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Securing the Conservation of biodiversity across Administrative Levels and spatial, temporal, and Ecological Scales

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SCALES briefs 3

Beta diversity of European fauna and flora: the role of dispersal limitations, climate and land-cover at multiple scales

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What is beta diversity and why is it important?

Biodiversity conservation and policy often focuses on species richness. This is called local or alpha diversity by scientists. However, there is another fundamental aspect of biodiversity that often receives less attention. Ecologists call it species turnover, spatial change in species composition, compositional similarity, or beta diversity. It applies to any change of species composition in space or even time. It can be expressed in many forms, from simple gains or losses of species one encounters while moving from site A to site B, to indices based on the numbers of species shared between two sites and the numbers of unique species at each site (see Koleff et al. 2003 for an overview). Moreover, beta diversity is the link between species richness (alpha diversity) at smaller and larger scales.

Knowledge about beta diversity and the factors that explain it can support applied biodiversity conservation and policy. It is particularly important in the design or assessment of networks of protected areas that together capture, in an efficient way, all of the targeted biodiversity and when assessing natural corridors and migration barriers. This knowledge is also important when designing monitoring schemes to secure that all targeted components of biodiversity are covered at an appropriate scale (see also SCALES brief #2 on monitoring).

Figure 1 a. **Winter Mediterranean landscape in Crete, Greece (Photo: Petr Keil)**

Figure 1 b. **Hardangervidda (Norway), mountain plateau with subarctic flora and fauna in summer (Photo: Reinhard Klenke)**

Beta diversity does not necessarily depend on species richness because we find high values of beta diversity in species rich areas like in the Mediterranean peninsulas as well as in the species poor areas of Scandinavia.

Multi-scale beta diversity in the EU and its implication for nature conservation

For birds, butterflies, vascular plants, amphibians, and reptiles beta diversity is higher and more variable at small spatial resolution (for data and methods see below). Hence, we propose that conservation efforts should be focused on preserving beta diversity at a local scale. In other words, the priority should be to preserve local uniqueness reflected by the network of protected areas. An assessment of the already existing network and the use of special tools for reserve site design could be very valuable to improve the current situation in this regard.

At a European scale, dispersal limitations play a major role in generating species turnover (Fig. 3). Hence, any efforts to conserve beta diversity (or local uniqueness) must carefully take into account not only the presence of natural migration corridors, but also natural migration barriers that can preserve beta diversity. It also means that European-wide modelling of shifts in species distributions must explicitly consider dispersal limitations. So far, this has rarely been done.

Climatic and land-cover (habitat) differences have additional influence on beta diversity, and the relative importance of these variables differs at different spatial resolutions (Fig. 3). This shows that species turnover is a phenomenon driven by a complex interplay between dispersal limitations and the climatic and habitat requirements of species. Correspondingly, conservation efforts on the continental scale (Europe) must consider all of the three phenomena by addressing climate change, connectivity (dispersal limitations), and land-use (management) on equal levels of importance.

At the scale of individual countries analysed (UK, Finland, and Catalonia), the most important factor influencing beta diversity was climate, which means that climatic envelope modelling of species distributions may be relevant and even useful within these smaller scales. It also shows that the expected climatic changes will most severely influence patterns of species turnover at the scale within individual European countries.

Finally, both species rich areas of southern Europe (Mediterranean peninsulas) and species poor areas of northernmost Europe (Scandinavia) have high beta diversity (Fig. 1, Fig. 4). Therefore, the value of the species-rich European areas lies not only in the species richness, but also in the rapid spatial species turnover. Moreover, it is also worth conserving the species poor areas in the north because they are unique – not only when compared with the rest of Europe, but also when compared with adjacent areas within Scandinavia itself (Fig. 4).

Methods and data used

We examined the scaling properties of beta diversity on the basis of high-quality distributional data for birds, butterflies, vascular plants, amphibians, and reptiles that were all arranged into a 50x50 km UTM grid across Europe (Fig. 2a). For the investigation of smaller-scale patterns, we used national distributional atlases of butterflies (Finland), birds (Czech Republic and Catalonia), and vascular plants (United Kingdom) (Fig. 2b-d). Within each of these datasets, we generated a series of 2–3 nested grids with the same spatial extent but with varying grain (resolution). For each cell within these grids, we generated high quality data describing land cover and climatic conditions. We then analyzed relationships between beta diversity, geographic distances, and environmental dissimilarities. We identified areas of rapid species turnover by mapping and analyzing patterns of beta diversity only in a set of adjacent grid cells (first distance class).

To estimate the effects of climate, land cover and geographic distance on beta diversity we used multiple regression of distance matrices and hierarchical variation partitioning (see Winter et al. 2010, and more technical details in Legendre & Legendre 1998). More details are available from the author on request. For complete results and details of the study see Keil et al. (2012).

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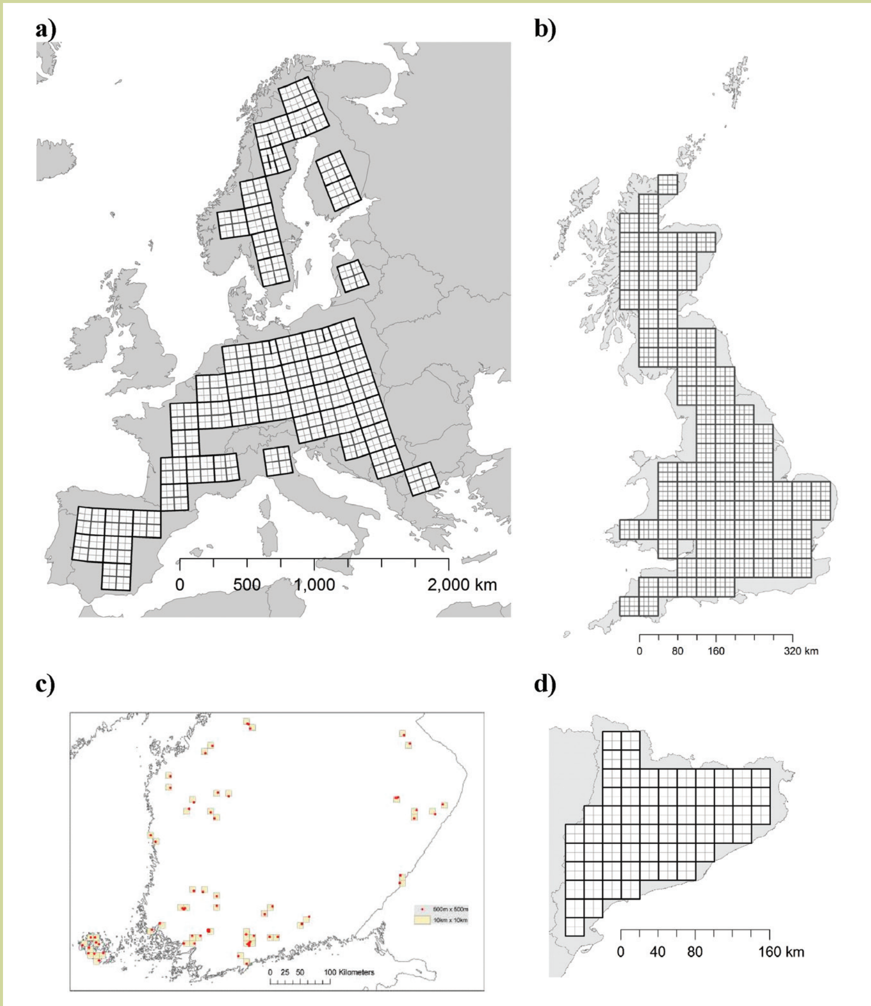

Figure 2. **Nested UTM girds used for the analyses of pan-European beta diversity patterns; a) across continental Europe, b) across the UK, c) Finland, and d) Catalonia. The different grains always cover the same area. We removed areas within the largest grid cells that overlapped sea, lack land-cover data, or were insufficiently surveyed.**

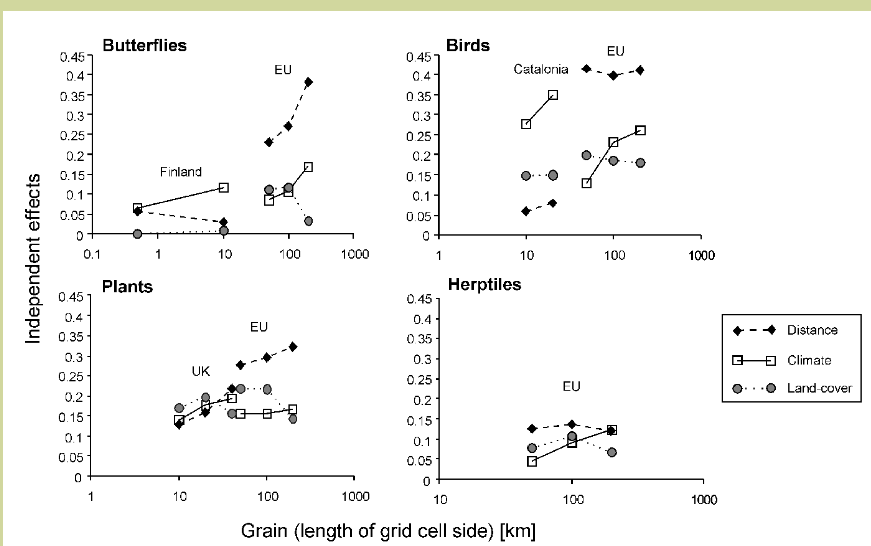

Figure 3. **Independent effects resulting from hierarchical variation partitioning of climatic, land-cover, and geographic distances on beta diversity (measured as βsim index) at various grain resolutions. At large scales geographic distance is the most important factor, while at small scales climatic dissimilarity plays a major role in shaping patterns of beta diversity.**

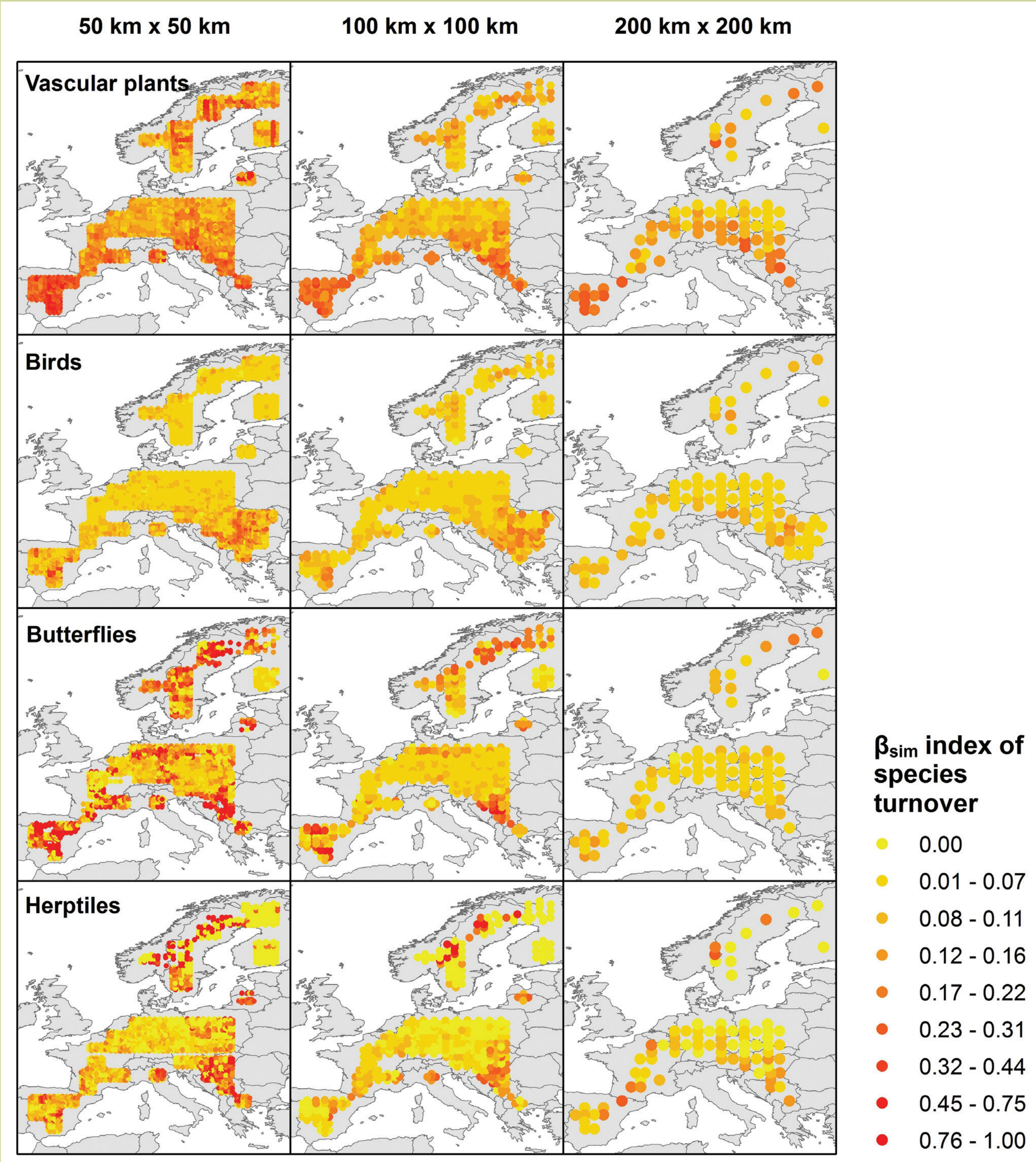

Figure 4. **Mapped geographic patterns of beta diversity (measured as βsim) at first distance class (all pair-wise comparisons of all adjacent grid cells) for the four taxonomic groups at three grain resolutions. A βsim value of 0 means identical species composition and a value of 1 means completely different composition of species.**

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