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Short communication

Regional biodiversity conservation projects enhance stoat populations in agricultural landscapes

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A B S T R A C T

Regional biodiversity conservation (RBC) projects, encompassing landscape-scale agri-environment schemes (AES) and other governmental or non-governmental nature conservation initiatives, aim to counteract biodiversity loss in rural areas. Many such projects target specific species, for instance stoat (*Mustela erminea*). While studies have examined the impact of landscape-scale AES, the effectiveness of other RBC project types, particularly in promoting small mammals, has rarely been assessed quantitatively. Despite a lack of scientific evidence, expert-based views suggest that collaborative, coordinated landscape-scale conservation projects that consist in installing suitable micro-habitat structures are effective tools to promote biodiversity in general and stoats in particular. This study tested whether the relative abundance of stoats differed between sites with and without RBC projects. Using a paired design, 28 study sites distributed across 14 regions of the intensively farmed Swiss Plateau were compared. All the RBC projects had in common a targeted deployment of small structures, such as branch and stone piles, aiming at supporting stoat populations. Stoat abundance was estimated using a combination of three methods: scat collection with trained detection dogs, direct visual scat searches and camera trap boxes. Results showed that stoat abundance in RBC project sites was 2.5 times higher than in pseudo-control sites. This demonstrates that regional, collaborative conservation efforts to enhance local micro-habitat heterogeneity promote stoat populations in intensively farmed landscapes, highlighting their valuable contribution to wider-scale biodiversity conservation.

1. Introduction

The removal of natural and semi-natural elements, such as hedgerows and small structures, to enlarge agricultural field sizes and optimise crop cultivation efficiency is largely responsible for the ongoing farmland biodiversity crisis (Benton et al., 2003; Diacon-Bolli et al., 2012). These alterations have not only led to the widespread loss of landscape features and configurational heterogeneity, but have also reduced habitat availability and connectivity for a wide array of wildlife species (Fahrig et al., 2015; Grass et al., 2019; Tiang et al., 2021; Vallé et al., 2023), particularly those depending on structurally rich landscapes for hunting, sheltering and breeding (Debrot and Mermod, 1983; Estrada-Carmona et al., 2022; Jerrentrup et al., 2017; Sullivan and Sullivan, 2023).

Public and political awareness of the farmland biodiversity crisis increased from the 1990s (Krebs et al., 1999; Naeem et al., 1994),

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triggering numerous initiatives to promote more environmentally friendly agricultural practices (land-sharing approaches) that can support both biodiversity and productivity (Grass et al., 2019). These initiatives progressively developed into the agri-environment schemes (AES) that are nowadays present in many agricultural policies of European countries, including Switzerland (Batáry et al., 2015; Zingg et al., 2019).

Most AES are run at field- or farm-scale, regulating local management practices like pesticide and fertilisation inputs, and the mowing date (e.g. Hold et al., 2022; Knop et al., 2006; Rödiger et al., 2024). In contrast, "collaborative landscape-targeted AESs" (e.g. Meier et al., 2024; also referred to as regional AES, as opposed to horizontal AES, see Kleijn and Sutherland, 2003) are relatively novel and less studied, but generally considered more effective than field-scale measures (Batáry et al., 2020; McKenzie et al., 2013; Meier et al., 2024; Nguyen et al., 2022; Roilo et al., 2023). In Switzerland, this type of regional AES requires coordination among stakeholders to select and position field-scale AES across farms, with the overarching goal of creating a wider regional ecological network (Swiss Federal Council, 2013). This network is often complemented by additional conservation measures such as the installation of bird nest boxes, the planting of trees and the placement small structures. Similarly, governmental and non-governmental conservation initiatives such as Swiss regional nature parks (www.parks.swiss) and the Wieselnetz projects (www.wieselnetz.ch) implement conservation measures at the landscape scale. Together, these landscape-scale efforts (regional conservation initiatives and regional AESs) are hereafter collectively referred to as regional biodiversity conservation (RBC) projects.

In recent years, many new RBC projects have been initiated throughout Switzerland targeting the stoat (*Mustela erminea,* also called short-tailed weasel or ermine) among other species (see Wiesellandschaft Schweiz, https://www.infofauna.ch/de/nationale-koordinationsstellen/kleine-saeugetiere). Stoats are charismatic animals that serve as flagship species for broader conservation goals. As carnivores specialised in hunting voles and mice, they also contribute to natural pest control (Debrot, 1981; Elmeros, 2006; Korpimäki et al., 1991). Due to their high ecological requirements, such as complex, well-connected, and structurally rich farmland habitats and abundant small-mammal prey, stoats serve as key indicators for biodiversity (Debrot and Mermod, 1983; Erlinge, 1977; Hernández and Zaldívar, 2016; King and Powell, 2007) and, like other mustelids, can act as umbrella species (Mortelliti et al., 2022) or as sentinels of global change (Marneweck et al., 2022). RBC projects typically involve building small structures such as branch or stone piles (Fig. 1), a simple, low-cost, space-efficient way to restore habitat heterogeneity and support stoats. These structures provide stoats with shelter, stepping stones, nesting sites or hunting grounds (King and Powell, 2007; Lisgo et al., 2002; Sullivan and Sullivan, 2023).

So far, most AES studies have evaluated field-scale AES (see for example Batáry et al., 2015; Bruppacher et al., 2016; European Commission, DG Environment; UWE, Science Communication Unit, 2017; Uthes and Matzdorf, 2013). Although scientific evidence on the effectiveness of landscape-scale AES is still limited, nature conservation experts and practitioners consider RBC projects (both AES and non-AES) to be effective tools for the promotion of biodiversity in agricultural landscape due to their coordinated implementation and professional ecological support (Chevillat et al., 2012; Tyllianakis and Martin-Ortega, 2021). However, some challenges have also been pointed out, including excessive administrative burden and difficulties in establishing effective collaborative networks (Schüler et al., 2025; Tyllianakis and Martin-Ortega, 2021).

If assessed, the success of RBC projects is usually based on input metrics, like the number of small structures installed (e.g. Fischer, 2015; Keller and Ratnaweera, 2021; Müri and Weinberger, 2013; Ratnaweera et al., 2021), rather than direct ecological outcomes. While some projects have monitored mustelid presence post-implementation using track tunnels (e.g. Eichenberger, 2022; Steffen, 2020), most lack comparative baseline data or control sites limiting robust quantitative assessment. To the best of our knowledge, no study to date has properly examined the effects of RBC projects on stoat populations (Rossier et al., 2021).

The present study evaluates the effectiveness of RBC projects in promoting biodiversity at landscape scale, and the efficacy of installing small structures for stoats in particular. Stoats were monitored in fourteen different RBC projects offering piles of branches and stones that had been established under professional supervision within a collaborative landscape network. RBC project outcomes

Fig. 1. Example of small structure. Photograph illustrating a textbook example of a stone pile of approximately 2.5 m in diameter, featuring large stones that create cavities and multiple tunnels providing access to a central nesting chamber (inside the pile; not visible). The study area also includes less developed or degraded stone and branch piles, which are not shown here.

were compared with pseudo-control sites, i.e. void of small structures, or with sites where the establishment of small structures was not professionally supervised. Egloff et al. (2025) recently demonstrated a positive correlation between the relative abundance of stoats and the density of small structures. However, it remains unclear whether this effect was driven solely by the presence of the structures themselves, or whether additional benefits arose from professional guidance and landscape-scale coordination that typically characterise RBC projects. While Egloff et al. (2025) assessed how the small structure and surrounding habitat characteristics influence stoat occurrence at local scale, our study looks at the same system from a conservation policy-oriented perspective. Specifically, we test the hypothesis that stoat relative abundance is higher in regions with RBC project (hereafter referred to as focal sites) compared to other regions without such project (pseudo-control sites). In other words, this approach allows us to assess the broader regional effects of coordinated conservation efforts.

2. Methods

2.1. Study sites and experimental design

The study was conducted on the Swiss Plateau. It is a typical western European densely populated lowland landscape dominated by intensive agriculture, though field sizes are relatively small (mean ± SD = 1.25 ± 0.4 ha; see Zingg et al., 2018). Fourteen regions were selected based on the presence of RBC projects aimed at promoting farmland biodiversity at the landscape scale (Fig. 2). The distance between two adjacent regions ranged from 7 to 42 km, which ensured that replicates were independent. All RBC projects had in common that they actively installed small structures (i.e. branch or stone piles) to promote stoat populations.

A paired-design approach was adopted, with two study sites, one focal and one pseudo-control, selected within each of the fourteen regions. The focal site was located within the boundaries of the respective RBC project (Fig. 2). The paired pseudo-control site was selected randomly five km away from the focal site based on the following additional criteria: absence of an RBC project and within a similar agricultural landscape (i.e. excluding forest or urbanized dominated areas).

A 500 × 500 m grid was placed over each site, dividing it into 25-ha squares (Fig. 2). Five connected squares were then selected for sampling, with matching arrangements between the focal and pseudo-control sites within each region. In each square, three 5-m radius circular plots were selected. In focal sites, each plot contained a small structure installed as part of the RBC project. In pseudo-control sites, plots were located along similar landscape elements (e.g. hedgerows) but without small structures, though some plots may have included small structures placed independently by farmers. Both types of small structures usually had a footprint of 9–10 m^2, with branch piles measuring on average 1.2 m in height and stone piles 0.9 m. A detailed description of the small structures and habitat characteristics can be found in appendices E & G in Egloff et al. (2025). Overall, the study covered 14 regions, each with two sites, five squares per site, and three plots per square, resulting in a total of 420 study plots.

2.2. Stoat sampling

Half of the regions were surveyed in May—August 2022 and the other half in March—July 2023. As recommended by Jachowski

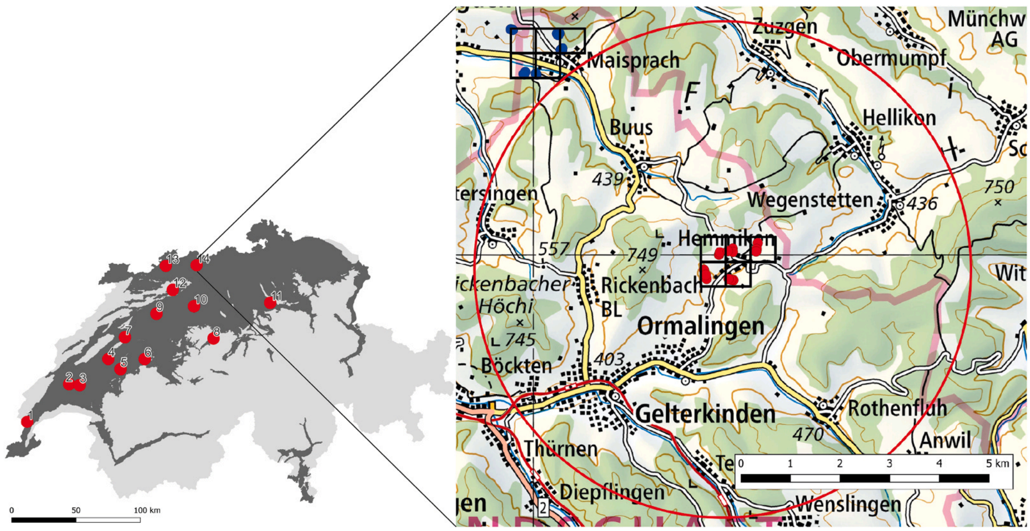

Fig. 2. Study regions in the Swiss lowlands and detailed view of a focal–control site pair. Map on the left shows the 14 paired study sites (red dots) distributed across the Swiss lowland (dark grey). The right panel provides a close-up of one selected region (Tafeljura), illustrating the spatial arrangement of a focal site (red dots) and its corresponding pseudo-control site (blue dots) within a 5 km radius (red circle). Lines indicate the connection between the overview map and the detailed inset. For coordinates and site-specific information, see appendix A in supplementary material.

et al. (2024) for *Mustela* species, study plots were monitored using two types of complementary, non-invasive methods: scat surveys and camera traps. Scat surveys were carried out in collaboration with Artenspürhunde Schweiz (www.artenspuerhunde.ch) using specially trained detection dogs. In addition, two out of three plots in each square were monitored with enclosed camera trap boxes (slightly modified "Mostela" type, Mos and Hofmeester, 2020) set for two consecutive weeks. Finally, all plots were visually searched for stoat scats following the scat surveys with the dogs, as well as when setting up and collecting back the camera boxes. All faecal samples collected were genetically analysed to ascertain species identification. For more information on the study design, plot selection and sampling methods see Egloff et al. (2025).

2.3. Data analysis

Generalized linear mixed-effects models with a Poisson distribution (*glmer* function from the *lme4* package, Bates et al., 2015) were used to analyse the relative abundance of stoats (i.e. the number of occupied plots per study site), with data from the scat surveys and camera trap pooled to determine plot occupancy. The predictor variable was the presence or absence of a RBC project, while accounting for the region as a random effect (see appendix B for details on statistical analysis). Including the density of small structures (i.e. the number of small structures within a 200-m radius buffer around all sampled plots) did not improve the model (based on the AICc value) and was therefore not included in the final model. Statistical analysis was performed with R version 4.4.1 (R Core Team 2024). Confidence intervals on the predicted values were calculated using the *easyPredCI()* function (Bolker, 2018) and Wald method. Pseudo R^2 values were calculated using the *r.squaredGLMM()* function of the *MuMIn* package (Bartoń, 2024).

3. Results

There was a significant 2.5-fold higher relative abundance of stoats (i.e. number of plots occupied) in focal sites (with RBC projects) compared to pseudo-control sites (Fig. 3). The model intercept (Estimate = 0.241, SE = 0.278, $P = 0.386$) corresponds to the estimated log-count for the focal sites. Compared to focal, the pseudo-control was associated with a significant lower relative abundance (Estimate = –0.999, SE = 0.442, z = –2.258, $P = 0.024$), accounting for regions as random effect. The predicted mean relative abundance of stoats was 1.27 for focal sites (95 % CI 0.74–2.19) and 0.47 for pseudo-control sites (95 % CI 0.21–1.05). The fixed effects explained approximately 18 % of the variation in relative abundance (marginal R^2 = 0.18), while including a region-level random effect increased the explained variance to about 27 % (conditional R^2 = 0.27, delta method; see table B.1 in appendix for full table of pseudo

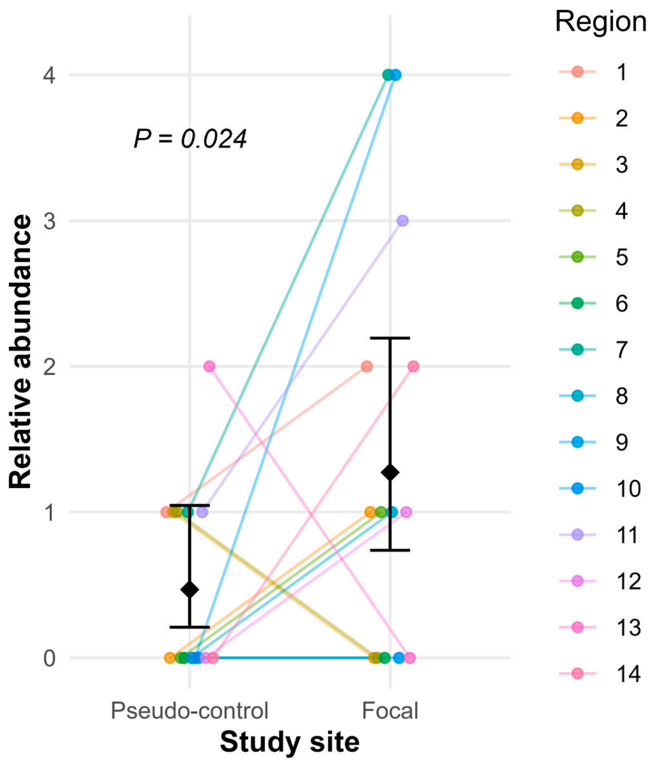

Fig. 3. Relative stoat abundance across focal and pseudo-control sites with model predictions. Comparison of stoat (*Mustela erminea*) relative abundance (i.e. the number of plots occupied) between paired focal (with regional biodiversity conservation projects) and pseudo-control sites across all 14 regions. Raw observed data points and connecting lines per region are shown in colour. Black diamonds represent modelled mean relative abundance predictions with 95 % confidence intervals indicated by error bars.

R^2).

Across all regions, focal sites contained a total of 122 branch piles and 73 stone piles, whereas pseudo-control sites contained a total of 64 branch piles and 21 stone piles. The mean density of small structures in focal sites was 37.7 ± 16.0 (± SD) structures within a 200-m radius buffer around the plots, while it was 9.1 ± 5.3 in pseudo-control sites.

4. Discussion

This study provides the first clear evidence that regional biodiversity conservation (RBC) projects are effective in promoting stoat populations at the landscape scale. Specifically, results showed that in focal sites (regions with RBC projects) the relative abundance of stoats (i.e. the number of occupied plots) was 2.5-fold higher than in pseudo-control sites (without RBC projects). These findings align with previous studies showing that coordinated AES efforts are key to promote biodiversity in agricultural areas (Batáry et al., 2015; McKenzie et al., 2013; Meier et al., 2024; Roilo et al., 2023). Together with these earlier findings, our study demonstrates that well-designed, collaborative conservation strategies aimed at supporting biodiversity through ecological networks in intensively farmed regions can promote a variety of taxa (see also Roilo et al., 2023; Zingg et al., 2019).

In the present study, pseudo-control study sites represented conventionally managed agricultural landscapes and functioned as meaningful reference points against which the relative abundance of the target species could be compared. They were located 5 km away from their respective focal sites to ensure data independence but were nevertheless comparable regarding key landscape features. Both the focal and pseudo-control sites contained small structures, but the difference was that their establishment in the pseudo-control sites was neither supervised nor encouraged by a professional. The presence of small structures in pseudo-control sites reduces the contrast between them and the focal sites, and this likely made our test of the hypothesis conservative. Egloff et al. (2025) have shown, in a previous phase of our research programme, that the number of small structures within a 100-m radius has a positive effect on stoat occurrence probability, while their volume also tends to play a positive role. Yet, including the density of small structures at site scale did not improve our model whereas including volume was not possible at landscape scale due to missing information. This suggests that, beyond the sheer number of small structures installed, their design and quality, such as their size, the material used and the presence of a central nesting chambers, are crucial for stoats. It is quite likely that some of these variables also correlate, such as larger piles are more prone to contain suitable nesting chambers. In our study, we were unable to assess the specific effect of the presence of a nesting chamber because we lacked information on which small structures contained one. However, it is reasonable to assume that the small structures built in focal sites contain a nesting chamber, as this feature is included in most expert-recommended construction guidelines (see for example Boschi et al., 2018). This would explain why the density as well as the volume of small structures were positively significant and marginally significant factors, respectively, at site scale (Egloff et al., 2025), a pattern not retrieved here at landscape level. Note that Egloff et al. (2025) had measured other ecological covariables, including prey abundance, small structure design and surrounding habitat complexity, but could not evidence any relationship with stoat occurrence.

Beyond the quality of small structures, their strategic placement within the landscape also likely plays an important ecological role (Prager, 2015). The added value of RBC projects for biodiversity appears to stem from the involvement of professional experts, who plan and supervise the placement of stone and branch piles to ensure they meet key functional criteria. By contrast, horizontal schemes often omit advising and training farmers, which can limit their effectiveness (Batáry et al., 2015). Expert guidance and coherent spatial planning therefore seem essential for a successful implementation of small structures for stoats.

4.1. Conclusion

Our study provides clear evidence that regional biodiversity conservation (RBC) projects are effective tools for promoting stoats at the landscape scale. Using a collaborative approach, the implementation of stone and branch piles has proven effective in boosting habitat suitability and population size of stoats. This supports the idea that targeted conservation efforts, even with limited spatial and financial resources, can yield great measurable ecological benefits.

While experts have long assumed that RBC projects benefit small mammals and other species that contribute to biodiversity, this assumption has lacked robust, quantitative support. Previous evaluations often focused on implementation metrics, such as the number of structures installed (e.g. Fischer, 2015; Keller and Ratnaweera, 2021; Ratnaweera et al., 2021), or lacked control comparisons (Steffen, 2020). Our study, by contrast, used a controlled design for a sound comparison and quantitatively measured the response of a target species, the stoat. Although our results center on this focal species, the use of stoats as informative bioindicators (Mortelliti et al., 2022) suggests that their positive response to RBC projects may indicate broader biodiversity benefits across farmland ecosystems. Importantly, this study confirms that the resources invested in these collaborative biodiversity initiatives operated at landscape scale do indeed translate into tangible outcomes, much more so than local (field-scale) and spatially isolated interventions. RBC projects should therefore be maintained, scaled up, and integrated into future agri-environmental policy and planning to ensure continued support for biodiversity in agricultural areas.

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CRediT authorship contribution statement

Dürst Andrin Christian: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Egloff Gregory Benjamin:** Visualization, Validation, Software, Methodology, Data curation, Conceptualization. **Laurent Schenker:** Validation, Methodology, Data curation, Conceptualization. **Raphaël Arlettaz:** Writing – review & editing, Resources. **Jean-Yves Humbert:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2026.e04082.

Data availability

Data will be made available on request.

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