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# Effects of Anticoagulant Rodenticides and Farm Habitat Structure on Avian Communities in Livestock Farms

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## Simple Summary

It is well known that intensive land use and the use of pesticides lead to a loss of biodiversity. Songbirds have become less common on farmland in recent years. Some studies show that rodenticides can also harm songbirds and may even kill them. This study looked at whether rodenticide application on livestock farms affects the number of birds. Bird surveys were carried out on farms with rodenticide use and on farms without rodenticide use. Surveys were carried out before, during, and after rat control periods. The structure of the farms, including the proportions of grassed areas and buildings, was also recorded. The results suggest that rodenticide application may be associated with patterns in bird abundance. At the same time, farm structures show possible associations with bird abundance and the occurrence of ground-nesting species. The proportion of buildings on a farm was associated with patterns in bird abundance, and the proportion of grassed area was associated with patterns in ground-species occurrence. However, these associations do not establish causation, and the pathways through which rodenticide application may influence bird communities remain to be clarified. These findings suggest that improving the habitat on farms, for example by keeping grassed areas and buildings, can benefit songbird populations. Rodenticide use, on the other hand, showed a possible association with bird abundance. More research is needed to understand possible long-term effects.

## Abstract

Rat control using anticoagulant rodenticides on livestock farms is a widely applied practice worldwide. Birds can be exposed to rodenticides through direct ingestion or secondary poisoning, resulting in mortality or sublethal health effects. While impacts on raptors and owls are well documented, potential effects on songbird communities in farmland settings have received limited empirical investigation. To address this gap, avifaunal surveys were conducted on 12 livestock farms in the Münsterland, Germany, during 2021–2022, comparing farms with and without rodenticide application to assess impacts on songbird and farmland bird communities. In addition, farm structures, such as the proportions of grassed areas and buildings, were quantified using spatial analysis (linear mixed-effects model). Farm structure showed patterns in bird abundance and community composition, with the proportion of buildings and grassed area showing the most notable associations with bird abundance and ground-nesting species respectively. Rodenticide application showed possible associations with the number of individual birds. However, none of those patterns reached statistical significance, and causal mechanisms remain unclear due to the observational design. Larger-scale studies are needed to assess population-level consequences and optimize rodenticide use alongside habitat management.

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## 1. Introduction

Agricultural intensification is considered one of the main drivers of global biodiversity loss, ranking second only to resource overexploitation as a threat to biodiversity [1]. In particular, declines in farmland bird populations have been strongly associated with intensified agricultural practices [2–6]. This intensification is closely linked to the widespread application of synthetic pesticides, which are regarded as key contributors to biodiversity decline [1,7]. In addition to insecticides and herbicides, anticoagulant rodenticides (ARs) have increasingly attracted scientific attention due to their potential ecological impacts, although research on their effects on biodiversity remains limited, particularly for sublethal and population-level effects [8,9]. Nevertheless, these impacts warrant further investigation, as rodent control using poison bait constitutes a common management practice on livestock farms worldwide [10].

Anticoagulant rodenticides act by inhibiting blood coagulation, ultimately causing internal haemorrhaging and death following ingestion [11]. The delayed toxic effect is an essential feature for effective rodent control, as it reduces the likelihood of bait aversion ("bait shyness") among rats [10]. In recent decades, the use of second-generation anticoagulant rodenticides (SGARs) has increased substantially, largely as a consequence of the development of resistance to first-generation compounds [10]. SGARs—including difenacoum, brodifacoum, bromadiolone, flocoumafen, and difethialone—are characterized by their high toxicity, persistence, and bioaccumulative properties, allowing lethal doses to be consumed in a single feeding event [8,10,11]. These substances may also affect non-target wildlife species through primary, secondary and tertiary exposure [1,9,12,13]. Detecting such effects in wildlife is challenging because poisoned animals often die several days after ingestion and frequently away from the bait site [10,11]. Nonetheless, evidence of exposure in non-target organisms is of considerable ecological relevance, as it may serve as an indicator of broader environmental impacts associated with rodenticide application [11].

Current research in Europe has focused predominantly on predatory and scavenging bird species that are exposed to ARs through the consumption of contaminated rodents or carrion [13–20]. Investigations have examined AR exposure in species such as the Western Barn Owl (*Tyto alba*), Common Buzzard (*Buteo buteo*), Common Kestrel (*Falco tinnunculus*), and Tawny Owl (*Strix aluco*) [18,21], as well as the Golden Eagle (*Aquila chrysaetos*), Eurasian Eagle-Owl (*Bubo bubo*) [22], Northern Goshawk (*Accipiter gentilis*), and Eurasian Sparrowhawk (*Accipiter nisus*) [14]. These studies reported high frequencies of AR contamination, with detectable residues found in at least 50% of examined individuals. In some cases, approximately 30% of liver samples exceeded concentrations regarded as potentially lethal (>100 ng/g wet weight), while five out of six focal species showed residue levels above this threshold [21]. Approximately 35% of examined individuals exceeded established toxicity thresholds, supporting the assumption that AR compounds may significantly impair affected birds in their natural environment [20]. A recent study identified poisoning as the leading anthropogenic cause of mortality in the Red Kite (*Milvus milvus*) in Germany, primarily due to the ingestion of rats or mice previously exposed to poison bait [23]. Nevertheless, exposure to lower, sublethal concentrations may still cause toxic effects, including coagulopathy and internal hemorrhaging [14], reduced bone density, and an increased incidence of bone fractures [18,20,24]. Collectively, these effects may impair individual fitness and survival, thereby contributing to long-term population declines. AR use may negatively affect reproductive success in raptors and

owls, as juveniles are assumed to be especially susceptible to toxicological effects [21]. Exposure risk increased with urbanisation, particularly among adult individuals [14]. Differences in AR residue concentrations between nocturnal and diurnal species have been reported, with nocturnal raptors showing significantly higher residue levels than diurnal species [20]. Similarly, species that primarily prey on small mammals exhibited higher AR concentrations than bird-eating species [20]. These patterns suggest that ecological behaviour and feeding strategies influence secondary exposure to ARs, although the specific mechanisms underlying these differences remain incompletely understood.

Exposure of songbirds to ARs may occur through both primary and secondary pathways. Primary exposure involves the direct ingestion of poisoned bait, whereas secondary exposure occurs through the consumption of contaminated invertebrates or insects [17,25]. For example, granivorous and insectivorous bird species such as the Red-legged Partridge (*Alectoris rufa*), Rock Dove (*Columba livia*), Eurasian Collared Dove (*Streptopelia decaocto*), Great Spotted Cuckoo (*Clamator glandarius*) and Common Starling (*Sturnus vulgaris*) consume bait directly or feed on invertebrates that have previously been exposed to ARs [20,26,27]. Although not all of these species are passerines (songbirds in the strict sense), they are commonly present on farmland and thus potentially vulnerable to rodenticide exposure. Consequently, our study examined both songbirds and other common farmland species to assess broader community-level impacts. Insects can consume poisoned bait without exhibiting immediate adverse effects and can facilitate the transfer of AR residues through the food web [20,28]. Although anticoagulant rodenticide exposure has been documented in passerine birds [29,30], current studies primarily focus on detecting residues or confirming exposure. Consequently, little is known about the toxicological significance of these exposures or their potential implications for individual fitness and population dynamics. Considering rodenticide application effects on songbird populations, rats may negatively affect birds because they act as nest predators and can substantially reduce reproductive success. Rodent control on agricultural land may benefit wild bird populations in adjacent natural habitats [31,32]. Reduced nest predation resulting from rat control has been associated with increased breeding success in affected bird species such as the North Island Robin (*Petroica longipes)*, particularly in island ecosystems where rats are invasive [31]. While rodent control can provide substantial conservation benefits, particularly in ecosystems where invasive rats threaten native bird populations, these benefits must be balanced against the potential exposure of non-target wildlife to anticoagulant rodenticides.

We examined effects of anticoagulant applications on songbird occurrence by recording species abundance and richness on farms with and without rat control measures, giving consideration to farm structures such as the proportions of grassed areas, orchards, field shrubs, arable land and buildings. By linking rodenticide application to songbird community patterns under real farming conditions, this study addresses an important knowledge gap beyond exposure assessments and provides a first observational basis for informing both rodent management practices and farmland bird conservation [2,4–6].

## 2. Materials and Methods

### 2.1. Study Area

The study area was located in the north of North Rhine-Westphalia, to the east of Münster near Warendorf and Sassenberg. As a designated rodenticide resistance area, the Münsterland requires intensive rodent management on farms. The analysed farm areas (buildings, grassland, and pasture) ranged from 2.4 to 3.8 hectares. All farms were managed as conventional livestock operations with mixed dairy and beef production [33]. The farms were located 1–10 km apart and were surveyed consecutively in a random order.

### 2.2. Avifauna Recording

Bird surveys were conducted once per week between sunrise and approximately four hours after sunrise. To maintain standardised survey conditions and capture peak avian activity, all farms were surveyed within a single day starting at dawn. A fixed line-transect route [34] of approximately 30 min duration was walked on each farm to standardise sampling effort. Birds heard and seen within a 50 m radius around the route were recorded on a tally sheet. The total number of individuals recorded was used as a measure of abundance without applying a detection-probability correction; therefore, we acknowledge that these raw counts may be influenced by differences in detectability among farms and seasons. The number of different species detected provided species richness values. The monitoring period comprised two surveys before rat control (pre-treatment), four during the treatment phase, and two after the treatment (post-treatment) [33]. For analyses, the recordings were afterwards summed into a single value per farm. Birds on control farms (without pest control measures) were monitored simultaneously. Birds observed in transit were not recorded to avoid potential double-counting of individuals. In addition, point-count stations were spaced at least 250 m apart, which generally exceeds the core activity areas of many breeding songbirds [35], further reducing the likelihood of recording the same individuals at different locations.

The rat control using brodifacoum was part of the project ResRaMa and was carried out in accordance with the good practice guideline. Rat infestation was assessed by determining bait-box activity rates [36,37]. The infestation rates on farms were medium, with 44–71% of bait boxes showing evidence of rat activity (Tables S1–S4). Parallel to the rat control procedure, we recorded the avifauna in November 2021, December 2021 and January 2022 and repeated the recording in spring in March, April and May of 2022. In addition, we installed wildlife cameras (Browning Moultrie M-100, PRADCO Outdoor Brands, Birmingham, AL, USA) on farms to capture nocturnal raptors.

### 2.3. Farm Structure

To minimize potential confounding effects, farms without rat control were selected to resemble farms with rat control as closely as possible with respect to farm type and overall farm structure. All sampled farms were part of the ongoing rodent management project and represented a comparison of control timing rather than fundamental differences in farm management. Farm pairs were comparable in terms of livestock production, buildings, surrounding land use, and other structural characteristics. Habitat features including buildings, arable land, grassland, and field shrubs were subsequently digitised from aerial photographs using ArcGIS (version 10.5), and their respective area proportions were calculated relative to the total farm area (Table S5).

### 2.4. Statistical Analysis

Statistical analyses were performed using R software (version 4.5.1) [38]. First, parameters were tested for correlation and data were checked for distribution. Variables with high correlations ($r > 0.6$) were removed, resulting in a final set of four predictors. After checking for the Gaussian distribution of response variables using the Shapiro–Wilk test, we ran a linear mixed-effects model fitted with the lmer function from the lme4 package in R [39–41].

Species richness, bird abundance and guild-specific species richness (i.e., the number of species within each nesting guild, such as ground-nesters, tree-nesters, and cavity-/building-nesters) were modelled as the response variables, with rodenticide application (included as a categorical factor), grassed area, field shrubs, and buildings included as fixed effects. To account for the paired structure of the sampling design, pair identity was

included as a random intercept. Model estimates were obtained using restricted maximum likelihood (REML). Model assumptions were assessed by visual inspection of residuals and fitted values. The significance of fixed effects in the linear mixed-effects model was assessed using likelihood-ratio tests, comparing the full model with reduced models via the drop1() function using F statistics in R. Model fit for the linear mixed-effects model was assessed using the conditional $R^2$, calculated with the r2() function from the performance package in R, which represents the variance explained by both fixed effects and the random intercept.

## 3. Results

### *3.1. Avifauna on Farms with and Without Rat Control*

In total, 64 bird species were assessed on the twelve farms (Table S6). On nine farms, the most common species was the House Sparrow (*Passer domesticus*). On the three remaining farms, the most common species were the Feral Pigeon (*Columba livia domestica*), Common Chaffinch (*Fringilla coelebs*) and Eurasian Jackdaw (Corvus monedula). Further common species were the Great Tit (*Parus major*), Blue Tit (*Cyanistes caeruleus*), Common Wood-Pigeon (*Columba palumbus*) and, on one farm, European Starling (*Sturnus vulgaris*). Certain species, such as Grey Wagtail (*Motacilla cinerea*), Eurasian Tree Sparrow (*Passer montanus*), Goldcrest (*Regulus regulus*), Eurasian Collared Dove (*Streptopelia decaocto*) and Fieldfare (*Turdus pilaris)* were only represented by single individuals.

### *3.2. Factors Influencing Songbird Abundance and Species Richness*

The results concerning the effects of rodenticide application and farm structures on the songbirds on farms are presented in Table 1. For none of the five outcome variables did any of the four predictors show a statistically significant effect (all $p > 0.05$). The lowest $p$-values were observed for the proportion of buildings in relation to the number of individuals with $p = 0.11$, and for the proportion of grassed area in relation to ground-nesting species with $p = 0.09$. For the number of individuals, the F-values for rodenticide application with F = 27.34, field shrubs with F = 27.86, and buildings with F = 29.12 were higher than those observed for other response variables. However, the DenDF for all predictors were below 2 (DenDF = 0.71–1.03), which severely limits the statistical power of the corresponding F-tests.

The conditional $R^2$ varied greatly between the outcome variables. The model showed the highest value of the number of individuals with $R^2 = 0.65$.

**Table 1.** Results of linear mixed-effects models on species richness, bird abundance and guild-specific species richness (ground-nesting, tree-nesting, cavity-/building-nesting) in response to rodenticide application and farm structure (Sum Sq = sum of squares, DenDF = denominator degrees of freedom).

| Farm Structure | Number of Species | | | | Number of Individuals | | | | Tree-Nesting Species | | | | Ground-Nesting Species | | | | Cavity-/Building-Nesting Species | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Sum Sq** | **DenDF** | **F** | ***p*** | **Sum Sq** | **DenDF** | **F** | ***p*** | **Sum Sq** | **DenDF** | **F** | ***p*** | **Sum Sq** | **DenDF** | **F** | ***p*** | **Sum Sq** | **DenDF** | **F** | ***p*** |
| Rodenticide application | 11.7 | 5.43 | 0.53 | 0.50 | 14,625.2 | 0.71 | 27.34 | 0.19 | 10.0 | 7 | 0.45 | 0.53 | 0.25 | 5.27 | 0.12 | 0.74 | 0.0 | 4.08 | 0.0 | 1.0 |
| Grassed area [%] | 5.4 | 5.76 | 0.24 | 0.64 | 2,814.2 | 1.64 | 5.25 | 0.18 | 17.4 | 7 | 0.78 | 0.41 | 8.57 | 6.08 | 4.19 | 0.09 | 1.8 | 6.99 | 1.0 | 0.35 |
| Field shrubs [%] | 60.2 | 6.87 | 2.72 | 0.14 | 14,920.8 | 0.79 | 27.86 | 0.17 | 64.2 | 7 | 2.87 | 0.13 | 0.34 | 6.67 | 0.16 | 0.70 | 0.1 | 4.90 | 0.08 | 0.78 |
| Buildings [%] | 0.1 | 6.77 | 0.01 | 0.94 | 15,596.4 | 1.03 | 29.12 | 0.11 | 3.5 | 7 | 0.16 | 0.70 | 1.48 | 6.93 | 0.72 | 0.42 | 0.10 | 6.19 | 0.05 | 0.82 |
| Conditional $R^2$ | 0.2 | | | | 0.65 | | | | 0.33 | | | | 0.24 | | | | 0.11 | | | |

## 4. Discussion

The present case study suggests possible associations between rodenticide application, farm structures, and songbird communities on farms, though none of the observed patterns reached statistical significance. Nevertheless, the observed patterns are broadly consistent with evidence from previous studies demonstrating that rodenticide applications and farm structure can affect farmland birds at multiple levels.

Our data suggest a possible association between rodenticide application and the abundance of songbirds. This is broadly consistent with previous research reporting 222 passerine birds of 13 species as bycatch during rat control operations on farms in North Rhine-Westphalia [30]. By using anticoagulant rodenticide, residues of brodifacoum were detected in approximately 30% of the sampled individuals, with brodifacoum accounting for the majority of detections (91.5%). Species such as the Great Tit (*Parus major*), European Robin (*Erithacus rubecula*), Common Chaffinch (*Fringilla coelebs*), and Dunnock (*Prunella modularis*) showed the highest residue concentrations and were identified as the most affected species [30]. Field evidence demonstrates that such exposure can lead to songbird intoxication under natural conditions [42], documented even in breeding songbirds, with nestling mortality recorded following brodifacoum exposure [25]. A global analysis of rodenticide poisoning incidents documented over 640 non-raptor birds affected, including songbirds, demonstrating the widespread nature of non-target exposure [43].

These results indicate that passerine birds can be exposed to rodenticides through multiple pathways. Primary exposure can occur via ground foraging when bait is poorly covered or when birds enter bait stations. A recent review further emphasizes that primary exposure is documented in some songbird species, particularly granivorous ground-feeders that are prone to consuming bait and accumulating residues [44]. Secondary poisoning can then occur through the consumption of insects or molluscs that have previously been contaminated with the bait [8,45]. Notably, the Common Chaffinch and Great Tit were identified as among the species most affected by rodenticide exposure [30], and were also among the most frequently recorded species in the present study, suggesting that the potential for rodenticide-related effects on bird abundance was not negligible in the study system. Species-specific effects could not be assessed within the scope of this case study. However, while exposure and individual-level mortality of songbirds due to rodenticide application is documented [25,42,43], population-level consequences remain unclear. Given that non-target exposure of passerines has been documented even under professional rodenticide use, unintentional exposure and poisoning of songbirds cannot be excluded. Such exposure could represent a potential mechanism underlying the pattern observed in bird abundance in the present study.

The consistent documentation of SGAR exposure and individual-level effects across multiple studies, combined with the patterns suggested by the present data, indicates that population-level impacts on farmland songbirds cannot be ruled out. Future research with greater statistical power should assess whether SGAR-induced mortality translates to sustained population declines or recruitment losses in farmland songbird communities.

However, the ecological challenge of rodent management in agricultural systems is more nuanced than a simple choice between rodent control and bird protection. Rats themselves can have severe impacts on bird populations through predation, and effective control measures may therefore be essential in certain conservation contexts. This is particularly evident in island ecosystems such as New Zealand, where rat control has been shown to benefit native bird populations, as well as on the Halligen in the German North Sea, where increasing rat populations threaten the breeding success of ground-nesting waders [31,32]. Consequently, the challenge is not whether rats should be controlled, but how control can be implemented while minimising unintended effects on non-target species.

Beyond rodenticide application, the data suggest possible associations between additional farm structure parameters and mutable aspects of the songbird community on farms. The proportion of field shrubs and buildings showed patterns in bird abundance comparable to those observed for rodenticide application, with buildings showing the most notable signal for bird abundance. For nesting guilds, a possible association was observed for grassed area in relation to ground-nesting species.

These patterns may reflect the broader importance of structural habitat diversity for farmland bird communities. Field shrubs and buildings can provide nesting opportunities and foraging resources that are otherwise scarce in intensively managed agricultural landscapes. Consistent with this, one study reports that species richness and abundance of farmland birds increase with decreasing mean field size and that various semi-natural habitats are associated with higher bird species richness and abundance [6]. These findings underline the importance of structurally diverse agricultural landscapes, including different vegetation structures and semi-natural habitat elements [5]. Agricultural intensification worldwide has systematically replaced habitat heterogeneity with homogeneity, particularly through farm unit specialization that concentrates production into simplified, large-scale monocultures [46]. Conversely, farms that maintain structural diversity—including multiple vegetation structures, semi-natural margins, and integrated management approaches—support higher bird populations [46]. Around one of the farms investigated in this study, crop hemp was left standing during the winter months. At this site, among other species, above-average numbers of Common Chaffinches (*Fringilla coelebs*) and European Greenfinches (*Chloris chloris*) were observed. Semi-natural uncropped habitats are very valuable to farmland birds, especially during winter, as they offer food and shelter [4,5]. Winter represents a critical period for resident birds because reduced food availability and shelter opportunities in homogeneous agricultural landscapes coincide with increased energy demands, particularly in small bird species [4,47]. Studies highlight that homogeneous crop fields and the rigorous removal of stubble fields in winter lead to one-sided food sources; hence farms and stables can be an important food source and shelter for songbirds in winter [4,6]. However, even during the summer months, some species explicitly depend on open sheds and cavity-like structures in buildings, including the House Martin (*Delichon urbicum*), Barn Swallow (*Hirundo rustica*) and Black Redstart (*Phoenicurus ochruros*), as well as the House Sparrow (*Passer domesticus*) and Eurasian Jackdaw (*Corvus monedula*) [48].

Ground-nesting species such as the Yellowhammer (*Emberiza citronella*), Dunnock (*Prunella modularis*) or Eurasian Oystercatcher (*Haematopus ostralegus*) require open to semi-open habitats with varying vegetation heights, densities, and structures, as well as the least possible amount of sealed or compacted ground [15,49]. Our results tentatively suggest a positive association between the proportion of grassed area and ground-nesting species.

Research comparing crop-only systems with integrated crop-livestock farms demonstrates that diversified farming systems with structural heterogeneity harbor significantly higher native bird density and richness [50], broadly consistent with the pattern observed in the present study between buildings and bird abundance.

*Implications and Limitations*

Taken together, the results of this case study suggest a possible association between rodenticide application, farm structural parameters, and songbird communities. The use of rodenticide on farms is often unavoidable for effective pest management. However, the possible association between rodenticide application and songbird abundance observed in this study suggests that mitigation measures to reduce non-target exposure of birds should be considered. At a minimum, the potential impact of rodenticide application on farmland

bird communities should be acknowledged in pest management planning and monitored as part of broader biodiversity assessments on farms.

Furthermore, the patterns observed for farm structures suggest that maintaining habitat diversity, such as buildings and grassed areas, may support songbird communities on farms. These findings are broadly consistent with existing recommendations for agri-environmental schemes that promote structural heterogeneity in agricultural landscapes.

Several limitations should be considered when interpreting these findings. Other local factors may influence the detection probability of certain species, such as weather conditions [51]. Since this case study could not account for all potentially relevant management practices, the observed patterns may reflect the influence of additional factors beyond those explicitly tested [52]. Although farm structure was measured and incorporated into analyses, other correlated management practices were not assessed and may confound our findings. As is typical for farm-level case studies with complex treatment designs, the number of replicates was inherently limited, which constrained the statistical power of the analysis. In particular, the low DenDF observed in several models indicate that the dataset was insufficient to reliably test all fixed effects, and the observed patterns should therefore be interpreted with caution.

Furthermore, the second sampling phase coincided with spring migration, which may have influenced species composition and may be a limitation of our data set; the first sampling phase (winter) provided baseline data unconfounded by migration.

Finally, the long-term impacts of rodenticide use may not be fully captured in this case study, as cumulative effects on bird populations may only become apparent over extended time periods. Future research with greater statistical power should assess whether SGAR-induced mortality translates to sustained population declines or recruitment losses in farmland songbird communities.

## 5. Conclusions

This study aimed to assess whether rodenticide application affects songbird communities on livestock farms. The results show that rodenticide application had no significant effect on species richness, nesting guild composition or songbird abundance, but suggest an association between rodenticide application and songbird abundance that warrants further investigation. In contrast, farm structure showed patterns tentatively consistent with habitat-dependent effects in songbird communities, with farm buildings showing the strongest signal for total bird abundance and grassed areas showing possible association with ground-nesting species.

These findings suggest the importance of maintaining structural farm diversity while carefully considering rodenticide application strategies in farmland management. Preserving habitat features such as buildings and grassed areas may support songbird communities, and the potential negative impacts of rodenticide use on bird populations warrant consideration in pest management practices.

Overall, the findings suggest that both rodenticide application and structural farm characteristics may influence farmland bird communities, though causal relationships cannot be established from this case study alone.

While the limited number of replicates and the observational design constrain causal inference, this study provides a first step in documenting possible links between rodenticide application, farm structure, and songbird communities at the farm level. Larger, replicated studies across multiple regions and seasons are needed to confirm whether the observed patterns translate to sustained population-level consequences and to disentangle the relative contributions of rodenticide application and habitat factors in farmland management practices.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/birds7040064/s1. Table S1: Infestation analysis of 04/03/2022 before bait control on farm 4.12. "X" means activity detected either by feeding or footprints. "0" means no activity. The farms are given a number here due to anonymity. Table S2: Infestation analysis of 05/11/2021 before bait control on farm 4.3. "X" means activity detected either by feeding or footprints. "0" means no activity. The farms are given a number here due to anonymity. Table S3: Infestation analysis of 06/11/2021 before bait control on farm 4.4. "X" means activity detected either by feeding or footprints. "0" means no activity. The farms are given a number here due to anonymity. Table S4: Infestation analysis of 07/11/2021 before bait control on farm 4.5. "X" means activity detected either by feeding or footprints. "0" means no activity. The farms are given a number here due to anonymity. Table S5: All investigated farms, with details of the location (in North-Rhine Westphalia in western Germany), the investigation area (total area) and the farm structures. The total area is given in hectares [ha]. The farm parameters are given as percentages [%] of the total area. Table S6: List with all detected species and the respective classification of the guilds. For reasons of anonymity, a number was given to the farms (4.3–4.12a). Farms with the same identifier are similar in size, structure and livestock husbandry. The letter "a" means that no rat control took place on this farm.

**Author Contributions:** Conceptualisation, B.A., A.E. and S.B.; methodology, B.A.; software, B.A. and S.B.; validation, B.A., S.B. and A.E.; formal analysis, B.A. and S.B.; investigation, B.A.; resources, A.E. and S.B.; data curation, B.A. and S.B.; writing—original draft preparation, B.A.; writing—review and editing, B.A., S.B. and A.E.; visualisation, S.B. and B.A.; supervision, A.E. and S.B. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

## Abbreviations

| | |
|---|---|
| AR | Anticoagulant rodenticide |
| SGAR | Second-generation anticoagulant rodenticide |

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