Behaviour and habitat use of Greylag Goose *Anser anser* families during brood rearing in eastern Jutland, Denmark

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Abstract

Greylag Geese *Anser anser* nesting in Denmark have increased dramatically in abundance and distribution since the mid-20th century, yet little is known about specific habitat use by brood-rearing families, which typically remain hidden in dense wetland vegetation and consequently are poorly represented in breeding surveys. We therefore used collar-mounted GPS/GSM trackers deployed on adults accompanying goslings to investigate the cryptic brood-rearing ecology of Greylag Geese at two sites in newly occupied eastern Jutland, Denmark, where breeding numbers have expanded markedly in recent decades. Brood-rearing families relied mainly on small (< 1.5 ha) wetlands embedded within agricultural landscapes. Across both sites, geese spent 61–79% of daylight hours and 74–99% of the night-time on open water, including reed-beds and flooded willow scrub. Agricultural crops were hardly used (birds spent < 5% of time in spring-sown barley and generally < 40% in grasslands), suggesting that brood-rearing geese are unlikely contributors to agricultural conflict, contrasting with larger post-fledging aggregations later in the season. Behavioural observations confirmed that goslings grazed short grass close to water, while mainly vigilant and preening attendant adults remained largely on the adjacent water. The findings suggest that brood-rearing Greylag Geese can remain undetected within intensively farmed landscapes, highlighting the inadequacy of traditional breeding surveys and confirming that counts of larger post-fledging aggregations remains the best method for monitoring goose productivity. The study also contributes information about the broader ecological importance of small kettle-hole wetlands, which provide predator-safe nursery

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habitat and may have been one of the factors that facilitated the species' recent range expansion.

Key words: agricultural landscapes, brood rearing ecology, GPS tracking, habitat selection, kettle-hole wetlands, predator avoidance.

The Greylag Goose *Anser anser* has undergone a marked increase in breeding numbers and range in Denmark, rising from *c.* 2,000 pairs in 1971–1974 to an estimated 15,000–17,000 pairs in 2015 (Moshøj 2020) and as many as 23,300 in 2024 (Fredshavn *et al.* 2025). The species has expanded within Denmark from being present in 338 5 × 5 km grid squares (14%) to 1,339 (59%) during the breeding season over the same period (Moshøj 2020). This expansion has been attributed to a combination of factors, including reduced hunting mortality resulting from the delay in the opening of the hunting season by one month (from 1 August to 1 September) from 1994 onwards, which substantially reduced mortality in the Danish-breeding population (particularly among juveniles) because most migrant Greylag Geese arrive after this period (Clausen *et al.* 2023). Improved overwinter survival associated with milder winters and short-stopping (partly due to drought exacerbated by drainage affecting former wintering areas in Coto Doñana, Spain; Bønløkke *et al.* 2006; Heldbjerg *et al.* 2011; Ramo *et al.* 2015; Powolny *et al.* 2018; Camacho *et al.* 2022; Fox *et al.* 2023; Heldbjerg *et al.* 2024) may also have contributed. In addition, increased availability of high-quality green forage (*e.g.* cereals and improved pasture) as well as spilled grain stubble fields present in modern agricultural landscapes all provide food for geese in Denmark in winter and throughout the year (Fox 2004; Moshøj 2020; Clausen *et al.* 2025). Together, these factors have likely contributed to improving the survival and body condition of Greylag Geese of Danish breeding provenance and supported the expansion of the breeding population into previously unoccupied areas (including eastern Jutland) between the mid-1990s and late 2010s (Moshøj 2020).

Despite this expansion, very little is known about the habitats used by Greylag Goose families during the brood-rearing season. When parent geese undergo wing moult to regrow new flight feathers and goslings have yet to fledge, families are highly cryptic, typically remaining concealed in dense wetland vegetation or on densely vegetated waterbodies, making them difficult to detect and virtually absent from breeding bird surveys. As a result, the extent to which recently colonised landscapes provide suitable nursery (*i.e.* brood-rearing) habitats and the degree to which brood-rearing geese interact with agricultural crops, remain poorly understood. This knowledge gap limits our ability to interpret population trends and their causes, assess potential agricultural conflict and identify key habitats of potential conservation importance.

To quantify habitat use in the latter stages of the gosling growth period, until the young fledged, we fitted GPS/GSM loggers to adult Greylag Geese accompanied by goslings caught at two sites in eastern Jutland, Denmark.

Specifically, we aimed to: (1) describe the availability and type of habitats used by brood-rearing families, (2) assess the importance of small wetlands and waterbodies for predator avoidance and daily activity, and (3) evaluate the degree of use of agricultural land during this cryptic life-history stage. Complementary behavioural observations were made at one site to verify patterns of habitat exploitation and feeding behaviour. Together, these data provide new information on how Greylag Geese successfully exploit recently colonised agricultural landscapes and should help to inform the future monitoring and management of this expanding breeding population.

Methods

Study areas, capture and tracking of Greylag Geese

We caught 31 Greylag Geese in family groups during the brood-rearing period at two sites on the Djursland Peninsula in eastern Denmark, by rounding up flightless birds in wet willow *Salix* sp. woodland and Common Reed *Phragmites australis* reed-beds and walking them into pre-erected nets. The catch sites were a small (160 m^2) and a medium-sized (590 m^2) water bodies, each surrounded by intensively managed lowland farmland, with small (1 ha) to large (12 ha) fields of spring-sown barley, autumn sown wheat, and grass cut for hay or silage. Of the captured Greylags, 22 (five adult females, five adult males, nine first-year females and three first-year males) were caught at Kastrup Mose, near Pindstrup (56.385°N, 10.379°E) on 7 June 2021. Nine more (an adult pair, five first-year males and two first-year females) were captured 14 km due west at Vasen, near Clausholm (56.393°N 10.165°E) on 8 June 2021. We fitted Ornitela OT-N44-3G 45 g Global Positioning System/Global System for Mobile Communication (GPS/GSM) collar-mounted trackers to five adult females at Kastrup Mose and on one adult male and one adult female and a first-year female at Vasen. One of the Kastrup Mose females was found mortally injured by a predator (probably a Red Fox *Vulpes vulpes*), retrieved and euthanised. The duty cycle set for the devices recorded positions every 10 min throughout the night and day, with the objective of assessing habitat use. All seven devices contributed usable data in this study. Previous studies have shown these devices deliver 45% of positions within 5 m accuracy and 89% within 10 m accuracy (Clements *et al.* 2022), indicating that they are very effective in relating bird position to the mapped habitat types used here. We compiled habitat data on these birds from the point of release after capture until the obvious and rapid onset of longer distance movements from overnight roosts, indicative of the goslings beginning to fly and families no longer having to walk between roosting and feeding sites.

Time budgets of caught birds

Vasen goslings were reared to fledging on the small lake, which could be viewed without hindrance from a 7 m high vantage point on a road 75 m from the nearest shoreline. We undertook scan samples of all individuals (mostly 13 adults accompanying 13 unfledged goslings, including tagged, marked and occasionally uncaptured

geese), recording individuals' instantaneous movement states every 5 min as: walk, swim or stationary, and their activity states as: terrestrial grazing, other feeding (mainly on *Phragmites* shoots while swimming), vigilant, preen, drink, aggression, sleep and "other" (Altmann 1974; Bateson & Martin 2021). Data were gathered opportunistically on 9, 10, 15, 18, 21 and 24 June 2021, throughout the day to cover the period from 04:00–20:00 h, except that no observations were made from 11:00–13:00 h. These provided 1,619 records of individuals' activities from 188 scans. All data were summed by age (gosling *vs.* adult) to give the overall time spent on each activity, summarised by hour of the day to generate means (± 95% CI) for the two age classes, to illustrate relative time invested particularly in feeding activities.

Individuals caught at Kastrup Mose were cryptically concealed in small willow-covered ponds and wetlands, making them impossible to observe.

Habitat availability and goose use

At Vasen, the brood-rearing lake was surrounded on the east and southern edge by reed-beds, willow scrub and wet woodland, on north and west sides by permanent grassland grazed by cattle, including two areas of conspicuously short-grazed swards very close to the edge of the waterbody (Fig. 1). The tracked birds were never observed to leave the confines of the lakes and their immediate shorelines before they dispersed elsewhere following fledging of the goslings.

At Kastrup Mose, the catch site and initial brood-rearing site comprised a small wetland within an extensive area of farmland landscape typical of this area. Available habitats in the immediate area consisted of a mixture of grass for silage and grazing, winter- and spring-sown cereal, with lesser areas of maize, oilseed rape and peas. These farmland areas were interrupted by woodland and punctuated with low-lying wet depressions containing either ponds (some of which are densely overgrown with willow scrub) or wetland vegetation (Fig. 2). After exploiting these small wetlands, two of our tracked geese moved to Smørmosen, a large, undisturbed lake 1.52 km from the catch site, surrounded by Greater Tussock-sedge *Carex paniculata* and reed-beds as well as extensive willow scrub, making human approach around all sides difficult.

To assign relative habitat use to each tracked bird, we overlaid each of the positions generated by the loggers onto a composite mapped landcover GIS data layer in both areas during the period from release to fledging of goslings. Agricultural and other land cover categories were extracted by combining three sources of land cover data into a master composite of land use types in areas used by the geese. These were a compilation of: (1) crop information relating to farmland on a field-by-field basis for June 2021, from The Danish Agricultural Agency (Danish Agricultural Agency 2023), (2) maps of protected nature areas from The Danish Environmental Protection Agency (Danish Environmental Protection Agency 2023), and (3) other Danish land use types (such as bog, forest, reeds, *Carex*, roads, buildings *etc.*) using Basemap03 mapped cover and definitions (Levin 2014, 2019). The habitat category for each individual GPS-location was determined

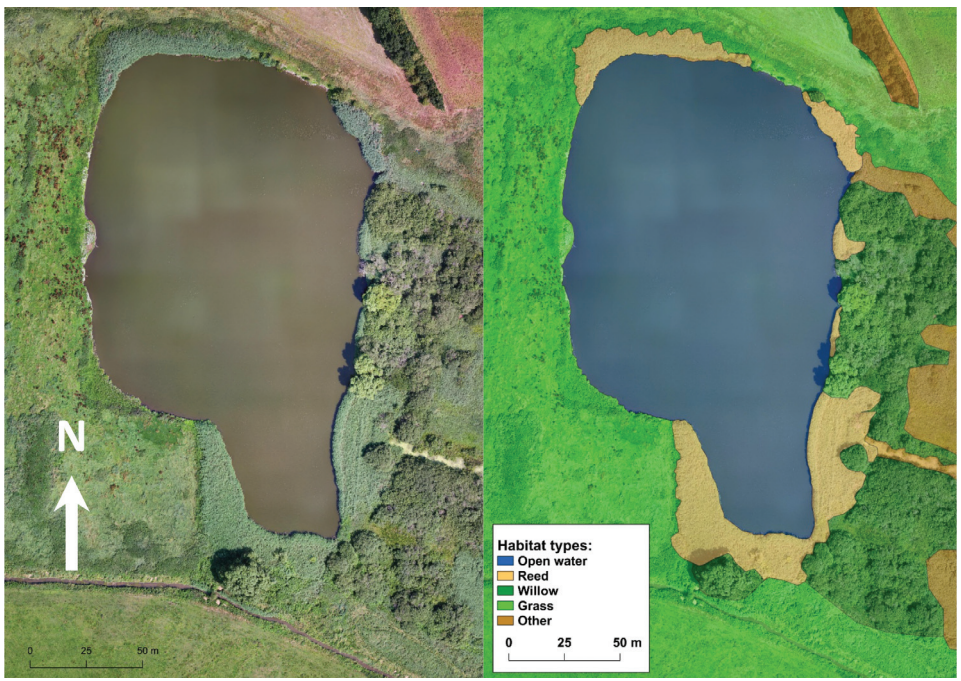


Figure 1. Drone image showing the Greylag Goose site at Vasen (56.393°N, 10.165°E; left), with habitat types mapped according to Basemap03 classification, crop information and protected areas imagery (right), used to assign habitat use of tracked individuals in this study (see Methods for details).

by overlaying the tracking data onto the composite land use type GIS layer. Some natural habitats were not always well defined; for instance, waterbodies under dense willow canopies were defined as willow scrub, whilst ponds adjoining meadows were frequently included within meadow polygons, which required manual visual resolution within the GIS platform. Geese were also conspicuously associated with ecotones between habitats (*e.g.* along shorelines of waterbodies), making it difficult to assign them to different categories of natural habitats with certainty. The overlay of goose positions on the agricultural GIS layers (also confirmed by field observations) showed that, of the 132 different crop/habitat types available (the vast majority of which were totally unsuitable as goose feeding habitat), almost all goose locations (> 98%) were in spring-sown barley and grassland. The remaining positions recorded on agricultural land (*i.e.* on crops other than grass and barley) therefore were assigned to an "other crop" category. Among the non-agricultural land-use cover types, goose families were recorded only on the following habitat categories: Willow, Reed, Bog, Open Water, Sedge *Carex* sp. and "other" (the latter accounting for < 1% of goose locations when combined with all other habitat types). We used these three field crop



Figure 2. Major habitat types at the Kastrup Mose Greylag Goose site mapped from Basemap03, crop information and imagery, overlaid with all the goose positions. Data presented are from the capture date (7 June 2021) until the following dates for each goose: 17592 1 July 2021, 17594 6 July 2021, 17596 and 17599 3 July 2021 and 17600 26 June 2021. The locations of Kastrup Mose catching site (KM – lake in bottom left of map totally obscured by goose positions; 56.385°N, 10.379°E) and Smørmosen (S – large open water area shown in blue; 56.396°N, 10.399°E) are indicated.

types and six other land use cover categories to present overall habitat use. All habitat locations recorded for each of the tagged birds (treated separately) were summed for the daylight (17.5 h) and nighttime (6.5 h) periods, and the percent of fixes recorded for each bird on each habitat during night and day were then calculated.

At the Vasen site, we also analysed the spatial distribution of the tracked geese by overlaying a 10 × 10 m grid on the lake and adjacent areas used by the geese. Each 10-min position recorded by each of the loggers for geese using the site was assigned to grid squares and the cumulative distribution recorded for each bird was summarised for day and night, then standardised per hour by correcting for 17.5 h of daylight and 6.5 h of night at this time of year.

Results

Observed time budgets of geese at Vasen (mostly of tagged birds)

Throughout the study period, adult Greylag Geese observed at Vasen spent on average

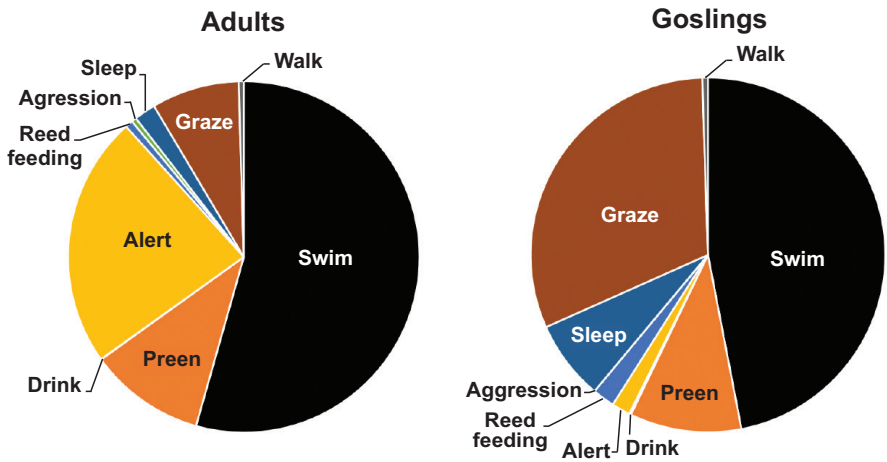


Figure 3. Gross daylight activity budgets of adult (left) and gosling (right) Greylag Geese at Vasen, Clausholm, Denmark (56°23'N, 10°09'E) between 9 and 24 June 2021, based on 1,619 individual observations in 188 flock scans.

54% of daylight hours swimming on the open water without foraging or social interaction compared with 47% for the goslings (Fig. 3). Adults invested considerable time in preening (11%), as did their goslings (10%). The adults also spent much time being alert (23%), whereas goslings were rarely alert (2%) but grazed much more than adults on terrestrial grassland (31% *vs.* 8%). Adults tended to remain alert or preen when close to their broods but whilst swimming on the water, as the goslings foraged nearby on land. Goslings slept (7%) and browsed emergent *Phragmites* (7%) more than adults (2% and 1%, respectively).

A diurnal grazing pattern was shown for adults but particularly for goslings observed at Vasen, with the birds increasingly feeding on pasture in the surrounding field in the middle part of the day (Fig. 4). Adults were most alert in the middle of each day, when they and the goslings spent less time swimming. Both goslings (growing new feathers and replacing down) and adults (in full wing and partial body moult) invested much time in preening, which resulted in much shedding of feathers in the immediate vicinity.

These results, together with preliminary examination of the accelerometry data from the Ornitela loggers deployed on the Vasen birds (to be the subject of future analysis) strongly suggest that the geese are more quiescent during the hours of darkness, which justifies our classification of their positions into night and day (see below).

Habitat use

At Vasen, the geese were largely confined to the western flank of the open water of the lake during daylight hours (Fig. 5) but also used the northeast corner to a lesser extent. By night, the geese showed similar use of the peripheral areas of the lake to that

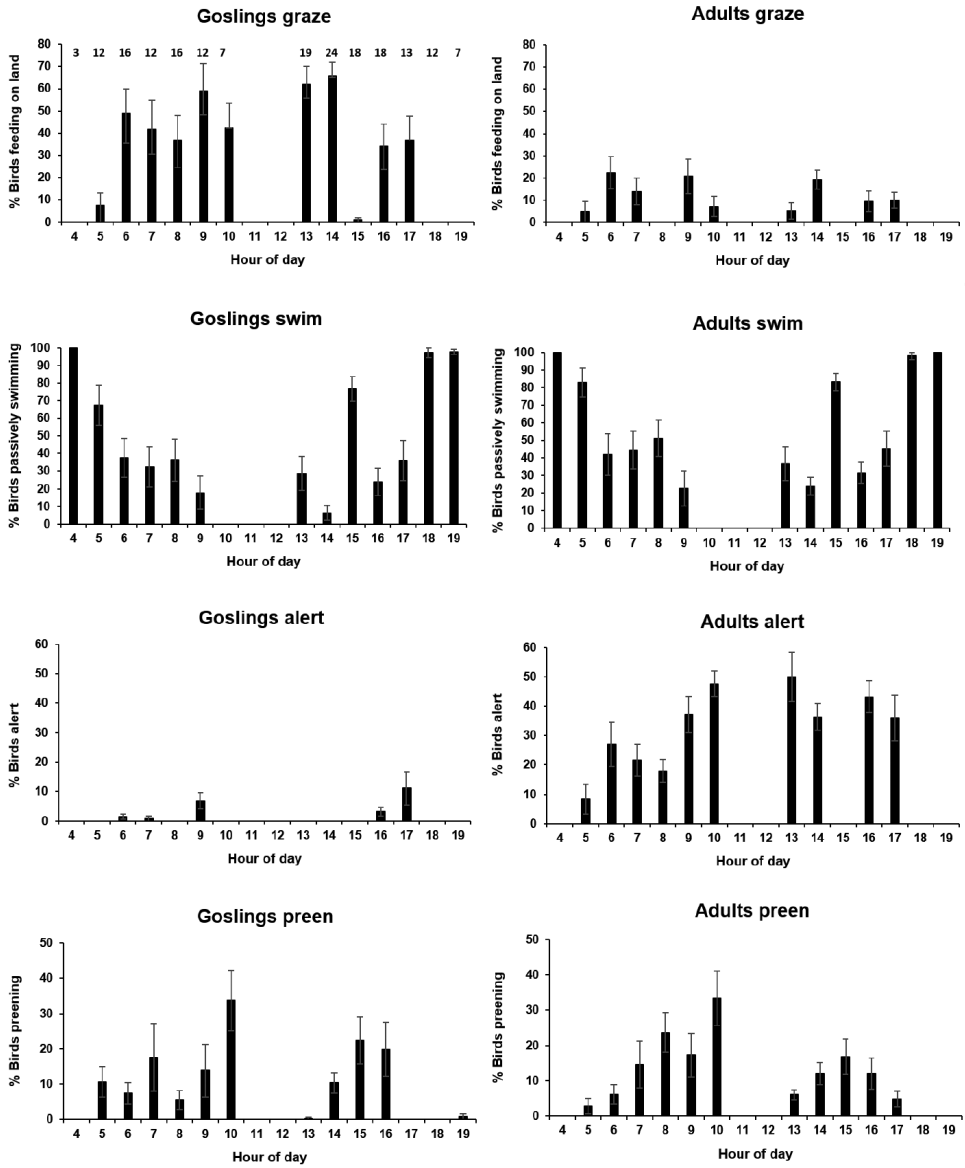


Figure 4. Diurnal patterns in four major activities of brood-rearing Greylag Goose families at Vasen, 9–24 June 2021, based on 1,619 individual observations recorded during 188 flock scans. Histogram columns indicate the mean percentage time spent feeding, swimming, being alert and preening (± 95% CI). Digits above top left graph show the number of scan observations contributing to each hour interval. Note that no observations were made between 11:00 and 13:00 h.

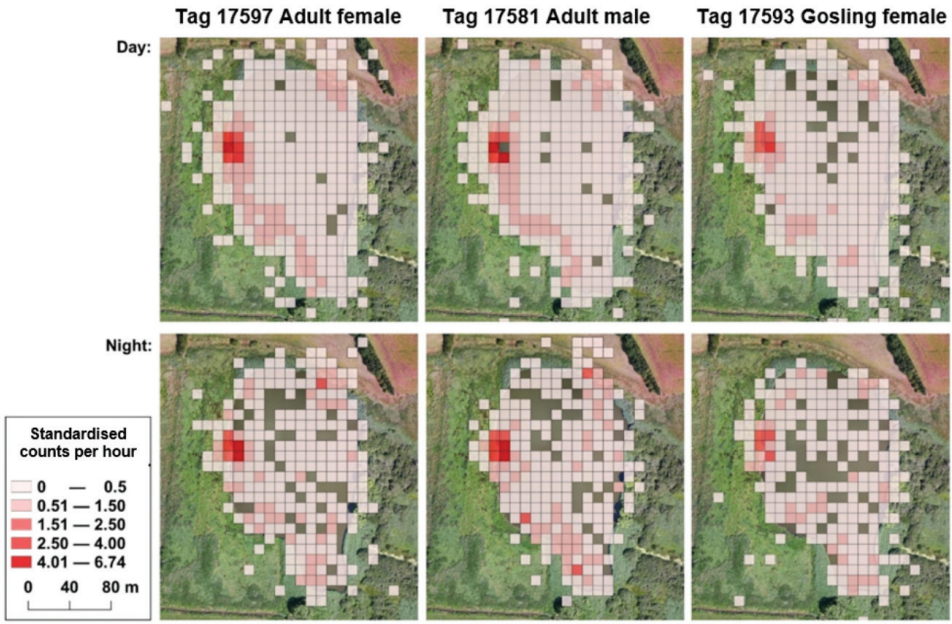


Figure 5. Cumulative distributions of each of the tracked Greylag Geese at Vasen, aggregated by 10 × 10 m grid squares. Data are summarised by relative frequency of positions per hour, corrected for length of day and night (17.5 h and 6.5 h, respectively). Data presented are from the capture date (8 June 2021) until the 25 June 2021 (for birds 17581 and 17597) and 21 June 2021 (for bird 17593), when these individuals left the site. Note: 17597 and 17581 were paired with three unmarked goslings, whilst 17593 associated with two unmarked parents and an unmarked sibling. Pink-shaded grid squares indicate those with at least one record for each bird during day and night, although some of the peripheral records furthest from the lake likely represent positional inaccuracy.

during daytime but surprisingly avoided using several grid squares in the middle of the open water, suggesting more restricted and less variable movements on the water surface by night. Overlaying goose positions on the habitat types showed the vast majority (> 65% by day and night) of positions were spent on the water (Fig. 6). By day geese spent 17–18% feeding on land in the grass meadow and grass margins, with the remainder of the time associated with peripheral willow scrub and reeds. During the behavioural observations, the geese were never seen to stray > 6 m from the water edge, so many of the positions in the surrounding areas were likely occasional GPS inaccuracies.

At varying times after release, all tagged goose families left Kastrup Mose, where they were originally marked, and dispersed from the site either to the other similar small patches of wetland within the farmland mosaic, or to the large Lake Smørmosen (Fig. 2). From the period from release after capture until the time the birds dispersed from the area when the young fledged, the

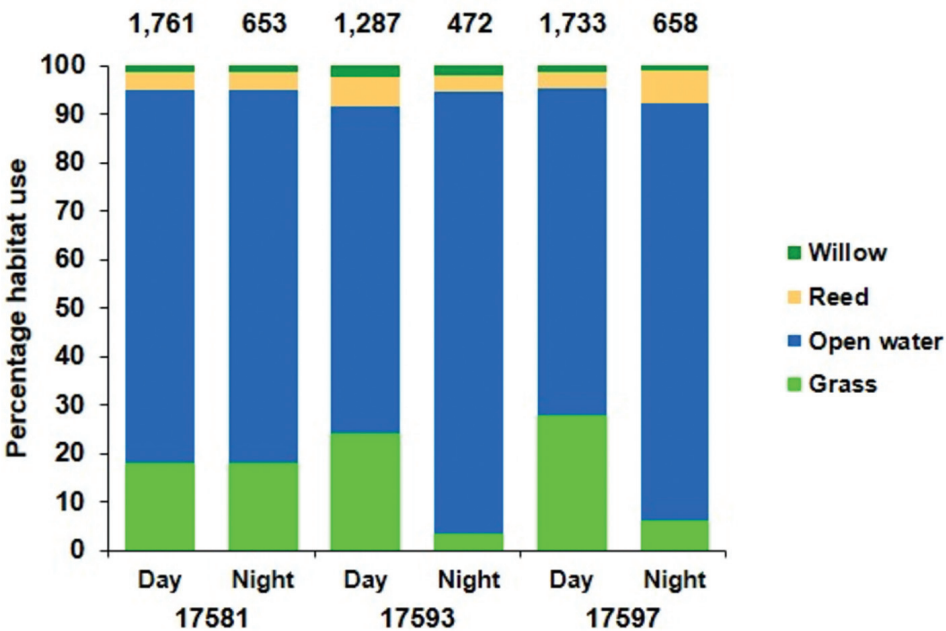


Figure 6. Percentage of day and nighttime habitat use by Greylag Geese at Vasen in summer 2021. Habitat classification is explained in the text, and the histograms show the percentage of positions received from the Ornitela tracking devices falling within each habitat type. Individuals are identified by their unique code (under the x-axis) and sample sizes for the numbers of positions from each individual are given above the histogram columns.

five geese spent the majority of daylight hours on open water (range = 61–97% between individuals), in reed-beds or in willow scrub, and this increased to between 74% and 99% at night. All birds spent < 5% of their time on spring-sown barley and relatively restricted time (2–35% by day; 1–21% by night) feeding on grasslands in the farmland matrix (Fig. 7).

Discussion

While we should be prudent and mindful that these results come from just two sites, seven tagged birds and only one year, these tracking data showed just how effective cryptic brood-rearing Greylag Geese can be at hiding themselves away in an agricultural landscape. The tracked geese at both sites spent the majority (61–79%) of daylight hours close to open water, in reed-beds or in willow scrub. In the case of the geese caught at Kastrup Mose, in an intensively farmed landscape, this would have made them extremely difficult, if not impossible to survey. Thus, despite being large-bodied and relatively abundant in agricultural areas, geese raising broods can remain virtually undetected when feeding on or adjacent to open water at the abundant kettle-hole wetlands (*i.e.* small, bowl-shaped water basins formed by melting blocks of stagnant glacial ice left behind by retreating glaciers,

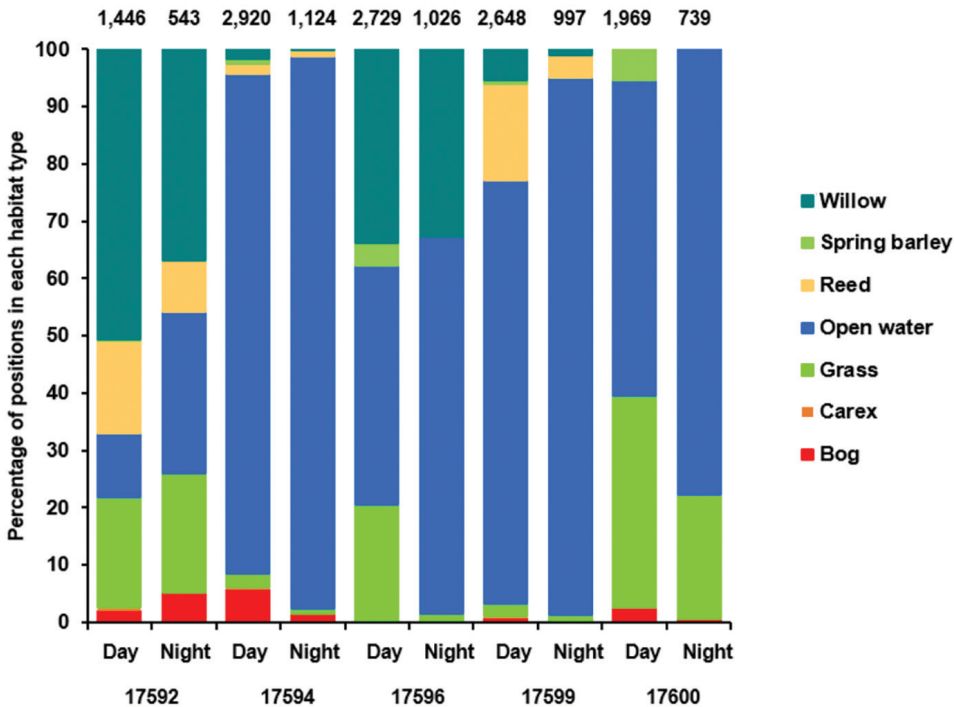


Figure 7. Percentage of day and nighttime habitat use by Greylag Geese captured at Kastrup Mose, near Pindstrup, in summer 2021. Habitat classification is explained in the text, and the histograms show the percentage of positions received from the Ornitela tracking devices falling within each habitat type. Individuals are identified by their unique code (under the x-axis) and sample sizes for the numbers of positions from each individual are given above the histogram columns.

now covered in dense wetland vegetation). Such habitats offer feeding in close proximity to open water to which the geese can resort to escape predation. Even the large lake Smørmosen, adjacent to a popular footpath along a former railway line (the dark track to the east shown in Fig. 2), is very difficult for humans to access. Extensive dense *Carex* and *Phragmites* beds surrounded by dense wet willow-dominated woodland make it impossible to count geese at ground level on Smørmosen. The use of drones at this and other isolated densely vegetated sites may enable collection of more accurate count data, depending on the birds not being disturbed by such devices. The goose families' use of both small and large islands of such largely inaccessible (at least to humans) aquatic habitat has major implications for our ability to census Greylag Goose broods with any reliability, confirming that counting post-fledging aggregations represents a far more effective means of assessing post-breeding productivity. Such a national count has been instigated for this purpose since 2022,

carried out in mid-August in Denmark under the NOVANA monitoring programme (Jensen *et al.* 2023). By this time, family groups of fledged goslings have amalgamated into large conspicuous flocks that gather in open water habitat, making them easier to count.

The association of Greylag Goose families with open water during brood rearing is not surprising, given the imperative to avoid terrestrial predators predating upon precocial waterbirds. Especially at night. However, these results demonstrated the ability of the geese to find small bodies of water (often inconspicuous old ice-age kettle-hole ponds overgrown with willow) to fledge their young in a complex landscape where such features are not so numerous. That said, such kettle-hole wetlands of varying size have, in recent times, been widespread and common in Jutland (Jacobsen 1976). It therefore seems likely that, in a landscape formerly unoccupied by Greylag Geese (likely due to earlier persecution, Meltofte *et al.* 2021), their existence facilitated the recent increase in population size, geographical range expansion, and local increase in breeding abundance. While providing predator-proof brood habitat for this and many other species of waterbirds (*e.g.* Mute Swan *Cygnus olor*, Shelduck *Tadorna tadorna*, Mallard *Anas platyrhynchos*, Coot *Fulica atra* and Moorhen *Gallinula chloropus*, Meltofte *et al.* 2009), wetlands embedded in farmland are often overlooked in conservation planning and site safeguard, yet are threatened by drainage, eutrophication and reed and willow encroachment (Meltofte *et al.* 2009). This is especially the case for kettle-holes which, as recent research has demonstrated, have considerable biodiversity value (*e.g.* Meltofte *et al.* 2009; Pätzig *et al.* 2012; Platen *et al.* 2016; Vasič *et al.* 2020; Savić *et al.* 2021)

The tracking results show that despite the presence of many vulnerable crops used by geese in the Kastrup Mose agricultural matrix, brood-rearing families were not responsible for crop damage in this area. They were rarely present on spring-sown barley and other potentially vulnerable crops, but rather fed on grasslands close to open water, in open water (potentially on submerged macrophytes), or in vegetated wetlands (with reed- or sedge-beds). Visual observations at Vasen found that the goose families feed occasionally on *Phragmites* and tracking suggested the broods spent considerable time along the edges of reed-beds during daylight hours. This raised the intriguing prospect that the species shows behaviour consistent with functioning as an ecosystem engineer, if sequential goose grazing of the reeds restrains the expansion of this and other territorialising plant species (Bakker *et al.* 2018; Reijers *et al.* 2019; Motpan *et al.* 2026), which warrants further study. If this is the case, the species could bring potential benefits for other aspects of biodiversity by introducing vegetational heterogeneity into the aquatic environment (*e.g.* Beemster *et al.* 2010; Svidenský *et al.* 2021), although there is currently no evidence that goose grazing influences the taxon richness or diversity of macroinvertebrates at a site (*e.g.* Kjeller *et al.* 2025).

We should be highly cautious about our interpretations from these data. Very few birds were caught in only two catches in one year, both on small water bodies, with

limited geographical spread. Because all tagged families were captured at wetland sites, our results inevitably reflect habitat use of geese already present in such areas; however, subsequent dispersal movements at Kastrup Mose show that families also use similar small wetlands in the surrounding landscape beyond the capture sites. Clearly, the marking of two adults that turned out to be paired at one site has generated a level of pseudo-replication among the Vasen-marked birds. Moreover, behavioural observations of the families at Vasen were especially limited. We should also be prudent about potential errors caused by attributing goose presence to habitats based on GPS positions on ecotone areas straddling habitat blocks. Nevertheless, the results do explain how large numbers of brood-rearing Greylag Geese can very effectively hide themselves in this landscape. Much of Djursland and throughout Jutland is a glacially-derived landscape, studded with small, undrained depressions, often associated with kettle-holes, which provides small wetland units within a matrix of densely cultivated cereal production and grazed/mown grasslands. Under these circumstances, the species has the ability to expand from its recent historical range into such a landscape, which offers a mosaic of habitats that provide potential brood-rearing opportunities (escaping predation and human disturbance) which were not previously occupied. This occurs despite an apparent general lack of extensive wetland habitat in a basically sandy-soiled intensively farmed agricultural area.

Overall, this study confirms the importance of maintaining and potentially enhancing the quality of small wetlands located within farmland via targeted habitat conservation. Small waterbodies and wetlands of > 100 m² are already protected from drainage or infilling under the Danish Nature Protection Act but their biodiversity value may be affected adversely through eutrophication and plant succession. Vigilance therefore is necessary to ensure enforcement of protection of small-scale wetland biotopes and to maintain and enhance the nature conservation interest of such important landscape features.

The positional data emphasise the need to distinguish between the effects on agricultural crops by brood-rearing Greylags, in contrast to those of the larger post-fledging aggregations of geese, on finding solutions to conflict management which typically occurs at other points in the annual cycle (Clausen *et al.* 2025). The results also confirm the value of using GPS tracking to good effect in revealing cryptic life-history stages, even in relatively large-bodied waterbirds like geese.

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Photograph: Female Greylag Goose tagged at Kastrup Mose, Pindstrup, Djursland, Denmark on 7 June 2021, by Henning Heldbjerg.