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RESEARCH ARTICLE

Can we trust vegetation resurveys?

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Abstract

1. Revisiting and resurveying historical vegetation plots has become a central tool for documenting changes in plant communities. However, theoretical studies suggest that reliable detection of long-term trends from a single resurvey is nearly impossible for species with high stochastic population fluctuations, though it may be relatively informative in more stable plant communities dominated by perennial species.
2. To empirically test how well data from a single resurvey align with estimated long-term trends in species richness and community turnover in European grasslands, we compiled permanent-plot time series from dry to wet grasslands that were sampled multiple times (most often annually) during the monitoring period. We then extracted pairs of surveys (baseline survey and one resurvey) from the individual time series and compared changes inferred from these pairs with trends inferred from the full time series using Bayesian multilevel regressions.
3. We found that in studied grasslands, data from a single resurvey can reliably reflect long-term trends in community turnover but deliver less reliable inferences of trends in species richness.
4. *Synthesis*. Despite limitations, single resurveys remain a useful tool for describing and understanding changes in plant diversity, at least in perennial grasslands. However, they should be used cautiously, especially regarding changes in species richness. In general, trend inference becomes more accurate as the number

of resurveys increases and the monitoring period lengthens. Unfortunately, such long-term, multiple-resurvey schemes still remain scarce.

KEYWORDS
bias, global change, sampling, temperate grasslands, vegetation, vegetation dynamics, vegetation plot

1 | INTRODUCTION

Over the past decades, environmental and socio-economic changes have had clearly negative impacts on biological diversity (Díaz et al., 2019). However, despite the well-documented global biodiversity decline, species richness of local communities has been found to decrease (Gonzalez et al., 2023), remain stable or increase (Dornelas et al., 2014; Jandt et al., 2022; Vellend et al., 2013) with increases most commonly documented in the case of plant communities (Häberlin & Dengler, 2025; Klinkovská et al., 2025). At the same time, local plant communities undergo constant vegetation turnover, often decoupled from changes in species richness (Hillebrand et al., 2017). Many studies report increasing community turnover consistent with biotic homogenisation (e.g. Daru et al., 2021), yet the magnitude and direction of these changes vary considerably across habitat types and regions. In contrast, the overall direction of species richness change remains more contested. Yet, even where a consistent long-term direction of community change exists, reliably detecting it from observational data remains challenging. Long-term trends and impacts of environmental conditions unfold slowly over decades, while many plant communities are simultaneously subject to short-term, typically interannual, stochastic variation driven by disturbances, climatic fluctuations or extreme climatic events (Erdős et al., 2024; Fischer et al., 2020). This random noise can easily obscure or mimic directional trends (Magurran et al., 2010). A reliable assessment of deterministic long-term changes in local plant communities can be based on permanently marked plots that are revisited and resurveyed multiple times over several years or decades (McCain et al., 2016). However, collecting such datasets is highly demanding and often rests upon the dedication of individual researchers who continue sampling despite discontinued funding. This makes such datasets particularly scarce and, consequently, insufficient for comprehensive assessments of plant diversity change across multiple habitats or larger geographical areas.

To overcome this gap in spatial coverage and extend our understanding of vegetation change further back in time, it has become common practice to revisit and resurvey old vegetation plots that were initially not sampled for this purpose (e.g. Jandt et al., 2022; Kapfer et al., 2017; Klinkovská et al., 2024; Knollová et al., 2024; Verheyen et al., 2018). A standardised plot-based sampling methodology that has been used relatively consistently for decades, at least in most of Western and Central Europe (Dengler et al., 2008), ensures that old and new surveys remain methodologically more or less compatible. However, the potentially large volume of data comes at a cost. In particular, if only two temporal observations are available (the baseline survey and a single resurvey), then only relatively simple, linear changes in diversity can be captured with unknown accuracy (McCain et al., 2016). If patterns of plant diversity change are more complex (e.g. saturating, non-monotonic, oscillating or fluctuating), then both the baseline survey and resurvey samples can deviate significantly from the long-term trend (de Bello et al., 2020). Theoretical studies suggest that the likelihood of false conclusions from a single resurvey depends on the demographic traits of the studied organisms and can be relatively high (McCain et al., 2016). However, these claims have not yet been evaluated with empirical vegetation data.

Here, we present the first empirical evaluation of the reliability of vegetation resurveys based only on two surveys in time. We used 20 datasets from permanent-plot monitoring time series in European grasslands that were surveyed multiple times and spanned 14–44 years between the first and last survey, with half of the datasets covering more than 20 years. We specifically ask how well a random combination of two surveys from each of these time series reproduces the trend in species richness and community turnover captured by the complete set of surveys.

2 | MATERIALS AND METHODS

We analysed 20 datasets of permanent-plot monitoring time series from the ReSurveyEurope and LOTVS databases (Table S1; Knollová et al., 2024; Sperandii et al., 2022). These datasets represented seven dry (35%), five mesic (25%), four mesic-to-wet (20%) and four wet (20%) grasslands. Each of these datasets comprised between 6 and 212 permanent plots. The interval between the baseline and final survey ranged from 14 to 44 years, during which all datasets were sampled at least 12 times, often with annual intervals. In datasets from experimental studies, we included control plots and plots managed in a manner typical of the given habitat, such as mowing, browsing or grazing. We analysed trends in species richness (i.e. the number of species detected in the plot during the survey) and in occurrence- and abundance-based community turnover, expressed by Sørensen and Bray–Curtis dissimilarity indices, respectively. From each time series datasets, we extracted all possible pairs of surveys, always consisting of the baseline survey and each resurvey between the sixth and the last year (e.g. a dataset of plots that were annually sampled for 20 years would provide the following 15 pairs: 1–6, 1–7, 1–8, …, 1–20). For each of these pairs, we computed two Bayesian

multilevel regressions (BRMS; Bürkner, 2017), one representing the best possible approximation of the long-term trend (hereafter 'trend model'; 'long-term' here referring to the trend captured by the entire monitoring period), and the second representing the same trend as derived from the focal pair of the baseline survey and a resurvey only ('two-visit model'). Since the two-visit model can inherently only be linear, we limit our analysis to linear terms in general. In the case of species richness, we allowed for varying intercepts for plot. We did not account for spatial, nor temporal autocorrelation. We assumed a Poisson (or negative binomial) and a Gaussian distribution of responses in the case of species richness and community turnover, respectively. For species richness, we tested each model via binned posterior predictive variance ratios; when these exceeded 1.2 in any of 10 bins, both complementary two-visit and trend models were refitted with a negative binomial distribution. For each model, we used four Markov chains with 2000 iterations each, and additionally 2000 warm-up iterations. We used the BRMS package's default weakly informative priors. Model diagnostics are documented in the Supporting Information (Figure S1).

We calculated the trend model based on all but the two focal surveys used for the two-visit model to minimise the dependency between both models (e.g. for a resurvey conducted in the 6th year, the trend model included the following surveys: 2nd, 3rd, 4th, 5th, 7th, ..., 20th). To quantify the difference between the two models, we used the posterior distributions of their regression slopes. Since turnover alone is already a measure of change between two surveys, we had to adopt a different strategy. We therefore shifted the time series so that the *x*-value representing the survey year was set to zero, and then extracted posterior distributions of intercepts instead of slopes from both models. The intercept of each model thus corresponded to the predicted turnover value (Sørensen or Bray–Curtis dissimilarity) between the baseline survey and the resurvey, that is the magnitude of compositional change between the two surveys, which is an ecologically meaningful quantity.

We subtracted the posterior distributions of model coefficients for the trend model from those for the two-visit model and derived the 0.025 and 0.975 quantiles of these differences. If this interval included zero (i.e. no significant difference between the two estimates), we considered both models as converging. The degree to which models converged ('goodness of fit') was then expressed using a coefficient of efficiency ($1 - \Sigma(\text{two-visit} - \text{trend})$ (Boch et al., 2022)/$\Sigma(\text{trend} - \text{mean (trend)})$; Boch et al., 2022; Nash & Sutcliffe, 1970). The coefficient of efficiency ranges from −Inf to 1, with 1.00 indicating perfect, values >0.75 indicating very good, values <0.5 poor alignment and values below 0 indicating no alignment (Moriasi et al., 2007). Lastly, since comparing regression slopes may indeed be rather a high bar for dynamic plant communities, we also report the directional agreement for species richness (note that for community turnover such measure is not meaningful since it is always positive). Specifically, we calculated the proportion of cases when both two-visit and trend models had significant positive, significant negative or non-significant model coefficients.

3 | RESULTS

We found that long-term trends in species richness were accurately captured by resurveys in 50% of cases. The alignment between the estimated trend and two-visit models had a coefficient of efficiency of −2.90 (Figure 1a). Correspondingly, the uncertainty in estimates of two-visit models with an average CI range of 0.024 was, on average, approximately four times greater than that of trend models with an average CI range of 0.006. This intuitively suggests that more frequent sampling leads to more accurate detection of species richness trends. Two-visit models more often overestimated these trends in both directions (i.e. faster decline or faster increase). When the trend model slope estimates were close to zero, slope estimates from two-visit models usually included negative, neutral and positive values.

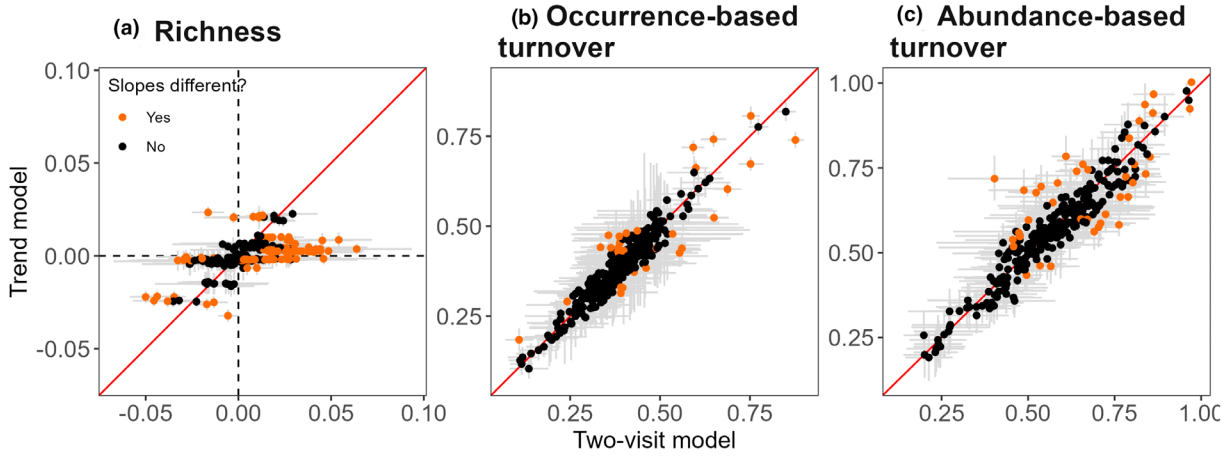

FIGURE 1 Coefficients from two-visit models (*X*-axis) and long-term trend models (*Y*-axis) for (a) species richness, (b) occurrence-based turnover (Sørensen dissimilarity) and (c) abundance-based turnover (Bray–Curtis dissimilarity). Error bars indicate credible intervals, that is 2.5% and 97.5% quantiles of their posterior distributions. Colour coding indicates whether the trend and two-visit model estimates differ significantly (orange) or not (black). The red line is a 1:1 identity line.

Agreement on the trend direction was reached in 63% of cases. The proportion of two-visit models that exhibited the same trend direction to trend models was 31%, 72% and 70% for cases when both trends were, respectively, significantly negative, significantly positive, not significant.

In contrast, two-visit models reproduced both abundance-based and occurrence-based turnover estimates of trend models well (Figure 1b–c). Posterior distributions converged with trend models in 86% and 90% of the explored two-visit models, respectively. Alignment was slightly better for occurrence-based turnover, with a coefficient of efficiency of 0.89, and also had slightly lower credible interval ranges (two-visit models: 0.134 and trend models: 0.101) than abundance-based turnover, which had a coefficient of efficiency of 0.86 and slightly higher credible interval ranges (two-visit models: 0.156 and trend models: 0.103). However, the uncertainty of estimates of both resurvey and trend models was relatively high.

4 | DISCUSSION

We found that models simulating two-visit resurveys in European grasslands provided information on changes in species richness comparable to repeatedly resurveyed plots in approximately half of the cases and on community turnover in the vast majority of cases. While a 50% success rate in estimating long-term trends in species richness might seem concerning, it can also be viewed as a surprising success. A theoretical study predicted that inferring long-term trends from two-visit surveys is essentially impossible (McCain et al., 2016), and accurately estimating the regression coefficients is a relatively high bar. Moreover, in most cases, both the two-visit models and the long-term trends agreed on the trend's direction.

The relatively low convergence between the two-visit and trend models for species richness is most likely mainly attributable to interannual variability in individual species populations within a community (Fischer et al., 2020; McCain et al., 2016). For plants, such variability is particularly pronounced in short-lived species that emerge only under suitable conditions and survive temporary unfavourable conditions either as seeds or in below-ground organs (Geißelbrecht-Taferner et al., 1997; Hájková & Krekule, 1972), thereby remaining undetected (Erdős et al., 2024). Consequently, plant communities with a high proportion of annuals, such as dry grasslands, are more prone to interannual variability than communities dominated by perennials, such as mesic or wet grasslands. The reasons for this interannual variability are, in part, stochastic demographic fluctuations and external disturbances, but most notably climatic fluctuations (Fischer et al., 2020). Such climatic fluctuations may have various outcomes depending on the sites' environmental conditions and local species pools. For instance, while a series of dry years might result in a decrease in species richness in dry grasslands (Fischer et al., 2020; Orbán et al., 2023), it can, in turn, increase species richness in fens or mires (Hettenbergerová & Hájek, 2011; Kolari et al., 2021; Navrátilová et al., 2022). To improve interpretability in this regard, researchers using two-visit resurveys should relate their results to climatic conditions before both the baseline survey and the resurvey, specifically considering deviations from long-term conditions.

Variability in species richness over time due to natural processes can be exacerbated by surveyor errors (Boch et al., 2022). However, these errors are also partly dependent on the natural dynamics of individual species, since a substantial decrease in a species' abundance proportionally decreases the likelihood of its detection (Vittoz & Guisan, 2007). It is important to note that all datasets analysed here were, from the initial survey, designed for subsequent revisiting and resurveying. In practice, this means they are based on permanently marked plots and, throughout the monitoring period, most were sampled by the same surveyor or the same group of surveyors. This is rarely the case in two-visit resurveys, which are likely to exhibit increased errors due to relocation inaccuracies and bias arising from varying sampling skills, effort and style among the surveyors (Kapfer et al., 2017). While relocation error likely introduces only a random noise, which might average out with a larger amount of data (Verheyen et al., 2018), and consequently not affect the conclusions drawn from resurvey studies systematically (Kopecký & Macek, 2015), surveyor bias tends to be more directional (Futschik et al., 2019; Vittoz & Guisan, 2007). Surveyor bias has been shown to most strongly affect estimates of species richness (Futschik et al., 2019; Verheyen et al., 2018), reflecting surveyor-specific sampling skills and differences in sampling intensity. While relying on species lists from the previous survey may be essential for identifying the correct location when location descriptions are inaccurate, its use during plot sampling almost certainly increases the likelihood of detecting species present in the baseline survey, even if some are particularly rare and would otherwise remain undetected.

Species richness as a community property metric has received relatively high popularity among vegetation ecologists. It has been studied in terms of its spatial distribution (Sabatini et al., 2022; Večeřa et al., 2019), dependence on disturbance (Connell, 1978; Huston, 1979), productivity gradients (Grime, 1979; Rosenzweig, 1995) and ecosystem constraints (Currie, 1991; Wilson et al., 2012). However, we should not forget that, as such, species richness is a net outcome of various processes. A single driver may trigger multiple processes that drastically change the community composition, while keeping the species richness constant over time (Hillebrand et al., 2017). No net loss or even an increase in species richness might be accompanied by a decline in habitat quality, manifested, for example in an increase of generalists and a decline of specialist species (e.g. Friesová et al., 2025; Klinkovská et al., 2025). Given the unreliability of species richness assessments, particularly when based on only two-visit resurveys, and the limited information content of species richness with respect to the magnitude of change a plant community experiences, we encourage more effort in analysing and interpreting changes in community composition rather than in species richness to advance understanding of the current biodiversity changes.

Because they provide a meaningful insight into changes in species composition, two-visit resurveys represent a valuable and often practical tool for understanding how plant communities respond to global environmental change. However, it is essential to approach these data critically and cautiously, in particular if they show changes

in species richness. Even though we argue that changes in species composition deserve more attention than changes in species richness, the latter certainly remain relevant in the ongoing biodiversity crisis. However, for species richness, our results for European grasslands suggest that trends can only be reliably assessed with monitoring schemes that include multiple surveys over a relatively long time period, even in plant communities that are predominantly composed of perennial species. Unfortunately, collecting such long-term data is often at odds with the short-term timeframes of most research grants, including most national monitoring programs. We therefore strongly urge better inclusion of long-term monitoring schemes in scientific funding efforts, as is currently underway in some initiatives (e.g. Bergamini et al., 2019; Wood et al., 2017).

AUTHOR CONTRIBUTIONS

Kryštof Chytrý conceived the idea, which was further developed with contributions of Klára Friesová, Adam Thomas Clark, Milan Chytrý, Stefan Dullinger and Jakub Těšitel. Kryštof Chytrý, Giuseppe Fenu, Tomáš Černý, Jiří Doležal, Miklós Kertész, Gábor Ónodi, Petr Petřík, Petra Hájková, Michal Hájek, Milan Chytrý, Ute Jandt and Helge Bruelheide contributed the data. Klára Friesová collected and prepared the data. Kryštof Chytrý analysed the data and wrote the manuscript with contributions from Klára Friesová, Stefan Dullinger, Milan Chytrý and Adam Thomas Clark.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest. Adam Thomas Clark is an Associate Editor of *Journal of Ecology* but took no part in the peer review and decision-making processes for this paper.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/1365-2745.70425.

DATA AVAILABILITY STATEMENT

The data that support the findings along with scripts for the analysis can be found in the Supporting Information and additionally on the ZEONODO digital repository under DOI 10.5281/zenodo.21786469 (Chytrý, 2026). The full monitoring series can be obtained from ReSurveyEurope and LOTVS databases on request.

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SUPPORTING INFORMATION

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

Data S1. Scripts.

Figure S1. MCMC convergence diagnostics for all fitted models, shown separately for trend (large) and two-visit (small) models across richness and turnover metrics.

Table S1. Characteristics of datasets used for the analysis.

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