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Movement patterns of common cranes at European stopover sites

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Abstract

The common crane *Grus grus* is a migratory bird with a wide distribution across Europe and Asia. During the migration the cranes rest at stopover sites were they roost in wetlands and forage on surrounding fields in the farmland. Due to an increase of the European population over the last decades, damage to crops has increased and so the conflicts between cranes and farmers. Therefore, knowledge about the movement of cranes is not only important for an increased understanding of the ecology and behaviour of the species, but also important from a crop damage preventative management perspective. This study has investigated the size of activity areas and flight distances from the roost of juvenile cranes on different stopover sites during the autumn migration, by using GPS transmitters. The results showed that average size of activity area was 31.5 km^2 and the average flight distance from the roost was 4.5 km. I found significant variation in both size of activity area and flight distance from roost between the countries along the flyway. Activity areas also varied between stopover sites and no clear latitudinal trend was found, which indicates that the variation rather depend on differences in local conditions. My study provides insight into the movement pattern of cranes, which could be applied when planning crop preventative measures in agricultural areas.

Populärvetenskaplig sammanfattning

Förståelse för djurarters rörelsemönster är av högsta betydelse för att kunna hantera problem inom bevarande- eller förvaltningsarbete. Genom att studera hur ett djur rör sig kan vi skaffa oss kunskap om dess beteende och ekologi, vilket kan användas vid planering av förebyggande åtgärder för att exempelvis förhindra konflikter mellan människor och djur. Ett exempel på storskaligt rörelsemönster är migration. Många fåglar migrerar varje år i syfte att finna bättre födo- eller häckningsområden. På grund av sin flygförmåga är fåglar inte begränsade av geografiska barriärer på samma sätt som landlevande eller havslevande djur och de kan därför färdas långa sträckor. Tranan är en flyttande fågel som har en stor utbredning i Europa, från västra Europa till östra Ryssland. Tranor som häckar i Sverige tillhör den västeuropeiska populationen och övervintrar främst i Frankrike och på den Iberiska halvön. Innan flytten samlas tranorna i stora flockar på rastlokaler där de äter upp sig inför den långa resan. Rastlokalen består i princip alltid av en våtmark eller en grund sjö där tranorna står under natten, samt omgivande jordbrukslandskap där de främst söker föda på stubbåkrarna under dagen. Tranan migrerar stegvis och stannar på flera liknande rastlokaler under flytten och hela flytten kan ta flera månader att genomföra. Då tranor flyttar i stora flockar kan de orsaka stor skada på omgivande åkrar och fält på de lokaler tranorna rastar vid under flytten. På senare år har den europeiska tranpopulationen ökat vilket har lett till ökade konflikter mellan tranor och lantbrukare. För att åtgärda dessa problem behövs mer kunskap om hur tranor rör sig under vistelsen på olika rastlokaler längs med flytten. Min studie har därför syftat till att undersöka hur tranor rör sig på olika rastlokaler i Europa och att jämföra rörelsemönstren mellan länder.

Mellan åren 2011och 2014 märktes 27 juvenila tranor med GPS-sändare. GPS-positionerna användes till att beräkna storlek på aktivitetsområden på individnivå och att mäta det avstånd de rör sig från övernattningsplatsen till födosöksområdena under dagen på olika rastlokalerna. I studien användes endast data från tranornas första levnadsår och endast positioner från flytten söderut. I genomsnitt rörde sig de individuella tranorna inom ett aktivitetsområde på 31,5 km^2 och befann sig i genomsnitt 4,5 km från övernattningsplatsen. Resultaten visade en stor variation i storlek på aktivitetsområden och hur långt tranorna rörde sig från övernattningsplatsen mellan länder. Det gick även att urskilja skillnader i rörelsemönstren mellan rastlokaler vilket tyder på att lokala förhållanden troligtvis har stor påverkan på hur tranorna rör sig. Några möjliga förklaringar till den här variationen i rörelsemönster kan vara hur landskapet är strukturerat och hur födan är fördelad runtom övernattningsplatserna. En annan förklaring kan vara tätheten av tranor på en rastlokal, där hög konkurrens om föda nära övernattningsplatsen kan tvinga mindre konkurrenskraftiga individer att söka föda längre bort. Även tranornas kondition samt störningar från trafik och annan mänsklig aktivitet är möjliga faktorer som kan påverka hur tranor rör sig.

Ett förslag på en metod för att minska skadegörelsen är att se till att några av de omgivande fälten runt övernattningsplatsen alltid är stubbåkrar. På så sätt kan skadorna på sådda åkrar minska. Då är kunskap om hur stora områden tranorna rör sig på viktigt för att kunna förutse i vilken utsträckning åtgärder bör tillämpas. Jag har med denna studie visat att tranans rörelsemönster kan skilja sig avsevärt mellan olika delar av Europa och mellan olika rastlokaler. Denna information är viktig att överväga när man planerar åtgärder för att förebygga de skador tranor orsakar i jordbrukslandskapet.

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Introduction

Movement, defined as changes in the spatial location of an individual in time, is a fundamental characteristic of life and plays an essential role in almost all ecological and evolutionary processes (Nathan *et al.* 2008). By studying movement patterns we will acquire valuable knowledge about the ecology and behaviour of an animal. For example, it can reveal feeding patterns, mating behaviour or interactions with other individuals. Movement is therefore important to consider when approaching problems in wildlife ecology and management work. Knowledge of movement patterns and foraging behaviour can thus guide us in our work to restore viable populations or resolve human-animal conflicts (Nathan *et al.* 2008).

Movements can occur randomly, for example a plankton drifting in the sea, but for most animals movements are determined by choice. The movement pattern of an animal depends on factors such as food availability, mating behaviour, predation risk and other environmental factors and their movement can change over a season or over a lifetime (Nathan *et al*. 2008). Migration is the seasonal movement of an animal over a long distance in search for suitable feeding or breeding grounds. Many birds are known migrants and they can travel great distances during a season. Because of their flying ability, birds are not limited by geographical barriers in the same way as terrestrial or marine animals (Newton 2008). The most common pattern for migratory birds is to migrate twice a year, from higher latitudes during breeding to lower latitudes to spend the winter. Some bird species may travel the migratory route in one stretch without breaks, while other species migrate for several months with many stops along the way (Newton 2008). The migratory routes for most species of birds are well studied, and usually there is good knowledge about the location of breeding, stopover and wintering sites. However, individual bird movements within stopover sites during migration is a topic that needs further exploration. Birds travel through many different conditions during a migration and the landscape and the climate may change significantly between localities and so affect the movement pattern within different stopover sites (Skagen 2006). I will focus this study upon whether the movement pattern of the migrating common crane varies between different stopover sites during their flyway through Europe.

The common crane *Grus grus* is a migratory bird with a wide distribution that ranges across Western Europe to the far east of Russia (Deinet *et al.* 2013). The west European population breeds in Fennoscandia and has its wintering grounds mostly in France and the Iberian Peninsula (Deinet *et al.* 2013). The majority of common cranes are gregarious during the non-reproductive season and they form large groups during the migration and wintering (Alonso *et al*. 2004). Cranes commonly act as a central place forager in most staging areas (Orians & Pearson 1979), i.e. they roost in shallow wetlands at night, and forage in flocks on surrounding cereal fields during the day before returning to the roost again (Alonso *et al.* 2008; Leito *et al*. 2015). The European crane population has increased during the last decades due to restricted hunting, habitat restoration and thanks to the modernization of agriculture with larger field units (Harris and Mirrande 2013; Deinet *et al.* 2013). This rapid population growth has contributed to intensified human-bird conflicts as the birds cause damage on crops (Nilsson *et al*. 2016). Therefore knowledge about movement patterns of cranes will not only lead to an increased understanding of the ecology of the species, but could also be important from a management perspective e.g. for planning measures to protect agricultural land (Månsson *et al.* 2013; Nilsson *et al.* 2016). Although the migration routes are well known for the common crane (Lundin 2005: Leito *et al.* 2015), there is still much to discover about the movement pattern within stopover sites at an individual level. With more advanced technology such as global positioning systems (GPS) it is possible to closely follow movement patterns and explore distribution on a smaller spatial scale.

The aim of this study is to increase the understanding of movement patterns and space use of individual cranes during their daily activities at different stopover sites by using GPS-backpacks. To see if the movement patterns varies between sites in different countries, my main focus will be to investigate 1) the size of their activity area and 2) the flight distance from a roosting position to a daily activity position and whether there are any differences between the countries along their flyway.

Methods

Study area

Common cranes that breed in Sweden most commonly use the western flyway with the goal of reaching France and Spain to spend the winter (Lundin 2005). The common crane is a gradient migrant and it takes several months for the birds to accomplish the journey (Lundin 2005). The migration starts in August when crane families leave their breeding territory and gather in large flocks at their first stopover site. The most visited stopover site in Sweden during the autumn are Kvismaren (59-60° and 15-16° E) in the south-central. When leaving Sweden a majority of the cranes aim for Germany where Rügen (54-55° N and 13-14° E) and Diepholzer Moorniederung (52-53° N and 8-9° E) are frequently used stopover sites. From October to the end of November, the migration continues through France where Lac du Der (48-49° N and 4-5° E) and and Plaine de la Woëvre (49-50° N and 5-6° E) in the northeast and Landes de Gascogne (44-45° N and 0- 1° W) in the southwest are frequent visited stopover sites and for some cranes also suitable wintering grounds. Cranes that move further usually aim for Gallocanta (40-41° N and 1- 2° W) in the north and Extremadura (39-40° N and 6- 7° W) in south-west of Spain where they arrive during October-November. Common features for these sites are wetlands providing good roosting sites combined with suitable foraging habitat in farmlands, commonly with threshed wheat and maize fields (Lundin 2005).

Field methods

Between 2011 and 2014, a total of 27 juvenile common cranes were captured and tagged with GPS transmitter backpacks (see Månsson et al 2013 for details). Fifteen cranes were tagged with Vectronics GPS-plus bird backpacks and 12 cranes with Cellular Tracking Technologies (CTT), where the latter was recharged by a solar panel. Nineteen of the juvenile cranes were captured within a 30 km radius of Grimsö (59-60° and 15-16° E) and 8 cranes within a 30 km radius of Tranemo (57- 58° N and 13-14° E) during the breeding season before they were fledged at an age of 6-8 weeks. Later, the fledged cranes migrated with their parents in late August or early September. Since juveniles are rarely seen without their parents during the first season of their life, it can be assumed that by tagging juveniles the movement of the whole family will be studied (Månsson *et al*. 2013).

Stopover sites and GPS-data

In this study a stopover site was defined as an area where a crane stayed a minimum of 10 days, this in order to obtain sufficient positions to adequately measure activity areas. The data used was limited to the first southward migration of the juvenile cranes, in the interval from the first of August to the last of April. In order to compare the movement patterns between cranes in a similar way, I selected four positions each day at times closest to 07.00 (morning), 11.00 (midday), 15.00 (afternoon) and 23.00 (night). The night position was always located in a roosting spot, in a lake or wetland. The data was sometimes limited by insufficient positioning during the winter months due to lack of sunlight (no recharging of batteries), especially during December and January. Consequently, some days lack roost positions and are therefore not included in the data when estimating flight distance to the roost, however, to estimate the size of the activity areas all days were included. When estimating the average number of days a crane stayed at a stopover site, only cranes that had positions throughout the entire season were used.

Activity area

Within a stopover sites, activity areas were estimated for each individual crane by producing a Minimum Convex Polygon (MCP) in ArcGIS, where the outermost positions from an individual crane defined the area. There was a large difference in number of positions for different activity areas, due to the variation of the length of the stay. Therefore, in order to compare the different sites, only the first 10 days, with a minimum of 30 positions, were included in the MCP estimations. To prevent including positions when migrating from one stopover site to another, i.e. not in a foraging mode, a roost position always was selected as the start of a stopover period. If the first night position were missing, the first whole day was excluded from the MCP estimation.

Distance to roost site

To calculate the flight distance from the roost within an activity area, the distance from each night position was measured to all three day positions from the following day. All data from a stopover site (i.e. not only the first 10 days) were included and every day with a night position was selected for measurements. The distance calculations were conducted in R version 3.2.2 (R Core team 2015) by using the adehabitatHR package (Calenge 2006)

Statistical methods

I tested whether there was a difference in size of the activity areas and distance to roost between countries by using a linear mixed model (lme4 package) (Bates *et al*. 2015) in R version 3.2.2 (R Core team 2015). Size and distance were included as dependent variables respectively, country as an explanatory variable and crane-id as a random factor to account for repeated individual measures. The result from the linear mixed model was tested against a respective null model and a consecutive model selection was carried out by using the Akaike information criterion (AIC), according to Burnham and Andersson (2004).

Results

The 27 tagged cranes visited in total 25 different stopover sites, for which in total 62 different activity areas were estimated (Figure 1). The stopover sites were located in Sweden (8), Germany (4), France (7), Spain (5) and Portugal (1). Out of the 27 cranes, 24 cranes had their first positions in Sweden, while three cranes positioned for the first time in Germany, which could be explained by the fact that these cranes did not stop long enough at a stopover site when leaving their breeding territory in Sweden. Thereafter I could track 17 individuals continuing from Sweden to Germany (including the cranes lacking positions from Sweden) and from Germany six cranes travelled onwards to France and four cranes to Spain. From Spain, one crane migrated further to Portugal. In Sweden and Germany tagged cranes used the same stopover sites to a larger extent than they did further south. Kvismaren in south-central Sweden was the most visited site with 19 visiting cranes, all cranes tagged around Grimsö stopped at Kvismaren after leaving the breeding territory. Other frequently visited sites were Rügen (10 cranes) in north-east Germany, Finnåker (7) in south-central Sweden, Diepholz Moorniederung (6) in north-west Germany and Huvenhoopsmoor (4) in the north-west of Germany.

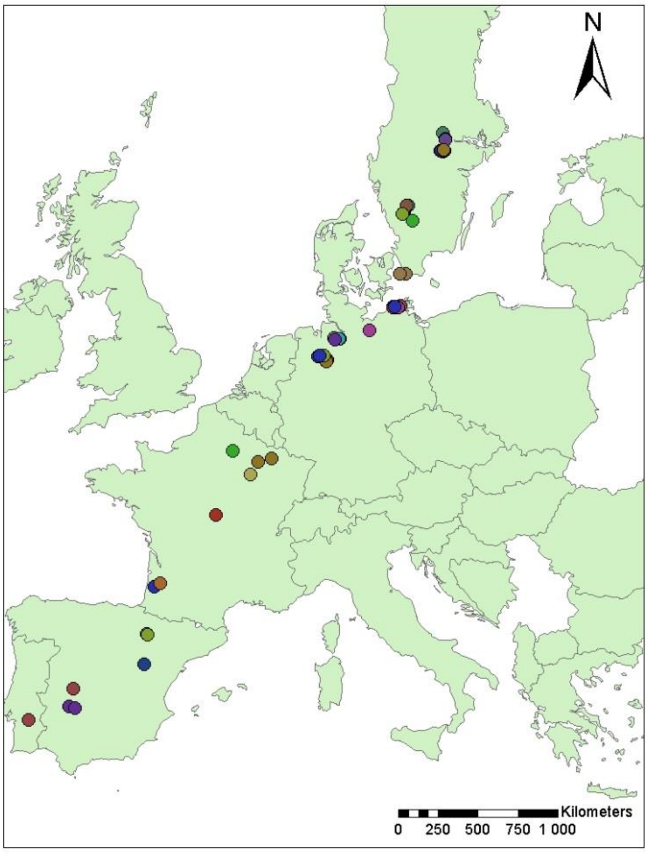

Figure 1. Activity areas on stopover sites for the 27 studied common cranes along the Western-European migration route. Each point represents an activity area and the colours indicate individual cranes.

On average the cranes stayed 43 days ± 31.7 SD. at each stopover site with a variation between 10 (our definition) and 199 days. Nine cranes obtained data for the entire season, (i.e. positions until last of April) and visited on average 2.9 stopover sites during a season. For the first 10 days on a new site, the activity areas ranged between 1.3 km^2 and 397.6 km^2 (average 31.5 ± 18.0 SD.). The model selection showed that both size of activity area and flight distance varied between countries (Table 1 and Figure 2). Furthermore, by comparing the top visited stopover sites a distinct variation in size of activity areas could be found between sites (Figure 3).

Table 1. The model selection estimates (AIC) for the effect of country explains the variation in activity area and flight distance from roost.

Activity area

Included variable	AIC	ΔAIC
Country	516.8	
Null	535.9	19.1

Flight distance from roost

Included variable	AIC	ΔAIC
Country	40962.3	
Null	41311.0	348.6

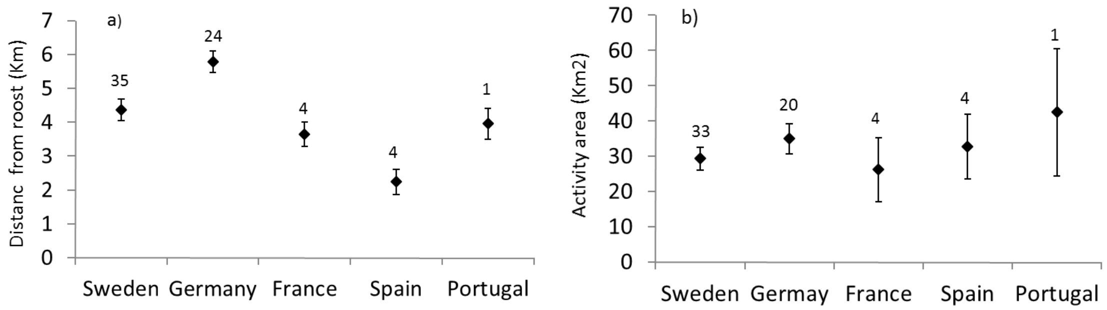

Figure 2. Estimates and variation (SD) for each country derived from the two models explaining a) size of activity area and b) flight distances from roosting position for the studied common cranes during the autumn migration. The numbers represent the number of tagged cranes studied in respective country.

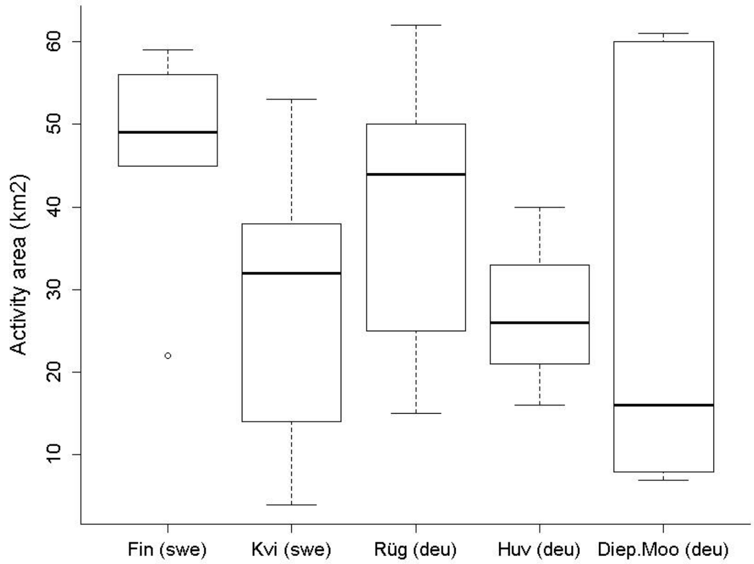

Figure 3. Median of the size of activity area between the five top most visited stopover sites, with whiskers and one outlier demonstrating the variation, for common cranes during the autumn migration. Fin= Finnåker (Sweden) 7 cranes, Kvi= Kvismaren (Sweden) 19 cranes, Rüg=Rügen (Germany) 10 cranes, Huv= Huvenhoopsmoor (Germany) 4 cranes, Diep.Moo= Diepholz Moorniederung (Germany) 6 cranes.

The mean distance between night positions and consecutive day positions was 4.5 km ± 4.1 SD and varied between 0 and 37.7 km. The distance from the night position to the morning positions (average 3.7 ± 4.0 SD) were considerably shorter than the midday (mean5.2 ± 4.1 SD) and afternoon (mean 4.7 ± 4.1 SD) positions (Figure 4).

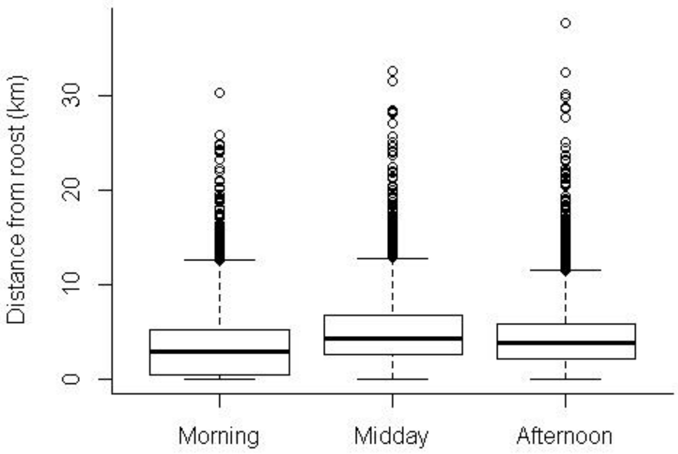

Figure 4. Median of flight distance from roost i.e. night location (positions closest to 23:00), to three different time points: Morning (position closest to 07:00), Midday (position closest to 11:00), afternoon (position closest to 15:00). Whiskers and outliers describe the variation in flight distance to roost.

Discussion

On average, the studied cranes moved within an area of 31.5 km^2 and were 4.5 km from the roost during the day, although a large variation between countries was found. These results imply that cranes move over larger areas at stopover sites compared with the size of breeding territories in Sweden (mean 2.5 km^2; Månsson *et al*. 2013) and winter areas for territorial families (mean 0.7 km^2; Alonso *et al.* 2004) and flocking birds (mean 11.7 km^2; Alonso *et al.* 2004) in Spain. Compared to a study investigating the movement of the sandhill crane within a staging site, the activity areas are about the same size (Sparling *et al.* 1994). In addition, they also found that size of activity area differed between roost types. A crane with a central roost had an average activity area of 39.6 km^2, while a peripheral roost had about half the size (17.4 km^2) (Sparling *et al.* 1994).

My results showed no continuous gradient in the size of activity area or flight distance between countries even though there is a natural continuous gradient over seasons and along latitude. This reasoning is supported by the documented variation in activity area size between the most visited stopover sites (Figure 3). Hence, the activity areas on different stopover sites do not appear to follow any natural gradient over Europe, the variation seems rather to depend on local differences. In this study I have not measured any environmental factors which could explain the mechanisms behind the variations in activity areas. However, earlier studies have explained the differences in activity size and flight distance with factors such as food availability, competition, disturbance, composition of the landscape and the body condition of the individual crane (Alonso *et al.* 1994; Bautista *et al.* 1995; Sparling and Krapu 1994; Farmer and Parent 1997; Matthews and Rodewald 2010)

Activity area and flight distance from roost

Presumably, the structure of the surrounding landscape and the distribution of food (Farmer and Parent 1997) are two important factors that determine the movement pattern of cranes, thereby the difference in activity areas may reflect the abundance of high energy food in close proximity of the roosting spot (Sparling and Krapu 1994). The same reasoning could be used when considering the flight distance, as cranes may fly longer distances in order to reach high quality foraging sites. In the same study Sparling and Krapu (1994) also showed that traffic disturbances might limit the activity range, where low flying cranes avoid crossing large roads. Activity areas and flight distances can also depend on the timing of the farmers threshing and ploughing of the surrounding fields, which in turn depends on the weather (Alonso *et al*. 1994). A rainy autumn means a more intense ploughing (Alonso *et al.* 1994), and since cranes find most of their food on stubble fields (Nilsson *et al.* 2016), it may force them to expand their activity area and fly longer distances in search for food.

Another explanation for the variation in flight distance and activity area could be the density of cranes at a stopover site at a particular time. A high density will increase the competition over the best foraging sites. The competition will be highest at foraging sites with high density of food and in areas close to the roost (Bautista *et al.* 1995). In the same study they found a clear individual difference in competiveness among common cranes when the level of success between aggressive encounters over food was measured. This could force the less dominant cranes to fly longer distances and extend their activity area. Bautista *et al* (1995) argued that the dominance ranking was most likely due to age and size differences between individuals. My study only followed juvenile cranes, therefore such a comparison between age classes was not possible, although it would be interesting to investigate further.

The individual body condition could also be of importance to explain the movement pattern at different stopover sites. The body condition could vary during the migration due to weather conditions or food supplies. Birds with decreased body condition typically move more and forage more intensely at stopover sites in order to restore fat recourses (Matthews and Rodewald 2010). A bird's body condition could also be influenced by age, gender and morphology (Maggini *et al*. 2013). During the migration, the juvenile crane develop, get older and becomes a more experienced flier which may increase the crane's possibilities to become a better forager and fly longer distances within stopover sites. Body condition, more specifically fat resources, have also been shown to play an important role in the length of the stay, were birds with lower fat resources stay longer on a stopover site (Yong and Moore 1997)

The flight distance to a morning position were on average shorter than to a midday or an afternoon position, this is probably because at 7 AM some cranes may not have left the roost site yet. Usually cranes fly out to forage at sunrise (Sparling and Krapu 1994), however, fog and precipitation could delay the departure in the morning (Noring *et al.* 1991). This could also account for the variation in departure time for common cranes in the morning. My results also showed that the afternoon positions generally were somewhat closer to the night position than the midday position, which could indicate that the cranes moved closer to the roosting site before they fly in for the night.

Distribution patterns

It is interesting to see how a few studied cranes, which comes from two relatively small breeding sites, disperse over Europe. In Sweden and Germany many of the studied cranes visited the same stopover sites, while further south the cranes chose different routes and none of them were found using the same site in France and Spain (Portugal only had one stopover site). Since 1990, the number of overwintering cranes in France and Spain have increased in numbers due to increased protection from hunting and increased cereal food abundance (Alonso *et al*. 1994; Alonso *et al.* 2008). Food abundance is more limited during the winter, than during the periods for spring and autumn migration when there is plenty more food available on the fields (Alonso *et al.* 1994) which may cause the cranes to disperse more during winter in search for good foraging grounds. In my study there was not enough data, since there were too few cranes continuing to France or Spain, to draw any such conclusions. However, with more tagged individuals it may be possible to investigate these patterns further.

Management implications

With this study I have shown that the movement pattern of the common crane varies between countries and that local variation in the landscape probably causes these differences in size of activity area and flight distance within countries. This research has contributed with increased knowledge about movement patterns of the common crane during its autumn migration. The fact that the size of the activity area and flight distance differed between countries is something worth considering when planning or preparing management measures to prevent damage on agricultural land. Distance from the roost have been shown to have an important role in the distribution of cranes at the fields and the probability of having cranes is higher in the vicinity of the roost (Nilsson *et al*. 2016). Consequently, risk of crop damage will be highest in the close proximity of the roost and therefore increased management efforts are best concentrated there. It has been demonstrated that cranes prefer stubble fields over growing crops and sown fields and therefor one suggestion to decrease damage on crops has been crop rotation planning (Nilsson *et al.* 2016). By making sure that stubble fields are available at the vicinity of the roost sites during the stopover period, damage on growing crops could be reduced. However, my study implies that the distance from roost and the activity area can vary considerably between sites in different countries. Therefore, each country should consider this variation and consider site-specific conditions when planning for management of cranes in agricultural areas. Nevertheless, more studies are needed to better understand the mechanisms behind the movement patterns of cranes. For instance, it would be interesting to investigate and compare the landscape structure and habitat selection at different stopover sites to further explain the variation in movement and space use of the common crane.

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