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ORIGINAL ARTICLE

Field preference of Greylag geese *Anser anser* during the breeding season

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Abstract Few studies address food preference of geese on agricultural land (utilization related to availability) and only a handful so for the breeding season. We studied Greylag geese *Anser anser* during the breeding season in an intensively farmed area in southern Sweden. Few of 22 available field types were truly preferred. Pastureland was the most consistently preferred, by goslings (with parents) as well as by non-breeders. In some sampling periods, goslings also preferred grazed hay, ley, and carrot fields. Non-breeders exploited a greater variety of crops/fields, feeding also on barley, fallow, grazed hay, lettuce, oats, potatoes, and carrots. Most of these crops were preferred on at least one sampling occasion, except for fallow, grazed hay, and wheat, which were always used less than expected from availability. GLMs revealed that goslings rested more than they fed and preferred shorter vegetation before higher. Moreover, goslings occurred in higher densities in younger age classes than in older and preferred near-shore areas. In contrast, density of non-breeders was only related to field type and sampling occasion (higher densities as the season progressed). The maximum number of broods observed (106) implies a breeding success of 34% based on 311 active nests earlier in the season. Brood size decreased from 3.5 to 2.1 during the study period. Our study shows that goose management during the breeding season should consider goslings and their parents separately from non-breeders, and it implies little potential conflict between Greylag geese and agriculture during the breeding period.

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Introduction

For a long time, increasing goose numbers were seen as a success story only, marking a welcome comeback from historical population lows due to overharvest and habitat loss. However, some populations have continued to grow, to numbers that create conflicts with humans. Airport bird strikes, over-grazing of natural habitats, eutrophication of wetlands, fouling of parks, and fear of zoonotic disease transmission are examples where soaring goose numbers (in North America mainly Snow goose *Anser caerulescens* and Canada goose *Branta canadensis*, in Europe Greylag goose *A. anser*, Pink-footed goose *A. brachyrhynchus*, and Barnacle goose *B. leucopsis*) create conflict and management challenges (Owen 1990; Jefferies et al. 2003; Fox and Madsen 2017). On both continents, the conflict with agriculture is especially widespread and multifaceted. Indeed, there are more geese on cropland and pastures than ever before, in all seasons (cf. van Eerden et al. 1996). This is due not only to increasing populations *per se* but also a result of expanding breeding ranges (e.g., Greylag goose and Barnacle goose in northern Europe) and of new migratory habits in response to climate change, leading to presence on agricultural land for a longer period of the year than before. In addition, geese have increasingly abandoned natural foraging habitats in fall and winter to instead feed on postharvest residual and winter-green crops provided by changed farming practices (van Eerden et al. 1996; Fox et al. online).

In monetary terms, the impact of geese on agriculture is substantial; for example, in 2007 €2.5 million were paid in management agreements in Scotland and €15 million in damage compensation and contracts with farmers to accommodate geese in the Netherlands (Stroud et al. 2016). This new and ever-changing scenario calls for new research efforts and new approaches; as highlighted in a recent review of geese as grazers in agricultural settings, most scientific knowledge available in this field was produced when climate, farming practices, goose numbers, and migration habits were different than they are today (Fox et al. online). In other words, there is 'a research debt' to pay to obtain a scientific foundation for improved goose management under present conditions. As a case in point, there are numerous previous studies about field (habitat) use by feeding geese, but rather few that address preference, i.e., utilization in relation to availability, and even fewer that address how preference varies between seasons (reviewed in Fox et al. online).

Geese are large-bodied obligate herbivores naturally adapted to a low-nutrient high-fiber diet. Accordingly, there is strong selection for adaptations to select the most profitable plant species and parts (Durant et al. 2004). That geese have the capacity to be such selective foragers is abundantly illustrated in the scientific literature (reviews in Sedinger 1997 and Fox et al. online). This allows them to swiftly switch to new food sources (growing crops as well as postharvest residual), as they become available short-term or seasonally, but also long-term because they have become more commonly grown or more nutritious due to genetic selection or increased fertilizing (Reed 1976; Stenhouse 1996; Patterson and Fuchs 2001; Jefferies et al. 2003; Fox et al. 2005; van Eerden et al. 1996, 2005).

The Greylag goose is widely distributed throughout the Palearctic region. Its breeding population in Western Europe has grown dramatically during the last 30 years (van Eerden et al. 2005), at the same time as its winter migration has been delayed, shortened, or curtailed altogether (Ramo et al. 2015). As a result, there are now vastly more Greylag geese for a much longer time of the year over large parts of Western Europe. This is certainly the case in Sweden, where the breeding population increased from ca. 300 pairs in the 1960s to ca. 40,000 in 2008 (Ottosson et al. 2012). Similarly, the number of staging Greylags in Sweden in September increased tenfold from an annual mean of 22,700 in 1982–1986 to 210,000 in 2007–2011 (Nilsson 2013).

Scania (Skåne) is Sweden´s southernmost province, densely populated, intensively cultivated, and home to a large breeding population of Greylag geese (ca. 8000 pairs in 2008; Ottosson et al. 2012). Conflict between geese and agriculture has been growing steadily in this region, although local co-management initiatives have shown some promise of alleviating conflict *per se*, albeit not by reducing goose numbers (Tuvendal and Elmberg 2015). One of the recurring issues in management efforts addressing the conflict between agriculture and Greylag geese, in Sweden and elsewhere, is whether they prefer or disfavour certain crops (e.g., Stenhouse 1996; Edberg 2003). This is central to the conflict, as farmland surrounds many of the wetlands where large concentrations of Greylags breed, in Scania and in many other areas in NW Europe.

The Greylag goose is one of the most studied goose species in general (Supporting Information Table S2 in Fox et al. online), with most research effort thus far carried out in late summer, autumn, and winter. There are also some studies of field use (and, implicitly, diet) in spring (e.g., Newton and Campbell 1973; Bell 1988; Stenhouse 1996; Nilsson et al. 2002; McKay et al. 2006) and of molting birds (Fox et al. 1998). However, to our knowledge, there is no scientific study published about foraging habitat preference in breeding Greylags (but see Nilsson et al. 2002 for field choice and field-specific densities), and very little such information from May and June in general. Studies of habitat preference and diet of Greylag geese during the breeding season are thus much called for, also because damage on crops in spring and summer may be more severe than in autumn (Fox et al. online).

For the present study, we selected an intensively farmed area with a large variety of crops, a history of goose conflict (Tuvendal and Elmberg 2015), and a large breeding population of Greylag geese. Our objective was to document usage and preference of different habitat types and crops during the breeding season. Specifically, we relate Greylag goose density (broods as well as 'non-breeders') and type of goose activity to field/crop type, vegetation height, distance to water, gosling age, and time of season. In addition, we study breeding success (number of foraging broods *versus* the number of nests from aerial counts) and how brood size changed over time.

Materials and methods

Study area

This study was carried out in 2014 at Lake Hammarsjön (55°58′N, 14°13′E) in the province of Scania in southernmost Sweden. It is a large (1680 ha) shallow eutrophic lake hosting a species-rich community of waterbirds, shorebirds, raptors, and songbirds. Hammarsjön is set in an intensively farmed landscape, where a large variety of crops is grown. The shores are either grasslands used as pastures or for hay production, or covered by dense reedbeds *Phragmites australis* with scattered willow bushes *Salix* spp. (Fig. 1). In addition, there are smaller areas of woodland close to the lake, mostly dominated by common alder *Alnus glutinosa*.

Hammarsjön is attractive to Greylag geese due to the combination of extensive stands of reeds, which are ideal for nesting, and surrounding open areas with diversified farming. Regular aerial surveys to count goose nests show that the

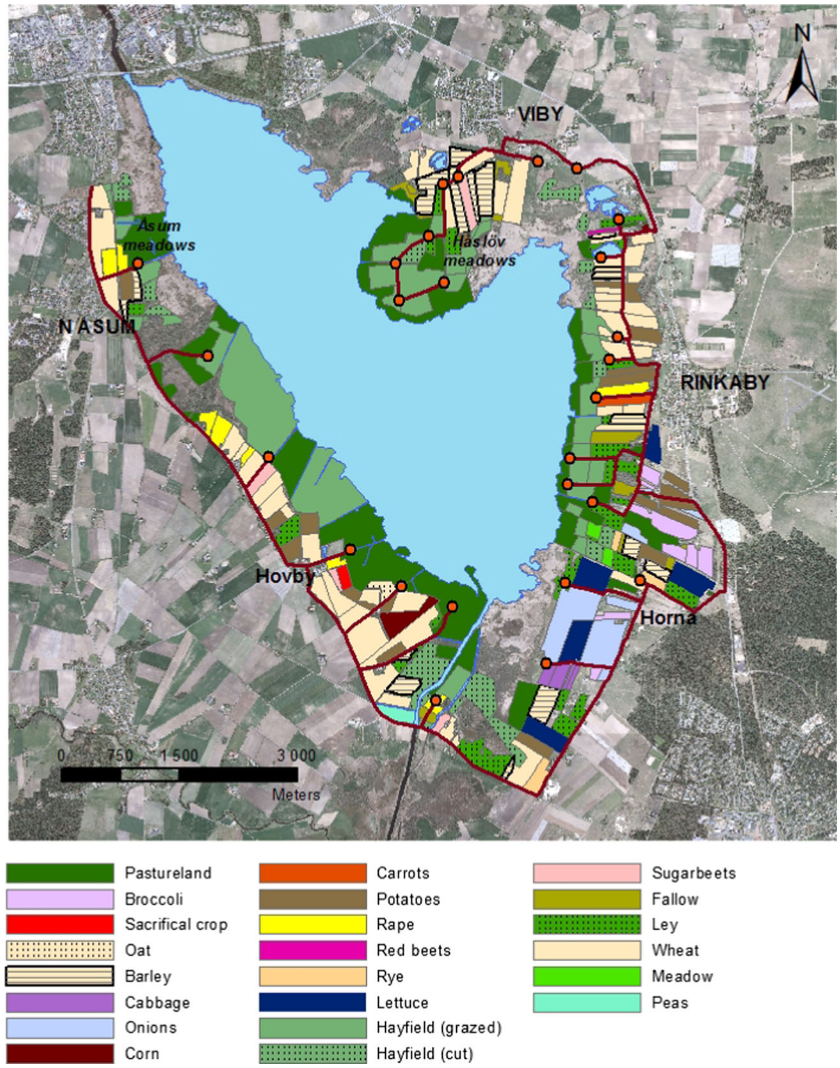

Fig. 1 The study area around lake Hammarsjön with field types in 2014 (see panel for color legend) and the roads (*red*) and points (*orange*) used to study Greylag geese. *Uncolored areas* inside the roads are reedbeds, thickets, and swamp forest that were not possible to census. Map reference: Orthophoto © Swedish Mapping Cadastral and Land Registration Authority, Dnr 2012/892.

number of breeding Greylags varied between 80 and 688 pairs over the last 10 years (Olofsson 2014).

We studied geese present on grassland and cropland surrounding lake Hammarsjön but inside the roads encircling the lake (Fig. 1). The study area is delimited to the north by the city of Kristianstad.

Field types

Most of the field types in the study area were easily classified by CO (Camilla Olsson), but we obtained additional information from landowners and leaseholders. The most common cereals were oat, barley, rye, and wheat, and these were grown both with and without intercropping. Some of the cereals had been seeded in spring 2014, others in the autumn of 2013. Other crops in the study area were broccoli, onions, corn, carrots, potatoes, rape, red beets, lettuce, sugar beets, peas, and cabbage (Fig. 1). Some of these, e.g., potatoes and rape, are harvested once a year, while others (e.g., lettuce) are sown and harvested multiple times.

There are several types of grasslands in the area, and they are managed differently depending on objectives. Pastures, meadows, and hayfields are more or less natural grasslands, cut at least once per season, after which grazing usually follows. Leys are cultivated grasslands cut at least twice per season, and in the study area, this field type was available both with and without intercropping. A couple of hectares were sacrificial crops (ley) used to attract geese off more sensitive crops. These fields were hence used by grazing birds only, and not for food or livestock feed production. Finally, some fields were fallows at the time of study, in previous years having been used as either hayfields, for grazing by livestock, or for crop production.

Since crops were planted and harvested at various seasons, a certain field type (as defined by crop species) may have vegetation of different height at any given time. Therefore, we estimated vegetation height and included it as a factor in the statistical analyses below. Since there were so many field types and crop varieties, we reduced them into fewer but biologically relevant general field types (e.g., lettuce varieties were one type, corn/maize varieties were one, etc.). These field type categories were marked on maps and later digitized (see below) (Fig. 1.). Field types varied considerably in areal extent (Table 1); e.g., pastures, natural hayfields, and wheat covered more than 50% of the study area, while 11 out of 22 field types each covered 1% or less.

Data collection

Geese present on land were observed from 26 predetermined points around lake Hammarsjön (Fig. 1), each visited on 9 occasions from May 16 to July 21, according to a specific route starting at Håslöv meadows and continuing clockwise to end at Åsum meadows (Fig. 1). Most of the study area was possible to observe from the 26 observation sites collectively, but if additional geese were detected from the car when traveling between observation points, we stopped to count them too, according to the procedure described below. One of the sites (Håslöv meadows) is a nature reserve and required a permit for access (County Administrative Board of Skåne, registration number 521-7547-2014 1290-206). The route was normally completed in one day, data collection started at approximately 6:30 a.m. and lasted 9 to 12 h depending on the number of geese present, road conditions, vegetation height, etc. Field work was not carried out on days with unfavorable weather such as heavy rain or high temperatures (>25 °C), since such conditions affect goose behavior. Accordingly, data collection was discontinued on 2 days (June 23 and July 14), to be resumed the next day, at approximately the same time as when it had been discontinued.

Table 1 Area and proportion of field types in the study area at lake Hammarsjön in 2014.

Field type	Area (ha)	Prop. of study area (%)
Pastureland	402	22.0
Hayfield (grazed)	337	18.4
Wheat	318	17.4
Ley	125	6.8
Heyfield (cut)	107	5.8
Potatoes	100	5.5
Barley	98	5.4
Onions	73	4.0
Lettuce	64	3.5
Broccoli	41	2.2
Rapeseed	39	2.1
Fallow	30	1.6
Sugar beets	19	1.0
Corn	15	0.8
Rye	15	0.8
Cabbage	13	0.7
Carrots	8	0.4
Oat	7	0.4
Peas	7	0.4
Meadow	6	0.3
Sacrifical crop	4	0.2
Red beets	2	0.1
Total	1830	

At each observation point, the surroundings were scanned with a spotting scope. In addition to any Greylag geese present upon arrival, arriving and departing geese were counted. Adult geese were classified as either ‘non-breeders’ or ‘breeders,’ based on presence of goslings. We here use the term ‘non-breeder’ throughout, although these birds are a mix of immature true non-breeders, adults that had already lost their nest or brood, and possibly fledged young of the year. Gosling age was determined using a modified protocol developed for Hawaiian goose (*B. sandvicensis*) (Hunter 1995); i.e., by plumage characteristics in combination with gosling size in relation to adults. Accordingly, there were seven age categories ranging from newly hatched to fledged. Goslings that were intermediate between categories were assigned to the younger category.

When possible to distinguish from each other, family groups were noted separately and brood size counted. Behavior of non-flying geese was classified as either ‘feeding’ or ‘resting.’ The approximate position of each goose or flock was marked on a field map using landmarks, and the average height of the vegetation used by the geese was estimated to the closest decimeter in the range 1–6 (alternatively to <1 dm, which was later replaced by the value ‘0.5’ to be able to run analyses). The latter estimate was obtained by relating vegetation height to adult geese, whose height is known.

All field work was done by the same person (CO). The present paper is based on parts of a dataset collected for a Bachelor’s Thesis in biology at Kristianstad University (Camilla Olsson, unpublished). An aerial survey (Olofsson 2014) provided data on the number of Greylag nests in lake Hammarsjön in 2014, and these were compared to the ground data collected in the present study.

Digitized maps

Field maps were scanned and digitized with geographic information system (GIS) (Arcmap 10.1) for further processing and illustration. The total area (hectares) of each field type could thereby be estimated by the software, and it was used to calculate goose density, i.e., the accumulated number of geese during the study period (i.e., ‘goose days’) per total area of a specific field type. GIS was also used to calculate the average distance in meters from each goose observation to the shoreline of lake Hammarsjön and other adjacent small waters (ponds, ditches, etc.).

Field type preference

We used Jacobs' index (Jacobs 1974) to assess field (habitat) type preference. It is calculated as $D = (r - p)/(r+p-2rp)$, where r is the proportion of geese in a specific field type, and p is the proportion of the total area consisting of this field type (Jacobs 1974). Thus, each field type is assigned an index value ranging from −1 (i.e., total avoidance) to +1 (used by all geese). One of the advantages of this method is that results thus obtained are readily comparable with other studies in which the index has been used (e.g., Nilsson and Persson 1991; Stenhouse 1996).

Statistical analyses

Jacobs' index (above) merely gives a picture of how much field types are utilized in proportion to their area but offers no explanatory power, as other field-level characteristics are not taken into consideration. Hence, we studied the effect of several variables on the density of goslings and non-breeders, respectively, with general linear models (GLMs). This was not done for breeding adults, as their distribution is not independent of that of their goslings (i.e., results for goslings can also be considered as a proxy for breeding adults). Independent variables in the GLMs were (1) *field type* used by the geese (cf. Table 1); (2) *behavior*, i.e., feeding or resting; (3) *study occasion*, ranging from 1 to 9; (4) *distance to shoreline*; (5) *vegetation height*; and for the analyses on gosling density also (6) *Gosling age*. Interactions that were potentially biologically relevant were also included in the analyses; i.e., if different field types were differentially preferred over the season, and if the effect of behavior varied between field types, height of vegetation, study occasion, or with distance to shoreline. For goslings, interaction terms were included to also test whether the effect of age varied with field type, distance to shoreline or vegetation height.

In an additional GLM, the effect of study occasion on brood size was studied. In cases where broods were difficult to tell apart, data on the total number of goslings divided by the number of present pairs were used instead.

Assumptions of equal variances and normality were evaluated by Levene's test and by doing P-P plots of the residuals in each model. As a result, data on the density of goslings and non-breeders were log-transformed to meet these assumptions. For all statistical tests, SPSS 22 was used.

Results

Goose numbers and brood size

The number of breeding Greylag geese was relatively stable during the study period (highest count was 151 on 7 July but decreased slightly toward the end; Fig. 2). Gosling number varied somewhat more, i.e., increased in the beginning of the study period to peak (count 255) on 9 June, and decreased thereafter (see also below for an overall linear negative trend for gosling density). Non-breeders varied more in numbers, from 968 on the first count occasion to only 13 on 9 June, and then increased dramatically to peak at 1847 on 4 July (Fig. 2) (see also below for an overall linear positive trend for the density of non-breeders).

Gosling number peaked at 255 on June 9 and decreased to 115 on July 21, when the study was concluded. Mean brood size decreased significantly from 3.5 (SD = 1.1) in the start of the study period to 2.1 (SD = 0.8) in the end (Table 2) (linear regression: $F_{1,\ 101} = 5.35$; $P = 0.02$; $\beta = -0.10$).

An aerial survey showed that there were 311 active Greylag nests in lake Hammarsjön in 2014 (Olofsson 2014).

Field type preference

In general terms, pasturelands and grazed hayfields (in that order) were the field types where most geese (regardless of category) were found. These field types were also the most common in the sense that they covered the largest area, but that they were genuinely preferred was shown by the fact that they also had the highest relative numbers (i.e., number of geese in relation to the total area of specific field types) (Figs. 3 and 4 and Tables 3 and 4). The common feature of these field types, especially where larger flocks (≥62 geese) were observed, is that they are open, flat, and have few or no trees and shrubs. As is obvious from Figs. 3 and 4, Greylag geese utilized rather restricted areas around lake Hammarsjön, and these included only half (11) of the 22 field types available in the study area. Among the 11 field types utilized by Greylags, preferences differed quite distinctly between goslings and non-breeders.

Goslings

Throughout the study period, goslings utilized fewer field types than non-breeders. Goslings particularly preferred pasturelands but commonly also utilized grazed hayfields (Table 3). A feature in common for these field types was close proximity to water (Fig. 3; see also below). Among the 20 other available field types, only three were utilized by goslings to some degree, although less than what was expected based on availability: leys (May, and in the end of June), carrots

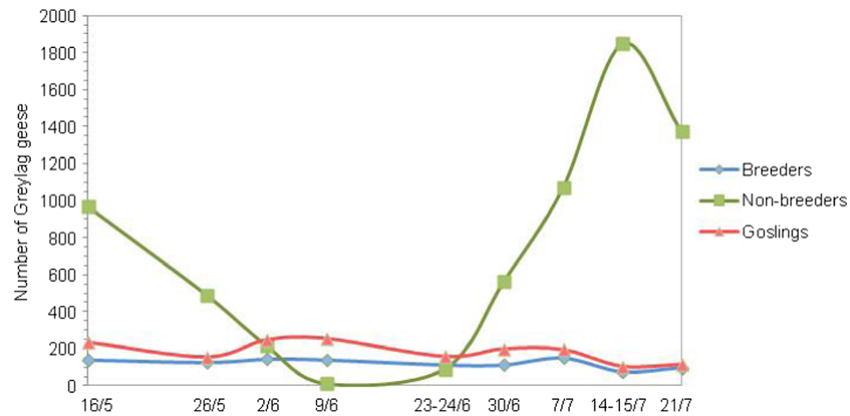

Fig. 2 Number of Greylag geese in the study area at lake Hammarsjön from May 16 through July 21. Sampling was done on the days given along the x axis. On 23–24 June and 14–15 July, 2 days were needed to complete counts (see the "Methods" section).

(early July), and wheat (July) (preference in that order; Fig. 3 and Table 3).

Non-breeders

Compared to goslings, non-breeding geese utilized more of the available field types; besides pastureland and grazed hayfields, also carrots, leys, barley, oats, potatoes, lettuce, wheat, non-grazed hayfields, and fallow fields were used (preference in that order; Fig. 4 and Table 4). In fact, based on the total value for Jacobs' index, carrots were more preferred than grazed hayfields (only pastureland was more preferred). The single carrot field in the study area was indeed disproportionally utilized, albeit only on two occasions in July, whereas grazed hayfields, along with pasturelands, were used during the entire study period. Leys were exploited to a relatively high extent in the end of May as well as in the end of June, and to a lesser extent (or not at all) during the rest of the study period. Fields with oats, potatoes, barley, and lettuce were mainly preferred during the beginning of the study period (positive values in Table 4 for May), but were avoided for the rest of the study period. Fallow fields were only used on one occasion in the end of the season but still less than expected based on availability. There was no specific temporal utilization pattern for non-grazed hayfields and wheat, which were used on several occasions during the study period, although less than expected (Fig. 4 and Table 4).

Table 2 Temporal change in mean brood size of Greylag geese in the study area at lake Hammarsjön in 2014

Sampling dates	Average	SD	Sample size
16 May	3.5	1.07	8
26 May	2.8	1.47	12
2 June	3.4	0.88	14
9 June	3.0	1.50	8
23–24 June	2.9	0.95	10
30 June	3.6	1.24	9
7 July	2.6	0.87	16
14–15 July	3.0	1.43	8
21 July	2.1	0.76	10

Effects on goose density

Goslings

Most of the independent variables affected variation in gosling density significantly (Table 5). The exception was *activity*, which was just above the significance threshold ($P = 0.07$), i.e., the density of resting goslings tended to be higher than that of feeding goslings. Besides a general effect of vegetation height (there were more goslings in shorter (mean 0.22 goslings/ha for 0–1 dm height, SD = 0.03) than in higher vegetation (mean 0.01 goslings/ha, for 5–6 dm height, SD = 0.01), the interaction between this factor and *activity* was significant, which is probably due to the fact that no resting goslings occurred in vegetation heights >3 dm, while feeding goslings were found in vegetation heights up to 5 dm.

Gosling density in general decreased slightly during the study period (i.e., an occasion effect, cf. above and Fig. 2) and also varied among field types (Table 5). Due to low sample sizes for some field types, proper post hoc tests to statistically evaluate differences between them could not be carried out. Nevertheless, a comparison among field types revealed higher densities on leys (mean = 0.12 goslings/ha, SD = 0.13), carrots (mean = 0.13 goslings/ha, SD = 0.02), pastureland (mean = 0.02 goslings/ha, SD = 0.02) and grazed hayfields (mean = 0.02 goslings/ha, SD = 0.02) than on wheat (mean = 0.01 goslings/ha, SD = 0.01), which corroborates the findings based on the preference index (Table 3).

There was also a significant effect of gosling age, with clearly lower density (mean = 0.01 goslings/ha, SD = 1.12) in the first age category compared to the others. Means in the latter were quite similar, from 0.03 goslings/ha (SD = 0.06) in age category 3 to 0.02 goslings/ha (SD = 0.01) in age category 7. Gosling density was generally lower away from the

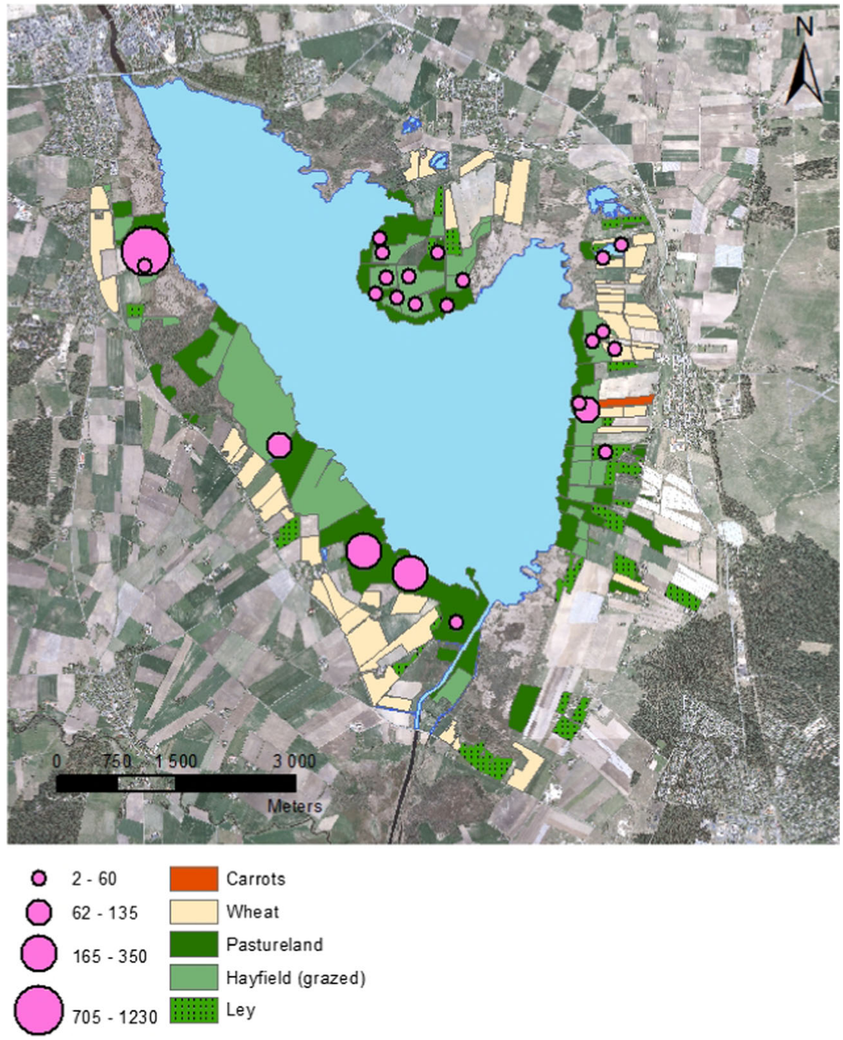

Fig. 3 Spatial distribution of 'goose days' (*circles*) of Greylag goose goslings at lake Hammarsjön in 2014. Only field types utilized by goslings are highlighted in color. Map reference: Orthophoto © Swedish Mapping Cadastral and Land Registration Authority, Dnr 2012/892.

shoreline (Table 5); in fact, no goslings were observed farther than 800 m from water (cf. Fig. 3).

Non-breeders

The GLM showed significant effects of occasion (i.e., a positive linear trend; cf. above and Fig. 2) and field type on the density of non-breeding Greylag geese (Table 5). Because of limited data for three of the field types (lettuce, oats and fallow), it was not possible to do post hoc tests to evaluate which field types differed from each other. However, a comparison of density values indicates that carrot and wheat fields had higher densities than other field types (means = 11.62 (SD = 9.02) and 5.38 (SD = 0.11) geese/ha, respectively, as compared to a mean density <1.00 in all other field types).

The interaction between *activity* and *field type* was marginally above the significance level at 0.07 (Table 5), indicating that different field types were likely used for feeding and resting, respectively. For example, although the utilization of fallow fields was relatively limited (mean = 0.07 geese/ha, SD = 0.01), none of the feeding non-breeders was ever found in this field type, but only resting geese. The opposite was found for wheat (mean = 0.11 geese/ha, SD = 0.11) and oats (mean = 1.00 geese/ha, SD = 0.01), in which only feeding geese were found (i.e., resting non-breeders avoided these field types entirely).

In contrast to in goslings, neither activity nor distance to water or vegetation height affected density of non-breeding Greylag geese.

Discussion

Goose numbers and brood size

Our study shows that lake Hammarsjön in 2014 harbored a major concentration of breeding Greylag geese. The study area thus remains an example of a wetland-agriculture setting with a high potential for conflict with geese in May-July. For more than half of the study period, non-breeders greatly

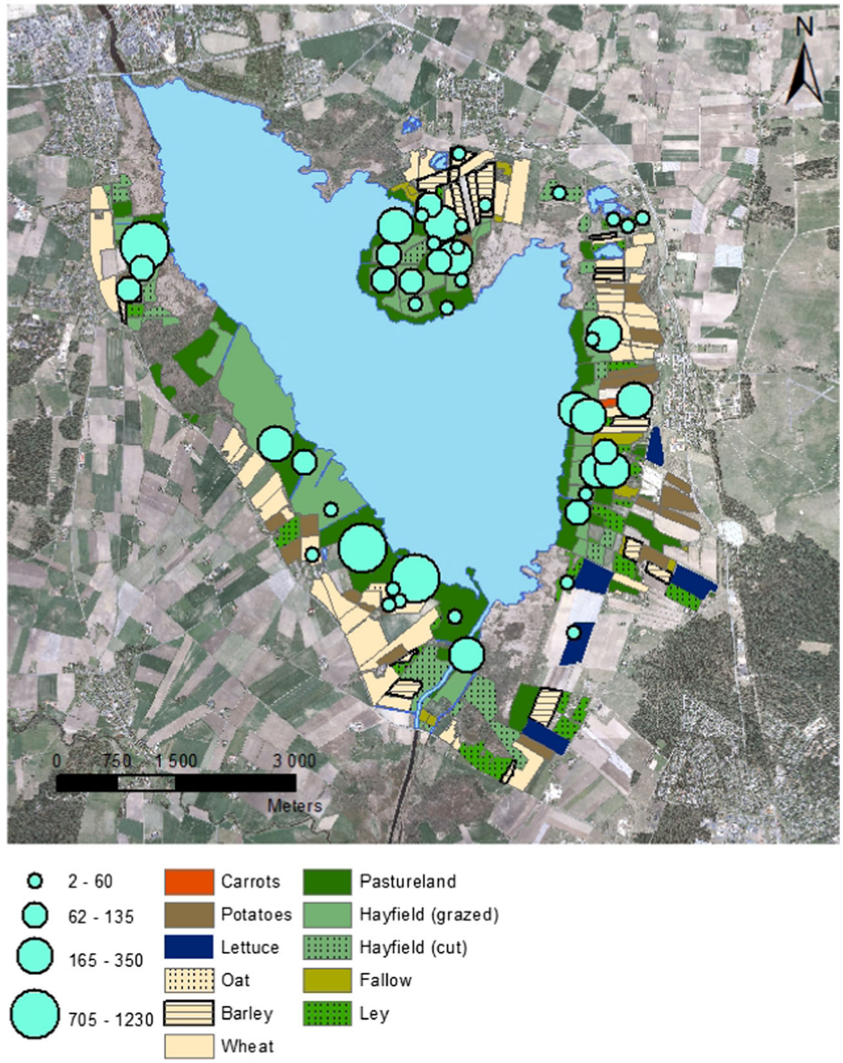

Fig. 4 Spatial distribution of goose days (*circles*) of non-breeding Greylag geese at lake Hammarsjön in 2014. Only field types utilized by non-breeders are highlighted in color. Map reference: Orthophoto © Swedish Mapping Cadastral and Land Registration Authority, Dnr 2012/892.

outnumbered goslings with parents, suggesting that the former may constitute a greater challenge than the latter when it comes to crop damage and its alleviation. The dip in numbers of non-breeders in June is likely due to redistribution to other areas to molt. It is worth emphasizing that the relative proportion of young non-breeders *versus* adult failed breeders among these birds is not known.

Gosling counts peaked at 255 on June 9, which translates into ca. 106 broods using the observed mean brood size for that date (Table 2). This can be contrasted with the aerial survey showing 311 active nests earlier the same season (Olofsson 2014), a nest success rate of 34%. Even if many goslings may have been depredated or otherwise lost before the peak count on June 9, we speculate that the nest success rate of Greylag geese breeding in lake Hammarsjön is well below 50%. This is low compared to the 54–69% observed over 14 years ($N = 540$ nests) in another study from southern Sweden (Nilsson et al. 2002), which in turn indicates a high predation pressure on nests or newly hatched goslings, or both, at lake Hammarsjön. The lake is a closed system to non-fledged birds, as it is completely surrounded by roads, farmland, and built-up areas. An indication that predation remains high throughout the gosling period is the negative relationship between brood size and time, leading to an observed brood size in July (2.1–3.0) clearly smaller than that found in Britain the same month (4.1; Young 1972) and possibly somewhat smaller than in two other studies from southern Sweden (range 2.2–3.9; Nilsson and Persson 1994; Nilsson et al. 2002). The most likely goose predators in the area at this time of the year are Red fox *Vulpes vulpes* and White-tailed eagle *Haliaeetus albicilla*. Below, we discuss what high predation risk may lead to in terms of field choice.

Field type preference

As is obvious from the spatial distribution (Fig. 3 *versus* 4); field type preference (Table 3 *versus* 4); and the GLMs (Table 5), goslings (with their adults) and non-breeders

Table 3 Field type preference in Greylag goose goslings expressed as Jacobs' index (see the "Methods" for details)

Field type	16 May	26 May	2 June	9 June	23–24 June	30 June	7 July	14–15 July	21 July	Total
Barley										
Red beets										
Broccoli										
Cabbage										
Carrots							0.08			−0.77
Corn										
Fallow										
Hayfield (grazed)	−0.19	−0.42	−0.17	−0.26	−0.47	−0.24	0.36	0.21	−0.01	−0.09
Hayfield (cut)										
Lettuce										
Meadow										
Ley	0.57	−0.84				−0.08				−0.4
Oat										
Onions										
Pastureland	0.74	0.95	0.91	0.93	0.95	0.88	0.74	0.82	0.85	0.87
Peas										
Potatoes										
Rape										
Sacrifical crop										
Rye										
Sugar beets										
Wheat							−0.86		−0.71	−0.95

The tabulated index values are averages based on the entire study period, and range from −1 to +1, where −1 equals no use (total avoidance, empty cells) and +1 is total preference (no other field type used). The field types marked in bold are those used by goslings during the study period

exhibited quite different habitat preference. This is in itself an important finding, as these categories have been analyzed separately in just one previous study of Greylag geese on agricultural land during the breeding time (Nilsson et al. 2002). It is thus warranted to treat these categories separately in future studies.

Goslings

Goslings occurred in only five of 22 available field types (Table 3), which is a more restricted utlization than in non-breeders (Table 4). In essence, broods with parents occurred almost exclusively on pastureland and grazed meadows. This is exactly what Nilsson et al. (2002) found in the only previous study in which Greylag families were considered separately from local non-breeding conspecifics.

Preference patterns like these provide a better understanding than does sheer field occurrence patterns, which have been the standard in goose studies. Nevertheless, field type preference data make still more sense when related to biologically relevant covariates, as in our GLMs of goose density patterns. A main message from the GLM for goslings is that at least four covariates and one interaction term explained where and when concentrations occurred in this agricultural landscape (Table 5). The observed tendency to select field types with short vegetation is a new insight for understanding spatiotemporal patterns of occurrence during this time of year. We also think that our results may shed light on the causality behind the occurrence patterns observed. First, although we acknowledge the difficulty in separating cause and effect (whether geese select short vegetation or if they keep the vegetation short by grazing), selecting field types with low vegetation may be profitable for goslings in at least two ways; short grass is better food, being more nutritious and containing less herbivore-deterring substances (cf. Kear 1970; Owen 1977), and it is easier to spot approaching predators early from such habitats. Second, GLMs show that goslings mainly occurred close to water, which most likely is an anti-predator strategy for them as well as for their parents, the latter which may be flightless due to molt at this time. If goslings and their parents prefer habitats with these characteristics, they should indeed select pastureland or grazed meadows, making the observed occurrence pattern an effect rather than a cause (cf. Fig. 1).

Non-breeders

That non-breeders utilized more field types than goslings is not surprising, as the former can fly and some have previous

Table 4 Field type preference in non-breeding Greylag geese expressed as Jacobs' Index (see the "Methods" section for details)

Field type	16 May	26 May	2 June	9 June	23–24 June	30 June	7 July	14–15 July	21 July	Total
Barley	0.40	0.31								0.40
Red beets										
Broccoli										
Cabbage										
Carrots							0.81	0.90		0.50
Corn										
Fallow									−0.84	−0.98
Hayfield (grazed)	−0.47	−0.52	0.03	0.82		0.01	0.44	0.09	0.47	0.17
Hayfield (cut)					−0.73			−0.69		−0.93
Lettuce		0.25								−0.07
Meadow										
Ley	−0.97	0.75			−0.03	0.61	−0.48		−0.91	0.04
Oat		0.58								−0.41
Onions										
Pastureland	0.63	0.43	0.87	0.22	0.95	0.64	0.63	0.73	0.65	0.68
Peas										
Potatoes	0.45					−0.83				−0.57
Rape										
Rye										
Sacrifical crop										
Sugar beets										
Wheat	−0.23						−0.90	−0.54	−0.67	−0.78

The tabulated index values are averages based on the entire study period, and range from −1 to +1, where −1 equals no use (total avoidance, empty cells) and +1 is total preference (no other field type used). The field types marked in bold are those used by non-breeding geese during the study period

Table 5 GLM results showing the contribution of independent variables on variation in density of goslings and non-breeding Greylag geese at lake Hammarsjön in 2014

	F	*P*	ß
General linear model			
Goslings			
Activity	$F_{1,\ 184} = 3.439$	0.065	–
Field type	$F_{4,\ 184} = 4.143$	0.003	–
Occasion	$F_{1,\ 184} = 15.718$	<0.001	−0.079
Distance to shoreline	$F_{1,\ 184} = 4.012$	0.047	−0.001
Vegetation height	$F_{1,\ 184} = 4.914$	0.028	−0.270
Age category	$F_{6,\ 184} = 3.491$	0.003	–
Activity × vegetation height	$F_{1,\ 184} = 4.886$	0.028	–
Non-breeding geese			
Activity	$F_{1,\ 138} = 0.355$	0.552	–
Field type	$F_{10,\ 140} = 4.651$	<0.001	–
Occasion	$F_{1,\ 140} = 8.583$	0.004	0.053
Distance to shoreline	$F_{1,\ 137} = 0.211$	0.647	–
Vegetation height	$F_{1,\ 139} = 2.243$	0.136	–
Activity × field type	$F_{5,\ 132} = 2.110$	0.068	–

experience of the area, providing them with knowledge what habitat is found where. Non-breeders thus have a much better opportunity to truly select among available habitats, crops, and field characteristics. This is evident from Table 4, which also indicates that geese responded to different farming practices in an opportunistic fashion on almost a week-to-week basis. Despite the wider and more flexible field preference in non-breeders, pastureland, and grazed hayfields were the most consistently preferred field types among these birds, just as in goslings. This preference is in line with previous studies of Greylag geese; breeders in Scania in April–May (Nilsson et al. 2002), residents in England in May (McKay et al. 2006), and wintering birds in Scotland in April before their departure to Icelandic breeding grounds (Stenhouse 1996). Preference for near-shore meadows, pastures, and hayfields during the breeding season of Greylag geese has been documented also in three studies from southern Sweden published in non-refereed outlets (e.g., Axelsson 2004; Wallgärd 2010; Tennfors 2013), and it thus appears to be a general phenomenon. Moreover, Newton and Campbell (1973) found preference for potatoes in April–May, which also was the case in our study; i.e., potatoes were preferred only on the first sampling occasion (May 16), but not later. When it comes to cereals, several previous studies have found that such are underused in spring (Axelsson 2004; McKay et al. 2006). If we had pooled our data for the different cereals, we could certainly have come to the same conclusion. Indeed, treated separately, we do find that some are not preferred at all (wheat and rye), whereas others are (oats and barley) but only so in May. The latter goes hand in hand with previous findings showing that geese prefer short vegetation (e.g., grass swards in Vickery and Gill 1999, but see Mandema et al. 2014); i.e., cereals grow too high in late season to be selected. A fondness for postharvest residual carrots observed in the present study has also been reported from the UK (Newton and Campbell 1973; Owen 1990). That carrots were preferred only on two occasions in July is likely due to the geese utilizing residuals from ongoing harvest (personal observation; cf. Newton and Campbell 1973).

The GLM result for non-breeders is quite different from that for goslings in showing that activity, vegetation height, and distance to water were of little or no importance in explaining variation in density. The fact that distance to water did not come out significant may indicate that the majority of birds in the non-breeder category are not molting at this time, as proximity to water would be a valuable anti-predator strategy for them, as it is in goslings. It may also indicate that non-breeding Greylags can simply focus more on selecting fields with the most profitable food and realize a strategy of more optimal foraging. Finally, the positive effect of occasion is expected since flocks in late season are joined by fledged juveniles and postbreeding adults.

Implications and conclusions

We selected the study area partly because of its unusually varied agriculture, with a truly wide variety of crops for geese to choose among. Against this background, it is worth noting that goslings as well as geese capable of flight at this time of year utilized rather few of the available field types. In other words, many field types were not utilized at all, including crops that have previously been claimed to be preferred and hard hit by geese at this time of year. Moreover, if a certain crop with a limited acreage had been much preferred, we would have seen it, at least in geese capable of flight. A limitation of this study is that it concerns only 1 year. However, while the acreage of different crops vary among years, most of the grasslands do not change much at all.

We subscribe to the view that results from agro-ecological systems of this type may be idiosyncratic, and that it may be difficult to make generalizations for other regions. Regardless, the present study highlights that future research in this field needs to address preference *sensu stricta* and include field-level covariates of the type used in our analyses. Disturbance, predation risk, field size, density dependence, and interspecific competition are examples of variables of putative high relevance.

The present study highlights that management of Greylag geese needs to consider goslings with adults separately from the more mobile non-breeders. As goslings strongly prefer open short-sward grassy areas close to water, there is little conflict potential with agriculture, unless gosling density is so high that grazing opportunities for livestock are reduced. Extreme grazing pressure, as by Lesser snow goose *Chen caerulescens caerulescens* in the Canadian Arctic, may lead to negative cascading ecosystem effects affecting plants, invertebrates, and vertebrates (e.g., Milakovic and Jefferies 2003; Abraham et al. 2005).

The present study does not provide any support for Greylags selecting peas, lettuce, sugar beets, and other sensitive crops, which they are often accused of doing (Nilsson and Persson 1998; Edberg 2003, p. 16; Axelsson 2004). This was true also for non-breeders, which have higher potential than breeders to find, utilize, and switch between crops that are more favorable to them at any given time. The strong preference for carrots was likewise not a conflict issue here, as geese fed on postharvest residual. In conclusion, even at very high goose densities as in this study, there was little conflict potential between Greylag geese and agriculture at this time of year, although the study area offered a large variety and some vulnerable crops. This is also confirmed by the fact that there were no reports about goose crop damage filed to the County Administrative Board by local farmers during the study period (Eva Johansson, in letter).

Fallow fields were only utilized by resting Greylag geese. This field type offers forage of lower nutritive quality than, e.g., wheat and oats (which were only utilized for feeding, not for resting). Since fallow fields are of lower economic importance than growing crops, the former could be used as sacrificial areas if fertilized or cut, actions both of which increase attractiveness for feeding geese (Owen 1977; Vickery and Gill 1999). In addition, cutting increases attractiveness by facilitating predator vigilance, as does creation of small wetlands in close proximity. On the other hand, if the goal is to displace geese, this study supports previous management advice saying that they can be discouraged from using fields by increasing vegetation height, making them less open, or in other ways create conditions more favorable for goose predators.

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