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The decline of the Starling *Sturnus vulgaris* in Denmark is related to changes in grassland extent and intensity of cattle grazing

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ABSTRACT

The Danish breeding Starling population declined at a mean annual rate of −2.24% ± 0.39 (95% CI) during 1976–2015 (a 60% decline overall). Starling density in the mid-1990s was positively correlated with dairy cattle abundance in 13 local areas. Regional declines in Starling abundance between 2001 and 2014 were positively correlated with loss of high intensity grazing pressure by dairy cattle, as more animal husbandry moved indoors. The long-term decline in national Starling abundance was positively correlated with the long term numbers of dairy cattle grazing outdoors. This study therefore confirms that not only does the extent of available grassland to breeding Starlings affect their relative abundance, but that the intensity of grazing of these grasslands is also of importance.

1. Introduction

Studies of farmland birds have tended to focus on species breeding and/or foraging on arable land (e.g. Robinson and Sutherland, 2002; Robinson et al., 2001). The annual cycle of tillage creates a series of temporary habitat states, with ploughing, for example, exposing invertebrates, seeds and plant storage organs, drilling providing seed, plant growth offering foraging habitat and harvest again providing food from spilled grain (e.g. Robinson and Sutherland, 1999). Not surprisingly, changes in cropping and agricultural practices have had a huge impact on some birds especially seed eating species (e.g. Chamberlain et al., 2000). This has been slightly to the neglect of those common species that are dependent on pastoral systems, a majority of which are more dependent on invertebrates and with seasonal patterns of food provision and availability that do not follow the same “boom and bust” cycle that occurs in arable agriculture (Vickery et al., 2001).

Denmark is predominantly an agricultural landscape (c. 60% of total land area is farmland; Levin and Normander, 2008) which has for centuries supported large numbers of dairy cattle. As the numerically dominant form of reared livestock, dairy cow abundance, nationally and regionally, is closely related to area of managed grassland. Although beef cattle contribute to grazing numbers, dairy cattle are numerically dominant: the ratio of dairy to beef cattle changed from 1:17 in 1982–1:6 in 2013. Dairy cattle require the best managed grassland, so dairy cattle are likely to constitute the key group of livestock that most drives relationships between cattle production, farmland practices, soil invertebrate fauna and their predators.

In this case study, we focus on the effects of regional changes in Danish agriculture on the changes in distribution and abundance of the Starling *Sturnus vulgaris*, a specialist grassland invertebrate feeder and a numerous and widespread species in Denmark as well as throughout Europe. Due to its abundance and association with human habitation it is a familiar and popular bird of societal interest. However, numbers of breeding Starlings in Denmark have declined during the last 40 years (Nyegaard et al., 2015). As a farmland species often associated with grazing cattle we hypothesized that radical changes in pastoral agriculture in the same period could have contributed to the Starling decline.

In this analysis, we first determine the degree to which the Danish Starling population has declined and if there were regional changes that correlate with the changes in the extent of grassland in these areas. Since the Starling depends on short grassland as foraging habitat for provisioning their nestlings

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(Feare, 1984; Devereux et al., 2004), we sought to establish a relationship between the extent of available grassland, the number of cattle and the density of Starlings.

The total area of grassland in Denmark has changed little since 1982, with recent large increases in rotational grassland balancing similar losses in set-aside land, due to the termination of set-aside schemes in 2007/2008 (Danmarks Statistik, 2016). In this context, set-aside land comprises agricultural land, which for a period was taken out of production, typically arable tillage in Denmark, with the aim to reduce agricultural production and which was mostly left as coarse uncultivated grassland. Numbers of dairy cows have declined by >40% from 1 million in 1982–2014 but have stabilized at c. 570,000 since 2004 (Danmarks Statistik, 2016).

Traditionally, dairy farms were small and evenly distributed over the country; milking herds were set out to graze on grassland every day during the warmest half of the year. Nowadays, economies of scale have concentrated dairy herds into larger units where grass is brought to cattle, which are increasingly kept indoors throughout the year (Seges, 2015; Danmarks Statistik, 2016). These changes have brought dramatic changes to the manuring of pastoral land as urine and faecal material is no longer applied "naturally" in a heterogeneous way in time and space by the animals themselves but applied as an intensive carpet of manure spread by the farmer a few times per year.

We investigate to see if regional changes, which comprise pronounced declines in the numbers of dairy farms and cattle in the eastern parts but far lesser declines in western Denmark, have affected the availability of grassland for Starlings, and hence their breeding status in these regions. Given a strong positive relationship between these measures, we reasoned that because dairy cows (and therefore traditionally managed grasslands) have declined most in the central and eastern regions of Denmark, the declines in breeding Starlings would be most severe in those parts of the country; by contrast because numbers of dairy cows and grassland area have changed least in the western part of the country, we would expect lower rates of declines in this area. We also investigated whether there has been a change in the numbers of cattle grazing outdoors to see if the degree to which this occurred could have any detectable effect on the regional Starling trends.

2. Materials and methods

2.1. Data collection

The Danish Common Bird Monitoring (CBM) programme uses point count census data to generate population indices and trends for more than 100 common breeding bird species. The annual sampling now involves circa 370 routes across the country (mean $\pm$ CI: 282 $\pm$ 32; median 321.5 routes per year during the time series 1976–2015), monitored in the period 1. May–15. June (Nyegaard et al., 2015). Most routes consist of 20 (but always $\geq$10) marked 'points' at which all birds seen and heard were recorded in a 5-min observation period (Heldbjerg 2005). All routes and points were counted in at least two successive years by the same observer, at the same time of year ($\pm$7 days), same time of day ($\pm$30 min) and under good weather conditions. Altogether, observations of 225,719 Starlings are included in this study.

The habitats surrounding each point are ascribed in quarters to one or more of nine predefined basic habitat types (Coniferous, Deciduous, Arable, Grassland, Heath, Dunes/Shore, Bog/Marsh, Lake and Urban). In total 29.0% and 8.1% of all habitat registrations were from arable habitat and grassland, respectively (Heldbjerg, 2005; Larsen et al., 2011). The majority of the surveyed plots were from 'mixed' habitats.

2.2. Estimating changes in annual abundance

Indices and trends were calculated by fitting a log linear regression model to point count data with Poisson error terms using the software TRends and Indices for Monitoring data (TRIM; Pannekoek and van Strien, 2004), where the count at a given site in a given year is assumed to be the result of a site and a year effect. The programme also estimates the dispersion factor, correcting for overdispersion where this occurs, and takes account of serial correlation between counts at the same site in different years. Standard errors for the indices are generated based on the assumption that the variance is proportional to the mean, and a pattern of serial correlation, which declines exponentially with time between counts (Pannekoek and van Strien, 2004). The TRIM assessment of rate of change was used in this study to generate species trends, taking the standard errors into account.

The population changes are described by indices (the proportional percentage change in the size of the Starling population in relation to the starting value) and we are therefore only interested in the relative changes (not the absolute number) during the study period, using the additive slope provided by TRIM. Based on the 95% confidence intervals generated about these estimates, we determined which of these datasets showed trends that significantly differed from zero.

In order to compare Starling trends in different regions of the country we analysed the trends for these. The number of counted points per year was reduced when limited to regions, so relatively poor coverage in earlier years constrained us to consider only the period 1990–2015 in the regional analyses.

2.3. Regional starling breeding densities

We used Starling breeding density assessments from the Danish Bird Atlas from 1993 to 1996 (2nd Atlas; Grell 1998). We only included data collected during 10–30 May, the typical nestling period in Denmark, to avoid data from periods including post-breeding flocking behaviour. The density data were derived from Atlas point count censuses consisting of 5-min registrations mostly from 10 points, systematically dispersed within each 5 $\times$ 5 km grid square. We included all birds counted in the selected period; 4258 points on 452 routes/squares out of a total of 1602 squares (28.2%).

Since the data on the Starling density were too sparse to use based on the 98 Danish Municipalities as a unit, we amalgamated the density data into the 13 local count areas (which closely corresponded to the former Danish counties) as sampling units. We used the centre coordinate of each atlas square to aggregate all squares within local count areas.

2.4. Regional analysis

For the regional analysis, we divided the country into four regions, three almost equally large parts, West, Central and East, together with the island of Bornholm, which is geographically relatively small and distant from the others (Supplementary material Fig. 3; Table 1). Starling trends were analysed for each of these to compare the rates of decline for support for the hypothesis that the decline was more pronounced in areas with the largest decline in dairy cattle.

2.5. Agricultural statistics

We used area data on the extent of key tillage crops, grassland management types and annual cattle statistics in Denmark obtained from StatBank Denmark, the online repository for Danish agricultural statistics published annually (Danmarks Statistik, 2016). While the data for the whole of the country is provided