Grazer density and songbird counts in a restored conservation area

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Grazing by large herbivores is increasingly used as a management tool in European nature reserves. The aim is usually to support an open but heterogeneous habitat and its corresponding plant and animal communities. Previous studies showed that birds may profit from grazing but that the effect varies among bird species. Such studies often compared bird counts among grazed areas with different stocking rates of herbivores. Here, we investigated how space use of Konik horses and Highland cattle is related to bird counts in a recently restored conservation area with a year-round natural grazing management. We equipped five horses and five cattle with GPS collars and correlated the density of their GPS positions on the grazed area with the density of bird observations from winter through the breeding season. We found that of the eight most common songbird species observed in our study area, the Eurasian Skylark and the Common Starling had the clearest positive correlations with grazer density, while the Blackbird showed a negative correlation. Skylarks and Starlings in our study area thus seem to profit from year-round natural grazing by a mixed group of horses and cattle.

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Abstract

Grazing by large herbivores is increasingly used as a management tool in European nature reserves. The aim is usually to support an open but heterogeneous habitat and its corresponding plant and animal communities. Previous studies showed that birds may profit from grazing but that the effect varies among bird species. Such studies often compared bird counts among grazed areas with different stocking rates of herbivores. Here, we investigated how space use of Konik horses and Highland cattle is related to bird counts in a recently restored conservation area with a year-round natural grazing management. We equipped five horses and five cattle with GPS collars and correlated the density of their GPS positions on the grazed area with the density of bird observations from winter through the breeding season. We found that of the eight most common songbird species observed in our study area, the Eurasian Skylark and the Common Starling had the clearest positive correlations with grazer density, while the Blackbird showed a negative correlation. Skylarks and Starlings in our study area thus seem to profit from year-round natural grazing by a mixed group of horses and cattle.

Introduction

Bird communities in open landscapes are often positively influenced by ungulate grazing, due to the heterogenous, structure-rich environment created by the grazers (Roth 1976; van Klink et al. 2016; VanWieren 1995; Vera 2000). Therefore, grazing by one or more species of large herbivores is increasingly used as a management tool in European nature conversation areas (Henning et al. 2017; Loucougaray et al. 2004; Rosenthal et al. 2012).

The extent to which bird species react to grazing likely depends on how much they rely on the particular niches affected by grazing (Milchunas et al. 1988). For example, shortened vegetation may provide suitable nesting habitat and higher food availability for some bird species, while others may be impeded by the effect of trampling (Leal et al. 2019; Sharps et al. 2017; Toepfer & Stubbe 2001). The Eurasian Skylarks *Alauda arvensis* is one example of a species that was shown to require open and structurally diverse habitat mosaics with relatively short vegetation to maximize their nesting attempts (Wilson et al. 1997). In contrast, trampling was reported to be the main cause of nest loss of Skylarks and Meadow Pipits on meadows grazed by livestock at high densities (Pavel 2004).

Studies so far mainly compared how the impact of grazing on bird communities differs between enclosures with different stocking rates of large herbivores (Baldi et al. 2005; Dross et al. 2018). For example, (Batary et al. 2007) found that grassland birds were more abundant on extensively grazed areas compared to intensively grazed areas, while this was not the case in non-grassland birds.

However, it was so far rarely examined how the effect of space use patterns of grazers on particular birds varies within a given grazed area. One example is Kohler et al. (2016) who investigated space use of horses in relation to a bird assemblage in a German nature reserve by using a GPS collar on one of the horses. The authors found that the density of bird observations, especially of the Skylark, was higher where the density of horse GPS positions was higher.

Here, we studied how counts of songbirds are related to the space use of a mixed assemblage of five Konik horses and five Highland cattle in a French nature reserve that was recently ecologically restored. The applied management approach is natural grazing, a low intensity (<0.5 animal units per hectare) year-round grazing regime with the aim of substituting extinct wild herbivores such as the wild horse (*Equus ferus*) or the aurochs (*Bos primigenius*) with domestic breeds kept in semi-wild conditions, i.e. without systematic winter feeding and with minimal human intervention (Linnell et al. 2015; Vermeulen 2015). We thus investigated how counts of the different bird species from winter through the breeding season correlate with the density of GPS positions of the horses and cattle equipped with GPS collars in a natural grazing regime.

Materials & Methods

Study site

Our study site is located on the Rhine Island of the nature reserve Petite Camargue Alsacienne in France, north of Basel, Switzerland. About 100 ha of the island has been part of an ecosystem restoration project since 2014. The former crop fields on the area have been turned into an alluvial environment. A mixed habitat of grassland scattered with bushes (hawthorn, dog rose) and gravel sites was constructed, surrounded by patches of old forests (oak, ash). Since the beginning of the restoration project, saplings of willow and poplar are increasingly growing on some parts of the area. The water of the Rhine is led through the island in small creeks, and several ground-water ponds have been created.

The study was done with permission of the national nature reserve Petite Camargue Alsacienne.

Grazer data

Konik horses and Highland cattle were gradually introduced into a 32-ha test enclosure on the island between September 2018 and March 2019 to contribute to the maintenance of the heterogenous and open habitat. We equipped all horses (n=5) and cattle (n=5) with GPS collars (Followit, type Pellego) recording their positions once per hour, starting from the time of their arrival to the area. We used data starting from January 2019 when three cattle and all five horses were present on the area; two additional cattle arrived in March 2019. The data were downloaded through satellite processing from the interface of the GPS collar provider (Followit), therefore no contact to the animals was necessary to access the data. Since decades, GPS collars have been widely used on cattle without causing harm or disturbance (e.g. Turner et al. 2000; Ungar et al.

2005), and as recently discussed by Collins et al. (2014), GPS collars also comply with animal welfare requirements for horses.

GPS accuracy may be affected by atmospheric conditions, satellite or receiver errors (Hurn 1993), satellite geometry (Dussault et al. 2001), topography, overhead canopies, or adjacent structures (Di Orio et al. 2003; Moen et al. 1996); therefore the GPS fixes in our dataset likely had some imprecision. Our applied GPS collars did not record HDOP (horizontal dilution of precision) data and we therefore did not correct for inaccuracy of the fixes. However, since only 3.32% of all grazer positions fell outside the fenced area (those fixes were not included into the analysis), we assumed that this rate would not strongly influence our results (see also Ganskopp & Johnson (2007).

For statistical analysis, we pooled all grazer positions; we considered the hourly GPS fixes positions of horses and cattle as describing their space use (i.e., the density distribution of all horses and cattle over the study area).

Bird data

In 2019, we made 22 bird surveys between 31 January and 24 July. Visits were carried out in favorable weather conditions, on days without rain and with little or no wind.

We surveyed bird abundance by transect walking on the grazed meadows; we did not include a 10.6-ha-area of old forests that was part of the enclosure, so that the final size of the studied area was 21.4 ha. We selected three line transects (Gregory et al. 2004; Laiolo 2005) over the meadow area, each of about 700 m length, so that all parts of the grazed meadow were in visual and/or auditory distance from a transect. A trained observer (L.L.) walked along the transects with a slow pace and marked the position of the observed birds on a digital map (Map Marker 2.11_1442). Every identified bird species was recorded; birds flying higher than 20 m above the ground without showing connection to the area were excluded (e.g., skylarks that made territorial songflights at >20 m elevation were counted, but raptors crossing >20 m over the meadows were not). Surveys were conducted in the mornings until noon, avoiding dawn hours to minimize detectability differences due to rapid changes in birds' conspicuousness and activity (Dawson (1981). The order of visits of the three transects per morning were alternated systematically. Differences in bird detectability between transects were probably rather small, due to the similar open habitat of the surveyed areas. To minimize the risk of double counts, we used a cut-off distance of 60 m to either side of the transects so that transects would not overlap but cover the entire grazed area, and followed the recommendation of Dawson & Bull (1975): unless it is reasonably sure that the same individual is observed, observations are counted as different individuals.

Eight bird species had sufficient sample sizes (n>20 counts) for statistical analysis: Barn Swallow (*Hirundo rustica*), Common Blackbird (*Turdus merula*), Common Starling (*Sturnus vulgaris*), Eurasian Skylark (*Alauda arvensis*), Great Tit (*Parus major*), Meadow/Water Pipit

(*Anthus pratensis/spinoletta*; these two species were merged for analysis), Red-backed Shrike (*Lanius collurio*) and White Wagtail (*Motacilla alba*).

Statistical analysis

For analysis, the study area was divided into 113 50x50 m grid cells using the corner points of the UTM grid. Numbers of bird counts and of recorded grazer positions were summed up per grid cell, resulting in measures of bird density and of grazer density. Grazer GPS positions per grid cell were summed over the last 30 days prior to a bird survey; we assumed that grazer space use patterns earlier than 30 days before the respective bird survey did not substantially influence bird space use. Because we assumed detectability of bird species to be relatively homogeneous across the study area and we were not interested in estimating the total number of birds present in the study area, we did not take detectability into account in our analyses (as e.g. Buckland et al. 2001). Due to the migratory behaviour of some bird species, species composition changed over the course of the study. For the analyses, we excluded periods when a migratory bird species was not regularly present in our study site, which was from the 9th survey session (17th April) for the Pipits; until the 7th survey session (23rd March) for the Barn Swallow; and until the 12th survey session (4th May) for the Red-backed Shrike. The surveys were distributed between winter, spring and summer in order to capture a large variety of environmental conditions (e.g. temperature, vegetation) as well as different bird behaviours (wintering, migrating, breeding).

We used a negative binomial mixed model with a logarithm link function to measure species-specific correlations between bird counts and grazer density. The logarithm of the size of grid cells was used as an offset in the linear predictor in order to make counts comparable between grid cells of different sizes (at the edges of the study area some parts of the grid cells fell outside of the fenced area). We log-transformed grazer densities and therefore replaced values of zero (i.e. zero observations in a grid cell) with half of the minimal non-zero value. The log-transformed grazer density was used as covariate and bird species was included as a random factor. Both random intercepts and random slopes were used to model species-specific correlations between bird and grazer density.

We fitted the model using Bayesian methods as implemented in Stan (StanDevelopmentTeam 2014) via the function brm from the package brms (Bürkner 2017) in R 3.6.1 (RCoreTeam 2016). The default flat prior distributions over the reals were used for the average correlation between bird and grazer density. Half-student t(3,0,10) was used for the variance parameters and Gamma(0.01, 0.01) was used as prior distribution for the shape parameter of the negative binomial distribution.

We assessed model fit by residual analyses and posterior predictive model checking. From the residuals we calculated a semi-variogram in order to check for spatial correlation, and we calculated the autocorrelations in order to check for temporal correlation. The semi-variance ranged between 2.5 and 3.5 over the distances 0 to 200 m and it did not increase with distance. Temporal autocorrelations measured within species and within the 50x50 m grid cell ranged from -0.002 to 0.004 for the lag of 1 to 10 weeks, and thus we judged these temporal correlations to be small enough to be ignored. We further simulated 2000 different virtual replicated data sets from the model (posterior predictive distribution) and compared the proportion of zero values as well as the variance between the replicated and the real data in order to check for zero-inflation and overdispersion. The proportion of zero values in the replicated data ranged from 0.97 to 0.98 (1 and 99% quantiles), which included the proportion of zero values in the data (0.98). Also, the standard deviation of the data (1.89) fell within the range of standard deviations of the replicated data from the model (0.80 to 8.21). Therefore, we concluded that the model described the variance and the proportion of counts of zero of our data well and did not suffer from apparent spatial and temporal correlation.

We used 2000 simulated random values from the joint posterior distribution of the model parameters to describe parameter estimates and their uncertainty. We used the median of the marginal posterior distribution as point estimate and the 2.5% and 97.5% quantiles as lower and upper limits of the 95% Bayesian compatibility intervals (Amrhein et al. 2019b).

Results

In total, we observed 2125 individuals from 64 bird species. From the eight species included in the analysis, we made a total of 1424 observations. The only species that certainly bred on the grazed area were the Skylark and the Red-Backed Shrike. The White Wagtail likely bred on the meadows in the study area. The Great Tit, Common Starling and Common Blackbird bred in the bushes and patches of forest in and around the fenced area. Barn Swallows were observed foraging in flight and Pipits mainly in flocks on the ground.

Median grazer density per grid cell did not change markedly over the course of the study (figure 1). Variance in grazer density increased in May, indicating that grazing occurred homogeneously on all cells in winter, while during spring and summer some cells were grazed with a higher intensity whereas others were largely avoided by the grazers.

Bird species that showed a relatively clear positive correlation with grazer density ($P(\beta>0)$ is relatively high; table 1, figure 2), given our statistical model, were Starlings and Skylarks. In the Starling, our data are most compatible with slopes between 0.28 and 1.02 and in the Skylark with slopes between -0.18 and 0.63 (table 1). Species with the clearest negative correlations were Blackbirds and Barn Swallows ($P(\beta>0)$ is relatively low): the data on the Blackbird are most compatible with slopes between -0.92 and 0.07, and in the Barn Swallow with slopes between -1.33 and 0.29 (table 1). Apart from the Starling, however, the patterns are quite uncertain, given the wide compatibility intervals (table 1, figure 2).

Discussion

We investigated responses of birds to natural grazing in a newly restored nature conservation area by using GPS collars on individual cattle or horses. We studied grazing pressure on a continuous scale, which differs from earlier studies that categorized grazing pressure, e.g., as "high" or "low" (e.g. Batary et al. 2007). Further, unlike previous studies that investigated either the breeding season or winter (e.g. Hartel et al. 2014; Leal et al. 2019), we considered bird observations starting from winter through the breeding season, with year-round presence of semi-wild grazers. The resulting correlations therefore describe not only territorial behaviour of breeding birds but average relationships between bird and grazer densities over many different environmental conditions and life-cycle stages of birds.

Among the eight investigated bird species, the density of Starling observations showed the clearest positive correlation with density of grazer GPS positions in our study site. This was to be expected, given that Starlings usually prefer grazed pastures rather than arable farmlands (Heldbjerg et al. 2017) and often follow grazing herds, profiting from flushed insects (Källander 2004). We also found a relatively clear positive correlation in the Skylark (although also slight negative correlations would be compatible with our data, given our model (Amrhein et al. 2019a). Skylarks have been suggested to both benefit from and be impeded by grazing (see reviewed by Donald 2010). This is because trampling by large herbivores may destroy nests (Pavel 2004), while the shortened vegetation height benefits Skylarks in terms of food availability and suitable nesting habitat (Odderskær et al. 1997; Wilson et al. 1997). In our study site, both Starlings and Skylarks bred on or around the grazed area and were present throughout the study period, i.e. also outside the breeding season.

Those results do not necessarily imply a causal relationship; in general, correlations between grazers and birds could arise because both prefer the same habitat. In our study site, however, the habitat was completely restored and ecological succession started from bare ground in 2014. Although in the meantime, some of the growing saplings were removed manually, horses and cattle contribute to keeping the vegetation short and to re-creating areas with bare soil (e.g. at resting areas) since autumn 2018. Although the degree of causality is hard to quantify, we think it is probably correct to say that Starlings and Skylarks seem to profit from the presence of horses and cattle by using habitat that is kept open by the grazers.

We observed the clearest negative correlations in Blackbirds and Barn Swallows. Possible explanations may be that Blackbirds are often found next to areas with more dense vegetation that may not be preferred by grazers, while Barn Swallows were often observed flying over the water ponds that naturally had low or zero densities of grazer GPS positions. The uncertainty in the correlations found for Pipits, Red-Backed Shrikes, White Wagtails and Great Tits seems too high to allow interpretation, although the slightly positive correlations in Red-Backed Shrikes and Pipits would fit what we would expect given that those species are often found on or next to areas with bare ground.

It will be interesting to investigate in future studies how the space use of birds and grazers varies depending on season and how this affects the correlations between bird and grazer densities. It would also be interesting to study the influence of vegetation and ecological succession on spatial behaviour of grazers and birds, although here again it would be difficult to disentangle cause and effect.

Similar to our study, (Kohler et al. 2016) found that associations between bird abundance and grazer density varies greatly among bird species. Also Neilly & Schwarzkopf (2019) described that responses of birds to grazing are often complex and will reflect habitat requirements of the individual bird species. Whether a possible effect of natural grazing in a nature reserve is meeting conservation goals thus depends on which species one aims to protect. Among the eight most often observed birds in this study, the two species that are most threatened are the Skylark and the Red-Backed Shrike (according to the IUCN Red List (BirdLife 2018; BirdLife International 2017)). The observed positive correlations with grazer densities in those species are encouraging from a conservational point of view, given that natural grazing with horses and cattle is usually implemented to enhance habitat diversity and to support species of conservation concern.

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Table 1(on next page)

Characteristics of the marginal posterior distribution of the model parameters: medians, 2.5 and 97.5% quantiles(limits of the 95% compatibility interval) and proportions of posterior mass above zero (P(*beta*>0)).

The posterior mass corresponds to the posterior probability of the hypothesis that the parameter value is positive; values close to 1 indicate strong evidence for a positive relationship, values close to zero indicate strong evidence for a negative relationship.

Table 1. Characteristics of the marginal posterior distribution of the model parameters: medians, 2.5 and 97.5% quantiles (limits of the 95% compatibility interval) and proportions of posterior mass above zero (P(β>0)).

The posterior mass corresponds to the posterior probability of the hypothesis that the parameter value is positive; values close to 1 indicate strong evidence for a positive relationship, values close to zero indicate strong evidence for a negative relationship.

Parameter	Median of posterior	2.5% quantile	97.5% quantile	P(β> 0)
Intercept	-10.5	-11.7	-9.2	-
grazer density average	0.02	-0.44	0.48	0.53
grazer density Skylark	0.21	-0.18	0.63	0.86
grazer density Pipits	0.12	-0.60	0.86	0.65
grazer density Barn Swallow	-0.48	-1.33	0.29	0.12
grazer density Red-backed Shrike	0.13	-0.35	0.67	0.71
grazer density Wagtail	-0.16	-0.74	0.38	0.26
grazer density Great Tit	0.03	-0.40	0.45	0.56
grazer density Starling	0.62	0.28	1.02	>0.99
grazer density Blackbird	-0.38	-0.92	0.07	0.06
sd species intercept	1.47	0.86	3.13	-
sd species grazer density	0.51	0.21	1.22	-
negative binomial shape	0.013	0.011	0.015	-

Figure 1

Grazer density during 22 surveys in the course of the study period (January to July).

Day of year corresponds to the dates of bird surveys (1 = 1st January) and box plots give the distribution of grazer density per grid cell (n = 113) on the log scale. The blue line indicates the standard deviation of grazer densities for each survey.

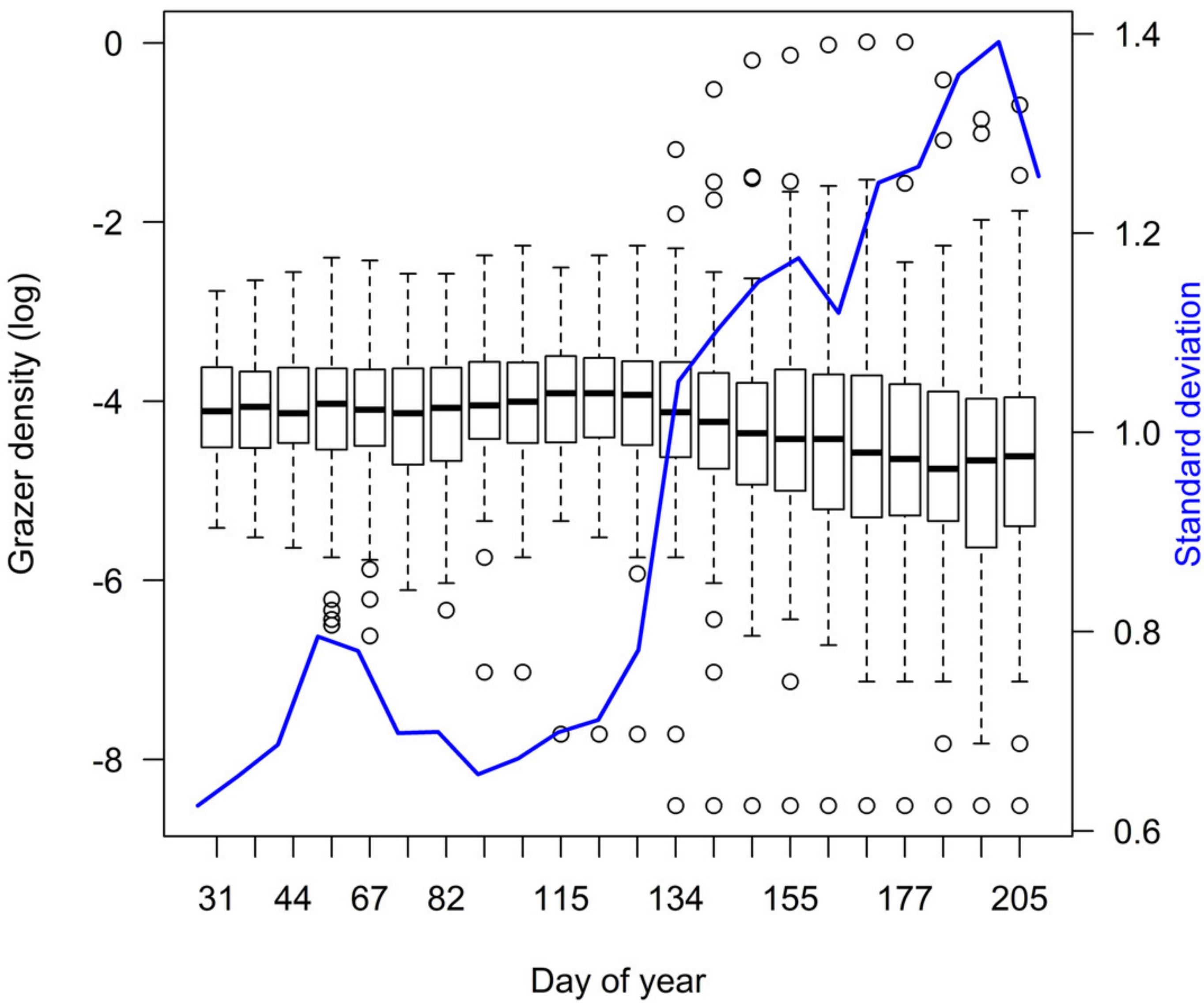
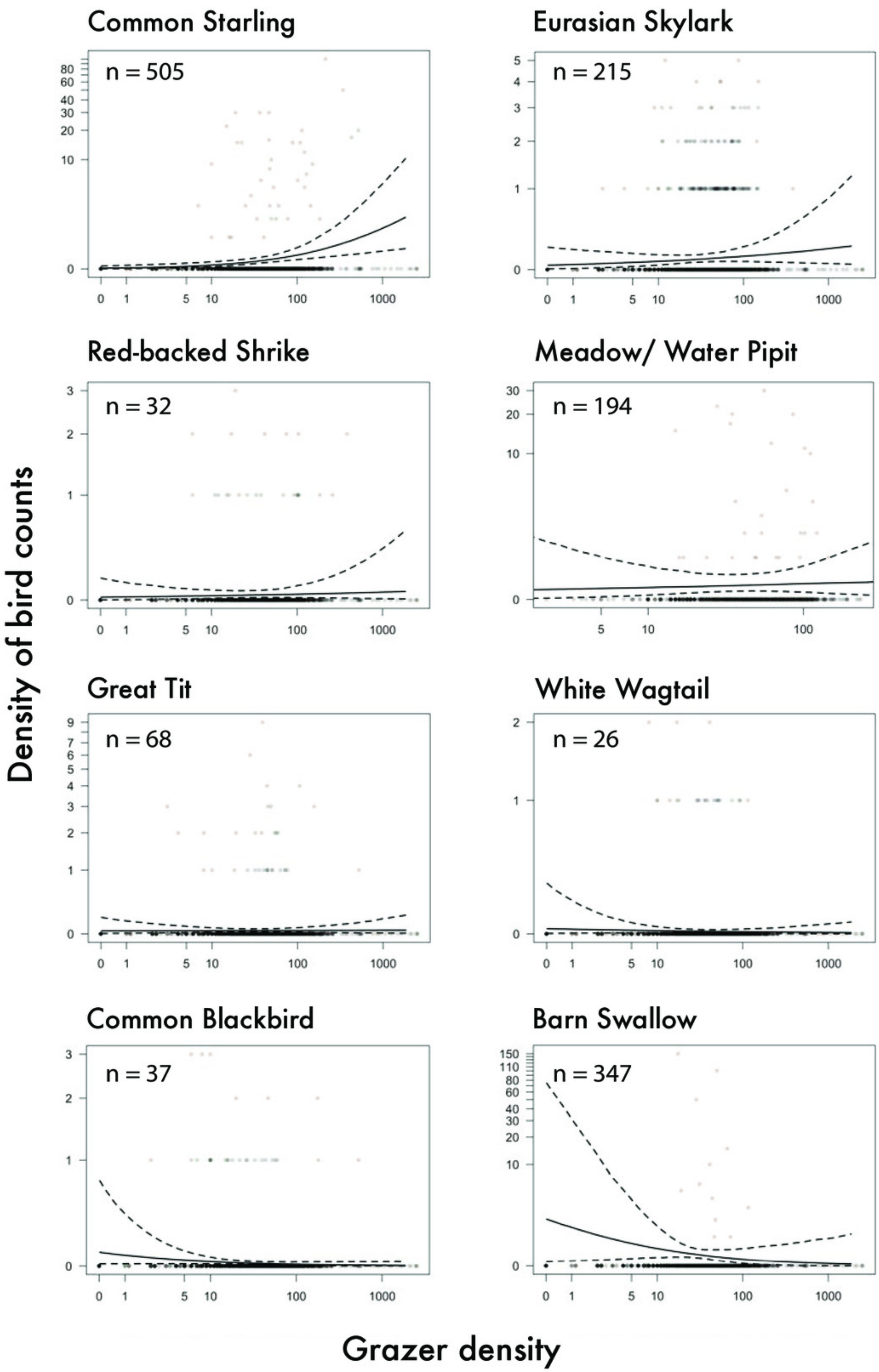


Figure 2

Correlations between bird count density (numbers of bird counts per survey per grid cell) and grazer density (numbers of GPS positions of horses and cattle per grid cell for the last 30 days prior to a bird survey).

Given are medians (solid lines) and 95% Bayesian compatibility intervals (dotted lines) of model predictions. Sample sizes (n) refer to the total number of birds counted in 113 grid cells during 22 surveys.


Common Starling
n = 505
Eurasian Skylark
n = 215
Red-backed Shrike
n = 32
Meadow/ Water Pipit
n = 194
Great Tit
n = 68
White Wagtail
n = 26
Common Blackbird
n = 37
Barn Swallow
n = 347
Density of bird counts
Grazer density