Common Cranes in Agricultural Landscapes

Linking Space Use and Foraging Patterns to Conservation and Damage Prevention

Lovisa Nilsson
Faculty of Natural Resources and Agricultural Sciences
Wildlife Damage Center, Department of Ecology
Uppsala

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Common Cranes in Agricultural Landscapes- Linking Space Use and Foraging Patterns to Damage Prevention

Abstract

Many populations of migratory cranes, geese and swans are increasing throughout Europe and North America. During migration, these birds congregate at staging sites, often located in landscapes with both wetlands and arable land. When foraging on newly sown or unharvested crops at staging sites they frequently cause harvest losses and thus conflicts between conservation and agricultural interests.

The aim of this thesis was to increase the knowledge about space use and foraging site selection of common cranes. Such knowledge is needed to guide management where and when crop damage might occur, and what damage preventive measures to implement under variable environmental conditions.

My studies are based on flock surveys and data derived from GPS transmitters in combination with field surveys of food availability and crop stages. I found that the Natura 2000 network fulfils its conservation intention for staging cranes along the flyway, but also that cranes spill over from Natura 2000 sites to surrounding arable land. This spillover may enhance the conflict between conservation of cranes and other bird species within Natura 2000 sites and agriculture. My studies further demonstrated that field selection by cranes was influenced by factors dependent on agricultural practices such as crop type, crop stage, time since harvest, food availability, but also human disturbance and distance to roost site. I further revealed an apparent mismatch between individual crane space use and current damage preventive management. To conclude, stubble fields with high availability of spilled grain close to the roost sites have the potential to steer cranes from unharvested crops and prevent crop damage. To mitigate conflicts between conservation and agriculture, ecological knowledge is needed, but also participatory involvement of stakeholders and international collaboration, such as a flyway management plan.

Keywords: Anser, Branta, crop protection, *Cygnus, Grus grus*, human-wildlife conflict, Natura 2000, protected areas, site-fidelity.

Author's address: Lovisa Nilsson, Wildlife Damage Center, SLU,
Grimsö 152, 730 91 Riddarhyttan, Sweden
E-mail: lovisa.uk.nilsson@ slu.se

Till mormor och morfar

Look deep into nature, and then you will understand everything better.
A. Einstein

Dissertation

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Evaluation committee: **Børge Moe**, NINA, Trondheim, Norway
Helena Westerdahl, Lund University
Vesa Ruusila, Luke, Helsinki, Finland
Åsa Berggren (reserve), SLU, Uppsala

Main supervisor: **Johan Månsson**, SLU, Grimsö
Assistant supervisors: **Jens Persson**, SLU, Grimsö
Nils Bunnefeld, Stirling University, Scotland

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Nilsson, Bunnefeld, Persson, & Månsson (2016). Large grazing birds and agriculture - predicting field use of common cranes and implications for crop damage prevention. *Agriculture, Ecosystems and Environment* 219, 163-170.

II Nilsson, Persson, Bunnefeld & Månsson. Central place foraging under disturbance risk - how do common cranes select arable foraging sites? (manuscript)

III Nilsson, Aronsson, Persson & Månsson. Drifting space use of common cranes - is there a spatial mismatch between ecology and management? (manuscript)

IV Nilsson, Bunnefeld, Persson, Žydelis & Månsson. The Natura 2000 network- both a conservation success and a source of conflict. (manuscript)

Paper I is published with open access.

The contribution of Lovisa Nilsson to the papers included in this thesis was as follows:

I Main author. Collected the data with contribution from field assistants. Designed the study together with co-authors. Analysed the data with contribution from N.B. and wrote the manuscript with contribution from co-authors.

II Main author. Collected the data with contribution from J.M. Designed the study together with co-authors. Analysed the data together with M.A. and wrote the manuscript with contribution from co-authors.

III Main author. Collected the data with contribution from J.M. and field assistants. Designed the study together with co-authors. Analysed the data with support from N.B. and wrote the manuscript with contribution from co-authors.

IV Main author. Collected the data with support from R.Z. and J.M. Designed the study with support from co-authors. Analysed the data with support from N.B. and R.Z and wrote the manuscript with contribution from co-authors.

1 Introduction

1.1 Protected animals may cause impact on human livelihoods

Space use and foraging patterns of an animal are the result of the individual's decisions on where to forage, breed and find shelter from disturbance and predation (Charnov 1976; Lima & Dill 1990; Harrison et al. 2013). Those decisions affect not only the fitness of the animal and population dynamic parameters, but also the structure and function of ecosystems which may enhance conflicts between different human interests, *e.g.,* conservation and human activities (agriculture, forestry or fishery *etc*.; Redpath et al. 2015; Fox et al. 2016; Vickery et al. 1997). The conflict between human interests becomes even more complex for migratory species due to their extensive and dynamic space use (Thirgood et al. 2004; Singh & Milner-Gulland 2011). Protection of habitats is a common conservation tool for migratory species. However, current protected areas are often too small and too fragmented to fulfill the spatial and energetic requirements of the species. The animals may thus be forced to use habitats that are also outside the protected areas, causing so called spillover effects. This further adds to the prospective impact on human activities (*e.g.,* agriculture and forestry), particularly in the vicinity of protected areas (Woodroffe 1998; Newmark et al. 1994). For example, many migratory species such as common cranes *Grus grus*, geese *Anser spp., Branta spp.* and swans *Cygnus spp.* (hereafter large grazing birds) are protected due to former habitat losses and hunting pressure (Harris & Mirande 2013; EC 2009). Along their flyway, these large grazing birds congregate at staging sites, which often coincide with protected wetland reserves (*e.g.,* Natura 2000 sites, Jankowiak et al. 2015). These protected wetland areas are often used for night roost, and the surrounding arable land is used for foraging (Jankowiak et al. 2015) with damaged crops as a consequence (Salvi 2010; Frank et al. 2016; Amano et al. 2008). Restorations of new protected wetland areas also commonly attract aggregations of large grazing birds which likely bring increased impact on agriculture (J.M.Wikland, County Administrative Board Örebro, pers. comm.). Since the risk of crop damage often is linked to protected areas, farmers commonly become reluctant towards conservation measures. Consequently, authorities and stakeholders face a multifaceted conservation challenge in mitigating damage to human livelihoods while also protecting the focal species (Thirgood et al. 2004; Bull et al. 2013; Singh & Milner-Gulland 2011). Regardless of population trends, these damages to crops need to be mitigated. To resolve interest conflicts, different management tools are available. Such tools might be scaring practices, population regulation by culling or diversionary feeding (*i.e.,* undisturbed foraging sites intended for the species). Independent of the measure used, the management procedure needs to be informed by scientific evidence and it is thus of importance to understand the ecology of the focal species since that affects the performance of measures (Pullin et al. 2004; Sutherland et al. 2004).

1.2 Increasing populations of cranes, geese and swans

Many populations of large grazing birds are increasing in numbers in Europe and North America (Fox et al. 2010; Anon 2016; Harris & Mirande 2013). For instance, the number of autumn staging cranes in Germany increased from 45,000 in 1987 to 225,000 in 2008, the number of geese in northwest Europe increased from about 3.5 million to 4.3 million between 1995 and 2008, and in Sweden the number of whooper swans *Cygnus cygnus* increased from 2000 to 8000 in the period 1970-2000 (Fox et al. 2010; Nilsson 1997; Harris & Mirande 2013). The increasing populations are likely a result of international agreements banning hunting and promoting wetland restorations[1,2,3,4,5]. The reproduction success of large grazing birds is probably also favoured by altered farming practices such as increased use of autumn sown crops and larger field units (Stoate et al. 2001; Jongman 2002; Fox et al. 2016). However, some populations of common cranes as well as other crane species (*e.g.,* whooping crane *Grus Americana*), as well as some goose species (*e.g.,* bean geese *Anser fabilis,* lesser white-fronted geese *Anser erythropus*) still have stable or

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[1]. Bonn convention: Council decision 82/461/EEC of 24 June 1982 on the conclusion of the Convention of the conservation of migratory species of wild animals

[2]. AEWA: Agreement on the Conservation of African-Eurasian Migratory Waterbirds

[3]. Bern convention: Convention on the Conservation of European Wildlife and Natural Habitats

[4]. Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds

[5]. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

decreasing population trends (Harris & Mirande 2013; IUCN 2016). Cranes are omnivorous, and in areas with high crane densities populations of vulnerable bird species reliant on wetlands and arable lands may be negatively affected through predation and competition (Anteau et al. 2011; Harvey et al. 1968). The herbivorous geese, on the other hand, may alter ecosystems through intense grazing of pastures, meadows and reed and may have a negative impact on for example waders and warblers dependent on these habitats (Vickery et al. 1997; Naturvårdsverket 2015).

1.3 Factors influencing foraging and space use

1.3.1 Food availability and distance to roost site

Knowledge of how cranes select resources in the landscape is central for predicting distribution, habitat requirements and where damage to crops might occur (Boyce & McDonald 1999; Fox et al. 2016). Foraging is one of the major processes shaping distribution patterns and space use by large grazing birds. One theory related to foraging decisions is the optimal foraging theory, which predicts that animals trade food intake against costs of movement and handling time to optimize gained net energy and fitness (MacArthur & Pianka 1966). However, for large grazing birds, the capability to optimize net energy intake is constrained by the repeated commuting to the central night roost (Chudzińska et al. 2015). To account for such movement constraints, the central place foraging theory was developed from the principals of optimal foraging theory (Kacelnik 1984; Orians & Pearson 1979). The two main predictions derived from the central place foraging theory are: first, that the probability of occurrence of an animal gradually decreases with the distance to the central location, and second, that selectivity for high-quality foraging sites increases with distance to the central location in order to compensate for energetic costs of movement (Orians & Pearson 1979; Rosenberg & McKelvey 1999; Schoener 1971).

1.3.2 Crop type and crop stage

Generally, cranes and other species of large grazing birds are dependent on high-quality forage, such as cereal crops with high content of protein and carbohydrates but with low content of fiber (Summers & Critchley 1990; Riddington et al. 1997; Bos et al. 2005). Cranes generally select cereal and corn fields, whereas they use grasslands to lesser extent (Lovvorn & Kirkpatrick 1982; Ballard & Thompson 2000; Vegvari & Tar 2002; Anteau et al. 2011). The selected cereals are durum wheat, wheat and barley (Sugden & Clark 1988; Sugden et al. 1988). In contrast to cranes, grasslands and pastures are commonly selected by geese and swans (Chisholm & Spray 2002; Ely & Raveling 2011; Ladin et al. 2011). Nonetheless, geese and swans also forage on cereals, oil-seed rape and root crops, especially during autumn staging when unharvested or stubble fields are available (Krapu et al. 1995; Gill 1996; Rees et al. 1997; Ely & Raveling 2011). Field use by large grazing birds is also influenced by current cultivation stage (*e.g.,* unharvested, stubble, harrowed), presumably because some food resources are more accessible at certain cultivation stages, such as spilled grain at stubble fields. Large grazing birds predominately select stubble fields, but also newly sown fields and growing crops (Frederick & Klaas 1982; Lovvorn & Kirkpatrick 1982; Krapu et al. 1984), whereas tilled and mulched fields generally are less attractive (Sherfy et al. 2011; Anteau et al. 2011).

1.3.3 Site fidelity

During migration large grazing birds exhibit site fidelity at several spatial scales; from staging sites along the flyway to specific fields within staging sites (Fox et al. 2002; Phillips et al. 2003). Site fidelity is closely linked to both the distribution and predictability of resources, as well as seasonal variability and prior knowledge of the environment (Switzer 1993; van Moorter et al. 2009; Martin et al. 2013; van Beest et al. 2013). For instance, field use of sandhill cranes *Grus canadensis* is explained by the previous year´s crane numbers. This suggests that cranes return to fields that are known to be profitable (Lovvorn and Kirkpatrick 1982). Understanding to what degree large grazing birds repeatedly return to specific areas (Switzer 1993), is essential for assessing the risk of crop damage.

1.3.4 Disturbance and predation risk

Disturbance can influence field use by large grazing birds, congregation patterns at staging sites, and temporal aspects of foraging (Madsen 2001; Bechet et al. 2004; Tømmervik et al. 2005). Disturbance is herein defined as any activity that triggers fear, such as predation risk, human activities (*e.g.,* traffic, scaring, culling, aircrafts), and generates increased vigilance, flight proneness and decreased time spent feeding (Madsen 1985; Mini & Black 2009; Webb et al. 2011). Field use may change as a response to human disturbance, *e.g.,* leaving productive for less productive fields (Bos & Stahl 2003; Bechet et al. 2004; Nolet et al. 2006). However, the behavioral response to disturbance varies between sites and is influenced by factors such as type of disturbance, species, flock size, habitat availability, crop type, individual behaviour and habituation (Bechet et al. 2004; Madsen & Boertmann 2008; Tømmervik et al. 2005). Indirectly, predation risk and disturbance may cause particularly swans and geese to select large fields with good visibility that facilitate detection of potential threats (Munro 1950; Frederick & Klaas 1982; Wisz et al. 2008). Also cranes have been shown to avoid fields with hampered visibility (Franco et al. 2000) even though they occasionally forage within more or less closed environments during breeding and in some areas along the flyway (Aviles 2004; Månsson et al. 2013).

1.4 Crop damage

Large grazing birds cause damage to crops mainly due to consumption but also due to trampling and contamination (Flegler et al. 1987; Parrott & McKay 2001; Crawley & Bolen 2002). Damage levels are closely linked to where and when the birds decide to forage, and is thus influenced by crop type and crop stage, as well as availability and quality of food (Amano et al. 2004; Anteau et al. 2011; Leito et al. 2008). The nature of crop damage varies with season and species. Cranes mainly cause damage to newly sown or pre-harvest cereal and potato fields. In contrast, geese often cause damage to newly sprouted cereal fields, grasslands used for hay production, and compete with cattle when grazing at pastures (Amano et al. 2007; Frank et al. 2016; Salvi 2010). Whooper swans, on the other hand, commonly cause damage to rapeseed fields by trampling during winter time (Laubek 1995). As the number of fields and farmers affected by damage from large grazing birds has increased, so have the costs for harvest losses, preventive measures, and compensation levels (Fig. 1). For example, farmers have been compensated for damage caused by cranes with ~190,000 € (in total 2005-2008) in Lake Der-Chantecoq, France (Salvi 2010) and ~200,000 € (2012) in Sweden (Frank et al. 2016). In addition to inspected and compensated harvest losses, there are likely many damaged fields that are not reported for compensation as indicated by the amount of damage reported by farmers in a recent questionnaire (The Swedish Board of Agriculture & Sweden Statistics 2014).

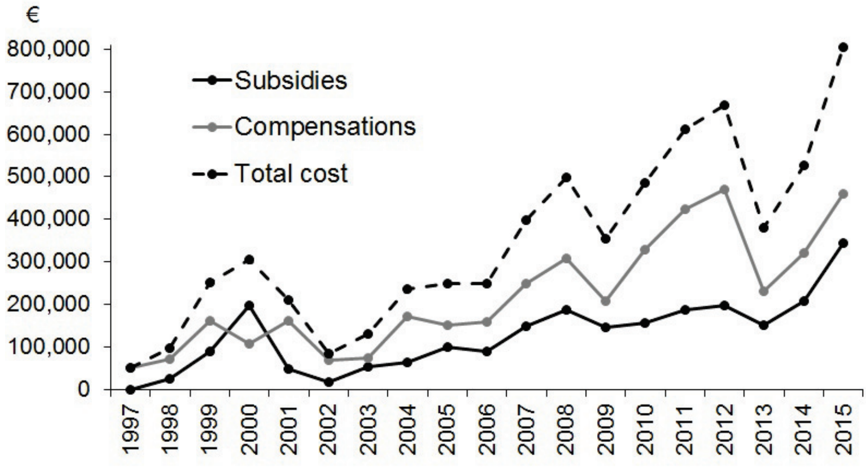

Figure 1. Compensation paid for inspected harvest losses caused by cranes, geese and whooper swans in Sweden 1997-2015, and subsidies paid for damage preventive measures (data from Frank et al. 2016).

1.5 Current damage preventive management

Many of the bird species causing damage to crops are protected, and preventive measures should therefore not affect population viability (Vickery & Summers 1992; Madsen et al. 2014). Crop damage preventive measures used today are in general based on two different strategies: 1) scaring the birds from fields with vulnerable crops (*e.g.,* by propane cannons, fireworks and scarecrows) or 2) attracting birds to arable fields intended to steer foraging activity away from vulnerable crops (Owen 1977; Vickery & Summers 1992; Vickery & Gill 1999). The strategies to scare and attract are similar to the "push and pull strategy" used within insect pest management which includes a component of attraction, *i.e.,* "pull", and a component of repellent, *i.e.,* "push" (Cook et al. 2007). Successful proactive management needs to be based on and evaluated in the light of the movement and foraging ecology of the birds to achieve successful results (Conover 2002). The need for linked knowledge between ecology and pro-active measures is highlighted by: 1) the general increase of large grazing bird numbers (MacMillan & Leader-Williams 2008; Nilsson 2002); 2) the fact that large grazing birds seem to use agricultural areas for feeding to a greater extent in the last 3-4 decades (Fox et al. 2005; Nilsson 1997); and 3) by increasing conflicts between stakeholders (Hake et al. 2010; Fox et al. 2016).

2 Objectives

The aim of my thesis is to increase the ecological knowledge about space use and foraging of cranes. Further, my objective is to link such ecological knowledge to conservation and damage prevention. More specifically I investigate the following ecological research questions:

Paper I	What factors influence field use by cranes?
Paper II	Do cranes select arable foraging sites according to the predictions from central place foraging theory?
Paper III	How large are daily and seasonal activity areas of cranes? How faithful are cranes to their daily activity areas, and how variable is the site fidelity?
Paper IV	How efficient is the Natura 2000 network in targeting cranes for protection? Is there a spillover of cranes from Natura 2000 sites to surrounding arable land?

3 The common crane

3.1 Cranes in myth

"...The Trojans advanced as a flight of wild fowl or cranes that scream overhead when rain and winter drive them over the flowing waters of Oceanus to bring death and destruction on the Pygmies, and they wrangle in the air as they fly...." (The Iliad, Homer ~800 B.C)

Cranes are in many ways iconic and particularly acknowledged for their pair bonding dance which recurs in myth and legends worldwide (Johnsgard 1983). For example, Homer told the story of how cranes frequently were in war with the Pygmies. According to the epic poem, the cranes drove the Pygmies out of their first city Geranea, and the Pygmies later made warfare with the cranes, attacking them with weapons and darts (Johnsgard 1983). Many words have also been derived from cranes. For example is the word ‘jangling’ thought to be derived from the call of the cranes ‘iangling’, and also ‘family tree’ was mentioned as a ‘cranes foot´ or ‘pied de grue’ which gave rise to ‘pedigree’ (Johnsgard 1983). Likewise, the name ‘*Grus’* is thought to be derived from the Roman ‘Grues’ which likely is onomatopoeic for the cranes grunting sounds (Johnsgard 1983). Cranes thus hold a large aesthetic value for people, which also need consideration when managing the species.

3.2 Population status

The common crane (hereafter crane) is one of 15 crane species in the world. The distribution of the crane species cover five continents; Europe, Africa, North America, Asia, and Australia (Harris & Mirande 2013). The distribution of common cranes ranges from Northern Europe to Eastern Russia with wintering areas in Northern Africa and Central and Eastern Asia (Johnsgard

1983). Eleven of the *Grus* species are threatened according to the IUCN Red list, predominately due to habitat losses and disturbances linked to human activities (Harris & Mirande 2013; IUCN 2016). In Europe, common cranes are assigned as a species of special conservation interest (Annex I) in the EU Birds directive (EC 2009). The Birds Directive is implemented through habitat protection in the Natura 2000 network (EC 2016). As a result of successful conservation measures, the population of common cranes along the Western-European flyway stretching from Sweden in the north to Spain and Portugal in the south (Fig. 2) has recovered (Harris & Mirande 2013). As part of the population recovery along the flyway the staging population in Sweden has also increased in numbers (Fig.3).

Figure 2. Locations from the 32 cranes during time of migration (1st of September-31st of March 2012-2016) (black dots) along the Western-European flyway, derived from GPS transmitters. The flyway is defined by a minimum convex polygon (100 % MCP) of all included locations (overseas locations excluded).

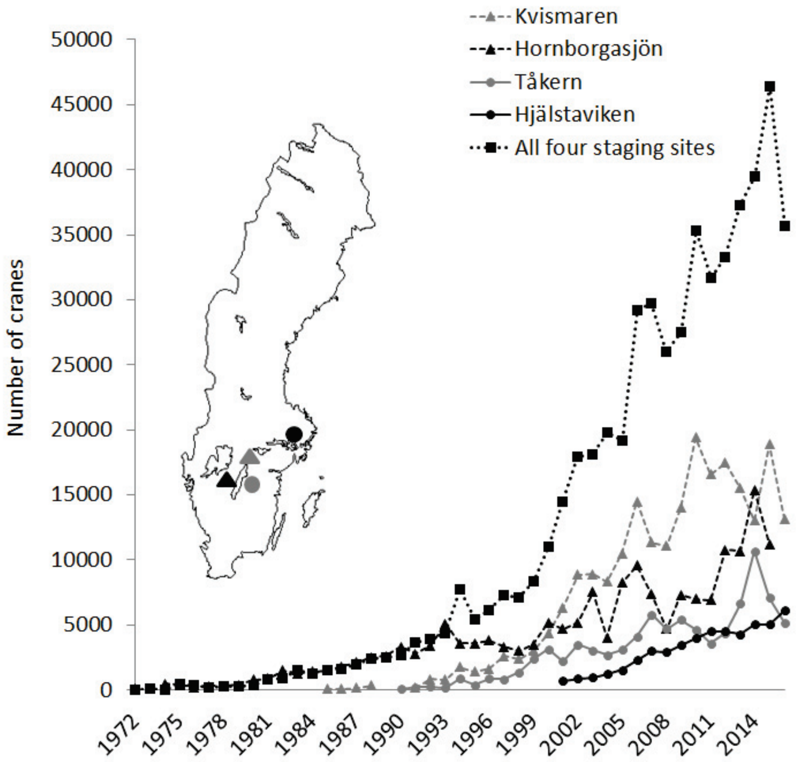

Figure 3. Maximum numbers of cranes during autumn (1972-2015) at the four major staging sites in Sweden. Data collected by Wildlife Damage Center, Kvismare Bird Observatory and the County Administrative Board Örebro in Kvismaren, Tåkern Field Station, Hornborga Bird Observatory and P. Westin in Hjälstaviken.

3.3 Crane ecology

Adult cranes have few natural predators, even though there has been occasional observations of predation by golden eagles *Aquila chrysaetos* (Munoz Pulido & Alonso 1992). During breeding however, cranes normally place their nest in wetlands or shallow lakes to prevent predation of eggs and chicks by for example red foxes (Månsson et al. 2013; Nowald 2001). The parental pair normally lay two eggs and one to two chicks are raised (Johnsgard 1983). During breeding the adult cranes are territorial (Månsson et al. 2013). When the chicks are fledged the family normally congregate with larger groups of cranes at staging sites along their migratory flyway (Alonso & Alonso 1993). Throughout the year, cranes have a dual habitat use as they repeatedly return to wetland night roosts and forage in the surrounding landscape during the daytime (Bautista et al. 1995; Nilsson et al. 2016). Cranes are omnivorous, eating invertebrates, small rodents, amphibians, eggs, berries, seeds and crops such as cereals, corn and potatoes (Alonso et al. 1983; Harvey et al. 1968). During the breeding period the food mainly consists of invertebrates, amphibians and berries, often found in wetlands, farmland and forested but moist habitats (Månsson et al. 2013; Nowald 2001). During staging and wintering, the food mainly consists of spilled grain on stubble fields and unharvested or newly sown crops (Alonso et al. 1983).

3.4 The crane as a model species for large grazing birds

The crane has many ecological and management characteristics in common with other species of large grazing birds, which leads to generalizations between different groups of birds. Cranes, geese and swans are most often migratory and have a dual habitat use during staging and wintering, with night roosts in wetland habitats and daily foraging activities in the agricultural landscape (Alonso & Alonso 1992; Leito et al. 2008; Giroux 1991). These species also have in common that the parental pair raise the chicks during at least the first half year, which means that the chicks are taught where profitable staging and foraging sites occur (*i.e.,* inherited site fidelity). Many of these species (*e.g.,* sandhill cranes, barnacle geese *Branta leucopsis*, pink-footed geese and whooper swans) are just as common as cranes, increasing in numbers due to legal protection, wetland restorations and modernized farming practices providing high quantities of high-quality food. The increasing numbers of large grazing birds combined with the fact that the species are flock-living and commonly congregate in high densities at staging sites results in significant damage to crops, conflicts between human interests and considerable costs to society through loss of agricultural production and increasing compensation payments (Borad et al., 2001; Bouffard et al., 2005; McIvor and Conover, 1994). As these species also commonly occur simultaneously at staging sites, current management practices of scaring, culling, diversionary feeding and compensation schemes are affecting all present species.

4 Study area

"…A crane trumpeted loudly at the meadow, and occasionally a marsh harrier turned by over the quagmire, chased by lapwings and curlews…"
(E. Rosenberg in Kvismaren 1923, translated from Flora och Fauna)

The study area for Paper I-III was Kvismaren (59°10´N/15°22´E), in the boreonemoral zone of south-central Sweden (Fig. 4). The core of the area is a wetland reserve consisting of two shallow eutrophic lakes, 2.5 km apart, surrounded by narrow strips of grazed wetlands. The area is assigned under the Ramsar convention of wetlands and is also a Natura 2000 site, listed under the Birds Directive (SPA) and the Habitats Directive (SAC/SCI) combined (EC 2016). The landscape is flat and dominated by productive farmland (~66 %), well suited for cultivating cereals, ley and potatoes. The study area is in total ~200 km^2. The average precipitation in September during the main study period is 50-75 mm (SMHI 2014).

In Paper IV the complete flyway constituted the study area (Fig.2), covering seven countries from Sweden in the north to Spain and Portugal in the south. The landscape characteristics ranges from being dominated by forests in south-central Sweden to gradually becoming more dominated by agricultural landscapes when moving southwards (EEA 2006).

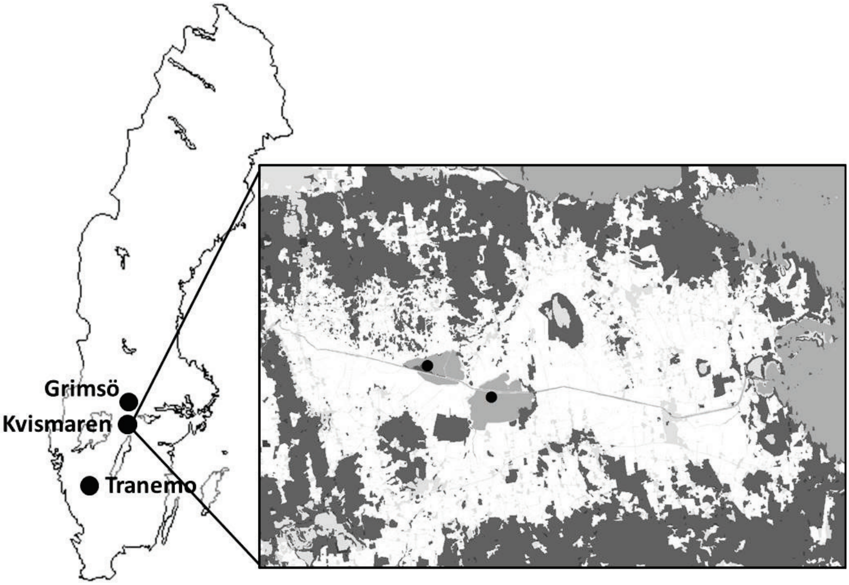

Figure 4. Cranes were captured and equipped with GPS transmitters at Grimsö and Tranemo 2012-2015 (left), and the studies for Paper II and III were conducted in Kvismaren 2012-2015. The core of the area consists of two protected wetlands/shallow lakes where the cranes roost overnight (black dots). The wetlands are mainly surrounded by arable land (white) and to a lesser extent by forested areas (dark grey).

4.1 Dynamic agricultural landscape

Arable landscapes are generally heterogeneous and dynamic in time and space in terms of crop characteristics and farming practices (*e.g.,* harvesting and tilling). This makes the availability of food for cranes to vary from day to day on both field and landscape level (Chudzińska et al. 2015). This pattern also applies for the study area in Kvismaren. Crops are generally harvested between mid-August and early October, but the timing varies due to weather conditions and crop types (Fig. 5). For example, autumn sown wheat is often ripe and harvested in mid-August, and is followed by spring-sown wheat and barley.

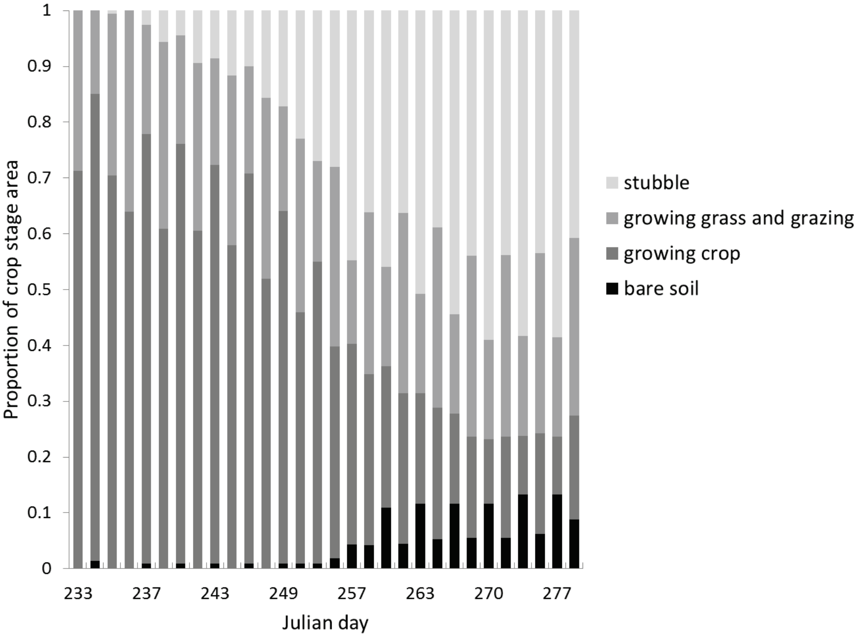

Figure 5. Proportion of different crop stages within the Kvismaren study area during the staging period (mid-August to early October) of cranes in 2012. Bare soil includes ploughed, harrowed and newly sown fields.

4.2 Large grazing birds in Kvismaren

The shallow lakes and the surrounding agricultural landscape in Kvismaren provide a combination of suitable roost sites and favorable foraging conditions for the cranes and other species of large grazing birds. Kvismaren has been a key staging site for cranes over the last 30 years, and hosts the largest number of cranes during autumn staging in Sweden. The maximum numbers of cranes in the period of 2009-2015 has ranged from 13,200-19,500 cranes. Other than staging cranes, Kvismaren also hosts spring migrating cranes (Fig. 6 & 7). Other large grazing bird species that occur in the area are bean geese and greylag geese in numbers of tens of thousands, and hundreds of barnacle geese, pink-footed geese, as well as occasional observations of white-fronted geese and lesser white-fronted geese (Artdatabanken 2016)

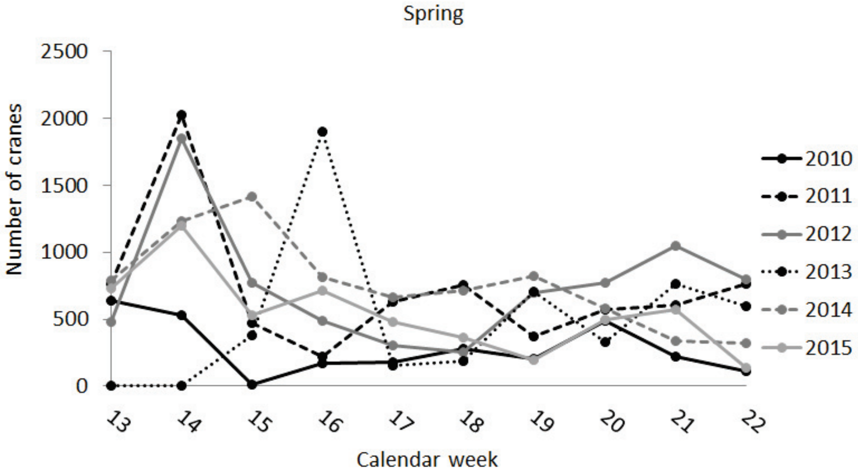

Figure 6. Number of cranes from late March to late May (2010-2015) counted when flying in to night roost in Kvismaren. Data collected by Wildlife Damage Center, SLU in collaboration with Kvismare Bird Observatory and Örebro County Administrative Board.

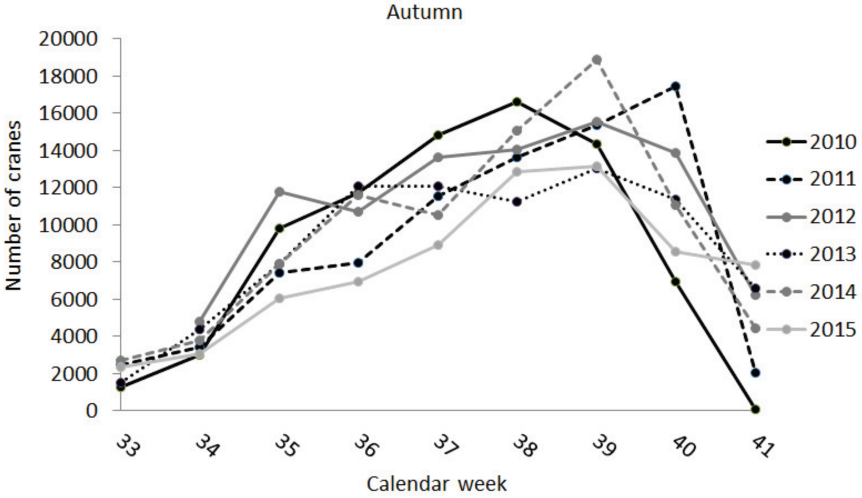

Figure 7. Number of cranes from mid-August to early October (2010-2015) counted when flying in to night roost in Kvismaren. Data collected by Wildlife Damage Center, SLU, in collaboration with Kvismare Bird Observatory and Örebro County Administrative Board.

4.3 Crop damage development and local management practices

The large concentrations of large grazing birds in Kvismaren cause damage to crops. Costs for preventive measures and damage compensations have ranged from 48, 000 € (in 2010) to 150, 000 € (in 2012) (J.M.Wikland, Örebro County Administrative Board, pers. comm.). Similar to other staging areas in Sweden, the preventive measures mainly consists of different scaring practices such as scarecrows, propane cannons, human silhouettes and flags along the field edges to prevent cranes from walking into unharvested crops. Also diversionary fields (*i.e.,* supplying food at undisturbed locations, stubble fields with spilled grain or allocated crops) and occasional local culling (Hake et al. 2010) are used. The level of scaring activity was hard to quantify as it was done uncoordinated by farmers and managers.

5 Methods

5.1 Population and individual level studies

Linking movements and space use to population dynamics is crucial to understand why and how a population changes and its responses to the surrounding environment (Bowler & Benton 2005; Morales et al. 2010; Sutherland 1996). Monitoring animal distributions and densities (*i.e.,* population level surveys) have been important in forming the current scientific knowledge of population dynamics and demography (Clutton-Brock & Sheldon 2010). However, such studies have their limitations, as individual decisions cannot be distinguished, thus it is hard to separate the effect of multiple influencing factors. However, by studying individuals many of these limitations are avoided (Clutton-Brock & Sheldon 2010). For example, space use of animals is often influenced by memory and previous experience of sites (*i.e.,* site fidelity) which also likely shapes the future outcome of space use and can only be described by data derived by recognizing individuals (Morales et al. 2010). In my thesis, I have included studies based on flock surveys in Paper I (*i.e.,* population level) and on location data derived from cranes equipped with GPS transmitters in Paper II-IV (*i.e.,* individual level). Paper I provides an understanding of how flocks distribute in the agricultural landscape and flock size, whereas the GPS data provides detailed information on how cranes take individual decisions of where to forage and how extensive the activity area is. The GPS data also allows for high-resolution calculations of distances from different landscape features that might influence space use, such as to the roost site and to roads and human settlements (*i.e.,* disturbance risk). However, there may also be shortcomings with studies of individuals such as restricted sample size. For example, 19 and 32 individuals are included in Paper II-III and IV, respectively, whereas flocks of a thousand individuals are included in Paper I. In my thesis, following individuals was also restricted to family groups, which may have limitations in representing the population as a whole. However, during the time of migration the family groups normally congregate with conspecifics in larger flocks (Aviles 2003) and constitute ~30% of the staging population (Månsson unpubl. data). Thereby, I generally assume that the studied family groups represent movements and habitat use of migrating and staging cranes in general.

5.2 Spatial scales

Research questions, patterns and interpretations is scale dependent (Wiens 1989; Thomas & Kunin 1999). Therefore, to fully understand the space use of animals, and to implement suitable management measures at an appropriate spatial scale, the full range of scales needs consideration in ecological studies. For the management of large grazing birds, flyway management plans are based on the flyway scale whereas damage preventive measures often are implemented on the scale of staging sites. Selection of resources can be defined at several hierarchal spatial scales. Johnson (1980) categorized these hierarchical scales of selection and defined the first order-selection as the distribution of the focal species, the second-order selection as the selection of home range, the third order selection as the selection of habitats within the home range and the fourth order selection as the selection of prey or food items. The studies included in my thesis cover selection of habitats ranging between the 2nd and 4th order, namely staging site selection at the migratory flyway level (Paper IV, 2nd order selection), field level within the staging site (Paper I, 3rd order selection) and foraging site/food item selection within fields (Paper II, 3rd or 4th order of selection). By covering several spatial scales the studies can provide a more holistic understanding of foraging patterns and space use of cranes.

5.3 Study season

Papers I-III target the staging period at Kvismaren (see 4. Study area), which is the first main staging site for the studied cranes along their southward journey along the Western-European flyway. Paper IV covers the full flyway, and thus also the wintering period in southern Europe and parts of the northwards spring migration (*i.e.,* 1st of September to 31st of March 2012-2016). The reason I have mainly focused on autumn-staging is that it is the time for major congregations of cranes at staging sites. During the autumn staging period, cranes spend a lot of time feeding to fuel energy for migration (Alonso &

Alonso 1992), which in combination with high availability of attractive crops results in harvest losses.

5.4 Flock survey (Paper I)

The study in Paper I was based on flock surveys. The surveys were carried out during the main period of staging for cranes, from mid-August to the beginning of October in 2012. The surveys were based on 39 survey locations evenly distributed in the agricultural landscape of Kvismaren, and covers the daily flight distance from the nearest roost sites (11 km; defined by the 19 GPS-equipped cranes within the study area; Nilsson & Månsson, unpublished data) (Fig. 6). At each location, we counted the number of cranes on all fields that were within sight with a telescope (*i.e.,* 244 fields and 3221 observations). Fields were defined by using maps of administrative field borders from the Swedish Board of Agriculture. The survey locations were divided into two routes that were surveyed continuously during Monday to Friday, *i.e.,* one route was done one day, and the other route the next day. The surveys were conducted from dawn to dusk, and the start of the daily route was altered to vary the time of survey for each respective survey location.

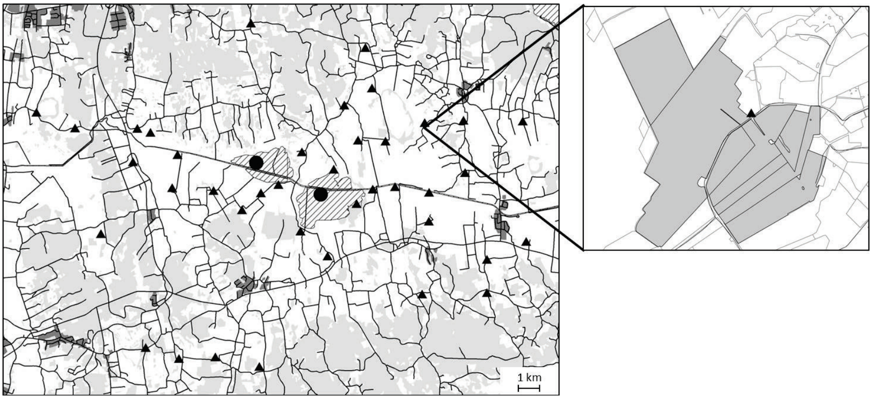

Figure 8. Flock surveys of cranes were conducted in 2012 along two car routes in Kvismaren study area, Sweden. The left map shows the distribution of observation locations (triangles), roost sites (points), wetlands (striped), arable land (white) and other land (grey) within the study area. The right map shows an example of arable fields (grey) surveyed from one of the observation locations.

5.5 Capture procedure and GPS positioning (Paper II-IV)

A total of 32 juvenile cranes were captured in the surroundings of Grimsö Wildlife Research Station (59°43′N/15°28′E, 85 km north of Kvismaren) and in the surroundings of Tranemo (57°29´N/13°20´E) and were equipped with backpack GPS transmitters. Cranes were captured by hand after a fast run from a car or a hide (Månsson et al. 2013). The juveniles were tagged in July to early August, just before getting fledged, at an estimated age of 6-8 weeks of age and weighed 2,800-4,350 grams. Three plastic colour rings were attached to each respective tibia and used for visual identification of individuals in the field (Fig. 9). In late August or early September, the fledged cranes, captured around Grimsö, migrated with the parental pair and occasionally one sibling (*i.e.,* a family group) to Kvismaren. The family normally splits at the wintering sites in the southern part of the flyway when the parents head northwards towards the breeding grounds (Alonso et al. 1984). This means that by tracking the juvenile for at least the first half year of life, I followed the movement of the whole family group in most cases. Capture and tagging fulfilled ethical requirements for research on wild animals after approval from the Animal Ethics Committee of central Sweden (C104/10 and C53/13).

Figure 9. Juvenile crane tagged with an individual combination of colour bands at Grimsö 2012. Photo: J.Månsson

Two types of transmitters were used; Vectronic GPS Plus bird backpacks (Vectronic Aerospace, Berlin, Germany) and transmitters from Cellular Tracking Technologies (CTT, Rio Grande, U.S). Both transmitter types send data via the GSM network. The transmitters were attached to the back of the juvenile with a harness made of an elastic band, which eventually will break off and remove the transmitter after the study period had finished. The CTT transmitters were recharged by solar panels. The studies in paper II and III were conducted in Kvismaren (2013-2015) and included 19 individuals fitted with transmitters (14 Vectronic, 5 CTT). Paper IV included 32 individuals (additionally 4 cranes tagged with Vectronic, Grimsö 2012-2015) and 9 individuals captured in the surroundings of Tranemo (CTT, tagged 2013-2014). During the staging period in Kvismaren, the transmitters were programmed for eight days of intensive positioning (1 location/30 min from dawn to dusk). Positioning started when the individual cranes arrived to Kvismaren and was then evenly distributed during the period (i.e. until late September) (Paper II & III). The solar panel transmitters allowed for continuous intensive positioning (at least 1 location/30 min) for the whole staging period. For the data in Paper IV the Vectronic transmitters were programmed to position daily at 7, 11, 15 and 23 UTC time. To match the time intervals of the CTT transmitters with the Vectronic transmitters, the locations closest in time available to 7, 11, 15, and 23 UTC time were derived in R (R Core Team 2015).

5.6 Additional data and data processing

5.6.1 Field borders, crop types and distance calculations

Borders of arable fields and cultivated crops were obtained from an administrative database held by the Swedish Board of Agriculture (SAM14, Swedish Board of Agriculture) (Paper I). As some crops were only available at a few fields, these crops were lumped into categories based on crop characteristics (see Paper I & II). For Paper I, distance to the roost sites was calculated from the centre of the field to the centre of the nearest roost site in ArcGIS 10.1. In paper II the distance to the roost site was calculated, using R, as the distance between GPS locations at night roost and at fields during the daytime. Distance to human disturbance was defined as distance from GPS locations to roads accessible by 2WD cars (agricultural roads only passable by tractors excluded) as well as to human settlements such as farms and houses. This data was derived from the GSD Terrain map in ArcGIS 10.1.3 (Lantmäteriet 2016) (Paper II).

5.6.2 Utilisation distributions and volume of intersection

For Paper III, activity areas were estimated by daily and seasonal utilization distributions (UD) for each individual using the fixed-kernel method (Worton 1989). Daily activity areas were defined for each individual as the 90% isopleth and daily core activity areas as the 50% isopleth (Kie 2013). To quantify the overlap between daily activity areas, (*i.e.,* the level of site fidelity) we calculated the volume of intersection index (VI) between the UD from different days for the same individual (Seidel 1992). We used overlap between all daily activity areas (total and core, respectively) to estimate activity area fidelity. Additionally, we calculated overlap between all daily activity areas for each individual to assess to what extent the crane returned to an area and the influence of number of days between activity area estimates. Both activity areas and VI were estimated using the 'adehabitatHR' package (Calenge 2015) in R (R Core Team 2015).

5.6.3 Flyway definition, resource selection and Natura 2000 data

In paper IV, I used location data derived from cranes equipped with GPS transmitters. The flyway for the studied individuals was defined as the minimum convex polygon (MCP) of all locations (Fig.1). Since I was interested in the crane's use of terrestrial land, I removed locations assumed to be migratory flight between staging sites and locations over open sea. To study resource selection patterns I compared the used locations with randomly distributed locations that was assumed to represent availability (Northrup et al. 2013). Only Natura 2000 sites designated under the Birds Directive or the Birds and Habitats Directive combined were included in the study because cranes are listed under the Birds Directive (EC 1992). Polygons of Natura 2000 sites (hereafter N2K sites) and information regarding site type was derived from the European Environmental Agency (EEA 2015) and listing of cranes in specific sites from the Natura 2000 Network Viewer (EEA 2016). Habitat characteristics to all included locations were derived from the Corine Land Cover data (EEA 2006) and were pooled into three habitat categories; arable, wetland/water and other. For day locations outside N2K sites, the distance to the nearest N2K site was assessed in ArcGIS 10.3.1.

5.7 Statistical methods

5.7.1 Binomial mixed models and resource selection functions

For Papers I, II and IV, generalized linear mixed models (GLMM) with binomial error structures and logit link functions were used to analyse probability of crane presence and resource selection scores (R package lme4; Bates et al. 2015). For Paper I, analyses were made on field level and whether or not cranes were present, *i.e.,* occupancy modelling (Royle & Nichols 2003). The use of binomial GLMM models in Papers II and IV was based on used locations (1) in comparison with available locations (0), *i.e.,* relative resource selection function (Lele & Keim 2006). Random effects were included due to repeated observations (field identity in Paper I and crane identity in Papers II &

IV). Explanatory variables that did not meet the criteria for normality were $\log_e$-transformed ($\log_e(x)$) or ($\log_e(x+1)$) when zeros were included in the data set (Zuur et al. 2010). Model selection was carried out using the function ‘dredge’ (R package MuMIn: Barton 2013) in compliance with the recommendations from Burnham & Anderson (2002). The top-ranked models in Papers I-IV were selected based on Akaike Information Criterion (AIC) and AIC weights (w_i) and were used to model the associated fitted values and their 95% confidence intervals after 1000 repeated simulations (R package arm: Gelman et al. 2014).

5.7.2 Gaussian mixed models combined with a Bayesian approach

In Paper III, GLMMs were used with a Gaussian error distribution to test for variation in size of activity areas (R package lme4; Bates et al., 2015). To test for variation in overlap (VI) over time the data were modelled in two steps to account for non-overlapping areas. The overlaps were first grouped into overlapping ($VI>0$) and non-overlapping ($VI=0$) daily activity areas and the probability of no overlap was modelled using the binary overlap as a response variable in GLMMs with a logit link-function (R package 'lme4'; Bates *et al.* 2015). Then the zeros were removed and the proportional overlaps were modelled as a continuous response variable in GLMMs with a beta error distribution and logit link-function using the R package 'glmmADMB' (Bolker *et al.* 2012). Crane identity was included as a random effect in all models. To estimate the final model parameters and to generate predictions, we further used the explanatory variables included in models with the highest ranks ($\Delta AIC \leq 4$) in a Bayesian Gibb’s sampler (JAGS: Plummer 2014) called from R using the ‘rjags’ package (Plummer 2014).

6 Results and discussion

6.1 Paper I: What factors affect field use by cranes?

I found that stubble fields had the highest probability of crane presence, and that the probability progressively decreased for grassland and grazing grounds, bare soil and growing crop. Five kilometres from roost site, the predicted probability of crane presence differed between crop stages and was highest for stubble fields and gradually decreased for grassland and grazing grounds, bare soil and growing crops. Moreover, the probability of cranes visiting a field was linearly and negatively related to distance to the roost site (Fig. 10). At stubble fields, the probability of crane presence decreased with time since harvest and was highest for barley with progressively lower probability on wheat and oat (Fig.11). The predicted scenarios showed that the probability of crane presence can be remarkably high if all favourable conditions coincide. For example, a field with barley stubble, one day after harvest and close to the roost site (1 km), has a probability of crane presence of 0.60 (0.42-0.77). In contrast, a field with growing crops, 10 km away from the roost site had a predicted probability of crane presence of only 0.02 (0.01-0.03), whereas a growing crop close to a roost site (1 km) has a crane probability of 0.09 (0.06-0.15).

With this study I show that the probability of crane presence at fields to a large extent is a result of agricultural practices such as crop and cultivation stage as well as time since harvest. Stubble fields provide easily accessible food in terms of waste grain, which likely explains the high probability of presence (Lovvorn & Kirkpatrick 1982; Shimada 2002; Sugden et al. 1988). Similarly, the declining probability with time since harvest at stubble fields may be explained by depletion of waste grain due to consumption by large grazing birds, smaller graminivorous birds and rodents (Galle et al. 2009; Pinkert et al. 2002). Cranes are also known to avoid sprouted grains, and therefore the food

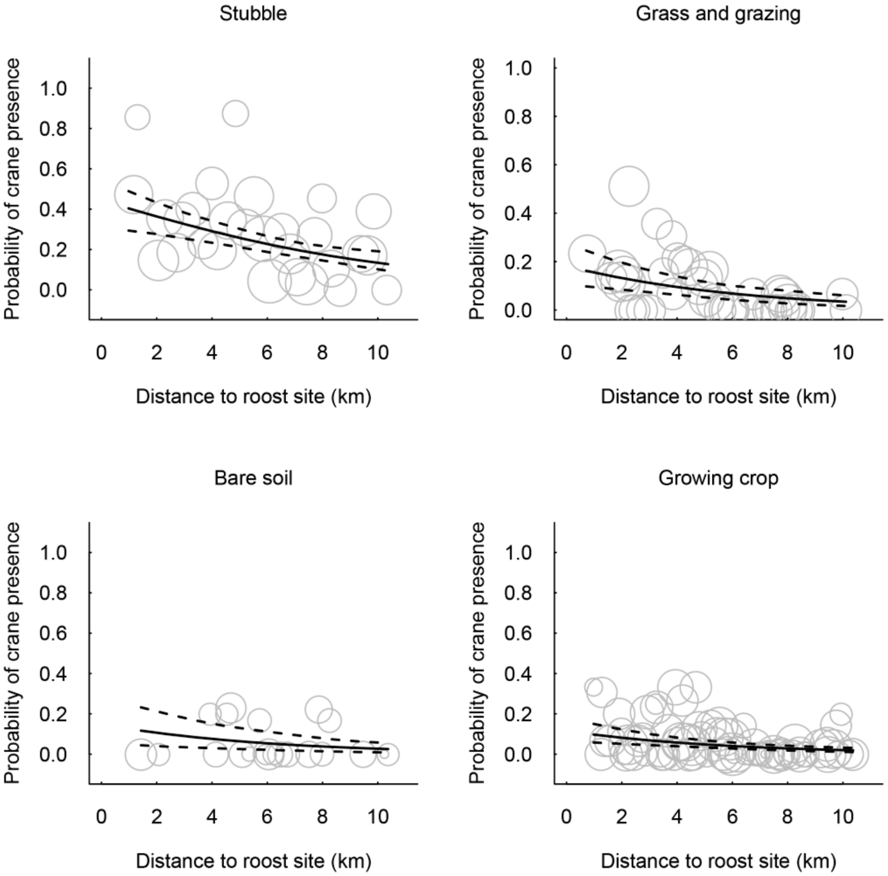

Figure 10. Probabilities of crane presence in relation to distance to nearest roost site at stubble fields, grassland and grazing ground, bare soil and growing crops in Kvismaren, autumn 2012. Predictions (solid lines) and confidence intervals (95%; dashed lines) are derived from 1000 model simulations using the top model estimates from the first step binomial generalized linear mixed model. For the predictions, time of day is kept constant to 0 (11 AM) and observed field area to the median size (5.30 ha) in the predictions. Circles are summarized data points, the circle size is in proportion to the number of data points.

availability probably declines due to progressive sprouting (Bautista and Alonso, 2013). I showed that the distance to roost site plays a central role for the probability of cranes at a field, which was expected, and presumably quite general, as large grazing birds should optimize their net energy intake by trading potential gain in terms of food availability against cost associated with flight distance. Thus, for a given level of food availability fields close to roost sites are more attractive (Bautista et al. 1995; Franco et al. 2000; Gill 1996).

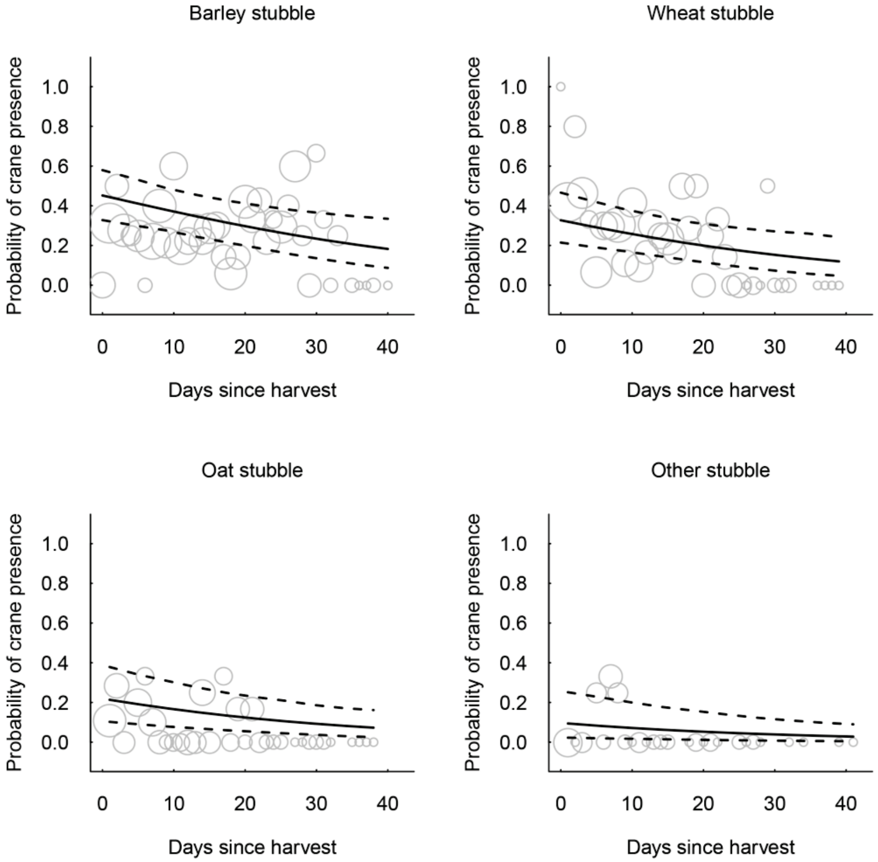

Figure 11. Probabilities of crane presence at barley, wheat, oat and other stubble in relation to time since harvest in Kvismaren, autumn 2012. Predictions (solid lines) and its confidence intervals after 1000 model simulations (95%; dashed lines) are derived from the top model estimates from the second binomial generalized linear mixed model. The time of day is kept constant to 0 (11 am), the observed field area to the median size (5.30 ha) and the distance to roost to its mean (5.70 km) in the predictions. Circles are summarized data points, circle size is proportional to the number of data points.

Time of day also influenced crane presence at the fields and peaked at midday. Earlier studies have found that large grazing birds had higher feeding activity in mornings and afternoons than during midday (Bautista & Alonso 2013; Owen 1972; Rees et al. 2005). However, the results in this study may be a consequence of a shifting aggregation pattern over the time of day; the more aggregated the fewer fields are visited *i.e.,* lower probability of visiting cranes at specific fields. The peak-shaped pattern of probability of presence may be explained by the fact that cranes leave the roost sites in large groups at dawn but later split up and distribute in smaller groups in fields during midday. In the afternoon they are known to aggregate again, most often adjacent to roost sites. Similarly, presence of pink-footed geese peaked during midday (Chudzinska et al. 2013).

6.2 Paper II: Do cranes select arable foraging sites according to the predictions from central place foraging theory?

In this paper, I showed that that the distance to roost affects selection of foraging sites in multiple ways. As predicted by central place foraging theory, cranes showed a strong selectivity for foraging sites with high food availability in the vicinity of the roost sites. However, contradictory to the prediction, the strength of selection for sites with high food availability decreased with distance to roost sites (Fig.12). My findings of high crane presence close to the roost sites is well supported by the central place foraging theory and also by earlier studies, presumably because cranes strive to reduce energetic costs of movement (Rozen-Rechels et al. 2015; Gils & W. Tijsen 2007; Elliott et al. 2009). However, the decreasing strength of selection for food availability with distance to the central place is more complex to explain. Contradictory to the results, it has been shown that cranes used high-quality sites at further distance to roost sites and higher feeding intensity at sites far from roost sites at a wintering site in Spain (Alonso et al. 1987). However, the central place foraging theory relies on the assumption that individuals have full information of the surrounding landscape to be able to optimize net energy intake (Charnov 1976; MacArthur & Pianka 1966). This assumption is presumably easily violated in agricultural landscapes because of high heterogeneity and dynamics in both time and space because of crop characteristics and farming practices (*e.g.,* harvesting and tilling) causing the spatial distribution of food to vary from day to day (Nilsson et al. 2016; Chudzińska et al. 2015). I found that

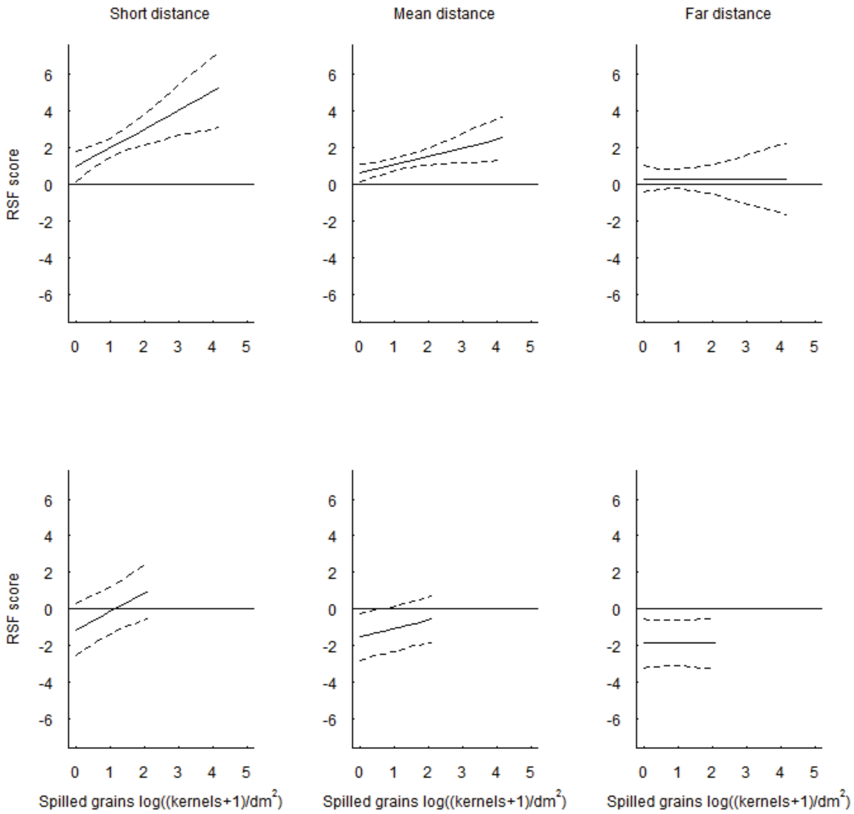

Figure 12. RSF scores (positive predicted values ± C.I indicate selection and negative values avoidance, whereas values overlapping 0 indicate use in proportion to availability) in relation to spilled grain availability ($\log_e$(kernels+1)/dm^2) at short (1.00 km), mean (5.91 km) and far (10.00 km) distances to roost sites, at wheat and barley stubble fields (upper row) and other stubbles (lower row) in Kvismaren 2013-2015. For the predictions, distance to human disturbance is kept constant to its median 0.15 ($\log_e$(km+1)). Predictions (solid lines) and confidence intervals (95%; dashed lines) are derived from 1000 model simulations using the top-model estimates. Predictions are only plotted for the range of available data on the x axis.

cranes were less selective at further distance to roost sites, which may be a result of the fact that the crane's ability to view the landscape assumedly decreases with distance to roost sites. This may be due to cranes spending more time searching for foraging sites close to roost sites, which provide them with better information and overview of the surrounding landscape in vicinity of the roost site. Also, as cranes, similar to geese, identify profitable foraging sites by using foraging conspecifics as informative cues, the relatively higher occurrence of cranes close to the roost sites may also provide better information for optimal net energy intake (Amano et al. 2006).

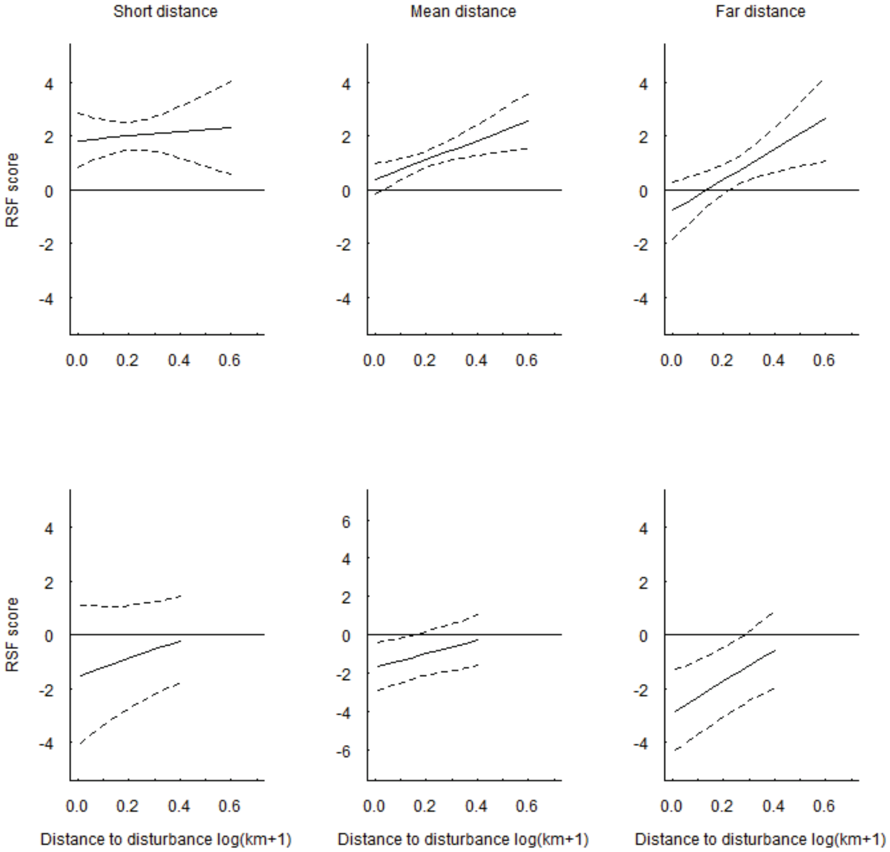

Figure 13. RSF scores (positive predicted values ± C.I. indicate selection and negative values avoidance, whereas values overlapping 0 indicate use in proportion to availability) in relation to distance to human disturbance at short (1.00 km), mean (5.91 km) and far (10.00 km) distances to roost sites, respectively at wheat/barley stubble fields (upper row) and other stubbles (lower row). Predictions (solid lines) and confidence intervals (95%; dashed lines) are derived from 1000 model simulations using the estimates from the top-ranked model. For the predictions, spilled grain availability is kept to its median 1.01 ($\log_e$(kernels+1)/dm^2)). Predictions are only plotted for the range of available data on the x axis.

The top-ranked model further indicated that selection of foraging sites in relation to features like roads and houses associated with human disturbance might be related to the distance to roost site (Fig. 13). Risk of human disturbance played a less pronounced role close to roost sites, whereas cranes increasingly selected foraging sites further away from human disturbances as the distance to roost site increased (Fig. 13). These findings are similar to the ability to find sites with high spilled grain availability. It may again be a result of cranes having better knowledge about landscape composition close to roost sites, which in combination with higher densities of conspecifics may contribute to a feeling of safety and higher risk propensity (Caraco et al. 1980). Risk of human disturbance thereby has the potential to limit the ability to select foraging sites with potentially high spilled grain availability, especially at far distances to roosts. Previous studies have found that cranes avoid areas close to roads or villages (Vegvari et al. 2011; Franco et al. 2000), and that geese and swans abandon fields when approached by humans or at high traffic intensities (Madsen 1985; Rees et al. 2005).

Moreover, the cranes´ selectivity for food availability in relation to distance to roost sites also differed between crop types on stubble fields. For example, on barley and wheat stubble, cranes selected for high food availability at short and mean distances to roost sites but the use was in proportion to availability at far distance to roost sites (Fig. 12 & 13). Similar selection for barley and wheat has been shown before, although selection patterns differ among areas due to local differences in quality and availability of crops (Nilsson et al. 2016; Sugden et al. 1988).

By combining central place foraging theory with detailed measures of food availability (*i.e.,* site quality) with crop type and disturbance risk, this study provides an enhanced understanding of why and how animals select for variable foraging sites under environmental and movement limitations due to repeated returns to the roost sites. Knowledge of how species respond to local and environmental conditions also forms the basis for risk assessment of where and when in the landscape conflicts may arise and can help managers to successfully implement conflict mitigating measures.

6.3 Paper III: Is there a mismatch between crane space use and management?

I found that mean daily activity area size used by cranes was 4.4 km² (CRI 2.8-6.0), of which 1.11 km² (0.68-1.5) was the mean for daily core activity areas (Fig. 13). Although the mean daily activity area in 2014 was slightly larger than previous years there was no difference between years (Fig. 14) or within season in either daily total or core activity areas. Seasonal activity area was on average 15.6 km^2 (9.2-22.0) and mean seasonal core activity area was 3.52 km^2 (2.0-5.1), which was approximately four times larger than the area used on a daily basis. The mean overlap between activity areas (VI) between days was about a third 0.28 (0.23-0.35) and 0.17 (0.13-0.21) for total and core, respectively. There was a clear difference between years (Fig. 14), with larger overlaps in 2013 and 2014 compared to 2012 for both daily total and core area overlap. Even though VI values were generally low, cranes often revisited

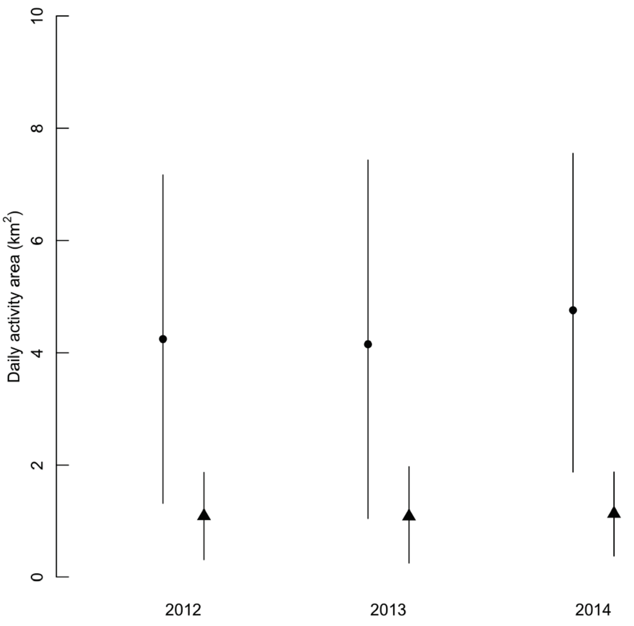

Figure 14. Predicted mean values of daily activity areas of staging common cranes, total (circles, 90 % isopleths) and core (triangles, 50 % isopleths) with 95% CRI (credible interval) each year.

areas used during previous days. The temporal effect on crane space use with high site fidelity on a seasonal scale but with lower fidelity at a daily basis is similar to the space use of foraging white-fronted geese (Wilson et al. 1991). Furthermore, I showed that fidelity decreased with increasing time (Fig. 16), which suggests that cranes gradually shifted their activity area over time. This spatiotemporal drifting of activity areas form a pattern analogous to the Olympic rings, previously also found for bears and rodents (Moorhouse & Macdonald 2005; Edwards et al. 2009). Food availability for cranes within agricultural landscapes is influenced by agricultural practices, such as crops, harvest timing, sowing and tilling (Sherfy et al. 2011; Anteau et al. 2011), as well as depletion due to consumption and germination (Lovvorn & Kirkpatrick 1982; Galle et al. 2009). Despite variation in food availability and competition within the staging season and between years (Stillman et al. 2002), I did not find any differences in size of daily activity area. Neither was there any signs of changes in space use in the late staging period due to pre-migratory

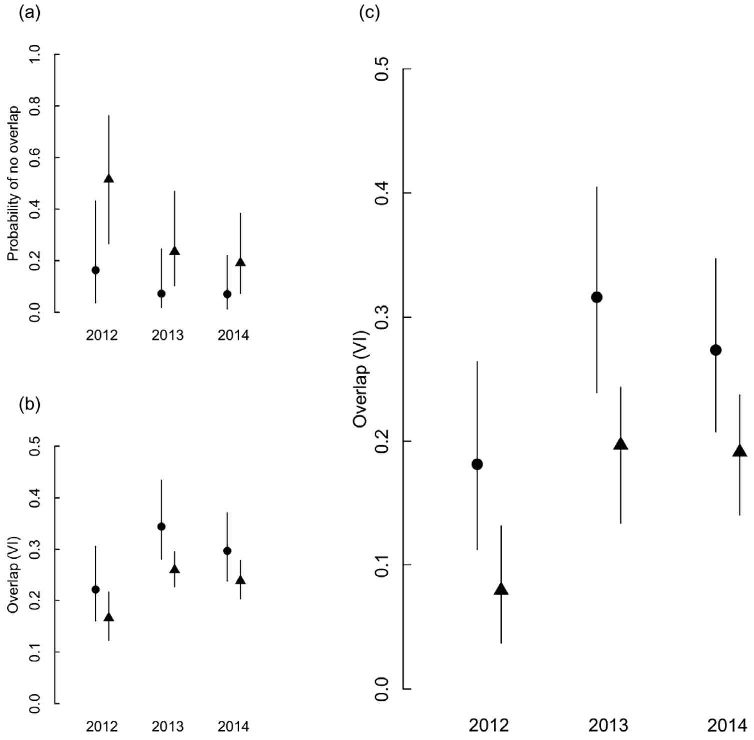

Figure 15. Predicted values with 95% CRI for daily total (circles, 90 % isopleths) and core activity area overlaps (triangles, 50 % isopleths) by cranes in Kvismaren each year 2012-2014) from (a) binary, (b) continuous and (c) the combined models.

restlessness (*c.f.* Cornelius and Hahn 2012; Eikenaar et al. 2014). The results also confirmed that the studied cranes moved according to a commuting foraging strategy, as they leave the roost site to undertake daily searches for food in a restricted and familiar area (Kareiva & Odell 1987; Weimerskirch 2007). The behaviour may indicate that food availability is homogenous and predictable at a seasonal scale with energetic advantages of site fidelity and local knowledge (Switzer 1993; Arthur et al. 2015). However, at a field and daily scale the energetic advantages of exploring and drifting to adjoining areas increases (Edwards et al. 2009; Switzer 1993), presumably as availability of food is more heterogeneous and unpredictable due to agricultural practices, weather and competition (Stillman et al. 2002; Oteros et al. 2015). Importantly,

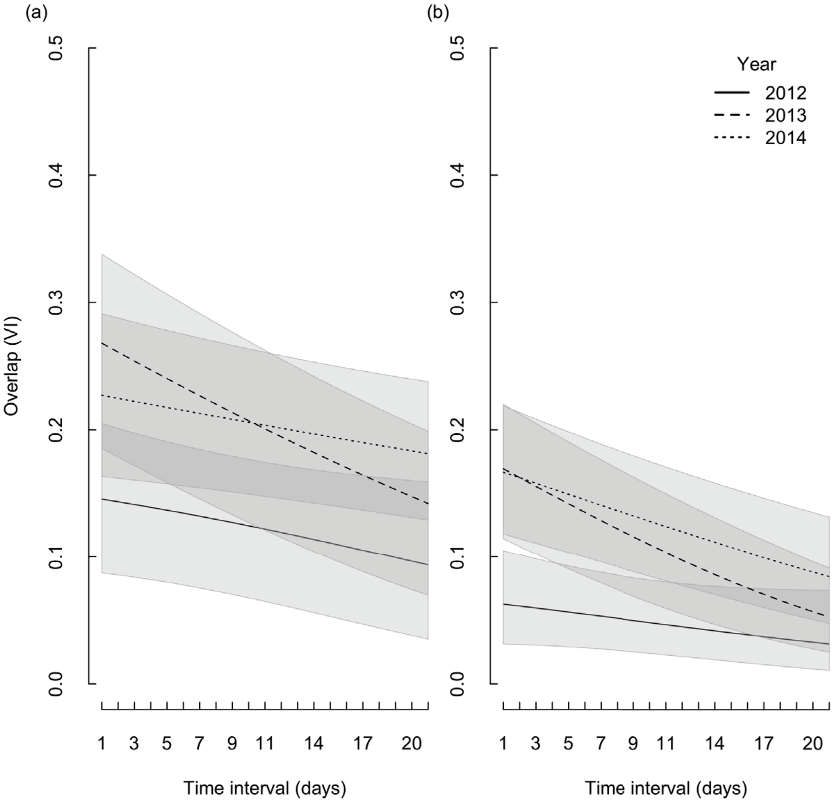

Figure 16. Predicted values with 95% CRIs for the effect of year and time interval on (a) total (90 % isopleth) and (b) core activity area (50 % isopleth) overlap of staging common cranes.

there is a mismatch between crane space use and the scale at which current management actions, such as damage prevention, is planned and implemented. For example, the size of daily activity areas (mean 4.4 km^2) shows that individual cranes cover multiple fields (mean field size 0.05 km^2) each day and may thus affect multiple farmers, whereas management actions are often implemented on a farm or even field level. Thus, management actions need to be implemented and coordinated at the scale of crane space use rather than land tenure borders.

6.4 Is the Natura 2000 network effective in serving cranes along the migratory flyway?

My findings clearly showed that the N2K network is successfully targeting cranes and thus fulfills the intention of functional habitat connectivity along the migratory flyway (EC 2016). Almost one third (30 %) of the used locations were within a N2K site, which can be compared to 10 % of the available locations. All individuals combined visited in total 98 different N2K sites, whereas each individual on average visited 6.2 ±5.8 (S.D.) unique N2K sites (range = 0-22). This may however be an underestimation of the number of visited sites as not all individuals are followed during the full study period. I also found that 59 % of the used roost locations were within N2K sites, which was also supported by the model demonstrating that N2K sites are mainly used for roosting in wetlands (Fig. 17). Such a dual habitat selection, although previously not linked to N2K sites, is well supported by prior knowledge of crane behavior (Vegvari & Tar 2002; Alonso et al. 1983). The overall effectiveness of the N2K network has been criticized mainly due to the lack of coordination between member states during implementation, resulting in low functional connectivity within the network (Popescu et al. 2014; Opermanis et al. 2012; Opermanis et al. 2013). However, the effectiveness of sites varies greatly due to the listed species life history characteristics and distribution (Orlikowska et al. 2016; Dimitrakopoulos et al. 2004; Żmihorski et al. 2016). The effectiveness of N2K sites in protecting species with restricted

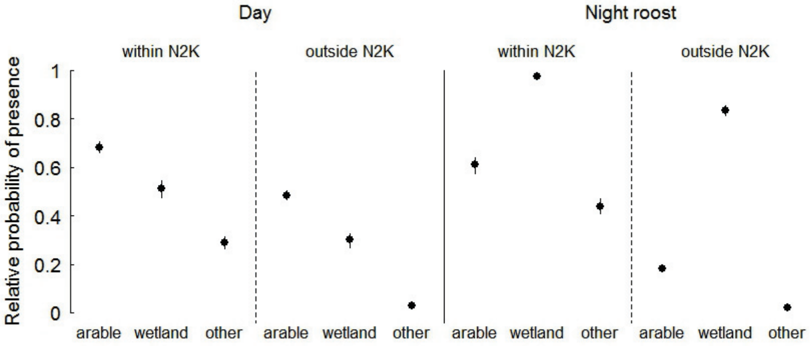

Figure 17. Relative probability of crane presence at arable, water/wetlands and other land during day and night within and outside N2K sites. The predicted estimates and their 95% confidence intervals are produced from 1000 model simulations based on the estimates from the top-ranked model.

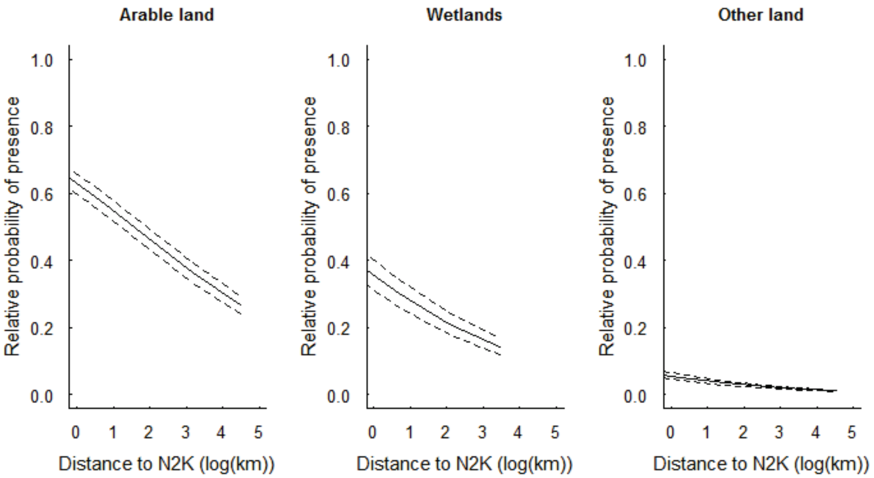

Figure 18. Relative probability of crane presence in relation to distance to nearest N2K site ($\log_e$(km)) at arable land, water/wetlands and other land along the flyway. The solid lines are predictions with their 95% confidence intervals as dashed lines. Predictions are only plotted for the range of available data at the x axis.

distribution, such as the cricket *Paracaloptenus caloptenoides,* has been proven to be insufficient, whereas mobile species, like the cranes according to my findings, or the European otter *Lutra lutra,* are often well served by the N2K network (Gruber et al. 2012).

Despite the great efficiency in serving cranes, the majority of cranes spent their days (70 % of used locations) outside N2K sites and predominately on arable land. The probability of crane presence at arable land close to N2K sites was high (0.65) but gradually decreased with increasing distance to nearest N2K site border, which show that there is an apparent spillover of cranes from N2K sites to adjacent arable land (Fig. 18). In general, protected areas are often too small to fulfil the spatial and energetic requirements particularly for migratory species (Woodroffe 1998; Thirgood et al. 2004). Consequent spillover effects often enhance conflicts with human interests in the surrounding landscape (Newmark et al. 1994; Naughton-Treves 1998) and have, for example, been observed for barnacle geese grazing on arable land in Scotland (Cope et al. 2003). Accordingly, when cranes congregate in large numbers, their foraging activity leads to significant risk of damage to crops (Frank et al. 2016; Salvi 2010; Anon 2016).

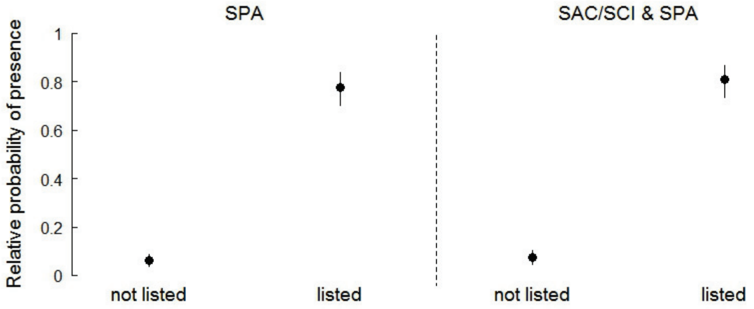

Figure 19. Relative probability of crane presence in N2K sites designated under the Birds Directive (SPA) versus sites designated under both Birds Directive and Habitats Directive (SPA &SAC/SCI &SPA) as well as the crane probability in N2K sites where cranes are listed in the site management plan (i.e. standard form) or not. The predicted estimates and their 95 % confidence intervals are produced from 1000 model simulations based on the estimates from the top-ranked model.

Furthermore, N2K sites where cranes were listed as a target species in the site-specific management plan were also the most efficient in serving cranes. This is likely because cranes were already present when the site-specific management plan was implemented, but probably also a result of retained on-site management measures to improve conditions for the cranes. However, the sites were only marginally more effective in targeting cranes when assigned under both the Birds Directive (SPA) and the Habitats Directive (SAC/SCI) compared to sites assigned under the Birds Directive alone. This suggests that the effectiveness of N2K sites is independent of site type. To conclude, the N2K network was effective in targeting cranes and thus fulfills its conservation intentions. However, the majority of daily foraging activity was still on arable land in the vicinity of the N2K sites, which may fuel a multi-faceted conflict between conservation interests of the imposed N2K sites and farming practices and thus risking the intention of socio-economic sustainability.

7 Management implications and future perspectives

Crop damage preventive measures today mainly include scaring, undisturbed diversionary fields and restricted culling (Nilsson et al. 2016; Hake et al. 2010). My results and previous evidence-based findings can inform management in their decisions and thereby improve damage mitigation and conservation of large grazing birds in the agricultural landscape. However, this needs to be achieved within a framework that acknowledges current international legislation and directives, which also may restrict the use of certain measures such as culling. On the other hand, Article 9 in the Birds Directive clearly states that EU countries are allowed to take actions 'to prevent serious damage to crops, livestock, forests, fisheries and water' or 'for the protection of flora and fauna' (EC 2009).

7.1 Preventive strategies in a heterogeneous landscape

My findings clearly exemplify that the probability of crane presence is influenced by the characteristics of fields (*i.e.,* distance to roost site, food availability, risk of human disturbance, time since harvest, crop type and crop stage; see Fig. 20 for schematic overview). Therefore agricultural landscapes should not be considered as homogenous areas, but rather as a mosaic of fields where the success of damage preventive measures and damage risk is dependent on environmental factors and farming practices (Papers I & II, Fig. 20).

7.1.1 Diversionary fields

Damage prevention should focus on providing stubble fields with high availability of spilled grain throughout the staging season to divert the birds away from unharvested and newly sown fields (Papers I & II). This can be achieved by careful crop rotation planning of winter-sown versus spring-sown cereals, *e.g.,* wheat and barley, to alternate timing of harvest and ploughing. As agricultural systems are dynamic and site-specific due to soil and climatic conditions and yearly crop rotation, such strategies need to be adapted to local conditions. Another factor that may restrict flexibility might be crop rotation to avoid weeds and pathogens but also national and international policies and conventions (*e.g.,* the Common Agricultural Policy) (Cope et al. 2003; Henle et al. 2008). Changes in crop choice may lead to higher costs for farmers that potentially could be compensated by subsidies to increase the acceptance for adapting agriculture practices to the birds (Hake et al. 2010). Supplemental provisioning of grain may also be an option to minimize effects of food depletion.

7.1.2 Scaring and culling

My studies mostly allow for recommendations for the use of diversionary fields, but the findings also apply for scaring practices and culling. According to my findings, scaring and culling should mainly be conducted in fields where the risk of crop damage is high, such as in unharvested cereal fields close to the roost sites. To successfully steer the large grazing birds away from vulnerable crops, scaring and culling should preferably be performed in combination with diversionary fields where the birds can forage undisturbed. These strategies could for example be implemented in buffer zones surrounding the wetland roost sites (see 7.1.3 Buffer zones, below).

7.1.3 Buffer zones

Buffer zones with special strategies or management is a common feature to alleviate impact on land within or surrounding protected areas and is applied around many wildlife reserves and sensitive forest environments (Bamford et al. 2014; Correll 2005; Wells & Brandon 1993). This way of planning may also be suitable in the crane/agriculture/wetland system as I show that there is an amplified risk of crane presence and damage to growing and newly sown crops in the vicinity of protected wetlands, often also assigned as Natura 2000 sites (Papers I, II & IV). The intensity of crop damage prevention should preferably be higher within buffer zones and especially diversionary fields as distance to roost sites highly influences field selection. It could also be beneficial to compensate or make incentive payments to farmers that adapt farming practices *e.g.,* to increase available area of stubble fields. The results from Paper IV also confirm that spillover of cranes from protected N2K sites to arable land is important along the flyway. In addition, buffer zones may help to fulfill the spatial and energetic needs of large grazing birds in connection to protected areas. Such buffer zones and compensation measures should preferably also be considered from the beginning *i.e.*, when planning and restoring wetland reserves.

7.1.4 Appropriate spatial scale for management

Independent of measures taken to prevent damage from large grazing birds, it is important to consider an appropriate spatial scale for implementation. Many preventive measures in Sweden are planned and conducted on a relatively small scale (*i.e.,* field and farm level). For example, culling permits are most often issued for a few specific fields during a limited time period (J.M. Wikland, Örebro County Administrative Board, pers. comm.). Also, measures to prevent damage are often conducted uncoordinated and as a reaction to presence of birds rather than preventively. The importance of increasing the scale of current management to better match crane space use was found in one of my studies (Paper III). I showed that cranes on average put 88 fields at damage risk each day when based on mean field size in Kvismaren (0.05 $km^{2)}$ and more than 300 fields during the whole staging period). In the light of my findings I suggest that measures (*e.g.,* scaring, culling, diversionary fields) should be coordinated over large areas in order to adjust measures to the individual crane’s space use during the staging period. One way to coordinate and get an overview of the measures taken within the entire staging site is to employ consultants for organising scaring and diversionary feeding between farmers and borders of land tenure.

7.2 Stakeholder participation and international collaboration

In Paper IV, I show that cranes select for N2K sites just as intended, but this may also fuel a multi-faceted conflict between the conservation interests of the imposed N2K sites and agriculture, which may risk the intention of socio-economic sustainability of the network. Overall, the N2K network have been described as a ‘hotbed’ of conflicts (Grodzinska-Jurczak & Cent 2011) mainly due to deficient involvement of local stakeholders and landowners, lack of coordination between the responsible authorities, land use restrictions (*e.g.,* altered grazing regimes, water rights), increased administrative workload, as well as inadequate financial compensation to affected landowners (Bouwma et al. 2010; Blicharska et al. 2016; Andrea et al. 2014). Increasing crop damage caused by cranes and other large grazing birds may enhance reluctance towards the N2K network and add to the conflict of land use restrictions due to N2K site management (Bouwma et al. 2010; Popescu et al. 2014; Blicharska et al. 2016). For example, managers at the County Administrative Boards in Sweden have experienced an increasing unwillingness from farmers to participate or contribute to wetland restorations due to the risk of increasing numbers of cranes and geese and the associated damage (J.M. Wikland, pers. comm). One way to alleviate such conflicts would be intensified measures and compensation in the vicinity of important staging sites. In Sweden, crop damage caused by greylag geese are generally not compensated as local culling is allowed year round when greylag geese are causing damage. However, recently, the Swedish Environmental Protection Agency changed recommendations to the County Administrative Boards and now recommend compensating farmers in buffer zones around protected areas as local conservation measures may have attracted geese (Månsson et al. 2015). However, there is no general strategy to compensate farmers and landowners within or close to protected areas within the EU and the strategies among countries range from complete lack of compensation, to contracts between authorities and landowners and land purchase (Bouwma et al. 2010; Andrea et al. 2014). However, the European Commission does endorse that compensations within Natura 2000 sites should be paid by the Common Agricultural Policy or occasionally with funding from LIFE projects (EC 2014). Although needed, there is currently no systematic compensation scheme for crop damage caused by protected birds on a European level, although it occurs in some member states like Sweden, Germany and France (Frank et al. 2016; Salvi 2010, H. König, pers. comm.). In Sweden, compensation is based on market prices and are paid after standardised inspections by regional authorities (Månsson et al. 2011).

My findings provide scientific evidence to inform management practices, but management of conflicts between conservation and agricultural interests is complex and requires not only scientific evidence and compensation strategies but also social aspects. Such social aspects can be international cross-boundary collaborations and a bottom-up approach through stakeholder participation and inclusion of local knowledge when deciding for or against management policies and measures (Blicharska et al. 2016; Peloquin & Berkes 2009; Kark et al. 2015). In Sweden, local stakeholder groups including farmers, ornithologists, hunters, researchers and managers have been encouraged to increase stakeholder participation in the management process (Hake et al. 2010). These groups meet a few times per year to share their perspectives on farming, damage levels, bird watching, hunting, conservation and to advise the county administrative boards where and when to allocate resources for damage prevention. These management groups have led to improved understanding between the different interests and can also help to implement new knowledge such as the findings in this study and previous studies, in an adaptive management framework (Maxwell et al. 2015; Hake et al. 2010; Young et al. 2016).

I showed that there is a risk for crop damages and interest conflict along the flyway but there are still no international, cross-border collaborations initiated by the European Commission on how to handle cranes or other protected species that cause damage within and in the vicinity of the N2K sites. Here, the adaptive and evidence-informed flyway management plan for pink-footed goose (UNEP 2016) can serve as a good example on how to collaborate across national borders (Madsen & Williams 2012). In this flyway management plan, countries like Norway, Denmark and the Netherlands have agreed on a joint population target together with stakeholders. The population size is estimated on an annual basis and the population is regulated if needed and so is the targeted population level if the management do not reach its intended goals (Madsen 2015; Madsen & Williams 2012).

Many of the preventive measures and strategies (scaring, diversionary fields *etc.*) used today and for which I provide guidelines will likely demand an increased effort in the future. The modern agriculture provides large amounts of food for these birds and a continued increase would not be surprising. In the case of larger populations it is questionable if these strategies alone are a long-term solution and population regulation may need to be considered such as was the case for the Svalbard population of pink-footed geese. However, more adapted management and conservation would be needed so that the population dynamics is also mirrored in conservation efforts. For example, the species lists in the Birds directive (annex I-III) would need a similar systematic revision as the IUCN Red list applies to adopt a more adaptive management, (Davis et al. 2014; Cogălniceanu & Cogălniceanu 2010; Cardoso 2012; IUCN 2016). As populations of cranes and other large grazing birds along the Western-European flyway are increasing, *e.g.,* with hundreds of thousands staging cranes at specific Natura 2000 sites (Anon 2016), there will most probably be an increased need for long-term solutions across national borders in the future.

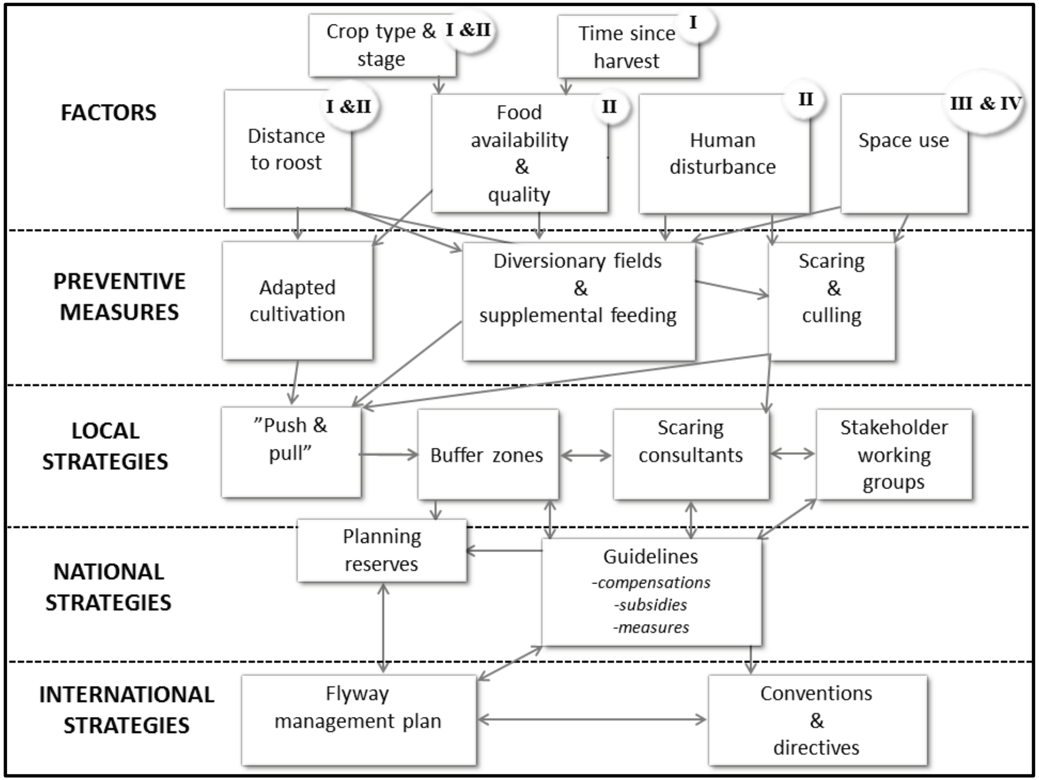

Figure 20. The studied factors and potential information linkage to measures and strategies of conservation and crop damage prevention. Roman numbers represent the studies where the factors have been studied.
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7.3 Future research needs

In Figure 20 I schematically show how the results from my studies can be used to inform and likely improve conservation and crop damage preventive strategies. However, there are still many additional aspects that may affect management performance and that are not covered in my thesis. Below I list some aspects which hence need further consideration in future research to further improve the management of large grazing birds:

- The influence of competition from conspecifics and other large grazing bird species on staging- and foraging site selection. As many of the large grazing bird species occur simultaneously at staging sites, there is also a need for multispecies management strategies.
- An assessment of what factors that can be generally applied to the management of large grazing birds and also what factors that are specific for species or localities.
- Crop damage levels in relation to foraging patterns, densities of large grazing birds and timing of harvest practices.
- Efficiency of crop damage preventive measures need to be further evaluated.
- Effects of human disturbances and scaring practices on behaviour and fitness of large grazing birds and other co-occurring species.
- Large grazing birds potentially do not only cause impact on agricultural land, but also on other bird species through predation and intense grazing. Further research on the large grazing bird species impact on other species and consequent ecosystem effects is thus needed.
- To alleviate interest conflicts linked to large grazing birds, social factors need to be considered in the management process. Such aspects could be strategies for conflict mitigation, mapping stakeholder interests, how to include stakeholders in the decision process and potential effects on stakeholder´s trust for authorities.

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9 Svensk sammanfattning

Djurens beslut om var, vad och när de ska söka föda, finna skydd och reproducera sig påverkar deras rörelsemönster på olika rumsliga skalor. Dessa beslut påverkar i sin tur överlevnad och reproduktionsframgång, men även ekosystemfunktioner och det mänskliga användandet av naturresurser. Påverkan på användandet av naturresurser leder ofta till konflikter mellan olika intressen som naturvård och areella näringar som jord- eller skogsbruk, då många av de arter som påverkar dessa näringar är fredade. Hanteringen av sådana konflikter är ofta svåra eftersom många djur rör sig över stora områden och förflyttar sig över administrativa gränser som kommuner, län och länder.

Naturreservat och habitatrestaureringar är ett vanligt sätt att förbättra livsutrymmet för skyddade arter. Naturreservaten är dock ofta för små för att rymma djurens behov, vilket gör att de söker sig ut på omkringliggande marker. På så vis uppstår en ökad skaderisk kring restaurerade och skyddade områden. Att förebygga dessa skador är därmed viktigt för att mildra konflikten mellan naturvård och de areella näringarna. Om de skadegörande arterna är fredade är åtgärderna begränsade till sådana som inte påverkar populationsstorleken negativt. Genom att studera djurens behov, till exempel födosök- och rörelsemönster, kan man både bedöma risken för påverkan på jord- eller skogsbruk och förbättra förebyggande åtgärder för att minska densamma.

9.1 Tranor, gäss och svanar ökar i antal

Många arter av tranor, gäss och svanar (stora betande fåglar) ökar i antal i Europa och Nordamerika som ett resultat av lyckad naturvård (till exempel ökat skydd och våtmarksrestaureringar) och ett moderniserat jordbruk som erbjuder fåglarna mycket mat av hög kvalitet. Några få arter, som sädgås och fjällgås, visar dock fortfarande stabila nedåtgående populationstrender.

Stora betande fåglar söker skydd i våtmarker och födosöker inte sällan på omkringliggande åkrar. Under rastperioderna sammanfaller därför ofta övernattningsplatserna med skyddade våtmarker, som Natura 2000-områden. Tranor är allätare, men födan består till stor del av spannmål (spillsäd och oskördat) under rastperioderna. Gäss å andra sidan är strikta herbivorer och betar gärna på vallar, strandängar, nysådda spannmålsåkrar och under höstarna även i moget spannmål och spillsäd. Födotillgången i jordbrukslandskapet är mycket dynamiskt på grund av aktiviteter som nysådd, skörd och plöjning, vilket medför att förutsättningarna för fåglarnas födosök kan förändras från dag till dag.

Fåglarnas födosöksmönster och rumsliga utnyttjande av landskapet påverkas av en rad faktorer som avstånd till övernattningsplats, födotillgång, mänsklig störning, grödotyp och vilket stadium grödan befinner sig i. När de födosöker på växande grödor orsakar de ofta skördeförluster för lantbrukarna, vilket skapar konflikter mellan jordbruks- och naturvårdsintressen. Syftet med den här avhandlingen är att öka kunskapen om tranornas rumsliga utnyttjande och födosöksmönster i jordbrukslandskapet och att länka den till bevarande och skadeförebyggande åtgärder.

9.2 Studieområde och metoder

Mitt huvudsakliga studieområde var Kvismaren, en unik våtmarksmiljö mitt på Närkeslätten strax sydost om Örebro. Två skyddade våtmarker är omgärdade av högproduktiv jordbruksmark där korn, vete och potatis är de huvudsakliga grödorna. Kvismaren är en av Sveriges viktigaste fågelsjöar, med mängder av häckande och flyttande fåglar. Under vår och höst samlas tusentals rastande tranor och gäss (grågäss, sädgäss, vitkindade gäss samt ett mindre antal bläs- och spetsbergsgäss) i området för att äta upp sig inför vår- och höstflyttarna. En del stannar även för att häcka. Det högsta antalet tranor som räknats hittills är 19 500 tranor hösten 2012.

Jag använde mig av data från både flockinventeringar (studie I) och GPS-märkta individer (studie II-IV). Dessa data kombinerades med inventeringar i fält av grödostadium (stubb, plöjt och så vidare) och födotillgång samt av bakgrundskartor i GIS för att få fram avstånd till bland annat övernattningsplats, vägar och hus (studie I & II).

9.3 Studie I: Vilka faktorer påverkar tranornas användande av åkrar?

Syftet med studien var att förstå vilka faktorer som påverkar tranornas val av åkrar. Jag undersökte hur grödostadium, grödotyp, avstånd till övernattningsplats, tid på dagen och tid efter skörd på stubbåkrar påverkar sannolikheten för att tranor ska besöka specifika fält. Resultaten visade att stubbåkrar hade högst sannolikhet att få tranbesök medan sannolikheten avtog gradvis för vall och bete, bar jord och växande gröda. För en stubbåker 5 km från övernattningsplatsen var sannolikheten för tranbesök 0.25 (0.1-0.32; 95 % konfidensintervall). Sannolikheten för tranor på olika fält minskade även linjärt med avståndet till övernattningsplatsen, exempelvis minskade sannolikheten för tranor på växande gröda från 0.09 (0.06-0.15) till 0.05 (0,03-0.07) när avståndet ökade från 1 km till 5 km från övernattningsplatsen. På stubbåkrar avtog sannolikheten för tranor med tid efter skörd. Sannolikheten för tranor var över lag högst på kornstubb för att sedan successivt avta på vete-, havre- och annan stubb. Prediktioner från mina modeller visade att sannolikheten för tranor generellt kunde vara hög om alla faktorer var gynnsamma; till exempel var sannolikheten för tranor på en kornstubb, en dag efter skörd och 1 km från övernattningsplatsen 0.60 (0.42-0.77).

9.4 Studie II: Hur påverkas tranors födosök av avstånd till övernattningsplats?

För att kunna förutsäga tranors fördelning i ett jordbrukslandskap krävs kunskap om på vilka grunder de väljer olika fält. En grundläggande födoresurs för tranorna är spillsäd. Enligt den ekologiska teorin ”Optimal foraging theory” värderar djur möjliga födointag gentemot den energetiska kostnad de skulle innebära (till exempel att flyga till olika platser och vilken ansträngning som skulle krävas för att få i sig och smälta födan), för att maximera energiintag och fitness. Tranors rörelsemönster begränsas dock av att de regelbundet återvänder till sin övernattningsplats, vilket man måste ta hänsyn till när man studerar deras födosöksmönster. ”Central place foraging theory´” är en alternativ teori, som inkluderar det regelbundna återvändandet till övernattningsplatsen och förutspår att sannolikheten för att ha födosökande tranor på ett visst fält avtar med avståndet till övernattningsplatsen. Teorin förutspår även att tranorna väljer fält med hög födotillgång när avståndet till övernattningsplatsen är stort för att kompensera för den energikostnad flygsträckan innebär.

Syftet med den här studien var dels att testa om tranorna väljer fält enligt ”Central place foraging theory”, dels att undersöka om födosökmönstren även påverkas av mänsklig störning och av vilken gröda det är på fälten. Som teorin förutspår fann jag att tranorna valde åkrar nära övernattningsplatsen och att sannolikheten för tranbesök på ett visst fält minskade gradvis med avståndet till övernattningsplatsen. Jag fann även att tranorna valde åkrar med stor födotillgång nära övernattningsplatsen, men att förmågan att finna åkrar med hög födotillgång avtog när avståndet ökade. Resultaten går därmed till viss del stick i stäv med vad som förväntas enligt ”Central place foraging theory”. Tranorna visade sig vara relativt toleranta mot mänsklig störning nära övernattningsplatsen, men valde åkrar längre bort från störning när avståndet till övernattningsplatsen ökade. Resultaten beror troligen på att tranorna inte har möjlighet att ha fullständig överblick över vad det dynamiska jordbrukslandskapet har att erbjuda och att den förmågan sannolikt avtar med avståndet till övernattningsplatsen.

9.5 Studie III: Hur ortstrogna är tranor?

Syftet med den här studien var att undersöka hur stora aktivitetsområden tranor använder under rastning, både på daglig- och säsongsbasis. Jag ville även studera om storleken förändrades under rastperioden och mellan år, vilket man kan förvänta sig eftersom förutsättningarna i landskapet ändras över tid. Syftet var även att undersöka hur ortstrogna tranorna var till de dagliga aktivitetsområdena.

Jag fann att de dagliga aktivitetsområdena (kernel 90 %) i snitt var 4.4 km^2 (2.8-6.0 km^2; 95 % konfidensintervall), av vilket en fjärdedel var kärnområde (kernel 50 %) på 1.11 km^2 (0.68-1.5 km^2). Däremot fann jag inga resultat som pekade på att aktivitetområdena förändras i storlek under rastperioden trots förändringar i tillgänglighet av olika grödostadier och att antalet tranor kontinuerligt ökar i området under den perioden. Jag fann heller inte några skillnader i storlek på aktivitetsområden mellan år. Totalt använde tranorna aktivitetområden som var ungefär fyra gånger så stora som de dagliga aktivitetsområdena: 15.6 km^2 (9.2-22.0 km^2) under hela rastperioden.

Jag fann att tranorna delvis återkom till samma dagliga aktivitetsområden och att det genomsnittliga överlappet mellan de dagliga aktivitetsområdena var 0.28 km^2 (0.23-0.35 km^2) och 0.17 km^2 (0.13-0.21 km^2) för kärnområdena. Det var även en tydlig skillnad mellan år då ortstrogenheten generellt var högre (2013 och 2014) och då den var lägre (2012). Även om överlappen generellt inte var så stora återbesökte tranorna områden som de besökt någon gång de senaste tre dagarna i 88 % av fallen. Ortstrogenheten till ett visst område avtog med tiden, vilket visar att tranorna successivt byter dagliga aktivitetsområden, vilket kan jämföras med de överlappande ringarna i symbolen för de Olympiska spelen. Det beror troligen på att jordbrukslandskapet förändras från dag till dag på grund av jordbruksaktiviteter som tröskning, plöjning och nysådd och att fler och fler tranor kommer till området för att födosöka inför flytten söderut. Det lönade sig sannolikt att upptäcka nya områden när nya resurser uppstod, maten tog slut eller konkurrensen blev för stor.

Mina resultat påvisar en tydligt dålig matchning mellan storleken på de områden som tranorna använder och det skadeförebyggande arbetet som pågår idag. De visar till exempel att en tranindivid potentiellt kan utsätta i genomsnitt 88 åkrar för skaderisk under en dag och 312 fält under en rastperiod. Det innebär att de skyddsjaktstillstånd som idag oftast ges till en enskild lantbrukare för ett fåtal fält under en relativt begränsad tid istället borde ges till flera lantbrukare och åkrar under hela rastperioden. Vidare bör avledningsåkrar anläggas på fler ställen och mer utspritt än vad som görs i nuläget för att täcka så många individers aktivitetsområden som möjligt.

9.6 Studie IV: Attraherar Natura 2000-områden tranor?

Migrerande djur som tranor rör sig över stora områden, vilket gör att det är svårt att skydda dem på ett effektivt sätt. En vanlig åtgärd är att skydda områden för att gynna de habitat tranorna är beroende av. De skyddade områdena lyckas dock inte alltid fylla tranornas behov. Om så är fallet flyger tranorna ut i det omkringliggande jordbrukslandskapet för att födosöka, vilket medför en skaderisk på grödor. För att öka förbindelserna mellan skyddade områden och för att implementera fågel- och habitatdirektiven har EU initierat Natura 2000-nätverket som totalt täcker nästan 20 % av EU:s landyta.

Syftet med studien var dels att utvärdera om Natura 2000-områdena fyller sitt ändamål att skapa förbindelser mellan habitat längs tranornas flyttvägar, dels att undersöka om sannolikheten var högre att tranorna födosökte i närheten av Natura 2000-områden. Jag fann att nätverket är effektivt i avseende att attrahera tranor längs deras flyttväg. Naturvården har lyckats utse och restaurera områden som verkligen väljs av tranorna. Tranorna använder främst Natura 2000-områdena för övernattning, men även till viss del för födosök på åkrar under dagarna. Trots att tranorna valde Natura 2000-områden, så fann jag att majoriteten av den dagliga tiden (70 %) spenderades på jordbrukmark utanför dessa. Jag fann även att sannolikheten för att ha tranor på jorbruksmark var som högst nära Natura 2000-områden, men att sannolikheten gradvis avtog när avståndet ökade.

Mina resultat påvisar en ökad risk för skador på gröda i närheten av Natura 2000-områden. Utöver denna skaderisk medför Natura 2000-områden ofta restriktioner i markanvändandet för lantbrukare. Sammantaget leder dessa faktorer till konflikter mellan olika intressen och misstro mot de myndigheter som genomför naturvårdsåtgärder. Dessa intressekonflikterna är ibland mycket svåra att lösa. Det är därför viktigt att skadeförebyggande åtgärder prioriteras i närheten av dessa områden och att olika intressegrupper involveras i de skadeförebyggande och bevarande åtgärder som genomförs.

9.7 Implikationer för förvaltningen

För att kunna utveckla skadeförebyggande strategier och att lindra intressekonflikten så krävs kunskap om hur tranor rör sig och födosöker i jordbrukslandskapet. Sådana strategier behöver dessutom beakta rådande direktiv och nationella lagar. Trots att tranorna är skyddade i EU:s fågeldirektiv så får myndigheter och privatpersoner göra vissa åtgärder för att 'förhindra allvarlig skada på gröda, boskap, skog, fiske och vatten' eller för att 'skydda flora och fauna'. De förebyggande åtgärder som används idag är främst skrämsel, avledningsåkrar och skyddsjakt.

9.7.1 Skadeförebyggande åtgärder

De resultat jag fann visar att jordbrukslandskapet är en mosaik av åkrar där sannolikheten för födosökande tranor på fälten beror på avstånd till övernattningsplatsen, födotillgång, mänsklig störning, gröda, grödostadie och tid sedan skörd. Alla dessa faktorer påverkar tillsammans risken för skada på olika fält och bör därför tas i beaktande när man genomför skadeförebyggande åtgärder.

I enlighet med de resultat jag fått så bör skadeförebyggande åtgärder under rastperioden på hösten fokusera på att bibehålla och tillgodose tranorna med stubbåkrar där de kan födosöka utan att orsaka skada på gröda. Det idealiska är om stubbåkrar med hög tillgång på spillsäd får ligga kvar utan att plöjas till dess att tranorna har flyttat söderut. Det här kan delvis åstadkommas genom att planera växtföljden med vår- och höstsådda spannmålsgrödor så att skördetiden under hösten varierar. Man kan även sprida spannmål på stubbåkrar för att hålla dem attraktiva för tranorna under längre tid. Förändringar i växtföljden kan däremot innebära förhöjda kostnader för lantbrukarna vilket förslagsvis kan ersättas med statliga medel för att öka acceptansen för sådana åtgärder.

Vidare fann jag att tranorna helst födosöker nära övernattningsplatsen vilket innebär att det kan vara fördelaktigt att planera zoner för extraordinära insatser ”buffertzoner” kring naturreservat där tranorna övernattar. I buffertzonerna bör skadeförebyggande åtgärder prioriteras och lantbrukarna som påverkas kan ersättas för eventuella grödoskador som uppstår. De skadeförbyggande åtgärderna bör bestå av skrämsel på växande grödor samt att se till att avledande stubbåkrar finns tillgängliga där tranorna kan födosöka ostört.

9.7.2 Internationellt samarbete och dialog med intressegrupper

För att kunna hantera och lösa konflikter mellan naturvården och jordbruket så krävs inte bara kunskap om tranornas ekologi. Man behöver även tänka på mänskliga aspekter så som involvering av intressegrupper från lokal till internationell nivå samt att samarbeta över administrativa gränser. I Sverige har man på flera av tranornas rastplatser skapat arbetsgrupper där representanter från olika intressegrupper som t.ex. lantbrukare, handläggare från länsstyrelse, besiktningsman, skrämselansvarig, forskare, jägare och fågelskådare, träffas och diskuterar problemetiken kring tranorna och vilka åtgärder som bör prioriteras i tid och rum.

Eftersom att många arter av stora betande fåglar ökar i antal så kan man förutspå att också nivåerna av grödoskador kommer att öka. Ökande skadenivåer innebär också att arbetsinsatserna som krävs för att förebygga skador med till exempel skrämsel och avledningsåkrar också kommer att öka och det finns ett stort behov av mer långsiktiga lösningar. På internationell nivå finns det inga tydliga gränsöverskridande riktlinjer om hur intressekonflikterna och skadeproblematiken bör hanteras långsiktigt. Här kan den flyttvägshandlingsplan ”flyway management plan” som nyligen upprättats för spetsbergsgäss bidra med ett gott exempel på hur man kan samarbeta kring förvaltningen av en migrerande art över landsgränserna. I handlingsplanen har bland annat Norge, Danmark och Holland gått ihop och satt ett gemensamt mål för populationsstorleken tillsammans med berörda intressegrupper. Populationsstorleken uppskattas årligen och populationen regleras med jakt för att nå uppsatta populationsmål och förvaltningen blir på så vis mer adaptiv. Det finns även ett behov av att synkronisera artlistorna i fågeldirektivet med till exempel IUCN:s rödlista. Artlistorna skulle med fördel behöva en systematisk revision likt den som IUCN genomför var femte år för att kunna genomföra en mer adaptiv förvaltning av tranor och andra stora betande fåglar samt för att sammanföra nuvarande direktiv, policys och Natura 2000-nätverket.

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