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Seeking greener pastures: crop selection by Greylag Geese (*Anser anser*) during the moulting season

Emily A. Strong, Steve M. Redpath, Teresa Montràs-Janer, Johan Elmberg & Johan Månsson*

E. A. Strong, Wildfowl & Wetlands Trust, Slimbridge, Gloucestershire, GL2 7BT, UK
E. A. Strong, University of Exeter, Penryn Campus, Treliever Road, Penryn, Cornwall, TR10 9FE, UK
*S.M. Redpath, T. Montràs-Janer, J. Månsson, Swedish University Agricultural Sciences, Grimsö Wildlife Research Station, 730 91 Riddarhyttan, Sweden * Corresponding author's e-mail: johan.mansson@slu.se*
J. Elmberg, Department of Environmental Science and Bioscience, Kristianstad University, 291 88 Kristianstad, Sweden
S.M. Redpath, Institute of Biological & Environmental Sciences, University of Aberdeen, Aberdeen, AB24 2TZ, UK

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Over the last 40 years, many goose populations have recovered from historic lows and are now more numerous than ever. At the same time, geese have shifted from natural foraging habitats to securing most of their nutritional demands from agricultural fields, leading to crop damage and conflict with agriculture. We studied field use by Greylag Geese (*Anser anser*) in the agricultural landscape surrounding a main breeding and moulting lake in Sweden. From 2012 to 2016, weekly roadside surveys were conducted from May to July. Data were collected on goose numbers, crop type and sward height in agricultural fields. Using a compositional analysis, we demonstrate that Greylag Geese show a strong selection for ley and pasture fields compared to other crop types (rank order: ley/pasture > oat > barley > wheat > other crops). This selection was consistent across years and between pre- and post-moult. Aside from ley and pasture, no other crop types were selected for, as they were used less than expected given their availability. Irrespective of crop type, geese foraged predominantly on short (0–10 cm) swards. The strong selection for ley and pasture may have been driven by higher nutritional quality of short, managed grass swards relative to other available foods. This suggests that during the summer grass fields may be more vulnerable to damage compared to other crop types. Our study provides a deeper understanding of the ecology of Greylag Geese, which may be used to inform management strategies focused on mitigating crop damage and alleviating conflict.

1. Introduction

Habitat selection is a central theme in animal ecology. In its essence, it describes how individuals use different habitats in relation to their availability (Block & Brennan 1993; Jones 2001). Given its influence on how individuals use the landscape around them, habitat selection not only plays an important role in determining the spatial distribution of individuals and species (Morris 2003), but also in population dynamics (Mayor *et al.* 2009; Boyce *et al.* 2015), the likelihood of human-wildlife interactions, and areas of potential conflict (e.g. Belant 1997; Knopff *et al.* 2014). In increasingly human-dominated landscapes, with current trends in land use change threatening natural habitats worldwide (Vitousek *et al.* 1997; Hoekstra *et al.* 2005), a comprehensive understanding of habitat selection is crucial to gain insight into ecological processes, inform effective management, and alleviate conflict.

Unlike many farmland bird species that have been negatively affected by modern agricultural practices (Donald *et al.* 2006), European and North American geese have generally benefitted from agricultural intensification and land use change (Fox & Abraham 2017). In recent years, many goose populations have essentially transitioned from using natural and semi-managed habitats to foraging primarily on intensively managed farmland (Fox & Abraham 2017). This can largely be attributed to the unique foraging opportunities provided by present-day agricultural landscapes, chiefly in the form of large, uninterrupted swathes of high-quality monoculture available for most of the year (Vickery & Gill 1999; Hassall *et al.* 2001; Fox & Abraham 2017; Dokter *et al.* 2018). The widespread implementation of modern agricultural practices, in conjunction with increased species and habitat protection, has subsequently been associated with the recovery of many goose populations in the northern hemisphere (Fox & Abraham 2017; Fox & Madsen 2017). Although this recovery has been widely viewed as a conservation success story, the potential for increased crop damage by rising goose numbers is of great concern to agricultural interests (Fox & Madsen 2017; Fox *et al.* 2016; Montràs-Janer *et al.* 2019).

Conflict over goose damage to agriculture is by no means a recent issue, with reports dating back to medieval times (Kear 2001). Nevertheless, rising goose numbers are likely to incur unprecedented levels of damage, exacerbating conflict (Patterson *et al.* 1989; Hanley *et al.* 2003). This damage is often localised in certain areas, with high financial burdens borne by relatively few farmers (Macmillan & Leader-Williams 2008). This can have a significant detrimental impact on livelihoods, even when overall loss of yield is minimal at larger scales (Newton & Campbell 1973; Macmillan & Leader-Williams 2008; Fox *et al.* 2016). Some countries have attempted to mitigate crop damage caused by grazing geese through the establishment of compensation schemes, or by agreeing management contracts with farmers, which have in turn incurred substantial societal costs (e.g. Cope *et al.* 2006; Koffijberg *et al.* 2017; Eythórsson *et al.* 2017; Montràs-Janer *et al.* 2019). With crop damage becoming more frequent and geographically widespread, particularly with climate change shifting population ranges (Gauthier *et al.* 2005; Ramo *et al.* 2015), there is a need to better understand the habitat selection processes of different goose species to be able to inform management and thereby improve damage mitigation.

Greylag Geese (*Anser anser*) are distributed across most of Europe and, like some other Palearctic goose species, have experienced a significant increase in numbers in recent decades (Madsen 1991; Fox *et al.* 2010; Fox & Madsen 2017). Numerous studies of habitat, field and crop use in Greylag Geese have been carried out in autumn, winter and spring (e.g. August–May in Lorenzen & Madsen 1986; September–May in Newton & Campbell 1973 and Aerts *et al.* 1996; October–April in Bell 1988; October–May in Stenhouse 1996), with notably fewer studies focusing on the breeding and moulting seasons during the summer months (but see McKay *et al.* 2006; Olsson *et al.* 2017). The onset of flightlessness during moult may have significant impacts on Greylag Goose habitat and crop selection. For example, increased vulnerability to predation may lead individuals undergoing wing-moult to forage at a closer proximity to water, where perceived predation risk is lower (Fox & Kahlert 2000; Kahlert 2003). Feather regrowth may also cause nutritional stress in individuals in moult (Hanson 1962, in Fox, Kahlert & Ettrup 1998), potentially leading geese to be more risk prone when foraging and seeking out more protein-rich foods (Caraco *et al.* 1990; Fox, Kahlert & Ettrup 1998).

In their review, Fox *et al.* (2016) recognised the lack of studies on herbivorous wildfowl that quantify both habitat use and availability, as use alone is not sufficient to determine whether habitats are being selected for. While some older studies of Greylag Geese do provide measures of both habitat availability and use (e.g. Newton & Campbell 1973; Stenhouse 1996; Aerts *et al.* 1996), there are few recent studies which focus on habitat selection (but see Olsson *et al.* 2017). Given the above, there is a notable need for new studies investigating field and crop selection in Greylag Geese during the summer moult, particularly given recent changes in Greylag Goose populations and agricultural landscapes.

In this study we investigated crop selection by foraging Greylag Geese in the agricultural landscape surrounding Lake Hornborga, in south-western Sweden. By linking field use to crop availability, we were able to determine whether Greylag Geese used certain crops at higher proportions than expected given their availability in the landscape. Furthermore, we explored potential differences in selection prior to and following the summer moult, as we suspected this could impact crop selection in foraging Greylag Geese.

2. Materials and methods

2.1. Terms and definitions

Greylag Goose 'observations' were carried out during surveys, and refer to sightings on agricultural land. Each observation was assigned a given 'field' i.e. a physical agricultural management unit (Fig. 1). Within any given year a field would have a specific 'crop type'. Since the presence of geese in a certain field may be the result of selection of a food crop, field size, predation risk, presence of other geese, etc. – or a combination of these factors – we refer to 'field use' when talking about goose presence and distribution in general, without specific reference to a certain crop. Finally, 'crop type' (Table 1) refers to observations of geese foraging on a certain crop type. We use the term 'habitat' mainly in the context of general habitat selection theory, but also in a few places where a wider view of use and selection are addressed. We therefore adhere to the classical definition of a 'habitat'; that is, "a particular environment in which a species lives" (e.g. Krebs 2009). We use 'availability' to refer to the proportion of the study area that contains a specific crop type, and 'use' as the proportion of geese present in a certain field or crop (i.e., foraging, resting, standing, etc.). 'Selectivity' refers to the disproportionate use of a specific crop type relative to its availability, and 'selection' is the process leading to a pattern of selectivity.

2.2. Study area

The study was conducted on agricultural land adjacent to Lake Hornborga (58° 19′ N, 13° 33′ E) in the province Västergötland, in south-western Sweden (Fig. 1). The lake has an area of approximately 3500 ha and is predominantly surrounded by agricultural land and mixed broadleaf and coniferous woodland. Although it was historically drained to increase the amount of land available for agriculture, the lake was restored between 1965 and 1995 and it now sits within a 4000 ha nature reserve, which has been designated both a Ramsar and Natura 2000 site. The agricultural land in the surrounding area primarily consists of ley (i.e. non-permanent grasslands for silage and hay), cereals, and pastures (permanent grasslands for cattle grazing). The first annual harvest of ley fields generally starts in early June, with one or two more harvests occurring each summer. Cere-als are harvested in August and September, resulting in a dynamic availability of crop types and crop stages throughout the growing season.

Greylag Geese use the lake and adjacent farmland for breeding (~ 200 pairs in 2016), spring staging (~ 2000 individuals in 2016), moulting (~ 27000 individuals in June 2016), and autumn staging (~ 9000 individuals in 2016) (Berg 2017). Geese which are about to moult arrive at the lake in mid-May and leave in early to mid-July after moult is completed (Berg 2017). During moult, Greylag Geese are flightless and largely restricted to the lake. Consequently, geese commonly use

Table 1. Pooled crop types are shown alongside the original crop species and other land uses as described by the Swedish Board of Agriculture for the agricultural fields surrounding Lake Hornborga. Crops grouped into the 'other' category were either uncommon or rarely used by geese.

Crop types	Crop species and other land uses
Ley & pasture	Mowed hay fields, pasture, grazing, straw, fallow
Oat	Oat
Barley	Barley (spring-sown or fall-sown winter-green crop)
Wheat	Wheat (spring-sown or fall-sown winter-green crop)
Other	Rye, rapeseed, legumes, sunflower, linseed, hemp, potato, vegetables, willow, aspen, apiculture, wetland, wet meadows

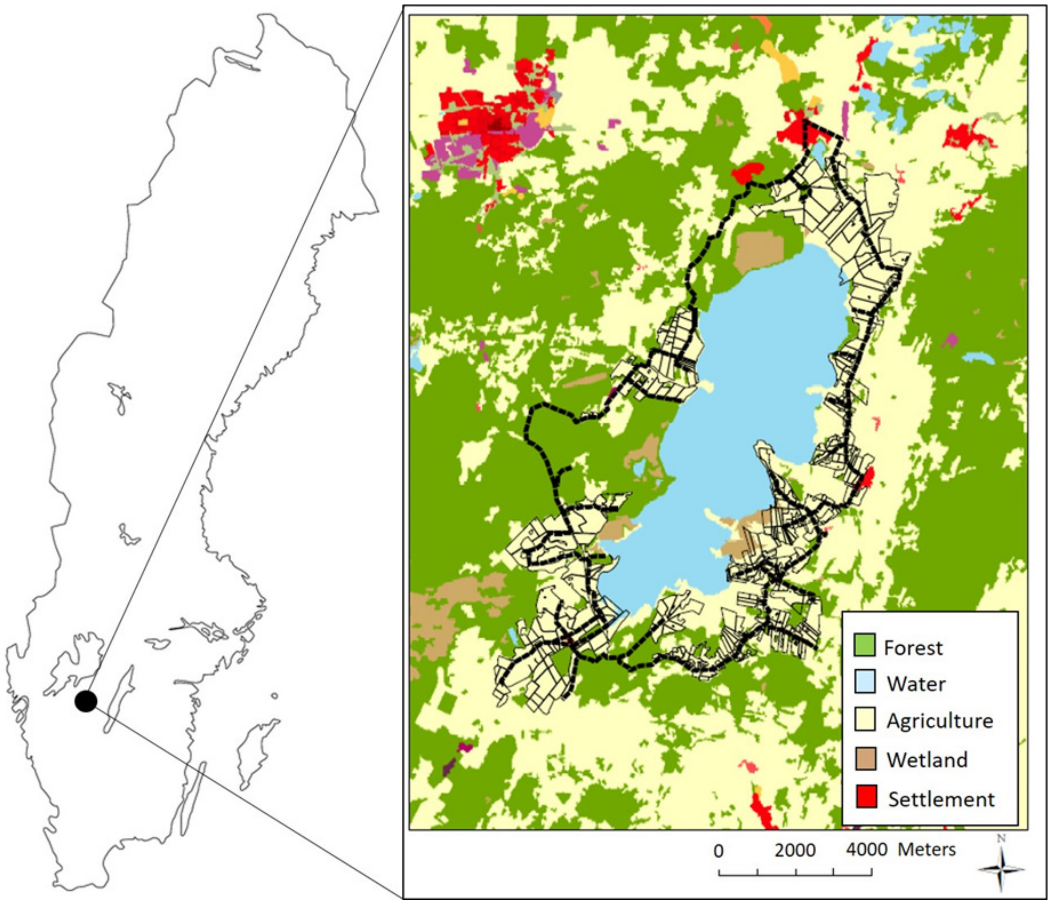

Fig. 1. Map of the study area showing the main landscape elements around Lake Hornborga (58° 19′ N, 13° 33′ E). Fields surveyed for Greylag Geese (*Anser anser*) from 2012 to 2016 are outlined (black polygons). Surveys were carried out weekly between May and July for a period of 8 to 12 weeks per year, depending on Greylag Goose presence, with survey routes marked by dotted black lines.

Table 2. Descriptive data for Greylag Goose (*Anser anser*) observations over the 5 year study period (2012–2016). For each year, the dates of survey periods and number of surveys are indicated, alongside the total number of flocks observed each year. The average flock size (± standard errors) is also shown, i.e. the mean number of geese counted per observation.

Year	Survey period	No. surveys	No. observed flocks	Mean flock size
2012	4th May–29th July	12	316	138 ± 15
2013	3rd May–27th July	12	221	143 ± 17
2014	15th May–31st July	12	205	119 ± 13
2015	20th May–28th July	9	187	142 ± 18
2016	5th June–21st July	8	127	191 ± 28

the agricultural fields for foraging for most of the growing season, with bimodal peaks in numbers on the fields just before and after moult (Fig. 2). Other species of large grazing birds, including other geese (*Anser spp.* and *Branta spp.*), Common Cranes (*Grus grus*), and Whooper Swans (*Cygnus cygnus*) also occur during early spring and autumn staging and use the same fields for foraging (Berg 2017). Farmers in the study area, as in other parts of Sweden, are known to perform both lethal and non-lethal scaring techniques to reduce crop damage from large grazing birds on agricultural land (Hake *et al.* 2010, Månsson 2017). Between March and April, local authorities also provide diversionary feeding to divert grazing birds, especially Common Cranes, from fields prone to crop damage (Hake *et al.* 2010).

2.3. Field surveys and crop data

Roadside surveys were conducted on a yearly basis from 2012 to 2016, between May and July. Each year, a single observer carried out weekly surveys for 8 to 12 weeks, with the number of surveys each year varying slightly depending on the practicality of carrying out fieldwork (Table 2). The surveys generally started between 7:00 am and 9:00 am, as Greylag Geese tend to primarily feed in the morning (Desenouhes *et al.* 2003). The observer followed a standardised route covering the same fields (in total 2800 ha) on each survey occasion, and for each Greylag Goose observation the following data were gathered: flock size (i.e. number of Greylag Geese per observation), approximate coordinates of flock, and sward height of field (classified into: short (0–10 cm), medium (10–20 cm), and tall (> 20 cm)).

Data on crop species and other land uses of agricultural fields (e.g. wet meadows and apiculture) were provided each year by the administrative database of the Swedish Board of Agriculture, with crop species typically changing between years. Coordinates of goose observations were subsequently overlaid onto crop maps in ArcGIS 10.5 (ESRI 2017) to determine the crops associated with each observation. A total of four goose observations were discarded between 2012 and 2016 due to an absence of crop type data. Following the method in Aebischer *et al.* (1993), crop species were pooled into categories (henceforth referred to as ‘crop types’; for further details see section 2.4. Statistical analysis). Crop species and other land uses and their corresponding crop types are shown in Table 1. Crop species and other land uses which were pooled into the ‘other’ category either had limited availability (i.e. were uncommon) or were seldom used by geese (Table 1).

2.4. Statistical analysis

Crop selection in Greylag Geese was explored using a compositional analysis (Aebischer *et al.* 1993). Compositional analysis tests for deviance from random use, in our case by comparing crop use (i.e. proportion of goose numbers in fields of a certain crop type) with availability (i.e. proportion of field area of a certain crop type available within the study area). If a significant crop selection is determined, using Wilks lambda, the compositional

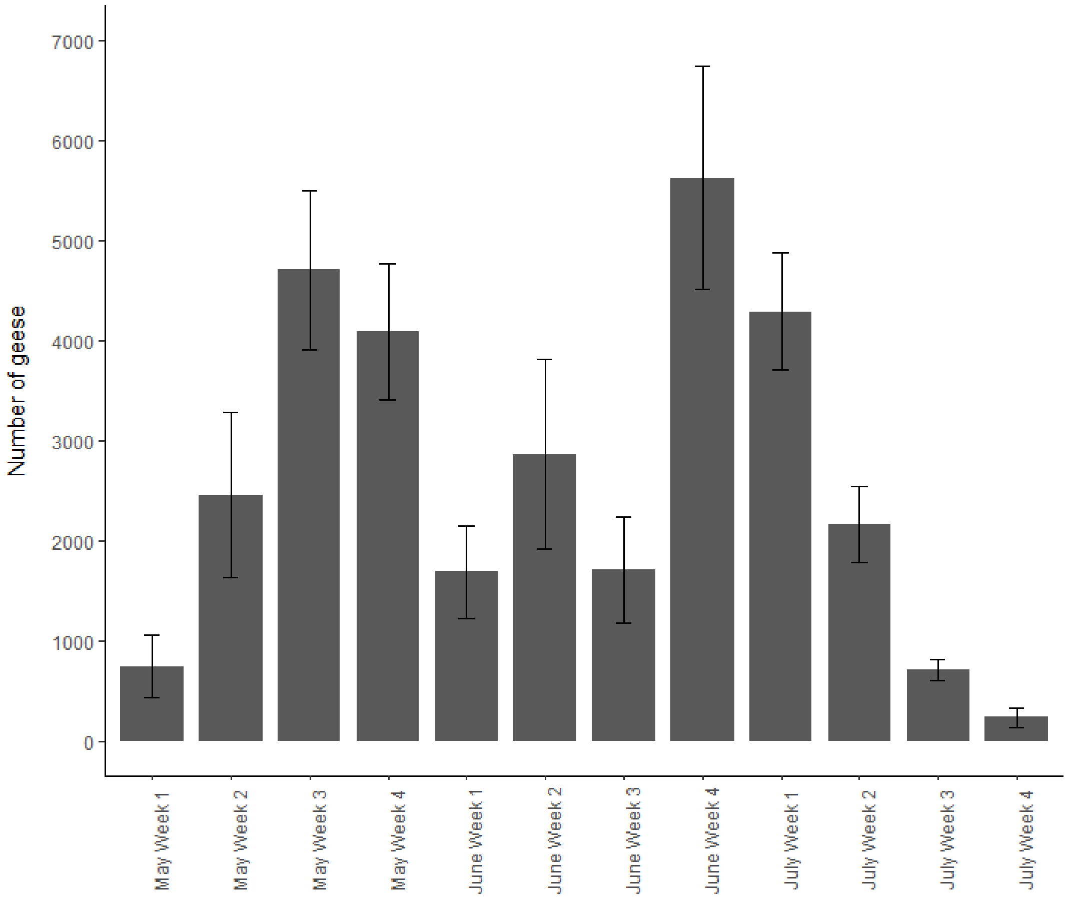

Fig. 2. Weekly mean abundance of Greylag Geese (*Anser anser*) on agricultural land surrounding Lake Hornborga (58° 19′ N, 13° 33′ E) from May to July. Abundance is averaged across the 5-year study period (2012–2016), with error bars showing standard errors of the mean.

analysis also ranks the crop types in a ranking matrix (based on the relative use and significance levels for the between-ranked habitats based on log-ratios See Appendix 1a & 1b). To determine availability, the proportion of the total study area allocated to each crop type was calculated for each year. Crop use was estimated by calculating the proportion of geese within each crop type relative to the total number of geese counted on each survey (total from all observations per day). As our data deviated from assumptions of normality, both the habitat selection tests and habitat rankings were performed using non-parametric randomisation tests. All zero values for used habitat were substituted by a small, non-zero value (0.0001), as per Aebischer *et al.* (1993). All statistical analyses were performed in R 3.4.2 (R Core Team 2019), with the 'adehabitatHS' package used to perform compositional analyses (Calenge 2006; Calenge 2007).

To determine any temporal variation in crop selection across years, crop use and availability were compared for each year as well as across the entire study period (2012–2016). To investigate any potential variation in crop selection by Greylag Geese during moult, crop availability for each year was compared to use of fields with different crops prior to and after moult. Surveys conducted prior to and including June 9th were classified as 'pre-moult' period, as abundance trends of geese on the fields surrounding Lake Hornborga between 2010

Table 3. Compositional analyses comparing overall, yearly, and periods of pre- and post-moult crop use by Greylag Geese (*Anser anser*) with crop availability in the agricultural land surrounding Lake Hornborga. Lambda (Λ) and p-values (*p*) are indicated alongside the degrees of freedom (*df*) and number of surveys included in each test (*n*). Significant values are shown in bold.

		Λ	*p*	*df*	*n*
Overall		0.065	**0.002**	4	53
Yearly	2012	0.001	**0.002**	4	12
	2013	0.065	**0.002**	4	12
	2014	0.069	**0.002**	4	12
	2015	0.054	**0.012**	4	9
	2016	< 0.001	**0.030**	4	8
Period	Pre-moult	0.094	**0.002**	4	20
	Post-moult	0.031	**0.002**	4	33

and 2016 show reduced numbers around this date (Fig. 2). Surveys conducted after June 9th each year were therefore classified as 'post-moult'. Due to individual variation in start and end date of moult, both periods ('pre-' and 'post-') will also include moulting geese. However, the vast majority of observations during these two periods should still be representative given this break-point-date (Fig. 2), as most birds stay in or very close to the lake during their flightless period. Given that the crop availability did not vary within each year (crop data provided by the Swedish Agricultural Board covered the period of a year), pre- and post-moult crop use was compared to the area of crop types available for the whole study period (2012–2016).

3. Results

A total of 1056 Greylag Goose observations were made between 2012 and 2016, with an average flock size (i.e. number of geese per observation) of 143 (SE ± 8) (Table 2). On average, the crops used by Greylag Geese were composed of 94% ley and pasture, 3% oat, 2% barley, 1% wheat and < 1% other crop categories, while the study area (i.e. crop availability) was on average composed of 72% ley and pasture, 9% oat, 10% barley, 4% wheat and 5% other crop types (Fig. 3). Used fields were predominantly characterised by short swards (Fig. 4).

The compositional analysis for crop selection across all study years suggested certain crop types were used significantly more than expected given their availability (Λ = 0.065, *df* = 4, *p* = 0.002; Table 3). The selection of crop types by geese ranked as follows: ley/pasture > oat > barley > wheat > other (Appendix 1a). There was a significant difference in selection between ley/pasture and oat, the two highest ranking crop types (Appendix 1a). The selection of oat also differed significantly from the three lower ranking crop types, while there was no significant difference between barley, wheat, and other crop types (Appendix 1a).

Yearly compositional analyses also indicated that geese used certain crop types significantly more than expected in individual years (Table 3; Fig. 3). Ley and pasture were the most selected crop types across all study years (Appendix 1b). The selection of remaining crop types was largely interchangeable across years, with the exception of 2012 when oat was selected significantly more than barley, wheat, and other crop types (Appendix 1b). Compositional analyses of pre- and post-moult crop use also suggested that certain crop types were used significantly more than expected based on their availability (Table 3; Fig. 5), with ley and pasture being the most selected (Appendix 1c). After ley and pasture, the remaining crop types did not differ significantly from each other in selection, and as a result their rankings were interchangeable (Appendix 1c).

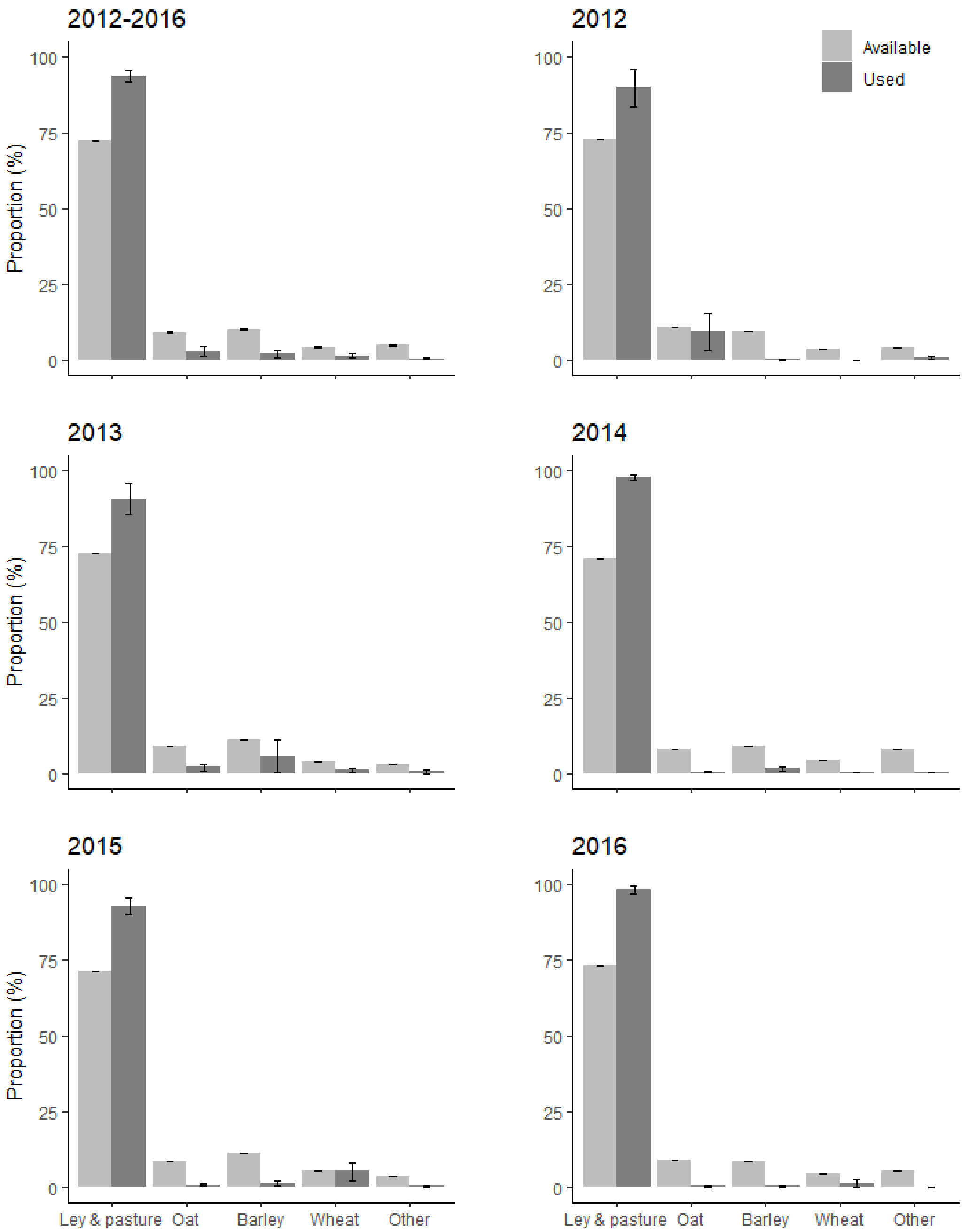

Fig. 3. Crop availability (light grey) and crop use (dark grey) by Greylag Geese (*Anser anser*) are shown for each study year alongside the overall study period (2012–2016) in agricultural land surrounding Lake Hornborga. The y-axis represents both a) the proportion of field area containing each crop type relative to the total area of fields surveyed each year; and b) the proportion of Greylag Geese observed on a given crop type relative to the total number of geese observed in each survey. Error bars represent standard errors of the mean.

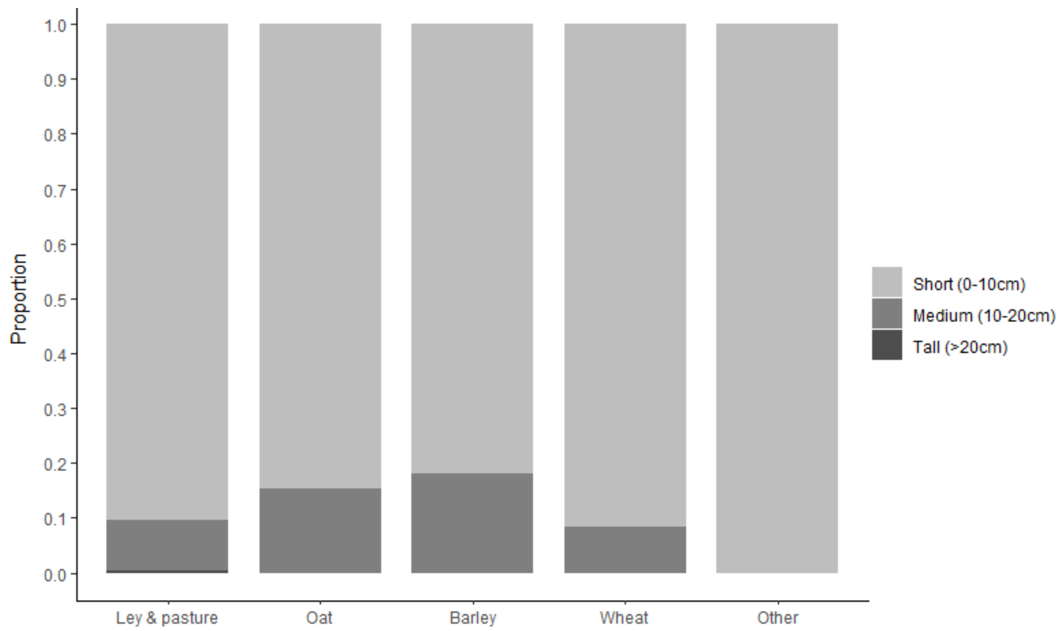

Fig. 4. The proportion of fields with swards of a given height class are shown for fields used by Greylag Geese (*Anser anser*) in agricultural land surrounding Lake Hornborga. Proportions are pooled across all study years (2012–2016).

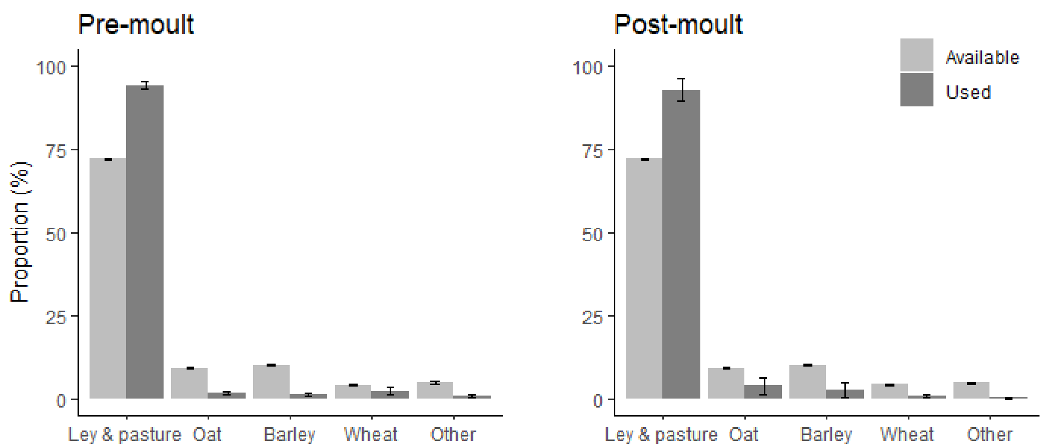

Fig. 5. Crop availability (light grey) and crop use (dark grey) by Greylag Geese (*Anser anser*) are shown for pre-moult (prior to 9th June) and post-moult (after 9th June) periods in agricultural land surrounding Lake Hornborga. The y-axis represents both a) the proportion of field area containing each crop type relative to the total area of fields surveyed each year; and b) the proportion of Greylag Geese observed on a given crop type relative to the total number of geese observed in each survey. Data are pooled across the study period (2012–2016). Error bars represent standard errors of the mean.

4. Discussion

Throughout the study, Greylag Geese used ley and pasture fields significantly more than expected given their availability (Fig. 1). This suggests geese strongly select for this crop type relative to other crops in the agricultural fields surrounding Lake Hornborga. This notable selection for ley and pasture was largely maintained across all study years, despite some differences in the use of other crop types between years (Fig. 3). For example, while oat was used more than wheat in 2012, this was reversed in 2015 (Fig. 3; Appendix 1b). Indeed, the fact that other crop types had interchangeable rankings across study years further reinforces a lack of clear selection among these.

Similar results have been documented in previous studies. For example, McKay *et al.* (2006) found that resident Greylag Geese grazed on grass fields more often than expected given their availability, selecting them over growing cereal fields, which were more available. Although in our study grassland was by far the most dominant field type, it was still selected for. Another study also found that grass was used by Greylag Geese in Scotland throughout the wintering season, but particularly so in spring months (Newton & Campbell 1973). This is likely driven by the need to build up fat stores and reconstruct flight muscles prior to migration, driving geese to forage on more protein and energy rich food sources in spring (Madsen 1985). During this time, grass provides an optimal food source, particularly given its rapid growth (Fox *et al.* 2016). By contrast, other resources such as spilled grain and stubble fields are more frequently used in winter months (Newton & Campbell 1973; Bell 1988; Fox *et al.* 2005), before switching to grass in late winter and early spring (Lorenzen & Madsen 1986; Patterson *et al.* 1989).

Given the physiological limitations of long-distance flight, geese have relatively simple digestive systems compared to many terrestrial herbivores in order to minimise their body mass (Dudley & Vermeij 1992). As a result, there is an increased need for the selection of high quality, easily digestible plant species, typically high in nitrogen and low in fibre (Sedinger 1997; Therkildsen & Madsen 1999). The nutritional quality of agricultural grass has improved over the years due to refined cropping systems and selective plant breeding, resulting in an increased digestibility and longer growing season (van Eerden *et al.* 1996, 2005). Previous studies have noted that short, managed swards provide a particularly favourable food source for geese, as taller, more mature stages of grass in general contain less nitrogen and more fibres (Hassall *et al.* 2001, van der Graaf *et al.* 2007). Throughout our study, the majority of goose observations was made on short swards (< 10 cm), with little variation between crop types (Fig. 2). The repeated harvesting that keep swards short on ley and pasture fields throughout the growing season, namely in the form of mowing and grazing, may have made them more attractive than other crop types such as cereals. Nevertheless, not all studies have found sward height to be a determining factor in increasing susceptibility to grazing by geese (e.g. Seamans *et al.* 1999). This discrepancy may be due to external factors influencing the nutritional content of swards. For example, differences in forage quality may not be evident in areas where nitrogen fertilisers are frequently applied (Hassall *et al.* 2001; Riddington *et al.* 1997).

There was not any sign of a change in crop selection between the pre- and post-moult periods. Rather, fields with ley and pasture were strongly selected during both periods. Given previous research on the nutritional demands of moult in Greylag Geese, it was expected that they may have shown a preference for more protein rich forage prior to moult (Fox, Kahlert & Ettrup 1998). Indeed, studies on Greylag Geese in Sweden have shown a dietary shift during this time, with post-breeding individuals initially feeding on grasslands but shifting instead to pea crops in July and August (Nilsson & Persson 1992; Nilsson & Kampe-Persson 2013). Greylag Geese in moult on the island of Saltholm, Denmark, were also found to select for the protein rich saltmarsh grass *Puccinellia maritima* (Fox, Kahlert & Ettrup 1998). However, such differences in diet prior to and after the onset of moult were not reflected in this study.

One explanation of the lack of change in crop selection may be that ley and pasture fields within our study area were harvested several times each year, as well as being fertilised during the summer. These shorter swards would provide a forage of higher nutritional value throughout the growing season. By contrast, other crop types such as cereals would not be harvested until the end of the growing season, leading to crops with higher biomass and lower nutritional value. Moreover, "ley and pasture" is a diverse category, encompassing various species of grasses, differing times since establishment, and potential variation in the frequency of fertiliser application. While the data available in this study did not allow for such detailed categorisation, future studies should look into how geese select between different types of ley and pasture fields. Another potential reason for the lack of differentiation prior to and after moult may have arisen from the comparison of seasonal crop use against yearly crop availability. It may be that in order to tease out within-year variation in crop selection, a more short-term snapshot of crop availability is necessary. The timing of moult can also be highly variable. Although the moulting period typically lasts three to five weeks, the actual onset of moult varies from individual to individual (Lebret & Timmerman 1968, cited in Loonen *et al.* 1991; Hohman *et al.* 1992). This may have dampened the effect of moult period on crop selection, as not all geese will have coincided in their moult, and any associated change in nutritional demand would therefore have been unlikely to occur in all individuals simultaneously.

It is worth noting that there are other factors that may have influenced field choice in Greylag Geese aside from the crop type present. For example, numerous studies have found that habitats are more often selected if they are in close proximity to water (McKay *et al.* 2004; Amano *et al.* 2007; Jankowiak *et al.* 2015). In our study, all surveyed fields were less than 3.5 km from the lake, which is considered within foraging distance for geese outside the flightless period (Bell 1988). However, geese typically remain closer to the lake during moult, as do breeders (Olsson *et al*. 2017). This preference may increase the selection for fields bordering the lake. Predator avoidance can also have a strong impact on foraging site selection (Lima & Dill 1990). For example, Rosin *et al.* (2012) found that proximity to woodlands was negatively correlated with flock size, with geese also preferring elevated sites that provide better vigilance opportunities. Field selection can also be influenced by human disturbance (Rosin *et al.* 2012; Harrison *et al.* 2018). This may be the case particularly where non-lethal scaring methods are used to discourage geese from foraging on agricultural land (Månsson 2017). Although these factors may have impacted field use in this study, the pronounced selection for ley and pasture over multiple years suggests crop type in general remains a key factor influencing field selection in Greylag Geese.

An understanding of the ecology of different goose species is essential to improve implementation of informed management strategies (Stroud *et al.* 2017). Indeed, ecological knowledge plays an important role for the success of such strategies, ultimately leading towards conflict resolution (Redpath *et al.* 2013; Redpath & Sutherland 2015). Our study provides one piece of ecological evidence which may allow more informed management and research strategies in the future. A comprehensive knowledge of goose crop and field selection will yield a deeper understanding of the areas where conflict is likely to arise, and inform potential management strategies to alleviate conflict, ultimately fostering coexistence. Although a measure of the impact on crop yield was not within the scope of this study, the results suggest there may be strong grazing pressure and damage risk on agricultural fields surrounding Lake Hornborga. More detailed studies are needed in order to quantify the effect on harvest yield by grazing geese on ley and pasture fields during the growing season.

Svensk sammanfattning

Under de senaste 50 åren har åtskilliga gåspopulationer återhämtat sig från historiskt låga nivåer till att nu vara större än någonsin. Samtidigt har gäss i stor utsträckning övergivit sina ursprungliga födosöksmiljöer för att numer finna nästan all sin föda på jordbruksmark, något som ibland leder till konflikt på grund av betesskador. Vi studerade grödoval hos grågäss (*Anser anser*) i ett jordbruksdominerat landskap kring en viktig häcknings- och ruggningssjö i södra Sverige. Från 2012 till 2016 skedde inventeringar från vägar i studieområdet varje vecka under maj, juni och juli. Vi noterade antalet gäss, grödoslag och grödohöjd på alla fält med grågäss. Statistiska analyser (*compositional analysis*) visade att grågässen starkt föredrog fält

med vall eller betesmark framför andra grödor (preferensordning: vall/betesmark > havre > korn > vete > övriga grödor). Preferensmönstret var det samma oberoende av år och period under sommaren (före resp. efter ruggning). Alla andra grödoslag än vall och betesmark var icke föredragna, eftersom de utnyttjades mindre än deras andel av studieområdet. Den starka preferensen för vall och betesmark kan vara en följd av en högre näringsmässig kvalitet hos gräs som ännu inte blivit högvuxet. Detta antyder i sin tur att fält med kort gräs är mer utsatta för gåsbete än andra grödor under sommarmånaderna. Denna studie ger ny kunskap om grågässens uppträdande på jordbruksmark under senvår och sommar, vilken kan ge förbättrade förvaltningsstrategier för att minska betesskador och reducera konflikten med jordbruksintressen.

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Appendix 1a. Overall matrices

Crop type rank matrix (2012–2016)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	−−−	+	+	3
Ley/pasture	+++	/	+++	+++	+++	1
Oat	+++	−−−	/	+++	+++	2
Other	–	−−−	−−−	/	–	5
Wheat	–	−−−	−−−	+	/	4

Ley/pasture >>> Oat >>> Barley > Wheat > Other

Mean log-ratio difference matrix (2012–2016)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−8.488	−2.093	0.742	0.023
Ley/pasture	8.488		6.395	9.230	8.510
Oat	2.093	−6.395		2.835	2.116
Other	−0.742	−9.230	−2.835		−0.720
Wheat	−0.023	−8.510	−2.116	0.720	

Λ = 0.065, P = 0.002, DF = 4, n = 53

Appendix 1b. Yearly matrices

Crop type rank matrix (2012)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	−−−	–	+	4
Ley/pasture	+++	/	+++	+++	+++	1
Oat	+++	−−−	/	+++	+++	2
Other	+	−−−	−−−	/	+	3
Wheat	–	−−−	−−−	–	/	5

Ley/pasture >>> Oat >>> Other > Barley > Wheat

Mean log-ratio difference matrix (2012)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−10.077	−7.863	−1.792	0.500
Ley/pasture	10.077		2.215	8.286	10.578
Oat	7.863	−2.215		6.071	8.363
Other	1.792	−8.286	−6.071		2.292
Wheat	−0.500	−10.578	−8.363	−2.292	

Λ = 0.001, P = 0.002, DF = 4, n = 12

Crop type rank matrix (2013)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	–	+	–	4
Ley/pasture	+++	/	+++	+++	+++	1
Oat	+	−−−	/	+++	+	2
Other	–	−−−	−−−	/	–	5
Wheat	+	−−−	–	+	/	3

Ley/pasture >>> Oat > Wheat > Barley > Other

Mean log-ratio difference matrix (2013)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−8.283	−2.404	1.251	−0.110
Ley/pasture	8.283		5.879	9.533	8.173
Oat	2.404	−5.879		3.654	2.294
Other	−1.251	−9.533	−3.654		−1.361
Wheat	0.110	−8.173	−2.294	1.361	

Λ = 0.065, P = 0.002, DF = 4, n = 12

Crop type rank matrix (2014)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	–	+	+	3
Ley/pasture	+++	/	+++	+++	+++	1
Oat	+	−−−	/	+	+	2
Other	–	−−−	–	/	–	5
Wheat	–	−−−	–	+	/	4

Ley/pasture >>> Oat > Barley > Wheat > Other

Mean log-ratio difference matrix (2014)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−6.986	−0.201	1.819	1.739
Ley/pasture	6.986		6.784	8.805	8.725
Oat	0.201	−6.784		2.020	1.941
Other	−1.819	−8.805	−2.020		−0.080
Wheat	−1.739	−8.725	−1.941	0.080	

$\Lambda = 0.069$, $P = 0.002$, DF = 4, n = 12

Crop type rank matrix (2015)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	+	+	–	3
Ley/pasture	+++	/	+++	+++	+++	1
Oat	–	−−−	/	–	–	5
Other	–	−−−	+	/	–	4
Wheat	+	−−−	+	+	/	2

Ley/pasture >>> Wheat > Barley > Other > Oat

Mean log-ratio difference matrix (2015)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−8.491	0.831	0.461	−3.432
Ley/pasture	8.491		9.322	8.952	5.059
Oat	−0.831	−9.322		−0.370	−4.263
Other	−0.461	−8.952	0.370		−3.893
Wheat	3.432	−5.059	4.263	3.893	

$\Lambda = 0.054$, $P = 0.012$, DF = 4, n = 9

Crop type rank matrix (2016)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	+	+	+	2
Ley/pasture	+++	/	+++	+++	+++	1
Oat	–	−−−	/	+	–	4
Other	–	−−−	–	/	−−−	5
Wheat	–	−−−	+	+++	/	3

Ley/pasture >>> Barley > Wheat > Oat > Other

Mean log-ratio difference matrix (2016)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−8.659	0.902	2.483	0.817
Ley/pasture	8.659		9.561	11.142	9.476
Oat	−0.902	−9.561		1.581	−0.085
Other	−2.483	−11.142	−1.581		−1.666
Wheat	−0.817	−9.476	0.085	1.666	

Λ < 0.001, P = 0.030, DF = 4, n = 8

Appendix 1c. Pre- and post-moult matrices

Crop type rank matrix (pre-moult)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	−−−	+	–	4
Ley/pasture	+++	/	+++	+++	+++	1
Oat	+++	−−−	/	+++	+	2
Other	–	−−−	−−−	/	–	5
Wheat	+	−−−	–	+	/	3

Ley/pasture >>> Oat > Wheat > Barley > Other

Mean log-ratio difference matrix (pre-moult)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−7.555	−3.146	0.567	−0.842
Ley/pasture	7.555		4.409	8.122	6.712
Oat	3.146	−4.409		3.712	2.303
Other	−0.567	−8.122	−3.712		−1.409
Wheat	0.842	−6.712	−2.303	1.409	

Λ = 0.094, P = 0.002, DF = 4, n = 20

Crop type rank matrix (post-moult)

	Barley	Ley/pasture	Oat	Other	Wheat	Rank
Barley	/	−−−	–	+	+	3
Ley/pasture	+++	/	+++	+++	+++	1
Oat	+	−−−	/	+++	+	2
Other	–	−−−	−−−	/	–	5
Wheat	–	−−−	–	+	/	4

Ley/pasture >>> Oat > Barley > Wheat > Other

Mean log-ratio difference matrix (post-moult)

	Barley	Ley/pasture	Oat	Other	Wheat
Barley		−9.053	−1.455	0.849	0.547
Ley/pasture	9.053		7.598	9.902	9.600
Oat	1.455	−7.598		2.304	2.002
Other	−0.849	−9.902	−2.304		−0.301
Wheat	−0.547	−9.600	−2.002	0.302	

Λ = 0.031, P = 0.002, DF = 4, n = 33