Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Ecology
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Abstract

The aim of this study was to increase the knowledge about whooper swan (*Cygnus cygnus*) ecology to enhance the ability to predict and also to prevent the crop damage they cause. The largest proportion of damage in Sweden has been reported at stopover sites during spring migration in February, March and April. Therefore, this study focused on an important stopover site, Lake Tysslingen, situated in south-central Sweden. Specifically, the relation between the duration and period migrating swans stage at the stopover site and mean temperature (measured at three different weather stations) for the years 2001-2010 was studied. Furthermore, the swans´ selection for certain fields in relation to field type, distance to roosting site, a supplemental feeding site and forest edge within agricultural land surrounding the lake was analyzed. I found a negative correlation between mean temperature in February (two last weeks) and the start of stopover period, i.e. a high mean temperature gives an early stopover start. Moreover, the duration of the stopover period depends on when the period starts, i.e. an early stopover start gives a long stopover period. During the study period the duration of the stopover period varied between 17 and 43 days. A supplemental feeding site used to attract swans within the area seem to be an efficient management tool since approximately 94% of the whooper swans stayed at this site and in the lake nearby during the stopover period. The remaining part (6%) was found on agricultural land and stubble fields were the most selected field type. Field site selection within the study area was not affected by the distance to roosting site, the supplemental feeding site or forest edge. Since stubble fields have already been harvested swans do not cause damage on these fields. The variation in temperature affects stopover duration and thereby also the risk of damage becomes difficult to predict between years.

Key words: whooper swan, Cygnus cygnus, migration, stopover, supplemental feeding, crop, damage, feeding, foraging, field selection, agricultural land

Sammanfattning

Denna studie har som avsikt att samla mer kunskap om sångsvanens ekologi för att öka möjligheten att förutspå och förebygga de skador som fåglarna kan orsakar jordbruket. Mer än hälften av skadorna orsakade av sångsvanar i Sverige (år 2001-2010) har rapporterats under februari, mars och april. Därför valde jag att fokusera på den perioden, dvs. framförallt då svanarna flyttar norrut under våren. Studien har utförts vid sjön Tysslingen i Närke som är en viktig rastplats under vårflytten. Det är framförallt sångsvanar som övervintrar i norra Tyskland, Danmark, södra Sverige och Norge som passerar genom Sverige på sin flytt till häckningslokaler i Norge, Sverige, Finland och nordvästra Ryssland. Mer specifikt har jag studerat hur tiden sångsvanarna använder rastplatsen beror av temperatur under åren 2001-2010, men också hur svanarnas val av åkrar styrs av fältsort, avstånd till övernattningsplats i sjön, utfodringsplats och närmsta skogskant.

Studien visar att medeltemperaturen för de två sista veckorna i februari (uppmätt vid två övervintringsplatser och rastlokalen) kan förklara starten (>100 svanar på rastlokalen). Dessa resultat visar exempelvis att år med låg medeltemperatur ger en sen start för rastperioden. Dessutom hänger rastperiodens längd samman med startdagen, nämligen att år med sen start ger en kort rastperiod. Tvärtom ger en varm medeltemperatur en tidig start och även en längre rastperiod. Även medeltemperaturen för hela mars i studieområdet gav samma samband med rastperiodens startdag och längd. Under studieperioden varierade längden på rastperioden mellan 17 och 43 dagar (dagar med >100 svanar på rastplatsen). Variationen mellan år gör rastperiodens längd och därmed risken för skada svår att förutspå.

Huvuddelen, 94 % av sångsvanar i studieområdet befann sig på matningsplatsen och i den angränsande sjön. Det betyder att den förvaltningsåtgärden fungerar effektivt för att samla svanarna och minska deras vistelse på jordbruksmarkerna kring sjön. De återstående 6 % av sångsvanarna spenderade sin tid på fälten och bland dem valde de allra flesta stubbåkrar. Att sångsvanarna går på stubbåker skapar inga skador då grödan redan är skördad, så att låta svanarna vara på stubbåker under rastperioden och vänta med att plöja till efter vintern lättar potentiella skador på andra grödor svanarna hade valt om åkrarna var upplöjda. Avstånden till övernattningsplats, matplatsen och skogskant påverkade inte svanflockarnas fördelning i studieområdet vilket betyder att oberoende av placeringen så har alla fält samma sannolikhet att drabbas av skador.

Nyckelord: sångsvan, Cygnus cygnus, migration, rastplats, utfodringsplats, gröda, skada, födosök, fältval, jordbruksmark

Table of Content

Introduction

Foraging wildlife may be subject to conflict with human interests, for instance when predators kill livestock, ungulates browse on forest or waterfowl graze on agricultural land (Weisberg & Bugmann 2003, Baker et al. 2008, Jensen et al. 2008). Waterfowl usually create most damage when they gather in flocks at wintering sites, stopover sites and in breeding colonies, affecting land at various locations in the area of distribution at different times of the year (Cooke & Sulzbach 1978, Jensen et al. 2008). The impact on agricultural crops caused by waterfowl partly depends on the number of grazing birds, choice of foraging site, season (crop sensitivity) and the duration of grazing period (Kear 1970, Rees et al. 2005).

In Sweden, damage caused by wildlife is partially regulated through hunting (Anonymous 2001). If the species creating damage are protected from hunting, the first step is to reduce the damage through preventive actions and the second step is governmental compensation of financial losses (Anonymous 2001). Furthermore, some restricted hunting to protect e.g. crops and livestock can be allowed (Anonymous 2001). Whooper swan (*Cygnus cygnus*) is one of the protected birds causing damage on commercially grown crops (Levin et al. 2010). Between 2001 and 2009 farmers reported 55 damages caused by whooper swans to the County Boards (single species flocks; J. Månsson, unpubl. data). The majority of these damage occurred in February, March and April (55% in total) and oilseed rape (*Brassica napus*) was the main crop damaged (87 %; J. Månsson, unpubl. data).

Whooper swans are connected to water both during breeding and wintering and their diet contains mainly of plants from water, marshland or the terrestrial environment (Rees et al. 1997a). On agricultural land whooper swans feed on various grasses, sugar beet (*Beta vulgaris*), turnip (*Brassica napobrassica*), barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), rye (*Secale cereale*), potato (*Solanum tuberosum*) and oilseed rape (Brazil 2003). Whooper swans first begun to search for food on agricultural land in 1940´s at wintering ground in Ireland eating potatoes (O'Connell et al. 2008). During 1960´s the behavior spread in Britain, Netherlands and Denmark and with the population increase the following decades the swans foraging on agricultural land increased in northwest Europe (Coulhoun & Day 2002). In Sweden, a change in habitat selection of whooper swans were noticed in early 1990´s when a part of the population left traditional foraging grounds connected to water and started to forage on agricultural land (Nilsson 2008). Laubek et al. (1999) distinguished two subdivisions of habitat choice in wintering areas for the northwestern population of whooper swan in Europe. The first division Netherlands, north Germany, Denmark and south Sweden (Scania) used terrestrial habitat (76% of observations) and the second division northeast Poland, Baltic States, Finland and Sweden (north of Scania) used aquatic habitat (91 % of observations).

To increase the ability to predict and also to prevent crop damage caused by wildlife including whooper swan we need knowledge about the ecology of the species (Conover 2002). For example it is essential to study foraging patterns such as 1) choice of field types and foraging locations but also the 2) duration of the period the birds feed on agricultural crops for example the length of stopover periods.

1. Choice of field type and foraging site

Studies at wintering sites in Europe (Jan-Mar) have shown whooper swans in Britain and Ireland to prefer root crops in January and cereals in February and March (Rees et al.1997b). In Denmark more than half of the swans were found on winter cereal and the remaining swans were distributed between oilseed rape, pasture and stubble (Laubek 1995). Overall in Sweden, Nilsson (2002) found whooper swans on 3 categories of fields in January: winter cereals, oilseed rape and grassland. Not only field types seemed to affect the choice of foraging sites among waterfowl but also distance to roosting sites (Chisholm & Spray 2002). During winter and migration waterfowl roost in shallow waters and mainly at night, but also during parts of the day (Crawley & Bolen 2002, de Jong 2010). In the mornings waterfowl leave roosting site to forage in the surroundings usually within 10 km (Madsen 2001, de Jong 2010). Studies on geese found the preferred distances between foraging and roosting to be less than 5 km and the maximum distances from 7 km to 10 km (Vickery & Gill 1999). Chisholm and Spray (2002) showed fields with swans to be significantly closer located to water than fields without swans. Also, Chisholm and Spray (2002) showed that fields used by swans are significantly larger than unused fields, but field selection was not affected by boundary objects such as fence or hedge. To influence the distribution of swans, one can scare the birds from valuable fields and suitable fields can be set aside and even use supplemental feeding to attract the birds (Vickery & Gill 1999). Similarly, as to the choice of fields in relation to distance to roosting site one could expect that also distance to supplemental feeding sites may affect the choice of foraging sites. Furthermore, the size of the field seem to have an effect of the feeding site selection and this may be linked to the swans´ ability to overview the surroundings (predation risk) and therefore distance to forest edge also may affect feeding site selection. However, few studies have information about the effect of both distance to supplemental feeding site and forest edge.

2. Duration of stopover period

Weather seemed to be an important factor influencing the bird migration (Nisbet and Drury Jr 1968), especially for whooper swans since they need open water for roosting (Brazil 2003). Mathiasson (1991) have suggested that the swans follow the isotherm for +3 °C/+5 °C (when the ice melts) on spring migration. Waterfowl use stopover sites to gain energy for migration and breeding (LaMontagne et al. 2001). Whooper swans can spend up to two weeks at stopover site, but usually individuals only stay between two and four days at each stopover site (Mathiasson 1991). As a consequence, weather can affect the migration and time spent at stopover sites and thereby also time spent on agricultural land and crop damage (O’Connell et al. 2008).

Since previous studies have focused on whooper swans´ foraging behavior at wintering sites (e.g. Laubek 1995, Rees et al. 1997b and Nilsson 2002) and the main part of damage in Sweden is created during the time for spring migration, this study focused on the behavior of whooper swans at an important spring migration stopover site in Sweden, Lake Tysslingen. I focused the study on how temperature affects stopover duration and also how swans choose fields in the area. Specifically, I related the variation in the duration, start (day of the year) and end (day of the year) at population level of the stopover period to temperature. I predicted that years with a cold spring would affect the stopover period to occur later than the years with warm spring. Furthermore, at the stopover site I studied factors affecting whooper swans´ choices of foraging sites. I predicted that swans mainly will use fields with winter cereals, grassland and oilseed rape. Furthermore, I predicted that fields closer to roosting site and the supplemental feeding site provided in my study area will be used more compared to fields further away and likewise that fields close to forest edges will be avoided.

Material and methods

Studied species

The whooper swans has a breeding range from Iceland in west through northern Europe, and far east Russia and the sites for overwintering are found slightly south of the breeding range (Brazil 2003, Rees et al. 2005). Whooper swans wintering in north Germany, Denmark, south Sweden and Norway pass through Sweden on their spring migration to breeding grounds in Norway, Sweden, Finland and northwestern Russia (Nilsson 1997, Laubek et al. 1999, Brazil 2003). The swan migration is carried out in family groups within larger groups (Mathiasson 1991).

During the 19th century whooper swans widely bred in the northern part of Sweden, east of the mountains (Nilsson et al. 1998). Due to hunting the population in Sweden was reduced to 20 pairs in the 1920´s (Nilsson et al. 1998). Since the protection from hunting year 1927 the population and distribution range has continued to increase from the remaining breeding grounds in the northernmost part of Sweden to spread over the whole country (Nilsson 2008). From 1995 midwinter counts of whooper swans in Sweden have been conducted (Nilsson 2008). In year 1995, 33% of the counted whooper swans (total number 7 269 swans) were found on agricultural land and the count year 2000 revealed 43 % of the swans (total number 6 712 swans) on agricultural land (Nilsson 2002). The swans cause damage on agricultural crops by grazing and trampling (Colhoun & Day 2002).

Study area

Lake Tysslingen, situated south-central of Sweden (59º 18'N, 15º 2'E; Figure 1), is an important stopover site for whooper swans during spring migration with maximum numbers of about 3500 staging swans annually (Ullman 2003, Anonymous 2008). The study area (122 km^2) is situated on the border between the boreal and boreonemoral zone, it mainly consists of agricultural land and is delineated by the surrounding forests (Figure 1). Annual mean temperature is 4°C to 6°C, mean precipitation is 600 mm and the length of the vegetation period (i.e. mean temperature > 5°C) is 180-190 days (Raab & Vedin

1995). The first day with snowfall usually occurs in late November and the last day with snow cover generally is in early April (Raab & Vedin 1995).

Lake Tysslingen is a eutrophic lake with a size of 5.5 km^2 with an average depth of 0.5 m and a maximum depth of 0.9 m (Anonymous 2008). The agricultural land of the study area (58%) is used for pasture (horses mostly and cattle partly), ley and arable land where mostly cereals are grown and a smaller portion of oilseed rape, peas (*Pisum sativum*) and potatoes (County Board Örebro unpubl. data).
In 1986 a restoration was conducted to improve the habitat for breeding and resting water birds in the lake, e.g. the area of open water was increased (Anonymous 2008). Since 2004 Lake Tysslingen is a Natura 2000 area (Anonymous 2008). During spring the foundation "Stiftelsen Tysslingen" have fed the birds (mainly whooper swans) with up to 30 000 kg of cereals at the supplemental feeding site in Rånnesta (northeast corner of the lake; H.E. Karlsson, pers. comm; Figure 1).

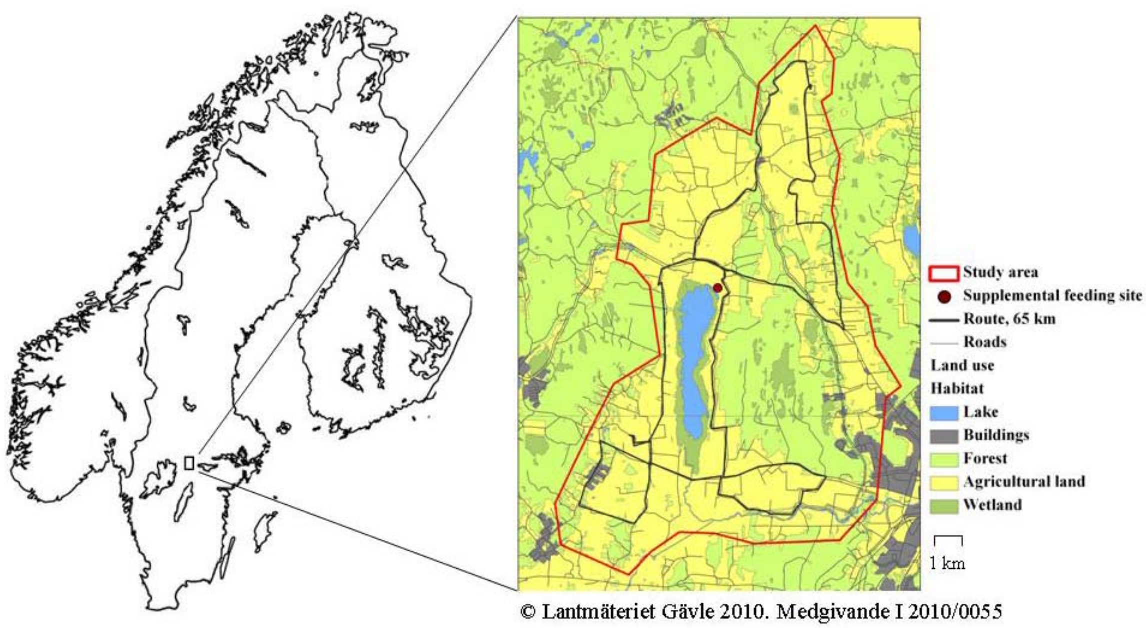

Figure 1. The location of the study area in Sweden, study area (122 km^2) with Lake Tysslingen in the middle, survey route (in dark grey) and supplemental feeding site.

Stopover duration

Number of birds

The number of whooper swans at Lake Tysslingen has been estimated by field surveys during the stopover period from 2001 to 2010 by the field personnel from the "Stiftelsen Tysslingen". The personnel consist of a core group with an experienced leader and assistants. The survey has started when migrating whooper swans arrive to the lake. The counting has been conducted during mornings when the swans fly from roosting site in to the supplemental feeding site. The results from the countings have been reported to the Swedish Species Information Centre's and Swedish Environmental Protection Agency's database Species Gateway from where I achieved the data. The database also include reports from voluntary ornithologists. The start of stopover period was in my study defined as the day when the number of swans within the area for the first time exceeded 100 individuals. Occasionally the number of swans was estimated to >100 individuals outside the stopover period but these counts were not included in the analysis. In the same way the end of the stopover period was defined as the last day when the number of swans >100 individuals.

Temperature data

The temperature data (year 2001-2010) were obtained from SMHI (Swedish Meteorological and Hydrological Institute). I used data from three weather stations; 1) Örebro (3 km south, from the study area), 2) Vänersborg (200 km southwest) and 3) Hörby (450 km south). Vänersborg and Hörby were used since a high concentration of whooper swans in Sweden stay around these two places during winter (Nilsson 2002). To find out if spring start affected the stopover period i.e. if years with cold spring affect the stopover period to occur later than the years with warm spring I chose to relate the start of the stopover period with mean temperature at two time periods, namely March and the two last weeks in February (15^{th} to 28^{th}). For the March period, I used the weather station in Örebro to indicate whether it was a cold or warm spring and whether there is a relation between temperature and start, end and length of stopover period. For the February period, I chose to also include data from Vänersborg and Hörby. The period of the last two weeks in February (15^{th} to 28^{th}) was the time when the earliest stopover period have started.

Field site selection

Swan distribution

Field work took place during 18 days between 3.29.2010 and 4.22.2010 (hereafter referred to as field period). Whooper swans were searched (14 days in total) on agricultural land by driving a fixed route (by car; 65 km) between 09.00 – 16.00, in the study area (Figure 1). When swans were found, the number of swans, field type, occurrence of flooding and possible scaring device was registered. The coordinates of the observed flocks were estimated by measuring the distance (with rangefinder Leica rangemaster 900) and direction (with a sight compass) from the GPS position where they were observed. The coordinates were later used to measure the distances to roosting site, the supplemental feeding site and forest edge.

Availability of different fields and selectivity index

One of my aims was to relate availability of different fields (area) in relation to fields used by swans. The field period begun 8 days after stopover period had started and at that time all land was covered by snow that made the crops inaccessible for the swans. Therefore, I only used observations for the analysis when snow covered less than 50% in average of the agricultural land, i.e. from 4.2.2010 to 4.14.2010 (when stopover period ended). In the analysis I used both observed flocks (n=24) and number of individuals (n=1019) to estimate selectivity index (same birds in both analysis but different resolution of data). An additional survey was added to estimate the snow cover during the time period snow remained on the ground (3.29.2010 to 4.6.2010). The survey of snow cover consisted of 60 positions (achieved by Hawth Tools in ArcGIS 9.3) evenly distributed along the route of which 30 positions were checked every second day. From these positions I randomized a direction (from random number table between 1-360°) to find the closest agricultural field used for visual snow cover estimation. The snow cover was estimated by using the following cover classes 100, 90, 75, 50, 25, 10 and 0%. To obtain an estimate of availability of the different field types within the study area a total of 266 random fields (26 km^2) have been recorded out of a total of 1348 fields (71 km^2). Random positions correspond to fields on agricultural land and some positions had to be excluded due to localization on a border between fields, on the same field as another position or because of practical reasons (hard to reach). The fields were divided into 7 categories (Table 1). An estimate of utilization of different field types by the swans was estimated by two approaches; firstly number (proportion) of individual birds using certain fields and secondly number of flocks (proportion) using certain fields. All observations of flocks were treated independently from flocks found other days.

Table 1. Categories used for the field types with additional description.

Field category	Description
Oilseed rape	Rape sown in autumn
Winter ceral	Cereals sown in autumn
Ley	Grasslands harvested for silage or hay
Stubble	Fields with cereals harvested in autumn
Ploughed field	Fields ploughed the autumn before
Pasture	Grazed by horses or cattle
Other	Soccer field or ditch

Distance to roosting site, the supplemental feeding site and forest edge

Closest distances to roosting site, the supplemental feeding site and forest edge for the in total 36 observed swan flocks found during field period were compared with 36 random points to find out whether they differ or not. Hawth Tools in ArcGIS 9.3 were used to randomly distribute points on agricultural land within the study area. Furthermore, the function Near (ArcGIS 9.3) were used to measure the closest distance from the centre of the swan flocks to the border of the lake, the central point of the supplemental feeding site and a forest edge. The border of the lake and forest edges was defined by GSD-Road Map (1:100 000), Lantmäteriet.

Statistical analysis

Linear regression was used to test for relation between the start, end and duration of stopover period and temperature. The analyses were performed in R (2.10.1).

The Manly's α index (i.e. proportion of use in relation to availability) was used to estimate an index (rank) of field selectivity (Manly 1974).

Two-sample t-test assuming equal variances were conducted in Microsoft Office Excel 2003 to evaluate differences in distance to roosting site, the supplemental feeding site and forest edge between observed swan positions and random positions.

Results

Stopover duration

The start of the stopover period at Lake Tysslingen (i.e. first day >100 whooper swans) varied between the 50th and 88th ordinal day during the study period (Figure 2 & Figure 5). Less variation was found for the day when the stopover period ended (i.e. last day >100 whooper swans) and ranged from the 90th to 111th ordinal day of the year (Figure 2, Figure 5). The stopover period (>100 individuals) varied between 17 and 43 days (Figure 3). The length of the stopover period was negatively and linearly related to the start of the stopover period ($p < 0.001$, df=8, R^2=0.78; Figure 4) but not to the end of stopover period ($p<0.3$).

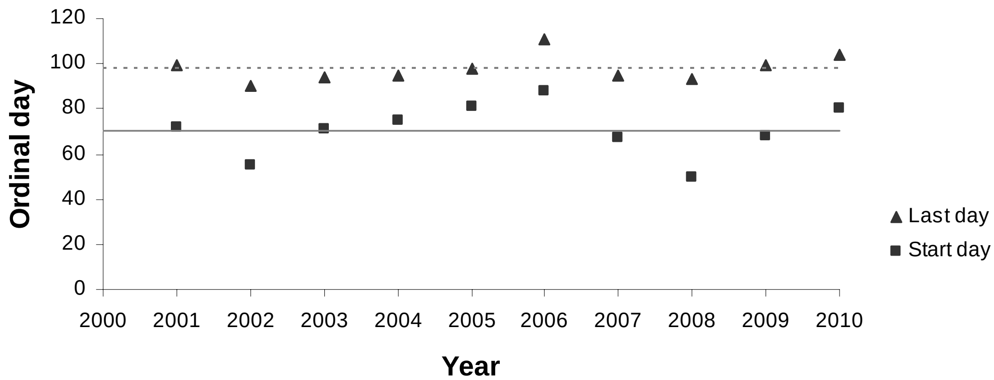

Figure 2. Ordinal day starting stopover period (squares), solid line mean start day 70.7 (s.d. 11.6), ordinal day ending stopover period (triangles) and dashed line mean last day 97.8 (s.d. 6.1).

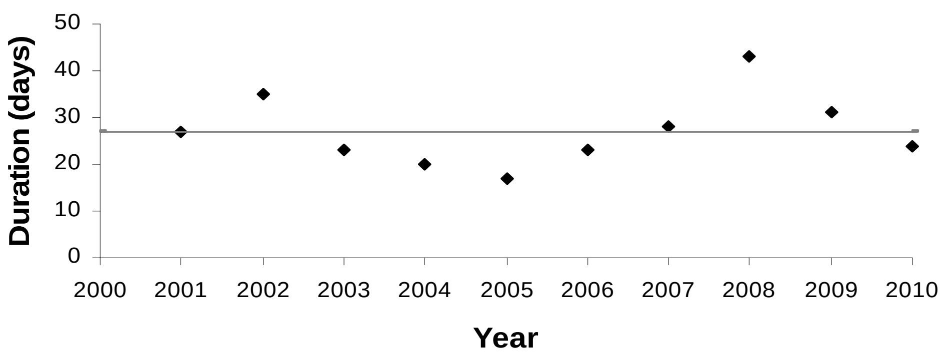

Figure 3. Number of days with more than 100 swans at stopover site. Grey line is mean number of days 27.1 (s.d. 7.7).

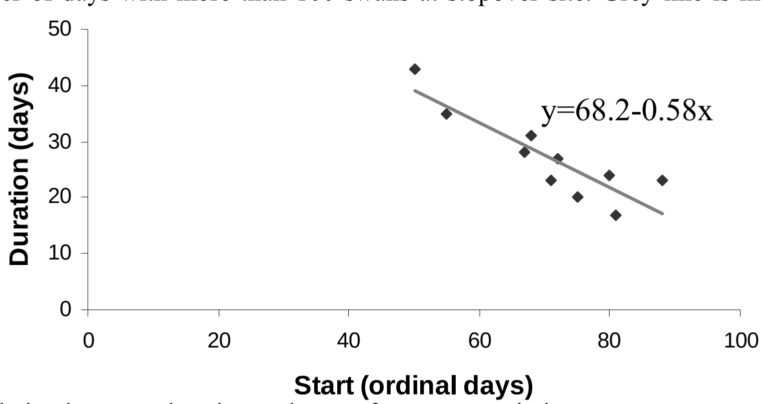

Figure 4. The relation between duration and start of stopover period.

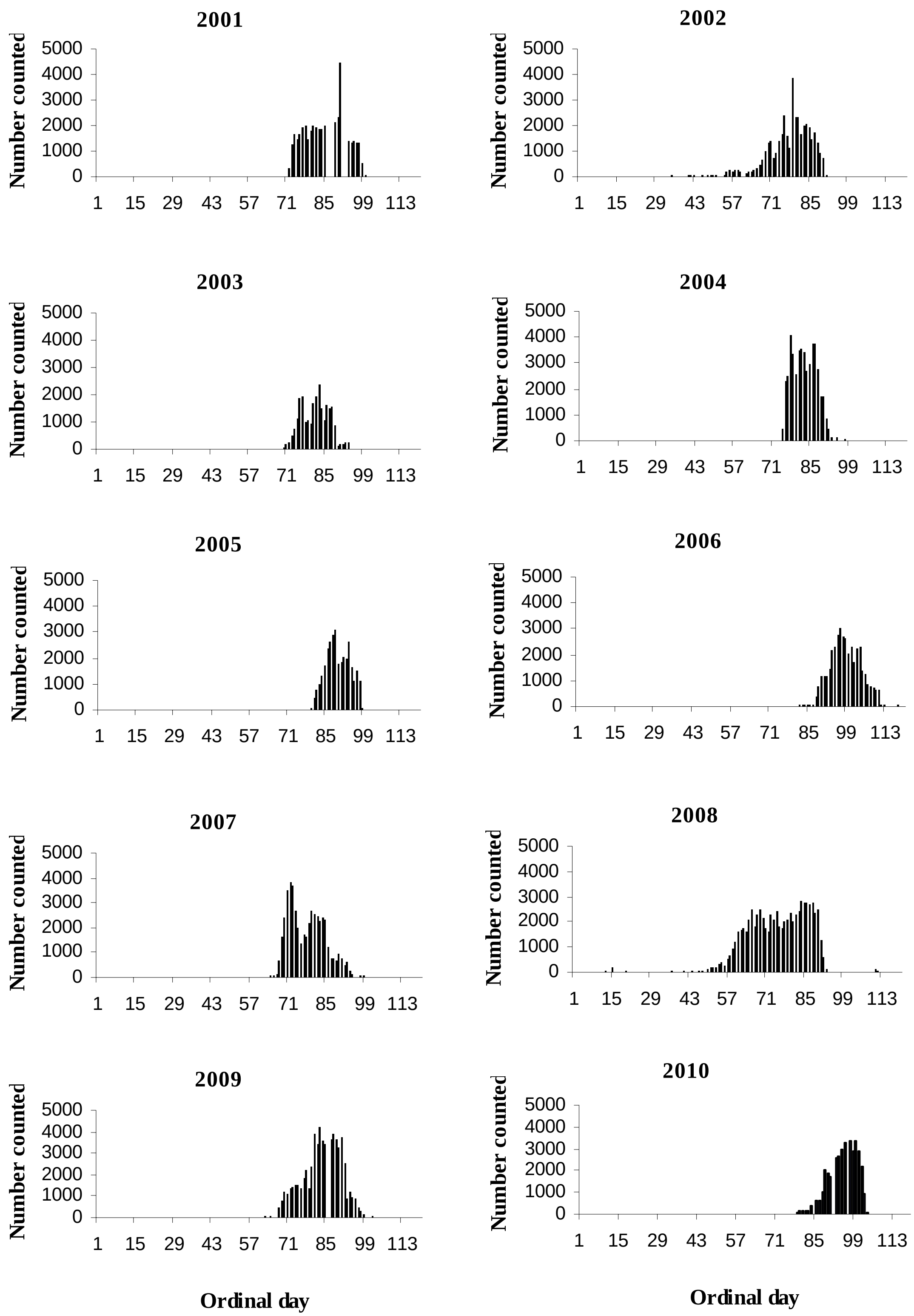

Figure 5. Number of whooper swans counted per day during the study period.

The ordinal day when stopover period started was negatively and linearly related to mean temperature in March in Örebro ($p < 0.05$, df=8, R^2=0.45; Figure 6: a), as well as the ordinal day ending stopover was negatively and linearly related to mean temperature in March in Örebro ($p < 0.005$, df=8, R^2=0.73; Figure 6: b). On the contrary, no linear relation was found for length of stopover period to mean temperature in March in Örebro ($p < 0.4$).

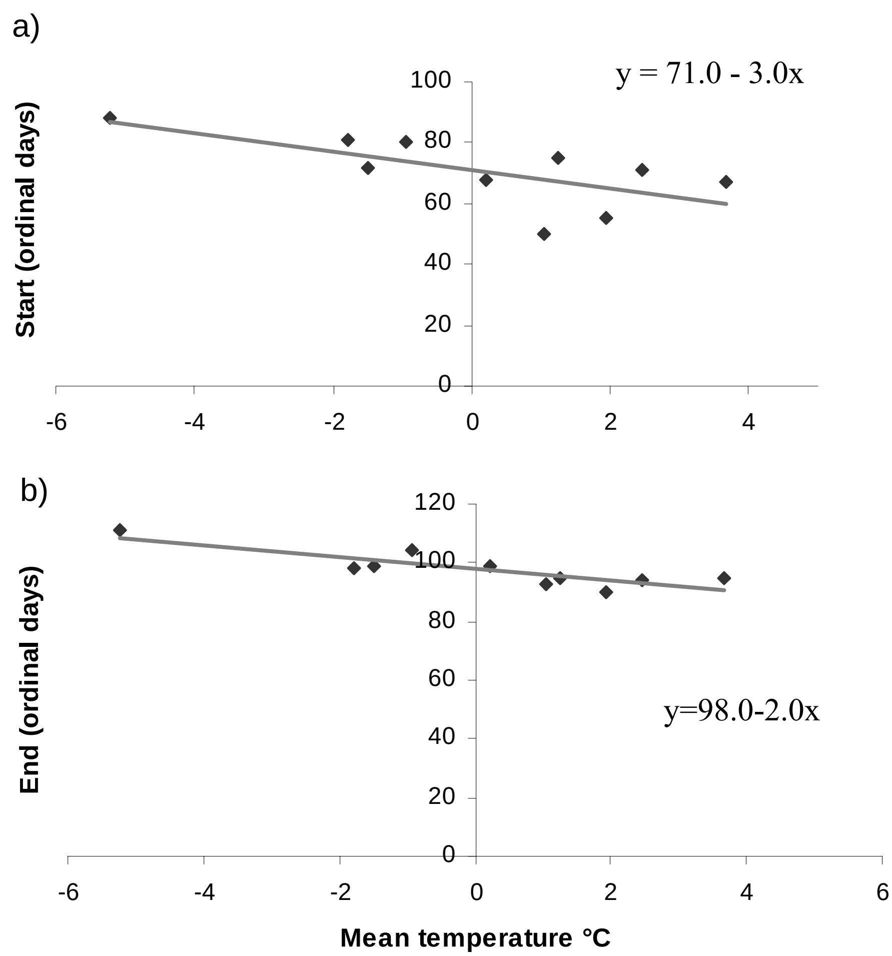

Figure 6. a) The relation between start of stopover period and mean temperature in March for Örebro, b) the relation between end of stopover period and mean temperature in March for Örebro. *SMHI*

Furthermore, the start of stopover period was also negatively and linearly related to mean temperature for a fixed period of the last two weeks in February (15th to 28th), for all weather stations Hörby ($p < 0.05$, df=8, R^2=0.56; Figure 7: a), Vänersborg ($p < 0.01$, df=8, R^2=0.62; Figure 7: b) and Örebro ($p < 0.05$, df=8, R^2=0.52; Figure 7: c).

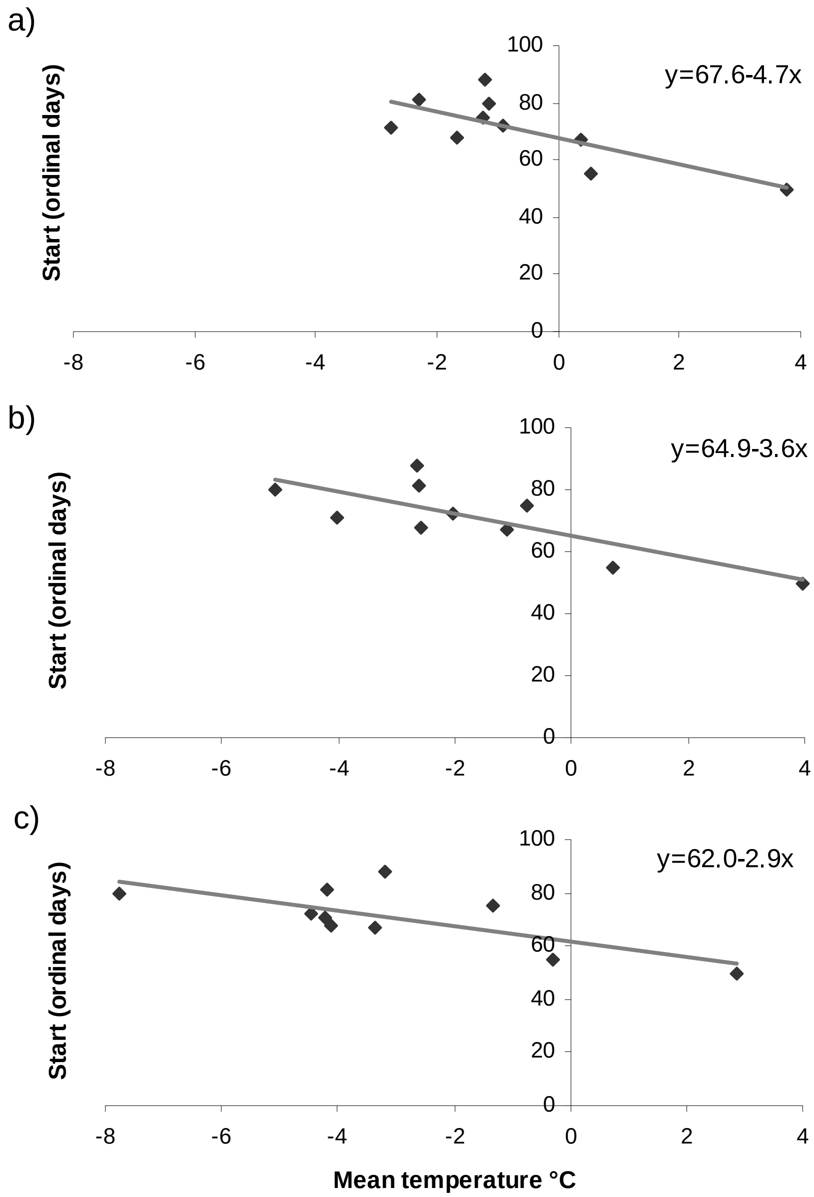

Figure 7. The relation between start of stopover period and mean temperature in a period 15th to 28th of February, a) Hörby, b) Vänersborg, c) Örebro. *SMHI*

Field site selection

In total 36 flocks with whooper swans were observed on agricultural land during field period (Figure 8). The median swan flock size was 14 (IQR = 70). The flocks sometimes consisted of a mixture with other bird species, e.g. Eurasian crane (*Grus grus*), greylag goose (*Anser anser*) and Canada goose (*Branta canadensis*). The mean number of swans on agricultural land was 109 per day (s.d. 125) and the mean number estimated at supplemental feeding site was 2260 per day (s.d. 979). The vast majority of number whooper swans in the study area was found on the supplemental feeding site and in the lake nearby (94 % of the total number of counted swans during the study period; 23 932 swans). No scaring devices were found within the study area.

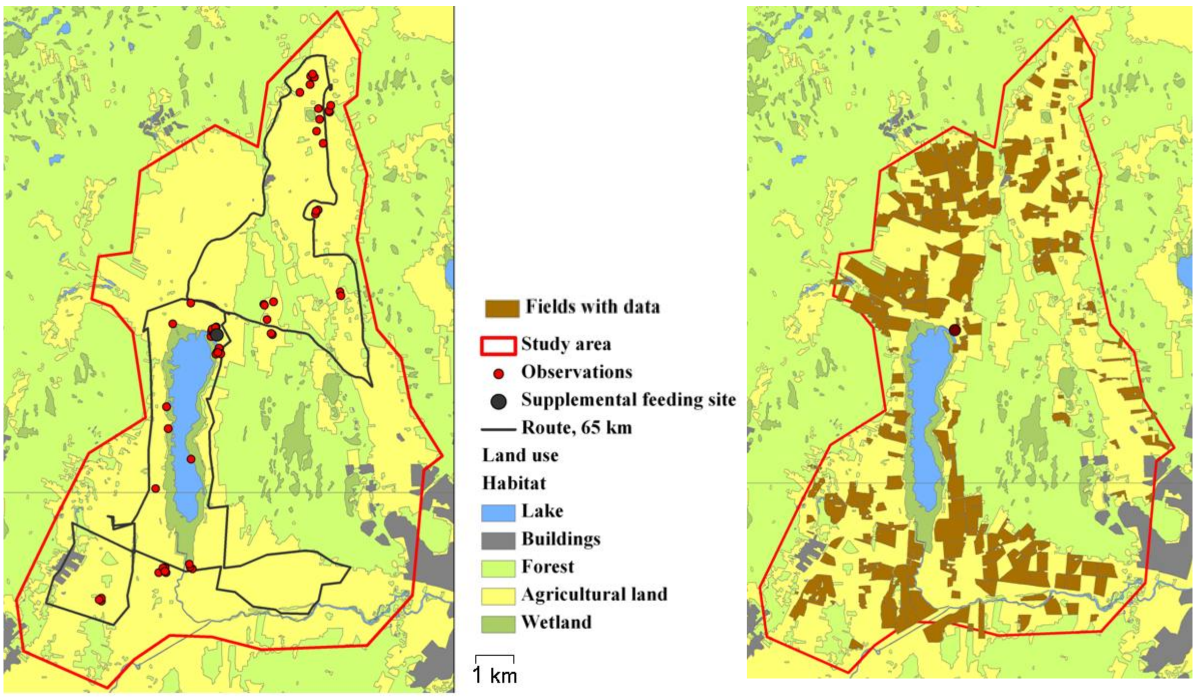

Figure 8. Positions with observations of whooper swans on agricultural land (left) and the 266 fields where field type were determined (right) *Lantmäteriet Gävle 2010. Medgivande I 2010/0055*

Field selection

Both approaches to estimate utilization (i.e. based on individual birds and flocks) of fields showed consistent results and the rank for field selection only changed between two field categories between the two approaches (Figure 9). The most selected field type was stubble field in both cases. By using the number of swan individuals as estimate of utilization the following rank was evident: 1) stubble, 2) ploughed field, 3) pasture, 4) winter cereal (Figure 9: a) and by using flocks the order of selectivity was: 1) stubble, 2) pasture, 3) ploughed field and 4) winter cereal (Figure 9: b). No swans were found on the other types of fields available.

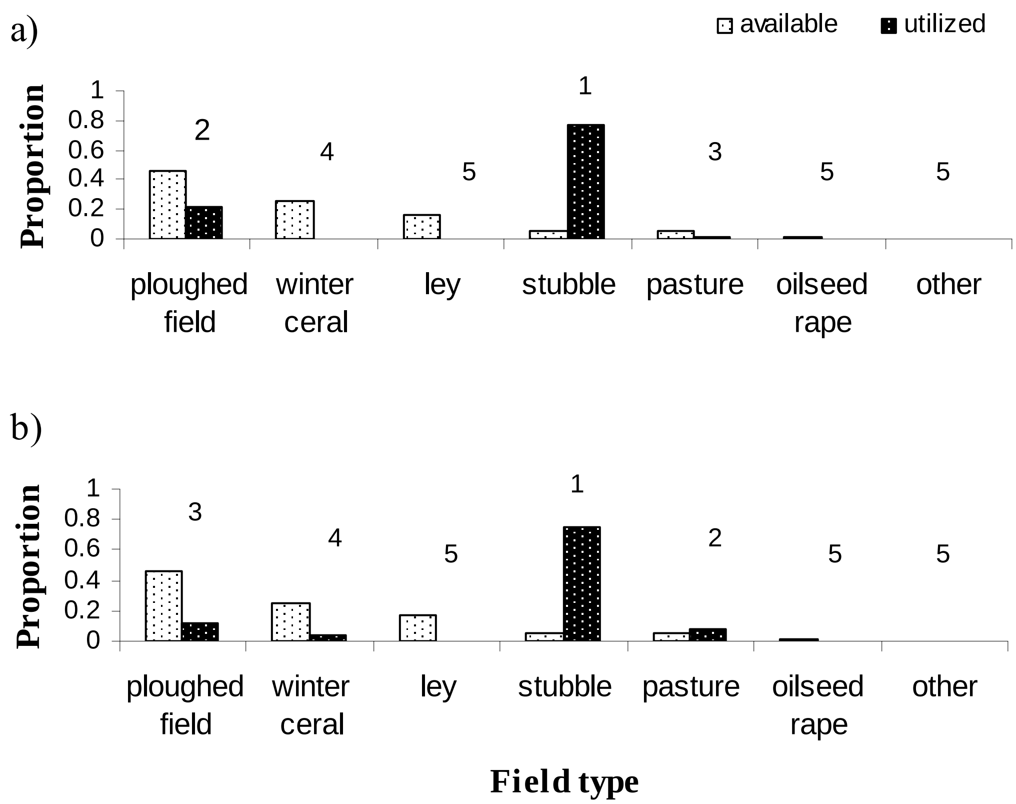

Figure 9. Proportions available (total area 26 km^2) and utilized field types when snow cover <50%, a) number of swans on agricultural land (n=1019), b) observed flocks on agricultural land (n=24). Figures above bars indicating selectivity ranking according to Manly´s α (no 1 most selected).

Distance to roosting site, the supplemental feeding site and forest edge

The mean distance to the roosting site from the total number observed flocks on agricultural land (n=36) were longer than for random points (n=36), however the difference was not significant (p=0.08; Table 2). The mean distance to the supplemental feeding site and forest edge from the observed flocks (n=36) did not differ from the mean distance to random points (n=36; Table 2).

Table 2. Mean distances (s.d. within brackets) and the comparison (t-test) between the 36 observed swan flocks and 36 random points.

	Swan observations (m)	Random points (m)	t	df	p
Roosting site	3925 (2578)	2931 (2212)	1.8	70	0.08
Supplemental feeding site	5137 (2393)	4985 (2471)	0.27	70	0.79
Forest edge	295 (225)	246 (184)	0.99	70	0.32

Discussion

My study showed that the whooper swan concentrations at stopover site occur during a limited period of the year. The start, end and duration of this period varied over the years and weather conditions (temperature) seem to be an important factor affecting the stopover period. During the stopover period most swans stayed at the supplemental feeding site. However, still swans were observed foraging on agricultural land and stubble fields were the most selected field type. The distance from the foraging sites and the lake, forest edge and the supplemental feeding site seemed to be of minor importance.

Both the duration and feeding site selection can affect the grazing pressure on agricultural land and thereby also grazing damage. The duration of the stopover period affects the time spent by birds within certain areas at a large spatial scale whereas the feeding site selection affects the grazing pressure at a smaller spatial scale. The spring temperature seems to determine when the swans start to migrate and arrive to stopover site, and also how long they stay at the site. Therefore, the variation in temperature will affect the stopover pattern and for that reason cause variation in grazing pressure and thereby also the risk of damage between years.

Stopover duration

In line with my prediction, I found that the mean temperature in March at the stopover site can be used to explain when the stopover period starts and ends, as the day for the start and end of stopover period was negatively related to temperature. Likewise, the mean temperature the two last weeks in February also predicted the start of the stopover period. Furthermore, the starting day can also be used to predict the length of stopover period. A low mean temperature at the end of February gives a late stopover start and thereby also a short stopover period whereas a higher mean temperature at the end of February gives an early stopover start and a longer stopover period. However, less variation was found for the end of the stopover period and that might be explained by the fact that other factors than weather conditions might affect when swans decide to leave a stopover site, e.g. energy level, plant phenology, internal clock, and the importance of establishing territories as soon as possible at breeding ground (Rappole & Warner 1976, Lindström et al. 1990, Mathiasson 1991, Duriez et al. 2009). Duriez et al (2009) tested decision rules for migrating pink-footed geese (*Anser brachyrhynchus*) and found that a combination of plant phenology, energy level and date to be most accurate. Other studies have found migration to follow the time for ice covered waters to melt and wind to affect migration plan (Mathiasson 1991, Gordo 2007). The analysis for mean temperature and start day gave a higher degree of explanation (R^2) achieved in the model when data from last part of February was used compared to the analysis for March. This can be due to that some start days of the stopover period already occurred in February and therefore were less related to the mean temperature in March. Also, a higher degree of explanation was achieved by using temperature data from Hörby and Vänersborg compared to the model where temperature from Örebro was used. This shows that a better explanation is achieved by using temperature data from wintering areas compared to the stopover area.

Mathiasson (1991) also showed that the time for departure at wintering grounds is dependent on the weather and the severity of the winter. Overall my conclusions are in accordance with previous studies showing weather to be an important factor influencing birds´ choices on migration route (Nisbet and Drury Jr 1968).

Field site selection

Field selection

In my study only 6 % of the swans spend their time on agricultural land. The remaining 94 % was found on the supplemental feeding site and the lake nearby. Studies on wintering birds in Sweden have shown that approximately 33 % and 43 % of observed whooper swans were found on agricultural land and the remaining part was found in traditional habitat connected to water (Nilsson 2002). Laubek et al (1999) showed that 91 % of whooper swan observations in northeast Poland, Baltic States, Finland and Sweden (north of Scania) were made on aquatic habitat during winter. Laubek et al (1999) also showed that 76 % of whooper swan observations in the region for wintering swans were done on terrestrial habitat and a part of these swans later use Lake Tysslingen for stopover during spring migration. The fraction of the swans foraging on agricultural land obviously differ between different studies and populations and in my study it was evident that a supplemental feeding site can have a large local effect on the distribution and foraging patterns of the swans.

My study showed that the most selected field type was stubble fields followed by ploughed field, winter cereal and pasture. Earlier studies in Sweden have found that whooper swan selected winter cereals, grassland (including ley) and oilseed rape (Nilsson 2002). In Britain and Ireland whooper swans preferred root crops, cereals (Rees et al.1997b) and in Denmark winter cereals was the most selected crop followed by oilseed rape, pasture and stubble (Laubek 1995). Of the field types available in my study area findings on winter cereals, pasture and stubble coincided with previous studies. In my study, surprisingly no swans were observed on the few oilseed rape fields available within the study area. Neither was any swans found on grassland or root crops (included in category: other). Another surprising finding was that many swans were found on one ploughed field even though it seemed as there was no food available there, however it seemed that the swans were attracted by a flooded part of the field. Fields with stubble has already been harvested the preceding autumn and that means that swans feeding on these fields do not cause any damage. On the other hand swans feeding on oilseed rape and winter cereals can cause damage and economic losses (Levin et al 2010).

Distance to roosting site, the supplemental feeding site and forest edge

My results showed no significant difference for the mean distances to the roosting site, the supplemental feeding site and forest edge for observed swans compared to random positions. These results were not in line with my predictions that the swans would be found closer to roosting site and the supplemental feeding site than random positions due to energy optimization strategy (de Jong 2010). The swans roost in the lake and most swans feed at the supplemental feeding site nearby; but no influence of these two factors was found on the distance to swans on the fields. Previous studies have shown that the distance to roosting sites affect the choice of foraging sites among waterfowl and the maximum distance from roost can be up to 10 km (Vickery & Gill 1999, Chisholm & Spray 2002, Brazil 2003, Rees et al. 2005). The maximum distance in my study from roosting site to the border of the study area is 10 km and thereby this might be the reason of not finding any effect of distance. Neither was my prediction to find swans on a longer mean distance to forest edge compared to random positions verified. Chisholm and Spray (2002) showed that fields used by whooper swans were larger than fields not used by swans and this may indicate that swans prefer sites where they have an overview of the surrounding landscape maybe to avoid predator risk when feeding.

Activity of swans

During fields work I did not note the specific activity of the swans on the fields. This can affect the conclusions since the choice of fields may be affected not only by field type but also by other factors such as availability of water (flooding). During the field period, almost all swan flocks observed on the fields seemed to forage on parts being flooded. When these places dried up the swans seemed to move to other fields where water was available. Consequently, no field was visited by swans all days during field period. The hypothesis of the importance of flooded areas for distribution of swans in the study area is supported by Mathiasson (1991). Days when the food had run out at the supplemental feeding site "Stiftelsen Tysslingen" had noticed that larger part of the staging swans used the agricultural land in the area.

Future studies

The results found in this study gave rise to further questions. For instance, whether it was the same individuals returning to certain fields day after day. Furthermore, the data in my study does not allow interpretation of the turnover rate and neither any total number of individuals staging at the stopover site. These questions can also have implications for the grazing pattern and risk of damage within stopover site and may therefore be further studied. The way to find answer on these questions would be banding to be able to separate individual birds and maybe also use VHF-transmitters to be able to follow the movements of the swans. Even more interesting would be to investigate what factors that make the smaller part of swans to feed on the agricultural land and what influence the flooded areas have on the distribution of the swans. The proportion of swans on agricultural land in my study area is much affected by the supplemental feeding so the same study would be interesting to do in an area without a supplemental feeding site. The results from a study without supplemental feeding site would be more comparable with previous studies and also to be used for more general conclusions.

Conclusion and management implications

The supplemental feeding site has a major effect on where whooper swans are distributed in the study area and is an efficient management effort to relieve agricultural land in the area from whooper swans. Most swans on agricultural land are found on stubble fields and there swans do not affect the harvest. Thus it is a wise strategy to let swans use stubble fields in spring and plough these fields after stopover period. The considerable variation in length of stopover period between years makes predictions about potential damage difficult. In turn, the variation in damage makes budgets for financial compensation difficult to make. For the future, UN´s climate panel IPCC predicts a warmer climate in the region that in combination with my results would give earlier stopover starts in warmer springs and thereby longer stopover duration (Houghton et al. 2001). However, a longer period does not automatically lead to greater damage, the important factors is number of accumulated bird-days spent on agricultural land that is not harvested. For this particular area all agricultural land have the same risk to be damaged in relation to distance to roosting site, the supplemental feeding site and forest edge.

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