LETTER

Moderately common plants show highest relative losses

Florian Jansen1 | Aletta Bonn2,3,5 | Diana E. Bowler2,3,5 | Helge Bruelheide4,5 | David Eichenberg5

1 Faculty of Agricultural and Environmental Sciences, University of Rostock, Rostock, Germany
2 Department Ecosystem Services, Helmholtz-Center for Environmental Research—UFZ, Leipzig, Germany
3 Institute of Biodiversity, Friedrich Schiller University Jena, Jena, Germany
4 Institute of Biology/Geobotany and Botanical Garden, Martin Luther University Halle-Wittenberg, Halle, Germany
5 German Centre for Integrative Biodiversity Research (iDiv), Halle-Jena-Leipzig, Leipzig, Germany

Correspondence
Florian Jansen, Faculty of Agricultural and Environmental Sciences, University of Rostock, Justus-von-Liebig-Weg 6, Rostock 18059, Germany.
Email: florian.jansen@uni-rostock.de

Funding information
Deutsche Forschungsgemeinschaft, Grant/Award Number: DFG FZT 118

Abstract
Nature conservation efforts often focus on rare species. Common and moderately common species, however, receive much less attention. Our analysis of occupancy change of flora using a grid survey in 1980 and a habitat mapping survey in 2000 in Northeast Germany revealed significant losses for most of the 355 modeled plant species. Highest losses were recorded for moderately common species. Plant species occurring in 20–40% of grid cells declined on average by 50% in 20 years, although there were some methodological uncertainties. We found no correlation between occupancy decline and Red List category, but habitat loss seems to be a main driver. We suggest to rethink conservation indicators by including previously common species in monitoring. Our approach to estimating trends, using the association of species to habitat types and occupancy–area relationships, can be applied to other regions with heterogeneous resurvey data, but it cannot replace urgently needed monitoring schemes.

KEYWORDS
biodiversity loss, citizen science, grid mapping, habitat mapping, land use, monitoring, occupancy–area relationship, plants, species–area relationship

1 INTRODUCTION

Biodiversity faces growing pressure from human actions. In 1962, the International Union for Conservation of Nature published the first list of endangered species (IUCN Survival Service Commission, 1962) and ever since public attention regarding biodiversity loss has focused primarily on those species threatened by immediate extinction. A discussion about the probability of a sixth mass extinction on Earth, induced by humans, is ongoing (Dirzo et al., 2014). However, the quiet decline of species that are neither rare nor belong to taxa that are routinely monitored goes mostly unnoticed because of a lack of data (Eisenhauer, Bonn, & Guerra, 2019). Overlooked declines happen despite evidence of increasing pressures on biodiversity due to eutrophication (Hautier, Niklaus, & Hector, 2009), disturbance (Barlow et al., 2016), habitat fragmentation (Krauss et al., 2010), and other drivers (Butchart, 2010; Newbold et al., 2015), which can affect both rare and widespread species. For European birds, Inger et al. (2015) found that common species are rapidly declining while rare ones are even, on average, increasing. At the same time, it is often the common species that provide important ecosystem services (Gaston, 2010). In the case of plants, they provide food, carbon sinks as well as nectar sources and hosts...
for insects and other species groups. Monitoring programs focus either on rare species or on the most common species (Mitschke & Sudfeldt, 2005).

While there is an urgent need for standardized monitoring data, novel methodologies can now be employed to analyze heterogeneous historical survey data from multiple sources with differing quality to assess changes in species occupancy (MacKenzie et al., 2002). Here, we investigate two surveys of plants from Northeast Germany, both not intended as monitoring schemes, to show that changes in grid cell frequency can be revealed for many plant species.

2 | METHODS

We compared species observations from a comprehensive grid survey of the period 1977–1988 with a mapping of selected habitats 20 years later (see Electronic Appendix Fig. S1) in Mecklenburg–Western–Pomerania. The Northeast of Germany is characterized by agricultural land (58% of the area) and forest (21%) (Statistisches Bundesamt, 2018). Inland water (5.5%) and mires are characteristic for this young postglacial region although mires have been almost completely drained. The methodological challenges of our approach were that the habitat mapping in 2000 (i) did not comprise all plant occurrences comprehensively and (ii) covered only a fraction of each grid cell area. First, we addressed incomplete species lists of individual habitats by calculating occurrence probabilities for all species in the second survey making use of the species affinity to certain habitat types (see Electronic Appendix paragraph “Incompleteness of species lists” for further explanations). Second, we addressed the incompleteness of covered habitats by excluding all species not covered by the selective habitat types, and using occupancy–area relationships (Gaston & He, 2011) to scale probabilities according to covered area (see Electronic Appendix Fig. S2). Our assumptions were that (1) there is no or little bias in spatial sampling of the grid as well as the habitat survey, (2) a general formula like the increasing exponential decay function (or a power law function, see Electronic Appendix Fig. S4b) is able to scale the occurrence probabilities with area appropriately, (3) there is no difference in the bias induced by the scaling of occurrence probabilities with area between rare and common species, and (4) that relative frequencies of species in vegetation plots and in habitat species lists can be compared.

2.1 | Data compilation

The floristic database of the federal state of Mecklenburg–Western Pomeranian was started in 1954 and now contains close to 2 million observations of higher plant species. Most of the data has not been collected systematically, and there has been only one attempt to make a comprehensive survey throughout the federal state. Between 1977 and 1988 the occurrence of all known higher plant species was recorded in grid cells of so called Messtischblattfeldquadranten (MTBQ). These are grid cells of approximately 5 km × 5 km area defined as quarters of the ordinance maps of the Prussian topographic maps 1:25,000, delineated by meridians with a size of 10° longitudinal width and 6° latitudinal height (Figure 1). The survey was part of the distribution atlas of Eastern Germany that was accomplished by Benkert, Fukarek, and Korsch (1996).

The only other survey that has been conducted for more than a selection of species and with a coherent methodology throughout the federal state was a ministerial mapping of endangered habitats (“Biotop-Kartierung”) by the Mecklenburg–Western Pomeranian Agency for the Environment, Nature Conservation and Geology (Landesamt für Umwelt, Naturschutz und Geologie, 1998), conducted in 1996–2006, that is, approx. 20 years after the first floristic survey.

The habitat mapping scheme defined 346 types (Landesamt für Umwelt, Naturschutz und Geologie, 1998), 185 of them are mentioned at least once as main habitat types, that is, in more than 50% of a mapped area. Of these, 101 habitat types are defined by plant species in the mapping scheme. This enabled us to compare the occurrence probabilities by habitat type with those from a vegetation database of Mecklenburg–Western Pomerania (VegMV, version 15, Jansen, Dengler, & Berg, 2012, http://www.givd.info/ID/EU-DE-001). We used this vegetation database to safeguard the calculations from the often incomplete 1996–2006 habitat species lists (Figure 2). The VegMV database contains 30,310 plots with sufficient location information and plot observations between 1990 and 2010. We assigned vegetation plots to habitat types of the mapping scheme by a specific number of diagnostic species occurring in a plot (see explanations in Electronic appendix). This assignment of vegetation plots to habitat types enabled us to calculate probabilities of occurrence also for the area outside of the protected habitats in the normal landscape, using all those plots not assigned to habitat types as a random subset of the remaining landscape. For a discussion of the representativeness see Jansen et al. (2012). The number of species needed to assign a vegetation plot to a specific habitat type will influence the occupancy of this species inside versus outside of this habitat type. However, only 20% of the species × habitat type probabilities were informed by the vegetation database (Electronic Appendix Fig. S3).

2.2 | Taxonomy

The taxonomy of the data sources had to be harmonized (see the Electronic appendix for explanations). The floristic database of Mecklenburg–Western Pomeranian contains...
2,982 taxa (2,747 at species level, 197 aggregates, 7 Sections and 6 Series; see also Henker & Berg, 2006). The floristic grid mapping from 1977–1988 contained a subset of 1,570 taxa, the habitat mapping 1,127 taxa, and the vegetation database VegMV 1,737 taxa. A total of 1,107 taxa occurred in the 1977–1988 as well as in the 1996–2006 survey dataset.

2.3 Selection of species

The procedures proposed here can only be reliable for species with high affinity to the mapped habitat types of the second survey. For all species regularly occurring outside of the selected habitat types, the uncertainties are too high, because for the occurrence probability information is derived only from the vegetation database. VegMV is comprehensive (Jansen et al., 2012) but not representative with respect to species commonness. To identify the species to be excluded, we used the vegetation classification of Mecklenburg–Western Pomeranian (Berg, Dengler, & Abdank, 2004). In this classification, nearly 50,000 vegetation plots, covering as much vegetation diversity as possible, have been used to assign vegetation records to 285 phytosociological associations, grouped in 34 classes. Habitat types can easily be matched to these classes (see also Janssen, Rodwell, Criado, & Gubbay, 2016). We excluded all species listed in Berg et al. (2004) as indicative for aquatic (classes 1–5), ruderal or temporal (8, 16, 17, 18, 26), or very small (19, 25) habitats.

To further prevent false trend detection, we additionally filtered all taxa frequently incorrectly determined in the habitat mapping (Ringel 2017, unpublished). In addition, cryptic species with expected low detection probability; known to be synanthropic; or species that can only be observed seasonally, were excluded. We also excluded species that did not occur in the vegetation database VegMV, or that did not occur at least six times in habitat lists from analysis. The detailed list of excluded species and filters can be found in Electronic Appendix Table S2. The filtering increased the plausibility of the individual species occupancy predictions (Electronic Appendix Table S1). However, the general occupancy trend distribution remained unchanged if the analysis was conducted with the complete unfiltered species set (Electronic Appendix Fig. S4a).

We had to exclude most of the rare species from modeling and acknowledge that the increasingly longer Red Lists (Metzing, Hofbauer, Ludwig, & Matzke-Hajek, 2018) suggest that rare species have become increasingly rare and threatened. A comparison of the regional red lists from 1985...
2.4 Analysis of species occupancy changes

To assess the probability to encounter a specific species in a site given the habitat type and size of that area, we attempted to calculate species-specific species–area curves (also called occupancy–area curves if assessed in a gridded setting). However, this was not possible without additional information on the observation bias. Thus, we had to discard these attempts and took a simplified approach.

To summarize our workflow, we first calculated the probability of occurrence of individual species per habitat type (ψ) based on three calculations: (1) using all species lists of a specific habitat (2) using only the 20% of species lists sampled most comprehensively, and (3) using relative frequencies from vegetation plots assigned to this specific habitat type (Figure 3). Afterward, we chose the highest probability from these 3 calculations to ensure conservative estimations of decline. For every grid cell, we scaled ψ by habitat area in this grid cell with an increasing exponential decay function to predict ψ for all habitats and within the normal landscape of the grid cell, and replaced this probability by 1 if the species was actually observed in this grid cell.

The species occupancy changes were then calculated as the relative difference between the number of grid cells occupied in the survey of 1977–1988 and the sum of modeled probabilities for the period 1996–2006. Significance was tested by building 95% confidence intervals of 1,000 Bernoulli trials of each probability.

To relate the observed occupancy changes to rareness or commonness of species, changes in the number of occupied cells are displayed by grouping the species into fixed frequency intervals by their grid cell frequency in the 1977–1988 survey. Significance tests of group trends being different from zero were done by Wilcoxon rank-sum tests. All calculations, graphs and documents were done with R version 3.5.3 (R Core Team, 2019).

3 RESULTS

The habitat mapping contained approximately 32,000 areas assigned to one of the 185 main habitat types. After omitting habitat types without any diagnostic species in the mapping scheme or with 10 or less recorded species lists, 98 habitat types remained.

From the 1,107 taxa recorded in both surveys, we were able to model 355 species, that is, 32% of the recorded and 13% of all species in the region (Henker & Berg, 2006).

3.1 Changes in species occupancy

Of the 355 species 311 showed a significant change in occupancy. A total of 102 species significantly increased in grid cell occupancy, while 209 significantly decreased
Species grouped in percentage occupancy classes of the 849 modelled grid cells of Mecklenburg-Western Pomeranian in the first survey. Number of species are consistently greater in the grid survey “g” (N total = 1535) than in the habitat mapping “h” (N total = 871). Both show “hollow curves” of decreasing numbers of plant species. Most species threatened according to the Red List occur in low number of grid cells. Examples for changes in distribution of rare as well as common species are given in Electronic Appendix Fig. S5 a-g. Panel (b) shows the change in occupancy from the 1st to the 2nd survey for the 310 filtered species with significant changes. Number of species per frequency class are listed in gray on the bottom, the significance for each occupancy class being different from 0 (no change in occupancy) tested with Wilcoxon Rank Sum tests is asterisked on the top. Non-significant changes were set to 0

(see Electronic Appendix Table S1). The mean change across all frequency classes was −12%. Highest losses were detected for species that occurred in 20–40% of all grid cells with a median decrease of −50% (Figure 4).

3.2 | Red list status and habitat loss

There is no significant correlation between occupancy trends and species red-list status. “Least concern” and “not threatened” species showed the same amount of decline in occupancy frequency as “endangered” species (see Figure 5). The number of modeled species, however, was lower for the smallest occupancy class (1–84 grid cells, see Fig. 4), which increases the uncertainty of the average trend. The 65 species of this class represent only 4% of the 1,772 species observed in 1–84 grid cells in the overall floristic database. Those rare species include the majority of the Red listed endangered species of Mecklenburg–Western Pomerania (Voigtländer & Henker, 2005).

Habitat specialists suffered much more than generalists (Figure 6). Those species being indicative for less than four habitat types are declining most in occupancy.

4 | DISCUSSION

We found a significant decrease in occupancy for > 60% of all analyzed vascular plant species studied at the level of 5 km × 5 km grid cells. This indicates a massive change in the species composition of a Central European landscape in the last quarter of the last century. The most common procedure for measuring species declines is to measure the changes in their population sizes; in case of vascular plants, this is usually conducted using abundances or cover estimates. Both surveys used here contain only presence–absence information. Hence, changes on the population level probably have been even greater for them to be visible at the level of occupancy within 5 km × 5 km grid cells.
4.1 Drivers of species occupancy loss

Probably the most important driver of the observed species occupancy decline is habitat loss (Figure 6). The protected habitat mapping was not repeated in a comparable way between both periods, but a detailed expert analysis of the threats to different vegetation types in Mecklenburg–Western Pomerania (Berg et al., 2004) shows that 61% of all vegetation types are vulnerable and most of these habitat types have lost a significant part of their former distribution. The most endangered habitat types are nutrient poor sites, mires, and dwarf-shrub heathlands. Ecological reasons for plant and habitat declines are eutrophication, frequency of biomass removal, drainage, habitat alteration by deforestation, ploughing and use of herbicides (Metzing et al., 2018). The threat from alien plant species that newly arrived in the study region can be excluded (Jansen, Ewald, & Zerbe, 2011; see also Vilà et al., 2011).

The list of protected habitats of Mecklenburg–Western Pomerania covers open as well as forest habitats, aquatic, semiaquatic to dry habitats, undisturbed as well as managed habitats, and many other site conditions. However, some important landscape elements are completely missing. For instance, we had to exclude species from managed fields from our analysis because of a lack of data, despite the apparent species losses in agricultural areas (Berg et al., 2004; Meyer et al., 2015). Among the most endangered habitats in our study region and beyond are dry or very wet grasslands with low management intensity (Berg et al., 2004). Many species that suffered most according to our analysis, such as *Anthyllis vulneraria*, *Ranunculus bulbosus*, *Carex diandra*, or *Senecio aquaticus* are indicative of these grassland types. Forest plant species decreased in occupancy probably as a result of canopy closure due to eutrophication (Bernhardt-Römermann et al., 2015) and mire species suffered from drainage (Joosten, Tanneberger, & Moen, 2017). In contrast, coastal species seem to have survived better, as indicated by stable or even increasing occupancy of species such as *Hippophae rhamnoides*, *Cakile maritima*, and *Suaeda maritima*.

4.2 Nature conservation measures and their effect across trophic levels

The observed decline of moderately common plant species might have large effects on ecosystem services (Baker et al., 2019) as well as the abundance of animals. The subsequent consequences for food webs cannot be underestimated (Schleuning et al., 2016). The observed decline in insect biomass (Hallmann et al., 2017) is most probably related to the decline in occupancy and abundance of formerly common plant species. If this is true, conservation focus mainly on rare plant species threatened by extinction will not be sufficient to counteract the losses of dependent taxa from other trophic levels.

A Europe wide application of our proposed analyses of heterogeneous datasets could improve and complement already available biodiversity indicators for birds, butterflies, and mammals (de Heer, Kapos, & ten Brink, 2005). Given that many species depend on plants, such a biodiversity indicator would have great value for research and policy. Our results suggest that measures with a focus on moderately common to common species threatened by extinction will not be sufficient to counteract the losses of dependent taxa from other trophic levels.

4.3 Methodological issues

There is a considerable lack of data to assess species occupancy changes for most species groups across most countries. This is especially true for moderately common species. More research is needed to develop methods for the analysis of heterogeneous datasets. Combining structured and opportunistic data (Kelling et al., 2019) and using emerging legacy data (Brueelheide et al., 2018) are likely to be the most promising avenues. The presented approach provides a tool to deal with heterogeneous observation data, especially for plants while it still contains several uncertainties and cannot replace
appropriate monitoring schemes, that are urgently needed, especially in Germany.

The individual occupancy change values for single species might be influenced by several sources of variation and uncertainty as explained in the methods section and the Electronic Appendix. The form of the species–area relationship, for instance, will considerably influence the estimated trends and, despite the efforts taken, detectability still remains an issue. However, our finding of a nearly neutral effect for those species classified as endangered by experts, which would have been expected to have decreased in occupancy, is either a sign of successful conservation measures for rare species or a demonstration that our approach is on the conservative side.

5 | CONCLUSIONS

If the focus of nature conservation efforts remains on rare and threatened species only, ignoring moderately common species, we might miss most of the biodiversity changes occurring in our landscapes (Gaston, 2010). On the other hand, many formerly frequent species should be considered as under threat according to IUCN criteria.

The loss of moderately frequent species is an important driver for subsequent losses in animal communities that depend on plant species for nutrition, larval or overwintering habitat. The loss of associated ecosystem services of these dependent species such as pollination, carbon sequestration, or pest control have in consequence a pronounced effect on society (Schleuning et al., 2016). Overall we need a broader approach to conservation that includes also (moderately) common species in monitoring and appropriate conservation action. Conservation measures are more likely to be successful by identifying declining species before they are threatened by immediate extinction.

ACKNOWLEDGMENTS AND DATA AVAILABILITY

We thank the editor Jörn Fischer and two anonymous reviewers for their helpful comments on earlier drafts which improved the manuscript considerably. We are grateful to all the field surveyors mapping flora and habitats since so many decades. We much appreciate the support of the German Research Foundation (DFG) for funding the sMon working group (trend analysis of biodiversity data in Germany) through the iDiv (DFG FZT 118) synthesis center sDiv. A.B., D.B. and D.E. also acknowledge direct funding through iDiv. We are very grateful to Karsten Wescche, Petr Keil, Ute Jandt and Markus Bernhardt-Römermann for discussions on scaling biodiversity and their help during the sMon workshop in January 2018. All data used in this article can be accessed through http://www.flora-MV.de.

ORCID

Florian Jansen https://orcid.org/0000-0002-0331-5185
Aletta Bonn https://orcid.org/0000-0002-8345-4600
Diana E. Bowler https://orcid.org/0000-0002-7775-1668
Helge Bruehlheide https://orcid.org/0000-0003-3135-0356
David Eichenberg https://orcid.org/0000-0001-5740-5621

REFERENCES

Baker, D. J., Garnett, S. T., O’Connor, J., Ehmke, G., Clarke, R. H., Woinarski, J. C., & McGeoch, M. A. (2019). Conserving the abundance of nonthreatened species: Conservation of abundance. Conservation Biology, 33, 319–328. https://doi.org/10/gwvldz
Barlow, J., Lennox, G. D., Ferreira, J., Berenguer, E., Lees, A. C., Nally, R. M., … Gardner, T. A. (2016). Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. Nature, 535, 144–147. https://doi.org/10/f8tmdr
Benkert, D., Fukarek, F., & Korsch, H. (1996). Verbreitungsatlas der Farn- und Blütenpflanzen Ostdeutschlands. Jena: Fischer.
Berg, C., Dengler, J., & Abdank, A. (2004). Die Pflanzenfamilien der Mecklenburg Vorpommern und ihre Gefährdung - Textband. Jena: Weisssdorn.
Bernhardt-Römermann, M., Baeten, L., Craven, D., De Frenne, P., Hédl, R., Lenoir, J., … Verheyen, K. (2015). Drivers of temporal changes in temperate forest plant diversity vary across spatial scales. Global Change Biology, 21, 3726–3737. https://doi.org/10/f3p3v
Bruehlheide, H., Dengler, J., Jimnez-Alfaro, B., Purschke, O., Hennekens, S. M., Chytrý, M., … Zveryc, A. (2018). sPlot a new tool for global vegetation analyses. Journal of Vegetation Science, https://doi.org/10/gftjx5
Butchart, S. H. M. (2010). Global biodiversity: Indicators of recent declines. Science, 328, 1164–1169. https://doi.org/10.1126/science.1187512
de Heer, M., Kapos, V., & ten Brink, B. (2005). Biodiversity trends in Europe: Development and testing of a species trend indicator for evaluating progress towards the 2010 target. Philosophical Transactions of the Royal Society B: Biological Sciences, 360, 297–308. https://doi.org/10/fmft3x
Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. I. B., & Collen, B. (2014). Defaunation in the anthropocene. Science, 345, 401–406. https://doi.org/10/fdbqbw
Eisenhauer, N., Bonn, A., & A. Guerra, C. (2019). Recognizing the quiet extinction of invertebrates. Nature Communications, 10, https://doi.org/10/gltjx5
Fukarek, F. (1985). Rote Liste der verschwundenen und gefährdeten Höheren Pflanzen von Mecklenburg. Botanischer Rundbrief für den Bezirk Neubrandenburg, 16, 3–43.
Gaston, K. J. (2010). Valuing common species. Science, 327, 154–155. https://doi.org/10/dhkd3
Gaston, K. J., & He, F. (2011). Species occurrence and occupancy. In A. E. Magurran, and B. J. McGill: Biological diversity: Frontiers in measurement and assessment (pp. 141–151). Oxford, United Kingdom: Oxford University Press.
Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., … De Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE, 12, e0185809. https://doi.org/10.1371/journal.pone.0185809

Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., … De Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE, 12, e0185809. https://doi.org/10.1371/journal.pone.0185809
Hautier, Y., Niklaus, P. A., & Hector, A. (2009). Competition for light causes plant biodiversity loss after eutrophication. Science, 324, 636–638. https://doi.org/10.1126/science.1170865

Henker, H., & Berg, C. (2006). Flora von Mecklenburg-Vorpommern. Jena: Weidorn.

Inger, R., Gregory, R., Duffy, J. P., Stott, I., Voříšek, P., & Gaston, K. J. (2015). Common European birds are declining rapidly while less abundant species’ numbers are rising. Ecology Letters, 18, 28–36. https://doi.org/10.1111/ele.12309

IUCN. (2012). IUCN red List categories and criteria. Version 3.1.

Jansen, F., Dengler, J., & Berg, C. (2012). VegMV, the vegetation database of Mecklenburg-Vorpommern. Biodiversity & Ecology, 4, 149–160. https://doi.org/10.7809/b-e.00070

Jansen, F., Ewald, J., & Zerbe, S. (2011). Ecological preferences of alien plant species in North-Eastern Germany. Biological Invasions, 13, 2691–2701. https://doi.org/10.1007/s10530-011-9939-4

Janssen, J. A. M., Rodwell, J., Criado, M., & Gubbay, S. (2016). MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Andrew, R., … Guralnick, R. (2019). Using semistructured surveys to improve citizen science data for monitoring biodiversity. BioScience, 69, 170–179. https://doi.org/10.1093/biosci/biz003

Krauss, J., Bommarco, R., Guardiola, M., Heikkinen, R. K., Helm, A., Joosten, H., Tanneberger, F., & Moen, A. (2017). Janssen, F., Ewald, J., & Zerbe, S. (2011). Ecological preferences of alien plant species in North-Eastern Germany. Biological Invasions, 13, 2691–2701. https://doi.org/10.1007/s10530-011-9939-4

Janssen, J. A. M., Rodwell, J., Criado, M., & Gubbay, S. (2016). European Red List of Habitats. Wageningen, NL. https://doi.org/10.2779/091372.

Joosten, H., Tanneberger, F., & Moen, A. (2017). Mires and peatlands of Europe. Borntraeger.

Kelling, S., Johnston, A., Bonn, A., Fink, D., Ruiz-Gutierrez, V., Bonney, R., … Guralnick, R. (2019). Using semistructured surveys to improve citizen science data for monitoring biodiversity. BioScience, 69, 170–179. https://doi.org/10.1093/biosci/biz003

Krauss, J., Bommarco, R., Guardiola, M., Heikkinen, R. K., Helm, A., Kuussaari, M., … Steffan-Dewenter, I. (2010). Habitat fragmentation causes immediate and time-delayed biodiversity loss at different trophic levels: Immediate and time-delayed biodiversity loss. Ecology Letters, 13, 597–605. https://doi.org/10.1111/j.1461-0248.2010.01449.x

Landesamt für Umwelt, Naturschutz und Geologie. (1998). Anleitung für Biotopkartierungen im Gelände. Neuenkirchen: LAUN.

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Andrew, R., … Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. Ecology, 83, 2248–2255. https://doi.org/10.1890/0012-7240(2002)083[2248:EOSSPO]2.0.CO;2

Metzting, D., Hofbauer, N., Ludwig, G., & Matzke-Hajek, G. (2018). Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands Bd. 7 - Pflanzen. Bonn-Bad Godesberg: Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands.

Meyer, S., Bergmeier, E., Becker, T., Wesche, K., Krause, B., & Leuschner, C. (2015). Detecting long-term losses at the plant community level—arable fields in Germany revisited. Applied Vegetation Science, 18, 432–442. https://doi.org/10.1111/avsc.12168

Mitschke, A., & Sudfeldt, C. (2005). Das neue Brutvogelmonitoring in der Normallandschaft Deutschlands, Erfassungsmethode und erste Ergebnisse. Vogelwelt, 126, 127–140.

Newbold, T., Hudson, L. N., Hill, S. L. L., Contu, S., Lysenko, I., Senior, R. A., … Purvis, A. (2015). Global effects of land use on local terrestrial biodiversity. Nature, 520, 45–50. https://doi.org/10.1038/nature14324

R Core Team. (2019). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Schleuning, M., Fründ, J., Schweiger, O., Welk, E., Albrecht, J., Albrecht, M., … Hof, C. (2016). Ecological networks are more sensitive to plant than to animal extinction under climate change. Nature Communications, 7, https://doi.org/10.1038/ncomms13965

Statistisches Bundesamt. (2018). Statistisches Jahrbuch - (Destatis). https://www.destatis.de/DE/Themen/Querschnitt/Jahrbuch/statistisches-jahrbuch-2018-dl.pdf?__blob=publicationFile

Strohbach, M. W., Kohler, M. L., Dauber, J., & Klimek, S. (2015). High nature value farming: From indication to conservation. Ecological Indicators, 57, 557–563. https://doi.org/10.1016/j.ecolind.2015.05.021

Vilà, M., Espinar, J. L., Hejda, M., Hulme, P. E., Jaroszk, V., Maron, J. L., … Pyšek, P. (2011). Ecological impacts of invasive alien plants: A meta-analysis of their effects on species, communities and ecosystems: Ecological impacts of invasive alien plants. Ecology Letters, 14, 702–708. https://doi.org/10.1111/j.1461-0248.2010.01449.x

Voigtländer, U., & Henker, H. (2005). Rote Liste der Farn- und Blütenpflanzen Mecklenburg-Vorpommerns. 5. Fassung. Schwerin: Umweltministerium Mecklenburg-Vorpommern.

**SUPPORTING INFORMATION**

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