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BRITISH ECOLOGICAL SOCIETY Ecological Solutions and Evidence

PRACTICE INSIGHTS

Evidence of greater dung beetle abundance in a rewilded area compared to nearby organic farms

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Abstract

1. Organic farms have been shown to harbour larger and more diverse invertebrate populations and associated ecosystem services compared to other conventional farming methods. However, data on the impacts of rewilding on invertebrates remain scarce.
2. Dung beetles contribute significantly to ecosystem function and are considered reliable indicators of ecological integrity. They have undergone serious population declines, largely due to changing agricultural practices.
3. Dung beetles were sampled simultaneously at each of four sites for a total of 120 trapping days at each site. Two of the sites had been rewilded using large, free-roaming herbivores, and two were nearby organic farms.
4. The rewilding sites yielded greater species richness and abundance compared to organic farms. The abundance of dung beetles was more than 20 times greater at the rewilded sites compared to organic sites.
5. One paracoprid (dung-burying) species, *Onthophagus similis*, was particularly abundant, comprising 95% of all individuals at the rewilded sites. Nonetheless, captures at the rewilding sites remained significantly higher even after this species was omitted from the analysis.
6. *Practical implication*: While additional research is necessary to ascertain whether our findings signify an atypical occurrence, the evidence from this case study suggests that rewilding with large herbivores may provide an effective strategy to combat dung beetle declines, restore ecological function and enhance ecosystem services.

KEYWORDS
conservation, ecological restoration, ecosystem function, insect, Knepp, Scarabaeoidea

1 | INTRODUCTION

Organic farming has gained recognition as a sustainable agricultural practice that can promote environmental health, enhance biodiversity and support ecosystem functioning (Gomiero et al., 2011). By largely avoiding synthetic pesticides and fertilisers, organic farming systems can benefit a variety of organisms, including insects. Studies indicate that organic farms can support higher insect diversity and abundance compared to conventional farming methods, which often rely on chemical inputs that can be detrimental to non-target species (e.g. Hole et al., 2005; Hutton & Giller, 2003; Stein-Bachinger et al., 2021). This increased biodiversity can be important for the provision of ecosystem services such as pollination, pest control and nutrient cycling (Sandhu et al., 2010).

In recent years, rewilding has emerged as a conservation strategy aimed at restoring ecosystems to more natural states through the restoration of non-human ecological factors and processes while reducing human control and pressures. This approach is thought not only to enhance biodiversity but also to contribute to ecosystem resilience and functioning (Perino et al., 2019). Rewilding can improve habitat connectivity and promote the recovery of native species, thereby supporting complex ecological interactions (du Toit & Pettorelli, 2019). The integration of rewilding into land management practices holds promise for ecological restoration and sustainable agriculture, yet there remains a need for empirical evidence to fully understand its benefits and implications.

Dung beetles (Coleoptera: Scarabaeoidea) serve as a valuable study system for assessing ecological health due to their critical roles in dung decomposition, nutrient cycling and soil aeration. These insects are important indicators of ecosystem function, as they contribute significantly to the recycling of organic matter and the regulation of pest populations (Beynon et al., 2012; Davis et al., 2004; Fincher, 1973). Furthermore, they are considered reliable indicators of ecological integrity due to their sensitivity to environmental change, ease of sampling and well-established taxonomy (Davis et al., 2004; Nichols & Gardner, 2011); among all insect groups, dung beetles may be particularly prone to population reductions (Sánchez-Bayo & Wyckhuys, 2019). Dung beetle diversity tends to be higher in organic farming systems, with studies showing that organic farms can support significantly greater species richness and abundance compared to conventional farms (Hutton & Giller, 2003; Sands & Wall, 2018). However, there is a notable lack of evidence regarding dung beetle populations in rewilding contexts, leaving a gap in our understanding of how these systems compare.

The aim of this study is to investigate whether active rewilding with large herbivores provides greater benefits for dung beetle biodiversity than organic farming. By conducting a comparative survey of dung beetle assemblages at an actively rewilded site and nearby organic farms, this research seeks to contribute to the growing body of evidence supporting rewilding initiatives and their potential integration into agricultural management strategies.

2 | METHODS

2.1 | Study area

The study was carried out in the Low Weald of West Sussex, UK, at two areas within the Knepp Castle Estate (North and South sections) and at two organic farms: Rudgwick Farm and Lee House Farm (see Figure S1 for locations). All are classed as being underlain by slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils (Soilscape 18; LandIS, 2016). All sites were located within 20 km of each other. The two sites at Knepp are approximately 4 km apart, have differing management histories, and are separated by non-rewilded parkland.

Eighteen years prior to this study, Knepp North (KN) was converted from a dairy farm to a 270 ha open grazed system of pasture and wood pasture, extensively grazed by cattle. Knepp South (KS) is a 530-ha site which, over the same time period, has been progressively converted from a mixture of intensive arable and pasture-based agriculture to a 'rewilded' landscape with small populations of cattle, Exmoor ponies, Tamworth pigs, fallow deer and red deer Rudgwick Farm (R) is a 44-ha organic beef farm, and Lee House Farm (LHF) is a mixed organic livestock farm of approximately 100 hectares, rearing cattle, sheep, pigs and poultry. Both farms have been managed organically since 1994 (24 years prior to this study) and are characterised by pasture in close proximity to woodland edges and hedgerows. Fields are rotationally cattle grazed during summer months, with cattle kept indoors over the winter period.

2.2 | Field survey

Ten pitfall traps were placed along transects in each of four randomly selected fields at each site (total 160 traps), with each trap a minimum of 10 m apart. Each trap consisted of a plastic bucket (20 cm diameter × 30 cm deep) buried flush with the ground and part-filled with a euthanising solution of polyethylene glycol. Traps were baited with 100 g of fresh cow dung suspended over the buckets on a mesh platform. Dung was collected from the same site and frozen for at least 24 h before the survey to ensure that any dung beetles already inhabiting the dung when it was collected did not enter the traps. Traps were deployed on 31 July 2018 and collected on 2 August 2018.

Specimens were stored in isopropyl alcohol prior to identification under a binocular microscope with ×10 magnification. All dung beetles were identified to a species level following Jessop (1986) and Skidmore (1991) and identifications were confirmed by Dr Darren Mann at the Oxford University Museum of Natural History.

2.3 | Data analysis

To test whether dung beetle abundance and species richness varied by site type, we employed generalised linear mixed models using the package lme4 (Bates et al., 2015) specifying field nested within location as random factors to account for repeated sampling. Site type (organic or rewilded) was specified as a fixed effect. Initial models assuming Poisson errors showed a high level of overdispersion for both richness and abundance; therefore, we specified a negative binomial error distribution with log link. An additional model testing for differences in abundance was run excluding the highly abundant species *Onthophagus similis* to assess whether differences between sites could be attributed solely to a single species response. Marginal r^2 values for the models were calculated using the package MuMin (Barton, 2019).

Rarefaction curves, sample coverage and expected species richness were calculated based on the incidence (presence/absence) of dung beetle species in each sample (pitfall trap). Incidence-based measures were used to avoid the high abundance of a single species skewing the results. Rarefaction curves and sample coverage were calculated using the R package iNEXT (Hsieh et al., 2016). Expected species richness was estimated using the improved Chao2 estimator iChao2 introduced by Chiu et al. (2014) using the R package SpadeR (Chao et al., 2016).

All analyses were carried out in R version 3.6.1 (R Core Team, 2019). The study was approved by UWE's Animal Ethics and Welfare Sub-Committee (ref R93) prior to the study's commencing.

3 | RESULTS

A total of 12,178 adult dung beetles belonging to 13 different species were collected across all sites. The total abundance of dung beetles caught on the rewilded sites was 11,666, while 504 were caught on the organic farms. *O. similis* was the most abundant species, representing 93% of all individuals caught ($n=11,399$). Ninety percent of all individuals collected were collected from Knepp South ($n=11,042$) of which 10,617 were *O. similis* (Table S1). Eleven of the species recovered were more abundant at the rewilded sites, with four species being found exclusively there. Only one species, *Geotrupes spiniger*, represented by one individual, was recovered exclusively from the organic farms.

The traps at the rewilded sites contained on average more species ($F_{1,13}=8.48$, $p=0.012$, $r^2=0.18$; Figure 1) and a greater individual abundance ($F_{1,13}=5.85$, $p=0.031$, $r^2=0.47$) of dung beetles than the organic farm sites (Figure 2a). Differences in bioabundance remained significant when *O. similis* was omitted ($F_{1,13}=4.71$, $p=0.049$, $r^2=0.15$; Figure 2b).

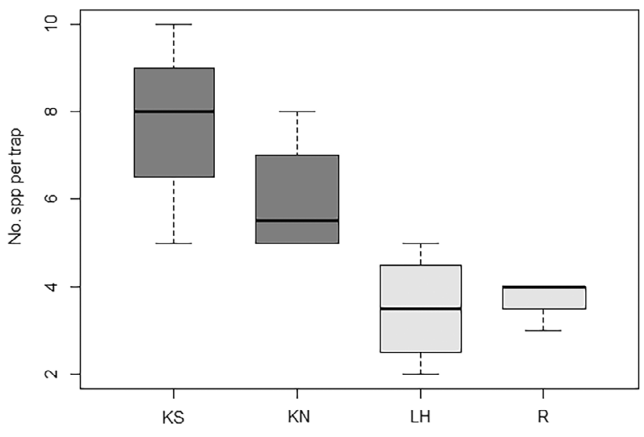

FIGURE 1 Median (+IQR) numbers of species of dung beetle caught per trap in each study location. Rewilded sites are shaded dark grey, and organic farms are shaded light grey.

Rarefaction analysis suggested that sample coverage was at least 90% in all cases (see Figure 3). Estimated total species richness appears to be significantly lower at one of the organic farms (Rudgwick; Figure 3) than at the other sites. While there is a tendency within the data for the rewilded sites to show higher estimated richness, there is not a clear distinction between rewilded and organic farms overall. These comparisons are based on visual inspection of the 95% confidence intervals, as there is not currently a validated statistical model for comparing Chao estimators; this method of establishing statistical significance is rather conservative (Colwell, 2013).

4 | DISCUSSION

We captured approximately 23 times more individual dung beetles at rewilded sites than at the organic farms, suggesting that rewilding practices may create conditions that allow for a considerable increase in the abundance of dung beetles. The number of species captured was higher at both rewilded sites, but overall species richness was estimated to be similar across all sites. It is possible that the comparative hyper-abundance of *O. similis* at the rewilding sites, where it comprised 95% of all individuals caught, may have resulted in overall species richness being lower than expected due to competitive exclusion by this species or by strengthened niche partitioning.

It is notable that the individual site with the highest abundance of dung beetles was Knepp South, the rewilded site with the highest diversity of large mammals, while Rudgwick farm, which is solely a cattle farm, had both the lowest abundance and species richness. However, we cannot discount that study area size is also an important factor, as the rewilded sites are both larger than the organic farms, and increasing habitat areas can impact population densities as well as species richness (Connor et al., 2000).

Nonetheless, the lack of empirical evidence on the effects of rewilding, especially on soil biota, makes this study noteworthy (see Andriuzzi & Wall, 2018). Our results suggest that the impacts of rewilding on dung beetle abundance are strongly positive. If these findings can be replicated both in time and space across other rewilding sites, it would suggest that the current dung beetle fauna of intensive agricultural habitats is highly depauperate. This will underpin the reduced provision of ecosystem services including nutrient cycling, carbon sequestration, and pest control, as well as populations of insectivores, in agricultural habitats (e.g. Manning et al., 2016; Manning & Cutler, 2018). If the increase in paracoprid abundance is a consistent effect of rewilding, it could be of particular importance for ecological function as these species transport dung into soil, burying carbon and recycling nutrients (Bang et al., 2005). However, it should be noted that the dynamics of dung beetle-mediated ecosystem service provision can be complex and may not simply be a function of dung beetle abundance and species diversity (e.g. Buse & Entling, 2020; Noriega et al., 2023).

This study highlights the case for further research into the impacts of rewilding on dung beetle populations, their associated ecosystem

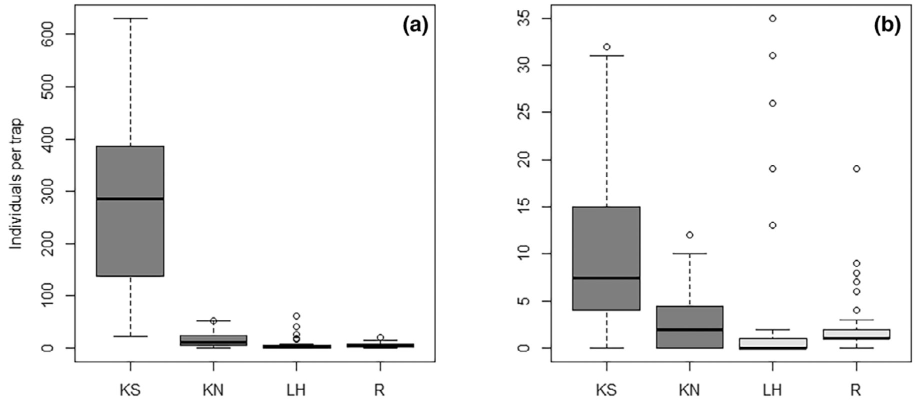

FIGURE 2 Median (+IQR) numbers of individual dung beetles caught per trap in each study location. Rewilded sites are shaded dark grey, and organic farms are shaded light grey. Panel (a) is for all species, and panel (b) shows the data with the highly abundant paracoprid species *Onthophagus similis* omitted. Open circles represent data points lying beyond 1.5 times the interquartile distance (outliers).

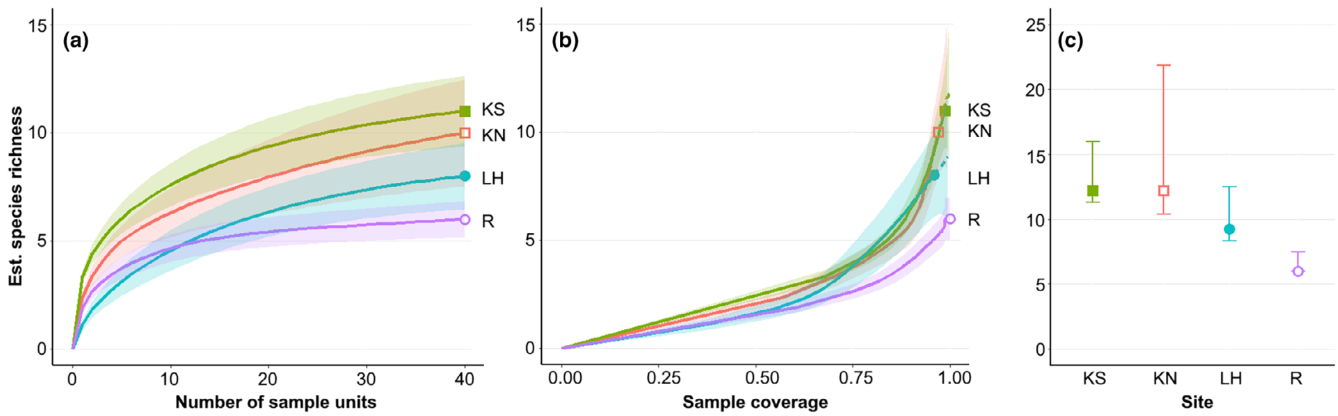

FIGURE 3 Incidence-based rarefaction curves for the species richness recovered from each sample site (a) and sample coverage (b). Dotted lines represent extrapolated values to 60 sample units. Interval plots (c) indicate the mean and 95% confidence intervals for the expected total number of species based on the iChao2 estimator (Chiu et al., 2014). Note the differing *y*-axis scale in panel (c). Knepp South (KS) and Knepp North (KN) are rewilded sites, and Lee House (LH) and Rudgwick (R) Farms are organic farms.

services, and whether these services spillover into surrounding agricultural areas. If our results can be replicated, they would strongly support the integration of rewilding land management practices within agri-environmental policies (see Merckx & Pereira, 2015).

AUTHOR CONTRIBUTIONS

The study was conceived and the manuscript prepared by all authors. Sarah Brompton designed the methods and implemented the study, contributed to the data analysis and drafted the manuscript; Sam Cotton co-supervised the project and oversaw the data analysis; Mark D. Steer co-supervised the project, prepared the data analysis and visualisation, and wrote the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.70017.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this research article are provided in the Supporting Information files and are also available at the DRYAD

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public repository: https://doi.org/10.5061/dryad.fbg79cp5r (Steer et al., 2025).

RELEVANT GREY LITERATURE

You can find related grey literature on the topics below on Applied Ecology Resources: Insect, Ecosystem function, Ecological restoration.

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REFERENCES

Andriuzzi, W. S., & Wall, D. H. (2018). Soil biological responses to, and feedbacks on, trophic rewilding. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, *373*(1761), 20170448. https://doi.org/10.1098/rstb.2017.0448

Bang, H. S., Lee, J. H., Kwon, O. S., Na, Y. E., Jang, Y. S., & Kim, W. H. (2005). Effects of paracoprid dung beetles (Coleoptera: Scarabaeidae) on the growth of pasture herbage and on the underlying soil. *Applied Soil Ecology*, *29*(2), 165–171. https://doi.org/10.1016/j.apsoil.2004.11.001

Barton, K. (2019). *MuMIn: Multi-model inference*. R package version 1.43.15. https://cran.r-project.org/package=MuMIn

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). *lme4: Linear mixed-effects models using Eigen and S4*. R package version 1.1-21. http://CRAN.R-project.org/package=lme4

Beynon, S. A., Mann, D. J., Slade, E. M., Lewis, O. T., & Morgan, E. (2012). Species-rich dung beetle communities buffer ecosystem services in perturbed agro-ecosystems. *Journal of Applied Ecology*, *6*, 1365–1372. https://doi.org/10.1111/j.1365-2664.2012.02210.x

Buse, J., & Entling, M. H. (2020). Stronger dung removal in forests compared with grassland is driven by trait composition and biomass of dung beetles. *Ecological Entomology*, *45*(2), 223–231. https://doi.org/10.1111/een.12793

Chao, A., Ma, K. H., Hsieh, T. C., Chiu, C. H., & Chao, M. A. (2016). *Package 'SpadeR'*. https://chao.shinyapps.io/SpadeR/

Chiu, C. H., Wang, Y. T., Walther, B. A., & Chao, A. (2014). An improved nonparametric lower bound of species richness via a modified Good–Turing frequency formula. *Biometrics*, *70*(3), 671–682. https://doi.org/10.1111/biom.12200

Colwell, R. K. (2013). *EstimateS: Statistical estimation of species richness and shared species from samples*. Version 9. User's guide and application. http://purl.oclc.org/estimates

Connor, E. F., Courtney, A. C., & Yoder, J. M. (2000). Individuals–area relationships: The relationship between animal population density and area. *Ecology*, *81*(3), 734–748. https://doi.org/10.1890/0012-9658(2000)081[0734:IARTRB]2.0.CO;2

Davis, A., Scholtz, C., Dooley, P., Bham, N., & Kryger, U. (2004). Scarabaeine dung beetles as indicators of biodiversity, habitat transformation and pest control chemicals in agro-ecosystems. *South African Journal of Science*, *100*, 415–424.

du Toit, J. T., & Pettorelli, N. (2019). The differences between rewilding and restoring an ecologically degraded landscape. *Journal of Applied Ecology*, *56*(11), 2467–2471. https://doi.org/10.1111/1365-2664.13487

Fincher, G. T. (1973). Dung beetles as biological control agents for gastrointestinal parasites of livestock. *Journal of Parasitology*, *2*, 396–399. https://doi.org/10.2307/3278842

Gomiero, T., Pimentel, D., & Paoletti, M. G. (2011). Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. *Critical Reviews in Plant Sciences*, *30*(1–2), 95–124. https://doi.org/10.1080/07352689.2011.554355

Hole, D. G., Perkins, A. J., Wilson, J. D., Alexander, I. H., Grice, P. V., & Evans, A. D. (2005). Does organic farming benefit biodiversity? *Biological Conservation*, *122*(1), 113–130. https://doi.org/10.1016/j.biocon.2004.07.018

Hsieh, T. C., Ma, K. H., & Chao, A. (2016). iNEXT: An R package for rarefaction and extrapolation of species diversity (Hill numbers). *Methods in Ecology and Evolution*, *7*(12), 1451–1456. https://doi.org/10.1111/2041-210X.12613

Hutton, S. A., & Giller, P. S. (2003). The effects of intensification of agriculture on northern temperate dung beetle communities. *Journal of Applied Ecology*, *40*, 994–1007. https://doi.org/10.1111/j.1365-2664.2003.00863.x

Jessop, L. (1986). *Handbook for identification of British insects: Dung beetles and chafers Coleoptera: Scarabaeoidea*. Royal Entomological Society of London. https://www.royensoc.co.uk/sites/default/files/Vol05_Part11.pdf

LandIS. (2016). *Soilscapes*. Cranfield Soil and Agrifood Institute. Cranfield University. www.landis.org.uk/soilscapes

Manning, P., & Cutler, G. C. (2018). Ecosystem functioning is more strongly impaired by reducing dung beetle abundance than by reducing species richness. *Agriculture, Ecosystems & Environment*, *264*, 9–14. https://doi.org/10.1016/j.agee.2018.05.002

Manning, P., Slade, E. M., Beynon, S. A., & Lewis, O. T. (2016). Functionally rich dung beetle assemblages are required to provide multiple ecosystem services. *Agriculture, Ecosystems & Environment*, *218*, 87–94. https://doi.org/10.1016/j.agee.2015.11.007

Merckx, T., & Pereira, H. M. (2015). Reshaping agri-environmental subsidies: From marginal farming to large-scale rewilding. *Basic and Applied Ecology*, *2*, 95–103. https://doi.org/10.1016/j.baae.2014.12.003

Nichols, E. S., & Gardner, T. A. (2011). Dung beetles as a candidate study taxon in applied biodiversity conservation research. In L. W. Simmons & J. Ridsdill-Smith (Eds.), *Ecology and evolution of dung beetles* (pp. 267–291). Wiley-Blackwell.

Noriega, J. A., Hortal, J., deCastro-Arrazola, I., Alves-Martins, F., Ortega, J. C., Bini, L. M., Andrew, N. R., Arellano, L., Beynon, S., Davis, A. L., & Favila, M. E. (2023). Dung removal increases under higher dung beetle functional diversity regardless of grazing intensification. *Nature Communications*, *14*(1), 8070. https://doi.org/10.1038/s41467-023-43760-8

Perino, A., Pereira, H. M., Navarro, L. M., Fernández, N., Bullock, J. M., Ceaușu, S., Cortés-Avizanda, A., van Klink, R., Kuemmerle, T., Lomba, A., & Pe'er, G. (2019). Rewilding complex ecosystems. *Science*, *364*(6438), eaav5570. https://doi.org/10.1126/science.aav5570

R Core Team. (2019). R: *A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Sánchez-Bayo, F., & Wyckhuys, K. (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation*, *232*, 8–27. https://doi.org/10.1016/j.biocon.2019.01.020

Sandhu, H. S., Wratten, S. D., & Cullen, R. (2010). Organic agriculture and ecosystem services. *Environmental Science & Policy*, *13*(1), 1–7. https://doi.org/10.1016/j.envsci.2009.11.002

Sands, B., & Wall, R. (2018). Sustained parasiticide use in cattle farming affects dung beetle functional assemblages. *Agriculture, Ecosystems and Environment*, *265*, 226–235. https://doi.org/10.1016/j.agee.2018.06.012

Skidmore, P. (1991). *Insects of the British cow-dung community*. Field Studies Council.

Steer, M. D., Brompton, S., & Cotton, S. (2025). Data from: Evidence of greater dung beetle abundance in a rewilded area compared to nearby organic farms. *Dryad Digital Repository*. https://doi.org/10.5061/dryad.fbg79cp5r

Stein-Bachinger, K., Gottwald, F., Haub, A., & Schmidt, E. (2021). To what extent does organic farming promote species richness and abundance in temperate climates? A review. *Organic Agriculture*, *11*(1), 1–12. https://doi.org/10.1007/s13165-020-00279-2

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Figure S1. Locations of study sites. Knepp South (KS) and Knepp North (KN) are rewilded sites, Lee House (LH) and Rudgwick (R) Farms are organic farms.

Table S1. Dung beetles captures at each study location and summed by farm system.

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