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Factors affecting field use of large grazing birds: a review

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Content

Abstract

Many large grazing bird species (i.e., cranes, geese and swans) have increased tremendously in numbers throughout Europe and North America. When migrating, these species normally aggregate in large numbers at staging sites along the flyways. The staging sites are often located in agricultural landscapes where suitable wetland night roosts are available. When aggregating, the birds generally refuel by foraging at arable land and so causing harvest losses and conflicts between conservation and agricultural interests. Knowledge of the space use and foraging behaviour of large grazing birds is essential to inform management where and when crop damage risk is apparent and how to allocate management measures to alleviate crop damage and associated conflicts between human interests.

The aim of this review is to synthesize knowledge about the factors affecting foraging decisions of large grazing birds and how this knowledge can be used to improve management practices. I focus on species in the genera cranes, swans and geese on the northern hemisphere and particularly species that are increasing in numbers. By reviewing the existing literature, I found that factors such as food availability and quality, distance to roost site, crop type, field size, interspecific competition and disturbance risk generally influence field use by large grazing birds and thus damage risk across the agricultural landscape. These factors can thereby potentially also inform managers where and when to allocate and priorities crop damage preventive measures. Based on these findings, I recommend a "push and pull" strategy where undisturbed diversionary fields with high food availability in the vicinity of the roost sites can function as a "pull" component to attract birds, in combination with scaring and occasionally hunting as a "push" component to steer birds from damage-prone crops. However, many of the large grazing bird species are steadily increasing in numbers and a "push and pull" strategy under such conditions would likely demand also steadily increasing management efforts. For such conditions an adaptive flyway management plan, as implemented for the Svalbard population of pink-footed geese, is to recommend. To mitigate conflicts between conservation and agriculture in such a flyway management plan, ecological knowledge is needed, but also participatory involvement of stakeholders and international collaboration.

1. Introduction

The foraging pattern of an animal is the results of its decisions about where and what to eat (Charnov 1976; Lovvorn & Kirkpatrick 1982; Alonso, Alonso & Bautista 1994). Those decisions affect not only the fitness of the animal but also the structure and function of ecosystems and thereby also potential conflicts between human interests such as conservation, agriculture and forestry (Owen 1990; Abraham, Jefferies & Rockwell 2005; Samelius & Alisauskas 2009). Hence, knowledge about the animal´s foraging and distribution patterns emerging from the animal´s decisions is of primary importance when choosing appropriate wildlife management tools to mitigate impact on human interests (Conover & Decker 1991; Sutherland *et al.* 2004).

One of the most common management tools to alleviate impact on human interests is to regulate populations through hunting (Hothorn & Muller 2010; Kuijper 2011). However, regulation is for different reasons not a feasible solution for many species, even though they may cause considerable damage. For example, species may be protected from all sorts of hunting or within certain protected areas. Species of large grazing birds such as cranes *Grus*, geese *Anser, Branta* and swans *Cygnus* occur in protected areas and several species are still vulnerable and not feasible to regulate due to legal protection in Europe (EC 2009). Large grazing birds also cause conflicts between conservation (i.e., species protection and wetland restorations) and agriculture worldwide due to consumption, trampling and contamination of agricultural crops (Flegler, Prince & Johnson 1987; Parrott & McKay 2001; Crawley & Bolen 2002). Moreover, a common pattern is that large grazing birds aggregate and feed in agricultural landscapes surrounding protected wetlands e.g., during migration and wintering (Jankowiak *et al.* 2015; Nilsson *et al.* 2016). When population regulation is not a feasible management option other measures need to be considered. In addition to regulation of populations, other pro-active measures can be performed to mitigate damage (Vickery & Summers 1992; Madsen, Bjerrum & Tombre 2014). Pro-active measures for large grazing birds are in general based on two different strategies; 1) scaring the birds from fields with vulnerable growing crops (e.g., by using propane cannons, fireworks and scarecrows) or 2) diverting grazing birds to arable fields where they cause less damage by managing some fields to attract birds (Owen 1977; Vickery & Summers 1992; Vickery & Gill 1999; Klaassen *et al.* 2008; Hake, Månsson & Wiberg 2010). The strategies to scare and divert 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, Khan & Pickett 2007).

Successful proactive management, e.g. push and pull strategy, needs to be based on and evaluated in light of the foraging ecology of the birds (Conover 2002). However, a small portion of former studies on birds have been conducted in a context of conflict mitigation, but rather on basic ecology and mere conservation issues - but see (McKay *et al.* 1996; Vickery & Gill 1999; Amano *et al.* 2004; Jensen, Wisz & Madsen 2008; Nilsson *et al.* 2016). Therefore the knowledge of the birds needs to be better linked to crop damage issues and conflict mitigation. The need of knowledge about foraging ecology and effective pro-active management is highlighted by 1) the general increase of large grazing bird species (Nilsson 2002; MacMillan & Leader-Williams 2008) and 2) the fact that large grazing birds seem to use agricultural areas for feeding to a greater extent the last 3-4 decades (Nilsson 1997; Fox *et al.* 2005).

The aim of this review is to synthesize knowledge about the factors affecting foraging decisions of large grazing birds and how this knowledge can be used to improve management practices. I focus on species in the genera cranes, swans and geese on the northern hemisphere and particularly species that are increasing in numbers. I chose to lump these species and call the group "large grazing birds". In general geese and swans are herbivorous, eating both terrestrial and aquatic plant material such as grass, herbs, cereals and sea grass (Inger *et al.* 2006; Ladin *et al.* 2011) whereas cranes are omnivorous (Mullins & Bizeau 1978; Guzman *et al.* 1999). However, a majority of the biomass consumed by cranes consists of plant materials such as cereals, acorns and bulbs, especially during wintering and staging periods (Munro 1950; Ballard & Thompson 2000; Aviles, Sanchez & Parejo 2002).

Even though there are some differences in the ecology of large grazing bird species that may need to be considered within specific management measures, they share many ecological characteristics; such as migration patterns, flocking and foraging behavior (Van Gils, Gyimesi & Van Lith 2007; Béchet *et al.* 2010; Pearse *et al.* 2010). Furthermore, all these species cause damage to arable crops and thereby also impact on human interests (Amano *et al.* 2004; Salvi 2010; Merkens, Bradbeer & Bishop 2012).

2. Factors affecting field use

2.1 Food availability

Large grazing birds in general occupy and use fields and foraging sites in relation to food availability (Bautista, Alonso & Alonso 1995; Prop *et al.* 1998; Anteau, Sherfy & Bishop 2011). Moreover, the same pattern has been found on a larger spatial scale as geese seem to utilize staging sites at the moments of peak in nutrient biomass according to the green wave hypothesis (Schwartz 1998; van der Graaf *et al.* 2006). However, it is not always a clear pattern, for example Bautista, Alonso & Alonso (1995) showed that the strength of the relationship between bird numbers on fields and food availability was dependent on crane density and total amount of resources in the landsape. Furthermore, Amano *et al.* (2006) and Anteau, Sherfy & Bishop (2011) could not find any effect of food availability on field choice by geese and cranes. The importance of forage biomass seems to vary with season and along the flyway (Arzel, Elmberg & Guillemain 2006) and is not unusally subordinate to other factors such as food quality (van der Graaf *et al.* 2007), distance to roost site (Amano *et al.* 2006b) and individuals´ dominance rank (Stillman *et al.* 2002).

2.2 Food quality

Large grazing birds are in general selective herbivores depending on high quality forage (Owen 1977; Bos *et al.* 2005), therefore the use of certain fields is dependent on the food quality in terms of high nitrogen or carbohydrate content, low fiber content and low live-dead organic matter ratio (Summers & Critchley 1990; Riddington, Hassall & Lane 1997; Bos *et al.* 2005). Food quality seems to be a more important spatial predictor than biomass for foraging geese as the bird seems to maximize their digestible nitrogen intake rate rather than dry matter intake rate at the field level and foraging patch level (Durant, Fritz & Duncan 2004; Bos *et al.* 2005; van der Graaf *et al.* 2007). For example, fertilization has been shown to increase the selection for grasslands. However, similar to biomass, food quality can occasionally also be of minor importance compared to other factors if the food quality at all available fields are above needed levels (Fox *et al.* 2005; Si *et al.* 2011). In summary, food quality has a general influence on field choice by large grazing birds. However, the magnitude of its influence can vary, depending on factors such as general heterogeneity of food quality in the landscape, and the spatial distribution of available fields in relation to, for instance, distance to roost sites.

2.3 Crop type, field stage and field size

The use of different crops differs between genera and species. Cranes generally prefer cereal and corn fields, while they use grasslands to lesser extent (Lovvorn & Kirkpatrick 1982; Ballard & Thompson 2000; Vegvari & Tar 2002; Anteau, Sherfy & Bishop 2011; Nilsson *et al.* 2016). Among cereals the most preferred types are durum wheat, wheat and barley (Sugden & Clark 1988; Sugden *et al.* 1988; Nilsson *et al.* 2016). In contrast to cranes, grasslands and pastures are widely used for foraging by both geese and swans (Chisholm & Spray 2002; Ely & Raveling 2011; Ladin *et al.* 2011). However, geese and swans also use cereals and other crops such as oil-seed rape and root crops (Krapu *et al.* 1995; Gill 1996; Rees, Kirby & Gilburn 1997; Ely & Raveling 2011). Geese generally select white clover over grass species e.g., perennial ryegrass, red fescue and timothy (Conover & Decker 1991; McKay *et al.* 2001; Van Liere, Van Eekeren & Loonen 2009). Field use by large grazing birds is affected by cultivation stage of fields. Presumably as some food sources are more accessible at certain cultivation stages such as spilled grain at stubble fields. Large grazing birds generally seem to select stubble fields, but also newly sown fields and growing crops (Frederick & Klaas 1982; Lovvorn & Kirkpatrick 1982; Krapu *et al.* 1984; Anteau, Sherfy & Bishop 2011). Moreover, grasslands with short sward heights (3-7cm) are in general selected over fields with taller swards (Riddington, Hassall & Lane 1997; Vickery & Gill 1999; Si *et al.* 2011). However, the selection for fields with different sward heights seems to differ among species, where larger goose species generally use taller swards than smaller species (Durant, Fritz & Duncan 2004). Fertilization, though, increases the nitrogen content of swards and can reverse the selection for short swards and thereby be a main determinant of grazing intensity (Riddington, Hassall & Lane 1997; Vickery & Gill 1999). Stages such as tilled, disced and mulched fields are in general less selected (Anteau, Sherfy & Bishop 2011; Sherfy, Anteau & Bishop 2011).

2.4 Distance from roost site

Large grazing birds are dependent of safe roost sites and regularly return to a central point, commonly wetlands, for night roost within their daily activity areas. The birds therefore face a trade-off between the costs of flying from the central roost site and the energy gained when foraging (Orians & Pearson 1979; Kacelnik 1984; Gils & W. Tijsen 2007). As a consequence, the probability of having birds at a given field is negatively related to distance to roost sites (Franco, Brito & Almeida 2000; Chisholm & Spray 2002; Sherfy, Anteau & Bishop 2011; Nilsson *et al.* 2016). Large grazing birds are distributed in the surrounding arable landscape up to radius of 10-16 km from the roost site but generally select fields closer i.e., 0-5 km (Lovvorn & Kirkpatrick 1982; Sugden & Clark 1988; Si *et al.* 2011). A few exceptions have, however, been noted especially for snow geese with mean distances of up to 26 km away from roost sites and with extreme observations of flocks of geese foraging up to 80 km from roost site (Frederick & Klaas 1982; Béchet *et al.* 2010). However, distribution patterns varies within season, among years and stopover sites due to local conditions and food availability (Alonso, Alonso & Bautista 1994; Bautista, Alonso & Alonso 1995; Gils & W. Tijsen 2007). For example, distance flown from roost sites may increase when food is depleted close to the roost site (Parker & Sutherland 1986; Fryxell 1991). Furthermore, the use of certain fields in relation to distance to the roost site may also change within a day. It has for example been shown that fields closer to the central point are more heavily used later in the day (Bautista, Alonso & Alonso 1992; Gill 1996; Bechet *et al.* 2003). This can be explained by lack of water in the landscape and that birds often return to larger water bodies during midday for drinking, resting and preening (Lovvorn & Kirkpatrick 1982; Phillips *et al.* 2003).

2.5 Disturbance and predation risk

Disturbance can change field use by large grazing birds and aggregation patterns as well as temporal patterns of foraging (Fox & Madsen 1997; Bechet, Giroux & Gauthier 2004; Tømmervik *et al.* 2005). Disturbance, here defined as any activity that triggers fear, such as predation risk, human activities (e.g., traffic, scaring, hunting, aircrafts) that cause increased vigilance and flight behavior and thereby decrease the time spent on feeding (Madsen 1985a; Mini & Black 2009; Webb *et al.* 2011). Large grazing birds in general avoid human activities, settlements and roads (Gill 1996; Larsen & Madsen 2000; Rosin *et al.* 2012). For example, field use can change as a response to human disturbance e.g., leaving productive fields or change use from large to small fields (Heinrich & Craven 1992; Madsen 2001; Bos & Stahl 2003; Bechet, Giroux & Gauthier 2004; Fox *et al.* 2005; Klaassen *et al.* 2006; Jonker *et al.* 2010). However, the behavioral response to disturbance, e.g., when birds stop feeding or move to other sites, varies a lot between studies and sites and seems to be dependent of factors such as type of disturbance, species, flock size, habitat availability, individual variation, habituation and crop type (Bechet, Giroux & Gauthier 2004; Tømmervik *et al.* 2005; Madsen & Boertmann 2008).

Large grazing birds generally keep a distance to fixed human constructions such as roads, power lines and wind turbines of 0 – 500 m when foraging, depending on sites and species studied (Madsen 1985a; Percival 1993; Ballasus & Sossinka 1997; Larsen & Madsen 2000; Rees, Bruce & White 2005). For more dynamic and mobile disturbances, geese and swans respond at different distances (100-1 350 m), with relatively short reaction distances for pedestrians, farm workers, cattle, vehicles and longer distances for eagles, hunters and aircrafts (Ward, Stehn & Derksen 1994; Rees, Bruce & White 2005). Reaction distances are in general shortened when disturbances are frequent at a daily basis, but with no evidence of long term habituation (Rees, Bruce & White 2005).

Indirectly, predation risk and disturbance cause large grazing birds to select fields that are large and provides good visibility that facilitate detection of potential threats (Munro 1950; Frederick & Klaas 1982; Wisz *et al.* 2008). Cranes have been shown to avoid fields with hampered visibility (Franco, Brito & Almeida 2000) even though they occasionally forage within more or less closed environments in some areas (Aviles 2004; Månsson, Nilsson & Hake 2013). Large open areas facilitate detection of approaching predators and increase distance to other disturbance factors (Larsen & Madsen 2000; Rees, Bruce & White 2005; Jensen, Wisz & Madsen 2008). However, field size and occurrence of forest edges or hedges do not always have a profound effect on field choice (Sugden *et al.* 1988; Gill 1996; Chisholm & Spray 2002; Anteau, Sherfy & Bishop 2011).

2.6 Flocking, site fidelity and interspecific competition

Flocks of foraging birds can offer protection from predation, but can also be a clue for birds searching for good foraging patches (Thompson, Vertinsky & Krebs 1974; Caraco, Martindale & Pulliam 1980; Sutherland 1983). Flocking behavior will thereby influence distribution and field use of foraging birds (Sparling & Krapu 1994; Amano *et al.* 2006b). Large grazing birds have been found to aggregate in denser flocks when food availability is high which in turn lead to prolonged use of certain patches (Alonso, Alonso & Veiga 1987; Alonso *et al.* 1995; Rees, Bruce & White 2005; Amano *et al.* 2006b).

Traditional site fidelity seems to influence patch choice of large grazing birds. For instance, Lovvorn and Kirkpatrick (1982) showed that staging sandhill cranes use of specific fields was explained by previous year´s crane numbers which indicates that large grazing birds return to fields earlier shown to be advantageous. Similarly, site fidelity to staging sites by geese have been reported (Hestbeck, Nichols & Malecki 1991; Fox *et al.* 1994; Phillips *et al.* 2003).

Further, interspecific competition may influence the field use of large grazing birds. For example, greylag geese shifted from using stubble fields and undersown stubbles to only use stubble fields when pink-footed geese were present. Whereas, the pink-footed geese selected both stubble fields and undersown stubble regardless of the presence of greylag geese (Madsen 1985b).

3. Recommendations – measures to mitigate damage

3.1 Refuges - "pull strategies"

Large grazing birds can be diverted from vulnerable arable fields by attracting them to alternative refuges, i.e., to "pull" birds from productive arable land and alleviate crop damage (Percival 1993; Vickery, Watkinson & Sutherland 1994; Gill 1996; Amano *et al.* 2007; Si *et al.* 2011; Merkens, Bradbeer & Bishop 2012). Refuges may be achieved by 1) setting aside fields with attractive crops (diversionary fields), 2) providing crop stages where birds do not cause damage, e.g., stubble fields or 3) supplemental feeding (Vickery & Gill 1999; Nilsson *et al.* 2016). Refuges are known to attract birds and potentially alleviate crop damage on surrounding fields (Percival 1993; Vickery, Watkinson & Sutherland 1994; Gill 1996; Amano *et al.* 2007; Si *et al.* 2011; Merkens, Bradbeer & Bishop 2012). Improved performance of diversionary fields can be achieved by integrating ecological knowledge of the large grazing birds in terms of foraging patterns and seasonality into the management of the refuges. Below I go through how the reviewed ecological knowledge can be used to improve the performance of crop damage preventive measures.

3.1.1 Food availability

Because food availability plays a major role for foraging and distribution patterns it is important to identify what food sources and fields that are preferred and the availability of food on diversionary fields compared to that of the surrounding landscape. Food availability on refuges should be higher than on fields in the surrounding landscape, and has to be adapted to the number of large grazing birds in the area. Intake rates can be used to predict how much food should be available on diversionary fields. For instance, Summers & Critchley (1990) suggested that a field of 50 hectare have to potential to sustain 1 000 geese during a wintering period.

3.1.2 Food quality

It is important to implement management of grasslands to provide attractive refuges, especially for geese. This can be achieved by keeping short sward heights either by repeated mowing, using re-seeding grass species, or by cattle or sheep grazing in early season (Percival 1993; McKay *et al.* 1996, 2001). Sward heights can be adapted to the body size of the focal species as larger species select for taller sward heights than small-bodied species (Durant, Fritz & Duncan 2004). Also, nitrogen fertilization may increase biomass production and attractiveness of refuges (Riddington, Hassall & Lane 1997; Bos *et al.* 2005).

3.1.3 Location of refuges and distance to roost sites

As disturbance can have a strong impact on the foraging pattern of large grazing birds, refuges should be placed where birds can forage undisturbed. Thus, they should be located away from disturbance factors such as human settlements and roads and away from habitat characteristics hindering visibility such as forest and reed edges (Madsen 1985a; Vickery & Gill 1999). As larger grazing birds repeatedly return to the central roost site and thus select fields in the vicinity of roost site to decrease flight distances, refuges should further be placed close to roost sites (Vickery, Sutherland & Lane 1994; Nilsson *et al.* 2016). Refuges should also be placed to minimize the flight distances to drinking water, either ditches or the roost sites (Lovvorn & Kirkpatrick 1982; Phillips *et al.* 2003). It may also be advantageous to distribute a network of diversionary fields in the landscape, to decrease competition and to reflect the average individual space use of the species (Summers & Critchley 1990; Jensen, Wisz & Madsen 2008). To keep large grazing birds at refuges, food should be provided continuously at the same fields. Thereby the large grazing birds learn where to find predictable food sources and may put less effort into searching food in the landscape to find food.

3.2 Farming practices

Damage risk on unharvested and productive fields may be alleviated by strategically planning the choice of crops as well as timing of cultivation practice (e.g., make sure stubble fields are available at the birds' arrival to the staging sites) and the location in the landscape (Nilsson *et al.* 2016). As large grazing birds mainly forage on different types of arable land, especially during staging and wintering periods (Owen *et al.* 1987; Ballard & Thompson 2000; Tinkler, Montgomery & Elwood 2009; Ely & Raveling 2011), food availability is largely dependent on farming practices. For example, plowing of land decreases the availability of spilled grain, whereas sowing increases grain availability (Frederick & Klaas 1982; Sherfy, Anteau & Bishop 2011). Farming practices can be used to provide refuges in the landscape. For exemple, harvest provide stubble fields at which the large grazing birds may forage without causing damage. Such refuges can also be provided by delaying the time of plowing to prolong the stubble availability during the staging period or by using crops that mature earlier in season to provide stubble fields when the birds arrive to the staging site. The selection pattern of large grazing birds may also be used to cultivate less preferred crops close to roost sites (Nilsson *et al.* 2016).

3.3 Scaring and hunting- "push" strategies

3.3.1 Scaring

Scaring practices have been used for decades to decrease crop damage caused by birds (Vickery & Summers 1992; Tømmervik *et al.* 2005; Simonsen *et al.* 2015). By using the knowledge of the birds' avoidance of foraging in risky areas, scaring can be used to decrease use of certain fields by mimicking danger. However, the effectiveness of scaring is not always evident and studies also show non-significant effects on field choice (Sugden *et al.* 1988). Diverging conclusions regarding the efficiency of disturbance across studies may be a result of differences in the studied systems such as methods, species and seasonality. An understanding of the effect of scaring is important since scaring practices often are deficiently cost-effective (Percival, Halpin & Houston 1997). Since the birds´ reaction to scaring can be assumed to be similar to other disturbance factors causing fear, an increased understanding of scaring practices may be achieved by learning from birds' avoidance of different disturbance factors.

The birds normally habituate to repeated disturbances and the effect of scaring will therefore decrease over time. The risk of habituation could probably be minimized by altering the type of scaring practices and devices both in time and space. Moreover, scaring devices should be used during as short time period as possible and only at fields with evident damage risk to minimize the probability of habituation. According to the distances at which birds react and the time to recover after disturbance, it seems like disturbance caused by natural predators (e.g., eagles) and disturbance similar to these predators (e.g. aircrafts) provides a greater scaring response compared to other disturbances (e.g., pedestrians and vehicles). Factors that cause disturbance at shorter distances and result in longer recovery time provide for the most efficient scaring of large grazing birds. Moreover, it takes birds longer to habituate to scaring devices mimicking natural phenomena e.g. distress and alarm calls compared to devices with no biological meaning (Spanier 1980). Thus, their fear of predators should be used to improve the efficiency of scaring (Beale & Monaghan 2004). Moreover, it seems that the birds´ time to recovery is dependent on flock and field size and it seems that the ability to succeed with scaring increases if performed on small fields and flocks. However, the increased misinterpretation of danger within large flocks may make larger flocks easier to scare.

3.3.2 Hunting

As many populations of large grazing birds have been threatened or vulnerable, they are still protected from hunting in large parts of their distribution (EC 2009). However, many populations have also recovered and hunting may therefore be a sustainable solution to decrease damage in some areas (Madsen & Williams 2012). Hunting as a management tool is commonly used to 1) regulate wildlife populations, 2) remove specific damage-prone individuals, 3) scare, and 4) alter animals' behavior (Conover 2001). Hunting of large grazing birds most commonly occur as 1) restricted local culling (i.e. culling of a few individuals to scare the flock away from growing crops and to increase fear of other scaring devices), and 2) open season hunting to regulate populations (Ebbinge 1991; Madsen 2001). Different studies have demonstrated contradictory effects of hunting on distribution and foraging patterns of large grazing birds (Sugden *et al.* 1988; Ebbinge 1991; Fox & Madsen 1997). According to earlier studies, it has been suggested that birds adapt and learn to use time periods and areas with less hunting activity and it may therefore also be possible to use the birds´ ability to learn by for example using scaring devices in combination with hunting and by mimicking hunting (Madsen 2001). However, few studies occur where the effect of scaring after hunting has been performed but it is likely that the effect of scaring practices might be enhanced.

3.3.3 Habitat alteration - "Obstacles, fencing" creating un-attractive features

Habitat alteration, likewise to planning of farming practices, can be a way to steer away or hinder the large grazing birds from visiting damage prone fields. By minimizing the size of open areas and decreasing the visibility, fields can be made unattractive for large grazing birds. This can be done by keeping or planting hedges and trees along field edges or in general keep obstacles hindering visibility.

Unfortunately this is contradictory to the recommendations and requirements in modern agriculture schemes and would need consideration at international level (EC 2016).

Fencing has been limited to very local management actions and only at places and times when the birds are unfledged, e.g., during breeding and moulting (Hake, Månsson & Wiberg 2010). At these times it is possible to fence the large grazing birds out from arable land and to keep them at wetlands or non-productive land. Fencing can either be implemented on land or in waterways.

3.4 Combination of "push" and "pull"

Scaring practices solely may scare birds from specific fields but at a landscape scale only move the problem to neighbouring fields. It is thus important to combine scaring practices as a "push" component with diversionary fields as a "pull" component i.e. to provide fields where birds don´t cause damage (Nilsson *et al.* 2016). I suggest that combining scaring and refuges will make both measures more effective due to the synergetic effect of both "pushing and pulling", when birds are left undisturbed in attractive areas after being pushed away.

3.5 Local and seasonal variation and adaptions

The great variability in field and crop use among species, seasonality and landscape composition at staging sites necessitates managament adaptation to local conditions (Inger, Ruxton et al. 2006, Tinkler, Montgomery et al. 2009, Ely and Raveling 2011). In terms of creating refuges for large grazing birds, the provided source of food must be adapted to the species, locality and season. For example, this could be to provide grasslands with clover and short sward heights to geese during spring and summer, and stubble fields of maize and barley to provide refuges for cranes during autumn staging.

4. Discussion

By reviewing the literature I found that field use by large grazing birds is influenced by a range of factors such as food availability, distance to roost site, competition and disturbance, which makes it intricate to predict damage risk in the landscape and to optimize the performance of crop damage preventive measures. Factors such as food availability and quality vary greatly due to agricultural practices and weather conditions and the success of implemented measures is also dependent on how well the measures are adapted to local conditions such as crop availability as well as current presence of species and bird numbers in the area. Despite varying factors and conditions, this knowledge have great potential to inform management about where and when to implement damage preventive measures, such as a "push" and "pull" strategy, to decrease the risk of damage. However, there are critical differences in population trends between the species of large grazing birds and to succeed with management and conflict mitigation in a long-term perspective, an adaptive management approach where population trends are considered is fundamental.

4.1 Differentiated recommendations dependent on population trends

The majority of the large grazing bird populations are increasing in numbers, but there are still some populations that are stable or even are decreasing. Due to conditional differences in population trends, management recommendations should be adjusted to influence the populations in aimed directions. For rapidly increasing populations, scaring and diversionary feeding are common measures to mitigate crop damage but the effort needed will continue to increase with the increase of the populations. Consequently, these management systems will not be sustainable in a long-term perspective, and new strategies must be developed. On the other hand, when populations are stable so will also the management effort be, and current practices of scaring and diversionary feeding may likewise be a more long-term solution in that sense. When populations are decreasing, negative effects of especially hunting but also scaring should be considered. Scaring and hunting may have short-term consequences for the birds such as altered foraging behavior as well as long-term effects such as decreased individual fitness and effects on population dynamics (Lima 1987, Ackerman, Takekawa et al. 2004, Klaassen, Bauer et al. 2006). To avoid such negative effects on decreasing populations, measures such as careful planning of farming practices and diversionary fields will be an alternative.

Even though the management practices and studies discussed above are found to be relatively effective for decreasing damage risk on crops, and thereby conflicts between conservation and agricultural interests, few real long-term management strategies are suggested so far. With increasing populations of many large grazing bird species, conflict levels are expected to rise and there is currently an undesired time lag in the management of these increasing populations (MacMillan and Leader-Williams 2008, Baveco, Kuipers et al. 2011). As large grazing bird populations are growing at the same time as agriculture becomes more modernized, conflicts become more complex. Concerns are not limited to impact of large grazing birds on agricultural interests but also concerns overgrazing of wetlands and alteration of vegetation communities by large grazing birds, as well as their direct or indirect influence on critical habitat for other birds species (Vickery *et al.* 1997; Alisauskas, Charlwood & Kellett 2006; Samelius & Alisauskas 2009). In addition, increasing populations of large grazing birds might aggravate conservation efforts for rare bird species and biodiversity as local farmers may become reluctant towards restoration of wetlands when the risk of large grazing bird aggregation consequently increases. Scientific knowledge about the ecology of large grazing birds as well as associated recreational and social values are therefore essential to form strategic management frameworks (Pullin *et al.* 2004; Walsh, Dicks & Sutherland 2015). Such frameworks are advantageously implemented on flyway-level to reach sustainable adaptive management. Such flyway management should not only integrate the ecology of the birds at different temporal and spatial scales but also cultural, social, economic, recreational and agricultural interests (Macmillan *et al.* 2002; Klaassen *et al.* 2008; MacMillan & Leader-Williams 2008; Madsen & Williams 2012). A newly established example of flyway-management is the plan for the Svalbard population of Pink-footed geese (Madsen & Williams 2012), which shows management frameworks and decision trees formed at national and landscape levels.

4.2 What to include in this sustainable management?

Successful adaptive management frameworks should be based on scientific knowledge, but there are knowledge gaps that need to be filled. In general, there is more knowledge available about geese than about cranes and swans, especially in the light of conflicts between conservation and agriculture. Most knowledge is based on small-scale studies, often at specific staging sites and as single-factor studies. However, studies of synergetic effects of for example disturbance, landscape features hindering visibility is needed as well as the influence of competition from conspecifics on staging- and foraging site selection. Research is also needed on crop damage levels in relation to foraging patterns, densities of large grazing birds and timing of harvest practices. As many of the large grazing bird species occur simultaneously at staging sites, there is also a need for multispecies management strategies.

I have now made recommendations on how to use the existing literature to improve the management, but to succeed in reality the understanding of the socio-economic aspects has to be improved to sustain long-term acceptance (Williams & Madsen 2013). To reach acceptance among conservation and agricultural interests, these interests have to be carefully monitored and considered in management strategy planning (Messmer 2000; Cope *et al.* 2003). One way to achieve that is to use a working model in adaptive management strategy, where working groups are formed with members from different stakeholder organizations. The aim is to improve and better integrate the different stakeholder interests into a management strategy framework, adapting to changing environmental conditions, large grazing birds densities and public attitudes (Hake, Månsson & Wiberg 2010). By integrating human interests and evidence-informed knowledge of the ecology of the concerned species into an adaptive flyway management plan, crop damages can potentially be reduced and interest conflicts hopefully be alleviated.

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