More losses than gains during one century of plant biodiversity change in Germany

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to the
handling Editor of
Nature
Dr. Armstrong

Unser Zeichen

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Halle, 21.07.2022

Nature manuscript 2021-08-12657C "Plant diversity change over one century in Germany: more losers than winners”

Dear Dr. Armstrong,

thank you again for allowing us to revise the manuscript another time. We are very grateful that we could improve many further aspects of the paper. The input of the reviewers was a tremendous help, which we greatly acknowledge.

Please find the final version of the manuscript attached. Our point-by-point reply has been uploaded as a separate document.

Compared to the previous version, the main improvements are:

- We have shortened the text, rephrased the abstract and introduced hypotheses for the null models.
- We have changed the layout of Fig. 2 and 3.

We have uploaded both a clean version and version in tracking mode.

Yours sincerely, also on behalf of my co-authors

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Senior Editor Nature, Anna Armstrong

Your manuscript entitled "Plant diversity change over one century in Germany: more losers than winners" has now been seen by referees 2 and 3. The referees remain largely happy. But in order to publish the paper we will need you to attend to all of the referees' continued concerns about presentation. No peer reviewed data should be removed altogether when making these changes.

> *We are sorry that we did not seem to have met all the expectations of the reviewers. However, we are happy that we have been given the chance to further improve the manuscript. We believe that we now have addressed all the issues raised.*
>
> *We have also uploaded all four "Related Manuscript Files" and made a suggestion for a cover photograph. If the suggestion is chosen, we are prepared to describe the four time series shown on the cover and provide the original photographs with high resolution.*

Referees' comments:

Referee #2 (Remarks to the Author):

The manuscript has improved substantially, I still like it a lot, and I only have minor comments related to writing and visual presentation of the figures. Specifically:

Visual part needs to be improved. Figures 2 and 3 still don't work, they are cluttered, confusing, with many unclear elements. What are the curly brackets for?

> *The curly brackets have been removed and the design of both figures has changed completely. In Fig. 2, the aggregation by species is now stated deliberately and illustrated for three plot records, with two species each. We no longer use arrows, but + and – signs to indicate decreases or increases.*

Do sizes of the plants bear any meaning?

> *The idea was that plants with a positive and negative change in cover become larger and smaller, respectively, which obviously did not work. We now only show different icon sizes in the very left part of Fig. 2 to show that decreases and increases in cover translate into – and +. Without changing icon sizes in Fig. 3, this figures has become much simpler.*

Can you shrink the plot to a printed page of Nature and will the legends be legible?

> Yes, we hope so, in particular as we removed the icons on the left-hand side. However, this will finally only be seen in the proofs.

Moreover, there are at least two different fonts used in the plots, many different sizes of fonts, several levels of thickness of lines, legends are positioned at different places in different panels (compare a with b)…

> *Fonts now are all Arial. We have also used the same font size and refrained from using bold fonts (except for the scenarios).*

…, there is a lot of redundancy with red and blue colors explained at least three times in the a-f panels, …

> *We now only use colors for the different assignment of cover changes at the observation or species level. Thus, we do also not explain it repeatedly.*

… and the arrows are all over the place, shifted to various positions (e.g. in Fig. 2).

> *The arrows have been removed.*

Further, some panels are labeled by a)b)c), while others (with the plant symbols) aren't.

In Fig. 2, the labels (a and b) now also comprise the icons. However, this was not possible in Fig. 3, as here the icons refer to the whole columns.

In Fig. 2b there are “losers” and “winners” labels next to a mix of red and blue arrows, which is confusing.

We redesigned Fig. 2.

I have a hard time believing that the graphics has been edited by a graphic designer (as the authors indicate in their reply). I worry that these are things that will be hard to fix at the typesetting stage, as they relate to fundamental design/content problems. Navigating and understanding particularly Figure 3 will be a challenge, and if you combine this with very long figure captions, it’s even more challenging. The authors need to try harder to improve, clarify, and simplify the figures.

We apologize, but before we had tried really hard to illustrate Fig. 3. Now, we made a new attempt in making them as simple as possible. Here, we had a great input from iDiv’s Media & Communication department (Volker Hahn and Stefan Bernhardt).

The text is still too long at places. Some of the paragraphs in the Results, Discussion, and figure captions can be shortened, condensed, or removed. I believe that it should be possible. Particularly paragraphs on lines 214-238 and 294-327, and captions to figures 2 and 3 (some of the text there seems to repeat the results section).

We shortened both paragraphs. However, in the paragraph (previously l 214-238) we had to add the descriptions on the analyses on the effect of length of observation interval and plot sizes as request of Reviewer #3 in the last review round. To shorten the text, we moved sections of the paragraph (l 294-327) to the Supplementary Methods. This part could also be shortened because we turned the scenarios into hypotheses.

There is some confusion about the terminology referring to scale. In the intro, I’ve found “local” (lines 151, 157, 162, 180), “plot” (lines 174, 182, 186), “community” (151, 157, 159, 180, 189), “metacommunity” (164, 188), “regional scales” (168), “larger region” (163), “regional studies” (171), “sampled area” (174), “sampling area” (150), “sampling plots” (160, 162), “global scale” (144), “vegetation plot records”(174), “plot-scale” (186), “plot records” (202), and “resurveys & surveys” (172). This also happens in the rest of the paper, e.g. the discussion. There is “species level” (line 373), “species scale” (line 405), “sites” (line 369), “locations” (410), “plots” (407, 413), “coarse spatial scales” (417) and “national scale” (401) etc. In all this, it is unclear which aspects of scale the authors have in mind: Local grain? Local extent? Local support? Region grain or extent?

Metacommunity grain or extent? What is the difference between plot, site, location, survey, sampled area, and community? What is a metacommunity and how it differs from community at a regional scale? What is species level/scale? I usually roughly get what the authors have in mind, but not always. At this final stage of polishing, I suggest simplifying and clarifying this terminology as much as possible.

Thank you for pointing out our inconsistency in using terms. We have to admit that part of this happened with the many rounds of internal edits among the many co-authors. We have now harmonized the above-mentioned terms:

- *“Local” is now more sparingly used. When referring to “local” and “regional”, we refer to grain, not extent, which we now make clear at the beginning of the Intro. However, we see no way to omit one of these two terms completely.*
- *The “community” is recorded locally. Nevertheless, we often point out that we here refer to species composition data recorded at fine grain, as this term has been also used across different grain sizes. Community composition is often observed in plots, but not exclusively*

(there are many marine or freshwater communities that have been recorded plot-less). Thus, when it comes to vegetation time series, we have to mention plots.

- *"vegetation-plot records" is a record made on a vegetation plot. Thus, we also use "plot record" as an abbreviation. The distinction between a "plot record" and a "plot" becomes necessary when the same plot is recorded more than once. This is common terminology in vegetation science.*
- *Similarly, the terms "survey" and resurvey" have concrete meanings. "Survey" is the act to record the species in a plot, "resurvey" is the act to repeat this in time.*

In contrast, we removed some terms from the manuscript:

- *Metacommunity: has been replaced by "regional"*
- *"larger region" has been replaced with "at regional extent"*
- *"regional studies" has been replaced by "large-grain studies"*
- *"sampling area" has been replaced by "sampled area", which refers to the area of a plot that is sampled*
- *"global scale" has been completely removed*
- *"plot-scale" has been completely removed*
- *"species level" and "species scale" have been removed, except in the Methods when "species level" refers to taxonomic harmonization.*
- *"sites" has been completely removed and was partly replaced by locations.*
- *"coarse spatial scale" has been replaced by "coarse spatial grain"*
- *"national" has been replaced by "regional"*

Line 165: Increase and decrease of what?

Added now "of species' mean cover"

Lines 176-179: All this seems tangential and unnecessary.

Deleted.

Lines 209-2011: Dtto. Tangential and unnecessary.

Deleted.

Line 224: Log ratio decreased (which seems to be the current message, and which would mean a second derivative of the trend), or SR decreased as indicated by the negative log ratio?

Actually, we refer to a decrease in log ratio between species richness observed at the end and the beginning of an observation interval. Extended Data Fig. 2a shows that $log_e(SR_{Y2}/SR_{Y1})$ *was positive for time spans* ≤ 2 *years (that is, SR increased), while it was negative for time spans > 10 years (that is, SR decreased). Per decade,* $log_e(SR_{Y2}/SR_{Y1})$ *decreased by 0.153. We now added: "indicating that more species were lost with time" (new line number 225).*

Line 235: "only a marginal and" is unnecessary. If it was insignificant, it wasn't even marginal.

Deleted.

Lines 236-237: I don't see how no change in median indicates no change in dominance structure. You can have identical median in both time periods, but a pronounced change in the dominance, for example if increase in the dominant (high cover?) species is offset by decrease in species with low cover. In any case, what exactly do you mean by "dominance structure"?

We agree and have deleted this sentence, as we explain the discrepancy between mean and median change in cover in the following paragraph.

Line 180: Typo.

Corrected.

Lines 376-378: I don’t see the direct link between homogenization and equality of change among losers and winners. Either prove/show the link mathematically, or drop the statement.

Probably, this disagreement is based on how we define homogeneity. In our opinion, homogenization is the direct consequence of redistribution of the species’ cover. If decreases are distributed more equally (that is also more homogeneously) across many species and increases in cover are concentrated in few species, the latter (that is the winners) will be increasing in many communities. In consequence, the dissimilarity in species composition between these communities has to decrease (given that a quantitative dissimilarity measure is used). Mathematically, this would have to be shown by a decrease in dissimilarity, which however, is difficult to demonstrate across all plot records in our data set as many communities have no species in common. In our opinion, homogenization probably occurs within habitat types, but opening this discussion and carrying out the analysis would open a can of worms. Thus, we have decided to down-tune this statement to: “Homogenisation occurs because, across all time series, few species consistently increase in their cover, meaning that the same species are winning in many communities.” (new l 372-374)

Referee #3 (Remarks to the Author):

As before, I commend the authors on their analyses and believe this paper makes a novel and important contribution by documenting long-term plant biodiversity changes in terms of cover that would have been missed by simply focusing on species richness, as most previous work has done. But while the authors have produced a strong revision of their paper, in my opinion several outstanding issues remain, and some important comments have only been partially addressed. I appreciate the new analyses that the authors have performed, and overall the analyses are appropriate and justified, and data are presented correctly, as far as I can judge. The framing of the study is also now more compelling, and I think the unique value of the dataset and insights arising from it are now harnessed more effectively. That said, I still have some concerns about the framing of the study, explained in my comments below. The Results section has also been improved, but remains difficult to read in places – again, I make specific suggestions below. Overall, while the length appears to have been reduced, the text still seems unnecessarily wordy in places (e.g. in the Results and figure captions).

Thank you for this positive assessment.

Another aspect I raised previously and has still not been resolved, in my opinion, is when results are considered to be ecologically relevant or not, and I think there could be greater transparency in the paper about this. This relates to the way the story is set-up, as mentioned in my previous review. Specifically, the authors note that due to the large sample sizes, changes in species richness can be statistically significant even if effect sizes are small, and therefore conclude that directional changes in species richness are “minor at best” (l.231). Yet on the other hand, even though the differences between winners and losers in their Gini coefficients are so small that they are imperceptible in Fig 2a, the authors note that these differences are “highly significant” (l. 245-6) and go on to interpret them. What is the reason for emphasising the ecological relevance of the latter result, but not of the species richness result? I find this troubling, since the set-up of the paper describes the paradox of changing global/regional but not local scale richness, and attempts to resolve that. Yet the paper does in fact describe significant local scale changes in richness. I think this should be acknowledged more transparently in the paper, and not brushed off; or it should be made clear why the small differences in Gini coefficients are considered important, but not the changes in species richness, even when both are statistically significant.

> *We fully agree here and have now down-tuned the emphasis on significances in the Gini coefficient, too. We now write (new l 246): "While the two Gini values were highly significantly different (non-overlapping CIs even at 99.9%), their small difference might not result in ecologically meaningful effects. Nevertheless, the finding that losses in cover were more equally distributed than cover gains might point to an important ecological mechanism. If cover losses tend to occur in more uniform steps while gains result from both small and large increments, many small cover losses in a plot might be offset by a few large cover gains. The significantly different Gini coefficients show that this was at least the case in a considerable number of our change observations."*
>
> *We also agree that we too much downplayed our observation of decreasing richness. We now write at the beginning of the discussion (new l 344): "While the observed decline in species richness might be linked to the greater number of species that lost than gained cover, our analyses demonstrate that richness change at the plot level is not a necessary prerequisite for this asymmetry." There are other places, where we also now refer to the finding of richness changes in our paper, too. However, we believe that the strength of our paper is to point to other mechanisms than richness change that can result in large-scale biodiversity change. This maybe explains why we might have too much downplayed species richness.*

Specific comments

l.125 This isn't really a research question/problem statement, rather a description of a method. More importantly, I don't think this question (i.e., the discrepancy between declines of species richness at regional and global scales vs marginal changes in community species richness at local scales) is actually addressed – has there been loss of richness at a regional scale in Germany over the last century? The documentation of declines in abundance imply that regional losses will occur, but haven't necessarily done so yet (l.156). I.e., this is why the authors claim that asymmetry of losses/gains in cover could be "early warning signs" of regional species loss (l.189), which implies that regional losses haven't happened yet in Germany. For clarity, I suggest the authors think carefully about the overarching question addressed by the study and rephrase it accordingly.

> *Thank you for pointing out these issues. Following your advice, we have completely rewritten the Abstract. The research statement now is: "However, the majority of studies focused on species incidence and did not account for local abundance. Here, we asked whether the analysis of plant species cover changes can reveal yet unrecognized patterns of biodiversity change and provide insights into the underlying mechanisms."*

l.129 I would advise against using the word "losses" in this context, and more specifically refer to "reductions in cover" or "cover losses" throughout the paper, were relevant. "Loss" by itself implies (to me at least) that a species goes locally extinct at a location (is "lost"), which is not necessarily the case. Greater precision is important to avoid the results being misinterpreted.

> *This sentence has been rephrased, too. In addition, we have carefully checked all places in the manuscript, where we refer to "losses" and in most cases now write "cover losses", except for those places where we draw conclusions on species loss as a consequence of these cover losses.*

l.189 “while many species are lost from a few communities only” should be phrased more like “while rare species (those occurring in a few plots only) are lost completely” – i.e. the current formulation doesn’t necessarily imply regional species richness loss.

> *Thank you. We have changed the sentence accordingly.*

l.203 Here a statement is missing of why these null models were developed.

> *We agree. As suggested we have also rephrased the null models as hypotheses (see below). We now write (new l 204): “To make sure that the observed patterns are not resulting by chance alone, we further developed null models that kept species richness constant and varied the amount and direction of change and the concentration of cover losses and gains on losers and winners. We hypothesized that the divergence in the distribution between cover losses and gains is driven by i) the proportion of species that undergo changes, ii) the ratio of increasing to decreasing species and iii) the degree to which cover losses are concentrated on a specific subset of species.”*

l.205 Again, why did you do this? What are the hypotheses regarding nativity and habitat affinity? The reason for these analyses becomes clear while reading the paper but is a bit murky to the reader at this point.

> *We also agree with this point. We now write (new l 210): “Then, to assess whether losers and winners (i.e. those species that lost or gained cover) differed in their floristic status or habitat requirements, we analysed whether the probability of a decrease or an increase in cover depended on species being native or non-native and their habitat preference.”*

l.221 “net loss of 6.04% of the species).” This should specify “per plot”, right? Although the sentence calls this “close to zero”, I would still consider a 6% loss to be concerning.

> *We apologize to have expressed this wrongly. A net decrease in* $log_e(SR_{Y2}/SR_{Y1}) = -0.062$ *corresponds to an absolute decrease of 0.06 species per plot (1-exp(-0.06233)). This does not refer to the initial richness of that plot. Corrected now.*

l.224-7 I don’t understand why species richness increases slightly when expressed per decade, “in consequence” of annual decreases (expressed on a log scale); perhaps I’m missing something, but please check phrasing here.

> *We apologize if this has not been clear enough before. As more species are lost, the longer the observation interval (*$log_e(SR_{Y2}/SR_{Y1})$ *decreased by 0.153 per* log_{10} *years), the positive richness trend for time spans ≤ 2 years (Extended Data Fig. 2a) turns into a negative one for time spans > 10 years (Extended Data Fig. 2c). Dividing the log ratio by decade (*$log_e(SR_{Y2}/SR_{Y1})$ *decade*$^{-1}$*) reverses this trend, as, for example, then the observed positive richness trend of periods of 1 or 2 years is multiplied by 10 or 5, respectively. Please, see also our comment to reviewer #1 on the same lines.*

l.228 The phrasing here, and elsewhere in the Results, is challenging to follow. E.g. “While loge(SRY2/SRY1) decreased by 0.064 per log10 increase plot area” could be phrased as “While decreases in species richness were greater in larger plots”. It would greatly help readability if results were phrased in plain English wherever possible and backed-up with the statistics.

> *Done. We now write (new line 228): “While decreases in species richness were greater in larger plots (mean change in* $log_e(SR_{Y2}/SR_{Y1})$ *-0.064 per* log_{10} *increase in plot area), species richness significantly decreased in all different categories of plot sizes (Extended Data Fig. 4a-4c).”*

L.231 “changes in local richness are minor at best” is misleading – Fig S2 and others show there can be huge changes in local richness, but with no strong average trend towards increasing or decreasing richness. Please check phrasing here (e.g. add “directional”).

> *Done. We now write (new l 231): “Because of the overall very small effect sizes, we conclude that directional changes in mean local richness are minor at best, which is in accordance with preceding studies*[1,3,4]*.”*

l.253 there are three different ways in which this result (l. 250-254) is phrased, which all seem subtly different – it would be clearer if you could express this in one way which captures the message you wish to convey. As mentioned above, the word “losses” is misleading here, because what you mean is cover change, which might or might not entail the loss of a species from a plot.

> *We completely rewrote and shortened this section (new line 246): “While the two Gini values were highly significantly different (non-overlapping CIs even at 99.9%), their small difference might not result in ecologically meaningful effects. Nevertheless, the finding that losses in cover were more equally distributed than cover gains might point to an important ecological mechanism. If cover losses tend to occur in more uniform steps while gains result from both small and large increments, many small cover losses in a plot might be offset by a few large cover gains. The significantly different Gini coefficients show that this was at least the case in a considerable number of our change observations.”*

L.267 Should “plants” be “plots” here? If not, then I believe it would be clearer to specify “changes in cover of individual plant species”

> *Replaced by “individual cover observations in plots”.*

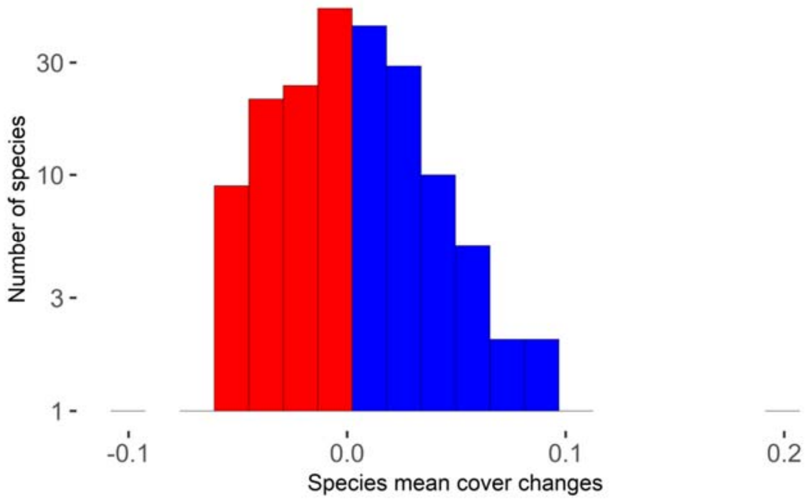
l.294 As mentioned in my previous review, this null model approach is a great addition to the paper. This paragraph remains, however, difficult to follow. I had to carefully consult Fig.3 and the supplementary methods to be able to follow it. I also mentioned previously that the rationale for the three scenerios wasn’t very clear, and this is still the case. One suggestion here would be to describe each scenario as a hypothesis to explain the empirical pattern, and then evaluate whether the null model lends support for that hypothesis or not. Currently the insights of the model are described as a series of results, and the reader is left largely to deduce the relevance of these.

> *We are grateful for the suggestion to turn the scenarios into hypotheses, which in our view made the approach much clearer. In addition to the graphical changes we made with Fig. 3 (see our reply to reviewer #1), we are confident that the null models now are much easier to grasp.*

L.314 This result is very interesting, but can you say why non-random cover changes across species lead to inequality in the Gini coefficient in the null model – i.e. what is the mathematical/statistical phenomenon here? And what are the implications of this for the biological interpretation of divergence between losers and winners that then follows from l.328?

> *The mathematical phenomenon behind this outcome can be explained as follows: For hypothesis iii) we deliberately kept constant the proportion of species affected by cover change at 0.8 and the proportion of increasing species at 0.5. Thus, we could redistribute exactly the same randomly created negative cover changes as gains to the other species in the community. For these reason, the red and blue curves in Fig. 3c are absolutely identical. As the model first determined the losses and then redistributed the gains, for decreasing species this often meant extinction, for which then new species entered the community (as species richness was kept constant). Extinctions always resulted in deviation from the geometric distribution in cover declines, as the decline could never exceed the current cover of the species. Thus, declines were often smaller and more evenly spread than expected from a geometric distribution. Then, according to this scenario, the species to be selected for a*

negative cover change were chosen non-randomly (i.e. in a directed way), thus, resulting in assigning these more evenly distributed declines more to the same species (please note that this was not deterministically, but simply weighted by using the species' IDs). In contrast, the gains were distributed randomly across all remaining species and new colonizers. This resulted in a larger spread, in particular of large gains, among species. This can be seen from the histogram of this scenario:



Thus, there were more winners with exceptionally high cover gains than losers with exceptionally high cover losses. This can also be seen in the extreme values and quartiles:

```
   Min.    1st Qu.     Median       Mean    3rd Qu.       Max.
-0.0948316 -0.0050650  0.0000000 -0.0004992  0.0012849  0.1155434
```

We also made the focus on concentrating losses on particular species now also clearer by using the "+" and "–" icons in Fig. 3.

Overall, we consider the way our model works in this particular aspect highly realistic. In a plot, the lower boundary of cover losses is always given by the extinction of a species in a plot. There is also a maximum that cannot be transgressed for winners, which is a relative cover of 1. However, as in nature, with the broken-stick distribution of initial cover values, there were only very few cases where species reached this upper boundary, and similar cut-off effects were observed as for declining species.

We also now added a clear interpretation of these results at new line 320: "We conclude that environmental changes that threaten specific species drive the inequality of mean cover changes of losers and winners."

l.348 Does this result refer specifically to the null model, since you did in fact observe significant richness change? This needs to be specified here. See my major comment above about this.

As said above, we changed this section. We now write (new l 341): "Our work reconciles some issues in the debate surrounding the "biodiversity conservation paradox"[12], i.e. the discrepancy between observing a loss of species at broad scales but marginal changes in species richness at the plot scale. With support of a null model, weshowed that the cover changes may affects winners and losers differently, even if plot richness does not change. While the observed decline in species richness might be linked to the greater number of species that lost than gained cover, our analyses demonstrate that richness change at the plot level is not a necessary prerequisite for this asymmetry."

l.397-400 The wording confused me here – having greater data density in the middle of the time period could give rise to a mid-domain effect, not be a consequence of it; however, the observed pattern of greater divergence could be a consequence of the mid-domain effect, i.e. a statistical artefact. Please check the phrasing (and its implications) here.

> *Thank you for pointing this out. We rephrased this as follows: "Second, data density on species change observations was highest in this intermediate period, which could give rise to a mid-domain effect*[29]*. In consequence, the stronger overlap of time series in the middle of the study period could have strengthened the observed trends."*

L.878 Units should be displayed in Fig1a x-axis

> *The unit is "number of species". However, we do not find this helpful as the axis is expressed as* $\log_e(SR_{Y2}/SR_{Y1})$*. Thus, we are afraid to refrain from changing this. Any change would also affect all figures in the Extended Data, which are all carefully prepared and provide no more space on the x axes labels for additions. We hope for your understanding.*

Cover page

Title: **Plant diversity change over one century in Germany: more losers than winners**

Article impact statement:

We provide a mechanistic understanding of biodiversity change using detailed time series data over the past hundred years from 7,738 (semi-)permanent vegetation plots from Germany, comprising 1,794 vascular plant species.

Running head: **More losers than winners**

Keywords: Biodiversity change, Biodiversity monitoring, Gini coefficient, Temporal change, Vascular plant species, Vegetation-plot resurveys

Word count: 4,424

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Author contributions

U.J. and H.B. conceived the idea for the project. All authors were involved in collecting datasets, developing the conceptual framework and interpreting the results. H.B. performed the statistical analyses and developed the null model. U.J. and H.B. wrote the first draft of the manuscript. All authors commented on and agreed with the final version of the manuscript.

Competing interests

The authors declare no competing interests.

Abstract

Recent long-term analyses of biodiversity data highlight a “biodiversity conservation paradox”: biological communities show substantial species turnover over the last century[1,2], but changes in species richness are marginal[1,3–5]. Most studies, however, focused on species incidence only, neglecting changes in local abundance. Here, we asked whether the analysis of plant species cover changes can reveal yet unrecognized patterns of biodiversity change and provide insights into the underlying mechanisms. We compiled and analysed a dataset of 7,738 (semi-)permanent vegetation plots from Germany that were surveyed between 2 and 54 times from 1927 to 2020 and in total comprised 1,794 vascular plant species. We found that i) decrements in cover, averaged across all species and plots, occurred more often than increments, ii) the number of species decreasing in cover was higher than the number of those increasing, and iii) decrements were more equally distributed among losers than gains among winners. Null model simulations confirmed that these trends do not emerge by chance, but are the consequence of species-specific negative effects of environmental changes. In the long run, these trends might result in significant species losses at both local and regional scales. Summarising changes by decade shows that the inequality in species mean cover changes of losers and winners diverged as early as in the 1960s. We conclude that species cover changes in communities convey an important but yet neglected dimension of biodiversity change and should hence be more routinely considered in time-series analyses.

Introduction

Biodiversity loss is one of the most critical environmental problems [6,7]. Globally, the extinction of many taxa has been well documented[8–10]. However, local-scale studies, that is those at the fine grain of communities, do not always reflect this global trend[2,3], which has sparked intense debates[11–13]. The main reason for this scale discrepancy is that species losses and gains through time are inherently asymmetric. At any spatial scale, it only takes one individual of a new species to result in a gain, but requires the loss of all individuals of a species to lead to a loss[14]. In consequence, at a given sampled area, the loss of all individuals of one species might be compensated by single individuals of a new colonizer[3,15]. Indeed, within local communities, species turnover, not species loss, has been identified as the main aspect of biodiversity change[16]. For example, 28% of species were found to be replaced per decade in an analysis of global marine and terrestrial community data[2]. However, except for recent studies from forests[17,18], these analyses ignored the changes in abundance that precede species turnover.

Time series of local communities often document the abundance of each species, an information rarely available at larger scales. Yet the strength of these data has been insufficiently exploited in global biodiversity assessments. In the case of plant communities, the most common abundance metric is the percentage of ground covered by all individuals of a species on a particular sampling plot. This allows calculating changes as percentage points of cover lost or gained, which helps nd detecting declines before local extinctions occur. Aggregating such cover changes across many sampling plots at regional extent allows calculating the rates of decrease or increase of species' mean cover, that is, identifying losers and winners. This might in turn help to understand the discrepancies in species richness trends found at different spatial scales.

For plant species, comparisons between losers and winners have only been conducted with respect to occupancy at larger grain sizes. Studies based on ~5 x 5 km grids reported contrasting trends in Denmark[19] or in Germany[20], with increasing and decreasing species richness, respectively. While both studies detected an imbalance between losers and winners, it is difficult to ascertain biodiversity changes at regional large-grains, as resurveys at that spatial resolution often differ in sampling intensity from the initial surveys. In 5 km-grid cells, species are easily overlooked, resulting in pseudo-turnover with erroneous gains or losses[21]. In contrast, small-grain vegetation-plot records, ranging from a few to several hundred square metres[22], are usually thoroughly checked not only for species presences but also for absences.

In vegetation science, the traditional way of analysing time series of local communities is following a plot's trajectory through time and aggregating the changing occurrence or cover of species in the form of plot summary metrics, such as trends in species richness, diversity indices, or more sophisticated measures, such as changes in species' mean ranks or abundance curves[23]. This type of analysis revealed both increasing (e.g. [4]) and decreasing (e.g. [24]) species richness trends, and global syntheses consequently did not detect general trends in community-scale species richness (e.g.[1,3]). However, constant community-scale richness may be combined with biodiversity loss at the regional scale. This might for example happen when few species colonise many communities anew, while rare species (i.e. those occurring in a few plots only) are lost completely. An early warning-sign of such a development would be an asymmetry of cover trends across species, i.e. the fact that increases in cover are concentrated in a subset of species while decreases are distributed more homogeneously across many species. Indeed, a recent global analysis of local species turnover has suggested that it is particularly widespread species, often non-native ones, that are increasing in abundance[25].

Here, we analyse cover changes of individual species in 7,738 vegetation-plot time series, spanning almost a century and a wide range of habitat types across Germany. Apart from comparing the magnitude of cover decrements and increments, we tested for the inequality in the distributions of cover losses and gains across all species. Therefore, we adopted the Gini coefficient, a metric developed in economics to evaluate the share of incomes across the inhabitants of countries[26]. Based on the Gini-coefficients we also, we tested whether cover losses were more evenly spread among losing species than cover gains were distributed among winning species. We here define losers and winners by their mean change in cover across all observation intervals and all plot records, which can be either negative or positive. To make sure that the observed patterns are not resulting by chance alone, we further developed null models that kept species richness constant and varied the amount and direction of change and the concentration of cover losses and gains on losers and winners. We hypothesized that the divergence in the distribution between cover losses and gains is driven by i) the proportion of species that undergo changes, ii) the ratio of increasing to decreasing species and iii) the degree to which cover losses are concentrated on a specific subset of species. Then, to assess whether losers and winners (i.e. those species that lost or gained cover) differed in their floristic status or habitat requirements, we analysed whether the probability of a decrease or an increase in cover depended on species being native or non-native and their habitat preference. Finally, we assessed the temporal dynamics of cover losses and gains and asked whether they occurred at the same point in time.

Results

The 7,738 vegetation-plot time series covered the period from 1927 to 2020 (Extended Data Fig. 1). Plot richness change, calculated as the log ratio of species richness (SR) at the end and the beginning of the observation time interval (Fig. 1a), varied more than tenfold in absolute numbers. Even though we observed a significant decrease in species richness over time, the estimated effect sizes were close to zero (mean $\log_e(SR_{Y2}/SR_{Y1}) = -0.062$, corresponding to a mean net loss of 0.06 species per plot). There was a tendency of shorter observation intervals having significant increases and longer observation intervals significant decreases in species richness (Extended Data Fig. 2a-2c). On average, $\log_e(SR_{Y2}/SR_{Y1})$ decreased by 0.153 per $\log_{10}$ years ($p < 0.001$ according to a mixed model), indicating that more species were lost with time. In consequence, the change in species richness was also close to zero but significantly positive when richness change was expressed per decade (mean $\log_e(SR_{Y2}/SR_{Y1})$ decade^{-1} = +0.062, Extended Data Fig. 3). While decreases in species richness were greater in larger plots (mean change in $\log_e(SR_{Y2}/SR_{Y1})$ -0.064 per $\log_{10}$ increase in plot area), species richness significantly decreased in all different categories of plot sizes (Extended Data Fig. 4a-4c). Because of the overall very small effect sizes, we conclude that directional changes in mean local richness are minor at best, which is in accordance with preceding studies[1,3,4]. Similarly, the effect sizes for Shannon's index of diversity, Pielou's index of evenness and the change in the species rank abundance curve (as a measure of curve-change[23]) were significantly negative, but of small magnitude (Extended Data Fig. 5a, b, c).

Across all plots, there were 458,311 change observations, i.e. species x plot records x time interval combinations. There were more negative (n= 172,252) than positive (n = 166,554) observations, and on average, decrements were larger than increments (4.05 and 3.97 percentage points, respectively, according to a t-test (p=0.003, df= 338,187). For each interval, species change was assessed as change in per cent cover, expressed as percentage points. Across all observations, the values of both negative and positive cover changes were not evenly distributed, which is illustrated by the Lorenz curves (Fig. 2a) and the corresponding Gini coefficients. Gini coefficients of 0.712 (95% confidence intervals (CIs) 0.710 and 0.714) and 0.718 (CIs 0.717 and 0.721) were obtained for negative and positive change observations, respectively. While the two Gini values were highly significantly different (non-overlapping CIs even at 99.9%), their small difference might not result in ecologically meaningful effects. Nevertheless, the finding that losses in cover were more equally distributed than cover gains might point to an important ecological mechanism. If cover losses tend to occur in more uniform steps while gains result from both small and large increments, many small cover losses in a plot might be offset by a few large cover gains. The significantly different Gini coefficients show that this was at least the case in a considerable number of our change observations. Moreover, cover changes also depended on interval length. Cover decreased significantly more in longer than in shorter observation intervals (by -0.042 percentage points per $\log_{10}$ interval length, $p < 0.001$ according to a mixed model) as well as in larger than in smaller plots (by -0.14 percentage points per $\log_{10}$ area, $p < 0.001$).

Across all intervals independent of interval length, there were more losers than winners per plot, with an average difference of 0.407 species (CIs 0.246 and 0.569, Extended Data Fig. 5d), which corresponds to the observed decrease in plot richness (Fig. 1a). Despite on average larger decrements than increments and fewer winners than losers in plots there was a significant increase of 2.5 percentage points in mean cover of all the species in a plot across all plot records (Extended Data Fig. 5e). In contrast, we observed a (insignificant) decrease of 0.7 percentage points in median cover (Extended Data Fig. 5f). These opposing directions of changes in mean and median cover are the direct consequence of a higher inequality of increments compared to decrements.

While these changes of individual cover observations in plots are so subtle that they may only be detectable in large datasets, they add up when species mean changes are calculated. Out of the total 1,794 vascular plant species in our study, there were 41% more losers than winners, with 1011 and 719 species, respectively. In consequence, the median across all species' mean cover changes was significantly negative (-0.063 percentage points, CIs -0.089 and -0.035, $p < 0.001$, Extended Data Fig. 6). Mean cover changes of species did not depend on their overall frequency in the dataset (regression of species' mean cover change on $\log_{10}$ frequency, $p=0.601$). Decreases in species mean cover were also consistent with respect to observation interval length (Extended Data Fig. 2d-f) and plot size (Extended Data Fig. 4d-f). In all analyses, there were not only more losers than winners, the amounts of cover losses and gains were also not distributed equally within both groups. This is demonstrated by Lorenz curves, which in Fig. 2b are based on mean cover changes per species. The Gini coefficients for species with mean negative (0.692, CIs 0.660 and 0.718) and positive changes (0.778, CIs 0.720 and 0816) differed by almost 0.1. The larger Gini coefficient for winners indicates that there were a few winners that gained disproportionately more mean cover than others, while the mean cover losses among losers were more equally distributed. Comparing Fig. 2a and 2b shows that two factors contributed to the inequality of biodiversity change. First, decreases occurred in smaller and more equal cover changes than gains. Second, the gains were concentrated in fewer winning species, while the cover losses were distributed among more losers.

These results also hold when rare species were excluded from the calculations. Fig. 1b shows the histogram of mean cover changes of the 578 species for which at least 100 time interval observations were available. Here, the change in mean cover was -0.165 percentage points ($p < 0.001$), showing that species mean losses in cover were significantly higher than species mean gains. In other words, there was a redistribution of species: fewer species increased in dominance and frequency while more species decreased in cover and potentially disappeared locally.

To understand the factors that determine the divergence in Gini coefficients between decreases and increases in cover and to disentangle those from possible species richness effects, we performed a series of null model simulations to test three different hypotheses. We hypothesized that the divergence in the distribution between cover losses and gains is driven by i) the proportion of species that undergo changes, ii) the ratio of increasing to decreasing species and iii) the degree to which cover losses are concentrated on a specific subset of species (Fig. 3, for further explanations and a graphical illustration see Supplementary Methods). In all null models, species richness of each plot was kept constant to avoid confounding effects of richness change, and only cover changes were redistributed among losers and winners (for details see Methods). In contrast to hypothesis i), the divergence in the distribution between cover losses and gains did not depend on the proportion of species that undergo change. While subjecting more species to cover changes increased the Gini coefficients for both negative and positive change observations (Fig. 3a), this did not propagate to the species mean change values (Fig. 3d). We could confirm hypothesis ii) which posited that the ratio of increasing to decreasing species drives the divergence in the Gini coefficients of decrements and increments (Fig. 3b). Inequality is higher for the kind of change that is more frequent. However, in the empirical data the increments were more unequal (Fig. 2a) although they are less frequent. As a corollary, the observed divergence of inequality is unlikely to be a mere consequence of the absolute number of losses and gains. There was also support for hypothesis iii).Concentrating losses on a specific subset of species did not affect the inequality of decrements and increments across all species (Fig. 3c). However, it resulted in mean cover losses of losers being more evenly distributed than the cover gains of winners (Fig. 3f), like in the empirical data (Fig. 2b). This pattern was not obtained by the other two model simulations. Neither was the proportion of species affected by cover change (Fig. 3d), nor had the proportion of increasing species (Fig. 3e) significant impacts on the divergence of the Gini coefficients between losers and winners. We conclude that environmental changes that threaten specific species drive the inequality of mean cover changes of losers and winners.

To determine the identity of losers and winners we focused on the 578 species with at least 100 time-interval observations, of which 161 showed significant differences in cover losses and gains across all plots (binomial test at $p < 0.05$, with Holm correction, Fig. 4). Among these 161 species with a directional change, native species decreased and neophytes increased more often than expected by chance (at $p < 0.05$). Comparing the species' habitat affinities revealed that significant decreases occurred among species of mires and spring fens (level 1 EUNIS habitat Q), grasslands (R) and arable land (V), while forest species (T) increased more often than expected by chance.

The times when cover losses and gains occurred were highly species-specific, as can be inferred from the temporal course of the Gini coefficients for the 1011 losers and 719 winners (Fig. 5). Changes started to be more unequally distributed among winners than among losers as early as in the 1960s. Since then, inequality of both gains and losses in cover increased, with cover gains always being significantly more unevenly distributed among winners than losses among losers until 2010.

Discussion

Our work reconciles some issues in the debate surrounding the “biodiversity conservation paradox”[12], i.e. the discrepancy between observing a loss of species at broad scales but marginal changes in species richness at the plot scale. With support of a null model, weshowed that the cover changes may affects winners and losers differently, even if plot richness does not change. While the observed decline in species richness might be linked to the greater number of species that lost than gained cover, our analyses demonstrate that richness change at the plot level is not a necessary prerequisite for this asymmetry. Overall, we found a higher number of losers than winners at the scale of Germany. This depends on two phenomena. First, cover losses were more evenly distributed than gains at the community scale. Second, cover losses and gains were concentrated in different species.

Finding 41% more losers than winners nationwide might even be considered a conservative estimate for Germany’s low to mid elevations, and certainly underestimates total plant biodiversity change. On the one hand, our study also includes plots in the alpine region, where positive richness changes have been described[27]. On the other hand, our work suffers of most of the shortcomings noted in other studies on local time series[13,28], including the lack of spatial representativeness, varying lengths of observation intervals and a bias towards habitats that are least affected by human activities (see Extended Data Fig. 7 and 8). For instance, time series are usually discontinued in case of substantial land-use change, such as when a (semi-)natural habitat is converted into agricultural or urban land (one of the few exceptions was Hundt 2001[29], included in our analysis). In consequence, it is not surprising that the predicted 30% of local species extinctions due to land conversion[30] remain mostly unnoticed in vegetation-plot time series like ours. We do not want to address all the criticism brought forward on calculating biodiversity change from local time series[13,28], which we think is mostly justified. Yet, we note that our time series covered about half the number of vascular plant species that occur in Germany, including rare habitats which often harbour rare plant species. This means that even if the spatial representativeness is incomplete for entire Germany, the representativeness at the level of individual species is unprecedented and grants robustness to our results.

Our results show that minor asymmetries of cover losses and gains in communities sum up when being aggregated by species, potentially hinting at population declines and extinctions at larger spatial extents. This is in agreement with trends observed across Germany[20,31–33], including biotic homogenisation[34], which was already put forward in earlier studies on time series[1,3], but had not yet been properly tested[13]. Homogenisation occurs because, across all time series, few species consistently increase in their cover, meaning that the same species are winning in many communities. This supposedly results in a decreasing dissimilarity between communities. Other studies that analysed species changes conform to our finding of a prevalence of losers over winners, such as from Denmark[35], the UK[36] or Germany[20].

Although neophytes were more frequently increasing than decreasing, confirming global observations[37,38], most winners were native species, as has been reported already for German forest communities[39–41]. Similarly, the habitat affinities of declining species being concentrated in mires, grasslands and arable land reflect both the trends revealed by Germany's Red List of vascular plants[42] and floristic mapping programmes[20].

Our time series also provide important temporal information on species losses and gains. The strongest asymmetry between cover losses and gains occurred between the end of the 1960s and the beginning of the 21st century, indicating rapid species turnover, most likely as a result of substantial land-use changes (e.g. [43]). All systematic monitoring programmes on vegetation, however, started only after year 2000, and thus, cannot provide information on the second half of the 20th century. Our findings confirm the early warnings from the first Red Lists in Germany[44] as well as estimated richness changes from floristic mapping programmes when intervals between 1997-2017 were compared to the ones between 1960 and 1987[20]. However, these results have to be interpreted with great caution for several reasons. First, it is probable that later time series were established at locations and habitats in the focus of nature conservation efforts, thus receiving a more favourable management than the average landscape. Second, data density on species change observations was highest in this intermediate period, which could give rise to a mid-domain effect[28]. In consequence, the stronger overlap of time series in the middle of the study period could have strengthened the observed trends. We note, however, that early inequalities in cover losses and gains at the plot scale will ultimately result in species extinctions at the regional scale, representing another aspect of extinction debt[45].

Overall, we consider the overarching analysis of numerous local vegetation-plot time series an important piece of evidence in the ongoing attempts to assess biodiversity change and understand the underlying mechanisms. We demonstrated that changes in species cover within communities are a neglected source of information when assessing biodiversity change at large spatial extents. We advocate therefore the compilation of further existing community time series worldwide, especially from vegetation plots of which few have already been mobilised in global databases, such as BioTime[46]. Compared to temporal database analyses[47] and meta-analyses[48], repeated observations on the same locations represent the most sensitive strategy for analysing temporal vegetation changes[49]. However, a careful quality control is a key prerequisite for this type of analysis[13]. In particular, aggregating changes across different communities by species rather than aggregating changes per plot requires much more attention for harmonising different taxonomies to prevent pseudo-turnover[21]. With appropriate care taken, plot time series of community data across larger regions should form a crucial backbone in future biodiversity monitoring. Unravelling the temporal taxonomic turnover at the community scale[1,2] allows insights into the mechanisms of species losses and gains that monitoring at coarser spatial grains, such as floristic mapping at grid sizes of several kilometres, alone cannot provide.

Methods

Data compilation

We compiled as many long-term repeated vegetation-plot records from Germany as we could access, including data from published studies, as well as results from grey literature and conservation assessments. The data includes 92 projects (Extended Data Table 1, for a description of the data see ref[50]).

The different steps of data preparation and analysis are summarised in Extended Data Fig. 9. Within each project, the plot resurvey ID indicates which plot observations from different times were made on the same plot or set of plots at the same site, allowing their comparison between different points in time. Plot resurvey IDs either refer to a single plot that was repeatedly visited, which was either permanently marked (using poles, magnets etc.) or was semi-permanent, e.g. provided with exact coordinates or other ways of descriptions of the exact locality. In some cases, when the exact locations were not precise, resurveys used several plots to match one previous plot, resulting in a one-to-many relationship. In this case, all plot records received the same plot resurvey ID and all plot records for the same point in time were combined. There were also resurveys with sets of plots at a site that could not be matched by single plots but only by another set of plots, resulting in a many-to-many relationship. Such resurveys were done to compare a particular community at a particular site at two points in time, each represented by a set of plots, which then all received the same plot resurvey ID. Accordingly, all plot records for the same point in time were combined by averaging the species cover values and then treated as a single observation. Some of our studies included experimental treatments with different management of habitats (e.g. abandonment or establishment of grazing, succession and disturbance). To exclude treatments that are not representative for biodiversity change in Germany, from these studies we included only the control plots[51], plots that reflected the ambient land use at the site[52], that were unfenced[53] or were subjected to continuous grazing[54]. Finally, 7,738 unique plot resurvey IDs remained, comprising a total of 23,641 vegetation-plot records, ranging from 1927 to 2020. We retrieved coordinates for all locations (longitude and latitude), either from the original sources or by looking up plot locations from maps. The duration and survey times of each project are shown in Extended Data Fig. 1. Since different projects used different cover scales, we converted cover into per cent, following the default conversion of the Turboveg 2 program[55]. For example, for the seven-grade Braun-Blanquet scale the transformation was r + 1 2 3 4 5 → 1% 2% 3% 13% 38% 63% 88%, respectively.

The location of all plots of all projects is displayed in Extended Data Fig. 7. We assigned the individual plot locations to the grid cells of the quadrants of German ordnance maps (“MTBQ,” 0°10’ × 0°6’, approximately 5.6 km × 5.9 km in the centre of Germany), and tested whether the grid cells analysed differed from those without observations with respect to population density, road density, urban cover, cropland cover and protected areas. This clearly revealed that the sampled grid cells were not representative for the whole area of Germany. Surprisingly, they showed significantly higher human population densities, road densities and urban cover, while cover of cropland and the amount of protected area was lower, which indicates that many time series were made in regions with higher human pressures. Our time series were also biased with respect to habitat types. This was illustrated by assigning all plot records of the time series to EUNIS classes, using the expert system EUNIS-ESy[56] and the corresponding R code[57]. Each time series was assigned to the habitat type by using the earliest plot record that resulted in level 3 EUNIS classification (Extended Data Fig. 8). While the time series covered 92 of the approximately 150 EUNIS habitat types encountered in Germany, most of the 23,641 plot records came from grasslands (level 1 EUNIS habitat R, n=14,849, 62.8%), followed by forests and other wooded lands (T, n= 5,440, 23%). In contrast, arable land, which makes up more than 36% of the land cover in Germany, was only represented by 816 plot records (V, vegetated man-made habitats, 3.5%).

Taxonomic harmonisation

All projects were linked to the standardized species list German SL 1.3[58]. The nomenclature for vascular plants followed the concepts of Wisskirchen et al.[59], with additional aggregations to higher taxonomic levels according to German SL 1.3[58]. As some authors recorded subspecies and other infraspecific taxa, species were aggregated at the species level, using vegdata[60]. Some closely related species that, from our experience, were often mistaken in the field were merged at the aggregate or genus level. Species aggregates were also used when different taxon names of the same aggregate occurred in different projects, to prevent that the same taxon might appear under different taxon names. The taxon name harmonisation was a crucial step in our approach, as our aim was to assess species cover changes across projects (Fig. 1). We used our own R code to merge taxon names and the notation of the ESy expert system[56] to protocol all steps. The species harmonisation forms the first section of the ESy system and shows which taxon names were aggregated under the name of a broader taxonomic concept (Extended Data Table 2). In addition, within single projects, we used customised aggregations when the same taxa were reported at different taxonomic levels at different points in time in the same plot resurvey IDs (Extended Data Table 3). For example, while in all but one year of a time series of a specific plot *Orchis militaris* was reported, only one year reported *Orchis* spec. at the genus level. Unaccounted for, such a leap between taxonomic levels within a time series would result in incorrect species change observations. To avoid losing the predominating information at the species level by aggregating all records to *Orchis*, we assumed that the taxon was also *Orchis militaris* in that particular year. If more than one taxon occurred in previous years, we equally distributed the cover among those taxa. This happened for example when a record was taken late in spring when the two species *Anemone nemorosa* and *A. ranunculoides* could no longer be distinguished.

The percentage cover values of the same aggregated taxon name as well as those of taxa occurring in different layers of the same plot were merged, assuming a random overlap of their cover values and making sure that the combined cover values cannot exceed 100%[56]. We removed bryophytes and lichens using the vegdata package in R[60].

Finally, the original list of 3,280 taxon names that included bryophytes and lichens was reduced to 1,794 taxon names of vascular plants. In the following, for the sake of simplicity, we refer to these taxon names as species.

Temporal change analysis

Instead of fitting trends for individual time series, different intervals of the same time series were treated as separate change observations. This was achieved by separating all records into 458,311 plot resurvey triplets, i.e. ID x species x time interval observations, where the interval designated two subsequent observations between year 1 and year 2 for the start and end of the interval, respectively. Separating a time series in its different intervals avoids the problem of establishing a baseline against which the changes are being compared[13,28].

Temporal change analysis at the plot level

At the plot level, the triplets were aggregated into plot resurvey ID x time interval combinations (in total n=13,987). With a total of 7,738 plot resurvey IDs, this corresponds to on average 1.81 resurvey intervals per plot resurvey ID. This means that, on average, a time series had about three observation events. While most plot resurvey IDs were only repeated once (one interval, n=6,006), 798 had two intervals, 213 had three intervals and 721 had four or more intervals. The longest time series comprised 54 intervals (Uwe Wegener, montane Harz meadows[61]). For each interval and plot resurvey ID, we calculated the change in species richness (SR), Shannon's index of diversity and Pielou's index of evenness. In addition, we calculated the change in the rank abundance curves, using the formula for curve-change in ref[23]. The change in rank abundance reflects the area between the two rank abundance curves for the later and earlier observation. Rank abundance curves are constructed by plotting the species' cumulative relative cover (ranging from 0 to 1) against the species' ranks in cover values, calculating ranks from highest to lowest cover and then dividing the ranks by the maximum rank (with scaled ranks ranging from 0 to 1). Furthermore, we calculated the number of species with decreases and increases in cover as well as mean and median cover across all species in a plot record.

For all change metrics calculated at the plot level, we calculated log response ratios of the metric at time Y2 divided by that at time Y1, except for the change in rank abundance curves and losses and gains, where we used the difference between area and number of species, respectively. To assess the impact of plot size on the change of species richness, we tested the effect of $\log_{10}$(surface area in m^2) on $\log_e(SR_{Y2}/SR_{Y1})$. Additionally, we analysed the distribution of plot records with respect to $\log_e(SR_{Y2}/SR_{Y1})$ separately for small (> 25 m^2), medium-size (25 m^2) and large plots (>25 m^2). A similar analysis was carried out for testing the effect of the observation length ($\log_{10}$ interval length in years) on the change of species richness and analysing the distribution of plot records separately for short (≤ 2 years), medium (> 2 and ≤ 10 years) and long observation intervals (> 10 years). We additionally expressed richness change per decade (mean $\log_e(SR_{Y2}/SR_{Y1})$ decade^{-1}). The departure of effect sizes and differences from 0 in all these analyses were assessed with mixed effects models, using the time-series ID as random factor, thus taking into account the non-independence of intervals from the same time series. As there were 13,987 plot resurvey ID x time interval combinations, the test statistics tended to be significant, even when the mean of the test metric was close to zero. We used mixed models to calculate confidence intervals using Wald-test approximation[62].

Temporal change analysis by species

In total there were 458,311 plot resurvey ID x species x time interval combinations, for which the difference in cover for every species *k* and time interval *m* was calculated as $\triangle cover_{k,m} = cover_{k,m,Y2} - cover_{k,m,Y1}$ and expressed as percentage points. Similar to our analyses for the change of species richness, we also tested the effect of $\log_{10}$(surface area in m^2) and of observation length ($\log_{10}$ interval length in years) on $\triangle\text{cover}_{k,m}$, using mixed effects models with the time-series ID as random factor.

Here, *Y2* and *Y1* refer to the end and the start year of an interval, defined as the two nearest points in a time series.

To compare the distribution of cover changes across all species, we considered positive and negative cover change observations separately (n= 184,678 and 192,162 time interval observations, respectively). We then sorted the cover changes in each category (positive or negative cover changes) according to increasing absolute values and plotted the cumulative sums of cover changes against the proportion of observations in each category, thus obtaining a Lorenz curve. We calculated the unweighted Gini coefficient for each category, according to [63] and using the bias correction implemented in the DescTools package[64]:

$$G_{cover} = \frac{\sum_i^n \sum_j^n \left|\Delta cover_i - \Delta cover_j\right|}{2\sum_i^n \sum_j^n \Delta cover_j}\frac{n}{n-1}$$

with $\triangle\text{cover}_i$ and $\triangle\text{cover}_j$ being cover changes of change observations *i* and *j* in plots, irrespective of species, and n the total number of change observations. G_{cover} is calculated separately for negative or positive change observations, using either only all negative or positive change observations. The Gini coefficient is a measurement of inequality in distribution[26], given as a value between 0 and 1 with 0 indicating a perfectly equal distribution.

Across all plot resurvey IDs, there were 458,311 species x time interval combinations with a value for cover change. For species comparisons, we aggregated cover changes by species across all plot resurvey IDs and intervals. We counted the number of positive, zero or negative cover changes per species and subjected them to an exact binomial test, using the stats package. We adjusted the significance levels for multiple testing using Holm correction. When showing changes by species in graphs (Fig. 4), we confined the list to those species with $p < 0.05$ after Holm correction and with ≥100 time interval observations (n=161). To compare the distribution of cover changes among all species, we calculated the mean cover change per species, expressed as percentage points in cover. As the cover changes were highly dependent on species and many species occurred only rarely in the time series, we tested the probability to increase with a non-parametric exact binomial test. We assigned the floristic status native, archaeophyte and neophyte (the latter two being exotic species arriving in Germany before or after 1492, respectively) to these 161 species, using the BIOLFLOR database[65]. We assigned species to their preferred habitat, using the level 1 habitats of the EUNIS habitat classification[66]. This was achieved by assigning all 225,606 vegetation plots in the German Reference Vegetation Database[67] to EUNIS classes, using the expert system EUNIS-ESy[56] and the corresponding R code[57]. We then calculated the affinity of the 161 species with a significant change to each of the 150 EUNIS classes that occurred in Germany, using the Φ coefficient of association[68,69]. Then, the habitat preference of a species was defined as the EUNIS class to which the species had the highest Φ coefficient. For further analysis, we used the highest hierarchy of the EUNIS system (level 1). To assess which categories of floristic status and EUNIS habitat level 1 preference departed from the expected probability to increase, which is 0.5, we scaled the probability response to -1 to 1 and calculated linear models without intercept. Additionally, we tested whether mean cover changes of species depended on their overall frequency in the dataset and analysed subsets of species based on different interval lengths and plot sizes in which the species occurred, using the same categories of interval lengths and plots sizes as used for analysing species richness.

We calculated the Gini coefficient for inequality of changes, separately for species with negative and positive mean cover changes (that is losers and winners), respectively. The Gini coefficient based on species means was also calculated using the DescTools package[64] and is defined as:

$$G_{\overline{cover}} = \frac{\sum_i^N \sum_j^N \left|\overline{\Delta cover}_i - \overline{\Delta cover}_j\right|}{2 \sum_i^N \sum_j^n \overline{\Delta cover}_j} \frac{N}{N-1}$$

with $\overline{\Delta cover_i}$ and $\overline{\Delta cover_j}$ being the mean cover changes of species *i* and *j* and N the total number of species. $G_{\overline{cover}}$ is calculated separately for losers or winners, using either only all negative or positive species mean cover changes. Applied in this way, the Gini coefficient $G_{\bar{x}}$indicates that either the losses or the gains in cover were not distributed equally among species. To assess the significance in the difference between the Gini coefficients of losers and winners, we calculated 95% confidence intervals from bootstrapping, using percentiles, bias correction and 1,000 replicates. For analysing the temporal course of the distribution of cover changes in the groups of winners and losers, we calculated the Gini coefficient $G_{\bar{x}}$ as described above using a moving window of five years, using only records from 1945 onwards because of data scarcity before this date. Cover changes of all resurvey ID x species x time interval combinations were aggregated by species and year for all years that fell into a window of five years. In every window, 300 species were resampled by chance, repeated 100 times, and Gini coefficients were calculated separately for all decrements and increments of the means of these 300 resampled species. Temporal trends with confidence intervals were calculated from the Gini coefficients from these 100 runs.

Null model scenarios

To assess the mechanisms that might drive the inequality of cover changes among losers vs. winners, we set up a simple model, serving as a theoretical null expectation (see illustration in Supplementary Methods). Corresponding to our data analysis, the null model was not spatially explicit. In contrast to previously developed null models, such as in[1], our aim was also not to model stochastic colonization or extinction but stochastic changes in cover, which to our knowledge had not been attempted before. Extinction only happened when cover decreased below zero, and then, was exactly counterbalanced by colonization. In this way we kept species richness constant, which contrasts null models such as in[1]. Our null model also differs from traditional null models in community ecology which reshuffle cover values across communities and/or species[70–72] but do not allow for random decrease and increase in cover.

Simulating random communities

We simulated random communities and subjected them to different scenarios. First, we created a pool of 200 species with frequencies randomly drawn from a log-normal distribution, using the rlnorm function in R (meanlog = 1.5, sdlog = 1.2). Summing up all frequencies resulted in a total of 1,810 occurrences. We then drew random species richness values for 100 communities from a normal distribution, varying the mean and standard deviation to obtain the same total number of occurrences (1,810), which was achieved by using a Gaussian distribution with mean=19.13 and sd=9 species). We chose these parameters in a way to be similar to the richness distribution of our empirical data set (mean=23.4, sd=13.7). Finally, cover values were randomly assigned to the species in each community according to a broken-stick distribution[73], using the drbs function of the sads package[74], which resulted in a sum of a total cover of 100% in each community.

Introducing cover change: three scenarios

We then introduced different types of change to this random community, using three different scenarios. In all scenarios species richness was kept constant, which reflected our own findings and those in refs[1,3–5]. However, we allowed species turnover by replacing species that – owing to randomly introduced decreases – had cover values <0. Newly colonising species were randomly selected from the pool of 200 species, with the drawing probability weighted by the species' frequency. In the scenarios 1 and 2, this made sure that the species frequency distribution in the species pool remained constant (except for random noise). Species decreases in cover were introduced by varying three parameters, which corresponded to the three scenarios in which these parameters were varied: 1) the proportion of species affected by cover change in a community (to simulate different rates of turnover in community composition), 2) the proportion of species with increase in cover among those species affected by change (to simulate differences in the distribution of cover losses and gains, irrespective of species) and 3) the identity of the species to decrease in cover (to simulate that cover losses and gains might be concentrated in certain species). Decrements were either assigned randomly or according to the descending ID of the species, which resulted in species with higher ID values being more frequently selected for losing cover than other species.

In each community, according to these parameters, species were randomly chosen that underwent a decrease. The cover of all decreasing species in each community was summed up and redistributed according to a geometric distribution. For example, in a community of 24 species where 50% of all species were selected to change in cover and 50% of those were subjected to decrease in cover, the summed cover of these six species was redistributed (but randomly assigned) to the same six species as 0.125, 0.0625, 0.03125, 0.015625, 0.0078125 and 0.0078125. Note that the smallest change occurred twice to result in a sum of 0.25. If the decrease in cover assigned to a species was larger than the current cover of that species, its cover became 0 and the species was replaced as described above. The actually applied decrements were then assigned to the species that – according to the given parameters – were selected for increase. The number of increasing species also comprised the newly colonising species in a community. If the number of decreasing and increasing species was the same, the exactly same cover changes of decreasing species were randomly assigned as increments to the increasing species, taking the decrements and changing their sign. In this case, the absolute values of all increments and decrements across all communities were exactly the same, and thus, could not result in differences in the equality of their distribution. If the number of decreasing species was higher than that of increasing species, each two randomly chosen decrements were combined until the number of required increments was reached. Vice versa, if the number of decreasing species was lower than that of increasing species, randomly selected decrements were divided by 2 until the number of required increments was reached. In the latter two cases, the equality of the distribution of decrements was no longer the same as that of the increments.

For all scenarios, we measured the inequality of increments and decrements by the Gini coefficient as described above. As in the empirical data, we calculated the Gini coefficient i) across all cover changes, separately for increments and decrements, but irrespective of species, and ii) on species-aggregated mean values of increments and decrements.

The analyses were calculated in R version 4.0.3 using the packages stats, foreign, reshape2, data.table, tidyverse, Hmisc, sads and Desctools. Graphs were produced with the packages ggplot2, egg and vcd.

Data availability

All data is available as data paper[50] and available at https://doi.org/10.25829/idiv.3508-c17blk under the terms specified by CC BY 4.0.

A current version of the data paper submitted to Scientific Data has been uploaded. As the Nature paper might be published before acceptance, we have also submitted the data paper to bioRXiv (also uploaded).

[Please note that the DOI link is not yet activiated, which will happen around July 22nd, 2022. In the meantime you can already access the metadata via https://idata.idiv.de/ddm/Data/ShowData/3508?version=0 and the full dataset here: https://cloud.uni-halle.de/s/wei1ljqnq2Wet0A

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Code availability

The R code to retrieve resurvey ID x species x time interval combinations and to calculate the results of this paper is provided in Supplementary Code 1 and on https://github.com/idiv-biodiversity/ReSurveyGermany_Analysis, the R code to produce the null models in Supplementary Code 2 and on https://github.com/idiv-biodiversity/ReSurveyGermany_null_models.

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Captions:

Fig. 1 | Temporal change in a) plant species richness of plots and b) mean cover change of species. The black dashed line shows zero change, while the red solid line in a) shows the mean change of richness and in b) the species' mean change in cover in percentage points. a) Comparisons of species richness (SR) in plots recorded at subsequent points in time (n=13,987). An effect size of ±0.69 corresponds to double or half the initial number of species, while an effect size of ±2.3 indicates tenfold or one tenth of the initial number of species. Estimated mean overall effect size was -0.062 according to a mixed effects model ($p=2 \times 10^{-16}$, df=5,310) with a 95% confidence interval between -0.071 and -0.053. b) Comparisons of species' mean cover changes between subsequent records. Only species with at least 100 observations of change (n=578) were included. The estimated overall mean of the species' mean cover change was -0.165 ± 0.089 according to a t-test ($p=3.1 \times 10^{-4}$, df=577).

Fig. 2 | Lorenz curves for cover decreases (red) and increases (blue), reported in percentage points across the whole observation period from 1927 to 2020 a) across all change observations irrespective of species (n= 172,252 and 166,554 observations of decrease and increase, respectively) and b) aggregated by species, by averaging all change observations from a) across all plots and time interval (n= 1011 and 719 losers and winners, i.e. species with negative and positive mean cover change, respectively). The icons on the left illustrate these two types of aggregation of cover changes for six change observations, from which each three decreased (-) or increased (+). In a) these decreases are sorted by sign (- or +), in b) they are averaged by species, defining losers and winners, exemplified here as one species each with negative or positive mean change, respectively. The Lorenz curves show the cumulative amount of cover decrease and increase (added in order of their ascending absolute values) as a function of the cumulative number of change observations (expressed as proportion of the total number of observations). The diagonal black line indicates the theoretical curve that would result if all observed changes would be equal in size. The Gini coefficient, a measure of inequality, is the area between this diagonal line and the actual Lorenz curve divided by the entire area under the diagonal line. Thus, 0 and 1 indicate maximal equality and inequality, respectively. The differences between the Gini coefficients in both graphs were significant at p=0.05 but the confidence intervals in a) are so small that they are invisible in the graph.

Fig. 3 | Lorenz curves based on null model simulations of changes in species cover. In all simulations, the number of species per community was kept constant, but species turnover (extinctions and colonisations) was allowed (for details see Methods and Supplementary Methods). The graphs in the top row (a, b, c) show cover changes by plot ID x species x time interval (corresponding to Fig. 2a), separated into negative (red) and positive (blue) change observations. The bottom row of graphs (d, e, f) show mean cover changes per species (corresponding to Fig. 2b), separated into species with average cover increase and decrease (losers in red and winners in blue. The columns correspond to ourcr three hypotheses. In each panel, the blue and red Gini coefficients next to each other refer to the same scenario; * indicates a statistically significant difference in the Gini coefficient between the two Gini coefficients from the same scenario, n.s. not significant (all at p=0.05).

Fig. 4 | Probability of increase in cover for the 161 species with a significantly negative or positive change (binomial test at $p < 0.05$, with Holm correction) and at least 100 change observations. Decreasing species are those with a probability to increase of <0.5, and thus, increase less often than expected by chance, and their names are plotted to the bottom of the y-axis at 0.5, while the names of increasing species are plotted to the top. The colours of taxon names show their floristic status, with black, purple and pink for native, archaeophyte and neophyte, respectively. The bar colour indicates the species' affinity to level 1 EUNIS habitats[66] and the error bars indicate the 95% CIs. The three most declining and increasing species are illustrated by name and photographs. Plant photographs were obtained from www.floraweb.de.

Fig. 5 | Temporal course of the Gini coefficient, calculated by a moving window approach with a window width of five years, separately for losers (species with mean cover losses, red) and winners (species with mean cover gains, blue) in this time window. The coloured lines show the mean values of 100 resampling events of 300 species each per time window, while the confidence bands show the standard deviations across these samples. Non-overlapping confidence bands indicate significantly different Gini coefficients between losers and winners. The increasing Gini coefficients indicate increasingly unequal distribution of cover changes with time.

Supplementary Figures

Extended Data Fig. 1 | Temporal coverage of the 92 projects included in the study. The coloured lines indicate the start and the end of a project, black diamonds show in which years surveys were made. Resurvey type refers to either studies that were repeated within a particular community across a site without attempts to match plots (community comparison), or were carried out on matched plots, which were either permanently marked or relocated from exact descriptions (semi-permanent). The lower graph shows the number of times a particular year was included in any of the time series.

Extended Data Fig. 2 | Impact of the observation interval length on the temporal change of species richness (SR) in plot records (a-c) and mean cover change of species (d-f). The responses are shown separately for short ($\leq$ 2 years), medium (> 2 and $\leq$ 10 years) and long observation intervals (> 10 years). The black dashed line shows zero change, while the red solid line in a) - c) shows the mean change of richness and in d) – f) the species' median change in cover in percentage points. According to a mixed effects model estimated mean overall effect size was in a) +0.025 ($p=3.9 \times 10^{-9}$, df=4,142), b) +0.007 (p=0.093, df=3,903) and c) -0.150 ($p<2 \times 10^{-16}$, df=8,612). In d) – f) plot Interval comparisons of the mean of all cover changes per species between time points Y1 and Y2 of the start and end year, respectively, are shown on an axis with a sign*square root-transformation. According to an exact binomial test estimated overall median of cover change was in d) 0 (95 per cent confidence interval 0 and 0.007), e) -0.02 (CI -0.02 and 0) and f) -0.26 (CI -0.53 and 0.002).

Extended Data Fig. 3 | Temporal change of plot records expressed per decade. Interval comparisons of species richness (SR) in plot records between time points Y1 and Y2 of the start and end year, respectively, and divided by the length of the interval in decades ((Y2-Y1)*10) (n=13,987). Estimated overall effect size was +0.062 according to a mixed effects model ($p=1.8 \times 10^{-7}$) with a 95% confidence interval between +0.039 and +0.086.

Extended Data Fig. 4 | Impact of plot surface area on the temporal change of species richness (SR) in plot records (a-c) and mean cover change of species (d-f). The responses are shown separately for small (> 25 m^2), medium-size (25 m^2) and large plots (>25 m^2). The black dashed line shows zero change, while the red solid line in a) - c) shows the mean change of richness and in d) – f) the species' median change in cover in percentage points. According to a mixed effects model estimated mean overall effect size was in a) -0.03 (p=0.064, df=487), b) -0.031 ($p=1.55 \times 10^{-13}$, df=4,204) and c) -0.095 ($p<2 \times 10^{-16}$, df=9,124). In d) – f) plot Interval comparisons of the mean of all cover changes per species between time points Y1 and Y2 of the start and end year, respectively, are shown on an axis with a sign*square root-transformation. According to an exact binomial test estimated overall median of cover change was in d) -0.017 (95 per cent confidence interval -0.065 and -0.001), e) -0.019 (CI -0.043 and -0.006) and f) -0.26 (CI -0.134 and -0.050).

Extended Data Fig. 5 | Temporal change of plot records. The histograms show the interval comparisons of plot records between time points Y1 and Y2 of the start and end year, respectively. The black dashed line shows the zero change, while the red solid line shows the mean change as predicted from a mixed effects model. a) Change in Shannon's index of diversity (H). Estimated mean effect size for H -0.055 ($p=2.2 \times 10^{-16}$, df=5,462, 95% confidence interval -0.064 and -0.047). b) Change in Pielou's index of evenness (E). Estimated mean effect size for E -0.019 ($p=2.6 \times 10^{-16}$, 95%

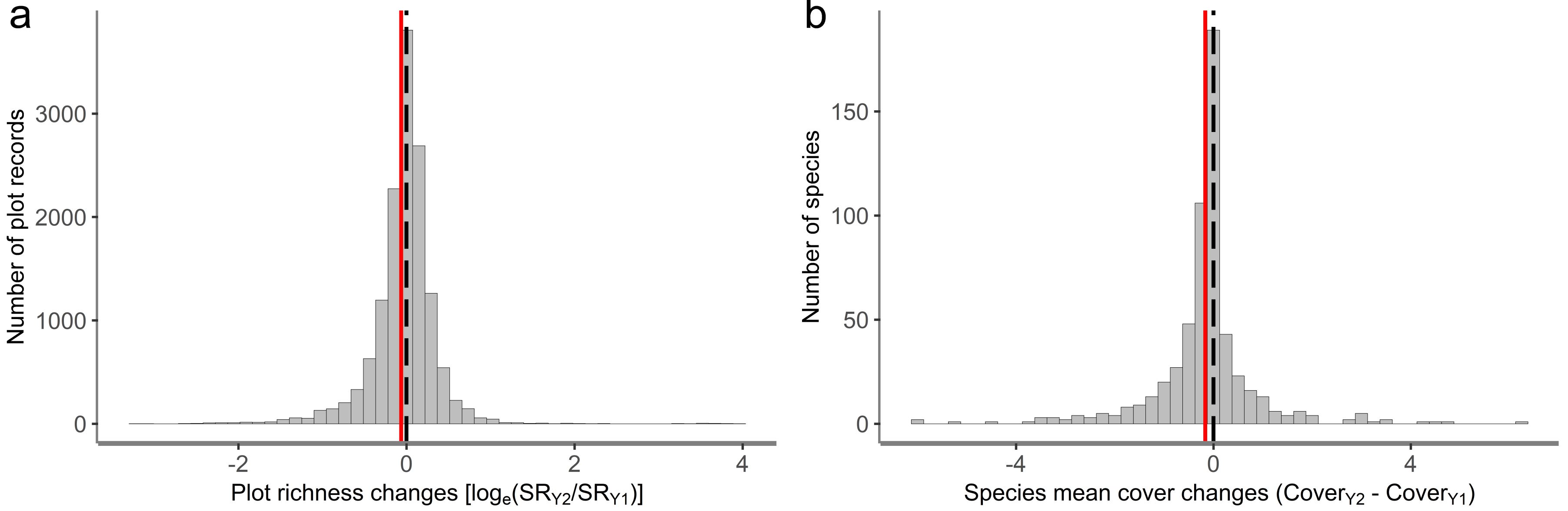
confidence interval -0.024 and -0.015). c) Difference in the area under the rank abundance curves. Estimated mean difference -0.143 (p=0.00211, 95% confidence interval -0.194 and -0.091). d) Difference in the number of cover gains and losses. Estimated mean difference -0.407 ($p=7.9 \times 10^{-7}$, 95% confidence interval -0.569 and -0.246). e) Change in mean cover of all the species in a plot (in per cent covered ground). Estimated mean effect size for mean cover +0.025 ($p=1.0 \times 10^{-10}$, 95% confidence interval +0.018 and +0.033). f) Change in median cover of all the species in a plot (per cent of covered ground). Estimated mean effect size for median cover -0.007 (p=0.2984, 95% confidence interval -0.021 and +0.007).

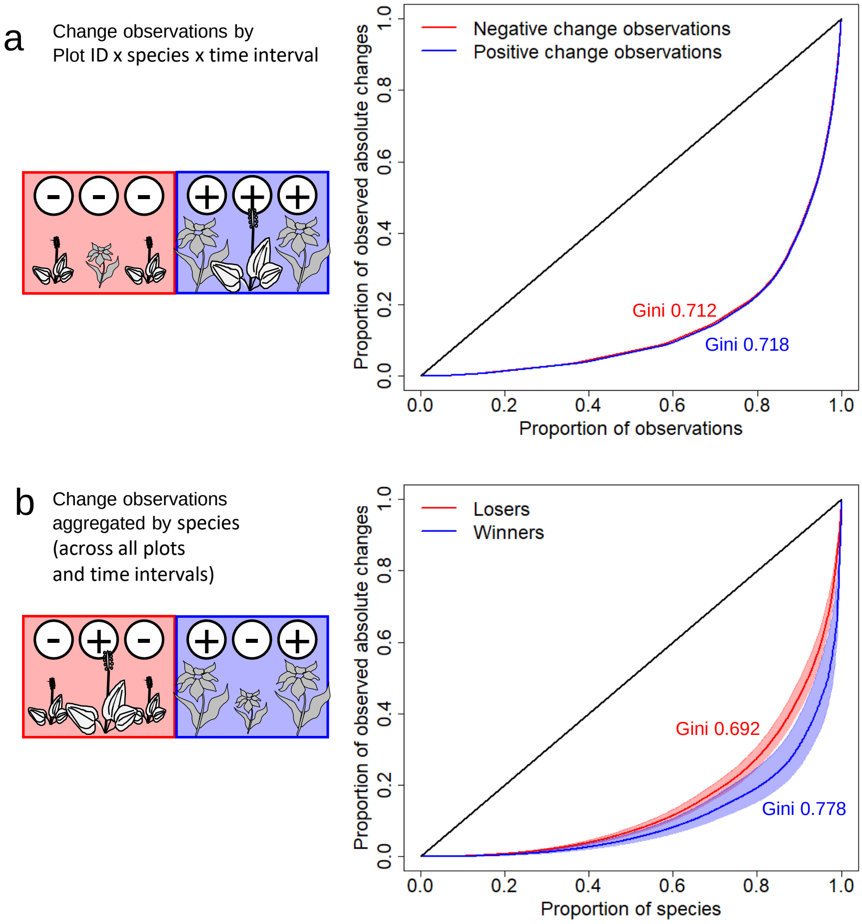
Extended Data Fig. 6 | Temporal change in mean cover change of all species in percentage points. Plot Interval comparisons of the mean of all cover changes per species between time points Y1 and Y2 of the start and end year, respectively, shown on an axis with a sign*square root-transformation. The black dashed line shows the zero change, while the red solid line shows the median change in cover across all species. All species in the dataset were included (n=1,794). Estimated overall median of cover change was -0.0625 (95 per cent confidence interval -0.089 and -0.035) and significantly different from zero according to an exact binomial test (p<0.001).

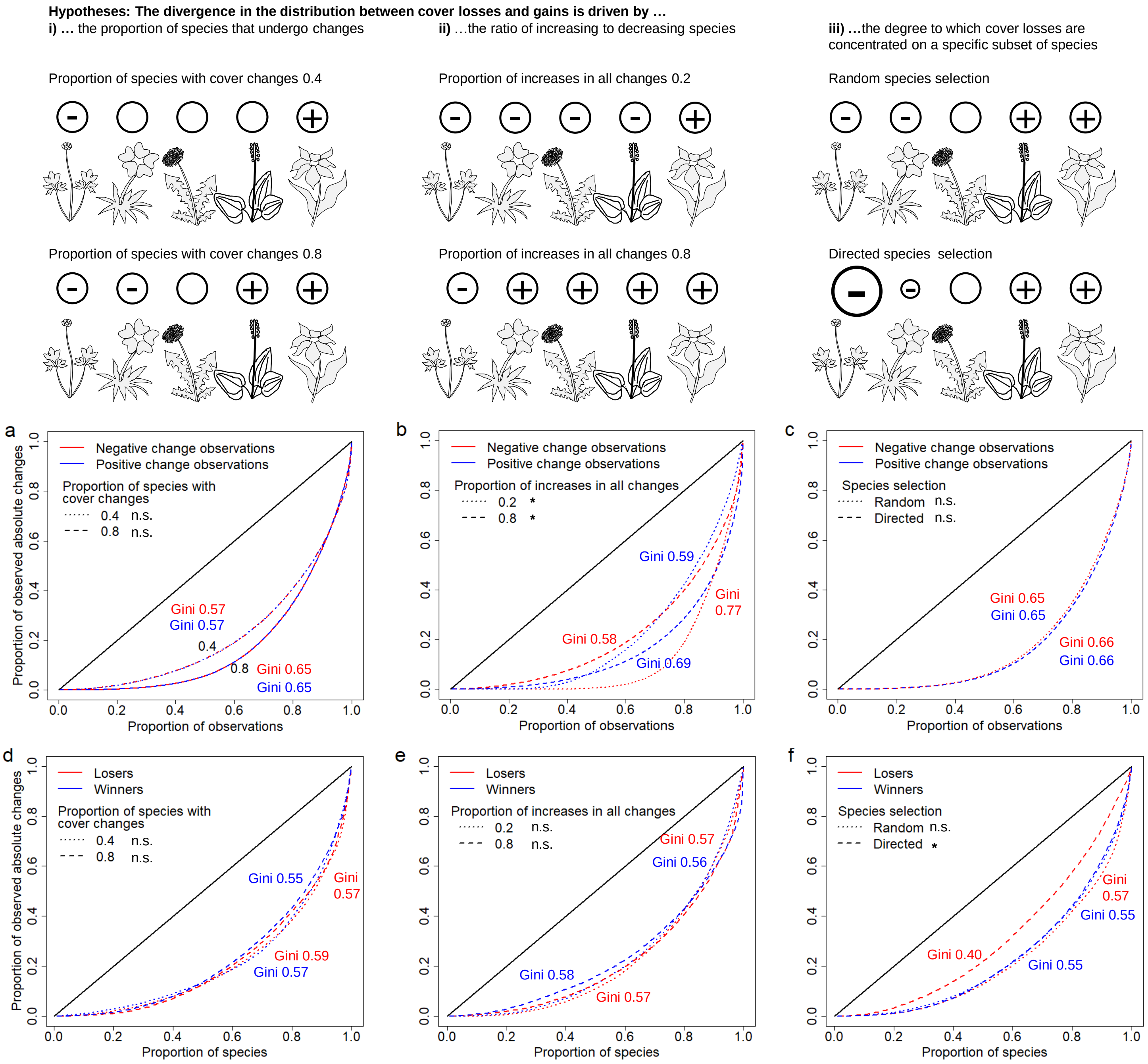
Extended Data Fig. 7 | Map of plot locations of all plots of all projects (n=23,641). One or several plots are summarised under the same plot resurvey ID (n=7,738). Note that the more complete coverage of Bavaria resulted from including the grassland monitoring Bavaria which started in 2002[75].

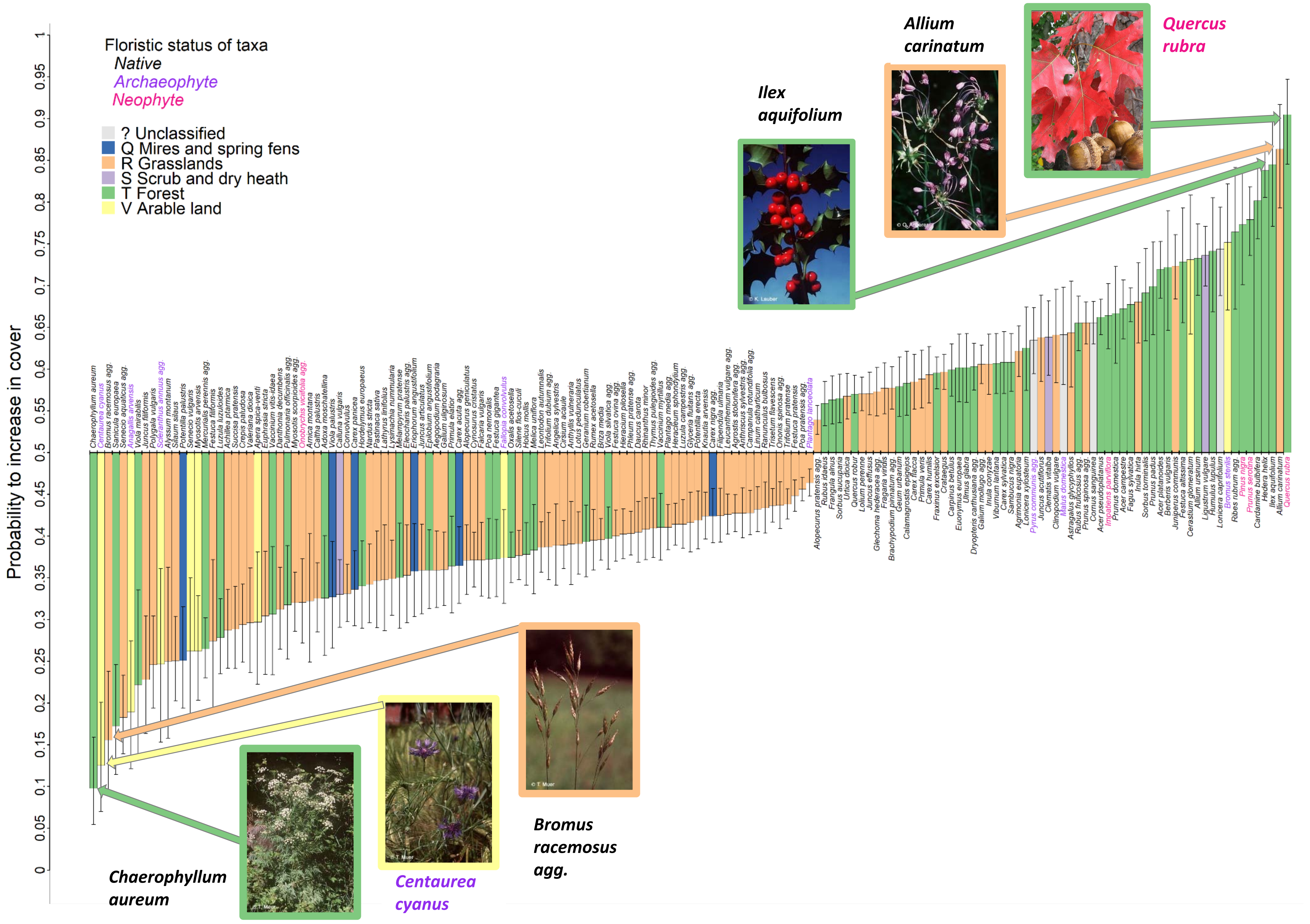
Extended Data Fig. 8 | Assignment of time series plot records to EUNIS habitat types. Each time series was assigned to the habitat type by using the earliest plot record that matched with the level 3 EUNIS classification. The classification was based on the EUNIS-ESy expert system[56] using the R code implementation[57]. ?: plots not assigned to any level 3 EUNIS habitat type, +: assigned to more than one level 3 EUNIS habitat type, A: Marine habitats, C: Inland surface waters, H: Inland sparsely vegetated habitats or devoid of vegetation, N: Coastal habitats, Q: Wetlands, R: Grasslands and lands dominated by forbs, mosses or lichens, S: Heathlands, scrub and tundra, T: Forests and other wooded land, V: Vegetated man-made habitats, including arable land. Labels for EUNIS habitats were only printed at the top of the corresponding bar section when the number of assigned records was ≥ 150.

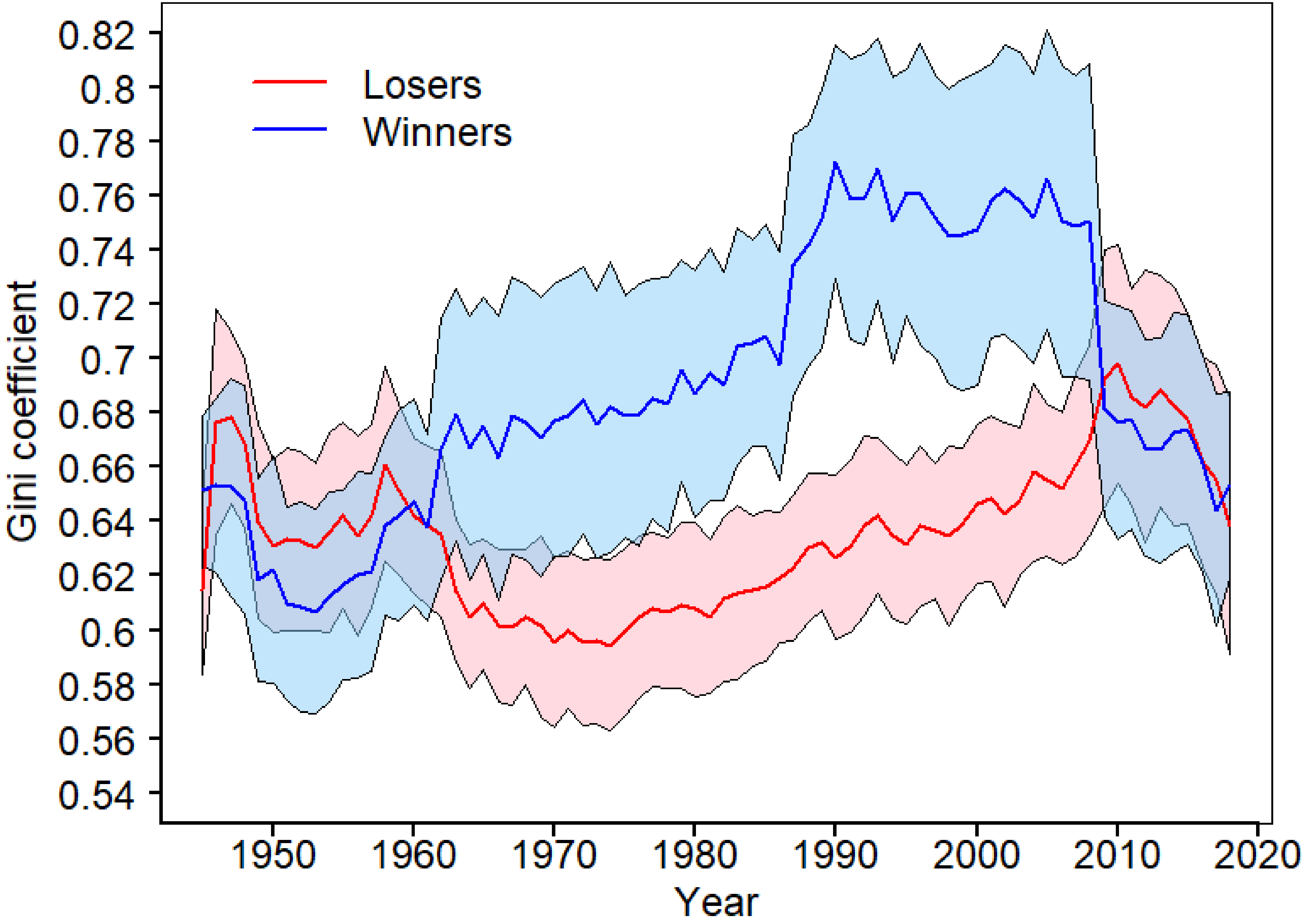
Extended Data Fig. 9 | Steps of data preparation and analysis.

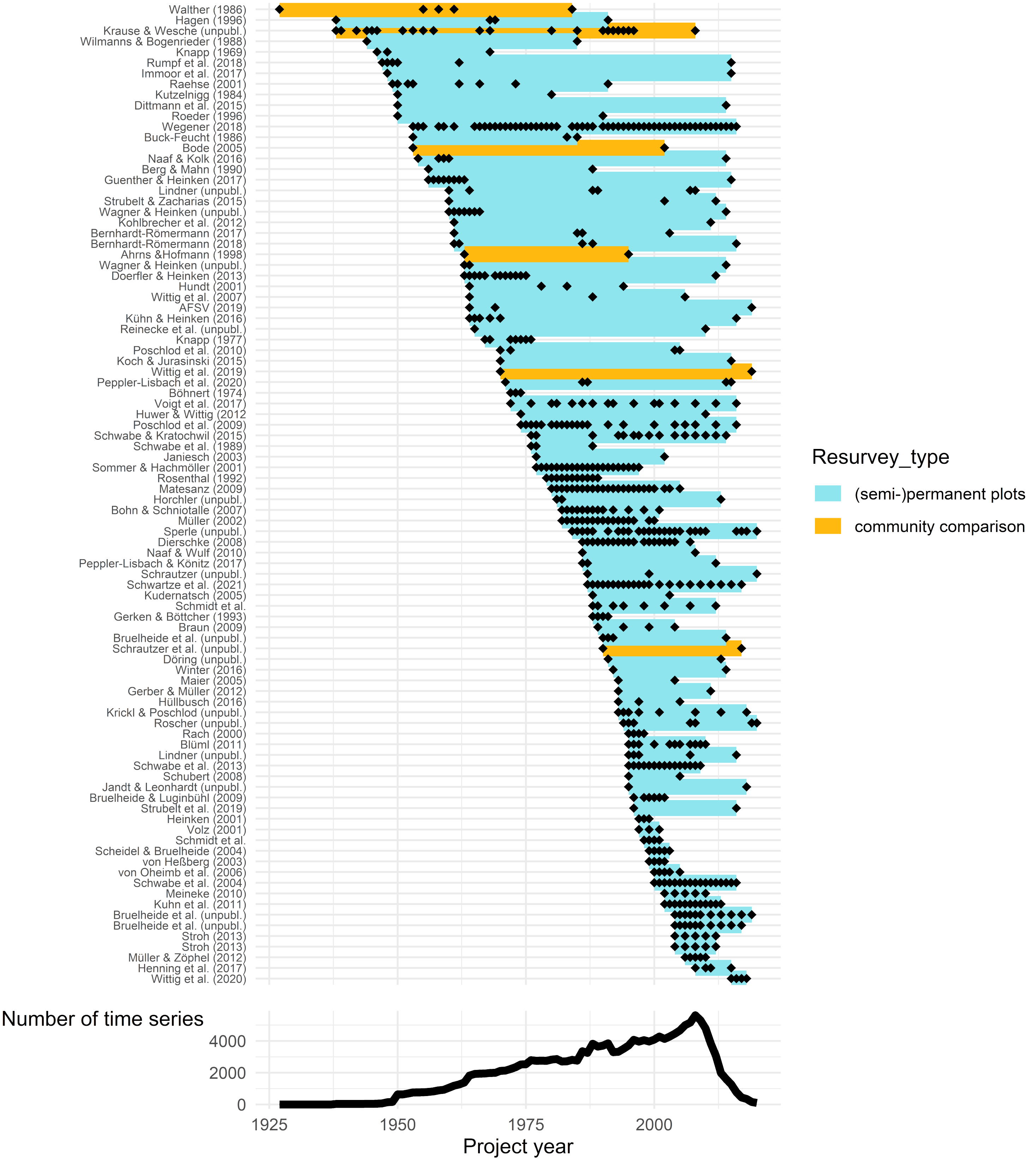

a
Number of plot records
3000
2000
1000
0
-2
0
2
4
Plot richness changes [$\log_e(SR_{Y2}/SR_{Y1})$]
b
Number of species
150
100
50
0
-4
0
4
Species mean cover changes ($Cover_{Y2}$ - $Cover_{Y1}$)


a
Change observations by
Plot ID x species x time interval
-
+
Negative change observations
Positive change observations
Gini 0.712
Gini 0.718
Proportion of observed absolute changes
Proportion of observations
0.0
0.2
0.4
0.6
0.8
1.0
b
Change observations
aggregated by species
(across all plots
and time intervals)
Losers
Winners
Gini 0.692
Gini 0.778
Proportion of observed absolute changes
Proportion of species


Hypotheses: The divergence in the distribution between cover losses and gains is driven by …
i) … the proportion of species that undergo changes
ii) …the ratio of increasing to decreasing species
iii) …the degree to which cover losses are concentrated on a specific subset of species
Proportion of species with cover changes 0.4
Proportion of species with cover changes 0.8
Proportion of increases in all changes 0.2
Proportion of increases in all changes 0.8
Random species selection
Directed species selection
a
b
c
d
e
f
Negative change observations
Positive change observations
Proportion of species with cover changes
0.4 n.s.
0.8 n.s.
Gini 0.57
Gini 0.57
Gini 0.65
Gini 0.65
Proportion of increases in all changes
0.2 *
0.8 *
Gini 0.59
Gini 0.77
Gini 0.58
Gini 0.69
Species selection
Random n.s.
Directed n.s.
Gini 0.65
Gini 0.65
Gini 0.66
Gini 0.66
Proportion of observations
Proportion of observed absolute changes
Losers
Winners
Proportion of species with cover changes
0.4 n.s.
0.8 n.s.
Gini 0.55
Gini 0.57
Gini 0.59
Gini 0.57
Proportion of increases in all changes
0.2 n.s.
0.8 n.s.
Gini 0.57
Gini 0.56
Gini 0.58
Gini 0.57
Species selection
Random n.s.
Directed *
Gini 0.57
Gini 0.55
Gini 0.40
Gini 0.55
Proportion of species
0.0
0.2
0.4
0.6
0.8
1.0


Floristic status of taxa
Native
Archaeophyte
Neophyte
? Unclassified
Q Mires and spring fens
R Grasslands
S Scrub and dry heath
T Forest
V Arable land
Probability to increase in cover
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
Chaerophyllum aureum
Centaurea cyanus
Bromus racemosus agg.
Sanicula europaea
Senecio aquaticus agg.
Anagallis arvensis
Viola mirabilis
Juncus filiformis
Polygala vulgaris
Scleranthus annuus agg.
Alyssum montanum
Silaum silaus
Potentilla palustris
Senecio vulgaris
Myosotis arvensis
Mercurialis perennis agg.
Festuca filiformis
Luzula luzuloides
Achillea ptarmica
Succisa pratensis
Crepis paludosa
Valeriana dioica
Apera spica-venti
Euphrasia stricta
Vaccinium vitis-idaea
Danthonia decumbens
Pulmonaria officinalis agg.
Myosotis scorpioides agg.
Onobrychis viciifolia agg.
Arnica montana
Caltha palustris
Adoxa moschatellina
Viola palustris
Calluna vulgaris
Convolvulus
Carex panicea
Hordelymus europaeus
Nardus stricta
Pastinaca sativa
Lathyrus linifolius
Lysimachia nummularia
Melampyrum pratense
Eleocharis palustris agg.
Eriophorum angustifolium
Juncus articulatus
Epilobium angustifolium
Aegopodium podagraria
Galium uliginosum
Primula elatior
Carex acuta agg.
Alopecurus geniculatus
Cynosurus cristatus
Falcaria vulgaris
Poa nemoralis
Festuca gigantea
Fallopia convolvulus
Oxalis acetosella
Silene flos-cuculi
Holcus mollis
Melica uniflora
Leontodon autumnalis
Trifolium dubium agg.
Angelica sylvestris
Cirsium acaule
Anthyllis vulneraria
Lotus pedunculatus
Geranium robertianum
Rumex acetosella
Briza media
Viola silvatica agg.
Festuca ovina agg.
Hieracium pilosella
Phleum pratense agg.
Daucus carota
Rhinanthus minor
Thymus pulegioides agg.
Vaccinium myrtillus
Plantago media agg.
Heracleum sphondylium
Luzula campestris agg.
Glyceria fluitans agg.
Potentilla erecta
Knautia arvensis
Carex nigra agg.
Filipendula ulmaria
Leucanthemum vulgare agg.
Agrostis stolonifera agg.
Anthriscus sylvestris agg.
Campanula rotundifolia agg.
Linum catharticum
Ranunculus bulbosus
Trisetum flavescens
Ononis spinosa agg.
Trifolium pratense
Festuca pratensis
Poa pratensis agg.
Plantago lanceolata
Alopecurus pratensis agg.
Rubus idaeus
Frangula alnus
Sorbus aucuparia
Urtica dioica
Quercus robur
Lolium perenne
Juncus effusus
Glechoma hederacea agg.
Fragaria viridis
Brachypodium pinnatum agg.
Geum urbanum
Calamagrostis epigejos
Carex flacca
Primula veris
Carex humilis
Fraxinus excelsior
Crataegus
Carpinus betulus
Euonymus europaea
Ulmus glabra
Dryopteris carthusiana agg.
Galium mollugo agg.
Inula conyzae
Viburnum lantana
Carex sylvatica
Sambucus nigra
Agrimonia eupatoria
Lonicera xylosteum
Pyrus communis agg.
Juncus acutiflorus
Clematis vitalba
Clinopodium vulgare
Malus domestica
Astragalus glycyphyllos
Rubus fruticosus agg.
Prunus spinosa agg.
Cornus sanguinea
Acer pseudoplatanus
Impatiens parviflora
Prunus domestica
Acer campestre
Fagus sylvatica
Inula hirta
Sorbus torminalis
Prunus padus
Acer platanoides
Berberis vulgaris
Juniperus communis
Festuca altissima
Cerastium glomeratum
Allium ursinum
Ligustrum vulgare
Humulus lupulus
Lonicera caprifolium
Bromus sterilis
Ribes rubrum agg.
Pinus nigra
Prunus serotina
Cardamine bulbifera
Hedera helix
Ilex aquifolium
Allium carinatum
Quercus rubra
Quercus rubra
Allium carinatum
© O. Angerer
Ilex aquifolium
© K. Lauber
Bromus racemosus agg.
© T. Muer
Centaurea cyanus
© T. Muer
Chaerophyllum aureum
© T. Muer


Losers
Winners
Gini coefficient
0.82
0.8
0.78
0.76
0.74
0.72
0.7
0.68
0.66
0.64
0.62
0.6
0.58
0.56
0.54
1950
1960
1970
1980
1990
2000
2010
2020
Year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Böhnert (1974)
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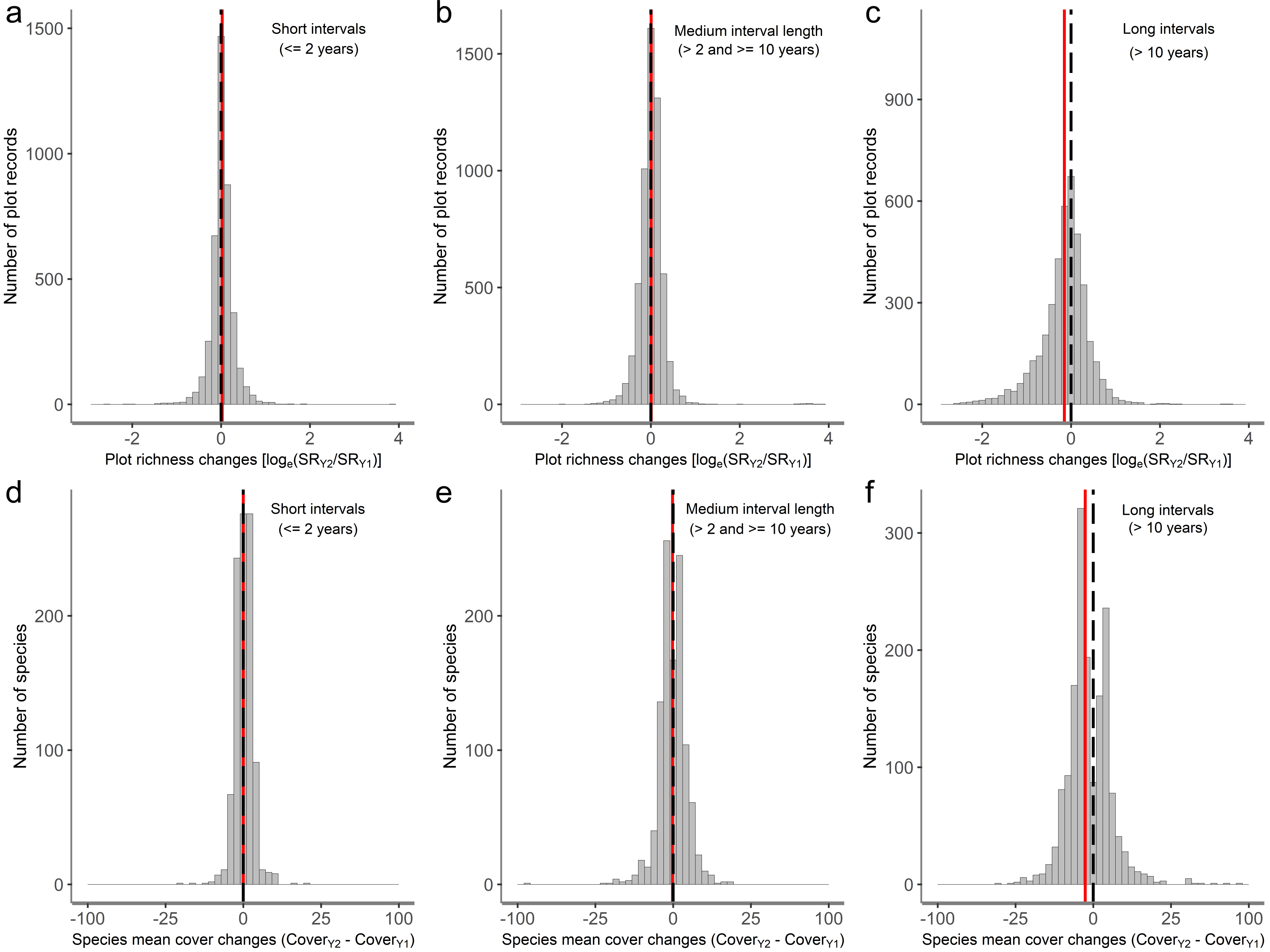
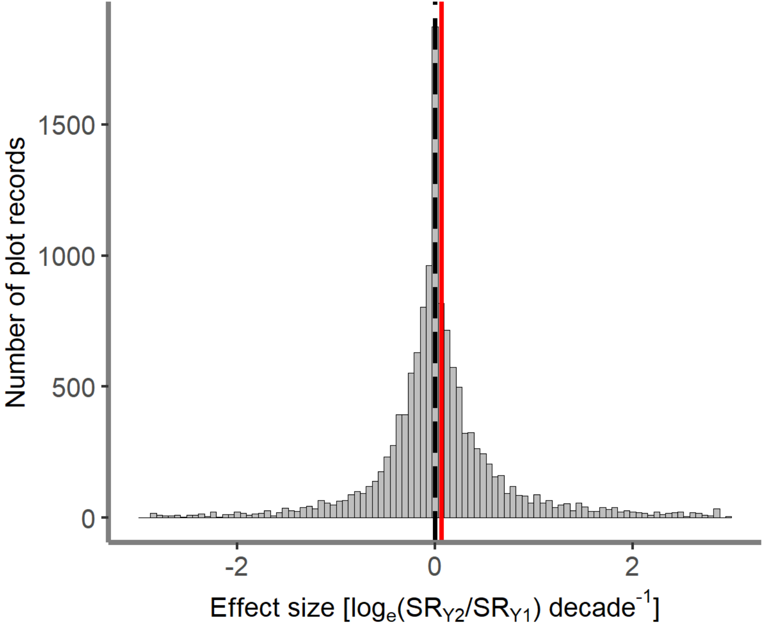
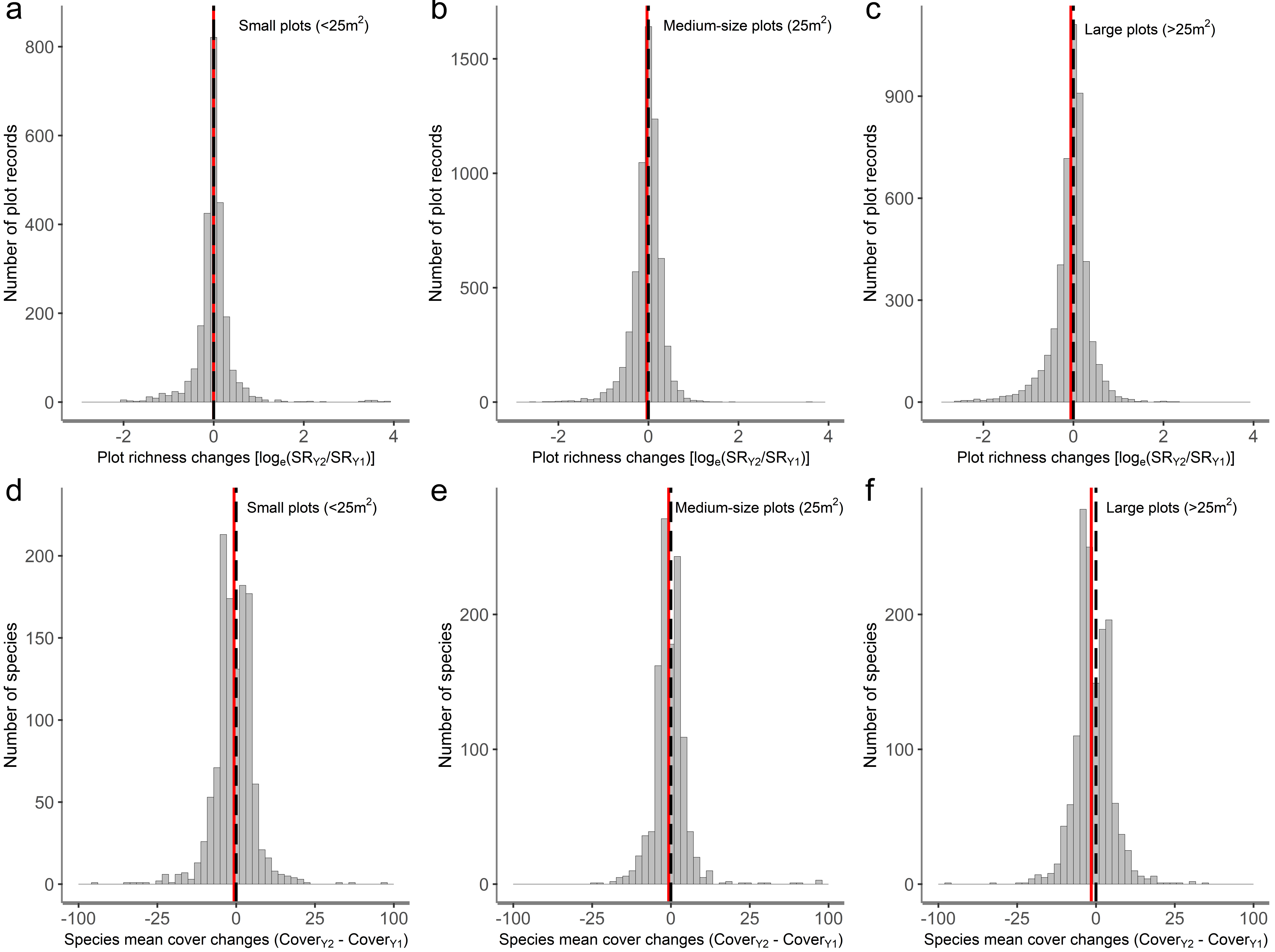
Stroh (2013)
Müller & Zöphel (2012)
Henning et al. (2017)
Wittig et al. (2020)
Resurvey_type
(semi-)permanent plots
community comparison
Number of time series
4000
2000
0
1925
1950
1975
2000
Project year


a
Short intervals
(<= 2 years)
Number of plot records
1500
1000
500
0
-2
0
2
4
Plot richness changes [$\log_e(SR_{Y2}/SR_{Y1})$]
b
Medium interval length
(> 2 and >= 10 years)
Number of plot records
1500
1000
500
0
-2
0
2
4
Plot richness changes [$\log_e(SR_{Y2}/SR_{Y1})$]
c
Long intervals
(> 10 years)
Number of plot records
900
600
300
0
-2
0
2
4
Plot richness changes [$\log_e(SR_{Y2}/SR_{Y1})$]
d
Short intervals
(<= 2 years)
Number of species
200
100
0
-100
-25
0
25
100
Species mean cover changes ($Cover_{Y2}$ - $Cover_{Y1}$)
e
Medium interval length
(> 2 and >= 10 years)
Number of species
200
100
0
-100
-25
0
25
100
Species mean cover changes ($Cover_{Y2}$ - $Cover_{Y1}$)
f
Long intervals
(> 10 years)
Number of species
300
200
100
0
-100
-25
0
25
100
Species mean cover changes ($Cover_{Y2}$ - $Cover_{Y1}$)



Number of plot records
0
500
1000
1500
-2
0
2
Effect size [$\log_e(SR_{Y2}/SR_{Y1})$ decade^{-1}]


a
Small plots (<25m²)
Number of plot records
0
200
400
600
800
-2
0
2
4
Plot richness changes [loge(SRY2/SRY1)]
b
Medium-size plots (25m²)
Number of plot records
0
500
1000
1500
-2
0
2
4
Plot richness changes [loge(SRY2/SRY1)]
c
Large plots (>25m²)
Number of plot records
0
300
600
900
-2
0
2
4
Plot richness changes [loge(SRY2/SRY1)]
d
Small plots (<25m²)
Number of species
0
50
100
150
200
-100
-25
0
25
100
Species mean cover changes (CoverY2 - CoverY1)
e
Medium-size plots (25m²)
Number of species
0
100
200
-100
-25
0
25
100
Species mean cover changes (CoverY2 - CoverY1)
f
Large plots (>25m²)
Number of species
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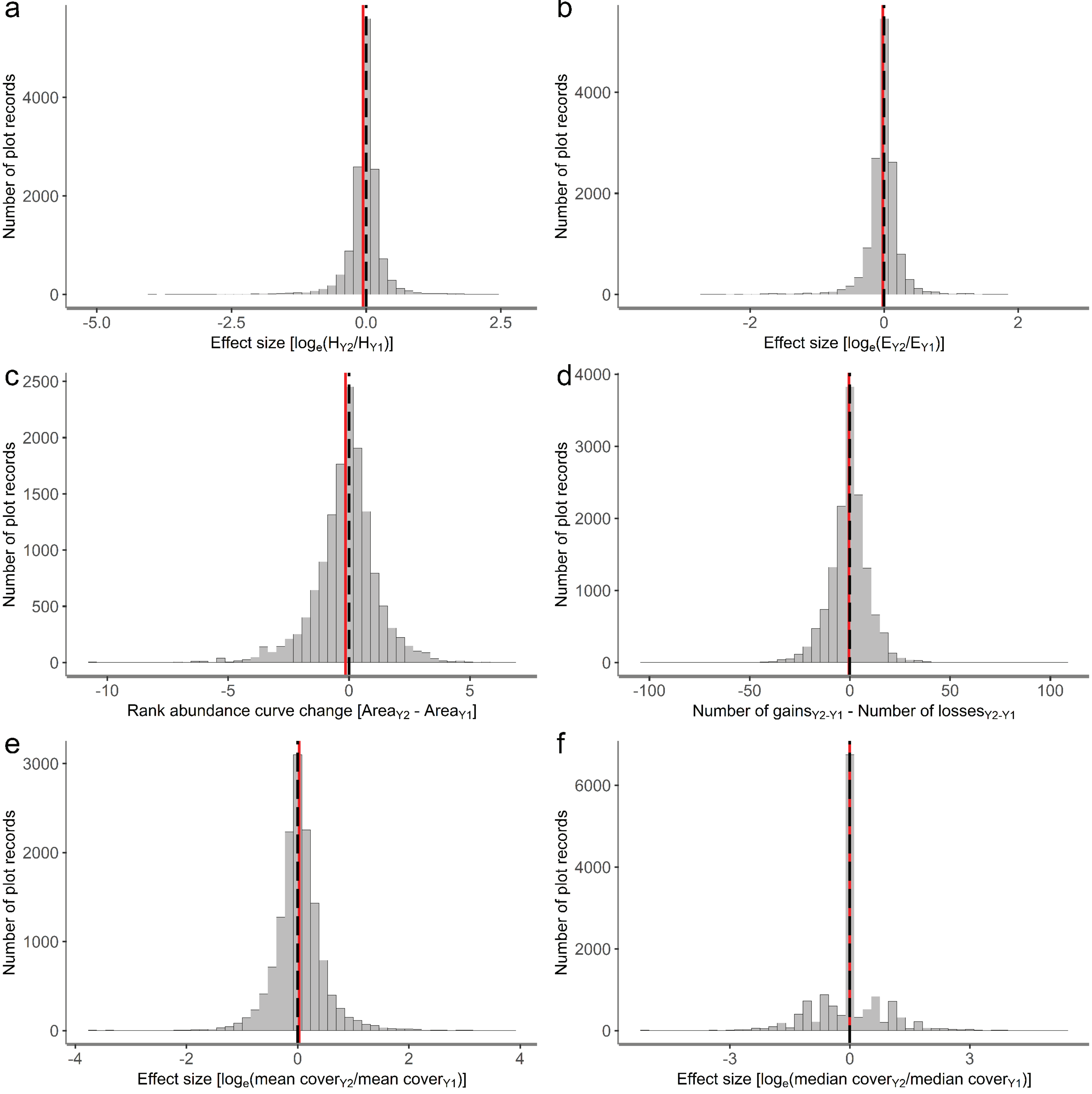
200
-100
-25
0
25
100
Species mean cover changes (CoverY2 - CoverY1)


a
Number of plot records
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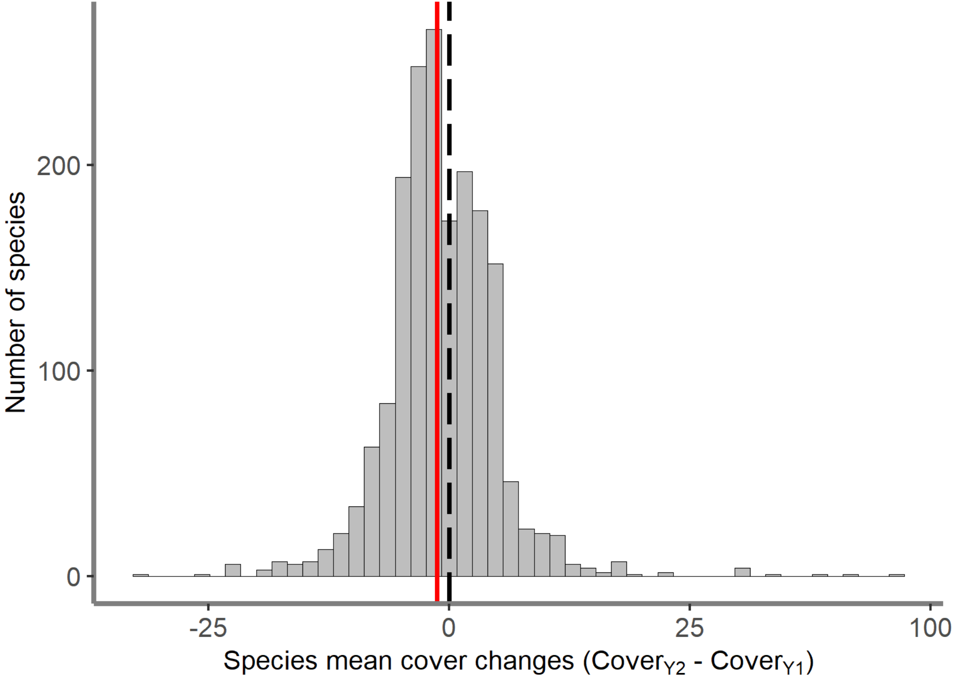
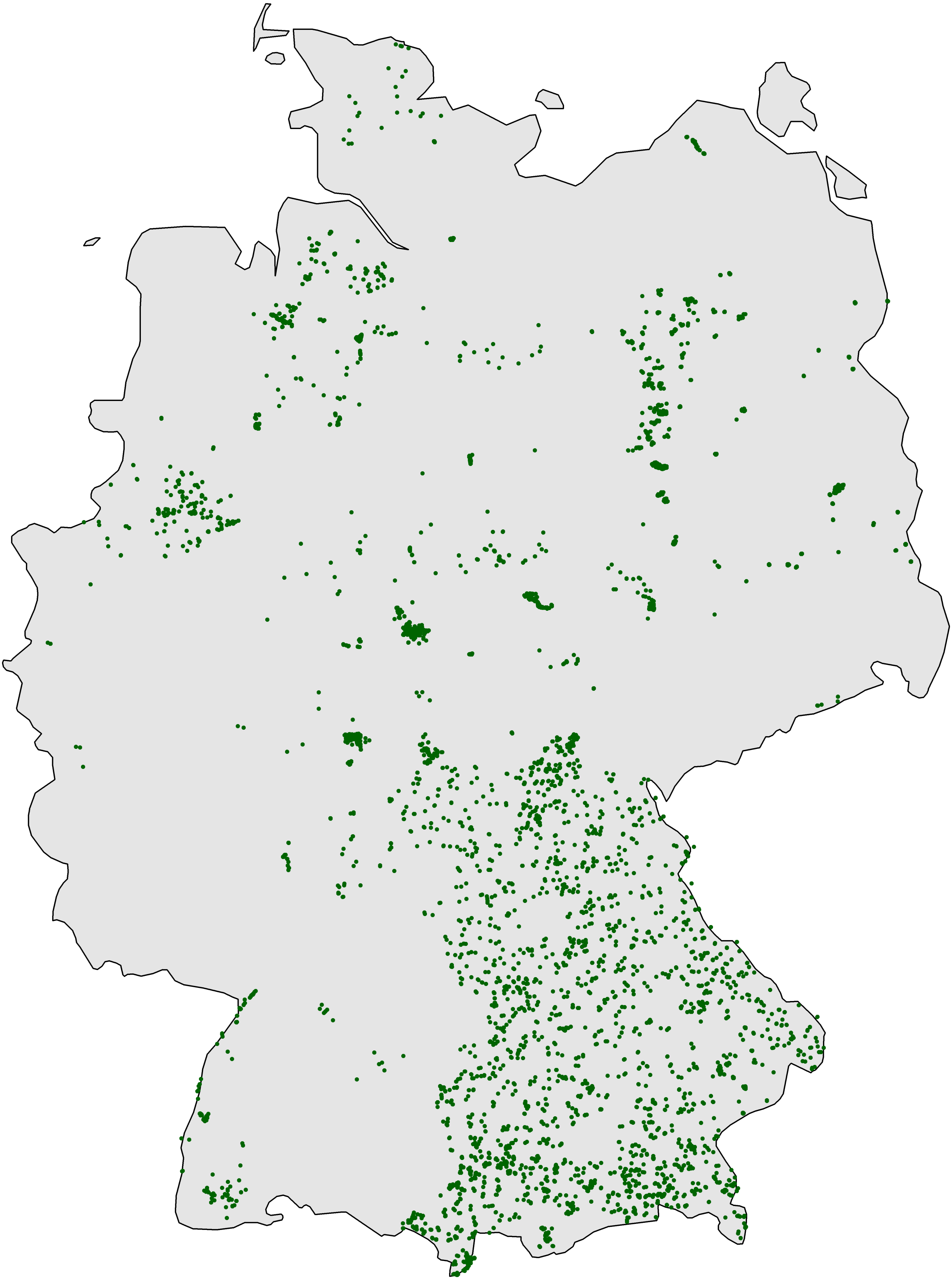
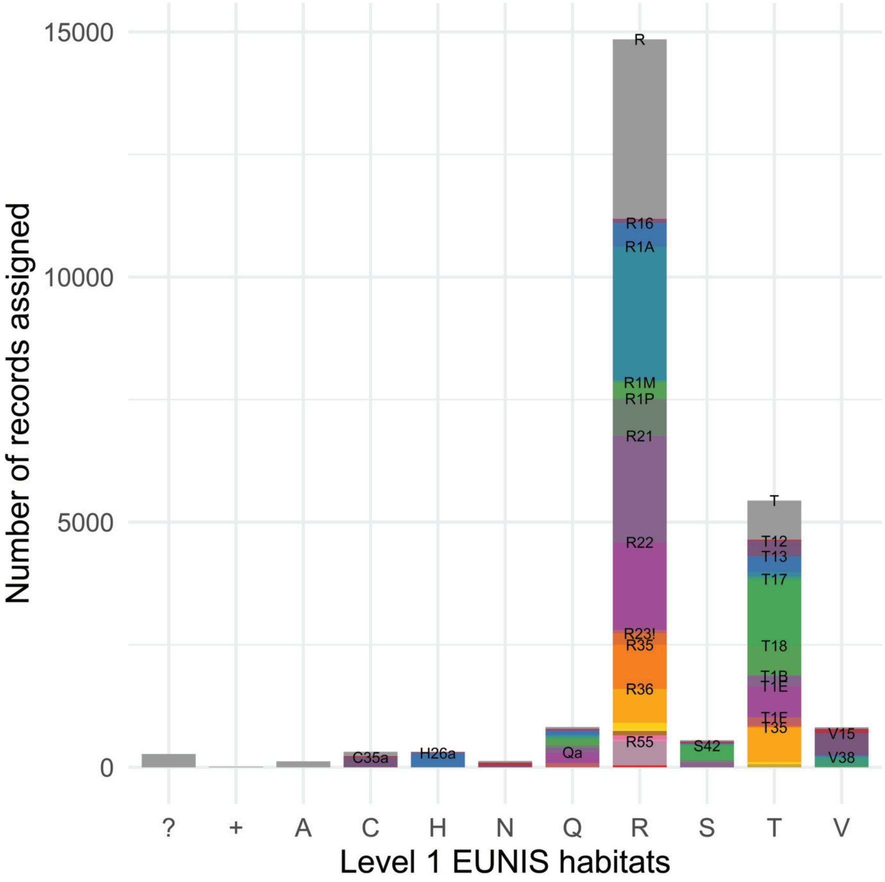
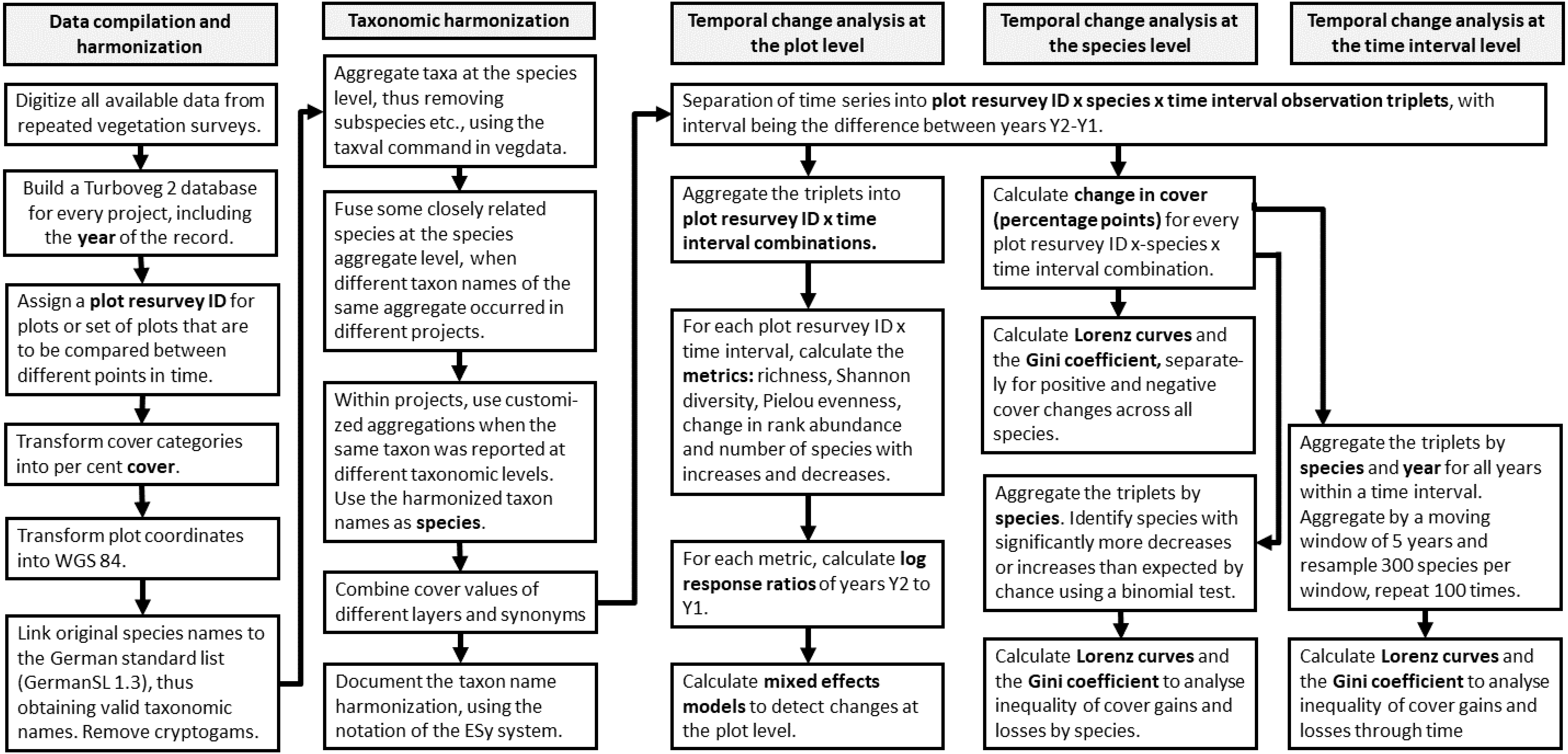
2000
4000
-5.0
-2.5
0.0
2.5
Effect size [log$_e$(H$_{Y2}$/H$_{Y1}$)]
b
Number of plot records
0
2000
4000
-2
0
2
Effect size [log$_e$(E$_{Y2}$/E$_{Y1}$)]
c
Number of plot records
0
500
1000
1500
2000
2500
-10
-5
0
5
Rank abundance curve change [Area$_{Y2}$ - Area$_{Y1}$]
d
Number of plot records
0
1000
2000
3000
4000
-100
-50
0
50
100
Number of gains$_{Y2-Y1}$ - Number of losses$_{Y2-Y1}$
e
Number of plot records
0
1000
2000
3000
-4
-2
0
2
4
Effect size [log$_e$(mean cover$_{Y2}$/mean cover$_{Y1}$)]
f
Number of plot records
0
2000
4000
6000
-3
0
3
Effect size [log$_e$(median cover$_{Y2}$/median cover$_{Y1}$)]


Number of species
200
100
0
-25
0
25
100
Species mean cover changes ($Cover_{Y2}$ - $Cover_{Y1}$)




15000
10000
5000
0
Number of records assigned
?
+
A
C
H
N
Q
R
S
T
V
Level 1 EUNIS habitats
C35a
H26a
Qa
R
R16
R1A
R1M
R1P
R21
R22
R23!
R35
R36
R55
S42
T
T12
T13
T17
T18
T1B
T1E
T1F
T35
V15
V38



Data compilation and harmonization

Digitize all available data from repeated vegetation surveys.

Build a Turboveg 2 database for every project, including the **year** of the record.

Assign a **plot resurvey ID** for plots or set of plots that are to be compared between different points in time.

Transform cover categories into per cent **cover**.

Transform plot coordinates into WGS 84.

Link original species names to the German standard list (GermanSL 1.3), thus obtaining valid taxonomic names. Remove cryptogams.

Taxonomic harmonization

Aggregate taxa at the species level, thus removing subspecies etc., using the taxval command in vegdata.

Fuse some closely related species at the species aggregate level, when different taxon names of the same aggregate occurred in different projects.

Within projects, use customized aggregations when the same taxon was reported at different taxonomic levels. Use the harmonized taxon names as **species**.

Combine cover values of different layers and synonyms

Document the taxon name harmonization, using the notation of the ESy system.

Temporal change analysis at the plot level

Temporal change analysis at the species level

Temporal change analysis at the time interval level

Separation of time series into **plot resurvey ID x species x time interval observation triplets**, with interval being the difference between years Y2-Y1.

Aggregate the triplets into **plot resurvey ID x time interval combinations.**

For each plot resurvey ID x time interval, calculate the **metrics:** richness, Shannon diversity, Pielou evenness, change in rank abundance and number of species with increases and decreases.

For each metric, calculate **log response ratios** of years Y2 to Y1.

Calculate **mixed effects models** to detect changes at the plot level.

Calculate **change in cover (percentage points)** for every plot resurvey ID x-species x time interval combination.

Calculate **Lorenz curves** and the **Gini coefficient,** separately for positive and negative cover changes across all species.

Aggregate the triplets by **species**. Identify species with significantly more decreases or increases than expected by chance using a binomial test.

Calculate **Lorenz curves** and the **Gini coefficient** to analyse inequality of cover gains and losses by species.

Aggregate the triplets by **species** and **year** for all years within a time interval. Aggregate by a moving window of 5 years and resample 300 species per window, repeat 100 times.

Calculate **Lorenz curves** and the **Gini coefficient** to analyse inequality of cover gains and losses through time

Supplementary Tables

Jandt, U., Bruelheide, H., Jansen, J., Bonn, A., Grescho, V., Klenke, R., Sabatini, F.M., Bernhardt-Römermann, M., Blüml, V., Dengler, J., Diekmann, M., Dörfler, I., Döring, U., Dullinger, S., Haider, S., Heinken, T., Horchler, P., Kuhn, G., Lindner, M., Metze, K., Müller, N., Naaf, T., Peppler-Lisbach, C., Poschlod, P., Roscher, C., Rosenthal, G., Rumpf, S., Schmidt, W., Schrautzer, W., Schwabe, A., Schwartze, P., Sperle, T., Stanik, N., Storm, C., Voigt, W., Wegener, U., Wesche, K., Wittig, B., Wulf, M. (2022): Plant diversity change over one century in Germany: more losers than winners. – Nature

Extended Data Table 1 | List of all projects included in this study. PROJECT_ID: internal reference number. EUNIS habitat types of time series were assigned to the habitat type by using the earliest plot record that resulted in level 3 EUNIS classification. The classification was based on the EUNIS-ESy expert system[56] using the R code implementation[57]. When a project included several habitat types, they are shown in decreasing numbers of plot records. Code for habitat types are ?: plots not assigned to any level 3 EUNIS habitat type, +: assigned to more than one level 3 EUNIS habitat type, A: Marine habitats, C: Inland surface waters, H: Inland sparsely vegetated habitats or devoid of vegetation, N: Coastal habitats, Q: Wetlands, R: Grasslands and lands dominated by forbs, mosses or lichens, S: Heathlands, scrub and tundra, T: Forests and other wooded land, V: Vegetated man-made habitats, including arable land.

PROJECT_ ID	Project Name	Reference	EUNIS habitat type
77	AFSV (2019)	Arbeitsgemeinschaft Forstliche Standorts- und Vegetationskunde (AFSV) (2019) Nordwest-Eifel - Standorte, Waldgesellschaften, Nutzungen gestern und heute. Exkursionsführer der AFSV-Tagung 2019 in der Nordwesteifel. Verlag Dr. Kessel, Remagen-Oberwinter.	T17
1	Ahrns & Hofmann (1998)	Ahrns, C. & Hofmann, G. (1998) Vegetationsdynamik und Florenwandel im ehemaligen mitteldeutschen Waldschutzgebiet "Hainich" im Intervall 1963 - 1995. Hercynia N.F. 31: 33-64.	T17
4	Berg & Mahn (1990)	Berg, C. & Mahn, E.-G. (1990) Anthropogene Vegetationsveränderungen der Strassenrandvegetation in den letzten 30Jahren-die Glatthaferwiesen des Raumes Halle Saale. Tuexenia 10: 185-195.	R22, R
2	Bernhardt-Römermann (2017)	(Echinger Lohe)	T1F, T1E, T13, T
3	Bernhardt-Römermann (2018)	(Sonneberg)	T35, T32, T1F, T18, T17, T, S42, R57, R, ?

5	Blüml (2011)	Blüml, V. (2011) Langfristige Veränderungen von Flora und Vegetation des Grünlandes in der Dümmerniederung (Niedersachsen) unter dem Einfluss von Naturschutzmaßnahmen. Dissertation, Universität Bremen.	R55, R36, R35, R21, R, Qb, Q52, Q51
6	Bode (2005)	Bode, F. (2005) Subrezenter Vegetations- und Landschaftswandel im Südschwarzwald. Dissertation, Albert-Ludwigs-Universität Freiburg.	S42
92	Bohn & Schniotalle (2007)	Bohn, U. & Schniotalle, S. (2007) Hochmoor-, Grünland- und Waldrenaturierung im Naturschutzgebiet "Rotes Moor", Hohe Rhön 1981 - 2001: Ergebnisse 20-jähriger wissenschaftlicher Begleituntersuchungen im Rahmen und im Anschluss an ein E+E-Vorhaben des Bundes. Bundesamt für Naturschutz, Bonn.	T12, S92, R37, R35, R23!, R23, R1M, Qa, Q24, Q22, ?
78	Böhnert (1974)	Böhnert, W. (1978) Ökologische Untersuchungen auf den Kreidesandsteinhöhen der Harslebener Berge bei Quedlinburg. Naturschutz und naturkundliche Heimatforschung in den Bezirken Halle und Magdeburg 15 (2): 11-23	S42, R
7	Braun (2009)	Braun, W. (2009) Ein Niedermoor wächst über Hochmoortorf. Ber. d. Bayerischen Botanischen Gesellschaft 79: 127-146. München.	Qb, Qa, Q25, Q24, H26a
88	Bruelheide & Luginbühl (2009)	Bruelheide, H. & Luginbühl, U. (2009) Peeking at ecosystem stability: making use of a natural disturbance experiment to analyze resistance and resilience. Ecology 90 (5): 1314-1325.	T1F, T1E, T17, T, H25
17	Bruelheide et al. (unpubl.)	(Bergwiesen)	R55, R37, R35, R23!, R22, R1M, R, Q24, ?
90	Bruelheide et al. (unpubl.)	(Preuk)	T35, T1B, T, Sa
91	Bruelheide et al. (unpubl.)	(Schiessplatz)	T35, R
8	Buck-Feucht (1986)	Buck-Feucht, G. (1986) Vergleich alter und neuer Vegetationsaufnahmen im Forstbezirk Kirchheim unter Teck. Mittelungen des Vereins für forstliche Standortskunde und Forstpflanzenzüchtung (32): 43-49.	T1E, T18, T17, T13, T
76	Dierschke (2008)	Dierschke, H. (2008) Dynamik und Konstanz an naturnahen Flussufern -27 Jahre Dauerflächenuntersuchungen am Oderufer (Harzvorland). Braunschweiger Geobotanische Arbeiten 9: 119-138.	R55

10	Dittmann et al. (2015)	Dittmann, T., Heinken, T. & Schmidt, M. (2018) Die Wälder von Magdeburgerforth (Fläming, Sachsen-Anhalt) – eine Wiederholungsuntersuchung nach sechs Jahrzehnten. Tuexenia 38: 11-42.	T35, T1E, T1B, T18, T17, T15, T13, T12, T
11	Doerfler & Heinken (2013)	Vegetation change of wet and moist forests in NE German nature reserves	T3M, T3J, T35, T1E, T17, T16, T15, T13, T12, T, S92, Qb, Qa, Q53, +, ?
12	Döring (unpubl.)	Feuchtwälder in den Landkreisen Diepholz und Uelzen; Wiederholungsaufnahmen von PD Dr. Wilfried Hakes [NW-FVA] im Rahmen des Forschungsvorhabens “NaLaMa-nT” erhoben	T1E, T16, T15, T13, T12, T
62	Gerber & Müller (2012)	Gerber, L. & Müller, F. (2012) Flora und Vegetation den Naturschutzgebietes Am Galgenteich Altenberg. Berichte der Arbeitsgemeinschaft sächsischer Botaniker N.F. 21: 65-123.	S42, S32, R1M, R
13	Gerken & Böttcher (unpubl.)	Abschlußbericht, unpubl.	V38, R22, R1A, R, H26a, ?
15	Günther et al. (2021)	Günther, K., Schmidt, M., Quitt, H. & Heinken, T. (2021): Veränderungen der Waldvegetation im Elbe-Havelwinkel von 1960 bis 2015. Tuexenia 41: 53-85.	T3M, T35, T1B, T16, T15, T13, T12, T, S92, S42
16	Hagen (1996)	Hagen, T. (1996) Vegetationsveränderungen in Kalk-Magerrasen des Fränkischen Jura. Laufener Forschungsbericht 4. Bayerische Akademie f. Naturschutz u. Landschaftspflege, Laufen, Salzach. 218 S.	R1A, R16, R13
79	Heinken (2001)	Heinken, A. (2001) Vegetationsentwicklung von Auengrünland nach Wiederüberflutung. Diss. Math.-Nat. Fak. Humboldt-Universität Berlin. 161 S.	R36, R22, R21, R, Qb, Q52, Q51
43	Heinrich, Marstaller & Voigt (2012)	Eine Langzeitstudie zur Sukzession in Halbtrockenrasen - Strukturwandlung in einer Dauerbeobachtungsfläche im Naturschutzgebiet “Leutratal und Cospoth” bei Jena (Thüringen). Artenschutzreport Jena 30: 1-80.	T36, T1H, T19, T17, T, Sa, S35, R51!, R22, R1A, R16, H26a, ?
68	Henning et al. (2017)	Henning, K.; Lorenz, A.; von Oheimb, G.; Härdtle, W.; Tischew, S. Year-round cattle and horse grazing supports the restoration of abandoned, dry sandy grassland and heathland communities by supressing Calamagrostis. Journal for Nature Conservation 40: 120-130.	V38, S42, R1P, R1A, N19, N15
54	von Heßberg (2003)	von Heßberg, A. (2003) Landschafts- und Vegetationsdynamik entlang renaturierter Flussabschnitte von Obermain und Rodach. Dissertation, Universität Bayreuth.	V15, T13, S91, R55, R21, H25

74	Horchler (unpubl.)	Horchler, P., Henrichfreise, A. Vollmer, I. (2013) Wiederholungsaufnahme von 54 Auenwald-Vegetationsaufnahmen am Oberrhein.	T1H, T1F, T1E, T13, T11, T, Sa, S35, R55, Q52, C23, ?
19	Hüllbusch et al. (2016)	Hüllbusch, E., Brandt, L.M., Ende, P. & Dengler, J. (2016) Little vegetation change during two decades in a dry grassland complex in the Biosphere Reserve Schorfheide-Chorin (NE Germany). Tuexenia 36: 395-412.	R22, R1P, R1B, R1A, R, N15!!
20	Hundt (2001)	Hundt, R. (2001) Ökologisch-geobotanische Untersuchungen an den mitteldeutschen Wiesengesellschaften unter besonderer Berücksichtigung ihres Wasserhaushaltes und ihrer Veränderung durch die Intensivbewirtschaftung. Mitteilungen aus dem Biosphärenreservat Rhön/Thüringen. 3. Monographie. 366 S.	V37, R55, R37, R36, R35, R23!, R22, R1M, R1A, R, Q53, Q43, +
48	Huwer & Wittig (2012)	unpublished data for: Huwer, A. & Wittig, R. (2012) Changes in the species composition of hedgerows. Tuexenia 32: 31-53. Göttingen.	T1E, T1B, T13, T12, T11, T, Sa, S37, ?
21	Immoor et al. (2017)	Immoor, A., Zacharias, D., Müller, J. & Diekmann, M. (2017) A re-visitation study (1948–2015) of wet grassland vegetation in the Stedinger Land near Bremen, North-western Germany. Tuexenia 37: 271-288.	R36, R35, R21, R, Qb
23	Jandt & Leonhardt (unpubl.)	(Kyffhäuser)	S42, R1B!, R1B, R1A, R16, R13
22	Janiesch (2003)	Janiesch, P. (2003) Vegetationsökologische Untersuchungen in einem Erlenbruchwald im nördlichen Münsterland - 25 Jahre im Vergleich. Abhandlungen aus dem Westfälischen Museum für Naturkunde: Vegetation und Fauna in Westfalen (ed Westfälisches Museum für Naturkunde), pp. 71-80, Münster.	T15, T13
70	Knapp (1969)	Knapp, R. (1969) Änderungen in der Vegetation Hessischer Gebirge in den letzten Jahrzehnten. Mitteilungen der Floristisch-Soziologischen Arbeitsgemeinschaft N.F. 14: 274-286	R35, R22, R1M, R
71	Knapp (1977)	Knapp, R. (1977) Dauerflächen-Untersuchungen über die Einwirkung von Haustieren und Wild während trockener und feuchter Zeiten in Mesobromion- Halbtrockenrasen in Hessen. Mitteilungen der Floristisch-Soziologischen Arbeitsgemeinschaft N.F. 19: 269-274	R1A
87	Koch & Jurasinski (2015)	Koch, M. & Jurasinski, G. (2015) Four decades of vegetation development in a percolation mire complex following intensive drainage and abandonment. Plant Ecology & Diversity 8: 49-60	T16, T12, T, R55, R35, Qb, Qa, Q53, Q52, Q51, Q43, Q42, Q41, Q24, C35a, ?

59	Kohlbrecher et al. (2012)	unpublished data for: Kohlbrecher, C., Wesche, K., Hilbig, W., Leuschner, C., Meyer, S. (2012) Veränderungen der Segetalvegetation am Kyffhäusergebirge in den letzten 50 Jahren. Landschaftspflege und Naturschutz in Thüringen 49: 1-9.	V15
24	Krause & Wesche (2011)	unpublished data for: Krause, B., Culmsee, H., Wesche, K., Bergmeier, E. & Leuschner, C. (2011) Habitat loss of floodplain meadows in north Germany since the 1950s. Biodiversity and Conservation 20 (11): 2347-2364.	R22, R21, R1P, R, C35a, A25c
84	Krickl & Poschlod (unpubl.)	(calcareous grasslands SW-Germany)	R1A, R16, H26a
65	Kudernatsch (2005)	Kudernatsch, T. (2005) Auswirkungen der globalen Erwärmung auf die Vegetation alpiner Kalk-Magerrasen im Nationalpark Berchtesgaden. Dissertation TU München, Department für Ökologie, Fachgebiet Geobotanik Weihenstephan. 151 S.	S22, R44, R43!, R
25	Kühn & Heinken (2017)	unpublished data for: Kühn, S.L., Heinken, T. (2017): Vegetationsveränderungen im NSG Bredower Forst im Verlauf von 50 Jahren – Analyse anhand historischer Vegetationsaufnahmen. Natursch. Landschaftspfl. Brandenbg. 26(4): 4-16.	T35, T1E, T1B, T18, T17, T, ?
14	Kuhn et al. (2011)	unpublished data for: Kuhn, G.; Heinz, S.; Meyer, F. (2011) Grünlandmonitoring Bayern, Ersterhebung der Vegetation 2002 - 2008. LfL Schriftenreihe Bayerische Landesanstalt für Landwirtschaft 3.	V38, V37, V15, V, S22, R55, R44, R37, R36, R35, R23!, R23, R22, R21, R1M, R1A, R16, R, Qb, Q53, Q52, Q51, Q43, Q41, C35d, ?
26	Kutzelnigg (1984)	Kutzelnigg, H. (1984) Veränderungen der Ackerwildkrautflora im Gebiet um Moers/Niederrhein seit 1950 und ihre Ursachen. Tuexenia (4): 81-102.	V37, V15
58	Lindner (unpubl.)	(Hechtmoor)	T1B, T16, T, Sb, S92, S41, R, Qb, Qa, Q51, Q42, Q25, Q24, Q21, ?
60	Lindner (unpubl.)	(Süderbrarup)	R55, R52, R22, R1M, R
27	Maier (2005)	Maier, M. (2005) Untersuchung zur Entwicklung von Flora und Fauna in einem Feuchtwiesenschutzgebiet (Naturschutzgebiet Bornhorster Huntewiesen). Diplomarbeit Landschaftsökologie an der Carl von Ossietzky Universität Oldenburg.	R36, R35, Qb, Q53, Q51
28	Matesanz (2009)	Matesanz, S., Brooker, R.W., Valladares, F. & Klotz, S. (2009) Temporal dynamics of marginal steppic vegetation	R16

		over a 26-year period of substantial environmental change. Journal of Vegetation Science 20 (2): 299-310.	
55	Meineke & Menge (2010)	Meineke, T, & Menge, K. (2010) Wirkungskontrolle zum PROFIL Kooperationsprogramm Naturschutz, Teilbereich Besondere Biotoptypen im FFH-Gebiet Bergwiesen und Wolfsbachtal bei Hohegeiß. Im Auftrag des Niedersächsischen Landesbetriebs für Wasserwirtschaft Küsten- und Naturschutz, Hannover.	R23!, R21, R
63	Müller & Zöphel (2012)	Müller, F. & Zöphel, B. (2012) Bestandssituation, Biologie und Ökologie von Gentianella lutescens im Osterzgebirge. Berichte der Arbeitsgemeinschaft sächsischer Botaniker N.F. 21: 139-184	R23!
29	Müller (2002)	Müller, N. (2002) Auswertung der Langzeituntersuchungen von Dauerflächen im Augsburger Stadtgebiet zur Renaturierung von Lechhaiden. Ber. Bayer. Landesamt Umweltschutz (Hrsg.): 97 S.	V38, V, R55, R37, R22, R1A, R16, N15, H26a
30	Naaf & Kolk (2016)	unpublished data for: Naaf, T. & Kolk, J. (2016) Initial site conditions and interactions between multiple drivers determine herb-layer changes over five decades in temperate forests. For Ecol Manag 366: 153-165.	T1H, T1E, T1B, T18, T17, T15, T13, T12, T, Q51, ?
31	Naaf & Wulf (2010)	Naaf, T. & Wulf, M. (2010) unpublished data for: Habitat specialists and generalists drive homogenization and differentiation of temperate forest plant communities at the regional scale. Biol Conserv 143: 848-855.	T1F, T1E, T17, T13, T12, T, Sa
32	Peppler-Lisbach & Könitz (2017)	Peppler-Lisbach, C. & Könitz, N. (2017): Vegetationsveränderungen in Borstgrasrasen des Werra-Meißner-Gebietes (Hessen, Niedersachsen) nach 25 Jahren – Tuexenia 37: 201-228.	S42, R37, R22, R21, R1M, R
44	Peppler-Lisbach et al. (2020)	Peppler-Lisbach, C, Stanik, N, Könitz, N, Rosenthal, G. (2020) Long-term vegetation changes in *Nardus* grasslands indicate eutrophication, recovery from acidification, and management change as the main drivers. Applied Vegetation Science 23: 508-521. https://doi.org/10.1111/avsc.12513	Sb, Sa, S42, R37, R35, R23!, R23, R22, R1M, R
83	Poschlod et al. (2009)	unpublished data for: Poschlod, P., Schreiber, K.-F., Mitlacher, K., Römermann, C. & Bernhardt-Römermann, M. (2009): Entwicklung der Vegetation und ihre naturschutzfachliche Bewertung. In: Schreiber, K.-F., Brauckmann, H.-J., Broll, G., Krebs, S. & Poschlod, P. (Hrsg.): Landschaftspflege und Naturschutz im Extensivgrünland. 30 Jahre Offenhaltungsversuche Baden-Württemberg. – Naturschutz-Spectrum Themen 97: 243-288.	T1E, R22, R21, R1M, R1A, N19

85	Poschlod et al. (2010)	unpublished data for: Poschlod, P., Kos, M., Roauer, S., Seemann, A., Wiesmann, O., Zeltner, G., Kohler, A. (2006) Long-term monitoring in rivers of south Germany since the 1970ies - macrophytes as indicators for the assessment of water quality. In: Müller, F., Baessler, C., Schubert, H. & Klotz, S. (Eds.): Long-term ecological research. Between Theory and Application. Berlin: Springer, pp. 189-199.	Qb, Q52, Q51, C23, C22b, ?
64	Rach (2000)	Rach, C. (2000) Charakterisierung von Renaturierungsprozessen in Bruchwäldern - Ökologische Untersuchungen in zwei Landschaftsräumen Nordwestdeutschlands. Dissertation Fachbereich Biologie, Geo- und Umweltwissenschaften Universität Oldenburg. 201 S.	T15, T12, T
36	Raehse (2001)	Raehse, S. (2001) Veränderungen der hessischen Grünlandvegetation seit Beginn der 50er Jahre am Beispiel ausgewählter Tal- und Bergregionen Nord- und Mittelhessens. Kassel, University Press GmbH. 222 S.	V15, S42, R55, R37, R36, R35, R22, R21, R1M, R1A, R, Qb, Q53, Q51, N19
37	Reinecke et al. (unpubl.)	unpublished data for: Reinecke, J., Klemm, G., Heinken, T. (2014): Vegetation change and homogenization of species composition in temperate nutrient-deficient Scots pine forests after 45 yr. J. Veg. Sci. 25: 113-121.	T35, T1B, T, S42, R54, ?
80	Roeder et al. (1996)	Röder, H., Fischer, A., Klöck, W. (1996) Waldentwicklung auf Quasi-Dauerflächen im Luzulo-Fagetum der Buntsandsteinrhön (Forstamt Mittelsinn) zwischen 1950 und 1990. Forstw. CB1. 115, 321-335	T35, T1H, T18, T, S42, R, ?
86	Roscher (unpubl.)	(East Thuringia)	R51!, R22, R1A, R16, R
38	Rosenthal (1992)	Rosenthal, G. (1992) Erhaltung und Regeneration von Feuchtwiesen. Vegetationsökologische Untersuchungen auf Dauerflächen. Diss. Bot. 182: 1-283. Berlin, Stuttgart.	V15, R55, R36, R35, R, Q51
67	Rumpf et al. (2018)	unpublished data for: Rumpf, S.; Dullinger, S. (2018) Range dynamics of mountain plants decrease with elevation. PNAS 115(8):1848-1853.	Sb, S42, S22, R56, R55, R44, R43, R41, R23!, R21, R, H32c, H26b, H24, H23
39	Scheidel & Bruelheide (2004)	Scheidel, U. & Bruelheide, H. (2004) Versuche zur Beweidung von Bergwiesen im Harz. Hercynia N.F. 37: 87-101	S32, R35, R, ?
33	Schmidt et al.	Garbitz, D. (1990): Vegetation und Standortsbedingungen im Naturwald "Staufenberg". Dipl.-Arb. Syst.-Geobot. Institut, Universität Göttingen. Melcher. S. (1999): Flora und Vegetation im Naturwald "Großer Staufenberg" (Forstamt Walkenried, Revier	T3M, T35, T1F, T1E, T18, T17, T, Sa, +, ?

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34	Schmidt et al.	Kompa T., Schmidt, W. (2005): Buchenwald-Sukzession nach Windwurf auf Zechstein-Standorten des südwestlichen Harzvorlandes. Hercynia N.F. 38: 233-261. Schmidt, W. (2002): Die Naturschutzgebiete Hainholz und Staufenberg am Harzrand – Sukzessionsforschung in Buchenwäldern ohne Bewirtschaftung. Tuexenia 22: 151-213. Schmidt, W., Heinrichs, S. (2012) 13 Jahre nach dem Sturm - Vegetationsentwicklung im Buchen-Naturwald "Königsbuche" (südwestliches Harzvorland, Niedersachsen). Hercynia 45: 81-110.	V39, T1F, T1E, T18, T17, T13, T12, T, Sa, S32, R57, R55, R, ?
73	Schrautzer (unpubl.)	Resurvey Eidertal	R55, R35, Q53, Q52
72	Schrautzer et al. (unpubl.)	Resurvey of Härdtle - Beckmann	T17, T13, T12, T
40	Schubert (2008)	Schubert, R. (2008) Vegetationsdynamik in einigen Naturschutzgebieten Sachsen-Anhalts. Mitteilungen florist. Kart. Sachsen-Anhalt (Halle 2008) 13: 53-75.	V38, T, S42, S38, R55, R35, R22, R1A, R, Q51, ?
42	Schwabe & Kratochwil (2015)	Schwabe, A, & Kratochwil, A. (2015) Pflanzensoziologische Dauerflächen-Untersuchungen im Bannwald "Flüh" (Südschwarzwald) unter besonderer	T18, T, S42, R52

		Berücksichtigung der Weidfeld-Sukzession. standort.wald 49: 5-49	
41	Schwabe et al. (1989)	Schwabe, A., Kratochwil, A. & Bammert, J. (1989) Sukzessionsprozesse im aufgelassenen Weidfeld-Gebiet des "Bannwald Flüh" (Südschwarzwald) 1976-1988 - Mit einer vergleichenden Betrachtung statistischer Auswertungsmethoden. Tuexenia 9: 351-370. Göttingen.	S42, R52, R1M, R, ?
89	Schwabe et al. (2004)	(Grundaufnahmen) unpublished data for: Schwabe, A.; Zehm, A., Nobis, M., Storm, C., Suess, K. (2004) Auswirkungen von Schaf-Erstbeweidung auf die Vegetation primär basenreicher Sand-Ökosysteme. Ber. NNA 1:/2004: 39-54.	V38, V37, V34, V, R1P, R1B, R1A, R13, R, N15!!
57	Schwabe et al. (2013)	unpublished data for Schwabe, A., Suess, K., Storm, C. (2013) What are the long-term effects of livestock grazing in steppic sandy grassland with high conservation value? Results from a 12-year field study. Tuexenia 33: 189-212. Göttingen.	V38, R1P, R1B, R1A, R16, R13, R11, R
69	Schwartze et al. 2021	Schwartze, P., Birkner, L., Velbert, F. & Hölzel, N. (2021) Vielfalt durch extensive Grünlandnutzung. – 30 Jahre Dauermonitoring auf unterschiedlich bewirtschafteten Feuchtgrünlandflächen. Natur in NRW, 1/2021, 16-21. Paderborn. part of unpublished data for: Poptcheva, K., Schwartze, P., Vogel, A., Kleinebecker, T. & Hölzel, N. (2009) Changes in wet meadow vegetation after 20 years of different management in a field experiment (North-West Germany). Agriculture, Ecosystems & Environment, 134 (1-2), 108–114.	R55, R37, R36, R35, R21, R, Q53
61	Sommer & Hachmöller (2001)	Sommer, S. & Hachmöller, B. (2001) Auswertung der Vegetationsaufnahmen von Dauerbeobachtungsflächen auf Bergwiesen im NSG Oelsen bei varierter Mahd im Vergleich zur Brache. Berichte der Arbeitsgemeinschaft sächsischer Botaniker N.F. 18: 99-135	R23!
9	Sperle (unpubl.)		V39, V11, T3K, T12, Sb, S42, S38, R56, R55, R37, R35, R22, R1A, R, Qb, Qa, Q51, Q42, Q41, Q25, Q24, ?
45	Stroh (2013)	Stroh, H.-G. (2013) Wiederholung der vegetationskundlichen Erfassungen an den Dauerbeobachtungsflächen der Kalkmagerrasen des Altendorfer Berges. Bericht für das Jahr 2012. Im Auftrag des Niedersächsischen Landesbetriebs für Wasserwirtschaft Küsten- und Naturschutz, Hannover.	R1A, ?
46	Stroh (2013)	Stroh, H.-G. (2013) Wiederholung der vegetationskundlichen Erfassungen an den	Sa, R1A, ?

		Dauerbeobachtungsflächen der Kalkmagerrasen der Weper und des Gladebergs. Zwischenbericht für das Jahr 2012. Im Auftrag des Niedersächsischen Landesbetriebs für Wasserwirtschaft Küsten- und Naturschutz, Hannover.	
47	Strubelt & Zacharias (2015)	Strubelt, I., Diekmann, M. & Zacharias, D. (2015) Langzeitmonitoring der Vegetation über 52 Jahre im Hartholzauenwald (Querco-Ulmetum minoris Issler 1924) im Haseder Busch (Landkreis Hildesheim). Braunschweiger Geobotanische Arbeiten 11: 173-247	T3M, T1F, T1E, T17, T13, T
66	Strubelt et al. (2019)	Strubelt, I., Diekmann, M., Peppler-Lisbach, C., Gerken, A. & Zacharias, D. (2019) Vegetation changes in the Hasbruch forest nature reserve (NW Germany) depend on management and habitat type. Forest Ecology and Management, 444, 78–88.	T1E, T1B, T18, T17, T13, T
56	Volz (2001)	Volz, H. (2001) Vegetationskundliches Monitoring im NSG Lange Rhön Gebiet Leitgraben. Bearbeitungszeitraum 2001. Gutachten Umweltplanung Volz, Giessen, 62 S.	R57, R35
35	von Oheimb et al. (2006)	v. Oheimb, G., Eischeid, I., Finck, P., Grell, H., Härdtle, W., Mierwald, U., Riecken, U., Sandkühler, J. (2006) Halboffene Weidelandschaft Höltigbaum. Perspektiven für den Erhalt und die naturverträgliche Nutzung von Offenlandlebensräumen. Naturschutz und Biologische Vielfalt 36: 1-280. Landwirschaftsverlag Münster.	V39, T13, T, R55, R52, R36, R35, R22, R21, R1P, R1M, R, Qb, Q53, Q52, N15, C35a, ?
50	Wagner & Heinken (unpubl.)		T3M, T35, T1H, T1E, T1B, T18, T13, T, S42, R, ?
51	Wagner & Heinken (unpubl.)		T35, T1F, T1E, T1B, T18, T17, T13, T12, T, R55, R51, R1M, R, ?
49	Walther (1986)	Walther, K. (1986) Die Vegetation des Maujahn 1984. Wiederholung der vegetationskundlichen Untersuchung eines wendländischen Moores. Tuexenia 6: 145-193. Göttingen.	T1B, R37, R35, R1P, Q51
52	Wegener (2018)	Wegener, U. (2018) Vegetationswandel des Berggrünlands nach Untersuchungen von 1954 bis 2016. Wege zur Erhaltung der Bergwiesen. Abh. und Ber. aus dem Museum Heineanum 11: 35-101.	R23
53	Wilmanns & Bogenrieder (1988)	Wilmanns, O. & Bogenrieder, A. (1986) Veränderungen der Buchenwälder des Kaiserstuhls im Laufe von vier Jahrzehnten und ihre Interpretation - pflanzensoziologische Tabellen als Dokumente. Abhandlungen aus dem westfälischen Museum für Naturkunde 48(2): 55-80	T18, T, ?

81	Winter (unpubl.)	Winter, R. (2016) Flora und Vegetationsentwicklung der Sukzessionsfläche "Wildnis am Bunker Valentin" in der Bremer Weseraue bei Farge. Bachelorthesis Hochschule Bremen, Studiengang Technische und angewandte Biologie, 61 S.	T, S42, Q51
18	Wittig et al. (2007)	unpublished data for: Wittig, B., Waldmann, T., Diekmann, M. (2007) Veränderungen der Grünlandvegetation im Holtumer Moor über vier Jahrzehnte. Hercynia N.F. 40: 285-300.	V38, V37, V15, V11, V, T16, T15, T13, T12, S92, S41, R55, R52, R37, R36, R35, R22, R21, R, Qa, Q53, Q51, Q22
75	Wittig et al. (2019)	Wittig, B., Müller, J., Mahnke-Ritoff, A. (2019) Talauen-Glatthaferwiesen im Verdener Wesertal (Niedersachsen). Tuexenia 39: 249-265. Göttingen	R22
82	Wittig et al. (2020)	Wittig, B., Müller, J., Quast, R., Miehlich, H. (2020) Arnica montana in Calluna-Heiden auf dem Schießplatz Unterlüß (Niedersachsen). Tuexenia 40: 131-146. Göttingen.	S42, R1M

Extended Data Table 2 | List of all taxa that were harmonized across all projects. The format of the list follows the rules of the ESy system[56]. The taxon names that were aggregated below a broader concept name are indented using five blanks. The number to the right shows the German SL 1.3[58] number for each taxon.

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Achillea atrata agg.                                            18
     Achillea atrata                                            19
     Achillea atrata agg.                                       18
Achillea millefolium agg.                                       27
     Achillea millefolium                                       31
     Achillea millefolium agg.                                  27
     Achillea millefolium subsp. collina                     20096
     Achillea millefolium subsp. millefolium                    32
     Achillea pannonica                                         34
     Achillea setacea                                           36
Acinos arvensis                                                 49
     Acinos arvensis                                            49
     Calamintha acinos                                         976
     Satureja acinos                                         23760
Aconitum lycoctonum                                          14242
     Aconitum lycoctonum                                     14242
     Aconitum lycoctonum subsp. vulparia                     20209
     Aconitum vulparia                                          68
Adonis aestivalis                                               76
     Adonis aestivalis                                          76
     Adonis aestivalis var. citrinus                         27247
Agrimonia eupatoria                                             99
     Agrimonia eupatoria                                        99
     Agrimonia eupatoria subsp. eupatoria                      100
Agrostis canina agg.                                           120
     Agrostis canina                                           121
     Agrostis coarctata                                      20180
     Agrostis stricta                                          122
     Agrostis vinealis                                       20684
Agrostis capillaris                                          20178
     Agrostis capillaris                                     20178
     Agrostis capillaris subsp. oreophila                     7086
     Agrostis tenuis                                           130
     Agrostis vulgaris                                       20179
Agrostis stolonifera agg.                                      127
     Agrostis alba var. stolonifera                          27181
     Agrostis gigantea                                         128
     Agrostis stolonifera                                      129
     Agrostis stolonifera agg.                                 127
     Agrostis stolonifera subsp. stolonifera                  6550
Aira caryophyllea                                            26920
     Aira caryophyllea                                       26920
     Aira caryophyllea subsp. caryophyllea                   20218
Alchemilla conjuncta agg.                                      154
     Alchemilla conjuncta agg.                                 154
     Alchemilla hoppeana                                       166
     Alchemilla nitida                                       10027
Alchemilla fissa agg.                                          177
     Alchemilla fallax                                         179
     Alchemilla fissa                                          180
     Alchemilla fissa agg.                                     177
Alchemilla hybrida agg.                                        190
     Alchemilla flabellata                                     194
     Alchemilla glaucescens                                    195
     Alchemilla hybrida agg.                                   190
     Alchemilla mollis                                         200
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86		Alchemilla acutiloba var. mollis	20237
87	Alchemilla vulgaris agg.		209
88		Alchemilla acutiloba var. stellata	11694
89		Alchemilla crinita	219
90		Alchemilla glabra	235
91		Alchemilla micans	20278
92		Alchemilla monticola	245
93		Alchemilla subcrenata	265
94		Alchemilla vulgaris	26467
95		Alchemilla vulgaris agg.	209
96		Alchemilla vulgaris auct.	20289
97		Alchemilla xanthochlora	273
98	Alisma plantago-aquatica agg.		275
99		Alisma gramineum	276
100		Alisma lanceolatum	277
101		Alisma plantago-aquatica	278
102		Alisma plantago-aquatica agg.	275
103	Allium scorodoprasum		12756
104		Allium rotundum	310
105		Allium scorodoprasum	12756
106		Allium scorodoprasum subsp. rotundum	20326
107	Allium senescens		6583
108		Allium montanum	294
109		Allium senescens	6583
110		Allium senescens subsp. montanum	20321
111		Allium senescens var. montanum	12712
112	Alopecurus pratensis agg.		334
113		Alopecurus pratensis	336
114		Alopecurus pratensis agg.	334
115	Alyssum alyssoides		345
116		Alyssum alyssoides	345
117		Alyssum calycinum	20351
118	Alyssum montanum		350
119		Alyssum montanum	350
120		Alyssum montanum subsp. gmelinii	26457
121		Alyssum montanum subsp. montanum	26456
122	Anagallis arvensis		393
123		Anagallis arvensis	393
124		Anagallis arvensis subsp. arvensis	394
125	Anemone narcissiflora		434
126		Anemonastrum narcissiflorum	20423
127		Anemone narcissiflora	434
128	Anthoxanthum aristatum		20071
129		Anthoxanthum aristatum	20071
130		Anthoxanthum puelii	466
131	Anthoxanthum odoratum agg.		463
132		Anthoxanthum alpinum	464
133		Anthoxanthum odoratum	465
134		Anthoxanthum odoratum agg.	463
135	Anthriscus sylvestris agg.		469
136		Anthriscus sylvestris	473
137		Anthriscus sylvestris agg.	469
138		Anthriscus sylvestris subsp. alpestris	20460
139		Anthriscus sylvestris subsp. sylvestris	20463
140	Anthyllis vulneraria		477
141		Anthyllis vulneraria	477
142		Anthyllis vulneraria subsp. carpatica	479
143		Anthyllis vulneraria subsp. pseudovulneraria	14783
144	Aphanes inexspectata		494
145		Aphanes inexspectata	494
146		Aphanes microcarpa	6554
147	Aquilegia vulgaris agg.		507
148		Aquilegia atrata	508

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     Aquilegia vulgaris                                    510
Arabis bellidifolia                                      20511
     Arabis bellidifolia subsp. bellidifolia             20512
Arabis glabra                                              520
     Arabis glabra                                         520
     Turritis glabra                                     24405
Arabis hirsuta agg.                                        521
     Arabis hirsuta                                        523
     Arabis nemorensis                                   20072
Arctium minus                                            13702
     Arctium minus                                       13702
     Arctium minus agg.                                    547
     Lappa communis                                      14348
Arenaria serpyllifolia agg.                                563
     Arenaria serpyllifolia                              13703
     Arenaria serpyllifolia agg.                           563
Armeria maritima                                           581
     Armeria elongata                                      577
     Armeria maritima                                      581
     Armeria maritima agg.                                 575
     Armeria maritima subsp. elongata                    20584
     Armeria maritima var. elongata                      20590
     Armeria vulgaris                                    26026
Artemisia campestris agg.                                  594
     Artemisia campestris                                  596
     Artemisia campestris agg.                             594
     Artemisia campestris subsp. campestris               6466
Artemisia vulgaris agg.                                    616
     Artemisia vulgaris                                    618
     Artemisia vulgaris agg.                               616
Arum maculatum agg.                                        622
     Arum maculatum                                        625
     Arum maculatum agg.                                   622
Asplenium ruta-muraria                                     674
     Asplenium ruta-muraria                                674
     Asplenium ruta-muraria subsp. ruta-muraria            676
Aster lanceolatus agg.                                   15106
     Aster lanceolatus                                     693
     Aster parviflorus                                   15085
Atriplex prostrata agg.                                  20706
     Atriplex calotheca                                    756
     Atriplex hastata                                    20693
     Atriplex hastata agg.                                 755
     Atriplex latifolia                                    760
     Atriplex prostrata                                    762
Atriplex sagittata                                         754
     Atriplex nitens                                     20702
Aurinia saxatilis                                          777
     Alyssum saxatile                                      354
Betonica officinalis                                       826
     Betonica officinalis                                  826
     Stachys officinalis                                 24165
Betula alba agg.                                         99014
     Betula pendula                                        829
     Betula verrucosa                                    20786
Betula pubescens                                           830
     Betula pubescens                                      830
     Betula pubescens subsp. carpatica                    6472
     Betula pubescens subsp. pubescens                    6471
Bidens frondosa                                            834
     Bidens frondosa                                       834
     Bidens melanocarpa                                  20788
Bidens tripartita                                          836
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	Bidens tripartita	836
	Bidens tripartita subsp. tripartita	838
Biscutella laevigata		844
	Biscutella laevigata	844
	Biscutella laevigata subsp. kerneri	6652
Bistorta officinalis		27744
	Bistorta officinalis	27744
	Persicaria bistorta	23029
	Polygonum bistorta	4420
Bistorta vivipara		20801
	Bistorta vivipara	20801
	Persicaria vivipara	23045
	Polygonum viviparum	4437
Bolboschoenus maritimus		852
	Bolboschoenus maritimus	852
	Schoenoplectus maritimus	23820
Bothriochloa ischaemum		854
	Andropogon ischaemum	20417
	Bothriochloa ischaemum	854
	Dichanthium ischaemum	21538
Brachypodium pinnatum agg.		862
	Brachypodium pinnatum	863
	Brachypodium pinnatum agg.	862
	Brachypodium rupestre	864
Bromus arvensis		883
	Bromus arvensis	883
	Bromus arvensis subsp. arvensis	7191
Bromus hordeaceus agg.		895
	Bromus hordeaceus	896
	Bromus hordeaceus agg.	895
	Bromus hordeaceus subsp. hordeaceus	897
	Bromus mollis	901
Bromus racemosus agg.		908
	Bromus commutatus	909
	Bromus racemosus	910
Bromus ramosus agg.		911
	Bromus benekenii	912
	Bromus ramosus	913
	Bromus ramosus agg.	911
Callitriche palustris agg.		999
	Callitriche obtusangula	1003
	Callitriche palustris	1004
	Callitriche palustris agg.	999
	Callitriche stagnalis	1006
Campanula rotundifolia agg.		1057
	Campanula rotundifolia	1072
	Campanula rotundifolia agg.	1057
	Campanula scheuchzeri	1073
Cardamine bulbifera		20944
	Cardamine bulbifera	20944
	Dentaria bulbifera	1896
Cardamine heptaphylla		20951
	Dentaria heptaphyllos	91015
Cardamine pratensis agg.		1105
	Cardamine dentata	20945
	Cardamine palustris	1109
	Cardamine pratensis	15133
	Cardamine pratensis agg.	1105
Cardaminopsis arenosa		1114
	Arabis arenosa	20509
	Cardaminopsis arenosa	1114
Cardaminopsis halleri		1116
	Arabis halleri	20518

275		Cardaminopsis halleri	1116
276	Cardaminopsis petraea		1117
277		Arabis hispida	20526
278	Carduus nutans agg.		1140
279		Carduus nutans	1143
280		Carduus nutans agg.	1140
281	Carex acuta agg.		26775
282		Carex acuta	20989
283		Carex acuta subsp. tricostata	6685
284		Carex gracilis	1230
285	Carex arenaria agg.		1159
286		Carex arenaria	1160
287		Carex ligerica	1161
288		Carex pseudobrizoides	1162
289	Carex atrata agg.		1164
290		Carex atrata	14018
291		Carex atrata agg.	1164
292	Carex elata		1204
293		Carex elata	1204
294		Carex elata subsp. elata	1205
295	Carex flacca		1216
296		Carex flacca	1216
297		Carex glauca	21026
298	Carex flava agg.		1219
299		Carex demissa	20011
300		Carex flava	1220
301		Carex flava agg.	1219
302		Carex flava var. oederi	25010
303		Carex lepidocarpa	1222
304		Carex oederi	1223
305		Carex serotina	21070
306		Carex tumidicarpa	1225
307		Carex viridula	6693
308	Carex muricata agg.		1249
309		Carex divulsa	1250
310		Carex leersiana	1251
311		Carex muricata	6687
312		Carex muricata agg.	1249
313		Carex muricata subsp. muricata	6689
314		Carex pairae	1252
315		Carex spicata	1253
316	Carex nigra agg.		1254
317		Carex fusca	21024
318		Carex nigra	1256
319		Carex nigra agg.	1254
320	Carex ornithopoda agg.		1262
321		Carex ornithopoda	1263
322		Carex ornithopoda agg.	1262
323	Carex ovalis		21055
324		Carex leporina	1240
325		Carex ovalis	21055
326	Carex vulpina agg.		1301
327		Carex otrubae	1302
328		Carex vulpina	1303
329		Carex vulpina agg.	1301
330	Carex × elytroides		10122
331		Carex × elytroides	10122
332		Carex acuta × nigra	90526
333	Carex × figertii		90596
334		Carex davalliana × dioica	90549
335	Carex × xanthocarpa		10137
336		Carex flava × hostiana	90562
337	Carlina acaulis		1306

338		Carlina acaulis	1306
339		Carlina acaulis subsp. simplex	1308
340	Carlina vulgaris		1312
341		Carlina vulgaris	1315
342		Carlina vulgaris subsp. vulgaris	21094
343	Castanea sativa		1323
344		Castanea sativa	1323
345		Castanea vesca	21097
346	Caucalis platycarpos		1329
347		Caucalis lappula	21108
348		Caucalis platycarpos	1329
349	Centaurea jacea		1347
350		Centaurea angustifolia	21122
351		Centaurea jacea	1347
352		Centaurea jacea agg.	24981
353		Centaurea jacea subsp. amara	21132
354		Centaurea jacea subsp. angustifolia	1348
355	Centaurea nigra		26577
356		Centaurea nemoralis	21138
357		Centaurea nigra	26577
358		Centaurea nigra subsp. nemoralis	1370
359	Centaurea scabiosa		1390
360		Centaurea scabiosa	1390
361		Centaurea scabiosa subsp. scabiosa	1397
362	Centaurea stoebe		25004
363		Centaurea maculosa subsp. rhenana	21134
364		Centaurea rhenana	21146
365		Centaurea stoebe	25004
366	Centaurium erythraea		1406
367		Centaurium erythraea	1406
368		Centaurium erythraea subsp. erythraea	1407
369		Centaurium umbellatum	21156
370	Centaurium littorale		1409
371		Centaurium littorale	1409
372		Centaurium minus	7104
373	Cerastium arvense		1431
374		Cerastium arvense	1431
375		Cerastium arvense subsp. arvense	1432
376	Cerastium fontanum agg.		1449
377		Cerastium caespitosum	21178
378		Cerastium fontanum	1450
379		Cerastium fontanum agg.	1449
380		Cerastium fontanum subsp. triviale	21187
381		Cerastium holosteoides	1451
382		Cerastium triviale	25269
383		Cerastium vulgare	21213
384	Cerastium pumilum agg.		1460
385		Cerastium glutinosum	1461
386		Cerastium pallens	21198
387		Cerastium pumilum	1462
388		Cerastium pumilum agg.	1460
389	Ceratocapnos claviculata		21221
390		Ceratocapnos claviculata	21221
391		Corydalis claviculata	1670
392	Cerinthe glabra		1473
393		Cerinthe alpina	21227
394	Chaerophyllum hirsutum		26947
395		Chaerophyllum hirsutum	26947
396		Chaerophyllum hirsutum agg.	1490
397		Chaerophyllum villarsii	1493
398	Chamaecytisus ratisbonensis		1504
399		Chamaecytisus ratisbonensis	1504
400		Cytisus ratisbonensis	21484

Chamaecytisus supinus		1506
	Chamaecytisus supinus	1506
	Cytisus supinus	21486
Chamaespartium sagittale		1509
	Chamaespartium sagittale	1509
	Genista sagittalis	21992
	Genistella sagittalis	2615
Chenopodium album agg.		1514
	Chenopodium album	1515
	Chenopodium album agg.	1514
	Chenopodium strictum subsp. striatiforme	6482
Cirsium acaule		1556
	Cirsium acaule	1556
	Cirsium acaulon	21327
Cirsium heterophyllum		1569
	Cirsium helenioides	21329
	Cirsium heterophyllum	1569
Cirsium vulgare		1579
	Cirsium lanceolatum	21330
	Cirsium vulgare	1579
Cirsium × rigens		26068
	Cirsium acaule × oleraceum	90817
Clinopodium vulgare		1593
	Calamintha clinopodium	978
Consolida regalis		1627
	Consolida regalis	1627
	Delphinium consolida	21510
Convolvulus		60816
	Convolvulus	60816
	Convolvulus arvensis	1632
Conyza canadensis		1638
	Conyza canadensis	1638
	Erigeron canadensis	21687
Crataegus		61165
	Crataegus curvisepala	1697
	Crataegus laevigata agg.	1701
	Crataegus laevigata	1701
	Crataegus lindmanii	1699
	Crataegus monogyna	1707
	Crataegus monogyna subsp. monogyna	1708
	Crataegus monogyna subsp. nordica	1709
	Crataegus monogyna var. monogyna	90937
	Crataegus oxyacantha	21400
	Crataegus rhipidophylla	26677
	Crataegus × macrocarpa	1705
	Crataegus × media	50021
	Crataegus calycina	6733
Crepis bocconi		21408
	Crepis pontana	1735
Cruciata laevipes		1766
	Cruciata laevipes	1766
	Galium cruciata	21963
Cystopteris fragilis agg.		1825
	Cystopteris alpina	21473
	Cystopteris fragilis	1827
Cytisus nigricans		21483
	Cytisus nigricans	21483
	Lembotropis nigricans	3333
Cytisus scoparius		1837
	Cytisus scoparius	1837
	Sarothamnus scoparius	5245
Dactylis glomerata agg.		1842
	Dactylis	397

464	Dactylis aschersoniana	21487
465	Dactylis glomerata	1843
466	Dactylis glomerata agg.	1842
467	Dactylis glomerata subsp. glomerata	13464
468	Dactylis polygama	1846
469	Dactylorhiza maculata agg.	1852
470	Dactylorhiza fuchsii	1853
471	Dactylorhiza fuchsii × maculata	90986
472	Dactylorhiza maculata	1857
473	Dactylorhiza maculata agg.	1852
474	Dactylorhiza majalis agg.	1861
475	Dactylorhiza majalis	1862
476	Dactylorhiza majalis agg.	1861
477	Dactylorhiza majalis subsp. majalis	1866
478	Dactylorhiza traunsteineri	1871
479	Dactylorhiza × carnea	13760
480	Dactylorhiza maculata × incarnata	90995
481	Danthonia decumbens	1874
482	Danthonia decumbens	1874
483	Danthonia decumbens subsp. decumbens	1876
484	Sieglingia decumbens	24019
485	Daucus carota	1886
486	Daucus	61271
487	Daucus carota	1886
488	Daucus carota subsp. carota	6753
489	Deschampsia cespitosa agg.	1903
490	Deschampsia cespitosa	1904
491	Deschampsia cespitosa agg.	1903
492	Deschampsia flexuosa	20725
493	Aira flexuosa	20226
494	Avenella flexuosa	783
495	Deschampsia flexuosa	20725
496	Dianthus gratianopolitanus	1934
497	Dianthus caesius	21522
498	Dianthus gratianopolitanus	1934
499	Dianthus superbus	1949
500	Dianthus superbus	1949
501	Dianthus superbus subsp. superbus	1952
502	Digitalis grandiflora	1960
503	Digitalis ambigua	21540
504	Dipsacus fullonum	1980
505	Dipsacus fullonum	1980
506	Dipsacus sylvestris	20021
507	Draba aizoides agg.	2000
508	Draba aizoides	2001
509	Draba aizoides agg.	2000
510	Drosera longifolia	21588
511	Drosera anglica	2025
512	Drosera longifolia	21588
513	Dryopteris carthusiana agg.	2030
514	Dryopteris × deweveri	50029
515	Dryopteris carthusiana	2032
516	Dryopteris carthusiana × dilatata	91118
517	Dryopteris carthusiana agg.	2030
518	Dryopteris dilatata	2033
519	Dryopteris expansa	2031
520	Dryopteris spinulosa	21604
521	Dryopteris filix-mas agg. s. l.	94728
522	Dryopteris affinis	2038
523	Dryopteris filix-mas	2037
524	Dryopteris filix-mas agg.	2035
525	Eleocharis palustris agg.	2087
526	Eleocharis palustris	2091

	Eleocharis palustris agg.	2087
	Eleocharis uniglumis	2094
	Scirpus palustris	23856
Elymus arenosus		27779
	Elymus repens subsp. arenosus	6543
Elymus athericus		27782
	Elymus pungens	27905
Elymus caninus		20145
	Agropyron caninum	103
	Elymus caninus	20145
	Roegneria canina	23598
Elymus repens		27778
	Agropyron repens	27914
	Agropyron repens subsp. caesium	6541
	Elymus repens	27778
	Elymus repens subsp. repens	27781
	Elytrigia repens	21639
	Triticum repens	24393
Empetrum nigrum agg.		2103
	Empetrum nigrum	2105
	Empetrum nigrum agg.	2103
Epilobium angustifolium		2113
	Chamaenerion angustifolium	21237
	Epilobium angustifolium	2113
Epilobium ciliatum		21642
	Epilobium adenocaulon	2109
	Epilobium ciliatum	21642
Epilobium tetragonum		2126
	Epilobium tetragonum	2126
	Epilobium tetragonum subsp. lamyi	2127
	Epilobium tetragonum subsp. tetragonum	2128
Epipactis atrorubens		2130
	Epipactis atropurpurea	21653
	Epipactis atrorubens	2130
	Epipactis rubiginosa	21664
Epipactis helleborine agg.		2131
	Epipactis helleborine	2134
	Epipactis latifolia	21660
Equisetum fluviatile		2143
	Equisetum fluviatile	2143
	Equisetum limosum	21674
Equisetum × mildeanum		91305
	Equisetum pratense × sylvaticum	91302
Erica carnea		21680
	Erica carnea	21680
	Erica herbacea	2163
Erigeron acris		2167
	Erigeron acris	2167
	Erigeron acris subsp. acris	2168
Erigeron annuus		2178
	Erigeron annuus	2178
	Erigeron strigosus	21695
Erigeron glabratus		21689
	Erigeron glabratus	21689
	Erigeron polymorphus	2186
Erodium cicutarium agg.		2197
	Erodium cicutarium	2199
	Erodium cicutarium agg.	2197
Erophila verna		12356
	Draba verna	21586
	Erophila verna	12356
	Erophila verna agg.	2205
	Erophila verna subsp. verna	21715

590	Erysimum maschallianum		2229
591		Erysimum durum	21726
592	Erysimum odoratum		2234
593		Erysimum erysimoides	21727
594		Erysimum odoratum	2234
595	Euphorbia verrucosa		2309
596		Euphorbia brittingeri	21740
597		Euphorbia verrucosa	2309
598	Euphrasia officinalis		13816
599		Euphrasia officinalis	13816
600		Euphrasia officinalis subsp. rostkoviana	26254
601		Euphrasia rostkoviana	2332
602		Euphrasia rostkoviana agg.	2329
603	Fallopia convolvulus		2359
604		Fallopia convolvulus	2359
605		Polygonum convolvulus	23228
606	Festuca brevipila		26591
607		Festuca brevipila	26591
608		Festuca duriuscula	21820
609		Festuca trachyphylla	2406
610	Festuca filiformis		21824
611		Festuca capillata	21813
612		Festuca filiformis	21824
613		Festuca tenuifolia	2405
614	Festuca ovina agg.		2385
615		Festuca guestfalica et ovina	91404
616		Festuca guestfalica	6483
617		Festuca lemanii	94730
618		Festuca ovina	2396
619		Festuca ovina s. l.	91415
620		Festuca ovina subsp. ovina	91418
621		Festuca ovina var. firmula	21845
622		Festuca ovina agg.	2385
623		Festuca ovina subsp. glauca	10352
624	Festuca pallens		2397
625		Festuca cinerea	2387
626		Festuca glauca	2392
627		Festuca glaucina	91400
628		Festuca pallens	2397
629		Festuca pallens * glaucina	91420
630		Festuca pallens subsp. pallens	6792
631	Festuca quadriflora		21852
632		Festuca pumila	2416
633		Festuca quadriflora	21852
634	Festuca rubra agg.		2417
635		Festuca heteromalla	7346
636		Festuca nigrescens	2420
637		Festuca nigrescens subsp. nigrescens	91414
638		Festuca rubra	2421
639		Festuca rubra agg.	2417
640		Festuca rubra subsp. commutata	21856
641		Festuca rubra subsp. fallax	13510
642		Festuca rubra subsp. rubra	2425
643		Festuca rubra var. genuina	21863
644		Festuca trichophylla	2426
645	Festuca rupicola		2402
646		Festuca rupicola	2402
647		Festuca sulcata	27166
648		Festuca valesiaca subsp. sulcata	10354
649	Festuca valesiaca		13712
650		Festuca pulchra	13523
651		Festuca valesiaca	13712
652	Festuca violacea agg.		2441

	Festuca norica	2443
	Festuca violacea agg.	2441
Filipendula vulgaris		2462
	Filipendula hexapetala	21900
	Filipendula vulgaris	2462
Frangula alnus		2472
	Frangula alnus	2472
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Fumana procumbens		2486
	Fumana procumbens	2486
	Fumana vulgaris	21921
Galeopsis ladanum agg.		2520
	Galeopsis angustifolia	2521
	Galeopsis ladanum	2522
Galeopsis tetrahit agg.		2526
	Galeopsis bifida	2527
	Galeopsis tetrahit	2528
	Galeopsis tetrahit agg.	2526
Galium aparine agg.		2532
	Galium aparine	2533
	Galium aparine agg.	2532
	Galium spurium	2534
Galium glaucum		2542
	Asperula glauca	20637
	Galium glaucum	2542
Galium mollugo agg.		2548
	Galium album	2549
	Galium album subsp. album	2550
	Galium mollugo	2555
	Galium mollugo agg.	2548
Galium palustre		2564
	Galium elongatum	2563
	Galium palustre	2564
	Galium palustre agg.	2561
	Galium palustre subsp. elongatum	21974
	Galium palustre subsp. palustre	21975
Galium pusillum agg.		2569
	Galium anisophyllon	2570
	Galium pumilum	2572
	Galium pusillum agg.	2569
	Galium valdepilosum	2577
Galium rotundifolium		2579
	Galium scabrum	21982
Galium saxatile		2585
	Galium harcynicum	2543
	Galium saxatile	2585
Galium verum agg. s. l.		94733
	Galium × pomeranicum	2599
	Galium verum	2600
	Galium verum agg.	2598
	Galium verum subsp. verum	24929
	Galium wirtgenii	2601
Gentiana acaulis agg.		91530
	Gentiana acaulis	2616
	Gentiana clusii	2624
Gentianella ciliata		2656
	Gentiana ciliata	22041
	Gentianella ciliata	2656
	Gentianopsis ciliata	22040
Gentianella germanica agg.		2657
	Gentiana germanica	22044
	Gentianella aspera	2659
	Gentianella germanica	2662

	Gentianella germanica agg.	2657
	Gentianella germanica subsp. germanica	7352
	Gentianella lutescens	2665
Geum × intermedium		50040
	Geum rivale × urbanum	91547
Glechoma hederacea agg.		2710
	Glechoma hederacea	2711
	Glechoma hederacea agg.	2710
Globularia punctata		2718
	Globularia bisnagarica	2718
	Globularia elongata	22079
	Globularia punctata	2718
	Globularia vulgaris	26117
	Globularia willkommii	22080
Glyceria fluitans agg.		2719
	Glyceria declinata	2720
	Glyceria fluitans	2721
	Glyceria fluitans agg.	2719
	Glyceria notata	26260
Helianthemum nummularium		26596
	Helianthemum nummularium	26596
	Helianthemum nummularium agg.	2774
	Helianthemum nummularium subsp. obscurum	22127
	Helianthemum nummularium subsp. ovatum	22128
	Helianthemum ovatum	2780
Helictotrichon pratense		20728
	Avena pratensis	20717
	Avenochloa pratensis	788
	Avenula pratensis	20732
	Helictotrichon pratense	20728
Helictotrichon pubescens		20729
	Avena pubescens	20718
	Avenochloa pubescens	789
	Avenula pubescens	20733
	Helictotrichon pubescens	20729
Helictotrichon versicolor		20730
	Avenula versicolor	20734
Hepatica nobilis		2815
	Anemone hepatica	20422
	Hepatica nobilis	2815
	Hepatica triloba	10391
Herniaria glabra		2832
	Herniaria glabra	2832
	Herniaria glabra subsp. glabra	2833
Hieracium angustifolium		25621
	Hieracium glaciale	2885
Hieracium caespitosum		2866
	Pilosella caespitosa	12173
Hieracium lactucella		2899
	Hieracium auricula	2857
	Hieracium lactucella	2899
	Pilosella lactucella	12147
Hieracium murorum		25659
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	Hieracium sylvaticum	2942
Hieracium pilosella		2923
	Hieracium pilosella	2923
	Pilosella officinarum	14992
Hieracium piloselloides		2924
	Hieracium piloselloides	2924
	Pilosella piloselloides	12226
Hieracium rothianum		25654
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779	Hieracium subramosum		10562
780		depr. Hieracium subramosum	94848
781	Hippocrepis emerus		21379
782		Coronilla emerus	1655
783	Hornungia petraea		2993
784		Hornungia petraea	2993
785		Hutchinsia petraea	22188
786	Hypericum maculatum agg.		3027
787		Hypericum × desetangsii	3029
788		Hypericum maculatum	20046
789		Hypericum maculatum agg.	3027
790		Hypericum maculatum subsp. maculatum	20047
791	Hypericum perforatum		3036
792		Hypericum perforatum	3036
793		Hypericum perforatum subsp. angustifolium	22208
794	Hypericum tetrapterum		3042
795		Hypericum quadrangulum	22214
796		Hypericum tetrapterum	3042
797	Inula conyzae		22227
798		Inula conyza	3069
799		Inula conyzae	22227
800	Jasione laevis		3117
801		Jasione perennis	22240
802	Juncus alpinus		22243
803		Juncus alpinoarticulatus	91853
804		Juncus alpinus	22243
805	Juncus articulatus		3136
806		Juncus articulatus	3136
807		Juncus supinus	22278
808	Juncus bufonius agg.		3140
809		Juncus bufonius	3141
810		Juncus bufonius agg.	3140
811	Juncus compressus agg.		3147
812		Juncus compressus	3148
813		Juncus gerardii	3149
814	Juncus trifidus		26603
815		Juncus monanthos	3165
816		Juncus trifidus subsp. monanthos	22281
817	Juniperus communis		3168
818		Juniperus communis	3168
819		Juniperus communis subsp. communis	3170
820	Kobresia myosuroides		22299
821		Elyna myosuroides	2102
822		Kobresia myosuroides	22299
823	Koeleria pyramidata agg.		3233
824		Koeleria	61398
825		Koeleria cristata	22305
826		Koeleria gracilis	22312
827		Koeleria macrantha	3235
828		Koeleria pyramidata	3236
829		Koeleria pyramidata agg.	3233
830	Lamium galeobdolon agg.		22337
831		Galeobdolon argentatum	21942
832		Galeobdolon luteum	20026
833		Galeobdolon luteum agg.	91498
834		Galeobdolon montanum	20027
835		Lamiastrum galeobdolon	3256
836		Lamiastrum montanum	3257
837		Lamium argentatum	24905
838		Lamium galeobdolon	22338
839		Lamium galeobdolon agg.	22337
840		Lamium montanum	22340
841	Larix decidua		3272

842		Larix decidua	3272
843		Larix europaea	10606
844	Lathyrus linifolius		3301
845		Lathyrus linifolius	3301
846		Lathyrus montanus	22390
847	Ledum palustre		3328
848		Ledum palustre	3328
849		Rhododendron tomentosum	28144
850	Leontodon helveticus		3346
851		Leontodon helveticus	3346
852		Leontodon pyrenaicus subsp. helveticus	7365
853	Leontodon hispidus		3347
854		Leontodon hastilis	25306
855		Leontodon hispidus	3347
856		Leontodon hispidus subsp. hastilis	22413
857		Leontodon hispidus subsp. hispidus	6837
858	Leontodon saxatilis		3354
859		Leontodon saxatilis	3354
860		Leontodon taraxacoides	22424
861	Leucanthemum atratum agg.		3375
862		Leucanthemum atratum agg.	3375
863		Leucanthemum halleri	3378
864	Leucanthemum vulgare agg.		3381
865		Chrysanthemum leucanthemum	21299
866		Leucanthemum ircutianum	3384
867		Leucanthemum maximum	3386
868		Leucanthemum vulgare	3387
869		Leucanthemum vulgare agg.	3381
870	Linaria vulgaris agg.		3429
871		Linaria vulgaris	3433
872		Linaria vulgaris agg.	3429
873	Lindernia dubia		3434
874		Gratiola anagallidea	13832
875	Linum perenne agg.		3454
876		Linum austriacum	3455
877		Linum leonii	3458
878		Linum perenne	26993
879	Lithospermum arvense		3475
880		Buglossoides arvensis subsp. sibthorpiana	20947
881		Lithospermum arvense	3475
882	Lotus corniculatus agg.		3505
883		Lotus corniculatus	3508
884		Lotus corniculatus agg.	3505
885		Lotus corniculatus subsp. corniculatus	22509
886		Lotus corniculatus var. ciliatus	25841
887		Lotus tenuis	3510
888	Lotus pedunculatus		22517
889		Lotus pedunculatus	22517
890		Lotus uliginosus	3516
891	Luzula campestris agg.		3530
892		Luzula campestris	3531
893		Luzula campestris agg.	3530
894		Luzula campestris subsp. multiflora	22525
895		Luzula multiflora	11817
896		Luzula pallescens	25388
897		Luzula sudetica	3536
898	Luzula luzuloides		3541
899		Luzula albida	3526
900		Luzula luzuloides	3541
901		Luzula luzuloides subsp. rubella	14424
902	Luzula sylvatica		3547
903		Luzula sylvatica	3547
904		Luzula sylvatica subsp. sylvatica	3549

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	Lycopersicon esculentum	3558
	Solanum lycopersicum	24088
Lycopus europaeus		3562
	Lycopus europaeus	3562
	Lycopus europaeus subsp. europaeus	3563
Malus sylvestris agg.		3580
	Malus sylvestris	3582
	Malus sylvestris agg.	3580
Matricaria		60765
	Chamomilla	67025
	Matricaria	60765
Matricaria discoidea		3597
	Chamomilla suaveolens	21249
	Matricaria discoidea	3597
Matricaria recutita		21248
	Chamomilla recutita	21247
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Medicago sativa agg.		3616
	Medicago × varia	3620
	Medicago falcata	3617
	Medicago sativa	11820
	Medicago sativa agg.	3616
Melampyrum pratense		3638
	Melampyrum pratense	3638
	Melampyrum pratense subsp. pratense	13853
Melica ciliata agg.		3643
	Melica ciliata	3644
	Melica ciliata var. nebrodensis	13015
Melica nutans agg.		3648
	Melica nutans	3650
	Melica nutans agg.	3648
	Melica picta	3651
Mentha spicata agg.		3676
	Mentha longifolia	3677
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Mercurialis perennis agg.		3691
	Mercurialis ovata	3692
	Mercurialis perennis	3694
Minuartia hybrida		3720
	Alsine tenuifolia	25807
Minuartia rubra		22674
	Minuartia fastigiata	3715
	Minuartia rubra	22674
Minuartia verna		26607
	Minuartia verna	26607
	Minuartia verna subsp. gerardii	22675
	Minuartia verna subsp. hercynica	6499
Molinia caerulea agg.		3756
	Molinia	61408
	Molinia arundinacea	3757
	Molinia caerulea	3758
Monotropa hypopitys agg.		3762
	Monotropa hypophegea	3763
	Monotropa hypopitys	3764
	Monotropa hypopitys agg.	3762
Montia fontana		3765
	Montia fontana	3765
	Montia fontana subsp. chondrosperma	3767
Mycelis muralis		3781
	Lactuca muralis	22329
	Mycelis muralis	3781
Myosotis arvensis		3782

968		Myosotis arvensis	3782
969		Myosotis arvensis subsp. arvensis	3783
970	Myosotis discolor		3785
971		Myosotis discolor	3785
972		Myosotis versicolor	22757
973	Myosotis ramosissima		3792
974		Myosotis hispida	22735
975		Myosotis ramosissima	3792
976	Myosotis scorpioides agg.		20051
977		Myosotis caespitosa	22731
978		Myosotis laxa	6500
979		Myosotis laxiflora	3788
980		Myosotis multiflora	12098
981		Myosotis nemorosa	3789
982		Myosotis nemorosa subsp. brevisetacea	22741
983		Myosotis palustris	22743
984		Myosotis palustris agg.	3786
985		Myosotis palustris s. l.	15315
986		Myosotis scorpioides	3791
987		Myosotis scorpioides agg.	20051
988		Myosotis scorpioides subsp. scorpioides	12104
989	Myosotis stricta		3804
990		Myosotis micrantha	22740
991		Myosotis stricta	3804
992	Myosotis sylvatica agg.		3793
993		Myosotis alpestris	3794
994		Myosotis decumbens	3795
995		Myosotis sylvatica	3802
996	Nigritella nigra agg.		3851
997		Nigritella nigra	7167
998		Nigritella nigra agg.	3851
999	Odontites luteus		3863
1000		Euphrasia lutea	21768
1001		Odontites luteus	3863
1002		Orthanthella lutea	3863
1003	Odontites vernus agg.		12023
1004		Odontites ruber	13749
1005		Odontites vernus	3866
1006		Odontites vernus agg.	12023
1007		Odontites vulgaris	3867
1008	Onobrychis viciifolia agg.		3906
1009		Onobrychis arenaria	3907
1010		Onobrychis sativa	93791
1011		Onobrychis viciifolia	3912
1012	Ononis spinosa agg.		3920
1013		Ononis procurrens	22831
1014		Ononis repens	3922
1015		Ononis repens subsp. procurrens	3923
1016		Ononis spinosa	3925
1017		Ononis spinosa agg.	3920
1018		Ononis spinosa subsp. maritima	22837
1019	Ophrys holoserica		3955
1020		Ophrys fuciflora	22852
1021		Ophrys holoserica	3955
1022	Ophrys insectifera		3956
1023		Ophrys insectifera	3956
1024		Ophrys muscifera	22859
1025	Oreopteris limbosperma		22909
1026		Dryopteris montana	21597
1027		Lastrea limbosperma	22377
1028		Oreopteris limbosperma	22909
1029		Thelypteris limbosperma	5910
1030	Orthilia secunda		4054

	Orthilia secunda	4054
	Pyrola secunda	23440
Oxalis stricta		22973
	Oxalis fontana	4065
	Oxalis stricta	22973
Oxytropis montana agg.		4080
	Oxytropis jacquinii	4084
	Oxytropis montana agg.	4080
Papaver dubium		10700
	Papaver dubium	10700
	Papaver dubium subsp. lecoqii	22999
Pedicularis palustris		4158
	Pedicularis palustris	4158
	Pedicularis palustris subsp. palustris	13828
Persicaria amphibia		23027
	Persicaria amphibia	23027
	Polygonum amphibium	4413
Persicaria dubia		11734
	Persicaria dubia	11734
	Persicaria mitis	23041
	Polygonum mite	4429
Persicaria hydropiper		23032
	Persicaria hydropiper	23032
	Polygonum hydropiper	4422
Persicaria lapathifolia		23034
	Persicaria lapathifolia	23034
	Persicaria lapathifolia subsp. pallida	13950
	Polygonum lapathifolium	4423
Persicaria maculosa		23038
	Persicaria maculosa	23038
	Polygonum persicaria	4435
Persicaria minor		23039
	Persicaria minor	23039
	Polygonum minus	4428
Petrorhagia prolifera agg.		4185
	Petrorhagia prolifera	4187
	Tunica prolifera	24402
Petrorhagia saxifraga		4189
	Petrorhagia saxifraga	4189
	Tunica saxifraga	24403
Phegopteris connectilis		23065
	Gymnocarpium phegopteris	12299
	Phegopteris connectilis	23065
	Thelypteris phegopteris	5912
Phleum alpinum agg.		4215
	Phleum alpinum	25110
	Phleum alpinum agg.	4215
Phleum phleoides		4222
	Phleum boehmeri	23073
	Phleum phleoides	4222
Phleum pratense agg.		4223
	Phleum bertolonii	4224
	Phleum pratense	4225
	Phleum pratense agg.	4223
	Phleum pratense subsp. pratense	27013
Phragmites australis		4229
	Phragmites australis	4229
	Phragmites communis	23084
Phyteuma orbiculare		26610
	Phyteuma orbiculare	26610
	Phyteuma orbiculare subsp. orbiculare	24940
Phyteuma spicatum		4264
	Phyteuma spicatum	4264

1094		Phyteuma spicatum subsp. occidentale	14758
1095		Phyteuma spicatum subsp. spicatum	4266
1096		Phyteuma spicatum var. coeruleum	23091
1097	Picea abies		4269
1098		Picea abies	4269
1099		Picea excelsa	23106
1100	Picris hieracioides		4274
1101		Picris hieracioides	4274
1102		Picris hieracioides agg.	4272
1103	Pimpinella major		4277
1104		Pimpinella major	4277
1105		Pimpinella major subsp. major	23108
1106	Pimpinella saxifraga agg.		4279
1107		Pimpinella saxifraga	4282
1108		Pimpinella saxifraga agg.	4279
1109	Plantago lanceolata		4320
1110		Plantago lanceolata	4320
1111		Plantago lanceolata subsp. sphaerostachya	23153
1112		Plantago lanceolata var. sphaerostachya	25683
1113	Plantago major		4321
1114		Plantago intermedia	23150
1115		Plantago major	4321
1116		Plantago major subsp. intermedia	4322
1117		Plantago major subsp. major	4323
1118	Plantago maritima agg.		4325
1119		Plantago alpina	4326
1120		Plantago maritima	27766
1121		Plantago strictissima	23161
1122	Plantago media agg.		4332
1123		Plantago media	4333
1124		Plantago media agg.	4332
1125	Poa annua agg.		4343
1126		Poa annua	4344
1127		Poa annua agg.	4343
1128		Poa supina	4345
1129	Poa pratensis agg.		4366
1130		Poa angustifolia	4367
1131		Poa humilis	7372
1132		Poa pratensis	4368
1133		Poa pratensis agg.	4366
1134		Poa pratensis subsp. angustifolia	23193
1135	Poa trivialis		26611
1136		Poa trivialis	26611
1137		Poa trivialis agg.	4372
1138		Poa trivialis subsp. trivialis	7161
1139	Polygala amara agg.		4390
1140		Polygala amara	4391
1141		Polygala amara agg.	4390
1142		Polygala amara subsp. amarella	23205
1143		Polygala amarella	4394
1144	Polygala vulgaris		4405
1145		Polygala oxyptera	23212
1146		Polygala vulgaris	4405
1147		Polygala vulgaris s. str.	10745
1148		Polygala vulgaris subsp. oxyptera	4406
1149		Polygala vulgaris subsp. vulgaris	4407
1150	Polygonatum odoratum		4410
1151		Polygonatum odoratum	4410
1152		Polygonatum officinale	27134
1153	Polygonum aviculare agg.		4415
1154		Polygonum aviculare	4417
1155		Polygonum aviculare agg.	4415
1156	Populus × canadensis		50080

	Populus × canadensis	50080
	Populus × euamericana	10760
Potentilla argentea agg.		4490
	Potentilla argentea	4491
	Potentilla argentea agg.	4490
Potentilla erecta		4511
	Potentilla erecta	4511
	Potentilla tormentilla	23354
Potentilla heptaphylla agg.		4515
	Potentilla heptaphylla	4517
	Potentilla rubens	23350
Potentilla incana		25757
	Potentilla arenaria	4539
	Potentilla cinerea	25853
	Potentilla cinerea subsp. incana	15377
	Potentilla incana	25757
	Potentilla × subarenaria	50084
Potentilla palustris		4528
	Comarum palustre	21352
	Potentilla palustris	4528
Potentilla verna agg.		4538
	Potentilla neumanniana	4541
	Potentilla pusilla	4542
	Potentilla tabernaemontani	20053
	Potentilla verna	23355
	Potentilla verna agg.	4538
	Potentilla verna subsp. vulgaris	28077
Primula veris		4570
	Primula officinalis	23378
	Primula veris	4570
	Primula veris subsp. veris	4575
Primula × digenea		92537
	Primula elatior × vulgaris	92534
Primula × media		50085
	Primula elatior × veris	92533
Pritzelago alpina		26680
	Hutchinsia alpina	3000
	Pritzelago alpina	26680
Prunus avium		4582
	Cerasus avium	21216
	Prunus avium	4582
	Prunus avium subsp. avium	24942
Prunus cerasus agg.		4585
	Cerasus vulgaris	21220
	Prunus cerasus	4586
Prunus mahaleb		4592
	Cerasus mahaleb	21219
	Prunus mahaleb	4592
Prunus padus		4593
	Padus avium	22980
	Prunus padus	4593
Prunus spinosa agg.		4597
	Prunus × fruticans	4598
	Prunus spinosa	4599
	Prunus spinosa subsp. fruticans	23396
Pseudolysimachion longifolium		23400
	Pseudolysimachion longifolium	23400
	Veronica longifolia	6261
Pseudolysimachion spicatum		23404
	Pseudolysimachion spicatum	23404
	Veronica spicata	6286
Pseudorchis albida		4601
	Leucorchis albida	3390

1220		Pseudorchis albida	4601
1221	Pulmonaria officinalis agg.		4636
1222		Pulmonaria obscura	4637
1223		Pulmonaria officinalis	4638
1224		Pulmonaria officinalis agg.	4636
1225	Pulsatilla alpina		15385
1226		Pulsatilla alpina agg.	4642
1227	Pulsatilla vulgaris		26617
1228		Anemone pulsatilla	20428
1229		Anemone pulsatilla subsp. grandis	20429
1230		Pulsatilla vulgaris	26617
1231		Pulsatilla vulgaris agg.	4656
1232		Pulsatilla vulgaris subsp. grandis	23437
1233	Pyrus communis agg.		4669
1234		Pyrus communis	6936
1235		Pyrus communis agg.	4669
1236		Pyrus communis subsp. pyraster	23449
1237		Pyrus pyraster	4671
1238	Quercus petraea agg.		4678
1239		Quercus petraea	4680
1240		Quercus sessiliflora	23468
1241	Quercus robur		4685
1242		Quercus pedunculata	23466
1243		Quercus robur	4685
1244	Ranunculus acris agg.		4689
1245		Ranunculus acris	4690
1246		Ranunculus acris agg.	4689
1247	Ranunculus aquatilis agg.		4697
1248		Ranunculus aquatilis	4698
1249		Ranunculus aquatilis agg.	4697
1250		Ranunculus peltatus	12030
1251	Ranunculus auricomus agg.		4709
1252		Ranunculus auricomus	11978
1253		Ranunculus auricomus agg.	4709
1254		Ranunculus auricomus s. l.	4710
1255		Ranunculus biformis	27241
1256		Ranunculus kochii	10821
1257		Ranunculus rectus	6956
1258	Ranunculus bulbosus		4717
1259		Ranunculus bulbosus	4717
1260		Ranunculus bulbosus subsp. bulbosus	12015
1261	Ranunculus ficaria		4721
1262		Ficaria verna	21893
1263		Ranunculus ficaria	4721
1264		Ranunculus ficaria subsp. bulbilifer	4722
1265	Ranunculus flammula agg.		4726
1266		Ranunculus flammula	4727
1267		Ranunculus flammula agg.	4726
1268		Ranunculus reptans	4728
1269	Ranunculus montanus agg.		4743
1270		Ranunculus breyninus	23477
1271		Ranunculus montanus	4747
1272		Ranunculus montanus agg.	4743
1273	Ranunculus polyanthemos agg.		4758
1274		Ranunculus nemorosus	4759
1275		Ranunculus nemorosus subsp. polyanthemophyllus	23501
1276		Ranunculus polyanthemoides	4760
1277		Ranunculus polyanthemophyllus	4761
1278		Ranunculus polyanthemos	4762
1279		Ranunculus polyanthemos agg.	4758
1280	Raphanus raphanistrum agg.		4778
1281		Raphanus raphanistrum	4780
1282		Raphanus sativus	4781

1283	Rhinanthus angustifolius		23544
1284		Rhinanthus angustifolius	23544
1285		Rhinanthus angustifolius subsp. angustifolius	23545
1286		Rhinanthus angustifolius subsp. grandiflorus	6569
1287		Rhinanthus serotinus	4832
1288	Rhinanthus aristatus agg.		4817
1289		Rhinanthus aristatus	23551
1290		Rhinanthus glacialis	4819
1291	Rhinanthus minor		4828
1292		Alectorolophus minor	20304
1293		Rhinanthus minor	4828
1294	Ribes rubrum agg.		4850
1295		Ribes rubrum	4851
1296		Ribes rubrum agg.	4850
1297	Rosa canina agg. s. l.		94740
1298		Rosa canina	26665
1299		Rosa canina agg.	4872
1300		Rosa canina agg. s. l.	94740
1301		Rosa corymbifera	26666
1302		Rosa obtusifolia	4897
1303	Rosa rubiginosa agg. s. l.		92752
1304		Rosa elliptica	4887
1305		Rosa micrantha	4893
1306		Rosa rubiginosa	4902
1307		Rosa rubiginosa agg. s. l.	92752
1308	Rosa spinosissima		23649
1309		Rosa pimpinellifolia	4899
1310	Rosa tomentosa agg. s. l.		92754
1311		Rosa tomentosa	4912
1312		Rosa tomentosa agg.	4907
1313		Rosa villosa agg.	4908
1314	Rubus canescens		4952
1315		Rubus canescens	4952
1316		Rubus tomentosus	25709
1317	Rubus grabowskii		7078
1318		Rubus thyrsanthus	5056
1319	Rubus latiarcuatus		24749
1320		Rubus vulgaris var. mollis	11374
1321	Rubus montanus		24778
1322		Rubus candicans	4951
1323		Rubus montanus	24778
1324	Rubus plicatus		5024
1325		Rubus affinis	4931
1326		Rubus plicatus	5024
1327	Rubus sect. Rubus		11351
1328		Rubus fruticosus s. l.	11886
1329		Rubus sect. Rubus	11351
1330	Rumex acetosa agg.		92799
1331		Rumex acetosa	5073
1332		Rumex thyrsiflorus	5108
1333	Rumex acetosella		26619
1334		Rumex acetosella	26619
1335		Rumex acetosella agg.	5074
1336		Rumex acetosella subsp. acetosella	26618
1337		Rumex acetosella subsp. tenuifolius	27201
1338		Rumex tenuifolius	5077
1339	Rumex arifolius		20080
1340		Rumex alpestris	5078
1341		Rumex arifolius	20080
1342	Rumex pseudoalpinus		23661
1343		Rumex alpinus	5079
1344	Rumex × pratensis		50156
1345		Rumex × pratensis	50156

1346		Rumex crispus × obtusifolius	92814
1347	Salix fragilis agg.		5167
1348		Salix × rubens	5169
1349		Salix fragilis	5168
1350	Salix myrsinifolia		5185
1351		Salix myrsinifolia	5185
1352		Salix nigricans	23730
1353	Salix repens agg.		27193
1354		Salix repens	27194
1355		Salix repens agg.	27193
1356		Salix repens s. l.	5191
1357		Salix repens subsp. repens	5193
1358	Salix retusa agg.		5196
1359		Salix retusa	5198
1360		Salix retusa agg.	5196
1361		Salix serpillifolia	5199
1362	Salix × multinervis		27195
1363		Salix × multinervis	27195
1364		Salix aurita × cinerea	92857
1365	Salix × smithiana		27196
1366		Salix × smithiana	27196
1367		Salix caprea × viminalis	92873
1368	Salix × wimmeriana		50108
1369		Salix caprea × purpurea	92872
1370	Salsola kali		5208
1371		Salsola kali subsp. tragus	5211
1372		Salsola tragus	23749
1373	Sanguisorba minor		5231
1374		Sanguisorba minor	5231
1375		Sanguisorba minor subsp. minor	5232
1376	Scabiosa columbaria agg.		5337
1377		Scabiosa columbaria	5338
1378		Scabiosa columbaria agg.	5337
1379		Scabiosa lucida	5342
1380	Scleranthus annuus agg.		5376
1381		Scleranthus annuus	5377
1382		Scleranthus annuus agg.	5376
1383		Scleranthus polycarpos	5378
1384	Scleranthus × intermedius		92980
1385		Scleranthus annuus × perennis	92978
1386	Securigera varia		21382
1387		Coronilla varia	1662
1388		Securigera varia	21382
1389	Sedum rupestre agg.		5429
1390		Sedum reflexum	5433
1391		Sedum rupestre	23907
1392		Sedum rupestre subsp. reflexum	23910
1393	Sedum sexangulare		5437
1394		Sedum boloniense	23894
1395		Sedum mite	23901
1396		Sedum sexangulare	5437
1397	Sedum telephium agg.		5440
1398		Hylotelephium maximum	7126
1399		Sedum maximum	5441
1400		Sedum telephium	27746
1401		Sedum telephium agg.	5440
1402		Sedum telephium subsp. maximum	23912
1403	Senecio alpinus		5467
1404		Senecio alpinus	5467
1405		Senecio cordatus	23945
1406	Senecio aquaticus agg.		5468
1407		Senecio aquaticus	5469
1408		Senecio aquaticus agg.	5468

	Senecio erraticus	5470
Senecio incanus		5485
	Senecio carniolicus	23942
Senecio jacobaea		5494
	Jacobaea vulgaris	25789
	Senecio jacobaea	5494
Senecio nemorensis agg.		5496
	Senecio fuchsii	5498
	Senecio hercynicus	5499
	Senecio nemorensis	94860
	Senecio nemorensis agg.	5496
	Senecio ovatus	23947
	Senecio ovatus subsp. alpestris	7006
Serratula tinctoria		27047
	Serratula tinctoria	27047
	Serratula tinctoria agg.	5524
Seseli libanotis		5540
	Libanotis montana	22460
	Libanotis sibirica	22463
	Seseli libanotis	5540
Sesleria varia agg.		5558
	Sesleria albicans	23996
	Sesleria albicans subsp. albicans	27051
	Sesleria albicans var. albicans	15414
	Sesleria caerulea	25028
	Sesleria caerulea subsp. calcaria	13441
	Sesleria varia	24991
Setaria pumila		24008
	Setaria glauca	5563
	Setaria pumila	24008
Silene		60691
	Lychnis	60681
	Silene	60691
Silene acaulis agg.		5578
	Silene acaulis	5579
	Silene acaulis agg.	5578
Silene coronaria		11625
	Lychnis coronaria	3551
Silene flos-cuculi		24031
	Lychnis flos-cuculi	3552
	Silene flos-cuculi	24031
Silene latifolia		7012
	Melandrium album	22627
	Silene alba	5581
	Silene latifolia	7012
	Silene latifolia subsp. alba	22546
	Silene pratensis	20058
Silene noctiflora		5603
	Melandrium noctiflorum	22630
	Silene noctiflora	5603
Silene nutans agg.		5604
	Silene nutans	5606
	Silene nutans agg.	5604
Silene viscaria		11627
	Lychnis viscaria	3554
	Silene viscaria	11627
	Viscaria vulgaris	24569
Silene vulgaris		5629
	Silene cucubalus	24029
	Silene inflata	25277
	Silene vulgaris	5629
	Silene vulgaris agg.	20067
	Silene vulgaris subsp. vulgaris	5634

1472		Silene vulgaris var. humilis	24046
1473	Soldanella alpicola		24100
1474		Soldanella pusilla s. l.	5678
1475	Solidago virgaurea		5682
1476		Solidago virgaurea	5682
1477		Solidago virgaurea subsp. virgaurea	5684
1478	Sonchus asper		5690
1479		Sonchus asper	5690
1480		Sonchus asper subsp. asper	5691
1481	Sorbus aria agg.		5696
1482		Sorbus aria	5697
1483		Sorbus aria agg.	5696
1484	Sorbus aucuparia		5700
1485		Sorbus aucuparia	5700
1486		Sorbus aucuparia subsp. aucuparia	5701
1487	Spergula pentandra agg.		5730
1488		Spergula morisonii	5731
1489		Spergula vernalis	24154
1490	Spergularia media		5734
1491		Spergularia maritima	24145
1492		Spergularia media	5734
1493	Stellaria alsine		5769
1494		Stellaria alsine	5769
1495		Stellaria uliginosa	5782
1496	Stellaria aquatica		24917
1497		Myosoton aquaticum	3805
1498		Stellaria aquatica	24917
1499	Stellaria media agg.		5774
1500		Stellaria media	5775
1501		Stellaria media agg.	5774
1502		Stellaria pallida	5777
1503	Stellaria nemorum		5778
1504		Stellaria nemorum	5778
1505		Stellaria nemorum subsp. nemorum	5780
1506	Stellaria palustris		11573
1507		Stellaria glauca	24184
1508		Stellaria palustris	11573
1509	Stipa calamagrostis		24197
1510		Achnatherum calamagrostis	47
1511	Stipa pennata agg.		5787
1512		Stipa joannis	5797
1513		Stipa pennata	24203
1514		Stipa pennata var. mediterranea	13411
1515		Stipa pulcherrima	13746
1516	Symphytum officinale		26629
1517		Symphytum officinale	26629
1518		Symphytum officinale agg.	5823
1519	Tanacetum corymbosum agg.		5841
1520		Chrysanthemum corymbosum	21294
1521		Tanacetum corymbosum	5843
1522	Tanacetum parthenium		5845
1523		Chrysanthemum parthenium	21315
1524		Tanacetum parthenium	5845
1525	Tanacetum vulgare		5846
1526		Chrysanthemum vulgare	21314
1527		Tanacetum vulgare	5846
1528	Taraxacum sect. Alpina et Hamata et Ruderalia		93219
1529		Taraxacum sect. Alpina	7424
1530		Taraxacum officinale agg.	7442
1531		Taraxacum sect. Alpina et Hamata et Ruderalia	93219
1532		Taraxacum sect. Ruderalia	7434
1533		Taraxacum officinale	14513
1534	Taraxacum sect. Erythrosperma		7428

1535		Taraxacum erythrospermum	14460
1536		Taraxacum laevigatum	14457
1537		Taraxacum levigatum agg.	14458
1538		Taraxacum sect. Erythrosperma	7428
1539	Taraxacum sect. Palustria		7433
1540		Taraxacum palustre	25514
1541		Taraxacum sect. Palustria	7433
1542	Tephroseris helenitis		23949
1543		Senecio helenitis	5482
1544		Tephroseris helenitis	23949
1545	Tephroseris integrifolia		23953
1546		Senecio integrifolius	5492
1547		Tephroseris integrifolia	23953
1548	Teucrium scorodonia		5889
1549		Teucrium scorodonia	5889
1550		Teucrium scorodonia subsp. scorodonia	5891
1551	Thalictrum minus agg.		5896
1552		Thalictrum minus	5898
1553		Thalictrum minus agg.	5896
1554		Thalictrum minus subsp. saxatile	5902
1555	Thlaspi caerulescens		5928
1556		Noccaea caerulescens	22785
1557	Thlaspi cepaeifolium		25000
1558		Thlaspi rotundifolium	5940
1559	Thlaspi perfoliatum		5938
1560		Microthlaspi perfoliatum	22667
1561		Thlaspi perfoliatum	5938
1562	Thymus praecox agg.		5955
1563		Thymus praecox	5957
1564		Thymus praecox agg.	5955
1565		Thymus praecox subsp. polytrichus	5959
1566		Thymus praecox subsp. praecox	5960
1567		Thymus serpyllum subsp. praecox	13239
1568	Thymus pulegioides agg.		5964
1569		Thymus pulegioides	5965
1570		Thymus pulegioides agg.	5964
1571		Thymus pulegioides subsp. pulegioides	7053
1572		Thymus serpyllum subsp. chamaedrys	13255
1573	Thymus serpyllum agg.		6456
1574		Thymus angustifolius	24265
1575		Thymus serpyllum	5966
1576		Thymus serpyllum agg.	6456
1577	Tragopogon pratensis		7141
1578		Tragopogon minor	5999
1579		Tragopogon orientalis	6000
1580		Tragopogon pratensis	7141
1581		Tragopogon pratensis agg.	5998
1582		Tragopogon pratensis subsp. orientalis	24325
1583		Tragopogon pratensis subsp. pratensis	7100
1584	Trichophorum cespitosum		27072
1585		Trichophorum cespitosum	27072
1586		Trichophorum cespitosum subsp. germanicum	24330
1587	Trifolium dubium agg.		6028
1588		Trifolium dubium	6029
1589		Trifolium dubium agg.	6028
1590		Trifolium minus	24352
1591	Trifolium pratense		6057
1592		Trifolium pratense	6057
1593		Trifolium pratense subsp. pratense	6061
1594	Tripleurospermum maritimum agg.		6096
1595		Matricaria inodora	22000
1596		Matricaria maritima	22580
1597		Matricaria perforata	22003

	Tripleurospermum inodorum	20061
	Tripleurospermum maritimum	6098
	Tripleurospermum perforatum	6097
Ulmus glabra		6137
	Ulmus glabra	6137
	Ulmus montana	24424
	Ulmus scabra	24425
Ulmus minor agg.		6139
	Ulmus campestris	24420
	Ulmus minor	6140
Utricularia minor agg.		6152
	Utricularia minor	6154
	Utricularia minor agg.	6152
Vaccinium oxycoccos agg.		6161
	Oxycoccus palustris	4070
	Vaccinium oxycoccos	6163
	Vaccinium oxycoccos agg.	6161
Vaccinium uliginosum		6166
	Vaccinium uliginosum	6166
	Vaccinium uliginosum agg.	6164
Valeriana officinalis agg.		6177
	Valeriana officinalis	6178
	Valeriana officinalis agg.	6177
	Valeriana pratensis	6179
	Valeriana procurrens	6180
	Valeriana wallrothii	6183
Veronica agrestis agg.		93432
	Veronica agrestis	6226
	Veronica persica	6271
	Veronica polita	6272
Veronica anagallis-aquatica agg.		6231
	Veronica anagallis-aquatica	6232
	Veronica anagalloides	6233
	Veronica catenata	6234
Veronica austriaca agg.		6237
	Veronica austriaca	13751
	Veronica austriaca subsp. dentata	24471
	Veronica austriaca subsp. teucrium	25019
	Veronica prostrata	13869
	Veronica teucrium	6243
Veronica chamaedrys		13752
	Veronica chamaedrys	13752
	Veronica chamaedrys agg.	6248
Veronica hederifolia		26766
	Veronica hederifolia	26766
	Veronica hederifolia agg.	6257
	Veronica hederifolia subsp. hederifolia	7101
	Veronica sublobata	6259
Veronica verna agg.		6292
	Veronica dillenii	6293
	Veronica verna	6294
	Veronica verna agg.	6292
Vicia cracca agg.		6301
	Vicia cracca	6302
	Vicia cracca agg.	6301
	Vicia tenuifolia	6306
Vicia sativa agg.		6328
	Vicia angustifolia	6329
	Vicia sativa	6334
	Vicia sativa agg.	6328
	Vicia sativa subsp. nigra	24521
	Vicia sativa var. nigra	24518
Vicia tetrasperma agg.		6338

Vicia tenuissima	6340
Vicia tetrasperma	6341
Vicia tetrasperma agg.	6338
Vincetoxicum hirundinaria agg.	6349
Cynanchum vincetoxicum	21465
Vincetoxicum hirundinaria	6351
Vincetoxicum officinale	24536
Viola canina agg.	24994
Viola canina	6367
Viola canina subsp. canina	6368
Viola persicifolia	6386
Viola persicifolia	6386
Viola stagnina	6394
Viola silvatica agg.	94746
Viola × bavarica	7420
Viola reichenbachiana	6390
Viola reichenbachiana × riviniana	93487
Viola riviniana	6391
Viola silvatica	24559
Viola tricolor agg.	6397
Viola arvensis	6398
Viola arvensis × tricolor	93457
Viola arvensis subsp. arvensis	7208
Viola tricolor	6402
Viola tricolor subsp. tricolor	6405
Viola tricolor var. arvensis	12796
x Festulolium krasanii	93548
Festuca arundinacea × Lolium multiflorum	91392

Extended Data Table 3 | List of all taxon names that were adapted within projects, in addition to the harmonisation across all projects, as shown in Extended Data Table 2. PROJECT_ID and Project_Name refer to the project in Extended Data Table 1, RS_PLOT is the plot resurvey ID, which identifies the groups of plots compared in time, RELEVE_NR is the plot observation ID in the Turboveg 2 database. Taxon_name_old is the name given by the original author, while Taxon_name_new_1 and Taxon_name_new_2 refer to newly assigned taxon names. In case of two new names the cover values of the old taxon were equally divided among the two new taxa.

PROJECT_ID	Project_Name	RS_Plot	RELEVE_NR	Taxon_name_old	Taxon_name_new_1	Taxon_name_new_2
6	Bode (2005)	HEIDE	331	Cuscuta	Cuscuta epithymum	
6	Bode (2005)	HEIDE	270	Fagus	Fagus sylvatica	
6	Bode (2005)	HEIDE	271	Fagus	Fagus sylvatica	
23	Jandt & Leonhardt (unpubl.)	32	138	Tragopogon	Tragopogon pratensis	
23	Jandt & Leonhardt (unpubl.)	63	190	Pulsatilla	Pulsatilla pratensis	
23	Jandt & Leonhardt (unpubl.)	56	182	Anthericum	Anthericum ramosum	
23	Jandt & Leonhardt (unpubl.)	80	214	Epipactis	Epipactis atrorubens	
23	Jandt & Leonhardt (unpubl.)	123	6	Trifolium	Trifolium repens	
23	Jandt & Leonhardt (unpubl.)	138	36	Epipactis	Epipactis atrorubens	
23	Jandt & Leonhardt (unpubl.)	146	38	Achillea	Achillea millefolium agg.	
23	Jandt & Leonhardt (unpubl.)	146	38	Tragopogon	Tragopogon pratensis	
23	Jandt & Leonhardt (unpubl.)	205	118	Tragopogon	Tragopogon pratensis	
23	Jandt & Leonhardt (unpubl.)	246	120	Epipactis	Epipactis atrorubens	
23	Jandt & Leonhardt (unpubl.)	251	128	Epipactis	Epipactis atrorubens	
23	Jandt & Leonhardt (unpubl.)	367	166	Tragopogon	Tragopogon pratensis	
23	Jandt & Leonhardt (unpubl.)	373	176	Tragopogon	Tragopogon pratensis	
16	Hagen (1996)	G04	180	Festuca	Festuca rupicola	
16	Hagen (1996)	G09	171	Anemone	Pulsatilla vulgaris	
16	Hagen (1996)	G15	183	Anemone	Pulsatilla vulgaris	
16	Hagen (1996)	G23	290	Epipactis	Epipactis atrorubens	

16	Hagen (1996)	Z20	377	Epipactis	Epipactis atrorubens
43	Heinrich, Marstaller & Voigt (2012)	A_CF5	857	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_16A	2014	Orchis	Orchis x hybrida
43	Heinrich, Marstaller & Voigt (2012)	CAT_14C	2004	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_16B	2015	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_18A	2026	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_18D	2029	Orchis	Orchis purpurea
43	Heinrich, Marstaller & Voigt (2012)	CAT_18E	2030	Orchis	Orchis purpurea
43	Heinrich, Marstaller & Voigt (2012)	CAT_19A	2032	Orchis	Orchis purpurea
43	Heinrich, Marstaller & Voigt (2012)	CAT_19B	2033	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_19D	2035	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_20A	2038	Platanthera	Platanthera chlorantha
43	Heinrich, Marstaller & Voigt (2012)	CAT_20C	2040	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_20D	2041	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_21B	2045	Orchis	Orchis x hybrida
43	Heinrich, Marstaller & Voigt (2012)	CAT_21C	2046	Orchis	Orchis purpurea
43	Heinrich, Marstaller & Voigt (2012)	CAT_22A	2050	Orchis	Orchis purpurea
43	Heinrich, Marstaller & Voigt (2012)	CAT_22B	2051	Platanthera	Platanthera chlorantha
43	Heinrich, Marstaller & Voigt (2012)	CAT_22E	2054	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	CAT_23A	2056	Orchis	Orchis purpurea

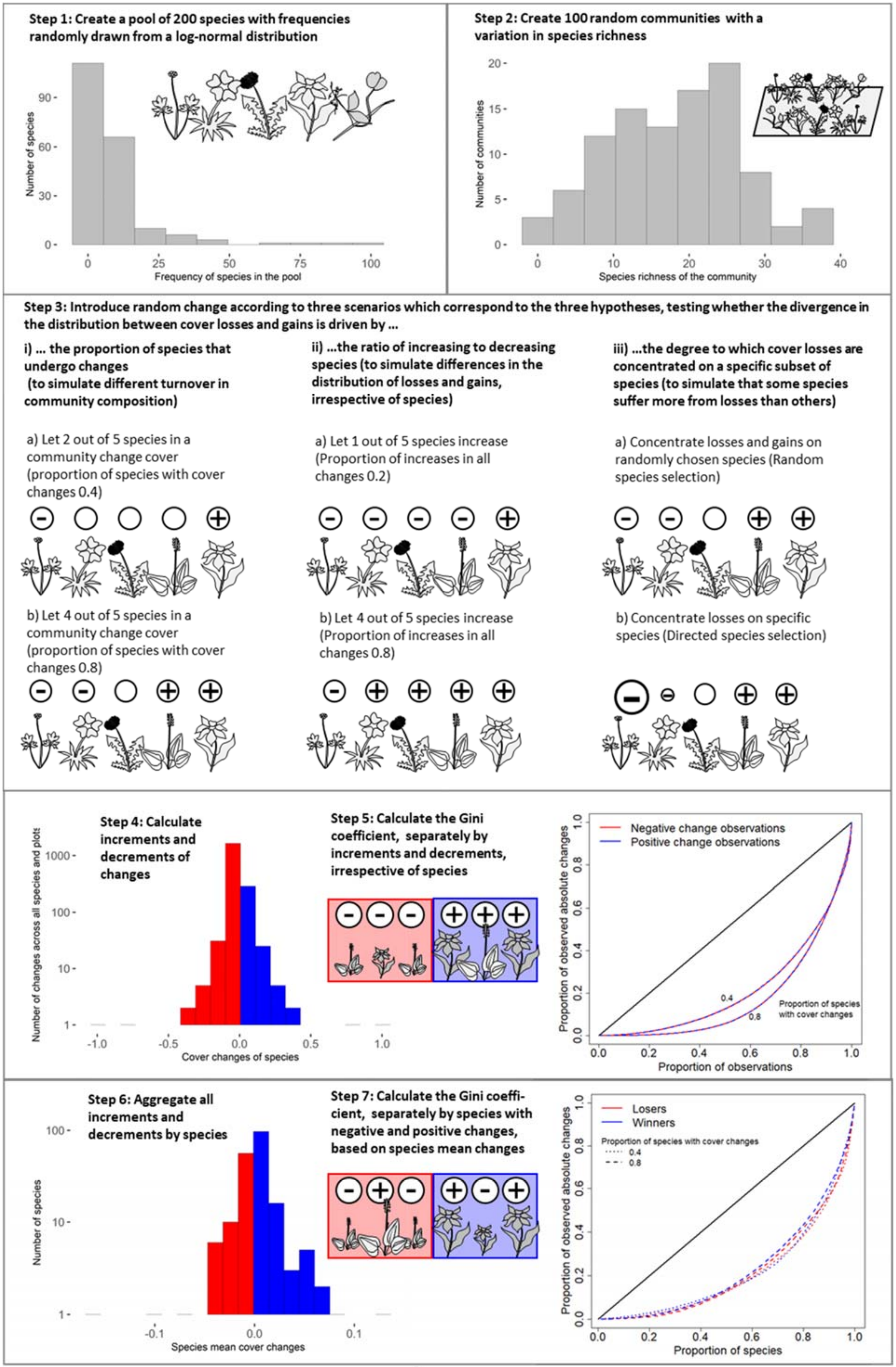
43	Heinrich, Marstaller & Voigt (2012)	CAT_23B	2057	Platanthera	Platanthera chlorantha
43	Heinrich, Marstaller & Voigt (2012)	CAT_28A	2086	Orchis	Orchis militaris
43	Heinrich, Marstaller & Voigt (2012)	M_CF3	471	Ulmus	Ulmus glabra
43	Heinrich, Marstaller & Voigt (2012)	M_CF3	495	Ulmus	Ulmus glabra
43	Heinrich, Marstaller & Voigt (2012)	M_CF3	519	Ulmus	Ulmus glabra
43	Heinrich, Marstaller & Voigt (2012)	M_CF4	568	Orchis	Orchis x hybrida
43	Heinrich, Marstaller & Voigt (2012)	M_CF6	570	Orchis	Orchis militaris
74	Horchler (unpubl.)	67	93	Callitriche	Callitriche palustris agg.
74	Horchler (unpubl.)	68	94	Callitriche	Callitriche palustris agg.
19	Hüllbusch et al. (2016)	MW9	28	Tragopogon	Tragopogon pratensis
14	Kuhn et al. (2011)	4350724.00_5487257.00	1608	Campanula	Campanula rapunculoides
14	Kuhn et al. (2011)	4365134.20_5531963.60	1300	Primula	Primula veris
14	Kuhn et al. (2011)	4365183.00_5532063.00	1301	Campanula	Campanula rapunculoides
14	Kuhn et al. (2011)	4365308.00_5532308.00	1302	Campanula	Campanula rapunculoides
14	Kuhn et al. (2011)	4377860.10_5547643.00	1357	Primula	Primula veris
14	Kuhn et al. (2011)	4395362.00_5271657.00	2024	Primula	Primula elatior
14	Kuhn et al. (2011)	4415784.00_5532303.00	832	Primula	Primula veris
14	Kuhn et al. (2011)	4420009.00_5433917.00	3580	Agrimonia	Agrimonia eupatoria
14	Kuhn et al. (2011)	4421750.00_5573096.00	34	Ajuga	Ajuga reptans
14	Kuhn et al. (2011)	4450612.00_5509207.00	769	Ajuga	Ajuga reptans
55	Meineke & Menge (2010)	DBF 4	16	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 4	17	Alchemilla	Alchemilla vulgaris agg.

55	Meineke & Menge (2010)	DBF 4	18	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 4	19	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 8	36	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 8	37	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 8	38	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 8	40	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 10	46	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 10	47	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 10	48	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 10	50	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 11	51	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 11	52	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 11	53	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 11	55	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 13	61	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 13	62	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 13	63	Alchemilla	Alchemilla vulgaris agg.
55	Meineke & Menge (2010)	DBF 13	65	Alchemilla	Alchemilla vulgaris agg.
29	Müller (2002)	K/SH1	119	Thymus	Thymus praecox agg.
32	Peppler-Lisbach & Könitz (2017)	N 86-192	56	Euphorbia stricta	Euphrasia stricta
32	Peppler-Lisbach & Könitz (2017)	N 86-193	57	Euphorbia stricta	Euphrasia stricta
36	Raehse (2001)	M546/50	880	Fragaria	Fragaria vesca

33	Schmidt et al. (unpubl.)	Hünstollen_KF1_37	1825	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_40	1828	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_41	1829	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_42	1830	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_43	1831	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_44	1832	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_45	1833	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_46	1834	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_47	1835	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_48	1836	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_49	1837	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_50	1838	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF1_51	1839	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_30	1869	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_32	1871	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_34	1873	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_35	1874	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_37	1876	Anemone	Anemone nemorosa	Anemone ranunculoides
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_41	1880	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_42	1881	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_43	1882	Anemone	Anemone nemorosa	
33	Schmidt et al. (unpubl.)	Hünstollen_KF2_44	1883	Anemone	Anemone nemorosa	
47	Strubelt & Zacharias (2015)	8	41	Campanula	Campanula trachelium	

Supplementary Methods

Jandt, U., Bruelheide, H., Jansen, J., Bonn, A., Grescho, V., Klenke, R., Sabatini, F.M., Bernhardt-Römermann, M., Blüml, V., Dengler, J., Diekmann, M., Dörfler, I., Döring, U., Dullinger, S., Haider, S., Heinken, T., Horchler, P., Kuhn, G., Lindner, M., Metze, K., Müller, N., Naaf, T., Peppler-Lisbach, C., Poschlod, P., Roscher, C., Rosenthal, G., Rumpf, S., Schmidt, W., Schrautzer, W., Schwabe, A., Schwartze, P., Sperle, T., Stanik, N., Storm, C., Voigt, W., Wegener, U., Wesche, K., Wittig, B., Wulf, M. (2022): Plant diversity change over one century in Germany: more losers than winners. – Nature



Step 1: Create a pool of 200 species with frequencies randomly drawn from a log-normal distribution

Step 2: Create 100 random communities with a variation in species richness

Step 3: Introduce random change according to three scenarios which correspond to the three hypotheses, testing whether the divergence in the distribution between cover losses and gains is driven by …

i) … the proportion of species that undergo changes (to simulate different turnover in community composition)

a) Let 2 out of 5 species in a community change cover (proportion of species with cover changes 0.4)

b) Let 4 out of 5 species in a community change cover (proportion of species with cover changes 0.8)

ii) …the ratio of increasing to decreasing species (to simulate differences in the distribution of losses and gains, irrespective of species)

a) Let 1 out of 5 species increase (Proportion of increases in all changes 0.2)

b) Let 4 out of 5 species increase (Proportion of increases in all changes 0.8)

iii) …the degree to which cover losses are concentrated on a specific subset of species (to simulate that some species suffer more from losses than others)

a) Concentrate losses and gains on randomly chosen species (Random species selection)

b) Concentrate losses on specific species (Directed species selection)

Step 4: Calculate increments and decrements of changes

Step 5: Calculate the Gini coefficient, separately by increments and decrements, irrespective of species

Step 6: Aggregate all increments and decrements by species

Step 7: Calculate the Gini coefficient, separately by species with negative and positive changes, based on species mean changes