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FACTORS BEHIND THE RISK OF CROP DAMAGE CAUSED BY WINTERING AND MIGRATING LARGE GRAZING BIRDS (GEESE AND SWANS)

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CONTENTS

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ABSTRACT

Populations of large grazing birds have increased in Europe over the last decades with increased crop damage as a result. In this essay, I review studies investigating factors affecting choice of staging site, choice of field within staging sites and, when grazing by geese and swans cause damage. At the large spatial scale, I review the factors driving attractiveness and popularity of staging sites, and factors impacting changes on this attractiveness. At the small spatial scale, I review studies investigating foraging strategies in relation to food and field preferences, and how these may change within and across years.

1. INTRODUCTION

Populations of geese and swans have increased worldwide due to a combination of decreased hunting, agricultural land use changes and conservation measures, such as wetland restoration and refuge creation (Ebbinge 1991, van Eerden et al. 1996, Fox et al. 2005, Fox et al. 2010). Especially the land use change in agriculture, from spring sown to autumn sown crops together with large areas of grassland monoculture, ensures abundant high quality food resources all year round (Fox et al. 2016). Geese and swans have clearly gained from these recent agricultural changes (Fox et al. 2005, Gauthier et al. 2005) especially when natural foraging habitats are lost or when they are of lower quality than at the croplands (Prop et al. 1998, Fox et al. 2005, Gauthier et al. 2005).

Large grazing birds tend to concentrate in big numbers around wetlands and their surrounding agricultural fields. That arises a conflict when foraging, trampling and puddling cause damage to the crops and a loss of yield for the farmers (Fox et al. 2016). This conflict between farmers and large grazing birds, takes a wider dimension when it includes restorations of farmland wetlands for the conservation of biodiversity and nutrient retention. Then, it becomes a direct conflict between farming activities and planned conservation actions. For example in Sweden, managers at the County Administrative Boards have experienced an increase reluctance from farmers towards wetland restorations, because of the risk of increasing numbers of cranes and geese that those actions imply and thus, a potential increase of associated damage (J.M. Wikland, *pers. comm*). In several European countries, the conflict has been solved by paying compensations to farmers (Fox et al. 2016). For example, Sweden spend about 35 million SEK over the last 5 years (J. Månsson, *pers.comm.*) to compensate costs due to crop damage by geese, swans and cranes. For some species, management plans have also been established in order to mitigate the conflict (Madsen and Williams, 2012).

However, foraging of geese and swans does not necessarily lead to damage, or even if they cause some damage, this does not necessarily induce a conflict. The spatial distribution of birds and damage is jointly affected by the behaviour of birds and landscape characteristics. Large grazing birds aim to optimize energy intake and minimize predation risk (Chudzińska et al. 2015, Jankowiak et al. 2015, Fox et al. 2016). Hence, knowledge of optimal foraging strategies and the main drivers causing spatiotemporal variations of bird distribution within landscape is one prerequisite to assess the risk of damage. Understanding the landscape characteristics that make a particular landscape attractive as a staging site for large grazing birds is also important when assessing risk of damage as also why some areas are used more than others within staging site.

2. GENERAL OBJECTIVES AND GOALS OF THE ESSAY

The current essay is a review of the known factors that increase or decrease the risk of crop damage caused by geese and swans. To understand those factors, it is necessary to evaluate the birds' distribution at two spatial scales; the selection of landscapes and the selection of fields within landscapes. At the large scale (i.e. country or along the flyway), I will identify which factors makes a particular landscape, or region, attractive for large grazing birds. At the small scale, I will investigate whether certain fields are more susceptible to damage than others.

3. DISTRIBUTION OF GEESE AND SWANS AT LARGE SCALE. FACTORS AFFECTING THE CHOICE OF A STAGING SITE

The first obvious requirement for a particular landscape to be selected as a staging site is, that it has to be within the species distribution area, including the flyway between breeding and wintering grounds. Wintering grounds should minimize thermoregulation demands, predation risk and disturbance (Belanger and Bedard 1989, Jankowiak et al. 2015), while maximize foraging efficiency (Jankowiak et al. 2015). Stopover sites are fuelling areas for migratory birds, along the flyway. Migrating geese and swans use a chain of stopover sites along their migration route. The geographical position of these staging sites within the flyway in relation to the landforms along the route, will play an important role, as it is expected a strong selection pressure during migration in order to optimize fuel accumulation strategies (Hedenström and Alerstam 1997). Because there is a narrow time window during migration with optimal foraging conditions at each step, foraging decisions and the resulting energetic consequences will be critical for migratory success (Hedenström and Alerstam 1997, Chudzińska et al. 2015, 2016). All staging sites must ensure suitable habitat for both roosting and foraging demands. These pre-requisites must be fulfilled in order to become an attractive staging site. Once that is ensured, there will be a list of factors adding up to why certain landscapes are more popular and why landscape attractiveness can change (Figure 1).

In short, geese and swans choose large staging sites that contain waterbodies in open landscapes, with suitable foraging grounds around them (Jankowiak et al. 2015, Jensen et al. 2016b).

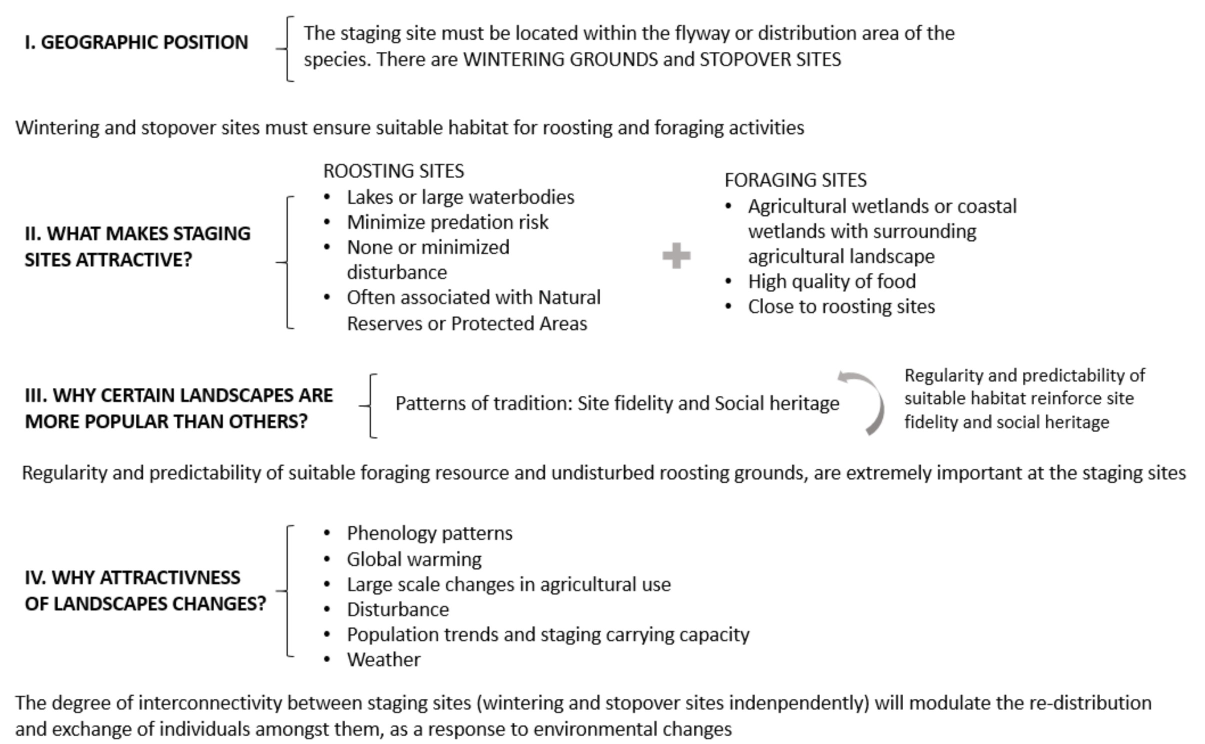

Figure 1. Factors affecting the choice of a staging site

3.1. FACTORS THAT MAKE A LANDSCAPE ATTRACTIVE

Roosting sites

The roosting site habitats are usually lakes or large waterbodies (Jankowiak et al. 2010, Rosin et al. 2012) as well as the seashore zone and mudflats (Madsen 1998). The size of the waterbody on the roosting site may determine the occurrence and flock size of roosting birds (Jankowiak et al. 2015) but, the overall carrying capacity of the staging site, will ultimately be defined by the amount of available food resources surrounding the roost (Baveco et al. 2011, Jankowiak et al. 2015). Larger waterbodies allows for both, a better possibility to spot predators and more birds to use the roost site which together will lead to a lower risk of predation (Jankowiak et al. 2015). Roosting site selection is a key factor for survival of large grazing birds, both in winter and when migrating. Roosting sites are often associated with nature reserves or protected areas where disturbance is minimized (Madsen 1998, Jankowiak et al. 2015).

Foraging sites

Geese and swans will forage on the surrounding area close to the roosting sites (Baveco et al. 2011, Fox et al. 2016, Jensen et al. 2016b). Agricultural wetlands or coastal wetlands and lakes, with surrounding agricultural landscape, will ensure high quality food (Fox et al. 2016). Fluctuation in food accessibility at the stopover sites will lead to changes in fuelling conditions, which could be reflected on the decision concerning departure fuel load (Hedenström and Alerstam 1997, Chudzińska et al. 2015), spending more time at the stopover and therefore, raise the risk of damage on the agricultural fields.

3.2. FACTORS DRIVING POPULARITY OF A STAGING SITE

Site fidelity and social heritage

There are many landscapes that fulfil suitable roosting and foraging grounds, but not all of them have the same popularity. Geese and swans, as many other waterfowl, show a high degree of site fidelity for staging sites along their annual cycle, particularly at breeding grounds (Kruckenberg and Borback-Jaene, 2004) but also wintering (Warren et al. 1992) and stopover sites (Clausen and Madsen 2015). Over 80% of roosting sites in Poland for example, are located near traditional goose wintering grounds (Jankowiak et al. 2015). Regularity and predictability of suitable foraging resource and undisturbed roosting grounds, are important at the staging sites. During migration, predictability of food will ensure and facilitate optimal fueling on the stopover sites (Hedenström and Alerstam 1997, Chudzińska et al. 2016). In winter, this predictability contributes to handling the loss of energy and the thermoregulation processes (Fox et al. 2016). Hence, fidelity to staging sites that offers regular and predictable foraging and roosting habitat will be a good strategy to achieve both migratory and wintering success if these sites are suitable for the birds. Consequently, landscapes with a traditional use by large grazing birds will be those with the highest potential for crop damage.

3.3. FACTORS IMPACTING CHANGES IN THE ATTRACTIVENESS OF THE LANDSCAPES

Phenology

Large grazing birds will maximize the match between timing of migration and routes with the spatiotemporal variation in the nutritional properties of plants, spring growth and onset of spring (Si et al., 2015). The “green-wave hypothesis” predicts that during spring migration, northern migratory herbivorous waterfowl from temperate latitudes will travel according to and taking advantage of the spring growth, at each stopover site along the flyway (Drent et al. 1978, Owen 1980). Studies on migrating barnacle Goose conclude that spring nutrient biomass is a key factor driving the timing of the annual spring migration. In this study, the Barnacle goose apparently has a differentiated strategy: geese arrive at the southernmost stopover site with the peak in nutrient biomass, to overtake the green-wave and match arrival at the breeding grounds with the onset of spring so that the peak in nutrient biomass, will ensure gosling benefit from it (Si et al. 2015). Hence, there is a predictable pattern of timing and occurrence during migration that will allow us to predict when birds will occur on a certain stopover site. Phenology curves are species-specific. They will be crucial to predict the timing of crop damage; in what species and potential magnitude of damage.

Global warming

Climate change may alter migration patterns worldwide, with a final result of a northward displacement of the wintering grounds and stopover sites along the flyway (Prop et al. 1998, Gauthier et al. 2005, Teitelbaum et al. 2016). This displacement often results with new staging sites settling within an intense agricultural landscape, and that leads to damage in new areas (Teitelbaum et al. 2016).

However, climate change does not only effect distribution pattern on a spatial scale but also at a temporal level. The warming trend has led to an earlier goose migration in spring in North America (Gauthier et al. 2005). This has also been found for European goose flyways (Tombre et al. 2008). Nevertheless, no change has been found in departure dates towards the breeding grounds or arrival there (Gauthier et al. 2005). Thus, earlier arrivals and longer stays at the stopover sites can increase conflict at two levels: one, because of the longer stay of grazing birds in the area; two, if the temporal displacement leads the presence of geese and swans to match availability of suitable agricultural foraging resource, that otherwise was not occurring.

<u>Agricultural, land use and wetland restorations</u>

Human land use can change conditions on a large scale and also drive important re-distributions of birds amongst staging sites (Gill et al. 1997, Prop et al. 1998, Fox et al. 2005, Clausen and Madsen 2015). One example from Norway showed that when people abandoned the small islands at the Norwegian archipelago of Helgeland, the summer grazing by sheep stopped. With increasing populations, the carrying capacity of those islands were soon reached and the geese were forced to move towards the more populated and larger islands closer to land, with intensive agricultural practices (Prop et al. 1998).

The number of waterfowl generally increase in wetlands refuges (Madsen 1998). As long as such refuges fulfil the birds' ecological and energetic requirements such as basic activities like feeding and roosting (Madsen 1998, Gauthier et al. 2005), numbers will increase and potentially lead to a higher risk of crop damage, and therefore conflicts, in nearby landscapes. If the refuges are implementations of local management plans conflict may be reduced or avoided (Tombre et al. 2013).

Some wetland restorations may take time to reach to the desired levels of occurrence, and it may even have the opposite restoration effects regarding some of the waterfowl, especially in the nearest following years after restoration. One example is the intensively cultivated open landscapes of Filsø, one of the most important autumn staging sites for Pink-footed Geese in Denmark. In 2012, the area was restored back to the old lake that originally were in the area before the cultivation. The result was a drop in up to 80% of staging geese during the following three years after restoration, that re-distributed in other staging sites in a 100km radius (Clausen and Madsen 2015). The time before desired effect can vary between sites. Again, this may lead to increased risk of damage on nearby farmland if the restored areas do not fulfil its intention of attracting more waterfowl.

<u>Disturbance</u>

Disturbances such as hunting, can potentially re-distribute geese within their distribution area (Béchet et al. 2003). In some cases even forcing flights on the opposite direction of the current migration (Béchet et al. 2003). That would result in presence of birds in areas where natural food resources had already depleted and therefore, increasing conflict with the farmers when risk of damage increase, especially if the only resource available are agricultural fields (Béchet et al. 2003).

Population trends and staging site carrying capacity

The carrying capacity of a staging site will be determined by the amount of available suitable food (Baveco et al. 2011, Jankowiack et al. 2015). When numbers in populations increase, food supply may become a limiting factor (Prop et al. 1998). This may drive birds to search for alternative staging sites, expanding their ranges towards other areas, altering their final distribution and thereby, arising risk of damage in other grounds. The different consequences of the increasing and expanding populations over farmlands lead obviously to conflict with farmers (Prop et al. 1998, Gauthier et al. 2005).

Weather

The weather is a totally hazardous factor but definitely a key driver for departures dates from wintering and breeding grounds, and the overall course of the migration (Månsson and Hämäläinen 2011). For example, at the Swedish spring stopover site of Lake Tysslingen, earlier arrival dates of Whooper swans were correlated with warmer temperatures previous to migration, and longer stays (Månsson and Hämäläinen 2011). However, the weather not only modulates the migration route in time. Also in space, forcing stopovers or pushing birds, miles away from their intended routes. Storms and hurricanes are clear examples of such phenomenon.

Interconnectivity of staging sites

Whatever happens to one stopover site may affect the nearby stopover sites in various degrees. This also applies for the wintering grounds, meaning that birds can re-distribute in response to environmental changes, moving between staging sites and therefore occur in various numbers in different areas (Béchet et al. 2003, Clausen and Madsen 2015). The interconnectivity (or degree of isolation) of staging sites and the cognitive plasticity of the birds (Clausen and Madsen 2015) will modulate this relationship and the resulting interchange of bird occurrence between them; leading to increasing or lesser risk of crop damage on a particular site.

4. DISTRIBUTION OF GEESE AND SWANS AT SMALL SCALE. FACTORS AFECTING THE CHOICE AT THE FIELD SCALE

At the large scale, geese and swans concentrate in open landscapes such as wetlands, surrounded by agricultural landscape where they forage, providing the combination of safe roosting sites with reliable high quality food in nearby areas (Jankowiak et al. 2015, Fox et al. 2016). What are, however, the drivers for crop damage within the landscape, i.e. at the field level?

At a small scale, it is useful to evaluate the choice of crop field in terms of optimal foraging, and foraging habitat selection (Macarthur and Pianka 1966, Fretwell and Lucas 1970). How herbivorous waterfowl optimise the use of foraging resources within the landscape, is crucial to understand their distribution and hence where crop damage may occur. Moreover, what are the drivers that lead to a certain risk of damage? Possible factors that may determine waterfowl distribution are summarised in Figure 2.

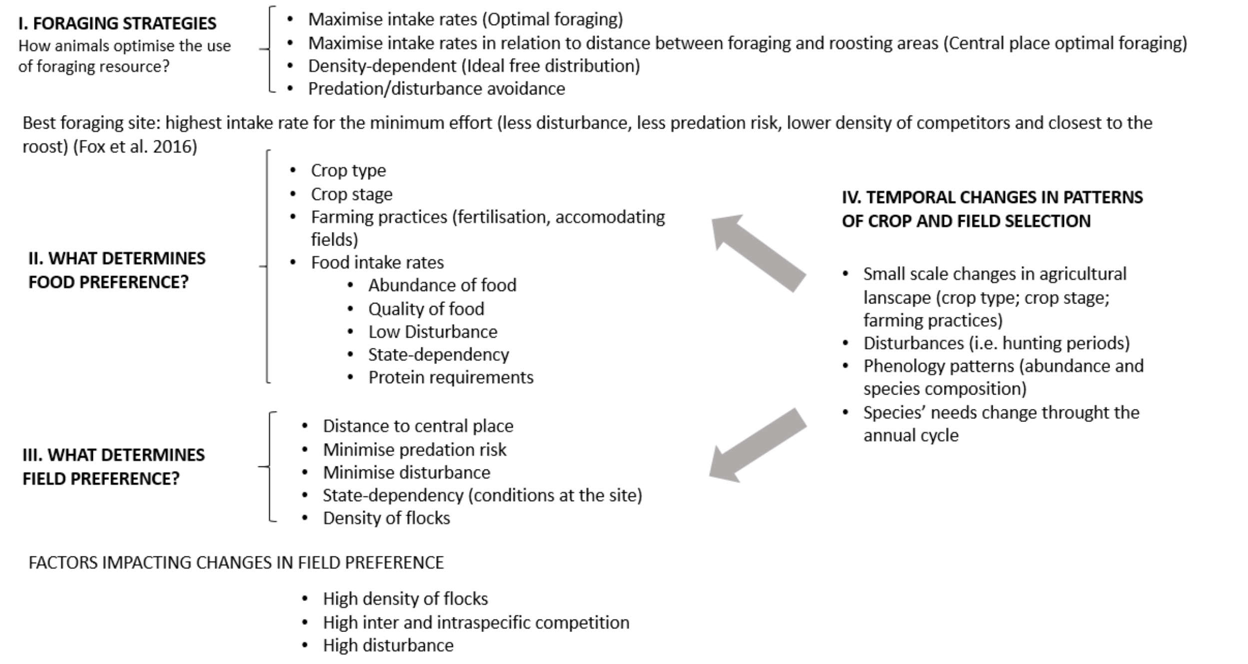

Figure 2. Factors affecting foraging distribution at small scale

4.1. FORAGING STRATEGIES

According to the Optimal foraging theory, animals will spend more time in patches that allow them to maximise both for energy and nutrient gain (MacArthur & Pianka, 1966). Thus, we may expect that fields allowing for nutrient intake maximization are the ones with higher risk of crop damage. However, other factors may also affect the birds foraging strategies, and hence the degree of crop damage.

Large grazing birds are limited by the distance between roosting and foraging areas, so that the balance between energy expenditure and energy gain turns up favourable. This is the central place optimal foraging theory (Schoener 1979, see an example in Baveco et al. 2011, and a review in Johnson et al. 2014). Accordingly, feeding sites closest to roost will tend to be exploited first (Baveco et al. 2011, Chudzińska et al. 2015) presenting a highest risk of damage.

Yet, there is another factor to take into account. According to the Ideal free distribution theory, animals would always first use the habitat with the highest food availability (Fretwell and Lucas 1970). In this respect, it considers habitat suitability as a function of the density of competitors at the same field. Consequently, large grazing birds may be more spread within the landscape when the density of competitors is higher. The risk of damage on the fields will therefore presumably increase correspondingly.

Besides, in agricultural landscapes where food resources have a high nutritional value and their availability changes quickly, food resource may not appear to be a limiting factor. As found on spring stopover sites in Norway (Chudzińska et al. 2015), the foraging behaviour appeared to be a trade-off between predation/disturbance avoidance and fat deposition (Chudzińska et al. 2015).

In conclusion, large grazing birds would optimize the use of foraging resources available in the landscape in accordance to: nutrient intake maximization, predation risk, central-place foraging (in relation to roost sites) and density-dependent habitat selection. Most likely, the resource utilisation by grazing waterfowl on farmland is driven by a combination of these, hence explaining their foraging distribution (Chudzińska et al. 2015). The best site would be the one that allows for the highest net energy intake rate whilst reducing the disturbance and predation risk, having lower densities of competitors and is closest to the roost (summarised in Fox et al. 2016).

However, what are the drivers that determine food preferences and field choice in relation to roosting site and foraging efficiency? Keeping in mind that the birds aim to optimize foraging within the landscape, the foraging strategy will be affected by different factors (e.g. agriculture, weather) that, will lead towards a strong selection for fields with higher digestible food, according to the flexible an opportunistic behaviour of non-breeding herbivorous waterfowl (de Jong 2010).

4.2. FACTORS LINKED TO FOOD PREFERENCES

Crop type

The crop types chosen by herbivorous waterfowl will depend on the landscape or location, but there are some general preferences. A review by Johnson et al. (2014), demonstrates that the most common terrestrial foraging habitats for waterfowl worldwide are corn, perennial grasses, rice, small grains/cereals, sorghum, soybeans, and winter wheat for Nearctic species; and perennial grasses, potatoes, small grains/cereals, sugar beets, winter wheat, and barley amongst the Palearctic ones (Johnson et al. 2014). Some other studies show that geese select sites with lower diversity of crops, for example preferring maize stubbles rather than winter cereal (Rosin et al. 2012).

Crop stage

Spilt grain and harvested root crops (potatoes, sugar beets, maize and grain) are an easy source of food, preferred by herbivorous waterfowl over winter cereals and grasslands (McKay et al. 2006, de Jong 2010, Fox et al. 2016). In spring, there is a high preference for sprouting grassland (Fox et al. 2016). In general, longer swards provide higher intake rates, but grasslands harvested for hay shortly before the arrival of wintering waterfowl appear to be more susceptible for damage because short swards have the highest amount of protein and the lowest the amount of fibre, hence preferred by the grazers (Fox et al. 2016).

Farming practices improving the quality

Use of fertilizers can increase the presence of grazing birds on the field. Experiments show that herbivorous waterfowl rapidly switch to crops subject to nitrogenous fertilization as they will be able to choose longer sward length, implying higher energy intake (Fox et al. 2016).

In order to decrease crop damage, some areas implement accommodating or sacrificial fields where geese and swans can feed undisturbed. Some farmers may also receive a subsidy in order to let the birds graze undisturbed on their fields (Tombre et al. 2013, Madsen et al. 2014). This may result in a decrease of crop damage at fields in close vicinity (Chisholm and Spray 2002, Madsen et al. 2014).

Food intake rates

Food intake rates relate to food quality. Large grazing birds will strongly select for those fields that offers the higher digestibility of food; more energy, more proteins and lower fibre content in order to satisfy their daily energy requirements (de Jong 2010, Fox et al. 2016). Factors explaining intake rates are: abundance and quality of food; state-dependency of the energy gain rates, predation risk or disturbance and protein requirements. If the daily energy requirements are not achieved, it may result in a switch of habitat (Nolet et al. 2002). Accordingly, fields that otherwise would not be exposed to damages, may under such conditions have the potential for grazing impacts.

4.3. FACTORS LINKED TO FIELD PREFERENCES

Distance to central place

Geese and swans are expected to distribute amongst the roosting sites and exploit surrounding areas, optimizing the use of foraging resources according to distance to roost (Chudzińska et al. 2015, Jankowiak et al. 2015, Jensen et al. 2016b). Maximum distances between roosting and feeding areas vary from 1km - 30 km within reviewed studies. The distance from roost to feeding site is dependent on factors such as species, geographical location, hunting pressure, human disturbance (farming activity), quality and quantity of food resources and distribution of the food within the landscape (de Jong 2010, Baveco et al. 2011, Johnson et al. 2014, Madsen et al. 2014, Jankowiak et al. 2015, Fox et al. 2016).

Predation risk

Large grazing birds will minimize predation risk on both roosting and foraging sites by choosing big fields in open landscapes (Chisholm and Spary 2002, Jankowiak et al. 2015, Jensen et al. 2016b), remote from forests and human settlements (Rosin et al. 2012), close to open water (Chisholm and Spray 2002, Fox et al. 2016), and avoiding sources of disturbance (Rosin et al. 2012, Simonsen et al. 2016). Predation risk lowers intake rates (Fox et al. 2016) as the birds need to spend more time on vigilance and relocation, which may further cause birds to forage on sites of less food quality. Therefore, large fields offers a safer option. It has been demonstrated that flock size increases with field size (Rosin et al. 2012). Thus, big fields will have a higher risk to crop damage.

Disturbance

The level of disturbance at a staging site will negatively correlate with the occurrence of large grazing birds, affecting its use as well as their activity (Belanger and Bedard 1989, Chudzińska et al. 2015). It has been shown that a sporadic and unpredictable disturbance can reduce the proportion of geese feeding in a site more than predicted based on the distribution without the disturbance (Chudzińska et al. 2015). Hunting near roosting sites and wetlands may cause temporary disruptions of normal activities by the birds, alters diurnal rhythms, increases escape flight distances and increases giving-up densities decreasing food consumption rates (Bélanger adn Bédard 1989, Jensen et al. 2016a). Aircraft passage is one of the biggest disturbance factors (Belanger and Bedard 1989). Simple recreational human activities may have less impact (de Jong 2010). Large grazing birds will also avoid roads and other land features such as wind mills or wind-breaks (Larsen and Madsen 2000, Jensen et al 2016b). Road and other urban constructions coverage are usually related to lower densities of geese (Rosin et al. 2012); although road density seemed not to influence roost site selection or abundance of geese at any spatial scales, amongst wintering and migrating geese in Poland (Jankowiak et al. 2015). Jankowiak et al. (2015) pointed out the reasons of such results: safety and energy gain in the surrounding fields is more important for habitat use than human disturbance, i.e. human disturbance may not be strong enough to force geese away from good roosting sites. Thus, the degree of disturbance is important when evaluating disturbance within a landscape and the characteristics of this landscape.

In order to decrease crop damage, some areas implement deterrent methods such as scaring actions or devices (e.g. Simonsen et al. 2016; summarized in Fox et al. 2016). The level of response to a disturbance will depend on the species, flock size, crop type, time of the year, physiological state of the bird and degree of disturbance (Simonsen et al. 2016). In one study, the response to scaring was depending on the time of season, with more efficiency at the beginning of the treatment (Simonsen et al. 2016).

State dependency of the conditions at the site

Geese seem to conduct a random search on arrival to staging site, as they lack knowledge about the current resource distribution (Chudzińska et al. 2016). On the other hand, they also seem to be able to learn and return to high quality patches (Chudzińska et al. 2016). Thus, geese may learn or benefit from the flock, as Amano et al. (2006) point out on their study of distribution models on white-fronted Goose in Japan. They found that the model that best predicted distributions of geese was the one assuming incompletely informed foragers, with benefits of group. Thus, supporting the idea that the expected gain rates may drive decision-making on diet choice, patch departure and flock joining (Amano et al. 2006). That particular behaviour should be keep in mind as for management implementation. This is, it will be crucial in order to attract geese to the accommodating fields from their arrival to the staging site, and discourage them from feeding on other fields with scaring devices.

Density of flocks, inter and intraspecific competition

Large grazing birds are social birds. Roosts are often shared by several species, potentially leading to resource competition in the surrounding fields. Density of flocks will stand for more or less competition between and within species (Fretwell and Lucas 1970, Chudińska et al. 2015, Jensen et al. 2016a). A higher density of the flocks will force a relocation of the individuals within the landscape in order to avoid foraging competition and thus increase daily energy intakes (Jensen et al. 2016a). That will result in a higher risk of damage for a major number of fields within the landscape.

A part from density of flocks and disturbances, the species composition in flocks may also affect the use of sites via interspecific competition.

Foraging coexistence between species is conciliate by allometric responses (relation of body size to shape) and bill morphology of the different species. For example, smaller species select for shorter sward height and tend to be more selective than bigger species (Fox et al. 2016). Also, species with thicker bills show a broader range of foraging behaviours than species with thinner bills (Fox et al. 2016). The competence between species leads to displacements of the weakest, that will be forced to move and/or change its habitat selection (Jensen et al. 2016a). But it can also lead to facilitation, as bigger grazing species may cut the grass to a length that becomes exploitable for smaller species (Baveco et al. 2011). Species composition will therefore assess for kind of risk of damage and to create attractive accommodating fields for the species occurring within the landscape.

4.4. TEMPORAL CHANGES

Crop and field selection will vary throughout the year. Temporal changes in agricultural land use at small scale, disturbances (i.e. hunting periods), and abundance and species composition (due to phenology patterns) will obviously lead to temporal variation in distribution patterns and crop selection (Teitelbaum et al. 2016). Hence, there will also be changes in species needs through their annual cycle.

Species needs through the year

According to the birds annual cycle, requirements will vary throughout the year. For example, rebuilding damaged tissues and fat stores after migration; or thermoregulation demands and loss of body mass over winter (Fox et al. 2016). This will result in variations amongst food preferences and foraging behavior and therefore, the crop and field selection. One example is the selection of food rich in proteins to rebuilt damaged tissues after migration and to avoid body weight loss during winter (Fox et al. 2016). Altogether, this will result in a different use and selection of habitats available and therefore, is another factor impacting the risk of crop damage (McKay et al. 2006, Chudzińska et al. 2015).

5. WHEN GRAZING BY GEESE AND SWANS CAUSE DAMAGE

Assuming a staging site where roosting requirements are fulfilled, crop damage may occur when the unharvested agriculture fields matches the requirements of geese and swans.

From autumn, through winter to spring, spilt grain and harvested root crops seem to be selected over winter cereals and grassland (McKay et al. 2006, de Jong 2010), because of the higher digestible energy content and low fibre (Gill et al. 1997, McKay et al. 2006, Fox et al. 2016). Feeding of harvest remains and spilt grains do not cause any damage to the farmland, however, still due to depletion of harvest remains and higher energy contents in unharvested crops, damage by geese and swans occur throughout the year.

Autumn

The problem during this period of the year, comes during autumn harvesting. This is a sensitive time as the staging migratory birds, may be attracted to partially harvested fields, with lots of available waste grain, and then walk in to the remaining unharvested crops, for feeding. Direct feeding, trampling and faeces accumulation would be the cause of the damage in this case. Bad weather conditions (heavy rains) may also cause crop lodging where the birds may land and start feeding in unharvested fields.

Winter

Winter crops sprout before the first frost. That makes them susceptible to damage by migratory (in autumn) and/or wintering large grazing birds as they offer a homogeneous and low diversity grassland, rich in protein and low fibre. Nevertheless, winter grazing damage seems to be lower than spring grazing (Fox et al. 2016). In this case, crop damage will be caused by direct feeding (Fox et al. 2016). However, intense grazing may increase the weed in the harvest (Bjerke et al. 2013) as herbivorous waterfowl graze selectively on crop plants.

Spring

These same crops in spring are vulnerable for migrating geese and swans once the snow melts. The resulting damage may be substantial because if the soil is frozen, or on its way of defrosting, small sprouts could be quite loose and therefore, easy to be pulled out the ground when large grazing birds feed on them, instead of just being cut. Overall, in spring, crop damage on grassland seems to be higher than for cereals (Fox et al. 2016).

6. DISCUSSION

This review suggests that the main requirements for a landscape to become an attractive staging site for large grazing birds are primarily regularity and predictability of suitable habitat, satisfying both roosting and foraging demands. This predictability of suitable habitat would establish patterns of tradition, ranking the use of certain landscapes over others, and will often occur on natural reserves and protected areas (Madsen, 1998; Jankowiak et al., 2015). Thus, agricultural landscapes near protected lakes and wetlands have a high probability of being exposed to large grazing birds and hence sensitive to damage. However, phenology, global warming, changes in agricultural practice at different scales, human disturbance (also including hunting activity) as well as population trends, cause variation and change the attractiveness of a particular landscape. Nevertheless, geese seem to respond well to unexpected habitat changes such as loss of habitat, showing a high cognitive plasticity finding alternative staging sites with no major implications on their individual body condition (Prop et al. 1998, Clausen and Madsen 2015). The interconnectivity amongst staging sites may modulate the re-distribution and exchange of individuals as a response to environmental changes (Tombre et al. 2008), which again may turn into an increase or decrease in the risk of crop damage on farmland. Global warming boosts a northward displacement of wintering sites in the northern hemisphere (Prop et al. 1998, Gauthier et al. 2005, Teitelbaum et al. 2016), i.e. a possible change in where damage and problems arise. For some species, it also leads to an earlier start of the spring migration (Tombre et al. 2008, Gauthier et al. 2005), but with no change in departure dates towards the breeding grounds or arrival there (Gauthier et al., 2005; Clausen & Clausen 2013). Longer stays may increase risk of damage as there is a higher chance that farming practices provide unharvested crops when migrating geese and swans are presence on the area. An underlying assumption in several management actions is that numbers play a role (e.g. more geese and swans, more damage). However, no studies have been found to document a reduction in conflict with fewer number of birds as, presence of large gazing birds does not necessarily imply conflict. Besides, warmer climate may increase productivity in some goose populations i.e. more conflicts (Jensen et al. 2014). Hence, climate change may drive towards higher risk of damage as there will be more geese foraging on farmland also, outside the breeding season.

When assessing for risk of crop damage, it is important to understand that not all fields and crops within the landscape are equally exposed; not among similar fields, and not even among the same kind of crops. Geese and swans will distribute throughout the foraging area optimizing for highest quality of food, at a certain distance to the roosting sites, avoiding density of competitors and minimizing predation risk. Crop type, crop stage, farming practices and the availability of resulting food intake rates will determine crop selection. The distance to a central place in the form of a roosting site, the predation risk, human disturbance, state dependency of the conditions of the site and flock densities will determine the selection of which field to utilize. Both crop and field preferences will vary between season through the year, in response to changes in agricultural landscape and agricultural practice (within the staging site); disturbances; phenology patterns; and the fact that the species have different needs depending on the period in their annual cycle.

Some general patterns can be identified that entails a higher potential for being exposed to crop damage. Large fields close to roosting sites, far from disturbance and with high quality/fertilised food (sprouting crops/grasslands or partially harvested crops) will be preferred by large grazing birds and therefore, will be as well more vulnerable in terms of crop damage (Gill 1996, Chisholm and Spray 2002, McKay et al. 2006, de Jong 2010, Jankowiak et al. 2015). Big fields may host larger flocks and they are preferred because of their lower risk of predation.

The flexible and opportunistic behaviour of large grazing birds selecting for high quality food, as well as their ability of learning from the flocking behaviour, are excellent traits when utilising agricultural landscapes where food availability changes quickly. However, this implies that damage can occur very suddenly and therefore, fields with the qualities listed above would be in high risk of damage. On the other hand, this behaviour and fast learning can also be used when managing these birds providing accommodating fields where they can feed undisturbed. Management plans where initiatives involving refuges with high quality fields combined with scaring actions at the vulnerable crop fields can reduce crop damages and conflicts with agriculture (reviewed in Fox et al. 2016).

An understanding of the factors behind crop damage has been reviewed and collected in the present essay. First, I have reviewed the literature concerning factors affecting the choice of staging sites at a large spatial scale, in order to understand what leads towards an attractive and popular staging site. Second, I have summarized the findings of crop and field selection and the overall foraging distribution of geese and swans within wintering and stopover sites. Finally, I have linked the above knowledge of habitat selection to the resulting risk of crop damage. Drivers behind risk of damage are then identified and understood. But crop damage displays a high spatiotemporal variation component at different spatial scales. And despite that, there is a lack of studies describing and understanding these patterns behind damage, and why they vary between localities and time periods. Therefore, there is a real need to study the mechanisms that drive these spatiotemporal patterns at different spatiotemporal levels. In order to develop spatial distribution models at different scales. With the goal to predict areas at risk and finally develop and assess preventive measures to reduce the risk of crop damage and in this way, mitigate the conflict between conservation measurements (e.g. wetland restoration) and agriculture.

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