Received: 23 August 2023 | Accepted: 22 December 2023

DOI: 10.1002/2688-8319.12302

Ecological Solutions and Evidence | BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE

Selection of a diversionary field and other habitats by large grazing birds in a landscape managed for agriculture and wetland biodiversity

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Funding information
Svenska Forskningsrådet Formas, Grant/Award Number: 2018-00463; Naturvårdsverket, Grant/Award Number: 19/128 and 19/129

Handling Editor: Christos Mammides

Abstract

1. Several populations of cranes, geese, and swans are thriving and increasing in modern agricultural landscapes. Abundant populations are causing conservation conflicts, as they may affect agricultural production and biodiversity negatively.
2. Management strategies involving provisioning of attractive diversionary fields where birds are tolerated can be used to reduce negative impact to growing crops. To improve such strategies, knowledge of how the birds interact with the landscape and respond to current management interventions is key.
3. We used GPS locations from tagged common cranes (*Grus grus*) and greylag geese (*Anser anser*) to assess how they use and select differentially managed habitats, such as diversionary fields to decrease impact on agriculture and wetlands protected for biodiversity conservation.
4. Our findings show a high probability of presence of common cranes and greylag geese in the protected area and in the diversionary field, but also on arable fields, potentially causing negative impact on agricultural production and wetland biodiversity.
5. We outline recommendations for how to improve the practice of diversionary fields and complementary management to reduce risk of negative impact of large grazing birds in landscapes tailored for both conservation and conventional agriculture.

KEYWORDS
adaptive management, *Anser anser*, common crane, conservation conflict, diversionary field, greylag goose, *Grus grus*, protected area, resource selection function, supplemental feeding

1 | INTRODUCTION

1.1 | Conflicts between objectives of conservation and agricultural food production

Conflicts concerning objectives of wildlife conservation and agricultural food production are increasing globally due to a growing human population, habitat fragmentation, and intensified agricultural land use (Jochum et al., 2014; Redpath et al., 2013; UN, 2022). Key to achieving these combined objectives is habitat protection and co-existence with wildlife in human-dominated landscapes (Ekroos et al., 2016; Grass et al., 2019). Co-existence is, however, often a complex challenge due to conflicting interests and uncertainties in social, economic and ecological aspects of the management systems (Game et al., 2014; Mason et al., 2018). This calls for an evidence-based approach in which management strategies are adapted and applied based on gained knowledge (Månsson et al., 2023; Mason et al., 2018). In the context of agricultural food production, there is also a need for interventions to be cost- and time-efficient in order to minimise crop loss caused by wildlife and to keep agriculture economically sustainable (MacMillan et al., 2004; Vickery & Summers, 1992).

1.2 | Impact of large grazing birds on agriculture and biodiversity

An example of such multifaceted management challenge is the hundredfold increasing populations of large grazing birds, such as common cranes (*Grus grus*) and greylag geese (*Anser anser*) in large areas of Europe over the last five decades. Populations of both species adapt to agricultural intensification and are now aggregating at staging and breeding sites in numbers up to hundreds and thousands of individuals (AEWA, 2019; Fox & Madsen, 2017; LPO, 2022). Such sites are often situated near protected wetlands (i.e. the implication of The Bern Convention in Ramsar sites or the EU implementation of conservation of birds and habitats in Natura 2000 sites) that provide feeding possibilities and protection, but foraging also takes place in the surrounding agricultural landscape (Nilsson et al., 2019; Teräväinen et al., 2022). Growing numbers of large grazing birds have increasing impact on agricultural production due to foraging, trampling, and grubbing, especially just after sowing, during sprouting and when ripened. For example, yield losses up to 50 and 82% caused by geese have been documented on pasture fields in spring (Bjerke et al., 2014; Percival & Houston, 1992) and losses up to 50% have recently been reported in wintering areas in Europe (Düttmann et al., 2023). As a case in point, ~1.4 million Euros were used for compensation and subsidies related to crop damage caused by large grazing birds in Sweden alone in 2020 (Frank et al., 2021). Hence, the increasing populations and damage cause frustration and negative emotions to wildlife among affected farmers towards the culprit species (Eriksson et al., 2021; Widemo et al., 2019). In addition to the challenges of crop damage, high densities of large grazing birds may be negative for sensitive ecosystems and biodiversity. For example, geese have been shown to have both significant negative effects on reed beds, wet meadows, and tundra vegetation due to overgrazing (Bakker et al., 2018; Kuijper et al., 2006; Moonen et al., 2023; Samelius & Alisauskas, 2009) and potentially also on nest success for meadow-breeding wader (Madsen et al., 2019; Moonen et al., 2023). There is also growing concern that predation by common cranes on eggs and chicks of other species may affect threatened wetland birds negatively (Sandgren, 2019; Wirdheim, 2019). Despite the increasing negative impact on agriculture and biodiversity, practical use of damage preventive interventions is limited. This is because the culprit species often occur in the vicinity of protected areas and is also due to the protection status in the EU Birds Directive (EC, 2009). For example, no open hunting is allowed on common cranes and only limited derogation shooting is allowed to protect human livelihoods, flora, and fauna. For greylag geese, on the other hand, there are possibilities for open hunting to limit the population, though not in protected areas (EC, 2009). Due to these legal and practical limitations, testing and improving non-lethal interventions are highly warranted in wildlife management.

1.3 | Understanding resource selection to suggest management strategies

Conventionally farmed fields are generally more attractive to large grazing birds than are traditionally used natural habitats, mainly due to abundant high quality food resources in the former (reviewed in Fox et al., 2017). One commonly used management strategy to reduce crop damage to such damage prone fields is to redirect large grazing birds by scaring them to less sensitive, but attractive, fields or refuge areas (Teräväinen, 2022). Undisturbed habitats for foraging and roosting in the landscape can be provided by diversionary fields (e.g. fields with sacrificial crops or supplemental food) and refuges in protected areas. Diversionary fields are widely used to reduce crop damage (Kubasiewicz et al., 2015) and have been proven to reduce crop damage caused by both mammals and birds (up to 50%; Parrott & McKay, 2001; Sutherland et al., 2021). However, the use of scaring and diversionary fields will most probably not only affect birds´ use of arable land but also their use of natural habitats such as wetlands (Teräväinen, 2022)., The latter may in turn, increase the risk of negative impact on wetland biodiversity. Previous studies have mainly limited their focus to selection of arable fields and effects of damage mitigation on fields (e.g. Aarseth, 2023; Nilsson et al., 2016; Teräväinen et al., 2022). It would hence be useful to gain a wider understanding of how the measures affect use (i.e. time allocation) and selection (i.e. attractiveness in relation to availability) of all habitats within a landscape. Thus, detailed knowledge about individual behaviour of large grazing birds and how they respond to, and interact with, the landscape and its current management practice (e.g. diversionary fields) is key to evaluate and adapt management accordingly (Chudzińska et al., 2016; Nilsson et al., 2019; Pekarsky et al., 2021).

1.4 | Study aim

The aim of this study is to assess how common cranes and greylag geese use and select for habitats in an agricultural landscape tailored and managed for protection of large grazing birds, wetland biodiversity, and economically sustainable farming. Specifically, we used GPS location data to investigate (1) which habitats have the highest use and probability of presence of common cranes and greylag geese in the wetland-agricultural landscape; (2) when greylag geese and common cranes forage on arable land, which crop types have the highest probability of their presence (i.e. damage risk); and (3) what is the use and probability of presence of common cranes and greylag at the diversionary field?

In the study, we predict how GPS-tagged cranes and greylag geese are selecting for differentially managed habitats (e.g. protected areas, arable land, diversionary field), and hence their putative negative impacts on agricultural production and wetland biodiversity. We also make recommendations about how to prioritise and improve the practice of diversionary fields and alternative interventions to reduce the risk of negative impact to agricultural production and wetland biodiversity.

2 | MATERIALS AND METHODS

2.1 | Study area

The study was conducted in the vicinity of lake Kvismaren (59°10′ N, 15°23′ E), southeast of Örebro in south-central Sweden (Figure 1) from 2017 to 2022. The landscape is flat and dominated by highly productive arable land (Table S1 in Supporting Information). The central parts of the study area consist of a mosaic of shallow, eutrophic lakes, reed beds and grazed wet meadows, designated as both a Natura 2000 (i.e. SPA and SAC) and a Ramsar site (EC, 2016; Wetlands: A Global Disappearing Act, 1970). Kvismaren is a national key area for protection of multi-functional wetland habitats and aimed for staging, breeding, and threatened bird species, for example waders, waterfowl, gulls. It is also intended to serve as a refuge area for large grazing birds (EC, 2009). The main species of the latter type staging in spring and autumn are common cranes, greylag geese, bean geese (*Anser fabalis*), and barnacle geese (*Branta leucopsis*). In addition, non-breeding common cranes and breeding and moulting greylag geese occur during the growing season. Kvismaren Bird Observatory estimated that 240 pairs of greylag geese bred in the area in 2017–2018. Cranes normally have a migration peak in mid-April, when up to 2000 individuals stage in the Kvismaren area on their way to breeding sites further north. Crane numbers normally decrease in late April before increasing slightly again when younger non-reproductive individuals use the area (approx. 500–1000 individuals; Nilsson, 2016). The shallow lakes and wetlands provide good roost sites and the surrounding agricultural landscape favourable foraging opportunities. A diversionary field (see below for details) and various scaring practices are employed in the study area to reduce the risk of crop damage caused by large grazing birds. The efficiency of the scaring practices has, so far, been difficult to quantify, as it is performed non-systematically and without coordination among farmers and managers. Nevertheless, the scaring practices can be assumed to be spatially and temporally frequent in the study area, and the scaring devices used during the autumn staging period have previously been estimated to approximately 35 propane cannons, 100 wooden human silhouettes, and 3500 pennants and fireworks (P. Nilsson, Örebro County Administrative Board, pers. comm.).

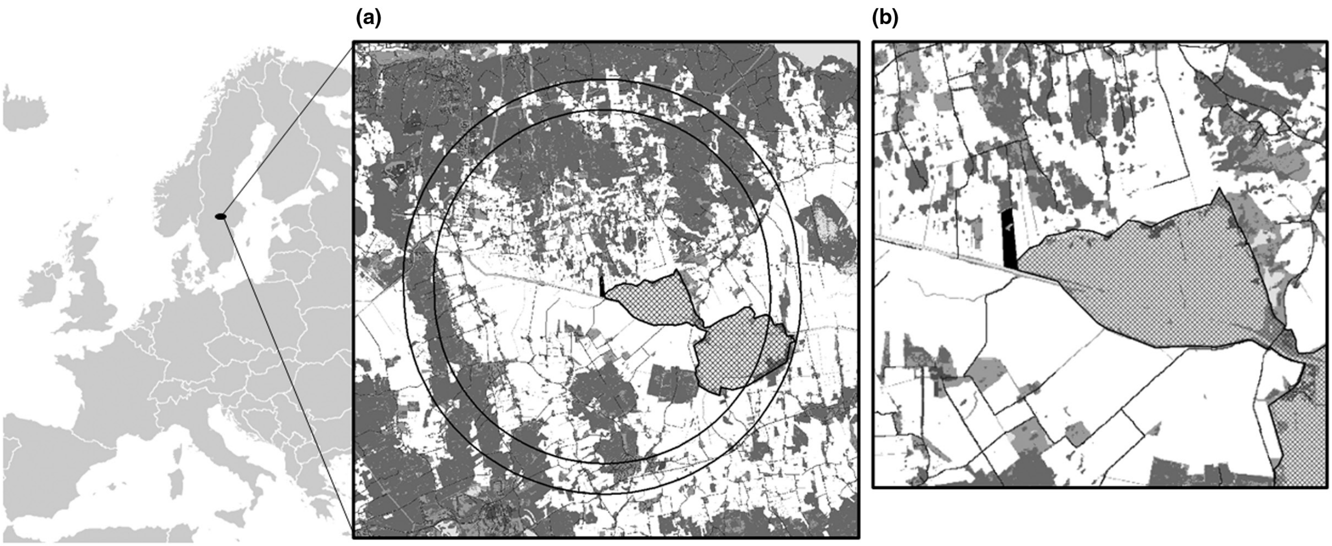

FIGURE 1 The Kvismaren study area in south-central Sweden showing (a) the protected wetland area (light grey grid), surrounding arable land (white), forested areas (dark grey), the diversionary field (black). The two circles indicate buffer zones of different radii from the diversionary field (greylag geese 3.82 km and common cranes 5.80 km). The buffers were used to define the uptake areas in which to derive habitat availability for the habitat selection analysis for distribution of available locations. The right panel, (b) shows detailed location of the diversionary field (0.08 km^2 in size).

2.2 | The diversionary field

In 2017, a 0.08 km^2 diversionary grass field with supplemental provision of barley was established close to the protected area in Kvismaren (Figure 1). It is subsidised and has been managed by the governmental Wildlife Damage Fund through the County Administrative Board in Örebro and a contracted farmer. The cost for the diversionary field is ~7400 Euros annually (min-max: 5000–10,000 Euros), depending on current grain prices and occasional practical limitations in spreading the barley. The aim was primarily to divert cranes to this field from newly sown or growing crops. However, greylag geese are also known to feed on cereal grain, and as they are present in the area during the growing season they may use the diversionary field as well. Grains of barley are spread in the field and the start of supplemental feeding is coordinated with arrival of staging common cranes, normally in April, when sowing of cereals has started in the region (for details about the supplemental feeding practice, see Table 1). Supplemental feeding normally ends in August, when the harvest of cereal starts and stubble fields and spilt grain become available as an additional abundant food source for large grazing birds. In 2022, there was a major flooding in the area, and the diversionary field was therefore not used for supplemental feeding until June 6. The management of the diversionary field varied over the years, but mowing was generally practiced to keep the grass sward short and between 200 and 1000 kg of barley were spread every 1–4 days throughout the season (Table 1).

2.3 | Capturing and tagging birds

This study was based on location data from 17 common cranes and 55 greylag geese equipped with GPS transmitters. We captured pre-fledgling common cranes after a short run from a car or a hide and equipped them with leg or harness mounted GPS transmitters (Ornitela) in July- early August in 2016–2020 within 70 km of Grimsö Wildlife Research Station, Lindesberg (59°43′ N, 15°28′ E; for details about capture procedures, see Månsson et al., 2013). Juvenile common cranes accompany their parents to the wintering grounds, where parents and juveniles usually part in January (Alonso et al., 1984). They most often visit the study area the second time as yearlings but sometimes postpone the second visit until they are older. Tagged cranes often return for several seasons (for details see Table S2 in Supplemental Information). Greylag geese were captured as adults and equipped with neck-band GPS transmitters (OT-N35, OT-N44) in June in 2017–2019. Captures took place in Kvismaren in early mornings by herding moulting, flightless greylag geese by canoes and by foot into net corrals (for capture details see Månsson et al., 2022). The GPS-tagged greylag geese present in the study area were included in the study, often for several consecutive seasons (for details see Table S2 in Supplemental Information).

2.4 | Data management

To model relative presence of common cranes and greylag geese in differentially managed habitats during the season of the supplemental feeding in the diversionary field (May 1 to August 15 each year), we compared the GPS locations of the birds (hereafter referred to as *'used'* locations) with randomly distributed locations ('*available*') (i.e. Resource Selection Functions, RSF's; Lele & Keim, 2006). For the study period, we assume that crops are growing and coincide with associated damage risk when the diversionary field was in operation (Table 1). The analyses were conducted in two steps for both species by assessing; (1) probability of presence in different habitats (e.g. arable land, protected area; model 1), and (2) probability of presence on different crop types in arable fields (e.g. barley, ley, diversionary field; model 2; Table 2). We defined an uptake area for the diversionary field (i.e. assumed to be within reach for the birds during the daily foraging activities) by using distance from the previous night's roost location, within our study area, to all daytime locations the following day. The 95% percentile of all these measured distances were then used to define a radius for the uptake area around the diversionary field (5.80 km for common cranes and 3.82 km for greylag geese; Figure 1). We included the GPS locations and randomly distributed available locations (ratio 1:1) within the uptake area, mirroring the available area for the birds' daily foraging bouts. The time until the common cranes and greylag geese started using the diversionary field was assessed as either: (1) the number of days until first use after the first supplemental feeding, or (2) if the feeding had

TABLE 1 Feeding practices of barley at the diversionary field aimed to attract cranes and greylag geese and thus reduce damage risk to conventionally farmed fields in Kvismaren.

Year	Start date	End date	Feeding occasions	Total supply (kg)	Mean/occasion (kg)	Min-max/ occasion (kg)
2017	April 11	August 28	52	44,700	860	—
2018	April 21	July 29	34	29,600	871	500–1000
2019	April 6	August 19	48	24,000	500	500–500
2020	March 30	August 13	51	27,000	529	500–700
2021	April 23	September 21	41	20,500	500	500–500
2022	June 2	August 22	26	9000	346	200–400

TABLE 2 A two-step model setup was used for the resource selection functions (RSF's) comparing used and available locations (1:1 ratio) by common cranes (*cc*) and greylag geese (*gg*) in the agricultural-wetland landscape (step 1) and on arable land (step 2). Identity of the tagged bird was added as a random effect.

Model	Species	Explanatory variable	Number of individuals	Number of used locations
1cc	Common cranes	Habitats (6 factors)	17	33,716
1gg	Greylag geese	Habitats (6 factors)	55	279,694
2cc	Common cranes	Arable fields (9 factors)	17	18,862
2gg	Greylag geese	Arable fields (9 factors)	54	66,816

started prior to arrival, as the number of days after arriving to the uptake area.

To ensure highly precise spatial data, we excluded locations with horizontal dilution of precision >7 (D'eon & Delparte, 2005) as well as locations fixed by less than three satellites (i.e. 2D). As the study focuses on habitat and field selection on the ground and during daytime foraging activities (i.e. damage risk), locations assumed to be when in flight with speed >10 km/h were excluded, as were night locations. Day and night locations were defined by the time of sunset and sunrise, that is all locations between sunset and sunrise were defined as night locations and subsequently excluded. The programming of GPS transmitters and the frequency of location fixes varied between 15 and 60 min. Thus, to standardise the positioning frequency and to meet the assumption of independence between consecutive individual locations to allow for potential individual movement to another habitat or field, the positioning frequency was standardised to one location/hr (Fieberg et al., 2010). Habitat types were derived from the national land cover data base (0.1 × 0.1 km; Naturvårdsverket, 2020) and the extent of the protected area (Ramsar site; Kvismaren) from the Swedish Environmental Protection Agency. To avoid overfitting of models, habitats with similar environmental characteristics and management were combined into the following categories: arable land (i.e. conventionally farmed fields with short rotation crops), diversionary field, non-protected wetland and water, other land (e.g. forest, exploited land), pasture (i.e. permanent grassland for grazing), and protected area (step 1; Table S1). For the locations on arable land (step 2), crop types were derived from the SAM14 database (The Swedish Board of Agriculture), which provides spatially explicit information about cultivated crops at the field level. Crop types were lumped into nine categories based on similar characteristics or sporadic occurrences: barley, beans and peas, diversionary field, ley (i.e. fertilised, productive grasslands for silage production), oat, potatoes, rye and triticale, wheat and other crop (e.g. rape seed, vegetables; step 2; Table S1). Data management was done in ArcGIS (version 10.7) and R (version 4.2.1).

2.5 | Statistical methods

Selection of habitat and arable fields was analysed by a RSF assessing the relative probability of presence in relation to landscape composition within the uptake area of the diversionary field (Lele et al., 2013; Lele & Keim, 2006).

We ran generalised linear mixed models with binomial error structures and logit link functions (R package lme4; Bates et al., 2015)

$$y_i(0,1) = \frac{\exp\left(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \varsigma_{x(i)}\right)}{1 + \exp\left(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \varsigma_{x(i)}\right)},$$

where y is the mean probability of presence (i.e. proportional use in relation to availability), $\beta_{0,1\ldots}$ are the focal explanatory variables (see Table 1 for models *1cc* & *gg* and *2cc* & *gg*), and ς is the random intercept for each respective individual i. Model selection was carried out by comparing the full models (Table 2) to null models based on AIC (i.e. ΔAIC < 4; Burnham & Anderson, 2002). From the highest ranked model, predicted model estimates and 95% confidence intervals based on 1000 simulations were assessed using the R package 'arm' (Gelman et al., 2014). Software R (version 4.2.1) was used for the statistical programming (R Core Team, 2019).

3 | RESULTS

3.1 | Use of habitats, diversionary field, and crop types

A majority of common crane individuals (76.5%) and about one third (36.4%) of the greylag goose individuals used the diversionary field any time during the study period. Common cranes and greylag geese that used the diversionary field found and started using it after on average 4.2 days in the area (range: 0–33) and 30.2 days (range: 0–120), respectively.

Common cranes spent approximately half of the daytime (i.e. percentage of locations) in the protected area (45.7%), followed by arable land (40.4%), the diversionary field (12.2%), other land (e.g. forest, 1.3%), pasture (0.2%), and non-protected wetlands and water (0.1%, Figure 2). When analysing locations on arable land only, most time was spent on ley (28.0%), followed by the diversionary field (21.7%), wheat (19.5%), barley (13.0%), other (13.0%), oat (2.5%), potatoes (0.7%), and rye and triticale (0.4%, Figure 3). Greylag geese, on the other hand, spent most of the daytime in the protected area (74.9%), followed by arable land (22.7%), other land (1.0%), non-protected wetlands and water (1.0%), and pasture (0.4%, Figure 2). When on arable land, almost half of the time was spent on ley (48.1%), followed by barley (17.3%), wheat (14.3%), other (11.9%), rye and triticale (4.5%), oat (2.2%), beans and peas (1.2%), the diversionary field (0.4%), and potatoes (0.1%; Figure 3).

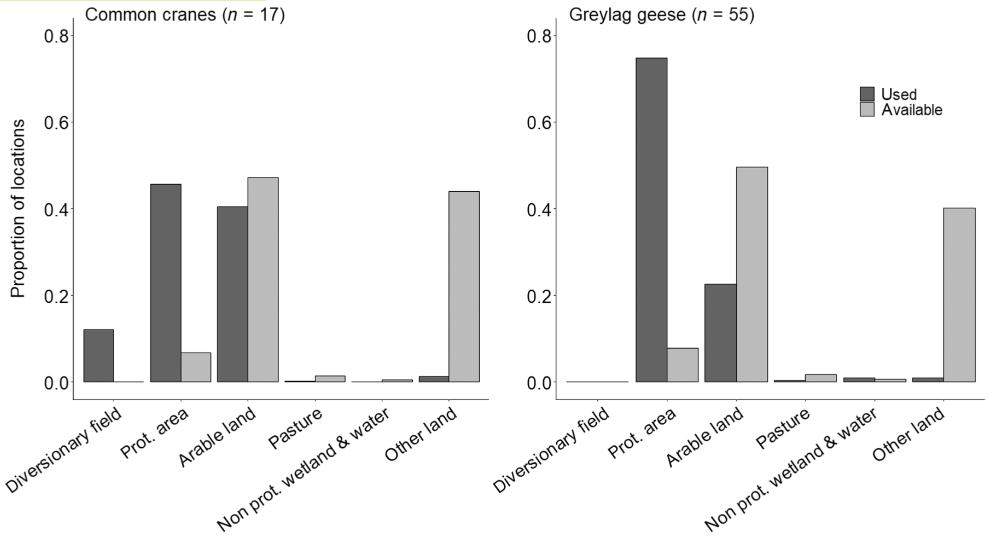

FIGURE 2 Use of habitats derived by GPS locations from 17 common cranes and 55 greylag geese versus randomly distributed available locations within the uptake area of the diversionary field (i.e. availability of habitats). The location for quantifying availability of habitats was randomly distributed within a radius of 5.80 and 3.82 km around the diversionary field for common cranes and greylag geese, respectively, mirroring distances (95% percentile) flown from roost sites to daytime foraging sites. For details about habitat categorisation, see Table S1.

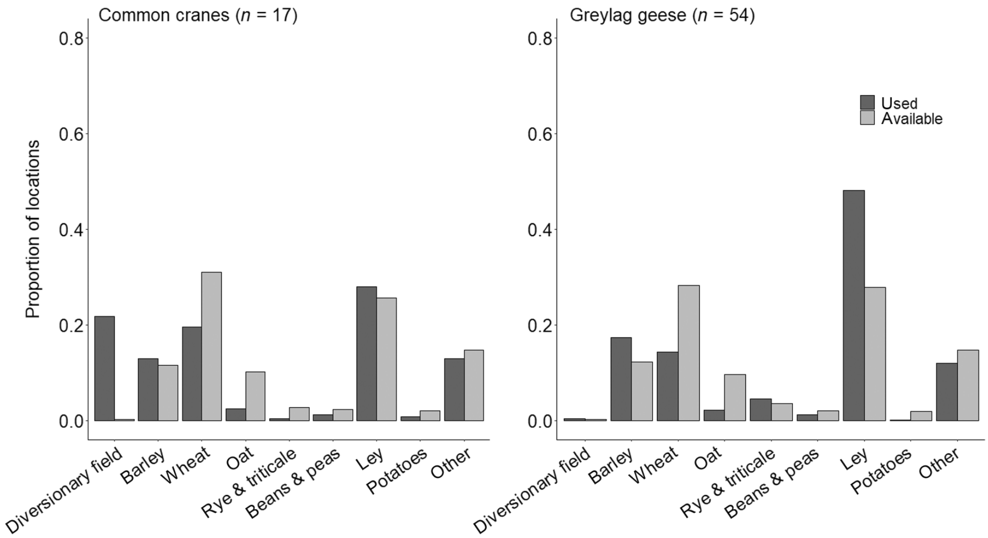

FIGURE 3 Arable field characteristics of used GPS locations of 17 common cranes and 54 greylag geese versus randomly distributed locations available within the study area. Available locations were distributed within arable land in a radius of 5.80 and 3.82 km around the diversionary field for common cranes and greylag geese, respectively, mirroring distances (95% percentile) flown from roost sites to daytime foraging sites. For details of categorisation of field characteristics, see Table S1.

3.2 | Selection of habitats in the wetland-agricultural landscape

The highest ranked RSF models show that the highest probability of presence was in the diversionary field for common cranes and the protected area for greylag geese from May to Mid-August (Figure 4, Table S3). For common cranes the highest probability of presence was in the diversionary field, followed by the protected area, arable land, non-protected wetland and water, pasture and other land. For greylag geese, the highest probability of presence was in the protected area, followed by non-protected wetland and water, the diversionary field, arable land, pasture and other land (Figure 4, Table 3).

3.3 | Selection of the diversionary field and crop types on arable land

When considering arable land only, the highest ranked RSF's showed that the predicted relative probability of presence was highest in

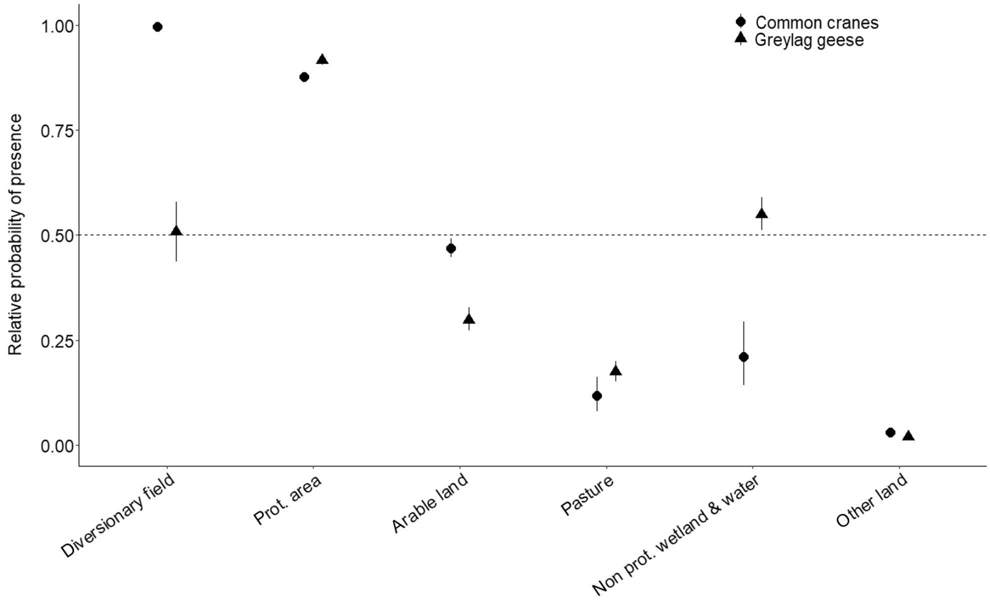

FIGURE 4 Relative probability of presence of common cranes ($n=17$) and greylag geese ($n=55$) in the habitat types protected area, arable land, pasture, non-protected wetland and water, and other land in May through mid-August. The predicted estimates and their 95% confidence intervals were derived from 1000 model simulations based on the estimates from the models *1cc* and *1gg* (Table 2). Dashed line indicates a use of habitat that is proportional to its availability in the uptake area.

the diversionary field for both species (common crane: mean = 0.99, 95% C.I: 0.99–1.00, greylag goose: mean = 0.71, 95% C.I: 0.64–0.77). For common cranes, the probability of presence was highest in the diversionary field, followed by gradually decreasing probability of presence on barley, ley, other land, wheat, beans and peas, potatoes, oat, and rye and triticale (Figure 5, Tables 3 and S3). For greylag geese, though, the second highest probability of presence was found for ley, and then gradually decreasing for barley, other land, rye and triticale, beans and peas, wheat, oat and potatoes (Figure 5, Tables 3 and S3).

4 | DISCUSSION

4.1 | High probability of presence in the protected area and the diversionary field, but still a risk of negative impact on arable fields

Our study illustrates how large grazing birds distribute in a landscape where a diversionary field is used to combine conservation needs with sustainable agricultural land use. In the present case, common cranes and greylag geese especially use and select for the protected area during daytime, but also use arable land to a great extent. This indicates a potential risk of negative impact to both wetland biodiversity and conventional agricultural food production. However, common cranes also show a selection for the diversionary field, as was also the original intention of the management. The strategy to divert large grazing birds and other wildlife from conventional farmland to diversionary fields and protected areas (i.e. refuges) is commonly implemented to reduce negative impact to agricultural production worldwide (Jensen et al., 2008; Kubasiewicz et al., 2015). However, by providing limited access of diversionary fields, the frequent scaring in the area will most probably push large numbers of large grazing birds into the protected areas. It is therefore important to consider that the strategy may have a two-sided effect; on the one side it decreases crop damage in conventional fields, but on the other side it may increase negative impact to wetland biodiversity.

We found that time use in the protected areas was considerable, especially by greylag geese (74.9%), but also by common cranes (45.7%), and typically in wetland or open water (89.0% and 89.5%, respectively). This suggests that the protected area works as a refuge, but also implies a potential risk of direct or indirect negative impacts of these birds on other flora and fauna (e.g. on reed beds by goose grazing and on wetland birds by predation by common cranes), as described for other superabundant populations (Bakker et al., 2018; Fox & Madsen, 2017; Westin, 2021). Common cranes are omnivorous and known to spend most of the daytime foraging in wetlands during other bird species' breeding period (time budget median: 69%; Ingerström, 2020) and there are growing concerns about predation by common cranes on chicks and eggs (Wirdheim, 2019). Similar concerns have been raised for the effects of high abundance of geese, as overgrazing of reed beds in wetlands and pastures may affect both flora and bird fauna negatively (Bakker et al., 2018). However, there are also findings of absence of negative impact on breeding waders due to goose grazing (Madsen et al., 2019) and of common cranes on the abundance of other peatland bird species (Fraixedas et al., 2020). Considering our findings and the presence of flocks of hundreds or thousands of common cranes and greylag geese in the protected area, we anticipate that there is a high risk for negative impacts, but also a need for further scientific studies to

Model setup	Explanatory variable	Estimate	S.E.	*p*-value
1cc	Arable land (intercept)	−0.12	0.05	0.013
	Diversionary field	5.64	0.32	<0.001
	Non-protected wetland & water	−1.22	0.24	<0.001
	Other land	−3.31	0.07	<0.001
	Pasture	−1.90	0.19	<0.001
	Protected area	2.09	0.04	<0.001
1gg	Arable land (intercept)	−0.86	0.07	<0.001
	Diversionary field	0.88	0.12	<0.001
	Non-protected wetland & water	1.05	0.04	<0.001
	Other land	−3.06	0.03	<0.001
	Pasture	−0.70	0.05	<0.001
	Protected area	3.25	0.01	<0.001
2cc	Barley (intercept)	0.16	0.07	0.015
	Beans & peas	−0.74	0.12	<0.001
	Diversionary field	4.92	0.26	<0.001
	Ley	−0.02	0.05	0.75
	Oat	−1.53	0.08	<0.001
	Other	−0.22	0.06	<0.001
	Potatoes	−1.16	0.15	<0.001
	Rye & triticale	−2.03	0.18	<0.001
	Wheat	−0.59	0.05	<0.001
2gg	Barley (intercept)	0.34	0.02	<0.001
	Beans & peas	−0.82	0.07	<0.001
	Diversionary field	0.56	0.16	<0.001
	Ley	0.21	0.02	<0.001
	Oat	−1.80	0.05	<0.001
	Other	−0.55	0.03	<0.001
	Potatoes	−3.01	0.16	<0.001
	Rye & triticale	−0.10	0.04	0.02
	Wheat	−1.02	0.03	<0.001

Note: Models *1cc* and *1gg*: assessment of relative probability of common crane and greylag goose presence during May- mid August in different habitats in the wetland-agricultural landscape (including the diversionary field). Models *2cc* and *2gg*: assessment of relative probability of common crane and greylag goose presence in arable fields (crop types and diversionary field). The top estimates in each model setup represent intercepts, and the following estimates (logit) are in relation to the defined intercept.

TABLE 3 Parameter estimates (logit) derived from the highest ranked resource selection functions based on GPS location data from common cranes and greylag geese, and available locations in each model setup (step 1–2, Table 1).

assess whether these have effects on population dynamics of wetland bird species or irreversible effects on the vegetation.

4.2 | Probability of presence on diversionary and arable fields

Common cranes spent a significant share of their time in arable fields at the diversionary field (21.7%), whereas greylag geese did not (0.4%). Yet, compared to the use of protected area and conventional arable land the use of the diversionary field was still low in greylag geese. However, when considering the availability of different habitat categories, the selection by common cranes was highest for the diversionary field compared to all other habitats and crop types, and there was also a relatively high probability of presence by greylag geese. The diversionary field may so reduce the pressure on arable fields and protected areas, especially for common crane presence. Moreover, the results suggest that the limited access to diversionary fields while scaring took place in conventional fields may cause a higher pressure of large grazing bird presence in the wetlands. Previous studies have shown that greylag geese often respond to scaring by leaving arable land for wetlands for up to 4h, but with no persistent scaring effect off arable land after 48h (Teräväinen, 2022). Part of the observed differences in habitat use and selection of the two species can be that adult greylag geese, in contrast to non-breeding common

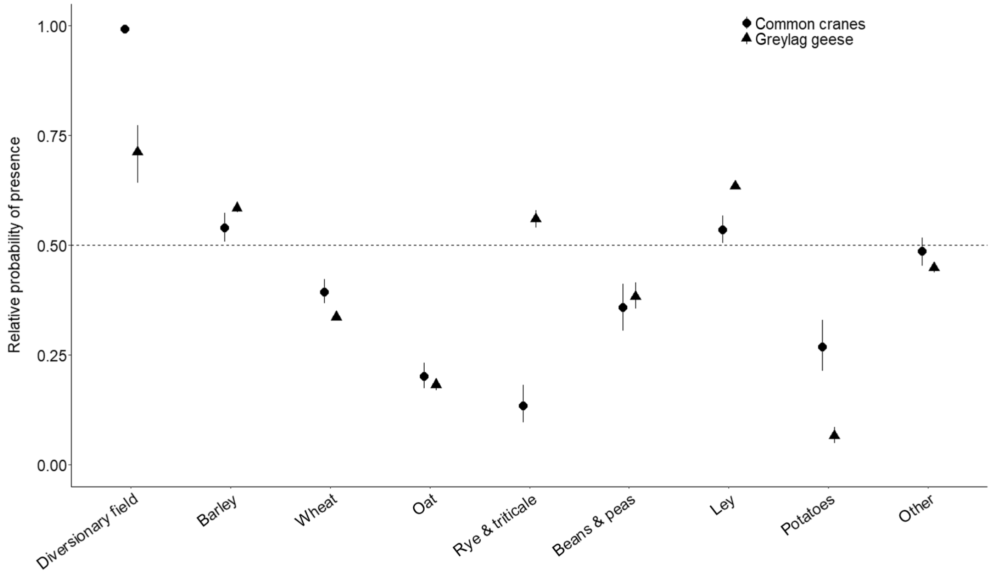

FIGURE 5 Relative probability of presence of common cranes ($n = 17$) and greylag geese ($n = 54$) in the diversionary field, fields with barley, wheat, oat, rye and triticale, beans and peas, ley, potatoes, and other crop in May to mid-August 2017–2022. The predicted estimates and their 95% confidence intervals were derived from 1000 model simulations based on the estimates from models *2cc* and *2gg* (Table 2). Dashed line indicates a use of habitat in proportion to its availability in the uptake area.

cranes, may be flightless (i.e., moulting or rearing young). This naturally restricts movements and thereby increases the use and selection of habitats and fields in close vicinity to the protected area (Olsson et al., 2017). Common cranes readily found and used the diversionary field (76.5% of individuals on average 4.2 days from the start of the feeding practice or arrival to the uptake area in cases when the feeding already had started), which is a result in line with the same species using a supplementary feeding station in Hula Valley, Israel (~80% of individuals; Pekarsky et al., 2021). Only about one third of the greylag geese (36.4%) used the diversionary field, and often later after the start of feeding or their arrival to the uptake area (30.2 days), which further support lower appeal of the diversionary field to greylag geese compared to common cranes.

When not foraging in the diversionary field, the probability of common crane presence was highest on ley and barley, followed by wheat, beans, peas, and potatoes. This suggests that ley and barley are the crops highest at risk when the diversionary field does not fulfil the daily resource needs for common cranes. Our findings about selection of these crops align with previous research on common cranes foraging on waste grains of barley, wheat and potatoes in autumn (Montràs-Janer et al., 2020; Nilsson et al., 2016). Second after the diversionary field, the probability of goose presence was highest on ley and barley, followed by rye and triticale, beans and peas, and wheat. This is in line with previous research on field occupancy during the growing season and corresponding reported crop damage (Montràs-Janer et al., 2020; Strong et al., 2021; Teräväinen et al., 2022). Our study was, however, limited to the growing season and to one diversionary field, consequently we could not analyse additional factors known to influence the use and selection of the landscape and consequent variation in damage risk to arable land (e.g. seasonality, distance to roost site, disturbance, agricultural practices, crop nutrient content; Nilsson et al., 2016, 2020; Fox et al., 2017).

4.3 | Sharing landscapes tailored for wetland biodiversity and conventional agriculture

We found that the diversionary field may reduce the risk of negative impact caused by common cranes to arable fields, but less likely greylag geese. In the study area, additional diversionary fields in alternative directions from the roost sites would be called for to increase the use by common cranes, whereas alternative management would be needed to specifically target the needs of greylag geese. Our study reveals that provision of barley or short sward ley fields within ~6 km from the roost sites (i.e. the closer the better) can be used to attract common cranes, and that short sward ley fields ~4 km from roost sites can be used to attract greylag geese. These results are in line with previous studies showing that fields close to roost sites are selected for, and especially short sward ley fields by greylag geese (Simonsen et al., 2017; Strong et al., 2021; Vickery & Gill, 1999) and barley fields by common cranes (Nilsson et al., 2016). Yet, the impact risk on sensitive crops has been found to be higher in fields in the very proximity of diversionary feeding, which calls for careful location of diversionary fields away from sensitive crops (Geisser & Reyer, 2004; Kubasiewicz et al., 2015; Van Beest et al., 2010). Moreover, additional landscape characteristics (e.g. distance to forest edge, roads, settlements) may affect field selection by large grazing birds and should thus also be considered to maximise use of birds of diversionary fields (Jensen et al., 2017; Nilsson et al., 2020). Knowledge about how large grazing birds respond to the combined strategy of scaring and diversionary fields is limited, but it has been shown that low refuge availability reduced the effectiveness of diversionary feeding and scaring, and that diversionary feeding may cause habitat shift and reduction in activity areas for common cranes (Pekarsky et al., 2021). Our results indicate that such habitat shifts may increase the use and selection of protected wetland areas and thus also the risk of negative impact on such ecosystems. To reduce such risk, the diversionary field should be integrated within the management of protected areas, aiming to fulfil the daily resource needs of large grazing birds. As part of such a strategy, also the cost efficiency of the diversionary field should be considered in relation to reduction of negative impact to agriculture or wetland biodiversity. In this study, cost efficiency was not possible to evaluate due to the lack of a control area where no management is conducted, yet the approximate annual cost of the diversionary field (~7400 Euros) can be put in relation to 31,000 Euros for crop loss compensations and 95,000 Euros for subsidising crop damage preventive interventions in 2021 in the focal county (*incl.* diversionary field, scaring, etc.; Frank et al., 2021).

To conclude, the combined strategy intended to steer birds away from growing crops by scaring and diversionary fields may reduce crop damage risk, however steering large numbers of common cranes and greylag geese to protected areas may cause increased impact on wetland biodiversity. Our study thus highlights a need for systematic evaluation of interventions, monitoring of potential negative impacts, and a consolidative management approach to landscapes tailored for both wetland biodiversity and sustainable agricultural production.

AUTHOR CONTRIBUTIONS

Lovisa Nilsson: conceptualisation, methodology, formal analysis, data curation, writing- original draft, writing-review & editing, visualisation, project administration, funding acquisition, Johan Månsson: conceptualisation, methodology, writing-review & editing, funding acquisition, Johan Elmberg: conceptualisation, resources, writing-review & editing, funding acquisition, Niklas Liljebäck: resources, writing-review & editing, Ingunn Tombre: conceptualisation, methodology, resources, writing-review & editing, funding acquisition.

ACKNOWLEDGEMENTS

The authors thank M. Bhardwaj for statistical advice, P. Nilsson and J. Månsson Wikland for providing data about the feeding practice at the diversionary field, S. Svensson for managing the feeding at the diversionary field, and D. Ahlqvist and all volunteer field assistants for help during capture and tagging of common cranes and greylag geese.

FUNDING INFORMATION

The study is funded by The Research Council Formas (no. 2018-00463) and The Swedish Environmental Protection Agency (no. 19/128 and 19/129).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interests to declare.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.12302.

DATA AVAILABILITY STATEMENT

Data available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.hhmgqnkp8 (Nilsson et al., 2024).

ETHICS STATEMENT

All captures and tagging of birds adhered to ethical requirements for research on wild animals after approval from the Animal Ethics Committee of central Sweden (common cranes: C104/10, C53/13, greylag geese: 5.8.18–03584/2017).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Lumping of habitat and crop categories for models 1-2*cc*, *gg*. Habitats were derived from the Swedish Land Cover data base and crop categories from the SAM14 database (see Methods).

Table S2. Individual ID of common cranes and greylag geese with number of GPS locations per individual and year (May 1–August 15) included in the study of habitat use and selection (models 1*cc* and 1*gg*). The number of locations represents both used and available locations (1:1 ratio of GPS locations and randomly distributed locations in the study area).

Table S3. Multi-model interference from the binomial generalised mixed models based on habitat in models 1*cc* and 1*gg* (i.e. arable land, diversionary field, protected area, pasture, other land, wetland & water) and in models 2*cc* and 2 *gg* crop type (i.e. beans & peas, diversionary field, other, ley, oat, barley, potatoe, rye & triticale, wheat), with birdID fitted as a random factor.

How to cite this article: Nilsson, L., Månsson, J., Elmberg, J., Liljebäck, N., & Tombre, I. (2024). Selection of a diversionary field and other habitats by large grazing birds in a landscape managed for agriculture and wetland biodiversity. *Ecological Solutions and Evidence*, *5*, e12302. https://doi.org/10.1002/2688-8319.12302