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Maize stubble as foraging habitat for wintering geese and swans in northern Europe

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ABSTRACT

Agricultural crops have become increasingly important foraging habitats to geese and swans in northern Europe, and a recent climate-driven expansion in the area of maize fields has led to a rapid increase in the exploitation of this habitat. However, due to the novelty of maize foraging in this region, little is known about the abundance and energetic value of this resource to foraging birds. In this study we quantify food availability, intake rates and energetic profitability of the maize stubble habitat, and describe the value of this increasingly cultivated crop to wintering geese and swans in the region. Our results indicate that the maize resource varies considerably among fields and years, but also that the energetic returns from maize foraging is substantial. As such, fields with extensive spill allow foraging birds to fulfill their daily energetic demands in 4 h of active foraging. Both the area of cultivated maize fields and the importance of this habitat to foraging birds are expected to increase in years to come. This may alleviate conflicts with other more vulnerable crops such as winter cereals, and have the potential to affect migratory decisions, site use and population dynamics of geese and swans wintering in northern Europe.

1. Introduction

During the last decades, wintering waterfowl across the northern hemisphere have increasingly exploited agricultural areas as foraging habitats (Abraham et al., 2005; Fox and Abraham, 2017). The shift in habitat use from natural wetlands to farmed croplands has mainly been driven by differences in the accessibility and quality of available foods (Madsen, 1985; Béchet et al., 2004; Nolet et al., 2014; Fox and Abraham, 2017), and has likely been a driving factor of recent population increase in many waterfowl species (Van Eerden et al., 1996; Fox and Madsen, 2017). Early evidence of waterfowl foraging on crops can be traced back to the medieval period (Kear, 2001), but it was not before the twentieth century when large areas of wetlands were reclaimed and inorganic fertilizer developed, that many waterfowl went through the transition to forage mainly on agricultural land (Van Eerden et al., 2005; Fox and Abraham, 2017). Nowadays, the phenomenon has spread to cover many swan and goose species and a wide array of different exploited crops (Madsen and Cracknell, 1999; Chisholm and Spray, 2002; Nolet et al., 2002).

In the U.S. and Southeast Europe waterfowl exploitation of maize (*Zea mays*) stubble fields has taken place for many years (Glazener, 1946; Alisauskas et al., 1988; Sutherland and Crockford, 1993), but only recently, in response to a global warming-induced increase in maize cultivation in northern Europe, has this food resource been exploited by waterfowl wintering in this region (Kenny and Harrison, 1992; Odgaard et al., 2011). The first observations of swans on maize in Northwest Europe were reported in Germany in the mid-1990s (Degen et al., 1996) and the first substantial numbers of geese on maize stubble was made in the Netherlands in 2008 (Cottaar, 2009) and in Denmark and Poland in 2009 (Rosin et al., 2012; Madsen et al., 2015). Since then, the use of maize stubble has increased considerably in this region, in parallel to a steep increase in the available area of maize stubble habitat (Clausen et al., 2018).

Due to the novelty of this food source in northern Europe little is known about the amount of food available on harvested fields and the profitability of this habitat to wintering geese and swans in this region. Studies from the U.S. suggest that waste maize can be a highly valuable food resource to waterfowl (Alisauskas et al., 1988; Gates et al., 2001), but in northern Europe where maize is cultivated close to its northern thermal limit, and used mainly for silage produced from immature cobs and vegetative parts, energetic gains might be less profitable (Kenny and Harrison, 1992; Andersen, 2000). In this study we investigated the

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Table 1
The amount of available maize forage on harvested maize fields at three study sites in Denmark. In Drengsted the same fields were visited for three consecutive years. * indicates that these fields were downed by a storm leading to suboptimal harvest and substantial spill.

Field	Available forage (g/m^2)	Location	Year
1	6.04	Drengsted	2015
2	3.42	Drengsted	2015
3	5.03	Drengsted	2015
4	6.52	Drengsted	2015
5	1.80	Stadilø	2015
6	3.71	Stadilø	2015
7	3.47	Lund Fjord	2015
8	2.46	Lund Fjord	2015
9	5.61	Lund Fjord	2015
10	0.85	Drengsted	2016
11	0.37	Drengsted	2016
12	1.22	Drengsted	2016
13	0.74	Drengsted	2017
14	1.48	Drengsted	2017
15	8.58	Drengsted	2017
16	400.22*	Drengsted	2017
17	316.84*	Drengsted	2017

profitability of maize stubble fields as a food resource to wintering waterfowl in northern Europe. This was achieved by 1) Assessing the amount of food available on harvested fields, 2) Investigating intake rates of wild birds foraging on maize stubble habitat and 3) Examining the energetic profitability of maize consumed by captive birds. Collectively, this enabled us to evaluate the value of maize stubble as a food resource in the north European agricultural landscape.

2. Methods

2.1. Food availability and its relationship with goose usage

Availability of spilled maize was investigated in Denmark at the three study sites Drengsted (55.08 N, 8.86 E), Stadilø (56.17 N, 8.16 E) and Lund Fjord (57.10 N, 9.03 E, Table 1, Supplementary appendix, Picture 1) in the autumns of 2015, 2016 and 2017. Drengsted was visited in all three years to test for annual differences. Food availability was estimated by counting the number of maize cobs in areas of 10 × 10 m on harvested maize fields. Each field was randomly sampled several times (5 to 10 plots depending on size) to obtain an overall average estimate of cob density. In two fields where the maize crop had been downed by an October storm and subsequently harvested, the resource was manifold bigger compared to all other fields. Due to time constraints food availability in these fields was assessed by estimating the number of cobs in 5–10 samples of 9 m^2 (equivalent to the area between two rows of crops for 10 m).

Ten full cobs were collected at random to determine the mass of available maize grain on individual cobs. The number of grain on individual cobs was determined, and 10 grains from each cob dried at 80 °C to constant weight to obtain the dry mass. The mass of available grain per cob was calculated by multiplying the number of grains on individual cobs with the average dry weight of individual grains. Fields were visited up to two weeks after harvest was completed, and on a few fields that had already been visited by geese (seen by the presence of droppings), we accounted for the already exploited resource by including empty cobs in our estimate of cob numbers (see Supplementary appendix, Picture 2). This ensured that preceding exploitation by birds and small mammals was likely to only have had a limited impact. However, both roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) may remove entire cobs from harvested fields. The initial resource just after harvest might therefore have been slightly larger.

In 2015 some of the fields in Drengsted were heavily used by Pink-footed Geese (*Anser brachyrhynchus*) and Barnacle Geese (*Branta leucopsis*). On these fields we counted the number of droppings and cobs in randomly placed circles with radius 1 m. These data were used to investigate whether there was a relationship between food availability and goose usage of the maize stubble habitat.

2.2. Intake rates of maize-foraging wild birds

Intake rates of free-ranging birds were inferred from video recordings of foraging birds in actual maize stubble fields at Stadilø in November 2015. We used a wireless surveillance system (ABUS TVAC 16000 B modified to our needs) to record the number of geese and time spent foraging in three sampling areas of 40 m^2 (8 × 5 m). The rectangular sampling areas were outlined with 4 small bamboo sticks, and baited with a pre-determined amount of maize forage (from 25 to 90 entire cobs) to attract foraging geese (Supplementary appendix, Picture 3). The small recorders were placed at one end of the sampling areas on thin iron poles, and camouflaged with a few intact maize stems. The power supplies (car batteries) were buried on the field beneath the video recorders. The setup was inspected at intervals of 2–3 days, and when clear signs of foraging were observed data on ingested mass and foraging time were collected. Ingested mass was derived by judging the proportions of each maize cob eaten and the knowledge of grain mass per cob derived above. Foraging time was determined by assessing the number of geese present on the video footage at intervals of 1 min, and summarising across the entire foraging event to estimate the total number of "goose minutes" spent foraging. Geese were always actively foraging when on the sampling area, but our definition of "foraging time" includes finding and handling the food, in addition to occasional aggressive encounters with conspecifics. We used our knowledge of ingested food mass and goose foraging time to derive intake rates in the following way:

$$Intake\ \ rate\ \left(g\ dw/min\right) = \frac{Mass\ \ of\ \ maize\ \ grain\ \ eaten\ \ (g\ \ dw)}{Foraging\ \ time\ \ (min)}$$

2.3. Energetic profitability of maize forage

Energy content of the maize forage at Stadilø was measured using a bomb calorimeter (C-5000, IKA, Staufen). Assimilation efficiency was investigated using three wild-caught adult Bewicks' Swans (*Cygnus columbianus*) held at Netherlands Institute of Ecology (NIOO) in Heteren, The Netherlands. The swans had been acclimated to the experimental set-up by 7–9 identical measurements with other carbohydrate-rich food sources prior to the maize measurements. Each swan was held in a two-chamber metabolic cage with maize forage for four consecutive days in early December. Maize forage and water was supplied ad libitum and weighed at 09:00 and 17:00 each day. A control food supply was also weighed to correct for possible desiccation or water absorption. In order to minimize stress, the swans were not handled during the trial. The swans were weighed each morning at 09:00 by allowing them to step into a mobile weighing cage with an electronic balance (IB-34, Sartorius, Nieuwegein) underneath the floor. The swans were then transported to the adjacent, clean chamber. The excreta in the first chamber were collected from the tray below the grid floor (70 × 70 cm) and together with a sample of the maize forage stored at −24 °C until further analysis. The food sample and a 100 g sample of the excreta were freeze dried at −80 °C, the rest of the excreta was dried to constant weight at 70 °C. For each day gross energy intake (GEI, kJ/day) and excreted energy (EE, kJ/day) were calculated as the product of dry weight (ingested or excreted per day) and the energy content as measured by the bomb calorimeter. Because the calculation assumes energy balance, days with a body weight difference > 2% and with a GEI < 500 kJ were omitted, leaving data of three trial days for each swan, for which GEI and EE were averaged. The assimilation efficiency (AE) was calculated as: