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## Assessing sampling coverage of species distribution in biodiversity databases

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1 **Assessing sampling coverage of species distribution in biodiversity**  
2 **databases**

3

4 **Running title:** Sampling coverage by box-counting

5

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53

## 54 **Abstract**

55 **Aim:** Biodiversity databases are valuable resources for understanding plant species distributions and  
56 dynamics, but they may insufficiently represent the actual geographic distribution and climatic niches  
57 of species. Here we propose and test a method to assess sampling coverage of species distribution in  
58 biodiversity databases in geographic and climatic space.

59 **Location:** Europe.

60 **Methods:** Using a test selection of 808,794 vegetation plots from the European Vegetation Archive  
61 (EVA), we assessed the sampling coverage of 564 European vascular plant species across both their  
62 geographic ranges and realized climatic niches. Range maps from the Chorological Database Halle  
63 (CDH) were used as background reference data to capture species geographic ranges and to derive  
64 species climatic niches. To quantify sampling coverage, we developed a box-counting method, the  
65 Dynamic Match Coefficient (DMC), which quantifies how much a set of occurrences of a given  
66 species matches with its geographic range or climatic niche. DMC is the area under the curve  
67 measuring the match between occurrence data and background reference (geographic range or climatic  
68 niche) across grids with variable resolution. High DMC values indicate good sampling coverage. We  
69 applied null models to compare observed DMC values with expectations from random distributions  
70 across species ranges and niches.

71 **Results:** Comparisons with null models showed that, for most species, actual distributions within  
72 EVA are deviating from null model expectations and are more clumped than expected in both  
73 geographic and climatic space. Despite high interspecific variation, we found a positive relationship in  
74 DMC values between geographic and climatic space, but sampling coverage was in general more  
75 random across geographic space.

76 **Conclusion:** Because DMC values are species-specific and most biodiversity databases are clearly  
77 biased in terms of sampling coverage of species occurrences, we recommend using DMC values as  
78 covariates in macroecological models that use species as the observation unit.

79

80 Keywords: Chorological Database Halle (CDH), climatic niche, Dynamic Match Coefficient (DMC),  
81 European Vegetation Archive (EVA), macroecology, multi-scale, realized niche, sampling bias,  
82 spatial scale, species range, vascular plant, vegetation-plot databases.

83

## 84 **1 Introduction**

85 Large-scale biodiversity databases (e.g. Global Biodiversity Information Facility (GBIF), Edwards,  
86 Lane, & Nielsen, 2000; Botany Information and Ecology Network (BIEN), Enquist, Condit, Peet,  
87 Schildhauer, & Thiers, 2009; sPlot, Bruelheide et al., 2019) are valuable resources for understanding  
88 species distributions and dynamics. Possible applications include broad-scale analyses across species  
89 or community types (e.g. Bruelheide et al., 2018; Jiménez-Alfaro et al., 2018), species distribution  
90 models (SDM) (Gomes et al., 2018; Wasof et al., 2015); and monitoring biodiversity changes over  
91 time (Bertrand et al., 2011; Jandt, von Wehrden, & Bruelheide, 2011). For broad-scale analyses  
92 covering the entire range of species, the quality of the sampling coverage across a given species range  
93 or throughout its realized niche is crucial. Hence, consistent data distribution is highly desirable across  
94 both the geographic and environmental space (Broennimann & Guisan, 2008; Pearman, Guisan,  
95 Broenniman, & Randin, 2008; Troia & McManamay, 2016). However, biodiversity databases often  
96 suffer from sampling gaps and biases limiting their application potential. Because of the uneven  
97 collection effort (Daru et al., 2018; Soria-Auza & Kessler, 2007; Speed et al., 2018) often caused by  
98 difficult access to some areas (Sousa-Baena, Garcia, & Peterson, 2014), broad regions of the world  
99 remain poorly sampled. Even comprehensive databases of species occurrences in well-surveyed  
100 regions are prone to geographic (Yang, Ma, & Kreft, 2013) and taxonomic biases (Pyke & Ehrlich,  
101 2010; Soberón, Jiménez, Golubov, & Koleff, 2007). In an in-depth evaluation, Meyer, Weigelt, &  
102 Kreft (2016) found severe geographical bias in the GBIF database (Edwards et al., 2000), concluding  
103 that data limitations are rather the rule than the exception for most species and regions.

104 Species distribution models (SDM) are commonly used for macroecological niche analyses. They  
105 represent the estimation of species occurrence probabilities based on observed geographic  
106 distributions. Thereby, SDMs are sensitive to poor sampling coverage, especially if spatial bias results

107 in climatically biased sampling (Fourcade, Engler, Rödder, & Secondi, 2014). In such situations,  
108 SDMs tend to misestimate species climatic niches (Titeux et al., 2017). Thus, for reliable analyses of  
109 biodiversity distribution patterns, sampling coverage needs to be representative for both the climatic  
110 and geographic space (Hortal, Jiménez-Valverde, Gómez, Lobo, & Baselga, 2008; Troia &  
111 McManamay, 2016). Unbiased sampling is typically obtained by meeting two interrelated  
112 requirements: sufficient sample size and even coverage of geographical and environmental gradients.  
113 Towards coarser spatial resolution, good coverage is easier to achieve and, as a consequence, sampling  
114 bias typically decreases. Consequently, the negative impact of sampling bias is clearly related to  
115 spatial grain. Several studies have analyzed the importance of spatial scaling in niche studies (e.g.  
116 Pearman et al., 2008; Soberón et al., 2007; Hortal, Borges, & Gaspar, 2006). Recently, procedures  
117 have been developed to assess the completeness of a spatial dataset at different spatial resolutions in  
118 geographic space (*KnowBR*, Lobo et al., 2018; *downscale*, Marsh, Barwell, Gavish, & Kunin, 2018).  
119 At large spatial extent, climate is among the most important factors determining species distributions  
120 (Woodward, 1986). However, although including climate seems straightforward, until now, few  
121 studies have accounted for how evenly occurrence data cover species ranges in climatic space (e.g.  
122 Bruelheide et al., 2018). To our knowledge, no study has explicitly tested the degree to which the  
123 spatial distribution of occurrences represents the geographical range as well as the climatic niche of  
124 the sampled species.

125 Here we test the spatial and climatic coverage of plant occurrence data using an example dataset of the  
126 European Vegetation Archive (EVA). EVA is a key macroecological resource that incorporates  
127 information from 57 countries on approximately 1.5 million vegetation plots containing more than  
128 10,000 vascular plant species (Chytrý et al., 2016). EVA data are used for various research objectives,  
129 yet the degree of unevenness in sampling effort across Europe's geographic and environmental space is  
130 unclear. A species distribution database covering EVA's spatial extent, but otherwise independent  
131 from EVA, is the Chorological Database Halle (CDH) (Welk et al., unpubl.). CDH stores  
132 georeferenced information (range polygons and point occurrences) on the distribution range of more  
133 than 1,200 European vascular plant species. Species distribution data from CDH have already been  
134 used in several biodiversity studies (e.g. Csergő et al., 2017; San-Miguel-Ayanz, de Rigo, Caudullo,  
135 Houston Durrant, & Mauri, 2016; Schleuning et al., 2016) and as basis for biogeographical  
136 experiments on plant range limits (Bütöf et al., 2012; Hofmann, Bütöf, Welk, & Bruelheide, 2013;  
137 Welk, Welk, & Bruelheide, 2014). Here, we made use of expert-based range maps stored in CDH to  
138 extract information on both species geographic ranges and climatic niches and assess the sampling  
139 coverage of species occurrences stored in EVA across each of these two backgrounds (geographic and  
140 climatic).

141 To quantify sampling coverage, we developed the Dynamic Match Coefficient (DMC), a measure  
142 based on the area-under-the-curve (AUC) derived from threshold-independent box-counting statistics

143 across variable spatial grains. We compared the observed DMC values with the values of plots  
144 randomly distributed across the species range and niche. Thereby, we produced an expected null  
145 reference distribution (Nunes & Pearson, 2017) within both the geographic and climatic space for a  
146 given sampling effort (sample size) and corresponding to the observed species frequency in the  
147 database. This enabled us to evaluate the observed plot distribution in geographic space ( $DMC_{GEO}$ ) and  
148 climatic space ( $DMC_{CLIM}$ ) in comparison to expectations of randomly distributed plots across the  
149 species range and realized climatic niche. We tested four hypotheses on sampling coverage of species  
150 occurrences across both the geographic and climatic space:

151 (1) Sampling coverage within the climatic space depends strongly on good sampling coverage across  
152 the geographic space because climatic conditions are spatially autocorrelated. We expect a positive  
153 correlation between sampling coverage in the geographic and climatic space.

154 (2) Sampling coverage is less representative in the climatic space than in the geographic space. The  
155 reason is the asymmetric transferability between points in the climatic and geographic space: a single  
156 point within the climatic space might translate to several geographic locations, while a single  
157 geographic location can only translate to one point in the climatic space. An increase in sampling  
158 coverage within the geographic space might thus be without positive effect on sampling coverage  
159 within the climatic space.

160 (3) Given the general sampling issues of biodiversity databases mentioned above and the  
161 heterogeneous nature of their source data, we expect that sampling coverage of the realized niches of  
162 plant species by such data is largely imperfect because of an underdispersed (clumped) distribution of  
163 species observations within the geographic space and supposedly also within the climatic space.

164 (4) Finally, for a given range size and macroclimatic niche size, we expect sampling coverage to  
165 increase with increasing sample size.

166

## 167 **2 Material and Methods**

168 We assessed the sampling coverage of European vascular plant species ranges (using species range  
169 data from the Chorological Database Halle, CDH) by a test selection of species occurrence data taken  
170 from vegetation plots from the European Vegetation Archive (EVA, Chytrý et al., 2016). We did this  
171 both in the geographic space (distribution range data from CDH) and in the climatic space (realized  
172 climatic niche space derived from CDH geographical distributions). We focused on species presence  
173 data (i.e. locations of vegetation plots in which the focal species was recorded) and examined the  
174 relationship between the geographic and climatic sampling coverage, as well as interspecific  
175 variability. The study area comprised all European countries plus Turkey, Georgia, Armenia and  
176 Azerbaijan (Figure 1a).

177

## 178 **2.1 Background data on species geographic range and climatic niche**

179 The Chorological Database Halle (CDH) stores information on distribution ranges of about 17,000  
180 vascular plant taxa. For 5,583 taxa, maps were compiled based on published distribution range maps  
181 (Meusel, Jäger, & Weinert, 1965; Meusel, Jäger, Rauschert, & Weinert, 1978; Meusel & Jäger,  
182 1992), national and floristic databases and further maps from floristic literature (see bibliographic  
183 details in Index Holmiensis, Tralau, 1969-1981; Lundqvist & Nordenstam, 1988; Lundqvist, 1992;  
184 Lundqvist & Jäger, 1995-2007). CDH data can be requested for research objectives via  
185 <http://chorologie.biologie.uni-halle.de/choro/>. We retrieved from CDH the available geographical  
186 information for the distribution ranges of 1,200 European vascular plant species in electronic format  
187 (range polygons and point occurrences) in October 2015. The species range information was processed  
188 as raster layers of 2.5-min cell resolution, which is about 15 km<sup>2</sup> in Central Europe (Figure 1a). The  
189 multi-dimensional climatic space (climatic niche) was determined by principal components analysis  
190 (PCA) of 19 bioclimatic variables from Worldclim with 2.5-min cell resolution (Hijmans, Cameron,  
191 Parra, Jones, & Jarvis, 2005) (for detailed information see Appendix S1 in the Supporting  
192 Information).

193

## 194 **2.2 Vegetation plots**

195 A test selection of vegetation plots was provided by the European Vegetation Archive in October  
196 2015, containing information on 10,082 species from 933,228 vegetation plots. This selection included  
197 all the plots that were available in EVA at that time. Data for intraspecific taxa such as subspecies  
198 were merged at the species level. Further, we matched species names and checked for synonyms  
199 according to (i) the taxonomic reference list for Germany (German SL version 1.2, Jansen & Dengler,  
200 2008) and (ii) all taxonomic reference lists available via the R package 'taxize' (Chamberlain & Szöcs,  
201 2013; Chamberlain et al., 2018). We excluded trees, bryophytes, lichens, fungi, algae and species  
202 exotic to Europe. We also excluded 67,200 vegetation plots with location uncertainty larger than 10  
203 km and 417 species that occurred in less than 10 plots.

204 After matching EVA and CDH species, 808,794 vegetation plots contained at least one of the 564  
205 vascular plant species (herbs, dwarf shrubs and shrubs) with available digitized geographic  
206 distribution data in CDH. A list of these species and all the databases that provided vegetation plot  
207 data can be found in Appendices S2 and S3 in the Supporting Information. The 808,794 vegetation  
208 plots from EVA were heterogeneously distributed across the study area in the geographic space. While  
209 some geographic regions were represented very well and with high density (e.g. the Czech Republic,  
210 the Netherlands), other regions were represented sparsely (e.g. Norway, Sweden, Finland, Belarus,  
211 parts of Russia; Figure 1a). In contrast to geographic space, the study area was well represented by  
212 EVA vegetation plots in climatic space, except some marginal parts of the climatic background space  
213 (Figure 1b). The maximum density of species was 396 species per 2.5 min raster cell in geographic  
214 space (Figure 2a) and 528 species per cell in climatic space (Figure 2b). Stacked CDH ranges of the

215 564 study species covered 98.5% of the study area in geographic space (154,455 raster cells of 2.5-  
216 min in total) (Figure 2a) and 100% in climatic space (9,931 cells in total; Figure 2b).

217

### 218 **2.3 Dynamic Match Coefficient (DMC) - a measure of plot sampling coverage across spatial** 219 **scales**

220 Sampling bias is mainly a result of two interrelated issues: insufficient number of samples and  
221 inadequate sample distribution. The impact of sampling bias is related to spatial scale (spatial extent  
222 and grain size) and should decrease with increasing grain size. The spatial arrangement of sampling  
223 locations could be evaluated by classical methods of point pattern analysis (Boots & Getis, 1988;  
224 Wiegand & Moloney, 2013). However, there are two main issues related to the spatial pattern in the  
225 ecological domain of the data of interest. First, because of the generally irregular, often non-  
226 contiguous geometry of plant distribution ranges, traditional Euclidean geometry often fails to  
227 estimate characteristics of point patterns correctly (Pentland, 1984). Second, species ranges and niches  
228 cannot be regarded as merely geometric phenomena. Spatio-temporal population processes often result  
229 in complex range structures of genetic diversity, demographic performance and abundance (Peterson  
230 et al., 2011; Ricklefs, 2004).

231 To measure how well, i.e. how uniform vs. clustered and simultaneously how dense or scarce  
232 vegetation plots containing the focal species are located across the species` range or niche, we  
233 developed a measure inspired by fractal dimension analysis (Hall & Wood, 1993), which we call the  
234 Dynamic Match Coefficient (DMC). The DMC represents a measure of cell matches between a point  
235 pattern and spatial layers that are iterated across different raster cell resolutions (grain sizes), from fine  
236 to coarse (Figure 3). Here, 20 iterative scaling steps were used, which resulted in a maximum  
237 achievable DMC of 2000 ( $20 \times 100\%$  match). The obtained values were standardized to 0-1. For all  
238 species, the starting grain size in geographic space was  $1/20^{\text{th}}$  of the respective species maximum  
239 North-South and East-West range extent. Hence, the initial grain size was smaller for small-range  
240 species (e.g.  $50 \text{ km} \times 20 \text{ km}$  for *Centaurea deustiformis*) than for large-range species (e.g.  $211 \text{ km} \times$   
241  $273 \text{ km}$  for *Plantago major*) (see Appendices S2 and S4.1 in the Supporting Information for  
242 distribution of initial grain sizes in DMC calculations). Among the chosen starting grain sizes for the  
243 geographic space, even the finest grid cells ( $50 \text{ km} \times 20 \text{ km}$ ) are at a spatial resolution where climate  
244 conditions are considered the most important (Pearson & Dawson, 2003). The scaling procedure used  
245 in the climatic space was similar to that in the geographic space. Here the initial grain size was derived  
246 as the  $1/20^{\text{th}}$  fraction of the respective species maximum niche extent along the first two PCA axes.  
247 High DMC values indicate high sampling coverage, i.e. a more regular distribution and density of  
248 EVA vegetation plots across a species distribution range or within its realized climatic niche. In  
249 contrast, low DMC values indicate underdispersed sampling coverage, i.e. clumped distribution and/or



250 inappropriately low density of EVA vegetation plots across a species distribution range or within its  
251 realized climatic niche (Figure 3).

252

253 Figure 4 shows how the DMC approach works for the geographic and climatic space and for two  
254 contrasting species: *Hieracium murorum*, a species with clumped distribution in EVA plots, and  
255 *Calluna vulgaris*, a species with a more regular distribution in EVA plots, both in the species range  
256 and in the realized climatic niche (Figure 4a). Range size and the number of vegetation plots are  
257 similar in both species. The cell match ratio between species range and EVA vegetation plots was  
258 calculated in 20 iterations from fine to coarse raster cell resolution for both species in the geographic  
259 and climatic space (Figure 4b). The cell match ratio at the 20 single raster steps was summed up, and  
260 this sum is what we term the final DMC value of a species in the geographic space ( $DMC_{GEO}$ ) and  
261 climatic space ( $DMC_{CLIM}$ ). For *Hieracium murorum*, DMC values reached 0.42 and 0.58 for the  
262 geographic ( $DMC_{GEO}$ ) and climatic ( $DMC_{CLIM}$ ) space, respectively. For *Calluna vulgaris*, DMC values  
263 reached 0.74 for both the geographic ( $DMC_{GEO}$ ) and climatic ( $DMC_{CLIM}$ ) space.

264

#### 265 **2.4 Observed vs. expected distributions**

266 In order to quantify how far the observed DMC deviates from an expected random distribution, we  
267 applied a null model simulation (Nunes & Pearson, 2017) for each species. We randomly distributed a  
268 number of species occurrences for each species ( $n$  = number of plots containing the species) across its  
269 geographic range and climatic niche. We calculated the  $DMC_{GEO}$  and  $DMC_{CLIM}$  values for 100 such  
270 random distributions in the geographic and climatic space, respectively, and compared the simulated  
271 DMC distribution with the observed value. To quantify the deviation of the observed DMC value from  
272 the median of the simulated ideal random distribution ( $DMC_{NULL}$ ) we calculated a DMC ratio as:

$$273 \quad DMC \text{ ratio} = \frac{(DMC_{NULL} - DMC \text{ observed})}{DMC \text{ observed}}$$

274

275 A high DMC ratio corresponds to an underdispersed distribution of the EVA plots containing the  
276 species, while a low DMC ratio corresponds to a more random distribution. A negative ratio  
277 corresponds to an overdispersed distribution.

278

#### 279 **2.5 Effect of sample size on the DMC value**

280 We analysed the effect of sample size (number of EVA plots containing a given species) on DMC  
281 values while accounting for range size (or niche size) by applying linear models with  $DMC_{GEO}$  (or  
282  $DMC_{CLIM}$ ) values as the response variable, sample size as the main explanatory variable and range size  
283 (resp. niche size) as a covariate to correct for potential confounding effects of range size or niche size.  
284 In a first step, for each species, the percentage match of the species range (derived from CDH) by the

285 respective EVA vegetation plots where the species occurred was calculated at 2.5-min raster cell  
286 resolution. Multiple occurrences per raster cell were reduced to presence-absence data per species and  
287 2.5-min raster cell. In the second step, species ranges and the respective vegetation plots were  
288 projected into the climatic space. The study area in the climatic space is well represented by its first  
289 two PCA axes, which explain 88.0% of the data variance (for details see Appendix S1 in Supporting  
290 Information). Finally, the percentage of a species climatic niche matched by vegetation plots where the  
291 species occurred was calculated as the ratio of PCA cells of the respective EVA vegetation plots where  
292 the species occurred to all raster cells matched by the species range in the PCA space (species  
293 percentage match of its range and niche by EVA vegetation plots is provided in Appendix S2 in the  
294 Supporting Information).

295

### 296 **3 Results**

297 Overall, sampling coverage of European vascular plant species ranges by EVA vegetation plots was  
298 more complete within the geographic space than within the climatic space (Figure 5), i.e. consistently  
299 higher DMC values were within the geographic space ( $DMC_{GEO}$ ). The mean of  $DMC_{GEO}$  was slightly  
300 higher than that of  $DMC_{CLIM}$ , with values of 0.56 and 0.49, respectively. Species  $DMC_{GEO}$  values  
301 ranged from 0.08 to 0.94. For half of the species the  $DMC_{GEO}$  was between 0.48 and 0.65 (25<sup>th</sup> and  
302 75<sup>th</sup> percentile).  $DMC_{CLIM}$  values ranged from 0.08 to 0.82 and for half of the species the  $DMC_{CLIM}$   
303 was between 0.40 and 0.60 (25<sup>th</sup> and 75<sup>th</sup> percentile). We found a highly significant positive  
304 correlation (Spearman's  $\rho = 0.768$ ;  $p < 0.001$ ) between species geographic DMC values ( $DMC_{GEO}$ )  
305 and their climatic DMC values ( $DMC_{CLIM}$ ) (Figure 5).  $DMC_{CLIM}$  values were higher than  $DMC_{GEO}$   
306 values for only 119 species (21.1%), while 445 species (78.9%) had higher  $DMC_{GEO}$  values than  
307  $DMC_{CLIM}$  values. Furthermore, some species showed a high deviation in DMC values between the  
308 geographic and climatic space. For instance, *Arabis alpina* was more randomly sampled within the  
309 climatic space ( $DMC_{CLIM}$ : 0.55) than within the geographic space ( $DMC_{GEO}$ : 0.24), while this was the  
310 opposite for *Vinca major* ( $DMC_{GEO}$ : 0.63,  $DMC_{CLIM}$ : 0.29). In general a positive relationship between  
311 species range size and niche size could be observed (Spearman's  $\rho = 0.805$ ;  $p < 0.001$ ; Appendix  
312 S4.2 in Supporting Information).

313

#### 314 **3.1 Deviation of the observed DMC from the expected random distribution**

315 We found a positive correlation between the observed DMC values and the expected DMC values,  
316 based on our null model, for both the geographic space (weaker, Spearman's  $\rho = 0.389$ ;  $p < 0.001$ )  
317 and the climatic space (stronger, Spearman's  $\rho = 0.824$ ;  $p < 0.001$ ) (Figures 6a and 6b). Importantly,  
318 a large majority (92.0%) of the observed species distributions in EVA were significantly  
319 underdispersed in both the geographic and climatic space. This is indicated by the position of most of  
320 the points above the 1:1 line, especially in the climatic space. Exceptionally, for a small number of

321 species in the geographic space (43 species, 7.6%) (Figure 6a) and for two species in the climatic  
322 space (Figure 6b), the observed DMC values were higher than the null random expectation, indicating  
323 overdispersion.

324 For each species, we calculated the deviation of the observed DMC values from the null model DMC  
325 values in geographic and climatic space. While a low deviation of the observed DMC values from the  
326 null expectation indicates a more regular distribution of occurrences for a given species across its  
327 reference range or realized climatic niche, a high deviation indicates an underdispersed (more  
328 clumped) distribution. We found a positive correlation for the deviation of observed DMC values from  
329 the null model DMC values between geographic and climatic space (Spearman's  $\rho = 0.615$ ;  $p$   
330  $< 0.001$ ). Despite a higher variability, DMC deviation from the null model was on average slightly  
331 lower in geographic space ( $\text{min}_{\text{DEV\_GEO}}: -0.31$ ,  $\text{max}_{\text{DEV\_GEO}}: 2.47$ ,  $\text{median}_{\text{DEV\_GEO}}: 0.46$ ) than in climatic  
332 space ( $\text{min}_{\text{DEV\_CLIM}}: -0.10$ ,  $\text{max}_{\text{DEV\_CLIM}}: 2.09$ ,  $\text{median}_{\text{DEV\_CLIM}}: 0.47$ , see Figure 7).

333

### 334 **3.2 Effect of sample size on DMC values**

335 In geographic space, the percentage match of species ranges by EVA vegetation plots containing the  
336 same species (measured as the percentage of the range containing the EVA plots at 2.5-min raster cell  
337 resolution) ranged from 0.01% to 67.6%. For half of the species, the percentage match was between  
338 0.5% and 2.3% (25<sup>th</sup> and 75<sup>th</sup> percentile), with a mean of 1.1% in the geographic space. In the climatic  
339 space, the percentage match of species niches by EVA vegetation plots ranged from 0.5% to 72.7%  
340 and for half of the species the percentage match was between 7.6% and 22.1% (25<sup>th</sup> and 75<sup>th</sup>  
341 percentile), with a mean of 14.1%. The applied linear models revealed a positive effect of sample size  
342 (vegetation plots) on DMC values while accounting for range size or niche size in both the geographic  
343 space (multiple  $R^2: 0.212$ ) and climatic space (multiple  $R^2: 0.571$ ). We found a significantly positive  
344 correlation between the percentage match of the species range by EVA plots in both the geographic  
345 space (Spearman's  $\rho = 0.726$ ;  $p < 0.001$ ) and climatic space (Spearman's  $\rho = 0.901$ ;  $p < 0.001$ )  
346 (Figure 8a and b). Furthermore, we encountered a significantly negative relationship between  
347 percentage match of species ranges by EVA vegetation plots and deviation from the null model in the  
348 geographic space (Spearman's  $\rho = -0.601$ ;  $p < 0.001$ ) and climatic space (Spearman's  $\rho = -0.651$ ;  $p$   
349  $< 0.001$ ) (Figure 8c and d). Apart from this, a significantly positive correlation between the percentage  
350 match of the species range by EVA plots in the geographic space and climatic space could be found  
351 (Spearman's  $\rho = 0.865$ ;  $p < 0.001$ ; Appendix S4.3 in Supporting Information).

352

## 353 **4 Discussion**

### 354 **4.1 Plot sampling coverage across spatial scales**

355 In line with the general positive relationship between range size and niche size (see Appendix S4.2 in  
356 Supporting Information), we assumed that (1) a species will be well sampled throughout its

357 multidimensional climatic niche (reaching high  $DMC_{CLIM}$  values) only if it is well sampled throughout  
358 its geographic range (high  $DMC_{GEO}$  values). The demonstrated positive correlation between  $DMC_{CLIM}$   
359 and  $DMC_{GEO}$  confirms the first hypothesis. However, the relationship was far from perfect, since there  
360 are also species that are well sampled within the geographic space (reaching high  $DMC_{GEO}$  values) but  
361 less well sampled in the climatic space (reaching low  $DMC_{CLIM}$  values), and vice versa. Exceptions  
362 from the suggested positive relationship can arise especially due to high spatial heterogeneity in  
363 climatic conditions, e.g. in mountain regions (Hirst, Griffin, Sexton, & Hoffmann, 2017; Köckemann,  
364 Buschmann, & Leuschner, 2009).

365 Because of the one-to-n relationship between climatic and geographic data points we expected (2) a  
366 sparser species sample coverage (lower DMC values) in the climatic space. Accordingly, we found  
367 that the sampling coverage (DMC value) of species distribution in EVA was more random in the  
368 geographic space ( $DMC_{GEO}$ ) than in the climatic space ( $DMC_{CLIM}$ ) for 77.9% of the studied species.  
369 This more random sampling coverage in geographic space is explainable by the niche–biotope duality  
370 (Hutchinson, 1978). The same combination of climate factors can occur in only one location in  
371 geographic space, but will more likely occur in several localities with increasing spatial extent  
372 (Colwell & Rangel, 2009; Soberón & Nakamura, 2009). However, the rules that define the niche–  
373 biotope duality are not reciprocal (Colwell & Rangel, 2009; Soberón & Nakamura, 2009), and the  
374 climatic niche of a species might be fully captured even if only a part of its geographic distribution  
375 was sampled (Guisan, Petitpierre, Broennimann, Daehler, & Kueffer, 2014). This seems to be the case  
376 for 22.9% of the studied species that occupy ranges with highly heterogeneous climatic conditions  
377 (e.g. in mountain regions as mentioned above). For those species, the sampling coverage was higher in  
378 the climatic space ( $DMC_{CLIM}$ ) than in geographic space ( $DMC_{GEO}$ ).

379 Large-scale biodiversity databases consist of heterogeneous, non-systematically sampled datasets with  
380 underdispersed observations within the geographic space and supposedly also within the climatic  
381 space. We therefore expected (3) the sampling coverage of species geographic ranges and climatic  
382 niches to be largely imperfect due to sampling biases. Accordingly, we found limited sampling  
383 coverage for most of the studied species. In almost all cases, the observed species distributions in EVA  
384 significantly underrepresented both the species geographic range and climatic niche space. It is  
385 achievable to identify species which are poorly represented in biodiversity databases relative to their  
386 geographic ranges or realized climatic niches (Boakes et al., 2010; Hoffmann et al., 2014). Since the  
387 observed and expected DMC values were highly positively correlated, the applied null model  
388 approach supports the usefulness of the presented DMC metric to assess sampling bias in the  
389 distribution of species occurrences in biodiversity databases.

390 We assumed that (4) on condition that range size and climatic niche size are correlated, sampling  
391 coverage increases with increasing sample size. The applied linear models revealed a positive effect of  
392 sample size on DMC values while accounting for range size and niche size, which supports our fourth

393 hypothesis. Nevertheless, especially for the geographical space, high percentage cover of species  
394 range by the EVA plots cannot directly indicate high DMC values. In general, the correlation of  
395 percentage match of a species range by the EVA plots at 2.5-min raster cell resolution with DMC  
396 values was highly positive in geographic space. Nevertheless, there were species with higher  
397 percentage match that only reached lower DMC values while there were also species with lower  
398 percentage match that reached higher DMC values. Our results show that the number and thereby the  
399 density of observations across a species distribution range remains crucial. On the one hand, too small  
400 number of plots representing a species distribution range may be a sample of insufficient size even if  
401 the plots are distributed randomly (as suggested by the null model calculations). On the other hand,  
402 even a large number of vegetation plots may underrepresent a species range if their spatial distribution  
403 is underdispersed. Consequently, both clumping and density of occurrence observations have to be  
404 considered, computed and estimated simultaneously to evaluate the representativeness of biodiversity  
405 databases.

406

#### 407 **4.2 Possible applications of the DMC**

408 Occurrence data and distribution maps for species of various taxa are increasingly being made  
409 available from biodiversity databases (e.g. Map Of Life, Jetz, McPherson, & Guralnick (2012); The  
410 IUCN Red List, IUCN (2019); Euro+Med Plantbase, Euro+Med (2019); The PLANTS Database,  
411 USDA, NRCS (2019)).

412 (I) Our DMC approach enables evaluation and comparison of the coverage of occurrence data across  
413 irregular and even non-contiguous background spaces. Thus, it helps identifying species with a  
414 suitable representation of their range / niche by existing point samples. In species distribution  
415 modelling, uneven or inconsistent representation of environmental gradients by occurrence records can  
416 strongly influence the model accuracy (Tessarolo, Rangel, Araújo, & Hortal, 2014), which can result  
417 in limited applicability for climate change predictions (Araújo & Guisan, 2006; Titeux et al., 2017).

418 (II) The DMC value calculation is applicable in both the climatic and geographic space and can help  
419 evaluate the coverage of species samples for species distribution modelling. Using such information  
420 derived from the DMC metric inside the modelling framework of SDM is likely to improve SDM  
421 predictive performance. Nevertheless, independent information on species geographic distribution is  
422 needed to correctly evaluate point sampling coverage for SDM studies. It is not recommended to  
423 generate range models based on sampling data of unknown coverage. While  $DMC_{(GEO)}$  values  
424 generated this way might be used to gather information on species geographic point sampling quality,  
425  $DMC_{(CLIM)}$  values might be highly biased. Without independently generated distribution information,  
426  $DMC_{(CLIM)}$  values are not applicable for SDM evaluation. Since observed and expected DMC values  
427 (see the applied null model approach) were highly positively correlated, the deviation from the  
428 expected DMC is a suitable measure for the representativeness of species occurrence data. A high

429 deviation corresponds to an underdispersed distribution of plots, while a low deviation corresponds to  
430 a more random distribution of plots and a negative deviation corresponds to an overdispersed  
431 distribution of plots.

432 (III) Data limitations (i.e. lack of fine-resolution data of species occurrences over large spatial extents)  
433 will remain the norm for most species and regions, and best-possible use should be made of limited  
434 information (Hoffmann et al., 2014; Meyer et al., 2016). Here, based on the curves resulting from the  
435 DMC calculations it would be possible to determine the raster cell resolution where results of the  
436 analyses are least vulnerable to errors due to the existing sampling gaps by calculating the inflection  
437 point of the DMC curve. Nevertheless, one must be aware that the achievable raster cell resolution  
438 always depends on the spatial extent of the study (e.g. regional, continental or global scale) (Hartley &  
439 Kunin, 2003; Pearson & Dawson, 2003; Willis & Whittaker, 2002).

440 (IV) The efficacy of database platforms strongly depends on the completeness of species inventories  
441 and the survey coverage across space and the environment (Hortal et al., 2008; Troia & McManamay,  
442 2016), therefore it is necessary to continue surveys in undersampled areas (Beck et al., 2012;  
443 Engemann et al., 2015). Here, results of the DMC analyses can be used to identify these undersampled  
444 areas and help focus search efforts for data information in relevant literature or further databases. This  
445 would be possible by selecting undersampled parts of the niche and translate them back to the  
446 geographical space. Furthermore, the results of DMC analyses can be used to guide future botanical  
447 explorations and practical fieldwork, to make new sampling in geographical and climate spaces cost-  
448 efficient.

449 (V) Including both the DMC metrics as covariates in any model with species as the observational unit  
450 may help to account for potential confounding effects due to the varying sampling coverage of the  
451 sampled species distribution within both the climatic and geographic space. Since DMC values are  
452 species-specific, they can be included as weights in macroecological analyses and models, where well-  
453 represented species might be weighted higher than less-well represented species. Nevertheless, it  
454 might be necessary to apply re-sampling methods (e.g. Lengyel, Chytrý, & Tichý, 2011) to prevent  
455 spatial autocorrelation in model residuals.

456

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461

#### 462 **Author contributions**

463 EW and MS developed the DMC concept, with considerable input by GS and HB. MS wrote the first  
464 draft of the manuscript, with considerable input by EW, HB, PK and UJ. MS and GS harmonized data  
465 retrieved from EVA and CDH. GS wrote R code for DMC calculation. PK wrote R code for the null

466 model application for DMC calculations. MS carried out statistical analyses and produced the graphs.  
467 All other authors contributed data. All authors contributed to writing the manuscript.

468

#### 469 **Data accessibility**

470 The R code for DMC calculation with an application example is available from Figshare Digital  
471 Repository: <<https://doi.org/10.6084/m9.figshare.7924934.v2>>.

472

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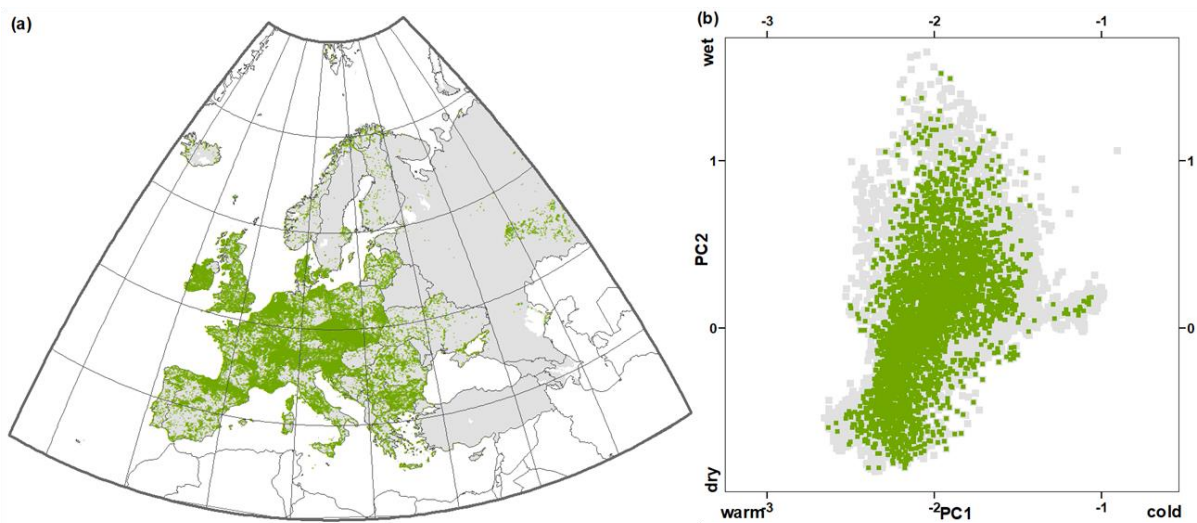
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649 **Figures**

650

651 **Figure 1** Distribution of the 808,794 vegetation plots (green dots) extracted from EVA (European  
652 Vegetation Archive). Only plots with at least one of the 564 study species are shown. The study  
653 species merged distributions based on CDH are represented by grey cells. White areas (large water  
654 bodies, glaciers, and deserts) represent regions where none of the studied species occurs. (a)  
655 Distribution of vegetation plots in the geographic space. (b) Distribution of vegetation plots in climatic  
656 space represented by its first two PCA axes (74.1% and 13.9% variance explained by PC1 and PC2,  
657 respectively), where PC1 and PC2 were negatively and positively related to temperature and  
658 precipitation, respectively.

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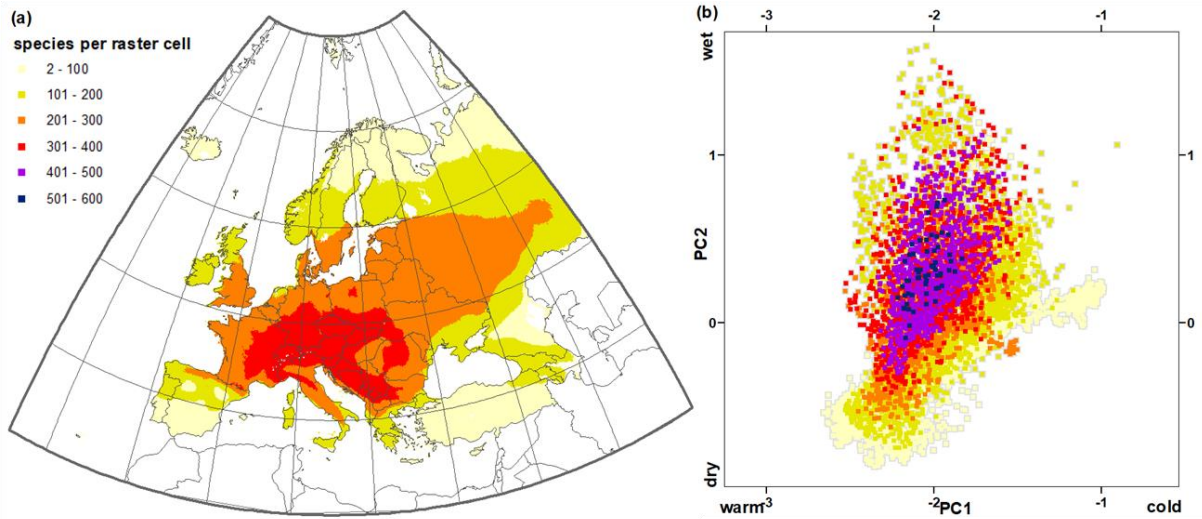


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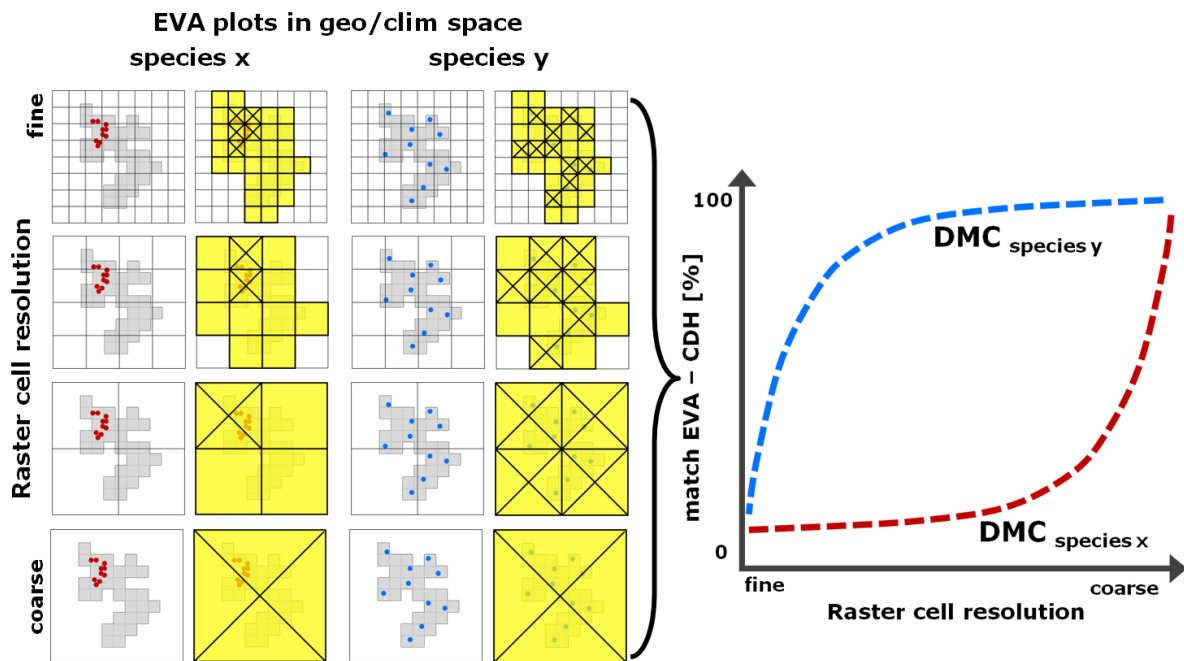
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663 **Figure 2** Study species data density in the geographic and climatic space. (a) Data density on species  
664 geographic ranges of 564 vascular plant species included in this study in 2.5-min resolution raster.  
665 White areas (large water bodies, glaciers, and deserts) represent regions where none of the studied  
666 species occurs. (b) Data density on climatic niches of 564 species in the respective common climatic  
667 space represented by its first two PCA axes (74.1% and 13.9% variance explained by PC1 and PC2,  
668 respectively), where PC1 and PC2 were negatively and positively related to temperature and  
669 precipitation, respectively.



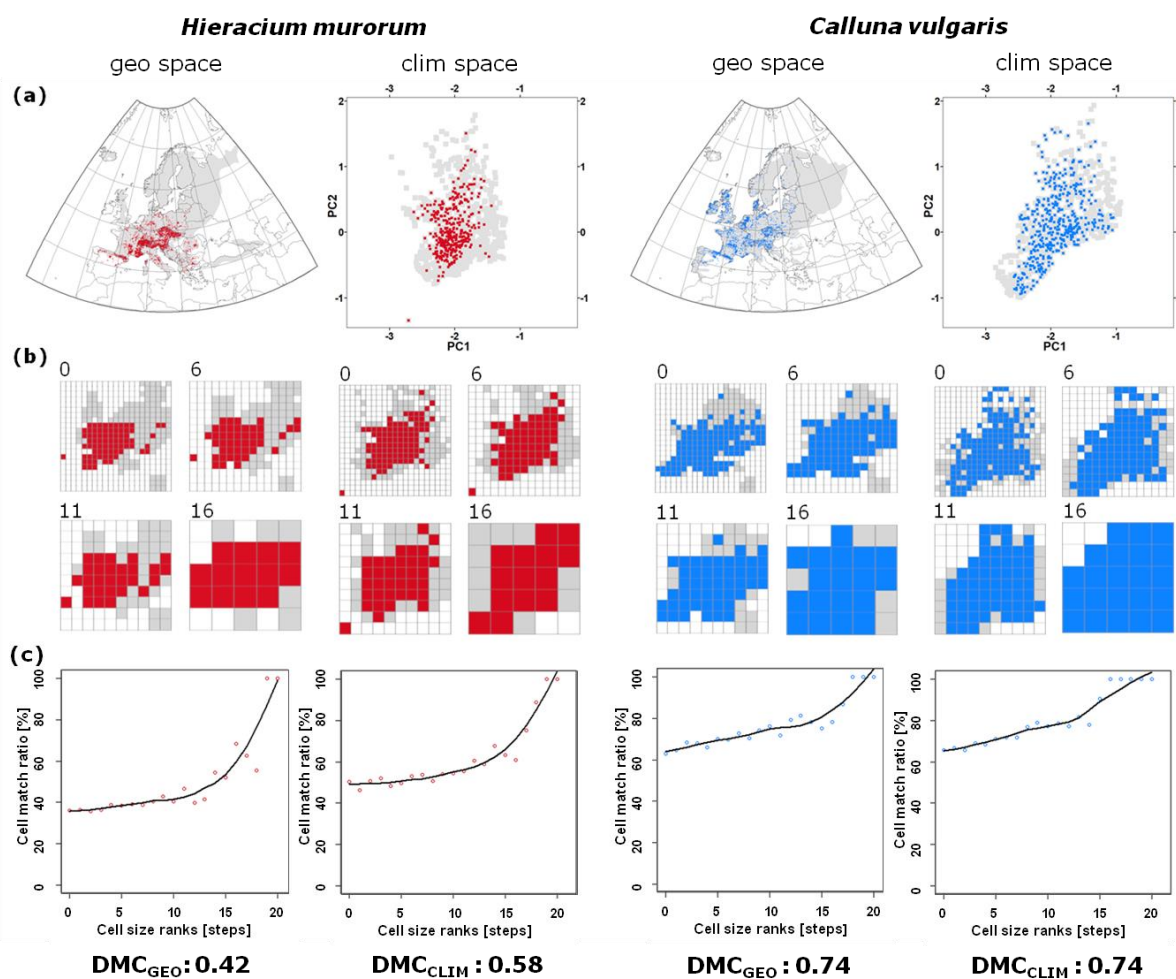
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674 **Figure 3** Dynamic Match Coefficient (DMC) calculated for two example species X and Y with  
 675 different plot distributions but similar ranges and climatic niches. DMC measures sampling coverage  
 676 from fine resolution to coarse resolution as the area under the curve (AUC). Scaling for species X,  
 677 with clumped plots (10 red dots) in the species range or climatic niche (grey background), results in a  
 678 low DMC value. Scaling for species Y, with more regularly distributed plots (10 blue dots) in the  
 679 species range or climatic niche (grey background), results in a high DMC value.  
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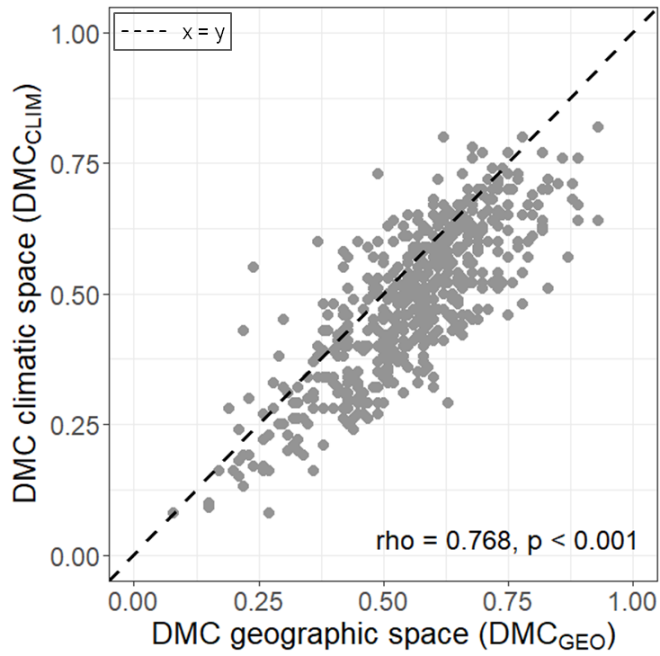
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684 **Figure 4** The DMC scaling approach applied to the distribution of EVA vegetation plots inside  
 685 species ranges in geographic space and inside species niches in climatic space (grey cells). (a) The  
 686 distribution of EVA plots containing *Hieracium murorum* (left, red) and *Calluna vulgaris* (right, blue).  
 687 (b) Four selected scaling steps from fine to coarse raster-cell resolution in geographic space (left-hand  
 688 four panels in each set) and climatic space (right-hand four panels in each set). (c) The resulting DMC  
 689 curves along 20 scaling steps, where the cell match ratio is the percentage of grey raster cells (species  
 690 range or climatic niche) matched by a vegetation plot containing the species. In all cases, the  
 691 maximum achievable DMC is 1 (100% cell match in all scaling steps). DMC values reached 0.42 and  
 692 0.58 for the geographic ( $DMC_{GEO}$ ) and climatic ( $DMC_{CLIM}$ ) space for *Hieracium murorum* and 0.74  
 693 for both the geographic ( $DMC_{GEO}$ ) and climatic ( $DMC_{CLIM}$ ) space for *Calluna vulgaris*.



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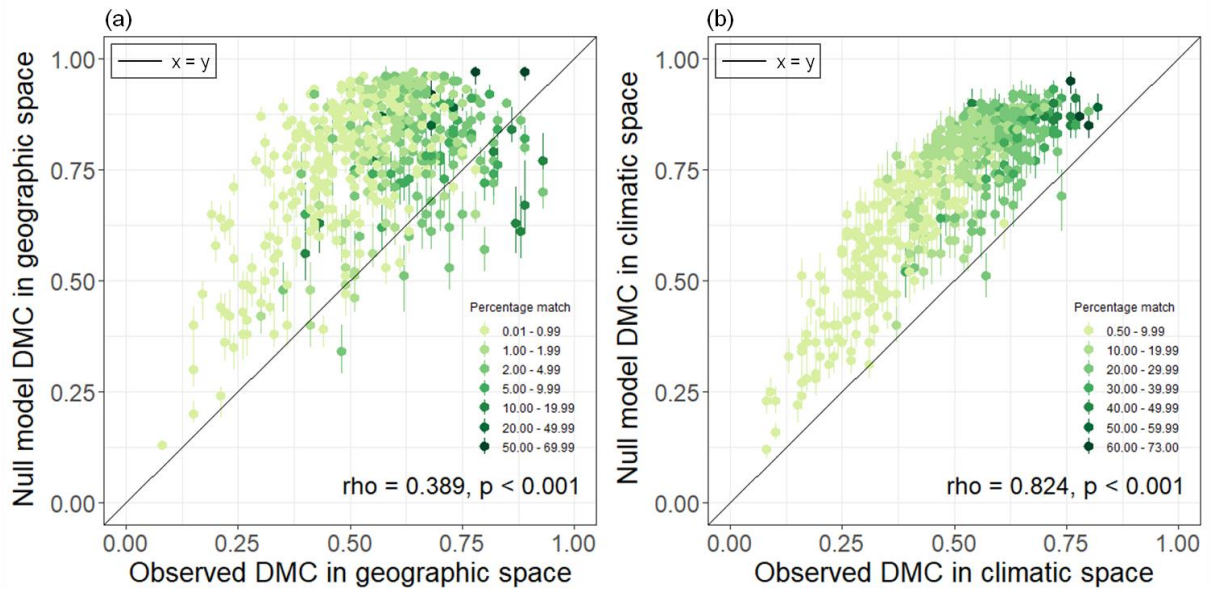
697 **Figure 5** Scatterplot and Spearman correlation coefficients ( $\rho$ ) of the relationship between DMC  
698 values in geographic space ( $DMC_{GEO}$ ) and DMC values in climatic space ( $DMC_{CLIM}$ ) for 564 plant  
699 species. Low DMC values indicate an underdispersed (more clumped) distribution of species  
700 occurrences in EVA vegetation plots, while high DMC values indicate a homogenous distribution in  
701 EVA vegetation plots, in the geographic range or realized climatic niche of a species.



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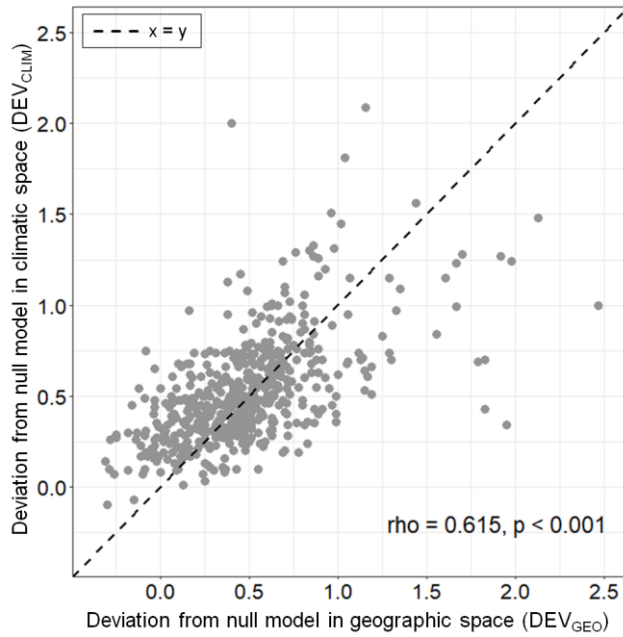


705 **Figure 6** Scatterplots and Spearman correlation coefficients ( $\rho$ ) of the relationships between the  
 706 observed DMC and expected DMC derived by null models for (a) geographic space and (b) climatic  
 707 space. Dots are medians; lines are inter-quartile ranges of the simulations from the null model. Colour  
 708 gradient represents the percentage match of a species range by EVA vegetation plots in the geographic  
 709 space (match at 2.5-min raster cell resolution) or climate space (ratio of PCA cells matched by EVA  
 710 plots to all species-specific raster cells matched by the geographic range data in the PCA space).



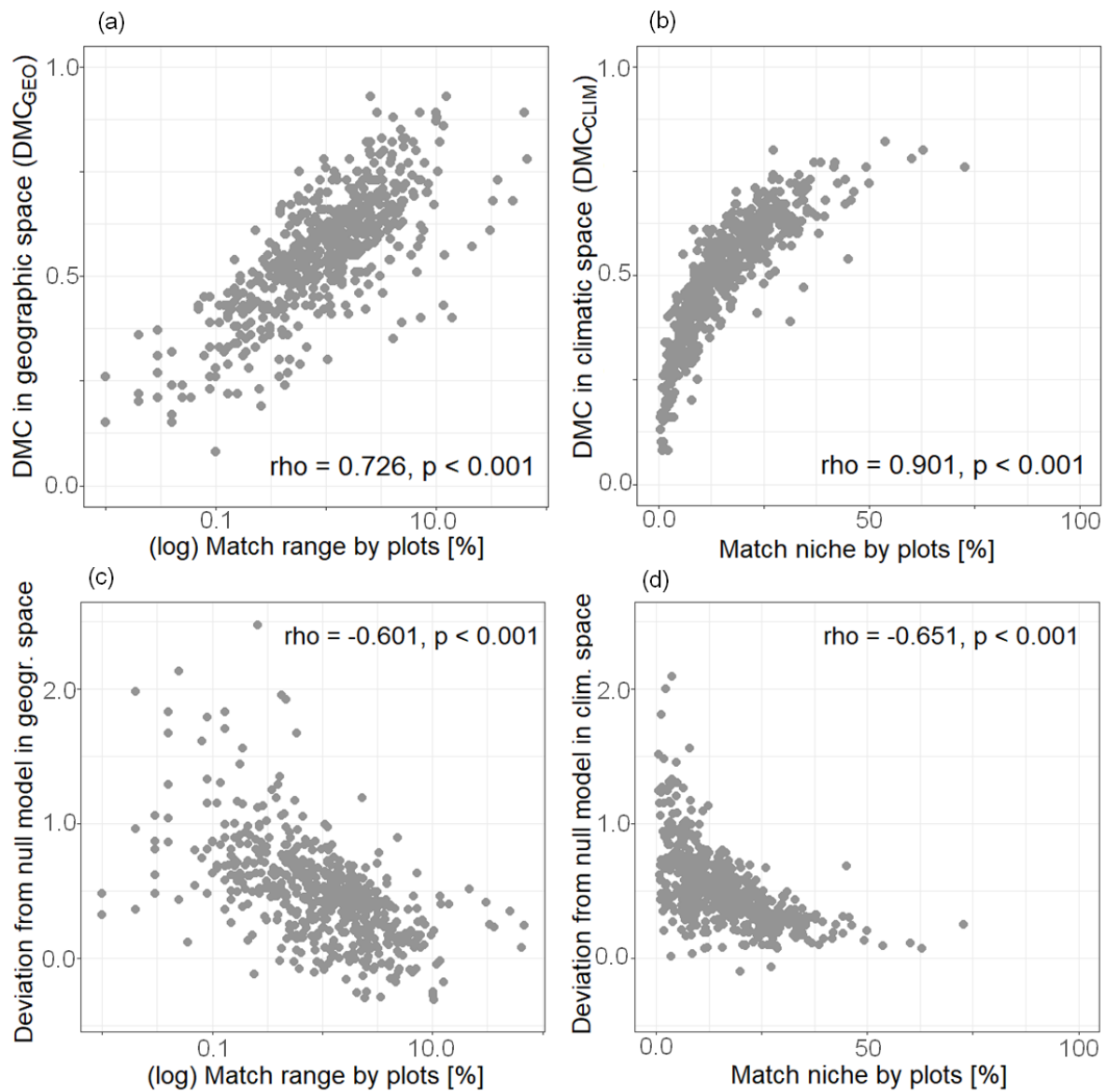
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714 **Figure 7** Scatterplot and Spearman correlation coefficients ( $\rho$ ) of the relationship between the  
715 deviation of the observed DMC values from null model DMC values in the geographic space  
716 ( $DEV_{GEO}$ ) and in climatic space ( $DEV_{CLIM}$ ). Low deviation of the observed DMC values from the null  
717 expectation indicates a more regular distribution of occurrences for a given species across its reference  
718 range or realized climatic niche, a high deviation indicates an underdispersed (more clumped)  
719 distribution.



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725 **Figure 8** Scatterplots and Spearman correlation coefficients ( $\rho$ ) of the relationships between  
726 percentage match of species ranges by EVA vegetation plots and (a) observed DMC in geographic  
727 space ( $DMC_{GEO}$ ); (b) observed DMC in climatic space ( $DMC_{CLIM}$ ); (c) deviation of observed DMC  
728 values from null model DMC values in geographic space ( $DEV_{GEO}$ ); (d) deviation of observed DMC  
729 values from null model DMC values in climatic space ( $DEV_{CLIM}$ ).



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731

732 **Supporting Information**

733 **Appendix S1** Climatic resampling procedure and background PCA niche space of the study area.

734 **Appendix S2** Information on the 564 species included in this study.

735 **Appendix S3** Information on the 59 databases that provided vegetation plots included in this study.

736 **Appendix S4** Information on initial grain size in DMC calculations; correlation between percentage  
737 match of species ranges by EVA vegetation plots in geographic vs. climatic space; correlation between  
738 species range sizes and niche sizes.

739

740

1 Supporting information to the paper  
2 Sporbert, M. et al. Assessing sampling coverage of species distribution in biodiversity databases.  
3 *Journal of Vegetation Science*.

4  
5 **Appendix S1** Climatic resampling procedure and background PCA niche space of the study area

6  
7 Multivariate approaches such as PCA or clustering algorithms are sensitive to the frequency  
8 distribution of the (e.g. climatic) values and more average conditions might be lumped in the presence  
9 of extreme values. To minimize the spatial autocorrelation between species occurrences in terms of  
10 climatic data, it is desirable to sample climatic conditions equally.

11 **Climatic resampling procedure**

12 We developed a stratification based on a climatic resampling procedure as follows:

13 **1.** We used global layers with monthly mean values of temperature and precipitation at 2.5-min raster  
14 cell resolution (hemisphere-adjusted). All precipitation values were log-transformed to take into  
15 account the decreasing ecological importance of differences with increasing precipitation. Monthly  
16 mean values of temperature and (log) precipitation were separately standardized (0-1).

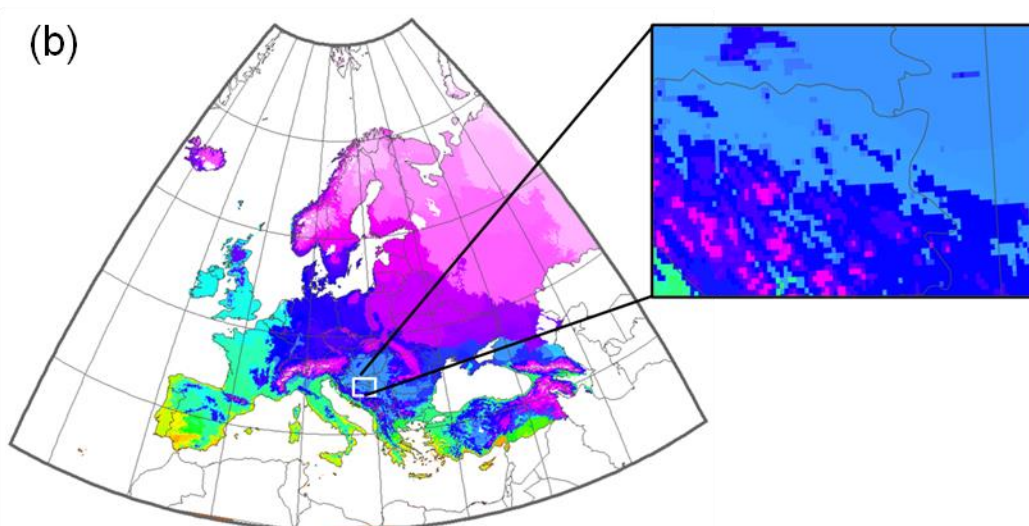
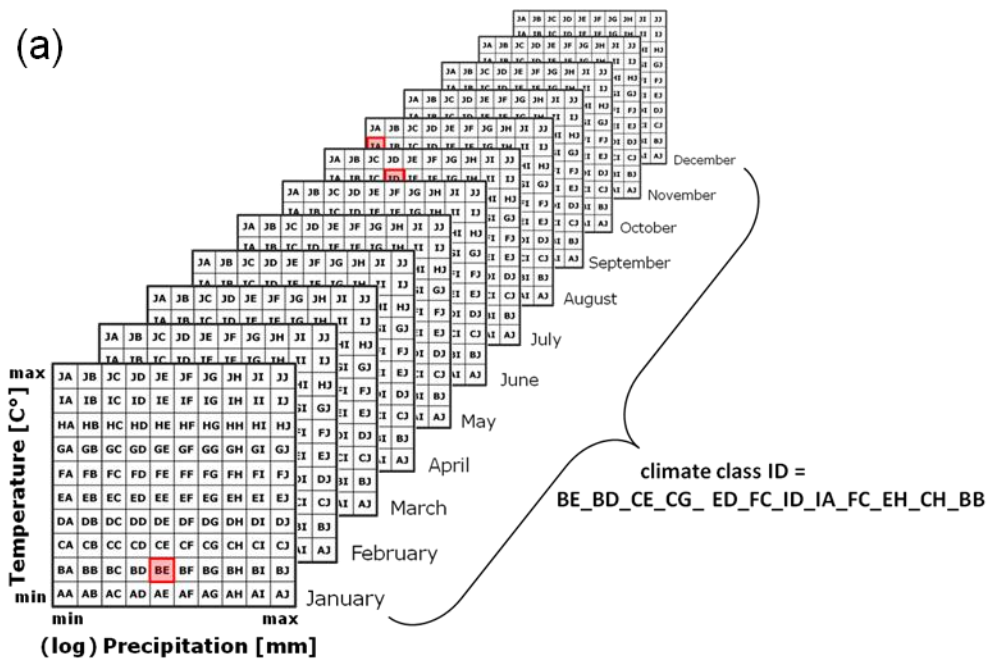
17 **2.** After standardization (0-1), 10 classes (class width 0.1) per variable (cf. temperature and (log)  
18 precipitation) were derived and labelled “A” to “J” (see Figure S1.1a).

19 **3.** The cells of a unique climate class are defined by an identical string of class labels (= climate class  
20 ID) containing of 12 “A” to “J” combinations, one for each month.

21 All 2.5-min raster cells of one climatically homogenous region are labelled by an identical climate  
22 class ID. In total, 2,144 unique climate class ID were built in EVA space by the applied climatic  
23 resampling procedure. One climatically homogenous region may be represented by one to many  
24 geographical patches of different size (see Figure S1.1b). The smallest climatically homogenous  
25 region consists of only one 2.5-min raster cell while the largest climatically homogenous region  
26 consists of 38,577 2.5-min raster cells.

27 Based on this spatial pre-partitioning, any climatic data extracted at species occurrences can be  
28 subsampled evenly from differently sized, yet climatically homogenous regions.

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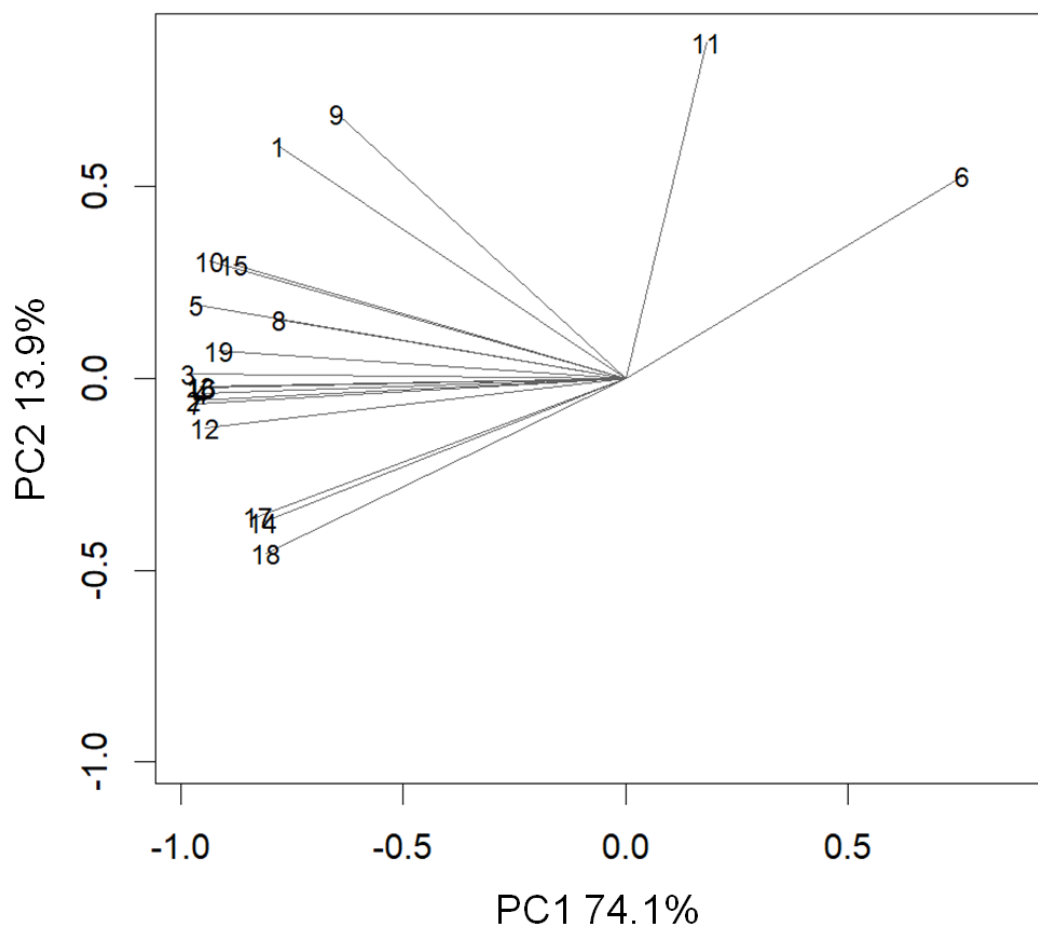


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**Figure S1.1** Illustration of the climatic resampling procedure. (a) Monthly mean values of temperature and (log) precipitation were separately standardized (0-1). 10 classes (class width 0.1) per variable were derived and labelled “A” to “J”. Cells of a unique climate class are labelled by a unique climate class ID. (b) All cells of one climatically homogenous region are represented by identical colour. Black lines represent the country borders on the continent.

38 **Background PCA niche space of the study area**

39 Per homogenous climatic region (identical climate class ID from climatic resampling) we aggregated  
40 mean values for each of the 19 bioclimatic variables from Worldclim with 2.5-min raster cell  
41 resolution (Hijmans et al., 2005). The multi-dimensional climatic space (or climatic niche) was  
42 determined by principal components analysis (PCA). The common European climatic space is well  
43 represented by the first two PCA axes which explain 88.0% of the data variance. Accordingly, unique  
44 PCA space locations are representing unique climate classes and were considered (and counted as)  
45 niche cells. Results of Pearson correlations between the 19 bioclimatic variables (BIO 01 – BIO 19)  
46 and the first two axes of the principal component analysis (PC1 and PC2) are given in Table S1.3.  
47



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50 **Figure S1.2** Biplot of the principal component analysis (PCA) for bioclimatic variables in the  
51 European study space. The two principal components (PC1 and PC2) explained 88.0% of total  
52 variation in bioclimatic data. PC1 was negatively related to temperature and PC2 was positively  
53 related to precipitation.

54

55 **Table S1.3** Results of Pearson correlation between the 19 bioclimatic variables (BIO 01 – BIO 19)  
 56 and the first two axes of the principal component analysis (PC1 and PC2).

Bioclim variable	PC1	PC2
BIO1 = Annual Mean Temperature	-0.650	-0.064
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	-0.583	0.065
BIO3 = Isothermality (BIO2/BIO7) (* 100)	-0.526	0.071
BIO4 = Temperature Seasonality (standard deviation *100)	-0.436	0.014
BIO5 = Max Temperature of Warmest Month	-0.611	-0.067
BIO6 = Min Temperature of Coldest Month	-0.526	-0.051
BIO7 = Temperature Annual Range (BIO5-BIO6)	-0.495	0.048
BIO8 = Mean Temperature of Wettest Quarter	-0.565	0.016
BIO9 = Mean Temperature of Driest Quarter	-0.641	-0.098
BIO10 = Mean Temperature of Warmest Quarter	-0.628	-0.074
BIO11 = Mean Temperature of Coldest Quarter	-0.574	-0.048
BIO12 = Annual Precipitation	-0.210	0.115
BIO13 = Precipitation of Wettest Month	-0.255	0.085
BIO14 = Precipitation of Driest Month	-0.192	0.176
BIO15 = Precipitation Seasonality (Coefficient of Variation)	-0.348	-0.129
BIO16 = Precipitation of Wettest Quarter	-0.248	0.085
BIO17 = Precipitation of Driest Quarter	-0.197	0.175
BIO18 = Precipitation of Warmest Quarter	-0.177	0.166
BIO19 = Precipitation of Coldest Quarter	-0.224	0.057

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Supporting information to the paper: Sporbert, M. et al. Assessing sampling coverage of species distribution in biodiversity data

Appendix S1 Information on the 564 species included in this study.

Information on species range/niche size: (occupied raster cells at 2.5-min raster cell resolution) in geographical/climatic space

EVA sample geo/clim: number of EVA plots at 2.5-min raster cell resolution including the focal species in geographic/climatic space

DMC geo/clim: results of DMC calculations in geographical/climatic space;

DMC geo Null/clim Null: results of Null model DMC calculations in geographical/climatic space;

ratio geo = (DMC geo Null - DMC geo) / DMC geo; ratio clim = (DMC clim Null - DMC clim) / DMC clim;

range percent: percentage of a species range matched by EVA vegetation plots at 2.5min raster cell resolution;

niche percent: percentage of a species niche matched by EVA vegetation plots (= ratio of PCA cells matched by EVA plots to total PCA cells)

starting grain size [km<sup>2</sup>] in DMC calculations, bandwidth of scaling steps were calculated species specific according to the species range

Species name

*Achillea atrata*

*Achillea clavennae*

*Achillea crithmifolia*

*Achillea nobilis*

*Actaea spicata*

*Adenostyles alliariae*

*Adonis vernalis*

*Adoxa moschatellina*

*Aegopodium podagraria*

*Agrimonia eupatoria*

*Agrostis castellana*

*Ajuga chamaepitys*

*Ajuga genevensis*

*Ajuga reptans*

*Alliaria petiolata*

*Allium senescens*

*Alopecurus pratensis*

*Anchusa arvensis*

*Androsace chamaejasme*

*Androsace obtusifolia*

*Anemone baldensis*

*Anemone nemorosa*

*Angelica archangelica*

*Angelica palustris*

*Angelica sylvestris*

*Antennaria dioica*

*Anthemis tinctoria*

*Anthericum ramosum*

*Anthoxanthum odoratum*

*Anthriscus sylvestris*

*Anthyllis vulneraria*

*Apium repens*

*Aquilegia vulgaris*

*Arabis alpina*

*Arabis hirsuta*

*Arnica montana*

Artemisia alba  
Artemisia campestris  
Artemisia pontica  
Artemisia scoparia  
Artemisia vulgaris  
Aruncus dioicus  
Asperula arvensis  
Asperula tinctoria  
Aster bellidiastrum  
Aster tripolium  
Astragalus frigidus  
Astragalus glycyphyllos  
Astrantia major  
Asyneuma canescens  
Athyrium filix-femina  
Atriplex portulacoides  
Atriplex tatarica  
Atropa bella-donna  
Barbarea vulgaris  
Bartsia alpina  
Bellis perennis  
Bellis sylvestris  
Berteroa incana  
Betonica officinalis  
Betula nana  
Bifora radians  
Bistorta officinalis  
Brachypodium phoenicoides  
Brachypodium pinnatum  
Brachypodium sylvaticum  
Brassica nigra  
Briza media  
Bromus erectus  
Bromus hordeaceus  
Bromus squarrosus  
Bromus sterilis  
Bromus tectorum  
Buphthalmum salicifolium  
Bupleurum falcatum  
Bupleurum ranunculoides  
Bupleurum rotundifolium  
Cakile maritima  
Calamagrostis villosa  
Calluna vulgaris  
Calystegia sepium  
Campanula alpina  
Campanula glomerata  
Campanula patula  
Campanula persicifolia

Campanula ramosissima  
Campanula rapunculoides  
Campanula rapunculus  
Campanula rotundifolia  
Campanula sibirica  
Campanula trachelium  
Cardamine enneaphyllos  
Cardamine pratensis  
Cardaminopsis arenosa  
Cardaria draba  
Carduus acanthoides  
Carduus defloratus  
Carduus micropterus  
Carduus pycnocephalus  
Carduus thoermeri  
Carex alba  
Carex arenaria  
Carex brizoides  
Carex caryophyllea  
Carex distans  
Carex echinata  
Carex elongata  
Carex ericetorum  
Carex firma  
Carex hostiana  
Carex panicea  
Carex pilosa  
Carex pilulifera  
Carex pulicaris  
Carex remota  
Carex rostrata  
Carex sempervirens  
Carex umbrosa  
Carlina acanthifolia  
Carlina acaulis  
Carlina corymbosa  
Carlina vulgaris  
Carthamus lanatus  
Carum carvi  
Centaurea alba  
Centaurea calcitrapa  
Centaurea cyanus  
Centaurea deustiformis  
Centaurea jacea  
Centaurea maculosa  
Centaurea phrygia  
Cerastium arvense  
Cerastium semidecandrum  
Ceratocarpus claviculata

Chaerophyllum aureum  
Chaerophyllum temulum  
Chamaespartium sagittale  
Chimaphila umbellata  
Chrysanthemum segetum  
Cichorium intybus  
Cichorium spinosum  
Circaea lutetiana  
Cirsium acaule  
Cirsium erisithales  
Cirsium ligulare  
Cirsium montanum  
Cirsium oleraceum  
Cirsium rivulare  
Cirsium vulgare  
Clematis recta  
Clinopodium vulgare  
Coeloglossum viride  
Conium maculatum  
Consolida ajacis  
Convallaria majalis  
Coronilla coronata  
Coronilla vaginalis  
Cortusa matthioli  
Corydalis cava  
Corydalis solida  
Corynephorus canescens  
Crepis biennis  
Crepis capillaris  
Crepis praemorsa  
Crepis tectorum  
Crepis vesicaria  
Cruciata laevipes  
Crupina crupinastrum  
Crupina vulgaris  
Cyclamen hederifolium  
Cymbalaria muralis  
Cynosurus cristatus  
Cynosurus elegans  
Cytisus multiflorus  
Dactylorhiza fuchsii  
Dactylorhiza sambucina  
Daucus carota  
Deschampsia flexuosa  
Dianthus armeria  
Dianthus carthusianorum  
Dianthus deltoides  
Dianthus seguieri  
Dianthus superbus

Dictamnus albus  
Digitalis ferruginea  
Digitalis grandiflora  
Digitalis lanata  
Digitalis lutea  
Digitalis purpurea  
Digitalis viridiflora  
Dryas octopetala  
Dryopteris oreades  
Echinops ritro  
Echium vulgare  
Empetrum nigrum  
Epilobium hirsutum  
Epipactis atrorubens  
Erica cinerea  
Erigeron glabratus  
Eriophorum latifolium  
Eriophorum scheuchzeri  
Eriophorum vaginatum  
Erodium cicutarium  
Eryngium campestre  
Eryngium maritimum  
Erysimum cheiranthoides  
Eupatorium cannabinum  
Euphorbia amygdaloides  
Euphorbia cyparissias  
Euphorbia helioscopia  
Euphrasia officinalis  
Festuca altissima  
Festuca amethystina  
Festuca gigantea  
Festuca heterophylla  
Festuca pratensis  
Filago pyramidata  
Filipendula ulmaria  
Filipendula vulgaris  
Fragaria vesca  
Fragaria viridis  
Galeopsis bifida  
Galeopsis segetum  
Galeopsis speciosa  
Galium anisophyllum  
Galium aparine  
Galium aristatum  
Galium boreale  
Galium glaucum  
Galium heldreichii  
Galium laevigatum  
Galium octonarium

Galium pinetorum  
Galium rotundifolium  
Galium scabrum  
Galium spurium  
Galium timeroyi  
Galium triflorum  
Galium uliginosum  
Galium verum  
Gaudinia fragilis  
Genista anglica  
Gentiana acaulis  
Gentiana asclepiadea  
Gentiana clusii  
Gentiana cruciata  
Gentiana lutea  
Gentiana pannonica  
Gentiana utriculosa  
Gentiana verna  
Gentianella aspera  
Gentianella ciliata  
Geranium columbinum  
Geranium dissectum  
Geranium palustre  
Geranium pratense  
Geranium robertianum  
Geranium sanguineum  
Geranium sylvaticum  
Geum rivale  
Gladiolus imbricatus  
Glechoma hederacea  
Globularia punctata  
Gratiola officinalis  
Gymnadenia conopsea  
Hedysarum hedysaroides  
Helichrysum arenarium  
Helictotrichon pubescens  
Helleborus foetidus  
Heracleum sphondylium  
Herniaria glabra  
Hieracium aurantiacum  
Hieracium bifidum  
Hieracium glaucum  
Hieracium murorum  
Hieracium piliferum  
Hieracium pilosella  
Hieracium umbellatum  
Hierochloa odorata  
Hippocrepis comosa  
Hippocrepis emerus

Holcus lanatus  
Homogyne alpina  
Hordelymus europaeus  
Hypericum maculatum  
Hypericum pulchrum  
Hypochaeris maculata  
Inula britannica  
Inula conyzae  
Inula ensifolia  
Inula germanica  
Iris germanica  
Iris sibirica  
Jasione montana  
Juniperus sabina  
Knautia arvensis  
Koeleria macrantha  
Koeleria pyramidata  
Krascheninnikovia ceratoides  
Lactuca perennis  
Lactuca serriola  
Lactuca tatarica  
Lactuca tenerrima  
Lamium album  
Lamium maculatum  
Lamium purpureum  
Laserpitium latifolium  
Lathraea clandestina  
Lathyrus linifolius  
Lathyrus nissolia  
Lathyrus pratensis  
Lathyrus sphaericus  
Lathyrus tuberosus  
Lathyrus vernus  
Legousia speculum-veneris  
Leontodon autumnalis  
Leontodon crispus  
Leontodon hirtus  
Leontodon hispidus  
Leontodon incanus  
Leontodon tuberosus  
Lepidium ruderae  
Ligustrum vulgare  
Linaria vulgaris  
Linum catharticum  
Linum hirsutum  
Linum tenuifolium  
Lithospermum officinale  
Loiseleuria procumbens  
Lonicera alpigena

Lonicera etrusca  
Lonicera periclymenum  
Lonicera xylosteum  
Lotus pedunculatus  
Luzula luzuloides  
Luzula nivea  
Luzula pilosa  
Lycopus europaeus  
Lysimachia nummularia  
Malva pusilla  
Marrubium vulgare  
Medicago lupulina  
Melampyrum sylvaticum  
Melica nutans  
Melica uniflora  
Melilotus officinalis  
Mentha arvensis  
Miliium effusum  
Moehringia trinervia  
Myosotis arvensis  
Myosotis stricta  
Myosurus minimus  
Nardus stricta  
Neslia paniculata  
Oenanthe fistulosa  
Ononis arvensis  
Ononis repens  
Onopordum acanthium  
Ophrys insectifera  
Ophrys speculum  
Orchis militaris  
Orchis ustulata  
Origanum vulgare  
Orobanche caryophyllacea  
Oxalis acetosella  
Papaver rhoeas  
Papaver somniferum  
Paris quadrifolia  
Pastinaca hirsuta  
Pastinaca sativa  
Pedicularis kernerii  
Pedicularis oederi  
Pedicularis palustris  
Pedicularis recutita  
Pedicularis sceptrum-carolinum  
Pentaglottis sempervirens  
Petasites albus  
Peucedanum cervaria  
Peucedanum oreoselinum



Phyteuma globulariifolium  
Phyteuma orbiculare  
Phyteuma tenerum  
Pimpinella major  
Pimpinella peregrina  
Pimpinella saxifraga  
Plantago alpina  
Plantago lanceolata  
Plantago major  
Plantago media  
Platanthera bifolia  
Platanthera chlorantha  
Poa alpina  
Poa bulbosa  
Poa chaixii  
Poa glauca  
Poa hybrida  
Poa laxa  
Poa nemoralis  
Polemonium caeruleum  
Polygala amara  
Polygala amarella  
Polygala chamaebuxus  
Polygala comosa  
Polygala nicaeensis  
Polygonatum multiflorum  
Potentilla alba  
Potentilla anglica  
Potentilla anserina  
Potentilla argentea  
Potentilla erecta  
Potentilla micrantha  
Potentilla palustris  
Potentilla patula  
Potentilla recta  
Potentilla reptans  
Potentilla rupestris  
Potentilla sterilis  
Potentilla tabernaemontani  
Primula farinosa  
Primula veris  
Primula vulgaris  
Pritzelago alpina  
Prunella vulgaris  
Pseudofumaria alba  
Pulicaria dysenterica  
Pulmonaria officinalis  
Pulmonaria rubra  
Pulsatilla vulgaris

Pyrola chlorantha  
Ranunculus acris  
Ranunculus cassubicus  
Ranunculus ficaria  
Ranunculus flammula  
Ranunculus kochii  
Ranunculus lanuginosus  
Ranunculus neapolitanus  
Ranunculus peltatus  
Ranunculus polyanthemus  
Ranunculus repens  
Ranunculus reptans  
Reseda lutea  
Rhinanthus alectorolophus  
Rhinanthus groenlandicus  
Rhinanthus minor  
Ribes alpinum  
Rubus caesius  
Rubus chamaemorus  
Rubus saxatilis  
Rumex acetosella  
Rumex alpinus  
Rumex hydrolapathum  
Rumex tuberosus  
Salix reticulata  
Salvia aethiopsis  
Salvia pratensis  
Sambucus nigra  
Sambucus racemosa  
Sanguisorba minor  
Sanguisorba officinalis  
Sanicula europaea  
Saxifraga aizoides  
Scabiosa canescens  
Scabiosa columbaria  
Scabiosa graminifolia  
Scabiosa lucida  
Scabiosa ochroleuca  
Scabiosa triandra  
Scorzonera humilis  
Scorzonera parviflora  
Scrophularia nodosa  
Securigera varia  
Sedum acre  
Sedum album  
Sedum telephium  
Selinum carvifolia  
Senecio adonidifolius  
Senecio aquaticus

Senecio jacobaea  
Senecio paludosus  
Senecio papposus  
Senecio subalpinus  
Senecio viscosus  
Senecio vulgaris  
Sesleria caerulea  
Silaum silaus  
Silene coronaria  
Silene dioica  
Silene flos-cuculi  
Silene latifolia  
Silene noctiflora  
Silene nutans  
Sium latifolium  
Solanum dulcamara  
Solanum nigrum  
Solidago virgaurea  
Sonchus arvensis  
Stachys palustris  
Stachys recta  
Stachys sylvatica  
Stellaria graminea  
Stellaria holostea  
Stellaria media  
Stipa calamagrostis  
Stipa capillata  
Succisa pratensis  
Symphytum officinale  
Tanacetum corymbosum  
Tanacetum macrophyllum  
Tanacetum vulgare  
Teesdalia nudicaulis  
Tephrosia helenitis  
Teucrium botrys  
Teucrium chamaedrys  
Teucrium flavum  
Teucrium montanum  
Teucrium scorodonia  
Thalictrum aquilegifolium  
Thlaspi arvense  
Thlaspi perfoliatum  
Thymus vulgaris  
Tragopogon dubius  
Tragopogon pratensis  
Trientalis europaea  
Trifolium alpestre  
Trifolium arvense  
Trifolium fragiferum

Trifolium hybridum  
Trifolium medium  
Trifolium montanum  
Trifolium pratense  
Trifolium repens  
Trifolium spadiceum  
Turgenia latifolia  
Tussilago farfara  
Vaccinium myrtillus  
Vaccinium oxycoccos  
Vaccinium vitis-idaea  
Valeriana officinalis  
Valeriana saxatilis  
Valeriana tuberosa  
Valerianella carinata  
Valerianella locusta  
Verbascum thapsus  
Veronica alpina  
Veronica arvensis  
Veronica montana  
Veronica officinalis  
Veronica serpyllifolia  
Viburnum lantana  
Viburnum opulus  
Vicia cracca  
Vicia lathyroides  
Vicia sepium  
Vicia tetrasperma  
Vicia villosa  
Vinca major  
Vinca minor  
Viola arvensis  
Viola biflora  
Viola lutea  
Viola odorata  
Viola palustris  
Viola rupestris  
Xeranthemum annuum

range size	niche size	EVA sample geo	EVA sample clim	DMC geo	DMC geo Null	DMC clim	
3 217		426	145	82	0.65	0.74	0.49
3 410		513	166	88	0.39	0.74	0.43
4 427		384	324	96	0.4	0.65	0.48
242 396	5 039		571	198	0.49	0.84	0.29
355 510	3 199	3 998		665	0.43	0.84	0.57
33 302	1 691	1 614		469	0.76	0.85	0.7
3 244		385	699	152	0.57	0.87	0.64
497 713	2 631	2 892		502	0.55	0.92	0.53
518 745	3 649	9 467		776	0.55	0.91	0.57
566 800	7 949	6 201		793	0.66	0.95	0.46
30 295	1 788		692	317	0.65	0.69	0.52
283 332	7 033		602	224	0.44	0.86	0.26
314 205	4 476	1 671		318	0.45	0.77	0.35
410 733	3 735	12 873	1 092		0.6	0.89	0.65
351 315	4 384	4 919		632	0.54	0.85	0.49
100 151	2 192		916	265	0.61	0.72	0.43
668 369	4 853	9 630		570	0.56	0.95	0.47
364 066	3 357		978	126	0.43	0.77	0.28
4 389		446	114	67	0.52	0.6	0.39
4 799		597	68	48	0.48	0.59	0.32
3 006		488	60	41	0.51	0.51	0.35
332 673	3 262	10 660		989	0.64	0.88	0.61
242 346	1 549		356	98	0.47	0.59	0.4
	497	83	70	26	0.4	0.56	0.39
659 229	5 315	11 147		973	0.65	0.95	0.63
614 133	4 916	2 147		630	0.57	0.92	0.61
537 251	6 380	1 086		300	0.43	0.82	0.3
189 874	1 909	2 915		420	0.6	0.83	0.52
708 879	6 449	21 930	1 781		0.67	0.96	0.7
624 495	5 162	8 023		685	0.63	0.92	0.55
440 152	6 988	6 315	1 111		0.59	0.87	0.62
	994	203	41	19	0.35	0.48	0.25
289 311	2 836	2 134		593	0.57	0.89	0.65
170 278	6 098		726	363	0.24	0.71	0.55
571 772	6 412	2 169		569	0.42	0.93	0.47
63 192	1 488	1 298		381	0.64	0.79	0.63

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25 925	1 391		462	201	0.71	0.69	0.47
415 620	3 388	3 236		461	0.63	0.83	0.52
104 317		770	192	65	0.31	0.58	0.31
226 158	4 108		57	38	0.27	0.49	0.16
699 793	6 098	6 085		442	0.5	0.94	0.41
79 104	2 744	1 887		436	0.58	0.82	0.51
180 870	5 535		81	44	0.24	0.55	0.17
91 201		519	658	149	0.56	0.68	0.59
19 702	1 168	1 610		431	0.7	0.9	0.77
125 172	1 892	1 294		185	0.54	0.7	0.48
75 801	1 406		69	54	0.23	0.63	0.3
401 640	4 800	2 967		525	0.59	0.93	0.44
58 881	1 906	1 656		466	0.68	0.85	0.62
11 581		674	121	64	0.51	0.46	0.33
672 148	6 338	11 891	1 251		0.65	0.95	0.62
52 662	2 330		583	118	0.58	0.82	0.37
220 760	3 338		283	85	0.46	0.62	0.27
114 494	2 136		547	228	0.67	0.76	0.46
584 686	6 590		756	207	0.4	0.76	0.28
108 843	2 421		938	385	0.63	0.66	0.57
245 784	4 261	9 013		971	0.61	0.81	0.6
44 194	2 346		297	175	0.65	0.74	0.43
460 231	4 044	1 413		194	0.42	0.86	0.26
422 318	4 361	7 860		996	0.63	0.9	0.56
15 029		892	596	215	0.66	0.63	0.65
80 437	3 493		79	48	0.26	0.49	0.17
486 062	5 230	3 850		561	0.57	0.92	0.45
40 170	1 746	1 548		376	0.54	0.85	0.63
468 084	5 100	8 886	1 064		0.58	0.94	0.58
497 144	6 097	13 527	1 663		0.62	0.96	0.8
230 302	2 297		221	63	0.28	0.53	0.33
427 231	5 525	12 486	1 165		0.59	0.88	0.55
151 123	2 518	6 251		858	0.88	0.86	0.71
95 835	1 910	8 118		860	0.7	0.77	0.54
241 571	6 518	1 116		319	0.45	0.84	0.29
253 048	6 020	2 567		625	0.76	0.93	0.52
426 209	7 312	1 447		339	0.53	0.79	0.37
19 046	1 033	1 486		390	0.61	0.72	0.64
186 550	2 408	2 243		375	0.61	0.9	0.53
11 896		906	414	199	0.63	0.6	0.6
220 969	5 334		74	59	0.31	0.5	0.23
74 867	2 541		888	245	0.75	0.79	0.46
24 957	1 082	1 958		391	0.77	0.83	0.73
492 948	3 786	11 826	1 263		0.74	0.95	0.74
571 808	7 733	6 048		612	0.63	0.95	0.46
2 076		351	153	81	0.59	0.74	0.54
499 660	4 139	2 959		637	0.52	0.84	0.51
404 238	2 389	4 556		552	0.49	0.89	0.6
391 658	2 631	4 369		654	0.62	0.93	0.67

8 046		768	20	19	0.23	0.42	0.19
380 282	3 756	3 733		502	0.47	0.85	0.49
160 400	4 062	1 363		468	0.69	0.77	0.45
598 686	3 690	7 900		946	0.66	0.93	0.63
139 659	1 101		823	171	0.56	0.85	0.47
373 121	3 045	6 127		919	0.65	0.89	0.67
24 035		994 1 456		363	0.74	0.86	0.65
636 060	4 242	11 340		752	0.7	0.93	0.65
172 726	1 400	1 325		240	0.47	0.8	0.53
116 286	1 231		722	181	0.58	0.53	0.38
249 820	3 210	1 342		236	0.6	0.69	0.34
10 677		763 1 339		410	0.93	0.77	0.82
13 867		737	13	13	0.26	0.38	0.16
95 397	5 116		326	167	0.52	0.75	0.41
314 907	4 248		167	79	0.21	0.64	0.18
38 196	1 529	1 758		389	0.57	0.71	0.55
2 709		216 1 832		136	0.78	0.97	0.8
4 364		455 2 196		274	0.68	0.92	0.78
378 303	3 518	6 012		952	0.66	0.86	0.73
266 471	5 226	1 499		383	0.69	0.85	0.47
582 336	5 651	4 604		849	0.63	0.95	0.6
439 621	2 835	1 292		142	0.42	0.89	0.38
346 941	1 797		517	157	0.44	0.8	0.49
12 564		887	375	164	0.62	0.79	0.57
207 218	2 771	1 218		325	0.64	0.85	0.56
421 876	4 614	9 219		893	0.73	0.88	0.65
225 899	1 626	2 160		302	0.6	0.91	0.51
237 595	2 885	6 053		719	0.68	0.8	0.63
37 299	1 103	1 519		364	0.82	0.77	0.7
341 046	4 005	4 294		587	0.63	0.93	0.54
685 506	5 394	5 335		686	0.68	0.96	0.56
32 416	1 676	1 246		418	0.59	0.91	0.59
112 373	1 965		677	198	0.54	0.73	0.41
21 367	1 374		779	249	0.61	0.75	0.52
77 722	1 780	3 333		566	0.7	0.84	0.62
1 905		700 1 221		509	0.89	0.97	0.76
165 721	3 789	4 385		730	0.73	0.8	0.54
190 403	6 525		481	222	0.5	0.81	0.29
557 758	5 016	2 680		487	0.48	0.88	0.44
28 423	1 545		188	129	0.58	0.68	0.43
142 764	3 451		262	128	0.41	0.66	0.32
586 120	4 133	2 332		220	0.37	0.86	0.4
2 986		325	3	3	0.08	0.13	0.08
378 031	3 028	10 363		764	0.62	0.85	0.58
2 485		187	116	44	0.62	0.51	0.41
158 851		459	489	152	0.37	0.67	0.6
514 405	4 439	4 086		643	0.49	0.9	0.51
283 327	3 718	2 535		411	0.7	0.82	0.52
7 916		359	942	100	0.55	0.77	0.51

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40 089	2 538		645	284	0.41	0.48	0.4
275 711	3 304	2 124		380	0.58	0.78	0.48
68 330	1 766	1 746		416	0.69	0.86	0.6
223 185		813	258	57	0.32	0.74	0.29
129 726	2 759		241	66	0.38	0.59	0.34
647 909	8 378	3 579		541	0.57	0.94	0.35
4 410		553	20	13	0.27	0.38	0.08
309 820	4 489	6 310		735	0.62	0.92	0.5
109 423	1 660	3 229		496	0.89	0.8	0.64
17 168		953 1 061		316	0.7	0.78	0.7
13 342		833	223	95	0.55	0.56	0.5
6 884		593	26	23	0.26	0.43	0.22
344 237	1 584	5 381		447	0.6	0.89	0.67
75 419		952 1 793		255	0.75	0.83	0.65
630 010	6 394	4 952		599	0.54	0.93	0.46
196 855	2 158		531	188	0.4	0.8	0.33
533 191	6 868	7 353	1 280		0.57	0.92	0.57
599 766	4 264		659	303	0.39	0.85	0.46
589 507	7 826		503	217	0.45	0.82	0.32
25 137	1 645		61	37	0.44	0.39	0.24
454 950	3 986	5 980		659	0.61	0.91	0.47
22 677	1 268		175	83	0.45	0.66	0.27
12 936		778	336	171	0.68	0.68	0.54
33 784		401	127	64	0.3	0.45	0.45
141 018	2 187	1 296		360	0.62	0.72	0.5
341 891	2 888		658	214	0.38	0.82	0.39
136 565	1 398	1 730		205	0.73	0.82	0.6
235 059	2 233	3 857		426	0.62	0.79	0.52
209 972	4 082	2 720		435	0.57	0.79	0.42
200 485	1 212		285	136	0.42	0.7	0.55
473 203	2 071		611	109	0.43	0.72	0.34
105 382	2 524		942	350	0.73	0.71	0.51
255 626	5 188	2 583		620	0.59	0.9	0.46
68 734	4 589		136	111	0.42	0.63	0.4
90 297	3 448		681	286	0.51	0.78	0.46
32 291	2 084		892	388	0.58	0.72	0.62
210 654	3 669		337	155	0.45	0.76	0.33
332 132	4 179	10 300		991	0.64	0.88	0.56
27 429	1 673		196	142	0.55	0.69	0.61
10 128		465	213	76	0.57	0.8	0.45
215 317	1 950		918	300	0.43	0.76	0.46
1 947		571	644	282	0.68	0.85	0.76
450 341	7 451	10 510	1 049		0.62	0.87	0.52
546 715	5 222	13 780	1 453		0.67	0.93	0.68
116 918	2 428		500	207	0.52	0.56	0.42
54 326	1 147	2 715		396	0.83	0.76	0.7
360 594	2 302	1 882		318	0.57	0.77	0.54
2 435		408	245	121	0.87	0.63	0.57
423 390	2 310		394	153	0.39	0.84	0.43



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88 597	2 848		560	185	0.46	0.74	0.31
43 113	2 455		92	62	0.43	0.6	0.31
120 342	1 752	1 881		424	0.56	0.79	0.58
22 969		885	323	133	0.49	0.53	0.5
17 407	1 080	1 203		383	0.57	0.62	0.65
39 526	1 152	2 124		527	0.72	0.81	0.68
6 216		510	146	80	0.51	0.69	0.53
142 706	3 852		794	320	0.38	0.83	0.48
9 895		848	63	52	0.49	0.51	0.35
147 083	1 494		860	299	0.55	0.72	0.61
422 371	4 379	3 822		608	0.56	0.8	0.52
264 836	1 557	1 730		399	0.68	0.78	0.68
555 114	7 898	4 693		563	0.59	0.94	0.45
348 838	3 783	2 106		576	0.47	0.85	0.59
57 182	1 077	2 225		350	0.77	0.86	0.72
16 051	1 332		118	88	0.43	0.71	0.4
607 547	4 860	1 895		509	0.58	0.91	0.51
196 506	2 431		144	113	0.43	0.67	0.41
666 444	4 970	2 574		592	0.65	0.94	0.54
668 594	8 806	3 507		591	0.55	0.93	0.4
247 853	4 588	6 181		818	0.68	0.89	0.54
29 572	1 676		965	268	0.83	0.86	0.51
587 189	3 133	1 094		101	0.35	0.89	0.3
426 947	4 819	5 519		724	0.6	0.91	0.56
142 951	3 376	7 383	1 110		0.81	0.92	0.67
186 725	2 315	9 026		819	0.85	0.9	0.71
471 060	7 005	2 533		376	0.5	0.9	0.38
279 204	2 015	2 964		585	0.55	0.82	0.65
91 356	2 258	2 499		538	0.6	0.71	0.56
16 027		843	170	89	0.58	0.63	0.4
402 004	3 898	4 854		566	0.59	0.93	0.47
142 812	2 157	4 569		906	0.75	0.8	0.77
582 960	5 140	12 124		819	0.56	0.9	0.47
158 103	5 845		594	272	0.54	0.82	0.44
707 727	5 761	13 042		895	0.69	0.96	0.59
410 902	4 817	4 257		697	0.7	0.93	0.51
693 388	6 830	15 021	1 535		0.6	0.96	0.59
422 233	4 739	3 705		391	0.59	0.94	0.36
570 718	3 892	2 021		201	0.41	0.92	0.38
49 142		604	150	53	0.36	0.64	0.3
483 358	3 065	1 987		340	0.36	0.85	0.37
21 553	1 426		937	346	0.72	0.83	0.64
583 465	7 102	14 483	1 199		0.62	0.95	0.56
3 287		465	338	184	0.88	0.61	0.68
596 277	3 209	2 824		420	0.62	0.9	0.56
42 530		904	910	156	0.66	0.77	0.42
2 554		343	29	24	0.41	0.4	0.31
7 286		608	331	125	0.57	0.77	0.59
97 578		813	176	64	0.31	0.75	0.2

7 173		471	273	124	0.54	0.77	0.61
60 580	2 397	2 241		612	0.65	0.84	0.65
2 975		290	125	79	0.72	0.62	0.74
565 727	4 238		504	129	0.33	0.78	0.29
3 986		197	48	24	0.49	0.49	0.37
119 114		813	7	6	0.15	0.2	0.1
630 730	3 309	6 106		522	0.66	0.94	0.59
651 266	8 295	12 532	1 235		0.63	0.94	0.52
2 763		700 1 003		266	0.73	0.89	0.6
55 674		895 1 069		218	0.75	0.78	0.67
7 079		862	515	218	0.62	0.72	0.64
32 874	2 062	2 381		508	0.62	0.85	0.65
7 303		689	368	180	0.63	0.73	0.62
289 774	3 164		637	243	0.51	0.83	0.4
26 247	1 795	1 096		330	0.63	0.77	0.54
2 491		323	167	85	0.51	0.75	0.5
15 126	1 191		147	104	0.42	0.64	0.46
38 291	1 783		972	370	0.65	0.69	0.65
3 711		315	39	30	0.3	0.42	0.32
62 272	1 696		637	202	0.58	0.72	0.41
238 288	4 407	1 111		370	0.52	0.78	0.45
343 304	7 716	2 455		474	0.56	0.87	0.41
398 787	1 970	1 047		148	0.37	0.8	0.38
424 629	2 221	1 982		242	0.5	0.85	0.47
536 916	8 327	12 672	1 421		0.6	0.95	0.57
313 009	3 866	2 692		659	0.68	0.88	0.52
551 689	5 137	2 953		767	0.6	0.92	0.58
667 193	5 460	4 530		677	0.65	0.94	0.58
182 444	2 421		319	90	0.36	0.78	0.16
570 188	4 194	11 345		717	0.62	0.94	0.5
89 548	2 628	1 988		473	0.69	0.78	0.47
306 938	3 307		816	186	0.54	0.82	0.31
608 455	5 627	2 992		667	0.53	0.92	0.52
72 877	3 006		186	110	0.19	0.65	0.28
238 436	1 030		873	94	0.51	0.82	0.37
412 473	4 452	5 354		537	0.58	0.94	0.44
70 342	1 835	2 765		555	0.78	0.91	0.65
616 113	4 639	11 840	1 011		0.55	0.92	0.56
493 621	6 075		826	249	0.5	0.86	0.42
51 584	1 650		269	122	0.43	0.67	0.31
144 069	3 386		848	346	0.29	0.77	0.38
10 218		846	88	69	0.41	0.61	0.41
473 445	5 361	10 866	1 232		0.42	0.92	0.58
8 404		765	174	88	0.72	0.53	0.52
548 419	5 195	13 395	1 271		0.63	0.94	0.61
689 495	5 298	3 957		517	0.53	0.96	0.46
578 198	3 544		192	57	0.37	0.7	0.34
103 537	2 556	4 159		743	0.79	0.9	0.67
73 842	3 507	2 361		626	0.64	0.85	0.63

351 172	4 071	20 003	1 264		0.77	0.91	0.6
22 347	1 371	2 627		572	0.86	0.84	0.76
6 522		897 2 013		448	0.61	0.86	0.72
426 209	2 888	4 870		645	0.55	0.9	0.56
94 479	1 322	2 227		342	0.67	0.81	0.57
367 057	2 819	1 332		425	0.56	0.87	0.51
462 086	4 865	1 274		185	0.47	0.87	0.26
151 307	2 989	1 914		422	0.74	0.81	0.52
45 215	1 065		636	150	0.51	0.51	0.42
122 604	2 364		188	80	0.38	0.68	0.21
52 769	2 346		26	21	0.24	0.35	0.17
317 575	2 232		367	113	0.43	0.8	0.33
300 705	2 621	3 458		580	0.73	0.87	0.63
1 202		572	142	101	0.43	0.63	0.44
594 525	4 705	8 599		740	0.58	0.92	0.46
186 748	1 751	3 463		462	0.51	0.78	0.63
136 107	1 873	3 209		590	0.82	0.72	0.64
50 153	1 011		18	13	0.15	0.3	0.09
32 016	1 447		894	302	0.73	0.79	0.52
478 965	7 469	2 206		389	0.5	0.81	0.35
115 612	1 607		217	50	0.32	0.44	0.21
12 847		701	27	24	0.36	0.4	0.31
468 648	4 635	2 005		221	0.4	0.83	0.34
332 015	3 433	3 634		633	0.61	0.9	0.55
480 896	4 175	3 213		356	0.49	0.82	0.43
127 481	2 270	1 918		519	0.58	0.77	0.59
15 031		410	195	87	0.58	0.63	0.56
169 813	2 832	3 168		629	0.62	0.91	0.5
100 278	2 330		310	135	0.5	0.64	0.34
712 125	6 478	12 531	1 047		0.56	0.94	0.52
71 563	3 017		193	138	0.42	0.62	0.31
359 977	4 129	1 280		202	0.49	0.82	0.37
460 534	3 195	5 147		683	0.53	0.91	0.55
106 967	3 051		227	101	0.45	0.72	0.32
628 275	4 255	9 162		779	0.66	0.95	0.67
97 223	4 500	1 284		420	0.54	0.8	0.4
14 035		680	330	126	0.67	0.65	0.52
392 367	4 413	10 237	1 061		0.61	0.88	0.63
7 608		576	504	192	0.8	0.72	0.61
60 463	2 804		287	174	0.51	0.71	0.41
353 519	3 998		541	113	0.34	0.56	0.26
176 769	4 147	8 389		850	0.66	0.84	0.59
546 119	3 206	3 495		345	0.54	0.91	0.51
425 100	4 187	7 455		919	0.57	0.89	0.61
53 021	1 705		161	66	0.43	0.65	0.29
120 282	4 292	1 434		374	0.6	0.84	0.41
454 563	5 862		380	171	0.45	0.78	0.3
99 839	2 495		388	217	0.52	0.77	0.5
21 547	1 238	1 579		430	0.73	0.84	0.72

73 881	3 426	1 847		530	0.66	0.87	0.53
120 436	1 939	7 712		639	0.69	0.82	0.6
409 245	3 008	6 966		900	0.58	0.92	0.63
150 423	1 926	7 531		664	0.71	0.73	0.68
85 467	1 486	6 138		659	0.89	0.82	0.67
20 040		957 1 707		444	0.72	0.9	0.7
597 428	4 483	6 450		770	0.63	0.96	0.58
580 107	6 749	8 212		672	0.64	0.97	0.46
428 151	2 393	8 319		501	0.6	0.86	0.59
329 321	1 463		102	45	0.21	0.44	0.24
418 812	7 635		278	158	0.42	0.75	0.28
523 077	6 783	10 045	1 045		0.64	0.88	0.5
349 019	3 002	2 197		578	0.52	0.88	0.6
569 049	4 331	5 902		663	0.58	0.95	0.53
220 655	3 968	6 668	1 029		0.73	0.92	0.53
597 137	6 514	1 490		330	0.49	0.89	0.35
614 194	3 654	5 264		435	0.55	0.92	0.46
648 436	4 989	6 939		862	0.61	0.92	0.57
548 141	6 526	6 732		818	0.5	0.93	0.46
673 636	6 253	4 660		495	0.5	0.92	0.42
427 436	3 350	1 636		244	0.5	0.8	0.42
520 092	3 281		427	63	0.31	0.81	0.2
490 456	4 970	6 948	1 096		0.63	0.9	0.66
470 741	3 865		614	133	0.29	0.77	0.25
157 810	2 792	1 285		166	0.64	0.82	0.45
286 160	3 094		940	203	0.47	0.89	0.29
134 352	2 636	2 042		325	0.66	0.78	0.51
336 278	5 333		366	147	0.43	0.72	0.25
80 627	1 513		474	152	0.59	0.67	0.41
20 038		972	12	12	0.21	0.24	0.15
271 959	2 446		495	137	0.43	0.81	0.35
271 203	2 730		578	258	0.48	0.82	0.5
513 921	6 968	5 220	1 007		0.61	0.92	0.58
155 493	2 853		266	113	0.42	0.63	0.31
498 856	4 619	13 169	1 272		0.64	0.94	0.65
397 710	7 966	2 756		428	0.5	0.82	0.38
643 275	8 257		103	42	0.2	0.58	0.16
540 336	4 031	6 298		821	0.59	0.9	0.55
8 864		518	134	61	0.43	0.67	0.43
497 005	3 779	2 765		376	0.48	0.84	0.51
4 207		620	88	51	0.51	0.74	0.37
13 885		820	93	60	0.33	0.67	0.32
572 533	3 092	1 324		344	0.61	0.9	0.58
6 115		521	49	32	0.49	0.56	0.32
357 634	1 219		36	23	0.26	0.38	0.27
1 926		210	47	42	0.48	0.34	0.57
49 567	2 004	2 452		507	0.67	0.77	0.6
159 907	2 018	1 907		349	0.65	0.89	0.59
261 695	2 388	2 003		392	0.6	0.91	0.47

4 947		620	163	75	0.46	0.82	0.47
56 734	1 531	1 862		543	0.73	0.76	0.66
27 761		645	182	52	0.43	0.75	0.29
195 844	2 442	4 035		587	0.57	0.74	0.61
31 713	2 118		64	56	0.28	0.48	0.28
597 853	5 533	10 415		904	0.56	0.94	0.5
3 998		673	435	194	0.82	0.79	0.62
581 554	8 303	24 321	1 601		0.65	0.9	0.58
773 711	9 318	11 413		989	0.58	0.95	0.49
610 231	4 574	8 272		920	0.55	0.93	0.52
522 765	3 832	3 182		675	0.52	0.89	0.54
218 735	4 048	1 090		364	0.64	0.8	0.43
250 333	4 804	1 699		587	0.52	0.75	0.6
416 199	7 806	3 249		819	0.59	0.9	0.49
49 361	1 243	1 270		329	0.79	0.77	0.57
112 001	2 502		29	24	0.27	0.41	0.23
21 482		982	144	95	0.51	0.65	0.38
16 105		884	142	80	0.45	0.7	0.4
580 595	4 339	12 307	1 365		0.61	0.91	0.72
321 909	1 968		126	57	0.32	0.6	0.26
13 653		702	460	176	0.8	0.57	0.65
263 592	1 461		730	202	0.42	0.73	0.55
14 858		905 1 538		401	0.75	0.9	0.73
385 280	2 780	1 835		359	0.55	0.89	0.5
41 083	1 868		293	186	0.54	0.78	0.5
378 117	3 923	7 932		717	0.62	0.96	0.53
115 216	1 062		697	144	0.54	0.82	0.4
44 468		432	379	103	0.61	0.54	0.56
576 379	3 860	7 623		380	0.63	0.9	0.58
551 711	5 584	4 012		462	0.51	0.87	0.34
469 358	4 879	15 471	1 412		0.71	0.89	0.66
51 442	2 451	1 543		542	0.68	0.77	0.62
568 549	3 319	3 982		505	0.71	0.89	0.6
98 250		612	39	17	0.17	0.47	0.16
310 320	5 395	1 296		370	0.54	0.84	0.37
439 890	5 726	7 328		829	0.65	0.88	0.52
45 714	1 658		229	137	0.52	0.63	0.43
78 643	1 238	1 506		362	0.68	0.74	0.67
152 945	2 282	3 668		508	0.57	0.83	0.57
40 292	1 037		745	296	0.49	0.63	0.73
362 334	3 307	6 319		906	0.67	0.89	0.64
114 901	3 453	3 200		758	0.77	0.82	0.59
9 503		914	383	193	0.67	0.74	0.64
754 885	9 081	15 019	1 468		0.62	0.96	0.59
8 361		623	34	25	0.49	0.47	0.27
227 645	5 628	1 618		373	0.63	0.91	0.46
348 878	1 803	3 693		538	0.45	0.89	0.6
3 749		339	186	97	0.68	0.61	0.63
30 162		437	901	148	0.7	0.65	0.63

318 116	2 555		510	221	0.38	0.76	0.43
712 893	5 034	17 772	1 162		0.73	0.95	0.71
286 291		641	376	86	0.41	0.82	0.42
464 024	4 926	6 226		708	0.56	0.87	0.53
423 071	2 692	6 728		590	0.57	0.86	0.61
620 310	3 846	4 070		392	0.53	0.91	0.44
153 574	2 389	3 005		599	0.75	0.9	0.7
19 861	1 350		197	115	0.47	0.63	0.43
272 360	3 414		559	157	0.39	0.71	0.34
476 865	3 738	2 077		315	0.51	0.89	0.36
566 117	5 681	20 260	1 187		0.69	0.87	0.61
417 481	2 306		63	50	0.36	0.49	0.31
390 835	7 749	1 179		290	0.52	0.89	0.33
62 813	1 349	1 594		423	0.93	0.7	0.64
41 002		981	18	12	0.15	0.4	0.1
611 460	4 463	5 479		828	0.66	0.94	0.67
193 219	3 002	1 998		462	0.59	0.9	0.55
499 866	6 068	7 488		799	0.65	0.94	0.53
365 232	2 136		555	206	0.54	0.81	0.48
639 655	4 705	2 722		637	0.6	0.93	0.57
733 807	5 821	10 055	1 035		0.62	0.95	0.61
19 299	1 835		386	200	0.46	0.66	0.4
378 565	1 819	2 212		157	0.58	0.86	0.51
63 040	4 254		81	52	0.33	0.52	0.26
86 431	2 427		412	207	0.51	0.82	0.49
91 430	2 771		143	45	0.34	0.59	0.19
246 910	3 023	4 072		517	0.65	0.9	0.52
329 230	5 030	9 617		920	0.62	0.86	0.53
319 145	2 564	3 595		539	0.5	0.9	0.56
418 495	7 452	10 492	1 313		0.62	0.93	0.58
511 771	3 787	4 674		535	0.53	0.9	0.48
369 149	5 949	6 540	1 089		0.63	0.95	0.58
95 600	2 683		753	344	0.49	0.8	0.53
10 509		162	419	56	0.62	0.77	0.47
61 280	2 462	4 324		711	0.73	0.83	0.7
4 746		652	61	58	0.51	0.52	0.4
16 840	1 119		860	299	0.68	0.78	0.66
174 801	1 366	1 981		257	0.57	0.8	0.51
33 371	1 514		438	183	0.53	0.77	0.48
189 210	1 626	2 049		334	0.61	0.87	0.55
86 500	1 431		94	29	0.33	0.55	0.22
520 653	4 231	6 666		637	0.53	0.93	0.49
327 990	5 252	4 709		511	0.54	0.9	0.38
589 247	5 847	3 849		595	0.58	0.92	0.49
205 568	5 876	2 482		682	0.63	0.86	0.61
539 508	4 960		875	275	0.46	0.88	0.39
345 218	2 401	1 936		227	0.56	0.94	0.44
10 208		601	320	134	0.5	0.85	0.57
99 634	1 266	2 508		330	0.8	0.75	0.69

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457 606	3 975	5 499		544	0.61	0.83	0.56
209 660	1 100		372	75	0.46	0.75	0.4
14 113		759	23	19	0.22	0.36	0.19
4 245		361	255	87	0.55	0.74	0.54
209 510	2 569		793	159	0.44	0.71	0.34
635 356	6 503	3 042		475	0.5	0.89	0.45
39 852	1 410	2 506		544	0.82	0.74	0.77
79 350	1 187	1 317		198	0.78	0.65	0.48
46 171	1 391		505	163	0.57	0.74	0.47
276 924	3 306	4 024		668	0.52	0.81	0.6
590 661	4 603	10 253		729	0.55	0.93	0.49
662 285	5 247	3 832		617	0.56	0.91	0.52
284 879	1 464		764	79	0.35	0.69	0.34
280 659	2 412	4 458		821	0.6	0.76	0.68
455 498	2 558	1 233		114	0.48	0.86	0.45
583 534	7 038	6 288		636	0.52	0.95	0.43
456 676	4 628	1 700		282	0.5	0.73	0.39
714 829	6 099	11 734	1 427		0.71	0.95	0.68
676 579	4 929	3 472		317	0.5	0.95	0.46
614 216	4 956	4 370		320	0.5	0.94	0.42
228 288	2 446	3 532		657	0.73	0.92	0.58
511 568	4 939	7 262		845	0.57	0.95	0.49
673 894	4 469	9 422		798	0.57	0.94	0.54
519 514	4 338	7 465		817	0.63	0.94	0.54
782 025	8 283	9 448		868	0.6	0.93	0.49
30 351	1 795		557	263	0.61	0.85	0.57
69 780		819 1 336		267	0.6	0.62	0.61
461 261	3 616	7 717		805	0.66	0.92	0.64
435 063	2 841	4 563		320	0.53	0.87	0.44
251 708	3 758	3 858		743	0.64	0.91	0.49
13 904		817	32	26	0.33	0.38	0.2
711 463	5 046	3 318		302	0.46	0.9	0.39
113 442	1 569	1 334		189	0.6	0.82	0.42
24 466		583	76	36	0.38	0.58	0.28
84 595	1 993		410	148	0.55	0.79	0.36
229 477	6 489	8 389	1 173		0.67	0.93	0.56
20 396	1 465		415	202	0.65	0.82	0.48
88 296	2 643	2 748		635	0.79	0.87	0.6
111 379	2 060	5 977		877	0.83	0.84	0.72
252 896	2 514	1 866		618	0.61	0.88	0.64
543 757	5 267	2 423		181	0.36	0.75	0.28
334 891	7 459		951	289	0.53	0.87	0.38
17 154		879 1 737		331	0.89	0.67	0.64
254 899	3 481		987	301	0.66	0.85	0.44
251 538	2 693	4 888		635	0.69	0.82	0.62
470 853	2 183	1 899		377	0.67	0.89	0.62
258 641	2 959	2 771		526	0.57	0.92	0.5
600 686	7 134	4 716		722	0.6	0.92	0.45
401 603	6 989	1 750		349	0.6	0.89	0.32

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329 303	2 977	2 702		367	0.58	0.8	0.35
532 318	4 433	4 598		691	0.59	0.9	0.51
383 854	2 687	4 121		680	0.66	0.94	0.67
757 079	7 735	18 692	1 548		0.58	0.96	0.59
596 271	6 181	20 340	1 511		0.65	0.92	0.63
254 579	1 791		326	140	0.22	0.62	0.43
232 025	6 716		44	36	0.22	0.43	0.13
717 047	7 227	4 275		691	0.48	0.94	0.51
589 715	4 543	13 142	1 471		0.71	0.96	0.72
370 558	2 376	2 157		440	0.75	0.79	0.62
536 543	3 732	5 503		886	0.7	0.93	0.69
608 094	5 074	5 239		684	0.6	0.93	0.58
2 978		367	289	125	0.67	0.78	0.63
53 125	1 657		219	123	0.42	0.69	0.43
144 525	3 612		223	100	0.46	0.66	0.29
245 347	4 003		745	199	0.55	0.71	0.36
432 069	4 089		715	240	0.49	0.77	0.4
77 220	2 492		391	208	0.56	0.76	0.52
550 227	6 428	6 154		709	0.54	0.93	0.43
106 293	1 726	2 736		564	0.82	0.81	0.63
625 453	5 495	9 309	1 218		0.6	0.95	0.59
672 317	5 342	3 360		579	0.48	0.93	0.52
162 800	3 917	5 489		758	0.69	0.87	0.58
536 009	4 511	6 416		597	0.55	0.93	0.49
613 465	4 605	12 606		956	0.67	0.92	0.61
150 489	2 908		870	237	0.68	0.8	0.45
617 385	5 430	8 471		924	0.61	0.95	0.55
408 674	4 183	2 953		344	0.57	0.83	0.33
289 994	3 615	1 222		340	0.55	0.81	0.56
16 447	1 096		91	62	0.63	0.61	0.29
151 835	2 157	1 466		377	0.78	0.75	0.54
618 787	5 473	5 027		383	0.52	0.93	0.38
142 116	3 316	1 853		538	0.52	0.84	0.64
6 420		397	301	125	0.75	0.65	0.57
275 846	3 148	1 689		421	0.65	0.75	0.44
515 979	3 578	4 457		666	0.69	0.91	0.7
417 577	3 296		921	292	0.43	0.83	0.51
151 616	4 433		712	142	0.3	0.87	0.25



DMC clim Null	ratio geo	ratio clim	range percent	niche percent	starting grain size [km2]
0.59	0.15	0.2	4.51	19.25	3 030
0.6	0.89	0.4	4.87	17.15	3 356
0.64	0.63	0.32	7.32	25 11	624
0.6	0.7	1.07	0.24	3.93	24 509
0.82	0.97	0.45	1.12	20.79	33 113
0.8	0.11	0.14	4.85	27.74	10 719
0.81	0.51	0.27	21.55	39.48	25 425
0.83	0.66	0.56	0.58	19.08	32 083
0.89	0.64	0.56	1.82	21.27	37 190
0.79	0.43	0.71	1.09	9.98	45 669
0.75	0.05	0.44	2.28	17.73	29 609
0.6	0.98	1.31	0.21	3.18	26 899
0.71	0.73	1.02	0.53	7.1	29 742
0.87	0.49	0.34	3.13	29.24	34 448
0.81	0.57	0.66	1.4	14.42	38 824
0.69	0.18	0.6	0.91	12.09	26 252
0.82	0.72	0.76	1.44	11.75	39 217
0.55	0.8	1	0.27	3.75	34 442
0.53	0.15	0.37	2.6	15.02	2 648
0.44	0.23	0.39	1.42	8.04	3 981
0.42	-0.01	0.17	2	8.4	11 892
0.88	0.38	0.45	3.2	30.32	33 215
0.58	0.26	0.43	0.15	6.33	29 241
0.52	0.4	0.34	14.08	31.33	19 417
0.89	0.45	0.43	1.69	18.31	42 584
0.83	0.63	0.36	0.35	12.82	33 872
0.66	0.93	1.2	0.2	4.7	41 580
0.77	0.39	0.49	1.54	22	19 373
0.9	0.43	0.28	3.09	27.62	49 479
0.83	0.45	0.51	1.28	13.27	42 479
0.84	0.48	0.34	1.43	15.9	40 279
0.36	0.38	0.43	4.12	9.36	14 373
0.81	0.56	0.24	0.74	20.91	30 753
0.73	1.95	0.34	0.43	5.95	53 056
0.77	1.19	0.66	0.38	8.87	39 013
0.79	0.23	0.25	2.05	25.6	16 757

## 5dcae60ab9fa8e4c2030a70009f9

0.7	-0.03	0.48	1.78	14.45 10 364
0.75	0.31	0.45	0.78	13.61 35 098
0.51	0.85	0.68	0.18	8.44 14 903
0.34	0.81	1.06	0.03	0.93 21 107
0.78	0.87	0.91	0.87	7.25 41 908
0.79	0.41	0.56	2.39	15.89 17 271
0.36	1.29	1.15	0.04	0.79 19 692
0.74	0.22	0.25	0.72	28.71 19 431
0.86	0.28	0.11	8.17	36.9 4 986
0.68	0.29	0.43	1.03	9.78 36 968
0.51	1.79	0.69	0.09	3.84 23 932
0.77	0.58	0.76	0.74	10.94 29 785
0.8	0.25	0.29	2.81	24.45 12 489
0.49	-0.09	0.49	1.04	9.5 5 431
0.86	0.47	0.39	1.77	19.74 49 787
0.55	0.41	0.49	1.11	5.06 28 995
0.47	0.36	0.74	0.13	2.55 27 168
0.68	0.14	0.48	0.48	10.67 17 466
0.61	0.89	1.16	0.13	3.14 46 386
0.79	0.06	0.39	0.86	15.9 35 377
0.88	0.33	0.46	3.67	22.79 42 087
0.61	0.15	0.42	0.67	7.46 13 683
0.65	1.02	1.45	0.31	4.8 29 049
0.87	0.41	0.55	1.86	22.84 33 291
0.77	-0.05	0.19	3.97	24.1 33 982
0.38	0.86	1.27	0.1	1.37 19 162
0.79	0.62	0.77	0.79	10.73 36 782
0.79	0.59	0.25	3.85	21.53 13 607
0.85	0.61	0.47	1.9	20.86 35 839
0.88	0.55	0.1	2.72	27.28 35 796
0.48	0.87	0.43	0.1	2.74 38 513
0.87	0.49	0.59	2.92	21.09 35 001
0.88	-0.03	0.23	4.14	34.07 17 245
0.9	0.1	0.68	8.47	45.03 40 356
0.67	0.84	1.3	0.46	4.89 26 009
0.8	0.22	0.52	1.01	10.38 27 318
0.66	0.51	0.79	0.34	4.64 37 071
0.85	0.17	0.32	7.8	37.75 10 832
0.73	0.47	0.36	1.2	15.57 21 620
0.72	-0.04	0.19	3.48	21.96 9 088
0.4	0.62	0.73	0.03	1.11 27 755
0.68	0.06	0.5	1.19	9.64 31 360
0.83	0.08	0.13	7.85	36.14 7 841
0.91	0.28	0.23	2.4	33.36 43 845
0.75	0.5	0.63	1.06	7.91 44 450
0.61	0.27	0.12	7.37	23.08 3 357
0.81	0.62	0.58	0.59	15.39 33 560
0.87	0.8	0.45	1.13	23.11 33 717
0.89	0.51	0.33	1.12	24.86 27 679

## 5dcae60ab9fa8e4c2030a70009f9

0.29	0.88	0.55	0.25	2.47 4 470
0.79	0.81	0.6	0.98	13.37 35 835
0.76	0.11	0.67	0.85	11.52 23 845
0.91	0.4	0.44	1.32	25.64 44 256
0.72	0.52	0.54	0.59	15.53 16 237
0.85	0.37	0.27	1.64	30.18 31 856
0.85	0.16	0.3	6.06	36.52 6 056
0.89	0.34	0.37	1.78	17.73 43 324
0.74	0.71	0.4	0.77	17.14 22 886
0.67	-0.08	0.75	0.62	14.7 27 009
0.66	0.16	0.97	0.54	7.35 28 574
0.89	-0.18	0.09	12.54	53.74 9 050
0.24	0.48	0.45	0.09	1.76 6 586
0.6	0.45	0.44	0.34	3.26 30 925
0.45	2.13	1.48	0.05	1.86 28 392
0.82	0.25	0.5	4.6	25.44 25 515
0.85	0.24	0.07	67.63	62.96 22 526
0.87	0.35	0.11	50.32	60.22 13 744
0.9	0.31	0.23	1.59	27.06 34 678
0.7	0.24	0.5	0.56	7.33 36 276
0.87	0.51	0.44	0.79	15.02 41 493
0.65	1.13	0.7	0.29	5.01 29 689
0.67	0.81	0.34	0.15	8.74 27 830
0.69	0.28	0.21	2.98	18.49 4 381
0.76	0.33	0.37	0.59	11.73 25 076
0.86	0.21	0.33	2.19	19.35 39 834
0.76	0.52	0.48	0.96	18.57 18 878
0.86	0.16	0.38	2.55	24.92 37 186
0.83	-0.06	0.19	4.07	33 25 253
0.81	0.49	0.49	1.26	14.66 29 012
0.85	0.41	0.53	0.78	12.72 38 627
0.81	0.55	0.37	3.84	24.94 8 999
0.65	0.35	0.59	0.6	10.08 19 957
0.76	0.23	0.45	3.65	18.12 9 555
0.84	0.21	0.36	4.29	31.8 13 067
0.95	0.08	0.25	64.09	72.71 11 449
0.84	0.09	0.54	2.65	19.27 34 821
0.59	0.63	1.01	0.25	3.4 28 924
0.77	0.84	0.74	0.48	9.71 39 579
0.63	0.18	0.47	0.66	8.35 7 729
0.56	0.6	0.74	0.18	3.71 29 318
0.69	1.29	0.74	0.4	5.32 38 174
0.12	0.63	0.58	0.1	0.92 1 039
0.85	0.37	0.45	2.74	25.23 36 945
0.53	-0.18	0.3	4.67	23.53 3 938
0.74	0.83	0.24	0.31	33.12 22 781
0.84	0.85	0.63	0.79	14.49 46 044
0.73	0.17	0.39	0.89	11.05 32 749
0.65	0.4	0.28	11.9	27.86 14 019

## 5dcae60ab9fa8e4c2030a70009f9

0.7	0.19	0.74	1.61	11.19 30 421
0.73	0.34	0.52	0.77	11.5 30 320
0.8	0.25	0.34	2.56	23.56 11 883
0.48	1.3	0.7	0.12	7.01 17 302
0.48	0.56	0.39	0.19	2.39 35 939
0.71	0.66	1	0.55	6.46 47 842
0.23	0.4	2	0.45	2.35 3 644
0.82	0.49	0.63	2.04	16.37 31 149
0.82	-0.09	0.28	2.95	29.88 25 722
0.8	0.12	0.15	6.18	33.16 9 125
0.59	0.02	0.19	1.67	11.4 8 028
0.31	0.63	0.38	0.38	3.88 2 372
0.84	0.47	0.25	1.56	28.22 24 545
0.78	0.11	0.21	2.38	26.79 13 770
0.77	0.71	0.66	0.79	9.37 38 712
0.62	0.97	0.89	0.27	8.71 23 578
0.85	0.61	0.49	1.38	18.64 37 186
0.76	1.15	0.64	0.11	7.11 37 894
0.59	0.81	0.87	0.09	2.77 47 812
0.37	-0.12	0.54	0.24	2.25 16 725
0.84	0.49	0.78	1.31	16.53 34 358
0.51	0.47	0.87	0.77	6.55 15 546
0.72	0.01	0.32	2.6	21.98 5 730
0.56	0.49	0.25	0.38	15.96 23 584
0.73	0.16	0.44	0.92	16.46 24 675
0.68	1.14	0.71	0.19	7.41 31 915
0.73	0.13	0.22	1.27	14.66 19 834
0.77	0.28	0.5	1.64	19.08 22 924
0.74	0.39	0.75	1.3	10.66 32 488
0.65	0.69	0.19	0.14	11.22 22 876
0.56	0.68	0.63	0.13	5.26 36 362
0.73	-0.03	0.44	0.89	13.87 28 286
0.79	0.51	0.71	1.01	11.95 24 693
0.55	0.51	0.38	0.2	2.42 12 616
0.7	0.52	0.54	0.75	8.29 15 369
0.81	0.23	0.31	2.76	18.62 15 864
0.58	0.68	0.74	0.16	4.22 30 287
0.88	0.37	0.58	3.1	23.71 28 798
0.63	0.25	0.03	0.71	8.49 9 566
0.6	0.41	0.34	2.1	16.34 6 167
0.81	0.77	0.76	0.43	15.38 30 301
0.85	0.25	0.13	33.08	49.39 17 485
0.81	0.41	0.56	2.33	14.08 40 548
0.9	0.39	0.33	2.52	27.82 43 203
0.67	0.07	0.61	0.43	8.53 25 630
0.84	-0.08	0.19	5	34.52 16 035
0.78	0.35	0.45	0.52	13.81 34 856
0.71	-0.28	0.26	10.06	29.66 6 483
0.66	1.15	0.53	0.09	6.62 27 312

## 5dcae60ab9fa8e4c2030a70009f9

0.62	0.63	1	0.63	6.5 22 085
0.46	0.4	0.49	0.21	2.53 10 127
0.8	0.41	0.37	1.56	24.2 21 571
0.63	0.08	0.28	1.41	15.03 11 041
0.82	0.08	0.26	6.91	35.46 13 925
0.88	0.11	0.3	5.37	45.75 20 144
0.57	0.36	0.08	2.35	15.69 1 163
0.77	1.17	0.61	0.56	8.31 42 543
0.47	0.04	0.34	0.64	6.13 21 014
0.81	0.32	0.32	0.58	20.01 27 427
0.8	0.42	0.54	0.9	13.88 40 040
0.84	0.15	0.25	0.65	25.63 38 095
0.73	0.61	0.64	0.85	7.13 35 321
0.81	0.83	0.36	0.6	15.23 38 049
0.83	0.11	0.17	3.89	32.5 20 999
0.52	0.63	0.31	0.74	6.61 7 392
0.79	0.57	0.56	0.31	10.47 37 048
0.63	0.54	0.54	0.07	4.65 44 294
0.83	0.46	0.55	0.39	11.91 38 370
0.73	0.69	0.83	0.52	6.71 49 531
0.84	0.32	0.54	2.49	17.83 27 966
0.74	0.03	0.46	3.26	15.99 26 167
0.55	1.56	0.84	0.19	3.22 35 516
0.81	0.52	0.44	1.29	15.02 33 034
0.91	0.13	0.36	5.16	32.88 19 065
0.87	0.05	0.24	4.83	35.38 16 981
0.7	0.79	0.85	0.54	5.37 46 522
0.86	0.49	0.32	1.06	29.03 27 843
0.83	0.19	0.49	2.74	23.83 32 666
0.56	0.08	0.4	1.06	10.56 12 235
0.81	0.58	0.71	1.21	14.52 29 668
0.91	0.07	0.19	3.2	42 19 528
0.84	0.59	0.78	2.08	15.93 41 826
0.64	0.5	0.47	0.38	4.65 35 326
0.86	0.38	0.45	1.84	15.54 40 192
0.8	0.34	0.57	1.04	14.47 31 302
0.89	0.6	0.5	2.17	22.47 41 440
0.72	0.6	0.99	0.88	8.25 29 782
0.7	1.25	0.83	0.35	5.16 33 565
0.47	0.78	0.55	0.31	8.77 9 642
0.78	1.35	1.09	0.41	11.09 35 379
0.78	0.16	0.21	4.35	24.26 7 561
0.84	0.52	0.51	2.48	16.88 51 165
0.77	-0.31	0.14	10.28	39.57 5 169
0.83	0.45	0.48	0.47	13.09 39 631
0.68	0.17	0.62	2.14	17.26 8 995
0.36	-0.04	0.16	1.14	7 1 807
0.65	0.37	0.1	4.54	20.56 6 364
0.51	1.44	1.56	0.18	7.87 10 875

## 5dcae60ab9fa8e4c2030a70009f9

0.68	0.43	0.1	3.81	26.33 4 057
0.85	0.29	0.31	3.7	25.53 25 631
0.69	-0.15	-0.07	4.2	27.24 10 557
0.57	1.33	0.97	0.09	3.04 38 911
0.4	0	0.08	1.2	12.18 4 552
0.16	0.32	0.62	0.01	0.74 18 988
0.87	0.42	0.47	0.97	15.78 34 499
0.84	0.49	0.6	1.92	14.89 43 534
0.8	0.23	0.32	36.3	38 15 752
0.77	0.04	0.15	1.92	24.36 14 297
0.75	0.17	0.18	7.28	25.29 5 642
0.82	0.37	0.27	7.24	24.64 13 733
0.73	0.16	0.19	5.04	26.12 4 129
0.71	0.61	0.77	0.22	7.68 25 474
0.73	0.21	0.35	4.18	18.38 11 144
0.64	0.46	0.26	6.7	26.32 2 669
0.61	0.51	0.32	0.97	8.73 4 723
0.78	0.07	0.19	2.54	20.75 16 752
0.39	0.39	0.24	1.05	9.52 3 092
0.66	0.23	0.61	1.02	11.91 11 159
0.76	0.48	0.68	0.47	8.4 32 064
0.73	0.55	0.77	0.72	6.14 44 713
0.66	1.12	0.74	0.26	7.51 32 129
0.75	0.71	0.59	0.47	10.9 31 075
0.84	0.59	0.48	2.36	17.06 49 626
0.82	0.29	0.57	0.86	17.05 31 891
0.88	0.53	0.5	0.54	14.93 41 202
0.84	0.44	0.45	0.68	12.4 43 563
0.51	1.16	2.09	0.17	3.72 23 039
0.85	0.52	0.69	1.99	17.1 35 365
0.78	0.12	0.66	2.22	18 21 629
0.61	0.52	0.96	0.27	5.62 27 727
0.82	0.74	0.58	0.49	11.85 38 483
0.56	2.47	1	0.26	3.66 34 894
0.59	0.61	0.59	0.37	9.13 21 246
0.79	0.62	0.8	1.3	12.06 33 732
0.86	0.17	0.32	3.93	30.25 12 589
0.9	0.68	0.61	1.92	21.79 37 265
0.61	0.71	0.46	0.17	4.1 36 373
0.61	0.57	0.94	0.52	7.39 24 519
0.76	1.67	0.99	0.59	10.22 39 638
0.5	0.48	0.22	0.86	8.16 3 372
0.88	1.19	0.51	2.3	22.98 40 597
0.55	-0.26	0.07	2.07	11.5 8 300
0.89	0.48	0.46	2.44	24.47 36 295
0.8	0.81	0.74	0.57	9.76 36 600
0.46	0.87	0.35	0.03	1.61 41 960
0.86	0.14	0.28	4.02	29.07 13 911
0.84	0.33	0.32	3.2	17.85 20 491

## 5dcae60ab9fa8e4c2030a70009f9

0.89	0.18	0.49	5.7	31.05 39 318
0.87	-0.02	0.14	11.76	41.72 8 139
0.86	0.41	0.2	30.86	49.94 24 443
0.85	0.63	0.51	1.14	22.33 33 128
0.8	0.21	0.4	2.36	25.87 18 768
0.8	0.54	0.56	0.36	15.08 28 189
0.61	0.86	1.33	0.28	3.8 31 224
0.76	0.1	0.48	1.26	14.12 21 231
0.64	0	0.54	1.41	14.08 16 555
0.48	0.76	1.29	0.15	3.38 20 135
0.28	0.43	0.69	0.05	0.9 14 627
0.57	0.84	0.74	0.12	5.06 24 609
0.83	0.2	0.32	1.15	22.13 35 903
0.6	0.46	0.37	11.81	17.66 22 874
0.83	0.59	0.8	1.45	15.73 40 258
0.82	0.55	0.3	1.85	26.38 31 462
0.83	-0.13	0.3	2.36	31.5 30 550
0.25	1.04	1.81	0.04	1.29 23 317
0.77	0.07	0.49	2.79	20.87 11 406
0.68	0.62	0.93	0.46	5.21 42 756
0.4	0.38	0.95	0.19	3.11 29 208
0.31	0.13	0.01	0.21	3.42 6 484
0.67	1.06	0.95	0.43	4.77 37 188
0.83	0.48	0.5	1.09	18.44 29 609
0.71	0.69	0.66	0.67	8.53 49 302
0.81	0.34	0.38	1.5	22.86 20 495
0.61	0.09	0.09	1.3	21.22 8 644
0.85	0.47	0.69	1.87	22.21 25 032
0.59	0.28	0.75	0.31	5.79 22 600
0.86	0.68	0.66	1.76	16.16 43 074
0.55	0.48	0.78	0.27	4.57 32 591
0.64	0.67	0.74	0.36	4.89 29 512
0.86	0.72	0.58	1.12	21.38 30 266
0.53	0.61	0.65	0.21	3.31 17 997
0.88	0.45	0.32	1.46	18.31 42 584
0.74	0.47	0.87	1.32	9.33 15 183
0.65	-0.03	0.26	2.35	18.53 8 415
0.87	0.44	0.4	2.61	24.04 31 911
0.76	-0.11	0.23	6.62	33.33 4 292
0.61	0.41	0.46	0.47	6.21 12 746
0.52	0.62	1	0.15	2.83 46 637
0.84	0.27	0.44	4.75	20.5 27 915
0.78	0.67	0.54	0.64	10.76 30 604
0.86	0.57	0.41	1.75	21.95 40 192
0.5	0.52	0.73	0.3	3.87 10 526
0.71	0.41	0.71	1.19	8.71 17 451
0.58	0.74	0.93	0.08	2.92 36 238
0.73	0.48	0.45	0.39	8.7 34 250
0.84	0.14	0.17	7.33	34.73 7 050

## 5dcae60ab9fa8e4c2030a70009f9

0.78	0.32	0.47	2.5	15.47 22 364
0.86	0.2	0.43	6.4	32.96 21 532
0.92	0.59	0.46	1.7	29.92 32 820
0.86	0.03	0.27	5.01	34.48 37 622
0.87	-0.08	0.31	7.18	44.35 11 279
0.87	0.25	0.24	8.52	46.39 4 451
0.85	0.51	0.46	1.08	17.18 33 871
0.8	0.5	0.72	1.42	9.96 34 288
0.82	0.43	0.4	1.94	20.94 31 154
0.4	1.06	0.69	0.03	3.08 41 067
0.53	0.8	0.9	0.07	2.07 39 074
0.82	0.37	0.66	1.92	15.41 45 273
0.85	0.7	0.41	0.63	19.25 35 646
0.85	0.63	0.59	1.04	15.31 32 210
0.88	0.26	0.67	3.02	25.93 28 312
0.68	0.81	0.95	0.25	5.07 37 649
0.8	0.66	0.75	0.86	11.9 33 939
0.86	0.51	0.51	1.07	17.28 45 464
0.82	0.84	0.78	1.23	12.53 37 484
0.76	0.84	0.8	0.69	7.92 48 852
0.68	0.62	0.6	0.38	7.28 43 596
0.43	1.61	1.15	0.08	1.92 33 017
0.88	0.45	0.34	1.42	22.05 42 463
0.57	1.7	1.28	0.13	3.44 35 624
0.63	0.28	0.39	0.81	5.95 24 154
0.66	0.89	1.26	0.33	6.56 24 384
0.73	0.19	0.45	1.52	12.33 23 064
0.56	0.69	1.24	0.11	2.76 31 825
0.62	0.14	0.49	0.59	10.05 23 516
0.22	0.12	0.48	0.06	1.23 7 438
0.59	0.91	0.7	0.18	5.6 24 948
0.67	0.72	0.34	0.21	9.45 24 441
0.82	0.51	0.42	1.02	14.45 37 178
0.54	0.49	0.77	0.17	3.96 22 621
0.92	0.48	0.42	2.64	27.54 36 119
0.7	0.63	0.85	0.69	5.37 48 151
0.35	1.98	1.24	0.02	0.51 39 550
0.86	0.52	0.58	1.17	20.37 38 764
0.52	0.58	0.22	1.51	11.78 1 300
0.77	0.73	0.51	0.56	9.95 36 163
0.47	0.46	0.28	2.09	8.23 3 248
0.53	1.05	0.68	0.67	7.32 24 901
0.8	0.49	0.39	0.23	11.13 30 442
0.39	0.16	0.21	0.8	6.14 3 112
0.32	0.48	0.2	0.01	1.89 19 184
0.51	-0.3	-0.1	2.44	20 11 190
0.84	0.16	0.38	4.95	25.3 19 291
0.76	0.38	0.3	1.19	17.29 17 161
0.75	0.52	0.61	0.77	16.42 24 511



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0.56	0.78	0.19	3.29	12.1 3 243
0.86	0.03	0.31	3.28	35.47 11 502
0.47	0.73	0.64	0.66	8.06 8 171
0.82	0.31	0.34	2.06	24.04 28 687
0.42	0.69	0.48	0.2	2.64 11 434
0.84	0.69	0.68	1.74	16.34 36 203
0.75	-0.05	0.21	10.88	28.83 6 207
0.85	0.39	0.46	4.18	19.28 49 073
0.8	0.62	0.63	1.48	10.61 57 578
0.87	0.68	0.67	1.36	20.11 38 836
0.84	0.71	0.54	0.61	17.61 36 435
0.75	0.25	0.73	0.5	8.99 31 192
0.8	0.45	0.34	0.68	12.22 46 677
0.78	0.52	0.59	0.78	10.49 44 199
0.77	-0.02	0.35	2.57	26.47 12 769
0.33	0.48	0.43	0.03	0.96 43 771
0.58	0.27	0.53	0.67	9.67 6 526
0.52	0.55	0.3	0.88	9.05 6 888
0.9	0.5	0.25	2.12	31.46 41 749
0.47	0.86	0.84	0.04	2.9 29 315
0.72	-0.29	0.1	3.37	25.07 8 439
0.71	0.72	0.28	0.28	13.83 26 220
0.87	0.2	0.18	10.35	44.31 4 824
0.78	0.61	0.56	0.48	12.91 29 531
0.68	0.43	0.38	0.71	9.96 7 577
0.83	0.54	0.58	2.1	18.28 28 845
0.65	0.52	0.61	0.6	13.56 14 651
0.65	-0.11	0.17	0.85	23.84 26 336
0.78	0.44	0.36	1.32	9.84 42 863
0.72	0.7	1.1	0.73	8.27 36 065
0.91	0.25	0.37	3.3	28.94 43 204
0.83	0.14	0.34	3	22.11 16 116
0.85	0.26	0.42	0.7	15.22 40 011
0.27	1.83	0.7	0.04	2.78 12 071
0.69	0.54	0.9	0.42	6.86 28 375
0.82	0.36	0.58	1.67	14.48 42 042
0.57	0.21	0.33	0.5	8.26 17 580
0.81	0.09	0.22	1.91	29.24 19 803
0.79	0.46	0.38	2.4	22.26 20 709
0.79	0.3	0.09	1.85	28.54 21 732
0.85	0.33	0.33	1.74	27.4 36 855
0.86	0.07	0.46	2.79	21.95 30 548
0.71	0.1	0.1	4.03	21.12 13 296
0.85	0.54	0.44	1.99	16.17 54 535
0.34	-0.02	0.27	0.41	4.01 10 028
0.73	0.44	0.58	0.71	6.63 26 226
0.84	0.99	0.4	1.06	29.84 29 307
0.67	-0.1	0.07	4.96	28.61 3 611
0.74	-0.07	0.17	2.99	33.87 11 752

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0.69	1	0.62	0.16	8.65 32 963
0.92	0.31	0.29	2.49	23.08 43 002
0.57	0.99	0.36	0.13	13.42 18 387
0.82	0.53	0.55	1.34	14.37 38 815
0.88	0.52	0.44	1.59	21.92 42 724
0.8	0.72	0.82	0.66	10.19 35 870
0.84	0.21	0.21	1.96	25.07 15 703
0.61	0.34	0.4	0.99	8.52 7 065
0.59	0.85	0.75	0.21	4.6 34 245
0.7	0.74	0.92	0.44	8.43 27 707
0.87	0.27	0.42	3.58	20.89 49 786
0.43	0.36	0.39	0.02	2.17 34 019
0.63	0.71	0.92	0.3	3.74 38 735
0.82	-0.25	0.27	2.54	31.36 17 271
0.23	1.67	1.23	0.04	1.22 11 259
0.88	0.42	0.32	0.9	18.55 39 906
0.78	0.53	0.43	1.03	15.39 23 300
0.8	0.44	0.51	1.5	13.17 35 100
0.77	0.5	0.59	0.15	9.64 23 803
0.85	0.56	0.48	0.43	13.54 41 822
0.87	0.52	0.42	1.37	17.78 48 983
0.67	0.44	0.66	2	10.9 27 141
0.66	0.48	0.28	0.58	8.63 28 028
0.41	0.58	0.58	0.13	1.22 14 149
0.73	0.62	0.47	0.48	8.53 31 024
0.36	0.73	0.94	0.16	1.62 16 502
0.76	0.38	0.47	1.65	17.1 23 064
0.85	0.39	0.58	2.92	18.29 36 434
0.84	0.8	0.48	1.13	21.02 25 234
0.84	0.5	0.45	2.51	17.62 41 640
0.79	0.67	0.65	0.91	14.13 40 305
0.86	0.52	0.49	1.77	18.31 32 895
0.8	0.64	0.5	0.79	12.82 37 163
0.64	0.23	0.37	3.99	34.57 7 100
0.83	0.13	0.19	7.06	28.88 24 705
0.52	0.02	0.29	1.29	8.9 6 047
0.78	0.16	0.18	5.11	26.72 6 493
0.75	0.41	0.48	1.13	18.81 22 915
0.7	0.44	0.47	1.31	12.09 9 013
0.76	0.43	0.37	1.08	20.54 26 013
0.36	0.66	0.66	0.11	2.03 22 158
0.86	0.75	0.78	1.28	15.06 36 736
0.74	0.67	0.91	1.44	9.73 27 612
0.81	0.6	0.65	0.65	10.18 46 049
0.78	0.35	0.27	1.21	11.61 31 139
0.68	0.89	0.76	0.16	5.54 33 355
0.74	0.67	0.68	0.56	9.45 25 964
0.69	0.7	0.2	3.13	22.3 5 924
0.82	-0.07	0.19	2.52	26.07 18 318

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0.79	0.36	0.4	1.2	13.69 35 802
0.52	0.63	0.28	0.18	6.82 26 333
0.28	0.61	0.46	0.16	2.5 3 745
0.63	0.36	0.16	6.01	24.1 3 864
0.59	0.63	0.71	0.38	6.19 30 663
0.76	0.77	0.7	0.48	7.3 53 912
0.85	-0.09	0.1	6.29	38.58 23 632
0.69	-0.16	0.45	1.66	16.68 17 974
0.67	0.29	0.42	1.09	11.72 13 099
0.83	0.58	0.39	1.45	20.21 38 148
0.82	0.69	0.7	1.74	15.84 43 205
0.79	0.64	0.51	0.58	11.76 38 090
0.51	0.99	0.5	0.27	5.4 37 902
0.89	0.26	0.31	1.59	34.04 36 523
0.6	0.77	0.35	0.27	4.46 31 478
0.75	0.82	0.74	1.08	9.04 35 618
0.68	0.46	0.74	0.37	6.09 45 086
0.91	0.35	0.33	1.64	23.4 37 618
0.74	0.89	0.63	0.51	6.43 35 692
0.72	0.88	0.7	0.71	6.46 37 719
0.83	0.27	0.43	1.55	26.86 18 850
0.85	0.66	0.72	1.42	17.11 35 848
0.88	0.66	0.62	1.4	17.86 39 298
0.86	0.5	0.6	1.44	18.83 32 637
0.78	0.55	0.6	1.21	10.48 52 940
0.73	0.37	0.29	1.84	14.65 7 032
0.81	0.02	0.31	1.91	32.6 25 871
0.88	0.4	0.36	1.67	22.26 41 385
0.76	0.64	0.73	1.05	11.26 32 101
0.83	0.42	0.71	1.53	19.77 28 311
0.33	0.17	0.68	0.23	3.18 5 422
0.74	0.97	0.89	0.47	5.98 40 901
0.68	0.37	0.61	1.18	12.05 16 997
0.38	0.52	0.36	0.31	6.17 7 241
0.61	0.46	0.71	0.48	7.43 11 466
0.84	0.39	0.5	3.66	18.08 22 273
0.69	0.25	0.44	2.03	13.79 7 744
0.83	0.09	0.38	3.11	24.03 13 204
0.9	0.02	0.25	5.37	42.57 17 316
0.8	0.46	0.24	0.74	24.58 29 644
0.6	1.07	1.15	0.45	3.44 52 010
0.64	0.63	0.68	0.28	3.87 30 038
0.82	-0.25	0.29	10.13	37.66 11 639
0.72	0.28	0.63	0.39	8.65 25 018
0.83	0.2	0.33	1.94	23.58 33 707
0.84	0.32	0.35	0.4	17.27 27 734
0.8	0.61	0.62	1.07	17.78 22 331
0.78	0.53	0.73	0.79	10.12 49 738
0.67	0.49	1.08	0.44	4.99 43 720

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0.73	0.38	1.13	0.82	12.33 31 766
0.84	0.53	0.67	0.86	15.59 34 765
0.85	0.44	0.28	1.07	25.31 28 733
0.86	0.67	0.45	2.47	20.01 43 435
0.88	0.42	0.39	3.41	24.45 47 648
0.62	1.83	0.43	0.13	7.82 31 580
0.33	0.96	1.51	0.02	0.54 34 879
0.79	0.95	0.54	0.6	9.56 44 999
0.93	0.36	0.29	2.23	32.38 39 476
0.85	0.06	0.36	0.58	18.52 30 565
0.88	0.33	0.28	1.03	23.74 33 001
0.84	0.54	0.46	0.86	13.48 40 429
0.74	0.17	0.17	9.7	34.06 3 666
0.59	0.64	0.36	0.41	7.42 24 526
0.51	0.43	0.74	0.15	2.77 23 174
0.63	0.31	0.74	0.3	4.97 38 760
0.69	0.57	0.7	0.17	5.87 34 597
0.68	0.37	0.3	0.51	8.35 42 565
0.78	0.71	0.81	1.12	11.03 44 745
0.84	-0.01	0.33	2.57	32.68 20 519
0.9	0.59	0.54	1.49	22.17 41 442
0.84	0.93	0.6	0.5	10.84 42 237
0.83	0.26	0.45	3.37	19.35 23 257
0.82	0.69	0.69	1.2	13.23 33 561
0.87	0.38	0.42	2.05	20.76 42 741
0.7	0.17	0.56	0.58	8.15 24 383
0.87	0.56	0.58	1.37	17.02 40 506
0.72	0.45	1.17	0.72	8.22 34 330
0.73	0.49	0.32	0.42	9.41 34 525
0.48	-0.03	0.65	0.55	5.66 14 151
0.76	-0.04	0.4	0.97	17.48 21 664
0.73	0.8	0.9	0.81	7 50 425
0.84	0.62	0.31	1.3	16.22 34 689
0.73	-0.14	0.26	4.69	31.49 16 776
0.74	0.15	0.68	0.61	13.37 31 177
0.89	0.31	0.27	0.86	18.61 43 002
0.72	0.91	0.43	0.22	8.86 32 698
0.57	1.92	1.27	0.47	3.2 14 970

Supporting information to the paper

Sporbert, M. et al. Assessing sampling coverage of species distribution in biodiversity databases. *Journal of Vegetation Science*.

**Appendix S3** Information on the 59 databases that provide vegetation plots included in this project. Official database name, Databases code in Global Index of Vegetation-Plot Database (GIVD), Name of the database custodians the dataset used in this study is component of, total number of vegetation plot samples included in the dataset [data access: October 2015], number of vegetation plot samples included in this study, proportional contribution of the datasets plot samples to this study [proportion = (Count Dataset Sporbert et al. \*100) / 808794].

Database name	GIVD Code	Custodian name	Count Dataset total (10/2015)	Count Dataset Sporbert et al.	Proportion [%]
Vegetation Database of Albania	EU-AL-001	Michele De Sanctis	290	193	0.024
Mediterranean Ammophiletea database	EU-00-016	Corrado Marcenò	6 835	4 843	0.599
Austrian Vegetation Database	EU-AT-001	Wolfgang Willner	30 659	23 941	2.960
Balkan Dry Grasslands Database	EU-00-013	Kiril Vassilev	8 152	4 769	0.590
Balkan Vegetation Database	EU-00-019	Kiril Vassilev	9 579	7 092	0.877
Vegetation-Plot Database of the University of the Basque Country (BIOVEG)	EU-00-011	Idoia Biurrun	18 429	16 405	2.028
INBOVEG	EU-BE-002	Els De Bie	13 541	8 204	1.014
UK National Vegetation Classification Database	EU-GB-001	John S. Rodwell	25 485	24 104	2.980
Bulgarian Vegetation Database	EU-BG-001	Iva Apostolova	5 235	1 935	0.239
Croatian Vegetation Database	EU-HR-002	Željko Škvorc	8 517	8 249	1.020
Czech National Phytosociological Database	EU-CZ-001	Milan Chytrý	110 534	97 650	12.074
NATURDATA.DK	EU-DK-002	Jesper Erenskjold Moeslund	24 264	23 994	2.967
Vegetation Database of Eurasian Tundra	00-00-004	Risto Virtanen	1 132	294	0.036
European Coastal Vegetation Database	EU-00-017	John Janssen	4 311	2 251	0.278
European Mire Vegetation Database	EU-00-022	Tomáš Peterka	10 099	9 047	1.119

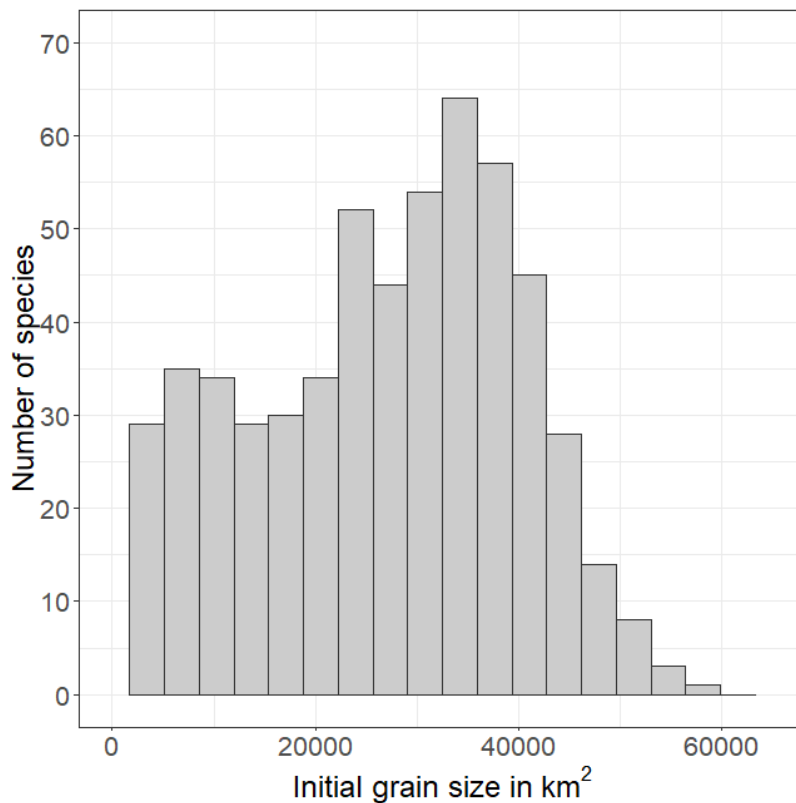
SOPHY	EU-FR-003	Henry Brisse	155 275	143 323	17.721
GVRD Vegetation Reference Database Halle	EU-DE-014	Ute Jandt	29 797	28 418	3.514
VegetWeb	EU-DE-013	Jörg Ewald	22 363	21 525	2.661
VegMV	EU-DE-001	Florian Jansen	49 631	44 410	5.491
Hellenic Woodland Database + Hellenic Beech Forests Database (Hell-Beech-DB)	EU-GR-006 + EU-GR-007	Ioannis Tsiripidis	3 199	636	0.079
Hellenic Natura 2000 database (HelNatVeg)	EU-GR-005	Panayotis Dimopoulos	4 857	4 295	0.531
CoenoDat Hungarian Phytosociological Database	EU-HU-003	János Csiky	5 104	812	0.100
Irish Vegetation Database	EU-IE-001	Úna Fitzpatrick	26 687	25 010	3.092
Italian National Vegetation Database (BVN/ISPRA)	EU-IT-010	Laura Casella	3 562	3 496	0.432
Georeferenced Vegetation Database - Sapienza University of Roma	EU-IT-011	Emiliano Agrillo	12 665	10 981	1.358
Semi-natural Grassland Vegetation Database of Latvia	EU-LV-001	Solvita Rūsiņa	5 594	5 581	0.690
Lithuanian Vegetation Database	EU-LT-001	Valerijus Rašomavičius	2 206	1 842	0.228
Vegetation Database of the Republic of Macedonia	EU-MK-001	Renata Čušterevska	1 269	370	0.046
Dutch National Vegetation Database	EU-NL-001	Joop H.J. Schaminée	93 812	83 968	10.382
The Nordic Vegetation Database	EU-00-018	Jonathan Lenoir	7 718	7 144	0.883
Nordic-Baltic Grassland Vegetation Database	EU-00-002	Jürgen Dengler	6 062	6 056	0.749
Polish Vegetation Database	EU-PL-001	Zygmunt Kački	56 989	53 381	6.600
Romanian Grassland Database	EU-RO-008	Eszter Ruprecht	4 962	4 718	0.583
Romanian Forest Database	EU-RO-007	Adrian Indreica	6 017	6 006	0.743
Vegetation Database Forest of Southern Ural	00-RU-001	Vassiliy Martynenko	997	222	0.027
Lower Volga Valley Phytosociological Database	EU-RU-002	Valentin Golub	11 846	5 320	0.658
Database Meadows and Steppes of Southern Ural + Database of South Ural Order Galietales veri + Database of South Ural Order Arrhenatheretalia	00-RU-003 + 00-RU-004 + 00-RU-005	Sergey Yamalov	2 034	1 093	0.135
SE Europe Forest Database	EU-00-021	Andraž Čarni	3 659	3 656	0.452
Vegetation Database Grassland Vegetation of Serbia	EU-RS-002	Svetlana Aćić	5 587	5 364	0.663
Database of Forest Vegetation in Republic of Serbia + Vegetation Database of Northern Part of Serbia (AP Vojvodina)	EU-RS-003 + EU-RS-004	Mirjana Krstivojević Ćuk	1 131	1 131	0.140
Slovak Vegetation Database	EU-SK-001	Milan Valachovič	36 266	33 320	4.120
Vegetation Database of Slovenia	EU-SI-001	Urban Šilc	10 986	10 750	1.329

Iberian and Macaronesian Vegetation Information System (SIVIM)	EU-00-004	Xavier Font	3 496	3 091	0.382
Iberian and Macaronesian Vegetation Information System (SIVIM) - Catalonia	EU-00-004	Xavier Font	3 875	3 512	0.434
Iberian and Macaronesian Vegetation Information System (SIVIM)	EU-00-023	Juan Antonio Campos	6 630	6 286	0.777
Iberian and Macaronesian Vegetation Information System (SIVIM) – Grasslands	EU-00-004	Maria Pilar Rodríguez-Rojo	7 331	7 199	0.890
Iberian and Macaronesian Vegetation Information System (SIVIM) – Sclerophyllous forests	EU-00-004	Federico Fernández-González	3 799	3 170	0.392
Iberian and Macaronesian Vegetation Information System (SIVIM) - Shrublands	EU-00-004	Xavier Font	3 007	2 386	0.295
Iberian and Macaronesian Vegetation Information System (SIVIM) - Wetlands	EU-ES-001	Aaron Pérez-Haase	6 539	4 507	0.557
Swiss Forest Vegetation Database	EU-CH-005	Thomas Wohlgemuth	14 193	14 182	1.753
Vegetation Database of Tatarstan	EU-RU-011	Vadim Prokhorov	7 426	2 301	0.284
Forest Vegetation Database of Turkey – FVDT	00-TR-001	Ali Kavgacı	144	127	0.016
Vegetation Database of the Grassland Communities in Anatolia	AS-TR-001	Deniz Işık Gürsoy	20	6	0.001
Vegetation Database of Oak Communities in Turkey	AS-TR-002	Emin Uğurlu	68	61	0.008
Ukrainian Grassland Database	EU-UA-001	Anna Kuzemko	4 043	3 954	0.489
Halophytic and coastal vegetation database of Ukraine	EU-UA-005	Tetiana Dziuba	4 399	13	0.002
Vegetation database of Ukraine and adjacent parts of Russia	EU-UA-006	Viktor Onyshchenko	3 325	3 192	0.395
VegItaly	EU-IT-001	Roberto Venanzoni	15 332	8 957	1.107
WetVegEurope	EU-00-020	Flavia Landucci	1 994	6	0.001

1 Supporting information to the paper  
2 Sporbert, M. et al. Assessing sampling coverage of species distribution in biodiversity databases.  
3 *Journal of Vegetation Science*.

4

5 **Appendix S4** Distribution of initial grain size (in km<sup>2</sup>) in DMC calculations (Figure S4.1).  
6 Scatterplots and Spearman correlation coefficients ( $\rho$ ) of the relationship between species range  
7 sizes and niche sizes (Figure S4.2). Scatterplots and Spearman correlation coefficients ( $\rho$ ) of the  
8 relationship between percentage match of species ranges by EVA vegetation plots and percentage  
9 match of species niches by EVA vegetation plots (Figure S4.3).

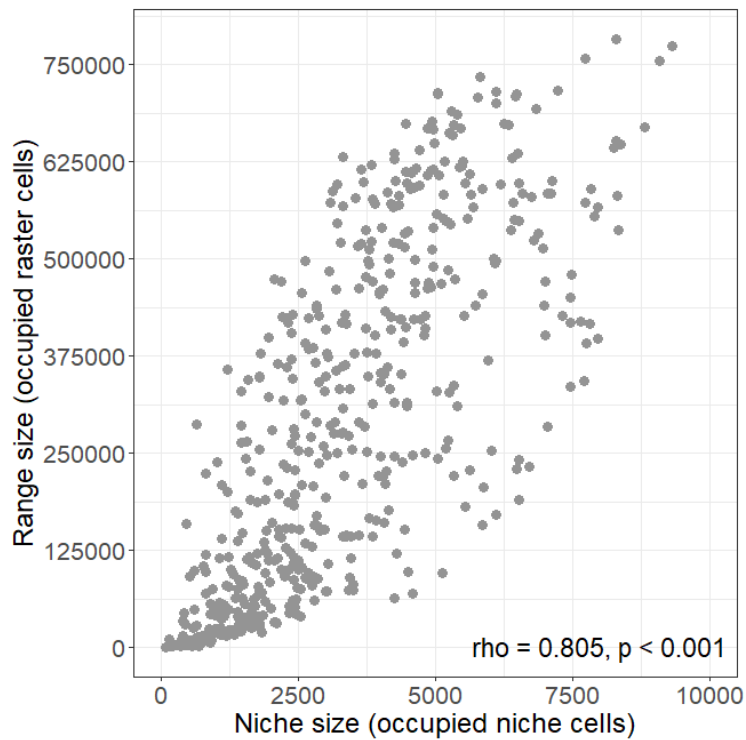


10

11 **Figure S4.1** Distribution of initial grain size (in km<sup>2</sup>) in DMC calculations. Bandwidth of scaling steps  
12 were calculated species specific according to the species range sizes at 2.5-min raster cell resolution in  
13 geographic space.

14

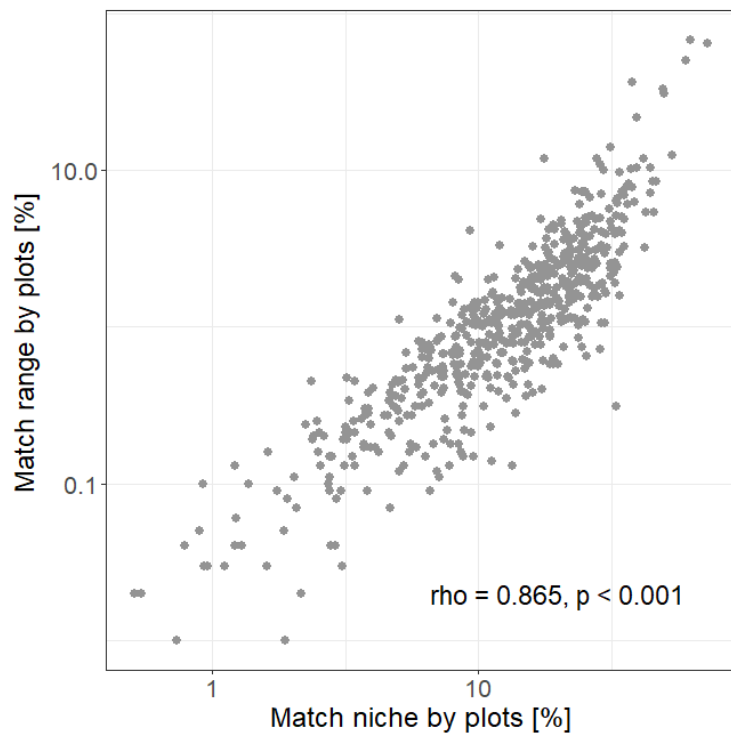




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16 **Figure S4.2** Scatterplots and Spearman correlation coefficients ( $\rho$ ) of the relationship between  
 17 species range sizes (occupied raster cells at 2.5-min raster cell resolution) in geographic space and  
 18 niche sizes (occupied niche cells) in climatic space.

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21 **Figure S4.3** Scatterplots and Spearman correlation coefficients ( $\rho$ ) of the relationship between  
 22 percentage match of species ranges by EVA vegetation plots and percentage match of species niches  
 23 by EVA vegetation plots. X axis and y axis are log-transformed.

24