conditions. This has led to the need for research on the effectiveness of different techniques to scare them away. These techniques include the use of scarecrows, kites and inflatable man. It is hypothesized that if these techniques are properly implemented, they may reduce geese impacts on crop hence leading to a stable agricultural economy. It could also increase crop yields in fields and reduce conflict between different societal interests such as conservation and farming. It also ensures that crops and other forms of flora and fauna escape risk of going extinct due to destruction of their natural habitats by high number of geese and their changing behavioral patterns. This ensures that the environment is not altered and thus available resources are used sustainably. This will in turn result to increased income to farmers and thus enhance economic sustainability. Effective scaring techniques are essential as farmers need economically viable methods of improving their agricultural production.

1.4 General objective

The main objective of the study is to investigate the effectiveness of different scaring techniques in preventing crop damage by Geese.

1.4.1 Specific objectives

1. To examine the numerical response of geese to specific scaring methods.

2. To evaluate the effectiveness of specific scaring techniques in relation to cost and effort.

3. To establish the relationship between various scaring techniques practiced by farmers and the decreasing numbers of geese.

1.5 Research questions

1. What are the behavioral and numerical responses of geese to specific scaring methods?

2. What is the effectiveness of these scaring methods in relation to cost and effort?

3. How does scaring techniques practiced by farmers relate with the decreasing number of geese?

CHAPTER TWO

LITERATURE REVIEW

2.1 Taxonomy and identification of Geese

The word geese refer to the two genera of Anser and Branta. Geese can be difficult to distinguish visually due to their similarities, especially in the case of bean goose, pink-footed goose and sub adult greater white-fronted goose (Hume et al., 2020). Due to this difficult in geese identification, it is necessary to adapt a table that will help in their classification (Table 2.1). Greylag goose and barnacle goose can be easily distinguished from other goose species based on plumage. According to (Fox et al., 2017), geese have a simpler and shorter digestive system than other herbivorous species, hence called obligate herbivores. Due to their simple digestive system, geese must consume large amounts of plant tissue relative to their body weight. Geese prefer plants with low fiber content and plants found in managed agricultural lands, making them to interact with these ecosystems. Plants with high content of protein and starch emerged due to green revolution in the 20th century resulting in higher production and increased harvest (Li et al., 2017). Geese are well adapted to feed on these plants as they have higher protein and starch content than those in natural ecosystems (Fox et al. 2017; Fox & Madsen 2017). Therefore, they have gradually shifted their foraging behavior from wild to agricultural plants (Li et al., 2017)

Table 2. 1: Goose species annually and naturally occurring in Sweden (adapted from SLU Artdatabanken 2021b).

Anser genus	*Branta genus*
Lesser white-fronted goose - *A. erytrhropus*	Barnacle goose - *B. leucopsis*
Taiga bean goose - *A. fabalis fabalis*	Canada goose - *B. Canadensis*
Tundra bean goose – *A. fabalis rossicus*	Brent goose - *B. bernicla*
Greylag goose - *A. anser*	
Greater white-fronted goose - *A. albifrons*	
Pink-footed goose - *A. brachyrhynchus*	

2.2 Scaring as a tool to minimize crop damage by Geese

The effectiveness of scaring geese varies with the type of method and tools used, the area and the season when the technique is used and the type of geese species (Summers and Hillman 1990). In recent studies, various scaring methods have been utilized, including human scares, trucks and firing shots over flocks which is the most common. According to Eythórsson (2017), local farmers in Nord-Trøndelag in Norway found it necessary to shift between various scaring methods in order to get results. However, most farmers were not aware of the need to be frequent in these scaring methods, and it appeared as though the scaring technique was based on personal beliefs rather than documented evidence.In general, it seems that there is a relationship between what farmers practice and the degree to which there is a challenge with goose damage.

For example, Madsen et al., (2017) observed that 40% of farmers who did not practice scaring techniques reported that geese were not in their farms, and that they were not a challenge. On the other hand, farmers reported that they had no time and willingness, and that the scaring techniques were ineffective. However, this technique may only provide short term protection, and some birds may even utilize them as perches especially when they get habituated to them. For best results, scarecrows should imitate some natural predators, be visible and in frequent movement to help prevent habituation (Bishop et al., 2003). To increase their effectiveness, the use of reflectors and brightly colored loose clothing may be a game changer. This is because geese respond more readily to colored and moving objects.

2.3 Government legislation on Geese

Current legislation in Sweden states that conventional hunting, lethal scaring and non-lethal preventive methods like scaring and diversionary fields that are cultivated to attract foraging birds should be used in cases of wildlife damages. In instances where the focal species are protected, and hunting is not applicable, other means should be used to prevent damage.

Efforts to decrease geese from vulnerable areas such as crops and airports have involved scaring, hunting and derogation shooting. Quantifying the effectiveness of these techniques is usually a challenge (Nolet et al., 2016, Simonsen et al., 2016, Månsson 2017, van der Jeugd and Kwak 2017). This leads to a growing demand for alternative techniques of geese displacement that are non-lethal and species specific.

2.4 The management toolbox for Geese

Despite the difference in real and perceived grazing damage, most studies have focused on means in which goose conservation and agriculture might be better integrated (Vickery & Gill, 1999). However, individual farmers lack proper tools for avoiding and reducing the damages caused by geese. Therefore, collaborative management over wide areas is more advantageous as it increases the chances of implementing effective management actions (Tombre et al., 2013a).

2.4.1 Geese population management

Due to the population size of geese in some parts of Sweden, farmers have called for reduction in the overall abundance (Soreng, 2008; Madsen et al., 2017). This is to be achieved by open hunting. In cases of the snow goose in North America, and controlled spring hunt where hunting is unlimited was introduced to increase hunting pressure (Shutler et al., 2012), as also the possibility to sell harvested geese to public. A population goal has not been defined for all European goose species yet but the African-Eurasian Water Bird Agreement Pink-footed Goose (AEWAPG) management plan has established a target interval of sixty thousand individuals (Madsen et al., 2017). The plan is built on the concept of adaptive management, integrating hunting, detailed population monitoring and scientific modeling to understand how changes in harvest affects population dynamics (Jensen et al., 2014).

CHAPTER THREE

REDUCING THE NUMBER OF GRAZING GEESE ON AGRICULTURAL FIELDS - EFFECTIVENESS OF DIFFERENT SCARING TECHNIQUES

3.0 ABSTRACT

Scaring is a widely used damage mitigation tool to make agricultural fields less attractive to wildlife, and by that reduce crop damage. However, few experimental studies exist where the numerical response of different scaring devices has been compared. The effect of three different scaring devices (kite, scarecrow, inflatable man) on the number of geese in fields with cereals, ley, rapeseed, potatoes, and carrots in Sweden were tested experimentally. Geese were counted by camera traps using two approaches: in a first (model 1), only geese within 50–150m of the scaring devices were counted, and in a second (model 2), all geese in the field were included. A total of 42,281 geese were counted: Greylag goose (*Anser anser*) was the most common species (87%), followed by bean goose (*Anser fabalis*) (6%), greater white-fronted goose (*Anser albifrons*) (3%), barnacle goose (*Branta leucopsis*) (2%), and Canada goose (*Branta canadensis*) (2%). During scaring, the number of geese significantly decreased for all three devices in model 2. The inflatable man decreased goose numbers by 90.0 %, scarecrow 64.6%, and kite 60.5%. A similar pattern was found in model 1, but the decrease was not significant. This study shows that the scaring devices studied can reduce goose grazing pressure for some time and locally. However, since geese continued to graze during scaring, scaring alone is not a final solution to mitigate crop damage. Future work to develop more effective control measures should address the efficiency of other management tools and scaring techniques in combination.

3.1 INTRODUCTION

A current and major challenge worldwide is to combine food production with biodiversity conservation (Brussaard et al., 2010). In many farmlands, bird species populations have decreased due to intensified agriculture (Donald et al., 2001, 2006; Wretenberg et al., 2006). However, expansion and intensification of agriculture is not necessarily negative for all; for example, several species of geese and cranes have benefitted from changed agricultural practices (Fox and Abraham, 2017; Hemminger et al., 2022).

Several goose species have increased in numbers in Europe and North America for more than five decades (Fox and Madsen, 2017; Lefebvre et al., 2017). This is partly due to improved foraging conditions provided by intensified farming systems, but also due to earlier conservation efforts and climate change (Fox and Abraham, 2017; Fox and Madsen 2017; Mason et al., 2018). Geese are obligate herbivores feeding on grain, roots, and green plant parts. They prefer a variety of crops such as wheat, maize, barley, and grasses - all providing high energy content and high digestibility (Fox et al., 2017). Recently, many geese have shifted from using traditional natural foraging habitats to well-managed and fertilized agricultural crops. This increased grazing pressure on cropland causes conservation conflicts and management challenges due to crop damage (Fox et al., 2017). Greylag goose (*Anser anser*) and barnacle goose (*Branta leucopsis*) have recently been considered as superabundant and they cause major economic damage to crops in Sweden and other parts of Europe (Fox and Madsen, 2017; Montras-Janer et al., 2019; Düttmann et al., 2023). Other less abundant species, such as greater white-fronted goose (*Anser albifrons*) and bean goose (*Anser fabalis*) can also occur in large numbers and cause damage in certain regions (Montras-Janer ` et al., 2019; Düttmann et al., 2023). Recently, cases of up to 50% harvest loss due to goose grazing has been recorded and millions of Euros are used annually for compensation to farmers in Europe for harvest loss (Jensen et al., 2018; Montras-Janer et al., 2019; Düttmann et al., 2023). Most European goose populations are considered as viable and in a favorable conservation status. Nevertheless, conservation conflicts occur since crop damage is often higher where important wetland reserves attract large number of geese to adjacent agricultural areas, and because some of the most abundant goose species are still protected (Si et al., 2011; Montras-Janer, 2021; Månsson et al., 2023).

Scaring is widely used as a strategy to make agricultural fields less attractive to geese and by that reduce crop damage and conservation conflicts (Hake et al., 2010; Simonsen et al., 2016; Conover and Conover 2022). Scaring is assumed to provoke fear in geese by mimicking predators and human presence (e.g., hunting activities) and can affect their use of specific fields, foraging behaviour, energy gain, and habitat selection (Madsen 2001; Teräväinen, 2022). Such techniques may include propane cannons, laser, kites, scarecrows, and firecrackers (Hake et al., 2010; Heim et al., 2022). Effectiveness of goose scaring can vary with the type of method, site, season, and species (Simonsen et al., 2016; Heim et al., 2022). Some scaring methods are used worldwide, but their effectiveness has surprisingly rarely been experimentally evaluated and compared (but see Clausen et al., 2019; Heim et al., 2022). There is thus a need for experimental studies to increase the knowledge about their relative effectiveness for guiding management and to improving crop protection measures.

There are many different scaring techniques available, creating both visual and auditory stimuli to scare geese. In the present study, the effectiveness of three devices were experimentally tested creating visual cues, and which are widely used in Sweden and other parts of the world: scarecrow, kite, and 'inflatable man' (Marsh et., al 1992; Pendlebury et al., 2006; Hake et al., 2010; Conover and Conover, 2022). The scarecrow and the inflatable man both mimic human presence. However, they differ in appearance, as the inflatable man is mostly hidden and pops up with a sound (more of a surprise), whereas the scarecrow is constantly visible and only moves slightly by wind. The kite used mimics a soaring raptor and moves constantly if there is wind (i.e., weather dependent).

Practical experience of these techniques is available from both Europe and North America (Hake et al., 2010; Fox et al., 2017; Conover and Conover, 2022), but little has been published on their relative effectiveness. There is therefore a need to evaluate under controlled conditions for further recommendations regarding crop protection. The study aimed at evaluating the numerical response of geese created by the three scaring devices. It's predicted that all three scaring devices would reduce the number of foraging geese at the field level, thus decreasing crop damage risk, but that there would be difference in effectiveness among them, as they mimic different kinds of threats (raptor vs. humans) to geese and differ in appearance (always visible vs. mostly hidden).

3.2 MATERIALS AND METHODS

3.2.1 Study site

The study was carried out in an agricultural landscape in southcentral Sweden (59◦10′ N, 15◦22′ E) (Fig. 1). The area has a humid continental climate (cold winters and warm summers) with four distinct seasons: winter, spring, summer, and autumn. The mean daily temperature in the area during summer is 15–18 ◦C, and around − 2 to 0 ◦C in winter (average values 1991–2020). Precipitation is distributed evenly over the year, with slightly more rainfall in the summer months. The study area is a flat landscape with two restored wetland reserves (Kvismaren nature reserve), surrounded by farmland dominated by pastures and fields of mainly cereals, ley, rapeseed, potatoes, and carrots. The two wetlands are shallow and eutrophic, bordered by narrow belts of grazed wet meadows. Agricultural fields range between 1 and 72 ha in size. The area hosts large numbers of geese. Greylag geese and bean geese are the most numerous (Spring and Fall), and both species use arable land to a large extent for foraging. In addition, greater white-fronted geese, pink-footed geese (*Anser brachyrhynchus*), barnacle geese, and Canada geese occur in the area but in smaller numbers. The greylag goose is the only species breeding in large numbers, arriving to the area in March and departing in early October (Månsson et al., 2022).

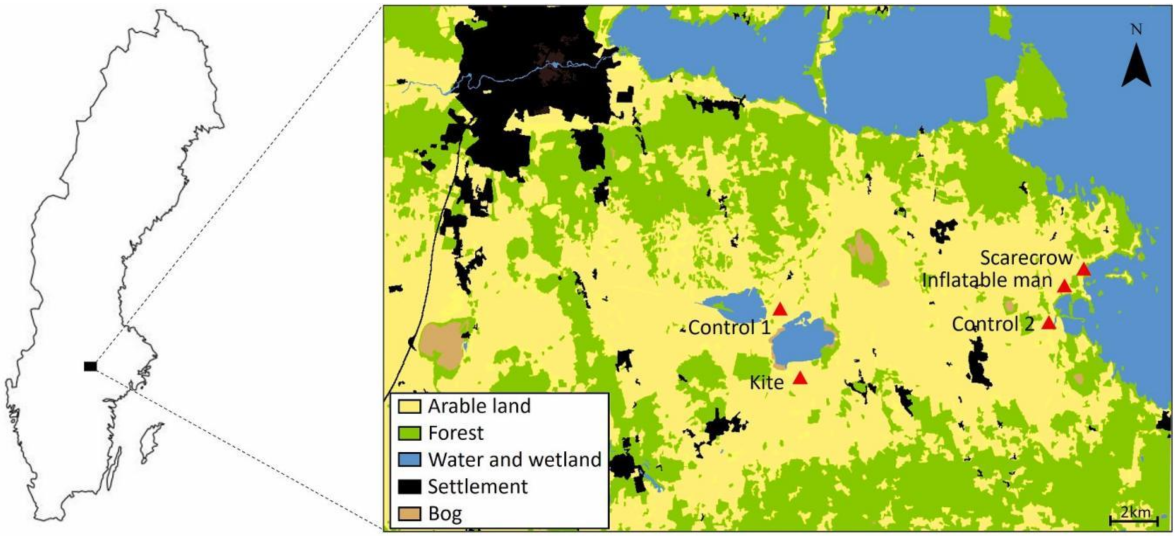

Figure 3.1: Location of the study area in Sweden where the effects of three different scaring devices (inflatable man, kite, and scarecrow) studied. Two lakes (the Kvismaren nature reserve) provide safe roosting sites for geese in the landscape. The panel shows main land cover types and one example of an experimental setup of a scaring trial, including four different treatments (two fields as controls, one field with inflatable man, kite, and scarecrow). In total, 15 trials were conducted from 2020 to 2022.

3.2.2 Scaring devices

Three different devices were evaluated as follows:

The kite consisted of a pole which was 13 m tall. To it was attached a plastic black silhouette with a string, hence mimicking a bird of prey (1.4 m wingspan). The kite moved in very light breeze, but the movement is directly dependent on wind strength.

The scarecrow was 1.4 m tall, made of grey fibre cloth, and had a yellow plastic head. The scarecrow was attached to a wooden pole with rubber bands allowing it to move in the wind. Two hanging plastic tapes were attached to the silhouette to mimic moving arms.

The inflatable man was 1.7 m tall and operated by a battery power source. It was made of bright orange cloth in the shape of a man. A timer activated a fan to inflate the figure and an artificial sound went off simultaneously (a siren similar to a car alarm). The operation interval was set to every 30 min, and when in operation the man pops up several times.

3.2.3 Scaring trials and experimental set-up

In total of 15 independent trials were conducted from February to October in 2020–2022 (see Fig. 3.1 for an example of the setup of one of the trials, and Table 1 for characteristics of included fields). In each trial four or five fields with four different treatments to compare the effect on the number of geese were used. The three scaring devices (kite, scarecrow, inflatable man) and one or two controls were used in each trial. In 10 trials two control fields were used and in 5 trials one control field. Two treatments in two of the trials had to be excluded because the farmer ploughed the field (kite, trial 3) or camera malfunction (scarecrow, trial 1; Table 3.1). The trials were conducted on growing wheat, barley, and ley fields, but in some trials stubble fields (harvested wheat and barley) and fallow were used for practical reasons (i.e., when no fields with growing crops could be used as controls because farmers wanted to scare in all fields to mitigate damage).It's assumed that the inclusion of different crops and crop stages in the trials should not affect the relative scaring effect, as the number of geese was compared before and during treatment within the same field. Each trial was designed as a Before-After Control-Impact (BACI) set-up (Smith et al., 1993). First, four to five similar fields with respect to crop type and stage, crop height and with occurrence of geese were selected (Fig. 3.1). The fields included were all situated within the same staging area and at a maximum of 14 km from the main night roost in the area (i.e., within maximum goose foraging flight distance <32.5 km; (Johnson and Schmidt, 2014). The minimum distance between the treatment fields were more than 600 m in all cases except in five trials. In these five trials the minimum range between treatment fields was between 250 and 430 m but in all these cases vegetation was obstructing visibility between fields. Camera traps were installed in the fields to take images of geese for two days (48hrs) without any scaring device. After two days, three fields were randomly selected for each of the three scaring devices and one or two fields as controls. The devices were then placed in the field (Fig. 3.2) and geese were counted in images taken for another five days (120hrs).

3.2.4 Goose counts

The cameras were placed 100 m from the scaring device and were set to take an image every 30 min during the seven days of each trial (Fig. 3.2). For each field two cameras, one pointing at the scaring device and one in the opposite direction were used. Two marking poles were placed 50m from the cameras. These poles allowed me to assess the distance between the geese, the camera and the scaring device (zone 1 and zone 2 in Fig. 3.2) when counting geese in the images. The number of geese counted within both zone 1 and zone 2 were 50–150 m from the scaring device. In zone 1 and 2 (within 50m of the cameras) it was possible to identify geese to species in 49% of the cases. In addition to the counts in zones 1 and 2, I counted all geese beyond the marking poles as long as they were in the experimental field and possible to identify as geese (i.e. these were counted regardless of distance to the scaring device).

3.2.5 Data management and statistics

General Linear Mixed Models (GLMM) were used to evaluate the effect of the treatments on the number of geese in each trial. The number of geese per image (Fig. 3.2) was used as a dependent variable. Treatment (kite, scarecrow, inflatable man, and control), time period (before/ during) and the interaction term between the two (treatment*period) were used as fixed explanatory variables. Trial_id (1–15), treatment, and day (1–7) were included as nested random factors to account for the repeated measures within each trial and to combine data from the same trial.

The analyses were conducted using two different models. Model 1) only included geese at a known distance (i.e., within 50–150 m) from the scaring device (or the marker pole in case of control treatment; i.e., zones 1 & 2; (Fig. 3.2)). Model 2) included the total number of geese counted in images from the two cameras in each field (i.e., independent of distance to the cameras). In the ten cases where two control fields were used, the mean was rounded to closest integer. The total number of observations was 11,705 for model 1. For model 2 it was slightly less, 10,520, as some observations had to be excluded because weather and light conditions restricted visibility at further range than zone 1 and 2 (Fig. 3.2). Each observation is based on the sum of geese counted on the images from both cameras (Fig. 3.2). The total number of nested groups (Trial:Treatment:Day) was 412 for model 1 and 393 for model 2. All analyses were performed in the statistical software R version 3.6.6 (R Core Team, 2013; packages lme4 and ggplot2).

Table 3.1: Trials were conducted from February to October 2020–2022. Each trial included four different treatments (control, inflatable man, kite, and scarecrow). Most of the trials (10 out of 15) included two control fields. Trials were conducted in fields with wheat (W), barley (B), ley (L) or fallow (F) with two different crop stages: growing/unharvested (U) or stubble/harvested (H) and two crop height classes: 0–15 cm and 16–30 cm. Two treatments had to be excluded, because the farmer ploughed the field (kite, trial 3) or because of camera malfunction (scarecrow, trial 1).

Trial	Month	Year	Control 1			Control 2			Inflatable man			Kite			Scarecrow		
			Crop	Stage	Height	Crop	Stage	Height	Crop	Stage	Height	Crop	Stage	Height	Crop	Stage	Height
1	July	2020	L	U	0–15	–	–	–	–	–	–	L	U	0–15	L	U	0–15
2	Aug	2020	W	H	0–15	B	H	0–15	W	H	0–15	B	H	0–15	B	H	0–15
3	Aug	2020	W	H	0–15	W	H	0–15	B	H	0–15	–	–	–	W	H	0–15
4	Mar	2021	W	U	0–15	W	U	0–15	W	U	0–15	W	U	0–15	W	U	0–15
5	Apr	2021	L	U	0–15	L	U	0–15	L	U	0–15	L	U	0–15	L	U	0–15
6	May	2021	W	U	0–15	W	U	16–30	W	U	0–15	W	U	0–15	W	U	0–15
7	July	2021	L	U	16–30	L	U	0–15	F	U	16–30	L	U	16–30	L	U	16–30
8	Sep	2021	L	U	0–15	L	U	0–15	W	U	0–15	W	U	0–15	L	U	0–15
9	Oct	2021	W	H	16–30	W	H	16–30	W	U	0–15	W	H	0–15	W	H	16–30
10	Feb	2022	L	U	0–15	–	–	–	W	U	0–15	W	U	0–15	W	U	0–15
11	Mar	2022	L	U	0–15	–	–	–	W	U	0–15	W	U	0–15	W	U	0–15
12	Mar	2022	W	U	0–15	–	–	–	W	U	0–15	W	U	0–15	W	U	0–15
13	Mar	2022	W	U	0–15	L	U	0–15	W	U	0–15	W	U	0–15	W	U	0–15
14	Sep	2022	W	H	0–15	W	H	0–15	W	H	0–15	W	H	0–15	W	H	0–15
15	Feb	2022	W	H	0–15	–	–	–	W	H	0–15	W	H	0–15	W	H	0–15

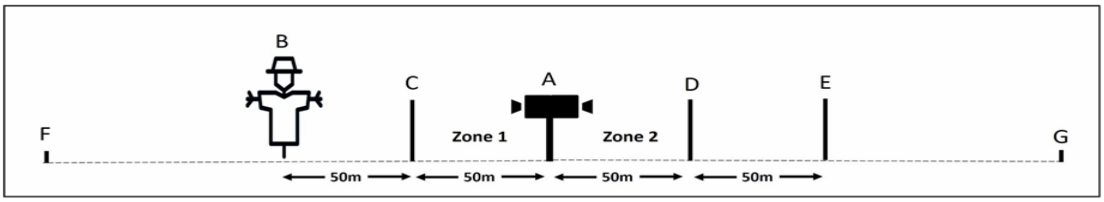

Figure 3.2: Experimental design of scaring trials, where A is two camera traps, one pointing towards the scaring device (B) and the other in the opposite direction. Three different scaring devices were tested; inflatable man, kite, and scarecrow. In all controls the scaring device was replaced by a marker pole. The poles (C, D and E) indicate the distance between the camera and scaring device. All geese in the field possible to identify as geese were counted regardless of distance (here indicated as F and G). In zones 1 and 2 (within 50 m of the cameras) it was possible to identify geese to species in 49% of the cases. Scarecrow and camera icons by Tanga Vigneshnd Brianna Holmes from NounProject.com.

3.3 RESULTS

3.3.1 Number of geese and species

Greylag goose was the most common species (1,896 (87%)) identified individuals), followed by bean goose (135(6%)), greater white-fronted goose (71(3%)), barnacle goose (45(2%)), Canada goose (44 (2%)). A total of 2,270 geese could not be identified to species. Over the 15 trials (Table 3.1), 42,281 geese were counted in the images, out of which 4,468 were within 50-150 m of the scaring devices (zones 1 & 2).

3.3.2 Numerical response

Based on predicted values from the two models, on average 0.52 and 10.20 goose individuals were in the images during the two days before treatment (models 1 and 2, respectively; Fig 3.3 & 3.4). After treatment started, there was a significant decrease in goose numbers for all three scaring devices in model 2 (parameter estimates for the interaction term in Table 3.2). The pattern effect of scaring on goose numbers was similar in model 1 and 2, but it was not statistically significant in model 1 (compare Figs. 3.3 and 3.4). There was no significant difference in relative change between the periods before and during treatment (i.e. the slope of the interaction term; Table 3.2) when comparing the three different scaring devices ($p>0.41$ in all cases; t-tests based on model parameters in Table 3.2). Still, in absolute terms the reduction of number of geese varied considerably between the three devices. For the inflatable man, the predicted mean decreased by 81% and 90% (models 1 and 2, respectively), for scarecrow (61.1% and 64.6%), and kite (40.7% and 60.5%) (Figs. 3.3 & 3.4). In control fields, the predicted mean number of geese instead increased by 5.1% and 21.7%

(models 1 and 2, respectively) from the first (before) to the second (during scaring) period.

Table 3.2: Parameter estimates of the general linear mixed model (models 1 and 2) predicting the effect of three different scaring devices on the number of geese. Period (before/during scaring), treatment (control, inflatable man (I), kite (K), scarecrow (S)) and the interaction term between period (P) and treatment were used as explanatory variables. The categorical estimates are in comparison to the intercept (i.e., the control before scaring).

	Estimate	S.E.	t-value	p-value
Model 1				
Intercept	0.59	0.16	3.76	<0.001
Period	0.03	0.18	0.19	0.84
Inflatable man	-0.15	0.22	-0.69	0.49
Kite	-0.05	0.22	-0.21	0.49
Scarecrow	-0.05	0.22	-0.23	0.82
P * I	-0.39	0.25	-1.57	0.12
P * K	-0.26	0.25	-1.01	0.31
P *S	-0.35	0.25	-1.43	0.15
Model 2				
Intercept	10.21	1.68	6.09	<0.001
Period	2.22	1.73	1.28	0.20
Inflatable man	-1.68	2.35	-0.72	0.47
Kite	3.5	2.42	1.45	0.15
Scarecrow	-1.85	2.40	0.77	0.44
P * I	-9.9	2.44	-4.06	<0.001
P * K	-10.52	2.5	-4.21	<0.001
P *S	-7.61	2.51	-3.03	<0.01

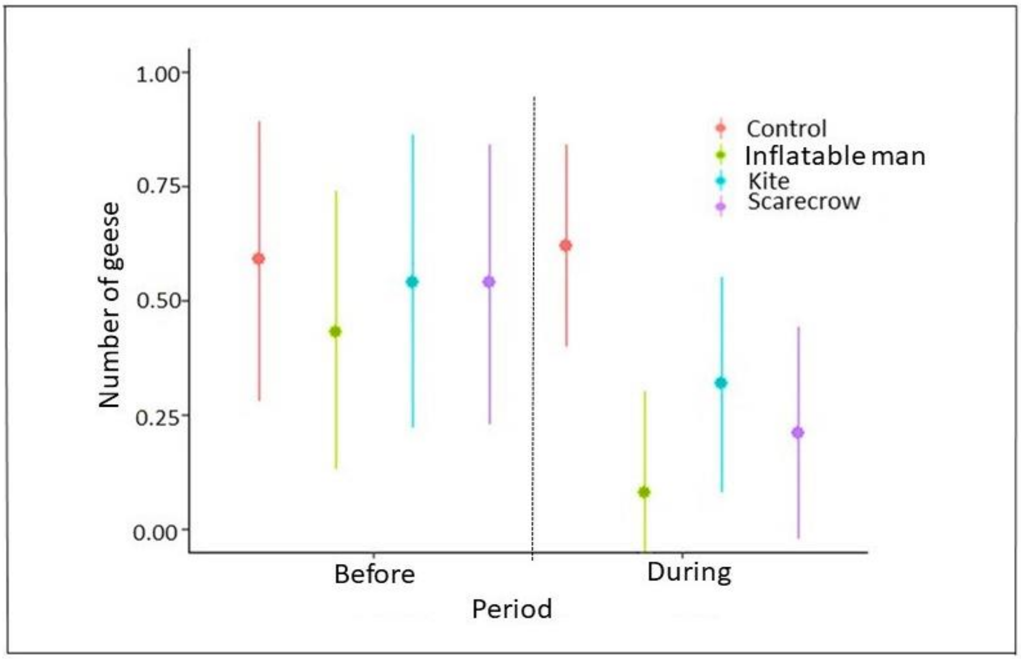

Figure 3. 3: Predicted means and CI (95%) for number of geese counted per image 50-150 m from the scaring devices (zone 1 and 2) before (left of dashed vertical line) and during scaring (right).

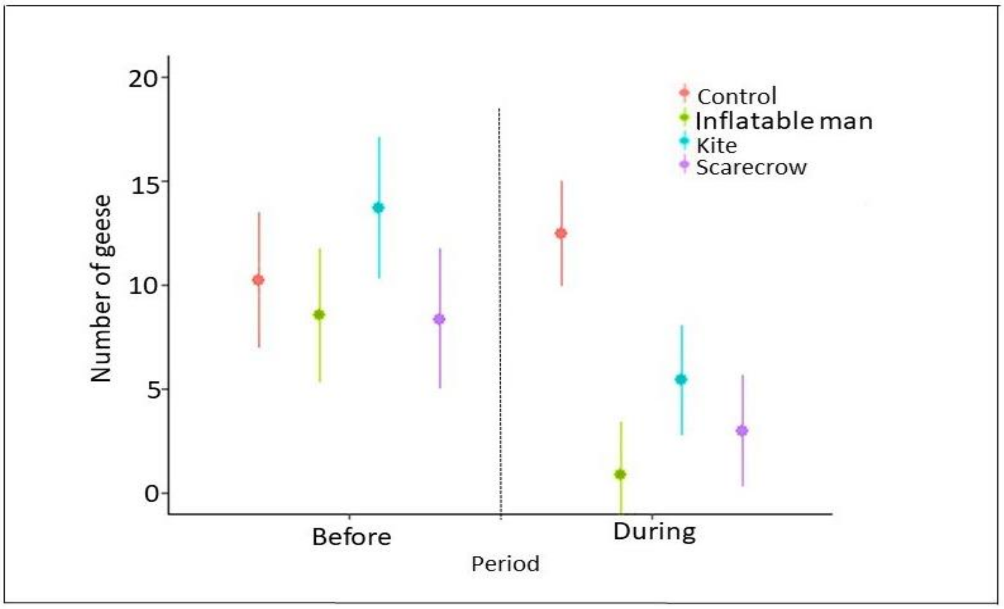

Figure 3.4: Predicted means and CI 95% for the number of geese counted per image regardless of the distance to the scaring device, before (left of the vertical dashed line) and during scaring (right).

3.4 DISCUSSION

This study shows that the tested scaring devices can substantially decrease the number of geese in agricultural fields. Both models showed the same pattern, but the effect on goose abundance was significant only when all geese in the field were included (i.e. model 2) and not limited to the closest vicinity of the scaring devices (i.e. model 1). There was no significant difference in scaring effect between the three devices. However, there was still a considerable variation in the relative change in number of geese before and during scaring among the three methods (ranged between 61 to 90% based on parameter estimates in model 2).

Given the increasing crop damage caused by growing goose numbers and the effort put into crop protection, surprisingly few experimental studies exist where the effect of different scaring devices has been tested with a consistent methodology allowing comparison. Three different devices commonly used to scare geese in Sweden and other parts of the world were included (Hake et al., 2010; Conover and Conover 2022). Earlier studies have evaluated the effect of other methods, such as propane cannons, flags, and fire-crackers on a wide range of bird species including geese (Conover, 2002; Bishop et al., 2003, Conover and Conover 2022). The results have been mixed, from no effect to a reduction of number of birds ranging between 19 and 82% (Summers, 1990; Percival and Houston, 1992). The differences in effect between studies may be due to factors such as method (e.g., time window for scaring, in this case relatively short i.e., five days), group of species, and landscape composition. Moreover, a study on the grazing effect by brent geese (*Branta bernicla*) in winter showed that scaring devices (scarecrows, propane cannons, and bags on poles) reduced yield loss by 10% to 75% in three different fields (Summers, 1990). Similarly, Summers and Hillman (1990) showed that scaring of brent geese from winter wheat fields by using a line of red tape reduced yield loss by 5%. Compared to these studies, the relative scaring effect found in this study is in the upper range (i.e., 61-90%). The results thereby support earlier findings that scaring devices placed in agricultural fields can reduce the number of foraging birds in general and geese in particular. True harvest gain of scaring as in Summers (1990) and Summers and Hillman (1990) was not but instead used goose number as a proxy of damage risk. Several studies have shown a clear relationship between goose numbers and harvest gain/loss (Percival and Houston 1992; Düttmann et al. 2023; Buitendijk et al., 2023).

When it comes to more active scaring techniques, e.g., when people scare geese by walking, drones, bangers, or lethal scaring, some recent studies have compared different methods (Heim et al., 2022; Teräväinen, 2022). The effect on goose numbers in the present study are in line with those found for active scaring techniques. For example, lethal scaring showed a ~60% reduction in goose numbers for three days (Månsson, 2017). Moreover, a recent study to reduce the number of geese grazing in agricultural grassland showed that fields subjected to laser treatments experienced seven times lower density of goose droppings than control fields where geese were not exposed to lasers. However, the latter study also found that the scaring effort was as costly as the resulting harvest gain (Clausen et al., 2019).

Scaring can be labour intensive and costly (Vickery and Summers, 1992). In some situations, the economic costs of scaring may even outweigh the potential economic benefits as shown in Clausen et al. (2019). Few cost-effective solutions are available to farmers at present (Sausse et al.,2021). In this study the three devices varied considerably in cost: ~400 Euros, ~40 Euros, ~20 Euros for the inflatable man, the kite, and the scarecrow, respectively, but they did not differ significantly in absolute scaring effect (i.e., reduction in number of geese). The time needed to mount the devices in the field was quite similar (~ 2 minutes for the scarecrow and inflatable man, and ~10 minutes for kite). In this specific case, an extra cost of several hundred Euros (purchase price of inflatable man) does not seem to reduce the number of geese more than the much cheaper scarecrow. Still, several devices may be needed for alternating the measures and thereby reduce the risk of habituation (Steen et al. 2015). Moreover, several devices will most probably be needed to cover fields larger than the areas surveyed in this study. The aim of the study, though, was to compare the effectiveness of the three devices. Consequently, further studies are needed to understand how many devices are needed to cover a certain field size.

In the present study, scaring was performed for five days, therefore possible habituation (here defined as increasing goose numbers over time due to a diminishing response to repeated scaring) to the devices could not be studied properly. Moreover, the time need for habituation may also vary between different types of stimuli (in this case devices mimicking both natural predators and humans was used) and can therefore vary between different types of scaring devices (Askren et al., 2022). Habituation of geese is one of the critical issues when it comes to long-term effectiveness of scaring

(Bradbeer et al., 2017; Fox et al., 2017). For example, a study by Platteeuw and Henkens (1997) showed that birds tend to habituate to repeated disturbance, leading to decreased scaring effect as the response to the fear-provoking stimuli does not affect fitness. It is therefore reasonable to assume that geese will habituate to the devices used in the study too, and that they only remain effective as long as the neophobia (fear of the new) of the birds persists (Baxter et al., 2010). Thus, there may be a need to move and switch scaring devices between locations to achieve a sustained effect over periods longer than five days.

As shown in earlier studies, the effect of scaring can vary among different types of devices and species, but it can also be context dependent (e.g., season, food availability, and internal stage of the birds) (Bishop et al., 2003; Simonsen et al., 2016; Fox et al., 2017). For example, there are studies indicating differences in the reaction to scaring among goose species; e.g., barnacle geese tended to be harder to scare than greylag geese and bean geese (Kvarnbäck, 2021). Generalisation of my results should therefore be made with some caution since the vast majority (86%) of the identified geese in this study were greylag geese and the results are most probably mostly mirroring the behaviour of this species. Still, it's found that several other goose species occurred in the fields (white-fronted goose, pink-footed goose, barnacle goose, and Canada goose) but unfortunately, i could not perform a species-specific analysis since there were too few observations of the other species.

This study covered several seasons and most of the months (February to October) when geese are present in the study area (Månsson et al. 2022). From a goose perspective, this includes the period from arrival at the breeding area to autumn migration. The study period also covers the sequence and shifts in agricultural practices from sowing, growing season to harvest. Hence, the intrinsic state and energetic needs of geese (Fox et al., 2017) but also the availability of suitable fields and food varied during the study period (see for example the supplemental information in Nilsson et al., 2016). Consequently, the scaring effect, too, may have varied over the studied period, as found for other bird species (Enos et al., 2023). Unfortunately, sample size restrictions did not allow us to do analyses by season. Although nutritional and energetic needs of geese vary with season, they do feed on crops in vulnerable stages and cause damage from March to October, in this part of Sweden with a peak in June to September (Montràs-Janer et al., 2020). This study thereby provides a general result for the entire period in the area when scaring devices are used by farmers and managers. However, more studies are needed to provide insights about possible inter-seasonal variation in the effect of scaring.

In sum, scaring is not a final solution to mitigate crop damage by geese, but the methods studied here can reduce goose numbers and grazing pressure locally and for some time. The extent to which these methods may reduce yield loss in absolute terms requires further study. Future work should also address the efficiency of other management tools and scaring techniques, especially when combined, to lead to more effective control in the future. For example, the evaluation of ‘push’ (scaring) techniques needs to be combined with ‘pull’ strategies, such as accommodation fields, to avoid the problem simply being moved around in the landscape (Heim et al 2022; Teräväinen, 2022).

CHAPTER FOUR

EVALUATING THE EFFECTIVENESS OF SCARING TECHNIQUES IN RELATION TO COST AND EFFORT.

4.0 ABSTRACT

Increase in population of geese in Europe and North America can be attributed conservation measures, availability of suitable habitats, and the adaptability of geese to urban and agricultural environments. Different scaring methods have been used to scare geese from agricultural fields to where they don't cause damage. Few studies have tested the effectiveness of the scaring techniques in relation to cost and effort. Literature review on ScienceDirect using the search terms "Geese" and "scaring" was conducted. The search was targeted in the entire article except for the references. The initial search yielded 223 results. However, 22 articles were inaccessible due to unavailability of authors, leaving us with 201 articles for further examination. To determine relevance, abstracts were scanned for indications of effectiveness and cost efficiency. For articles with relevant findings in the abstracts, examination of the full text was done, extracting data pertaining to the type of crop, season, methods employed, geographical region, the comparative efficacy of various scaring techniques, and the associated costs. Inflatable man had a high scaring effect (90%) and the initial purchasing cost for this scaring device was also high (364 USD) while kite had moderate scaring effect (60.5%) and associated initial purchasing costs was also moderate (18.2 USD). White plastic flags (0.8) had the least cost of scaring therefore low-cost efficiency. All analyses for this objective were performed in Microsoft excel. This study shows that all the scaring devices reduces geese at a given percentage but the higher the effect the higher the initial purchase cost. Therefore, a more comprehensive cost data would be necessary to make a definitive conclusion about the most cost-effective method.

4.1 INTRODUCTION

Geese are a group of waterfowl belonging to the family Anatidae, which also includes swans and ducks. They are obligate herbivores feeding on grain, roots, and green parts. They prefer a variety of crops such as wheat, maize, barley, and grasslands - all providing high energy content and high digestibility (Fox et al., 2017). There are several species found across the globe, including Canada geese *(Branta canadensis)*, snow geese *(Chen caerulescens)*, and greylag geese *(Anser anser)*. These migratory birds are known for their distinctive V-shaped flying formations and loud honking calls.

In recent decades, many goose populations have experienced a remarkable increase in numbers in Sweden and other parts of Europe (Fox and Madsen, 2017; Lefebvre et al., 2017). This trend can be attributed to various factors, such as the implementation of conservation measures, the availability of suitable habitats, and the adaptability of geese to urban and agricultural environments (Fox and Abraham, 2017; Fox and Madsen 2017; Mason et al., 2018). The growing conflict between geese and humans continues as reach and movement globally (Bradbeer et al., 2017)

Managing the growing goose populations has become a significant challenge, requiring substantial effort and resources from wildlife agencies and local communities (Lefebvre et al., 2017). The costs associated with mitigating the impacts of geese on crops can be substantial. Over 50% of harvest losses in Europe are attributed to geese where it is estimated that graylag and barnacle geese cause annual crop damages that need millions of euros for compensating farmers (Nilsson et al., 2016). For example, between the year 2000 and 2015, Sweden reported 90% of crop damage by geese caused by common crane *(Grus grus)*, barnacle goose *(Branta leucopsis)* and greylag goose *(Anser anser)* while bean goose *(Anser fabalis)* and whooper swan *(Cygnus cygnus)* caused 8 % of the reported damage (Montràs-Janer et al., 2019). This has led to increases in areas of conflict, especially in instances where the wild bird is protected and where non-lethal preventive tools do not have the intended effect (Hake et al., 2010). Similar situations have been reported in other European countries, such as the Netherlands and Denmark, where these geese have become a major concern for the agricultural sector (Tombre et al., 2017).

In Sweden different tools have been used to divert geese from crops that are economically sensitive to other alternative fields where they do not cause harm

(Conover, 2002, Fox et al., 2017). The scaring tools include; use of Scarecrow, Kite, Inflatable man, red tape, Lethal scaring(shooting), Human bird scarer, White plastic flags, plastic and Mylar flagging, use of propane cannons, camouflage nets and firecrackers (Vickery and Summers,1992, Vickery and Summers,1992, Conover, 2002). Much has been published on various scaring techniques but little information is available on the effectiveness of scaring techniques in relation to cost and effort. This study is aimed at evaluating the effectiveness of scaring techniques in relation to cost and effort. It is predicted that all the scaring devices would reduce the number of foraging geese at the field level, thus decreasing crop damage risk, but that there would be difference in effectiveness, cost and effort and thus farmers will prefer some techniques over others due to cost efficiency.

4.2 MATERIALS AND METHODS

4.2.1 METHODOLOGY

For this study, a thorough literature review was conducted using the ScienceDirect database to explore the effectiveness and cost efficiency of geese scaring methods. The search was focused on articles discussing "Geese" and "scaring," with these keywords searched throughout the articles but excluding references. Initially, 223 articles were identified from the database.

After the initial identification, 22 articles were found to be inaccessible due to unavailability of authors or lack of full-text access. This left a total of 201 articles available for further evaluation. To determine the relevance of these articles, their abstracts were screened. Articles were included for full-text examination if their abstracts indicated findings related to the effectiveness and cost efficiency of various geese scaring methods. Upon selecting relevant articles, full-text reviews were conducted and only articles that reported scaring effects and cost were considered. Data extraction focused on several key aspects: the types of crops affected by geese, seasonal patterns of geese activity, methods employed for scaring geese, geographical regions where studies were conducted, comparative efficacy of different scaring techniques, and the associated costs.

Data extracted from each article were recorded in Microsoft Excel for systematic analysis and comparison. This included compiling a structured summary table (Table

4.1) to present the extracted data, facilitating a comprehensive overview and comparison of geese scaring methods across different contexts.

Quantitative data extracted were analyzed using descriptive and comparative methods available in Excel. The ScienceDirect database was chosen as the primary source for this review due to its extensive coverage of scientific literature across various disciplines, particularly in environmental and agricultural sciences. This ensured a thorough retrieval of relevant studies on geese scaring methods, supporting the robustness and reliability of this study's findings.

4.3 RESULTS

4.3.1 Scaring Methods reported

The methods that were focused on for further analysis and discussion were those recorded from the selected articles. These included the following: use of Scarecrow, Kite, Inflatable man, red tape, Lethal scaring(shooting), Human bird scarer, White plastic flags, plastic and Mylar flagging (Table 4.1). The methods reported the scaring effect and initial purchase costs for the scaring devices.

4.3.2 Scaring Effect

Human bird scarer had 93%-100% scaring effect followed by inflatable man 90% scaring effect. Scarecrow, Lethal scaring and Kite reported moderate effect of 64.6%, 63% and 60.5% respectively (see table 1). Red flags reported the least scaring effect of 5% while White plastic flags, Plastic and Mylar flagging did not report any scaring effect (NA *).

4.3.3 Cost of scaring and cost efficiency

The cost of scaring was high when using inflatable man (364 USD) thus has the highest cost efficiency. Kite and scarecrow had moderate cost associated and cost efficiency (18.2 and 36.4 USD respectively) while White plastic flags and plastic and Mylar flagging (0.8 and 1.2 USD respectively) had the least cost of scaring therefore low-cost efficiency (see table 4.1).

Table 4.1: A review from ScienceDirect showing data pertaining to the type of crop, season during the study period, methods employed, region where the study was done, the comparative efficacy of various scaring techniques and the associated costs.NA * refer to the papers that did not define the proportion of the scaring effect and the associated costs while NA refers proportion of papers that did not report the cost of scaring therefore there is no cost efficiency.

Device	Species	Crop	Method	Region	Season	Scaring effect (%)	Cost (USD)	Cost efficiency (USD)	Source
Scarecrow	greylag goose	cereals, ley, rapeseed, potatoes, and carrots.	counting number of geese	Sweden	winter, spring, summer, and autumn	64.6	36.4	0.6	Robai et al.,2024
Kite	greylag goose	cereals, ley, rapeseed, potatoes, and carrots.	counting number of geese	Sweden	winter, spring, summer, and autumn	60.5	18.2	0.3	Robai et al.,2024
Inflatable man	greylag goose	cereals, ley, rapeseed, potatoes, and carrots.	counting number of geese	Sweden	winter, spring, summer, and autumn	90.0	364	4.0	Robai et al.,2024
Red tape	brent geese	wheat	counting goose droppings	Sussex and Norfolk	winter	5.00	NA	NA	Summers and Hilman,1990
Lethal scaring(shooting)	greylag goose	leys, cereal (barley and wheat), carrots and peas	counting geese	Sweden	Spring	63.0	NA	NA	Månsson,2017
Human bird scarer	Brent geese	winter wheat and oil-seed rape	Droppings	Norfolk and Holkham	winter	100.0	127.4	1.3	Vickery and Summers,1992
Human bird scarer	Brent geese	winter wheat and oil-seed rape	Droppings	Norfolk and Holkham	winter	93.0	NA	NA	Vickery and Summers,1992
White plastic flags	snow geese	Rye and winter wheat	droppings and goose tracks	New Jersey	winter	NA *	0.8	NA	Mason et al.,1993
plastic and Mylar flagging	snow geese	Rye, grass and clover	droppings and goose tracks	New Jersey	winter	NA *	1.2	NA	Mason and Clark,1994

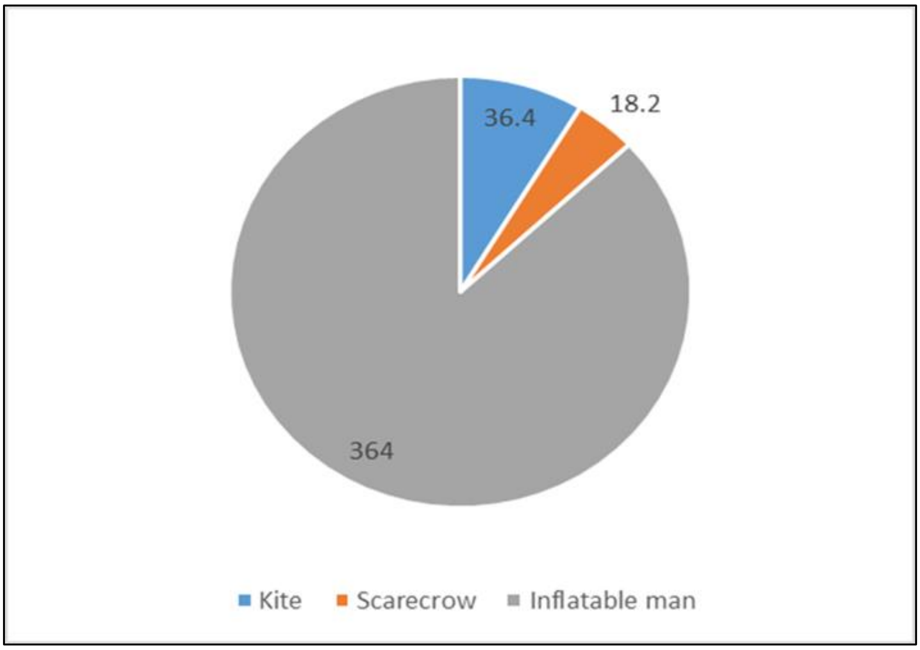

Figure 4.1: Purchasing cost in USD of the three commonly used in Sweden: inflatable man (364), kite (36.4) and scarecrow (18.2).

4.4 DISCUSSION

This study shows that different devices vary in terms of scaring effect, cost and efficiency when it comes to geese scaring from agricultural fields. Devices with the highest scaring effect (inflatable man 90%) have the highest cost of scaring (364) and thus highest cost efficiency. Devices with the lowest scaring effect have the least cost incurred thus they are less cost efficient (White plastic flags 0.8 and plastic and Mylar flagging and 1.2 USD).

As goose numbers continue to increase, there is increased damage caused to crops. Unfortunately, few studies exist that look into effectiveness of these commonly used scaring techniques (scarecrow, inflatable man, kite) in relation to cost and effort. Early studies have looked into effects of different scaring methods such as scarecrow, propane, use of red tape, flags, kites on different species of birds and geese (Conover, 2002; Bishop et al., 2003, Conover and Conover 2022). A study by Vickery and Summers (1992) in Norfolk and Holkham shows that the cost of scaring brent geese from winter wheat and oil seed-rape was 127.4 USD using human scarer that reduced the yield losses by geese by 100 %. Another study by Mason and Clark (1994) in New Jersey shows that the cost of scaring snow geese from Rye and winter wheat was 1.2 USD when using plastic and Mylar flagging. Moreover, a study on the effect of snow geese on Rye and wheat showed that white plastic flags reduced the number of geese at a cost of 0.8 USD. Compared to these studies, the relative effect found in this study (Robai et al., 2024) is in the upper range (i.e., 61-90%). This comes with a higher cost of 364USD for inflatable man,36.4 for scarecrow and 18.2 for kite (see fig. 4.1). These results therefore support early findings that scaring devices placed in the field have an effect of reducing the number of geese but this comes with a cost that varies from one scaring device to another.

Scaring birds away can be time consuming and costly (Vickery and Summers, 1992). Sometimes, the cost of scaring can be more than the benefits it brings (Clausen et al., 2019). Few cost-effective solutions are available to farmers at present (Sausse et al., 2021). In this study the three devices varied considerably in cost: ~364USD, ~18.2USD, ~36.4 USD (see fig. 4.1) for the inflatable man, the kite, and the scarecrow respectively. In this specific case, an extra cost of several hundred 364USD (purchase price of inflatable man) does not seem to reduce the number of geese more than the much cheaper scarecrow. Still, several devices may be needed for alternating the measures and thereby reduce the risk of habituation (Steen et al., 2015).

In Sweden, the presence of geese can pose significant challenges to agricultural and natural landscapes, prompting the need for effective scaring methods. One common approach involves the use of visual deterrents, such as reflective tape, which can be relatively inexpensive to implement but may have limited effectiveness, especially with habituated birds (Summers and Hilman, 1990). Acoustic deterrents, such as propane cannons or distress calls, offer another tactic that is often more successful in the short term, but their continuous operation can be costly and disruptive. Additionally, techniques like laser technology offer non-harmful yet startling stimuli for geese with higher initial investment costs.

The effectiveness of scaring devices in deterring geese varies depending on various factors including the species of geese, targeted crops, method of scare, and environmental conditions (Fox et al., 2017). Although scaring reduces the number of geese foraging at a field level (Robai et., al 2024), it’s not a final solution. More comprehensive data on costs would be necessary to make a definitive conclusion about the most cost-effective method. Further research considering both effectiveness and cost efficiency would provide valuable insights for farmers and wildlife management authorities.

CHAPTER FIVE

RELATIONSHIP BETWEEN VARIOUS SCARING TECHNIQUES PRACTICED BY FARMERS

5.0 ABSTRACT

Human-wildlife conflicts continue to pose significant challenges worldwide, especially in agricultural landscapes where wildlife causes damage to crops and property. Scaring is a tool used to divert animals' attention from foraging on agricultural fields to alternative places where they don't cause damage. However, there are few studies that exist where the relationship between various scaring techniques practiced by farmers and the decreasing number of geese has been experimentally tested. Scaring consultants who are employed by county administrative board to help farmer deter geese from the fields were interviewed. A total of 29 scaring consultants from 15 counties in Sweden participated in the interviews conducted from September 21st to October 4th, 2022. These counties, include: Dalarna, Gotland, Jämtland, Jönköping, Kalmar, Norrbotten, Örebro, Östergötland, Skåne, Södermanland, Uppsala, Värmland, Västerbotten, Västmanland, and Västra Götaland. Farmers were asked to rate the perceived effectiveness of commonly used scaring techniques for geese on a scale from 1 to 10, they provided assessments of the perceived duration of the scaring effect in terms of the number of days and the perceived cost efficiency of these techniques on a scale from 1 to 10. Fire crackers (4.6%) and Lethal scaring (4.5%) had the highest perceived effect, Exclosure river (3.7%) and Inflatable man (3.2%) had moderate effect and Rotating mirror pyramid (2.6%) and Rotating mirror (2.4%) had the lowest effect. In terms of cost efficiency, devices like birdalert (4.1%) and lethal scaring methods (4.0%) show high effectiveness relative to the resources expended. Propane cannons (3.9%) and netting along shores (3.5%) demonstrate moderate cost efficiency, while drones (2.3%) and rotating mirrors (2.3%) exhibit lower cost efficiency due to perceived lower effectiveness compared to the costs incurred. All analyses for this objective were performed in Microsoft excel. This study shows that all the commonly used techniques reduce goose grazing pressure locally. However, the duration of their scaring effect also varies, with some methods lasting less than a day (<1) to a maximum of 30 days. These results explain the importance of considering not only effectiveness but also cost efficiency and duration when selecting scaring devices for goose management.

5.1 INTRODUCTION

Human-wildlife conflicts continue to pose significant challenges worldwide, especially in agricultural landscapes where wildlife cause damage to crops and property (Conover, 2002). In Sweden, the continued increase in geese numbers has become a considerable concern for farmers, leading to economic losses due to conflicts between conservation and agriculture (Madsen et al., 2014). To mitigate these conflicts, farmers often resort to various scaring techniques to deter geese from agricultural areas. However, the effectiveness of these techniques and the perceptions of farmers towards them are crucial factors in devising sustainable wildlife management strategies.

Scaring devices represent a primary method employed by farmers to mitigate human-wildlife conflicts, including those involving geese (Robai et al.,2024; Simonsen et al.,2017). These devices consist of a wide range of tools and technologies designed to scare geese from foraging in agricultural fields. Common examples include auditory devices emitting distress calls or predator sounds, visual deterrents such as scarecrows or reflective tape, and tactile deterrents like fences or netting (Bishop et al.,2003).
The cost associated with implementing and maintaining scaring devices is a critical consideration for farmers seeking sustainable solutions to wildlife conflicts. While certain devices may offer immediate relief from goose depredation, their long-term cost-effectiveness requires careful evaluation. Factors such as initial investment, ongoing maintenance, and potential crop damage must be weighed against the economic benefits of mitigating wildlife-related losses (Hill and Wallace,2012). Furthermore, the duration of effectiveness of scaring devices is key in shaping farmers' perceptions and management strategies. Therefore, it is important to balance short-term and long-term deterrents in order to develop holistic wildlife management approaches that address the dynamic nature of human-wildlife interactions (Dolbeer, 2011).

Assessing the effectiveness of scaring devices is essential in understanding their impact on mitigating goose-related conflicts. Studies have examined various factors influencing the scaring effect, including the type of device used, its placement within the landscape, and the behavior of targeted wildlife species (Madsen et al., 2017).

While some devices may yield immediate results by causing geese to flee the area temporarily, long-term efficacy and habituation remain significant concerns. There is need for more studies to look into different perceptions by farmers on scaring techniques to effectively optimize the design and deploy these devices in agricultural settings.

Practical experience of different scaring devices is available from both Europe and North America, but little is published on the perception of farmers regarding scaring devices, scaring effect, cost efficiency and duration under controlled conditions. This study aims at evaluating different farmer's perception towards the different scaring devices. It predicts that some farmers will prefer a given scaring device over the other because of the affordability in cost and maintenance.

5.2 MATERIALS AND METHODS

5.2.1 METHODOLOGY

Scaring consultants who are employed by county administrative board to help farmer deter geese from the fields were interviewed. A total of 29 scaring consultants from various counties in Sweden participated in the interviews conducted from September 21st to October 4th, 2022. Data collection took place in 15 out of 21 counties, namely Dalarna, Gotland, Jämtland, Jönköping, Kalmar, Norrbotten, Örebro, Östergötland, Skåne, Södermanland, Uppsala, Värmland, Västerbotten, Västmanland, and Västra Götaland. During the interviews, the scaring consultants were asked to rate the perceived effectiveness of commonly used scaring techniques for geese on a scale from 1 to 10. Additionally, they provided assessments of the perceived duration of the scaring effect in terms of the number of days and the perceived cost efficiency of these techniques, also on a scale from 1 to 10. All responses were recorded, and data pertaining to the type of scaring device used to keep geese away from their agricultural lands, the perceived scaring effect, cost efficiency, and duration (in days, ranging from minimum to maximum) were entered into an Excel spreadsheet for subsequent analysis. (Refer to Table 5.1 for the list of commonly used scaring techniques for geese.)

5.3 RESULTS

5.3.1 Scaring devices

According to responses from different consultants, farmers used different scaring devices (see Table 5.1).

5.3.2 Scaring effect

Based on the responses from scaring consultants, the scaring techniques with the highest perceived effectiveness percentages were as follows: Fire crackers (4.6%), Lethal scaring (4.5%), Fireworks (4.4%), Netting along shores (4.3%), Propane cannon (4.1%), Fieldguard (4.0%), and String with bands (4.0%). Conversely, the techniques with the lowest perceived effectiveness percentages were Kite (2.9%), Plastic band/Flags (2.7%), Scarecrow plywood (2.7%), Rotating mirror pyramid (2.6%), and Rotating mirror (2.4%). Techniques such as Drones (3.8%), Birdalert (3.8%), Exclosure river (3.7%), and Inflatable man (3.2%) were rated as having moderate scaring effects. Compared to the previous study on effectiveness of different scaring techniques (Robai et al., 2024), inflatable man (90%) was rated to have the highest effect, then scarecrow (65%) and kite had the least effect (61%) and this present study, scarecrow and kite had least effect and inflatable man had moderate effect. This study therefore supports early findings

5.3.3 Cost efficiency

In terms of cost efficiency, devices like bird alert (4.1%) and lethal scaring methods (4.0%) show high-cost efficiency percentages relative to the resources expended. Propane cannons (3.9%) and netting along shores (3.5%) demonstrate moderate cost efficiency percentages, while devices like drones (2.3%) and rotating mirrors (2.3%) exhibit lower cost efficiency percentages due to perceived lower effectiveness compared to the costs incurred. Compared to the previous study (Robai et al., 2024), inflatable man had a cost efficiency of (4.0%) which in this study is rated among the highest effective relative to the resources expended. Scarecrow (0.6%) and kite (0.3%) had the lowest cost efficiency which is similar to this present study. Therefore, previous findings support this study.

5.3.4 Duration

The duration of their scaring effect also varies, with some methods lasting less than a day to a maximum of 30 days. These results explain the importance of considering not only effectiveness but also cost efficiency and duration when selecting scaring devices for goose management. In the previous study, a conclusion made was only for seven days but still inflatable man had a higher lasting effect compared to kite and scarecrow.

Table 5.1: Responses of scaring consultants in 15 counties of Sweden from 21st September 2022 to October 4th, 2022. The perceived effectiveness of commonly used scaring techniques for geese rated on a scale of 1 to 10, the perceived duration of the scaring effect in terms of the number of days and the perceived cost efficiency of these techniques on a scale from 1 to 10.

Scaring device	*Scaring effect*	*Cost efficiency*	*Duration (in days, min - max)*
Kite	*2.9*	*2.9*	*<1 - 10*
Propane cannon	*4.1*	*3.9*	*<1 - 30*
Inflatable man	*3.2*	*3*	*<1 - 14*
Plastic band/Flags	*2.7*	*3*	*<1 - 30*
Scarecrow plywood	*2.7*	*3.4*	*<1 - 7*
Fireworks	*4.4*	*3.7*	*<1 - 14*
Drone	*3.8*	*2.3*	*<1 - 3*
Field guard	*4*	*3*	*<1 - 7*
Bird alert	*3.8*	*4.1*	*<1 - 14*
Fire crackers	*4.6*	*3.4*	*<1 - 14*
Netting along shores	*4.3*	*3.5*	**
String with bands	*4*	*3.8*	*3-7.*
Exclosure river	*3.7*	*3.5*	*5-14.*
Rotating mirror pyramid	*2.6*	*3.1*	*<1 - 21*
Rotating mirror	*2.4*	*2.3*	*<1 - 3*
Lethal scaring	*4.5*	*4*	*<1 - 30*

5.4 DISCUSSION

According to this study, all the scaring consultants responded that all the scaring devices decreased the number of geese at a field level but there was a variation in the scaring effect, the cost efficiency and the duration it takes for a device to stay effective. The highest effect is in a range of 4.0 - 4.6 (field guard and fire cracks respectively), moderate effect is in a range of 3.2-3.8 (inflatable man and drone respect respectively) and the least effect was between 2.4-2.9 (rotating mirror and kite respectively). Bird alert (4.1) and lethal scaring methods (4.0) show the highest cost efficiency, Propane cannons (3.9) and netting along shores (3.5) demonstrate moderate and drones (2.3) and rotating mirrors (2.3) exhibit lower cost efficiency rotating mirrors (2.3) exhibit lower cost efficiency. There was variation in the duration of the scaring effect with least lasting up to 3 days (<1 - 3) and highest up to 30 days (<1 - 30).

As human wildlife interactions continue to pose a significant challenge between conservation and agriculture, there is need to for sustainable solutions (Conover, 2002). Unfortunately, there is little that has been published on perception of farmers towards a given scaring technique. Earlier studies have focused much on the effectiveness of different techniques used to scare geese from agricultural fields. The techniques include: use of scarecrow, propane cannons, red tape, kite, flags, bird alerts, inflatable man (Bishop et al., 2003, Conover and Conover 2022, Robai et al.,2024). A study by Månsson, (2017) showed that lethal scaring was effective in reducing the numbers of geese the by ~60% for at least three days. Moreover, a study on use of laser to reduce number of grazing goose show that fields subjected to laser treatments experienced seven times lower density of goose droppings than control fields where geese were not exposed to lasers. It also found that the scaring effort was directly proportional to the resulting harvest gain (Clausen et al., 2019). The findings from this study therefore support early findings that scaring devices reduce the number of geese at field level but the duration and cost vary from one device to another with some having high cost and long duration and others lower cost and lower duration (Robai et al,.2024). This variability may be attributed to differences in the behavior and adaptability of geese, as well as the specific environmental conditions in which the techniques are deployed (Cunningham et al., 2023).

The assessment of cost efficiency highlights the need for farmers to balance the effectiveness of scaring techniques with their economic feasibility (Vickery and Gill, 1999). Techniques like Bird alert and Lethal Scaring, which received higher cost efficiency ratings, may offer attractive options for farmers looking to invest in long-term goose management strategies. However, it is essential to consider not only the costs of implementing these techniques but also the potential long-term benefits in terms of crop protection and yield preservation.

Additionally, the duration of the scaring effect plays a crucial role in determining the practicality and efficacy of different techniques. Techniques with longer-lasting effects, such as Propane Cannon and Netting along Shores, may provide farmers with more reliable protection against geese over extended periods. However, shorter-duration techniques like Drone and Rotating Mirror may still offer value in specific scenarios, such as temporary field protection or targeted scare tactics. Furthermore, the regional variation in perceived effectiveness and cost efficiency highlights the importance of considering local context and conditions when selecting scaring techniques (Eriksson et al.,2020). Factors such as the density of goose populations, land use patterns, and agricultural practices can significantly influence the suitability and success of different strategies.

The findings of this study contribute valuable insights to the ongoing dialogue surrounding goose management in agricultural landscapes (Eythórsson et al., 2017). By understanding the strengths and limitations of various scaring techniques, farmers and policymakers can make informed decisions to mitigate crop damage while promoting sustainable coexistence between agriculture and wildlife. Further research into the long-term efficacy and ecological impacts of these techniques will be essential for advancing effective and environmentally sound goose management practices.

CHAPTER SIX

GENERAL OVERVIEW (SUMMARIES)

6.1 INTRODUCTION

This chapter gives a summary of the main results, proposed recommendations and the way forward concerning effectiveness of different geese scaring techniques in Sweden. The main objective of the study was to investigate the effectiveness of different scaring techniques in preventing crop damage by Geese. Below are the specific objectives:

1. To examine the numerical response of geese to specific scaring methods.
2. To evaluate the effectiveness of scaring techniques in relation to cost and effort.
3. To establish the relationship between various scaring techniques practiced by farmers and the decreasing number of geese.

6.2 SUMMARY OF THE MAJOR FINDINGS

6.2.1 To examine the numerical response of geese to specific scaring methods.

- A total of 42,281 geese were counted: Greylag goose Anser anser was the most common species (87%), followed by bean goose Anser fabalis (6%), greater white-fronted goose Anser albifrons (3%), barnacle goose Branta leucopsis (2%), and Canada goose Branta canadensis (2%).
- During scaring the number of geese significantly decreased for all three devices in model 2. The inflatable man decreased goose numbers by 90.0 %, scarecrow 64.6%, and kite 60.5%. A similar pattern was found in model 1, but the decrease was not significant.

6.2.2 To evaluate the effectiveness of scaring techniques in relation to cost and effort.

- Human bird scarer had 100% and inflatable man 90% scaring effect but the cost of scaring was high (127.4 and 364 USD respectively)
- Kite had 60.5% and scarecrow had 64.5% moderate scaring effect and cost associated (18.2 and 36.4 USD respectively)
- White plastic flags and plastic and Mylar flagging (0.8 and 1.2 USD respectively) had the least cost of scaring therefore low-cost efficiency.

6.2.3 To establish the relationship between various scaring techniques practiced by farmers and the decreasing number of geese.

- Scaring consultants who are employed by county administrative board to help farmer deter geese from the fields were interviewed.
- 29 scaring consultants from 15 counties in Sweden participated in the interviews conducted from September 21st to October 4th, 2022 (Dalarna, Gotland, Jämtland, Jönköping, Kalmar, Norrbotten, Örebro, Östergötland, Skåne, Södermanland, Uppsala, Värmland, Västerbotten, Västmanland, and Västra Götaland)
- Scaring consultants were asked to rate the perceived effectiveness of commonly used scaring techniques for geese on a scale from 1 to 10, they provided assessments of the perceived duration of the scaring effect in terms of the number of days and the perceived cost efficiency of these techniques on a scale from 1 to 10.
- Fire crackers (4.6) and Lethal scaring (4.5) had the highest perceived effect, Exclosure river (3.7) and Inflatable man (3.2) had moderate effect and Rotating mirror pyramid (2.6) and Rotating mirror (2.4) had the lowest effect.
- In terms of cost efficiency, devices like birdalert (4.1) and lethal scaring methods (4.0) show high effectiveness relative to the resources expended. Propane cannons (3.9) and netting along shores (3.5) demonstrate moderate cost efficiency, while drones (2.3) and rotating mirrors (2.3) exhibit lower cost efficiency due to perceived lower effectiveness compared to the costs incurred.

6.3 RECOMMENDATIONS, IMPLICATIONS AND WAY FORWARD

- More experimental studies are needed to provide a more comprehensive cost data to make a definitive conclusion about the most cost-effective method.
- Further research into the long-term efficacy and ecological impacts of these scaring techniques will be essential for advancing effective and environmentally sound goose management practices.

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