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Is it worthwhile scaring geese to alleviate damage to crops? – An experimental study

Caroline Ernberg Simonsen[1]*, Jesper Madsen[2], Ingunn M Tombre[3] and Jacob Nabe-Nielsen[1]

[1]*Department of Bioscience – Roskilde, Aarhus University, Frederiksborgvej 399, DK-4000 Roskilde, Denmark;* [2]*Department of Bioscience – Kalø, Aarhus University, Grenåvej 14, DK-8410 Rønde, Denmark; and* [3]*Arctic Ecology Department, Norwegian Institute for Nature Research, The Fram Centre, N-9296 Tromsø, Norway*

Summary

1. Increasing population sizes of geese are the cause of numerous agricultural conflicts in many regions of the Northern Hemisphere. Scaring is often used as a tool to chase geese away from fields, either as a means to protect vulnerable crops or as part of goose management schemes to drive geese to accommodation areas. Geese are quick to habituate to stationary scaring devices; hence, active scaring by humans is often employed. However, it remains undocumented how much effort is required for active scaring to be effective.

2. We explored the relationship between intensity of active human scaring on field use and behaviour by geese. Using an experimental framework, we applied four different scaring doses per day (geese were scared either 2, 5, 7 or 10 times per day), to random pastures in a pink-footed goose spring staging area in mid-Norway, and recorded goose flock sizes, fleeing response distances, and average weekly goose densities assessed by dropping densities. In addition, we counted droppings in fields without scaring. We used mixed models to test for changes in the effects of different scaring doses over time and compared observed with predicted dropping levels.

3. Cumulative dropping densities increased at different rates depending on the scaring dose. Scaring dosage did not affect flock size and fleeing response distance during the study period, but both flock sizes and fleeing response distances changed with time.

4. Scaring dose 2 did not show any decrease in relative goose use compared to the fields without scaring, whereas doses 5, 7 and 10 all showed 74–78% fewer droppings by the end of the spring staging period, indicating a possible threshold between dose 2 and 5. The largest effect of scaring appeared during the first week of scaring.

5. *Synthesis and applications*. This study is the first to show a dose–response relationship between active scaring and field use of flocking geese. For individual farmers, the study provides guidance on the level of scaring effort needed to be cost-effective. If implemented as part of a management scheme with subsidy/accommodation areas in combination with systematic and persistent scaring, it can be used as a tool to keep geese away from areas where they are not wanted, thereby assisting in the alleviation of goose–agriculture conflicts. The approach in this study can be adapted and used in a wider range of wildlife interactions with human economic interests.

Key-words: agricultural conflict, crop damage, crop protection, dose–response, experimental scaring, goose behaviour, pink-footed goose *Anser brachyrhynchus*, spring staging

Introduction

Since the middle of the 20th century, the majority of goose species have adapted their foraging behaviour to feed primarily on nutrient-rich agricultural crops outside the breeding season (Alisauskas, Ankney & Klaas 1988; van Eerden *et al.* 1996; Fox *et al.* 2005). At the same time, a steady increase in most goose population sizes has been observed (Fox *et al.* 2010), attributed to improved protection (Ebbinge 1991) and changes in agricultural

*Corresponding author. E-mail: ces@bios.au.dk

practices, providing geese with superabundant food resources (van Eerden *et al.* 1996). As a result, many populations have now reached unprecedented sizes (Fox *et al.* 2010). Consequently, farmers hosting geese have increasingly complained about crop yield losses, exacerbating conflicts between geese and agricultural interests throughout Europe, North America and parts of Asia (van Roomen & Madsen 1992; Ankney 1996; Lane, Azuma & Higuchi 1998). The farmers' concerns about yield losses caused by geese have been confirmed by several studies in north-western Europe and the British Isles (Summers 1990; Summers & Stansfield 1991; Percival & Houston 1992; Bjerke *et al.* 2014). To avoid damage to vulnerable crops, farmers have attempted to scare geese away from the fields (van Roomen & Madsen 1992). Reducing goose usage/foraging on specific fields can be achieved using many types of visual or acoustic stationary scaring devices, for example the use of propane gas cannons, scarecrows or flags (Heinrich & Craven 1990; Mason, Clark & Bean 1993), but geese often habituate to these devices (Conover & Chasko 1985). Hence, many farmers actively chase the geese away when they come into the fields (Eythórsson 2004; Søreng 2008). This is time-consuming, and since geese move around in the landscape, it is difficult for a farmer to scare efficiently. A few studies on the effect of active goose scaring have been carried out in Britain during winter, showing significant effects; however, these have not tested the relationship between scaring effort and subsequent reduction in goose densities (Summers & Hillman 1990; Vickery & Summers 1992; Percival, Halpin & Houston 1997).

Pink-footed geese *Anser brachyrhynchus* Baillon use staging sites in Nord-Trøndelag in central Norway and Vesterålen in northern Norway in April and May, before moving on to their breeding grounds in Svalbard. In Vesterålen, grass pastures are aggregated in a narrow lowland area situated between the shoreline and steep mountains. Here, farmers had success with scaring regimes organized around the clock between farmers during 1998–2003. This campaign caused a decline in goose usage of pastures/fields over wide areas (Tombre, Eythórsson & Madsen 2013). This campaign also forced geese to use less favoured fields that were less protected by the farmers as these were less vulnerable crops (Tombre *et al.* 2005). Active scaring of geese in the north of Norway (Vesterålen) is suggested as one of the reasons for the increased usage of spring staging sites in central Norway (Klaassen *et al.* 2006). Unlike Vesterålen, the region of Nord-Trøndelag is a mosaic of patches of farmland between forested or residential areas, making it difficult to organize widespread scaring. This means that in most areas of Trøndelag, individual farmers have to protect their crops by scaring on their own. Since 2005, a subsidy scheme has been in place in Norway by which farmers can apply for economic support to reduce some of the losses caused by geese (Eythórsson & Tombre 2013). This is on the condition that geese are not scared away (Madsen, Bjerrum & Tombre 2014). However, available subsidies are not sufficient to cover all the areas where farmers apply for subsidy and some farmers argue that the subsidy rate is too low, as grass yield losses can be substantial (Bjerke *et al.* 2014). Furthermore, because the grass is used to feed livestock, replacing lost crops is an inconvenience to affected farmers (E. Eythórsson, unpublished data). Therefore, many farmers still attempt to scare geese as a means of protecting their crops (C. E. Simonsen, unpublished data), but scaring activities are mostly uncoordinated and not integrated in the overall design of the subsidy system.

In this paper, we present the results of using an experimental design for systematic human scaring on grass pastures throughout an entire spring staging season of pink-footed geese in Nord-Trøndelag. We investigate whether scaring is a feasible tool and an alternative to the subsidy scheme for farmers in order to reduce crop damage caused by spring staging geese. With our design, we test the hypotheses that: (i) goose presence, flock sizes and weekly goose dropping densities decrease over time with increased scaring intensity – that is there is a dose–response relationship between scaring intensity and goose usage of fields; and (ii) over time geese will habituate to standardized scaring by decreasing their fleeing response distance, that is allow the scarer to get closer before taking flight at the end of the study compared to the beginning. Knowledge gained through this experimental study will provide farmers and wildlife managers involved in goose–agricultural conflicts with recommendations about whether or not scaring is an efficient tool to reduce goose grazing on specific fields. Furthermore, this study has the potential to be adapted to not only other waterfowl conflicts but to a wide range of wildlife interactions with human economic interests.

Materials and methods

STUDY POPULATION

The Svalbard breeding population of pink-footed geese has increased steadily during the last three decades. In the 1980s, the population was estimated to be 30 000 geese, growing to *c.* 40 000 in the 1990s and reaching an unprecedented peak of 81 500 in 2012 (Madsen & Williams 2012). During spring migration, the population migrates from Denmark to Svalbard via stopover sites in Nord-Trøndelag in mid-Norway and Vesterålen, northern Norway. Pink-footed geese started to use Nord-Trøndelag as a spring staging area in the late 1980s and the region has increasingly attracted more geese (Madsen, Cracknell & Fox 1999). The arrival of geese in the area has also advanced, probably related to a trend in earlier springs (Tombre *et al.* 2008). Today, the first geese arrive in Nord-Trøndelag in early/mid-April and numbers peak around the first week of May, when almost the entire population is concentrated in the region. On average, individual pink-footed geese stay in Nord-Trøndelag for 3 weeks before moving on to Vesterålen in north Norway (Bauer *et al.* 2008; Tombre *et al.* 2008).

STUDY AREA

Nord-Trøndelag is located in mid-Norway and is a semi-mountainous region with the Trondheim Fiord traversing from north-east to south-west. Sheltered shorelines and several large lakes offer roosting sites for geese. Geese feed in the lowlands surrounding the fiord and lakes. The lowland landscape consists of a mosaic of arable fields in between urban and forested areas. Crops primarily consist of spring-sown cereals (mostly barley), pastures and potatoes. Cereals are sown when the weather permits, usually around the first week of May. In April, geese feed on pastures, stubble fields left from the preceding autumn, waste potatoes and, when conditions permit, on unharvested barley fields. When sowing commences in early May, geese increasingly switch to feed on grain in the newly sown fields. In recent years, however, geese have started to depart from the area before sowing starts (Chudzińska *et al.* 2015). The main conflict between geese and agriculture is related to their use of pastures during spring (Bjerke *et al.* 2014).

EXPERIMENTAL SCARING

The core area used by pink-footed geese in Nord-Trøndelag is approximately 60 × 40 km, consisting of 16 208 registered agricultural fields (Fig. 1). We selected fields based on random stratified sampling within areas observed to be attractive to geese during spring staging in previous years. We contacted farmers to get their permission to experimentally scare geese, including an agreement that they refrained from scaring. We systematically scared pink-footed geese away from the selected fields every day from 18 April to 12 May 2012. Originally, 21 grass pastures not to be ploughed and reseeded that season were chosen. In addition, we included 11 pastures that were allocated for subsidy payments and used these as control fields as we knew geese would not be subjected to intentional scaring here. Five fields were removed from the data due to absence of geese (none or only one flock scared within the entire study period). One control field was ploughed during the study period and was therefore removed. The final data set consisted of 16 fields exposed to scaring and 10 control fields without scaring (Fig. 1), in total spanning *c.* 15 km in a north–south direction. Each field was given an ID number (‘field ID’) and randomly assigned a scaring intensity, that is a specific number of visits per day throughout the study ranging from 2 to 10 times during specific times in the morning (05·00–09·00 h), afternoon (13·00–17·00 h) and evening (18·00–22·00 h). The fields were visited in the same order day after day, meaning that each corresponding scaring event was carried out at the same time of day as the day before (±15 min). Some fields were neighbouring each other, others were solitary. Neighbouring fields were assigned the same number of scaring visits per day, conducted at the same time, to eliminate accidental scaring across field boundaries. At no point were geese observed moving from one field to a neighbouring field when scared off.

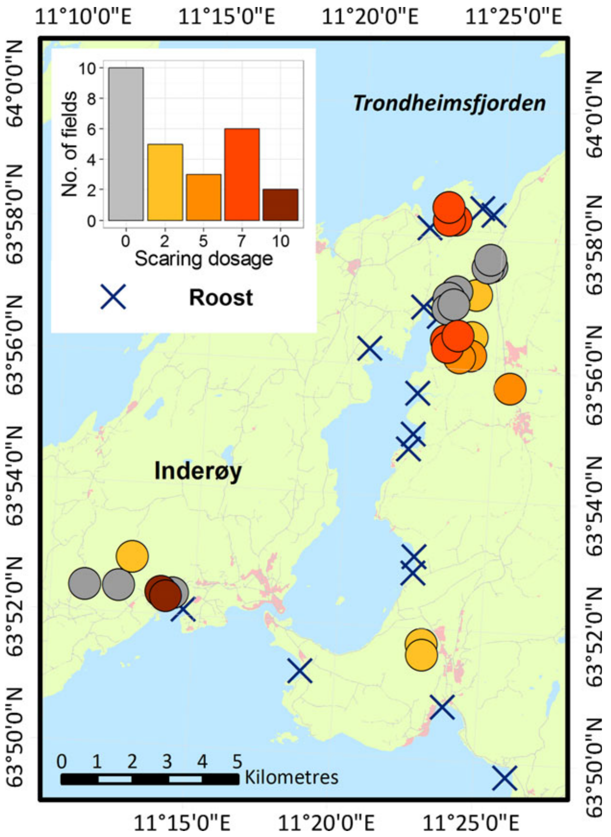

Fig. 1. Map of study site including number of fields investigated and their assigned scaring dose (top left corner). Scaring doses are coloured consistently throughout the present paper. Fields without scaring are grey and fields subject to scaring are coloured in a gradient of orange shades.

Flock size and fleeing response distance

The fields were visited by car. When geese were observed in a field, the observer counted the flock size by binoculars from the road and then walked into the field, clapping hands and waving arms until the entire flock had taken off. A questionnaire study carried out the previous year had shown that this type of scaring was the most commonly used and most successful method in Nord-Trøndelag (C.E. Simonsen, unpublished data). The fleeing response distance between the person scaring and the nearest goose in the flock when taking flight was visually estimated to the nearest 10 m.

Dropping counts and sward height measurements

Once per week, we visited each study field including control fields, to count goose droppings and calculate densities as a measure of grazing intensity in the field (Madsen 1985). Droppings were counted in three circles within a radius of 2 m, placed in the field centre, as well as two-thirds and one-third of the distance from the nearest source of disturbance, for example the road. After each count all droppings within the circle were removed. Each plot was marked with a small flag (a 20-cm stick with a 2 × 10 cm soft plastic strip attached at the top) to ensure that the exact same circles were visited each week. We did three separate 30-min observational studies to confirm that the flags did not affect the behaviour of the birds. Geese grazed uninterrupted within the close vicinity of the flags; hence, there was no apparent marker effect. At the beginning of the experiment we counted and removed droppings already present within the circle (‘initial droppings’). As an additional measure of grazing intensity, we measured grass sward height with a 25-cm plastic disc (weight 59 g) sliding down a measuring stick (Stewart, Bourn & Thomas 2001). We did three random grass height measurements within each circle (‘grassH’).

STATISTICAL ANALYSIS

In order to analyse whether increased scaring doses affected goose usage of grass pastures over the spring staging period, we used two different approaches: (i) daily morning and evening counts of flock sizes and (ii) weekly dropping counts on each field. Each approach represents different comparative advantages. The first provided data at a high temporal resolution, comparable from day to day, whilst the second provided a measure of the overall goose usage of pastures between weekly counts.

Flock size

The effects of scaring on flock size were analysed using a longitudinal design with 'field ID' as a random effect. In order to test for the effect of scaring we included: (i) scaring dose ('scardose'); as we cannot be sure whether the effect of scaring was linear we treated scaring dose as a categorical variable throughout our models, although we in general expected flock size to decrease when subjected to increased scaring doses. We also included (ii) time of day ('period') as a categorical variable because the number of geese foraging in a field was expected to vary according to diurnal levels of disturbance caused by general human activity (road traffic, farming activity) and (iii) number of days since the start of the study ('days') as an independent variable, along with (iv) observations of flock sizes the previous day at the same time of the day ('prevflock') to account for temporal autocorrelation. Finally, as we were interested in whether the effect of scaring on flock sizes changed over time, we added (v) the interaction between 'scardose' and 'days' to the model. To obtain a balanced data set for the flock size model where all fields contributed equally to the data, we only used observations corresponding to the lowest scaring dose, that is two times per day (first observations morning and evening). We log-transformed the flock size response variable to obtain normal distribution.

Fleeing response distance

To test whether pink-footed geese habituated to scaring we used a model similar to the one above except that (i) the response variable was fleeing response distance instead of flock size, (ii) the 'prevflock' was replaced by the fleeing response distance recorded at the same time the day before ('distprev') to account for temporal autocorrelation, (iii) flock size was included as an independent variable as we expect larger flocks to react to scaring sooner than smaller flocks (Madsen 1985) and (iv) all fleeing events were included in the model.

Dropping counts

As with the flock size model we used dropping counts to test whether scaring doses affected goose densities on each grass pasture. Again we used a longitudinal model design with 'field ID' as a random effect. We treated 'scardose' and number of weeks since the study started ('week') as categorical variables, because we did not necessarily expect a linear relationship between the two variables. As an independent variable, we used grass height ('grassH') as we expected geese to forage on fields with a preference for grass heights where intake rates, corresponded to an expected bell-shaped functional response rates with increasing grass height (Therkildsen & Madsen 2000). We added the interaction between 'scardose' and 'week' to the model as we specifically wanted to test our expectation that the effect of scaring changed over time. We log-transformed the dropping counts to account for skewness of the distribution.

To derive an expression of the effect of scaring on the relative reduction in goose usage of fields, we compared estimates of predicted and observed usage. Based on repeated dropping counts performed on the control fields, we calculated the relative change in goose usage from week to week. We used these changes to calculate the predicted density of droppings on each field exposed to scaring for weeks one, two and three relative to each field's dropping count in week zero, and assuming that, without scaring, the temporal trends would be similar to that of the control fields. We then used the difference between predicted and observed counts to calculate the potential relative decrease for each scaring dose.

We performed all analyses in R version 2.14.0 (R Development Core Team 2013). To run the mixed models we used the package LME4 (Bates *et al.* 2014). We used the Akaike Information Criterion (AIC) to compare full models for flock size, fleeing response distance and dropping count with the corresponding reduced models, retaining the most parsimonious one. Models with AIC values differing by more than two were considered different, that is the lower value expressing the stronger model (Anderson, Burnham & Thompson 2000).

Results

EFFECT OF SCARING ON GOOSE PRESENCE AND FLOCK SIZE

The relative influence of the different scaring intensities (doses) on the presence of geese in the study area remained constant throughout the study period ('days × scardose', ΔAIC = 4·77), which means that as the experiment progressed there was no change in the effect of each scaring dose (Model A, Table 1). Still, scaring dose did explain some of the differences in goose presence/absence observations. As we treated scaring dose as a categorical variable, the test only tells us that there is a difference between doses, but it gives no indication as to which doses differ from each other. Figure 2a shows how the lowest (2) and the highest (10) doses are only marginally different and leaves us cautious about interpreting too much from our model A results. There is no clear linear development between days since the study started and goose presence/absence (Fig. 2b), but there seems to be a slight tendency for increased goose presence in the middle of the staging period, corresponding to the fact that there are more geese in the study area. Most geese will have arrived from the south and only a few would have migrated further north at this time.

Flock sizes declined over the season for all four scaring doses (Fig. 3a), but the interaction between days and scaring dose was not included in the final flock size model (Model B, Table 1) meaning that even though the decline was most pronounced at the highest scaring dose compared to the rest, the effect was not sufficient to add to the model strength. The time of day was also included, reflecting that flock size differed between

Table 1. List of test results for all models relating goose presence, goose flock size, goose fleeing response distance and goose densities to scaring intensity

Model		AIC	ΔAIC
A	**Response:** goose presence/absence		
	Scardose (0–10) × days + period + prevpres	759·64	4·77
	Scardose (0–10) + days + period + prevpres	**754·87**	**1·74**
	Scardose (0–10) + days + prevpres	753·13	
B	**Response:** flock size (log)		
	Scardose (0–10) × days + period + prevflock	772·68	13·32
	Scardose (0–10) × days + period	759·36	10·24
	Scardose (0–10) + days + period	749·12	3·48
	Days + period	**745·64**	**0·63**
	Days	745·00	
C	**Response:** fleeing response distance (log) (m)		
	Scardose (0–10) × days + period + distprev + flock size	297·71	25·01
	Scardose (0–10) + days + period + distprev + flock size	272·70	19·24
	Scardose (0–10) + days + period + distprev	253·47	9·98
	Days + period + distprev	243·49	8·21
	Days + period	235·28	2·32
	Days	**232·96**	**−79·02**
	None of the variables	311·98	
D	**Response:** dropping density + 1 (log)		
	Scardose (0–10) × week + grassH	295·51	3·64
	Scardose (0–10) × week	**291·87**	**−5·07**
	Scardose (0–10) + week	296·94	
E	**Response:** dropping density + 1 (log)		
	Scardose (0–7) × week + grassH	278·58	3·65
	Scardose (0–7) × week	**274·93**	**−2·35**
	Scardose (0–7) + week	277·28	

All models are mixed models from the LME4 package in R. Stepwise reduction of models are presented. ΔAIC in bold indicates the most parsimonious model (ΔAIC is lower than two). Large negative ΔAIC values indicate loss of model strength if the variable is removed. Field ID was included as a random effect in all models. Brackets following scardose indicate whether all doses (0–10) or only doses 0, 2, 5 and 7 (0–7) are included in the model.

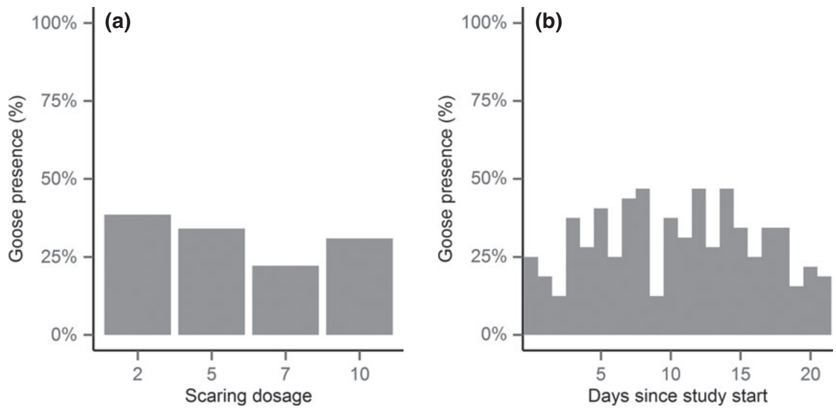

Fig. 2. Observed relative goose presence in grey per (a) scaring dose and (b) day.

morning and evening observations, with smaller flocks in the morning.

SCARING EFFECT ON FLEEING RESPONSE DISTANCE

We expected geese to allow the scarer to come closer as the season progressed, especially with higher scaring intensities, but our results showed the opposite. Our final model only included a temporal effect (Model C, Table 1). Neither the interaction ('days × scardose') nor 'scardose' improved the model. Figure 3b shows an almost identical increase in fleeing response distance during the study period for all four scaring doses, indicating that the increase in distance was due to something else other than scaring or that the threshold response is less than our lowest scaring dose of two scaring events per day.

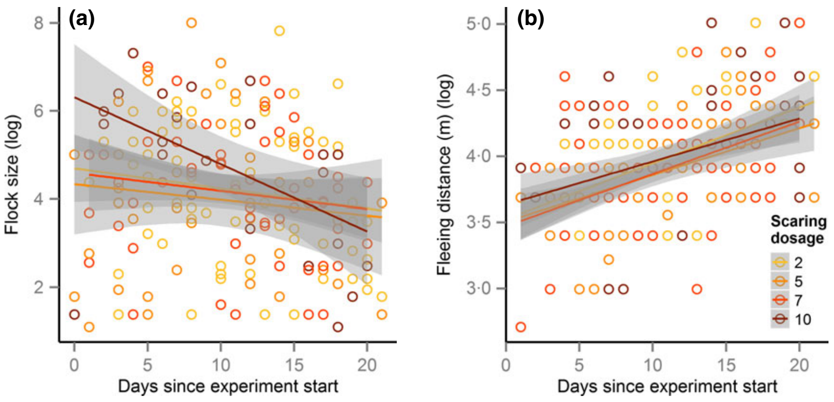

Fig. 3. Relationship between time and the observed (a) goose flock size and (b) goose fleeing response distance. Grey areas show confidence intervals of each linear fit.

SCARING EFFECT ON GOOSE DENSITIES

There was a general pattern of rapid increase in dropping densities in the middle of the spring season (Fig. 4), whereas they remained almost constant during the last part of the season. This nonlinear development underpins why we treated 'week' as categorical. The interaction between time ('week') and scaring dose was included in the final model (Model D, Table 1); hence, dropping density was dependent on the combination of which week and which scaring dose we investigated. As they are both categorical variables we do not know the specific relationship, for example whether the last week of the experiment showed fewer droppings in the highest scaring category. Because of the small sample size of scaring dose 10 we ran the models again without the highest dose. Comparing the new AIC values from doses 0–7 with the 0–10 we reached the same results, namely that the interaction between scaring doses and time as well as scaring on its own added to model strength (Model E, Table 1).

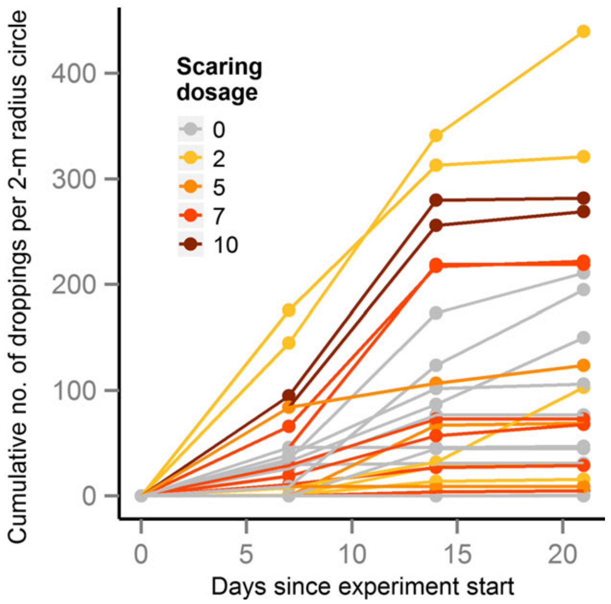

Fig. 4. Development of the average cumulative number of goose droppings per study field during the experimental period. Each field had three samples of 2-m radius circles (12·54 m^2). Days 7, 14, 21 correspond to week 1, 2 and 3 in the study design. Grey lines are control fields, that is subsidized fields without scaring.

By looking at the difference between the observed and predicted dropping counts for each scaring dose (Fig. 5), it is shown that for scaring doses 5–10, there were fewer observed droppings compared to the predicted levels. For dose 2, there were more observed droppings than predicted, but the predicted numbers are based on a very low count in week 0, which leaves little margin to observe a decline. Converting the difference between the observed and predicted into proportions the effect of scaring decreased goose use by more than 50% already after 1 week of scaring for any dose above five times per day. Also, doses 7 and 10 showed more than 95% decreased goose use in week 3 compared to the predicted level. On average doses 5, 7 and 10 showed 74, 78 and 74% less droppings, respectively, than expected during the entire study. Even if we correct for the anomaly of low initial dropping densities in fields with scaring dose 2, by using the initial average for all other fields, the effect of scaring for this dose remains marginal (15% less droppings than expected).

Discussion

All over the Northern Hemisphere increasing goose populations cause problems for farmers by foraging on agricultural land. Scaring is so far the only tool a farmer has to deter geese from foraging on vulnerable crops. Methods of scaring may include a variety of stationary devices such as scarecrows, flags, gas cannons, large farming equipment and subdivision of fields by strings on poles [see summaries in Mason (1995); Gosser, Conover & Messmer (1997)]. These measures are regarded as relatively cheap as they, when established, require little maintenance. The challenge with these methods is that geese often habituate quickly to non-moving objects. In contrast to passive scaring devices, active scaring by humans works every time a person approaches a goose flock and continues until the flock has left (Vickery & Summers 1992). This type of scaring is instantaneously effective but requires time and resources by means of human presence which is

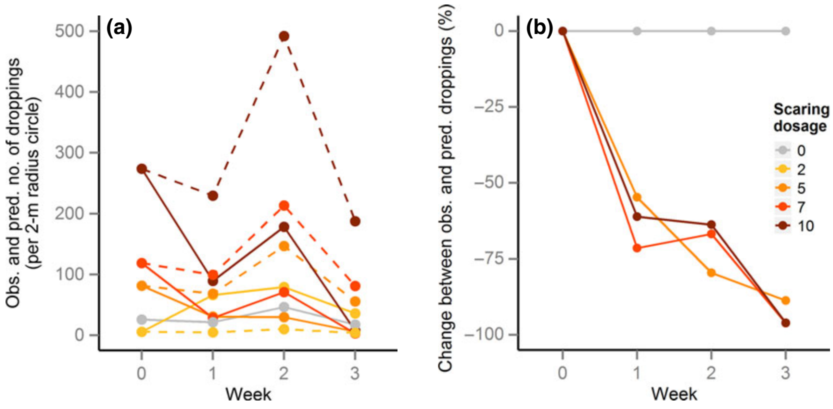

Fig. 5. (a) Observed (solid lines) and predicted (dashed lines) means of droppings per scaring dose week by week. The grey line is the mean from control fields, that is subsidized fields without scaring. Week 0 is set as the time immediately before the experiment was initiated. (b) Relative difference between the observed and predicted no. of droppings. Only decreasing trends are shown; hence, scaring dose 2 is not included in the plot as the observed counts were higher than its predicted counterparts.

more costly than stationary devices. Moreover, the geese may return to the field soon after the scarer has left.

We have demonstrated that active and systematic scaring may be an efficient tool and, as hypothesized, that increased intensity of scaring reduces goose pressure on pastures as shown by goose dropping density. Our results confirm the effectiveness of active scaring, but also demonstrate that a certain level of scaring is needed before a decrease in goose usage of fields is traceable. Low levels of scaring (e.g. 2 times per day) are ineffective, whereas high intensity doses (5 or more times per day) will result in lower goose usage and thereby less crop damage. Our results demonstrated an almost identical decrease in goose usage for all scaring doses of five or more, suggesting a possible threshold somewhere between scaring doses 2 and 5. Hence, for a farmer checking the fields and scaring five times per day will keep the goose use of pastures to a minimum, as increasing the intensity of scaring did not show any further effect. Furthermore, results indicated the effect of scaring to be most pronounced during the first week of the study, that is more than a 50% reduction in goose usage. Thus, intensive scaring at the beginning of the spring staging period is more effective than scaring evenly spread over the entire staging season.

We expected flock size to decrease with increased scaring intensity but it remained unaffected. Scaring appears to redistribute flocks from field to field rather than fragment flocks. This might be expected as all geese almost always left the field together in response to scaring. Flock behaviour and grazing strategy are dictated by a few experienced geese whereas the majority of individuals in the flock are 'followers'. The followers are not affected by scaring intensity as they do not decide field choice themselves. Presence/absence is thereby determined by the few experienced geese, whereas flock size will be influenced by other parameters such as time of day (Chudzińska, Madsen & Nabe-Nielsen 2013) and progression of the spring staging period; that is, flock sizes are generally expected to increase as the total number of staging geese builds up and decrease as geese start to fly north for the next stopover. Our temporal variable, either days or weeks since study start, is included in all our final models. In addition to the effect of the interaction between time and scaring intensity demonstrated in some of the models, it appears that changes in goose usage of pastures during the spring staging period in general is tied to temporal development of other unknown parameters that we have not accounted for in this study.

For the fleeing response distance model, scaring intensity and its interaction with time is not part of the final model. However, interestingly the change in fleeing distance over time is contrary to our initial expectations of habituation. Hence, geese took off at an increasing distance the longer the season progressed. This is good news for the farmers as these results demonstrate that the geese will be more easily scared as time goes by, instead of growing increasingly habituated to scaring attempts. One explanation may be related to the physiological state of the geese. During their stay in Nord-Trøndelag, pink-footed geese build up body reserves before their onward migration to the ultimate stopover site in Vesterålen, north Norway, and the breeding grounds in Svalbard (Madsen & Klaassen 2006). Carrying this extra weight possibly will make them slower at taking off, and therefore, they may be more nervous because of the risk of predation during the last phase before leaving Nord-Trøndelag. An alternative explanation is that in the course of the spring season geese came to associate a person with being scared away from a field and took flight sooner rather than waiting for the person to get close. Furthermore, based on satellite tracking of individual pink-footed geese it has been shown that geese move between several roosts and foraging areas within Nord-Trøndelag during a spring season (M. Chudzinska, unpublished data). Hence, for a given site, there will be a turnover of individuals which do not build up experience with local perceived predation risks including scaring, masking a possible habituation effect. This lack of persistent site fidelity is not only applicable with regards to the fleeing response distance but also for the effect of scaring intensity. As we cannot expect the same geese to return to the same field, systematic scaring is expected to be necessary to show a prolonged effect, not only within a given spring season, but by repeated scaring year after year. In Vesterålen, systematic scaring organized by farmers for several years has caused geese to abandon large parts of the most productive pastures (Tombre *et al*. 2005). This may possibly be explained by a synergistic effect of a long-term memory by geese making them avoid areas where they know they are not welcome.

Studies from Great Britain have demonstrated that active scaring can effectively reduce goose use of fields (Vickery & Summers 1992; Percival, Halpin & Houston 1997). These studies were carried out during winter when geese are in a different physiological state compared to when they are at spring staging areas. Compared to the winter situation, spring staging geese are under pressure to fuel body reserves to successfully conduct the subsequent migration and breeding episode in the Arctic (Ankney & Macinnes 1978; Prop, Black & Shimmings 2003; Madsen & Klaassen 2006). However, it is not clear how this will affect the response by geese to scaring. One possibility may be that they become more tolerant of risk and thereby more likely to return to fields with scaring to gain access to food resources. Another possibility may be that they become more risk averse in order not to spend extra energy on flight caused by disturbance. Therefore, it is not straightforward to compare the effects of scaring in the two situations. Furthermore, effects are likely to be dependent on the goose species in question, availability of alternative food resources and landscape characteristics.

To our knowledge, this is the first study where the dose–response relationship between scaring and goose use on agricultural crops has been investigated. We realize our design operated with relatively few samples within each of our scaring dose categories, yielding some uncertainty, especially with respect to initial dropping counts (week 0) that were used as a basis for the predicted dropping counts. Still, the general trend clearly demonstrated a dose–response relationship and a threshold level with five or more visits per day effectively reducing goose densities.

IMPLICATIONS FOR MANAGEMENT

Scaring geese away from vulnerable crops has been widely used to alleviate agricultural damage; however, few studies have tested the effect, and this is the first study to analyse the relationship between efforts and consequent reduction in goose use, applying an experimental dose–response framework. Our results can help to advise farmers and wildlife managers of goose–agricultural conflicts on the efficiency of active scaring with regard to effective dose and optimal timing of scaring. These results can be used in a wider socio-economic evaluation to answer the questions of whether scaring is cost-effective for individual farmers and, more widely in terms of planning how active scaring can be used in an integrated management design with 'go' and 'no go' areas for migrating species, that is combining accommodation areas or subsidized fields with scaring in fields where conflict species are not wanted. The dose–response relationships and thresholds found in this study are specific to pink-footed geese on their spring staging areas in mid-Norway and will probably vary with regard to species, their physiological state, densities, crop type and characteristics of the landscape. However, based on this study we believe that similar thresholds exist for other species and situations, not only waterbirds but wildlife in general, but they need to be established in a local context.

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Data accessibility

Data and R scripts: Dryad Digital Repository doi:10.5061/dryad.62b84 (Simonsen *et al*. 2015).

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