Final report – K 124796

Geodiversity and species preservation: the capacity of karst dolines as microrefugia

Aims of the project

The research plan focused on four major questions, that is:

- How spatial dimensions and related abiotic factors influence the capacity of karst dolines to provide microrefugia for certain plant and arthropod taxa? How does the macroclimate determine the geodiversity and biodiversity patterns of dolines?
- Are there any similarities in the distribution patterns of ants and plants in the microrefugia? How is the potential preservation capacity of dolines affected by abiotic factors and by the degradation of vegetation?

According to the work plan, we aimed to publish three papers in Q1 journals, two papers in Q2–Q4 journals, and at least two papers, which have a great importance for geography and conservation in Hungary during our NKFIH project.

Key results

Ants and plants in dolines – ***Bátori et al. 2019: Scientific Reports 9: 7176 (D1 paper); Bátori et al. 2021: Frontiers in Ecology and Evolution 8: 613738 (Q1 paper).***

Parallels in the distribution of ants and plants in dolines: To our knowledge, this is the first study to illustrate that the fine-scale topography of dolines provides microhabitats for diverse functional groups (cool- and moist-adapted versus warm- and dry-adapted) of both ants and vascular plants within tens of meters.

We found that fine-scale topographic complexity creates important microclimates that can facilitate species to grow outside their main distributional range and increase biodiversity locally. We showed that the distribution patterns of functional groups for organisms in two different phyla, Arthropoda (ants) and Tracheophyta (vascular plants), mirror the variation of microclimate that are drier and warmer (equator-facing slopes) and cooler and moister (pole-facing slopes and depression bottoms) than the surrounding climate. We found that north-facing slopes and bottoms of solution dolines in northern Hungary provided key habitats for ant and plant species associated with cooler and/or moister conditions. Contrarily, south-facing slopes of dolines provided key habitats for species associated with warmer and/or drier conditions. Species occurring on the surrounding plateau were associated with intermediate conditions. We conclude that karst dolines provide a diversity of microclimatic habitats that may facilitate the persistence of taxa with diverse environmental preferences, indicating these dolines to be potential safe havens for multiple phyla under local and global climate oscillations.

Effects of vegetation cover on ant distributions in dolines: Our findings underline the importance of dolines as local biodiversity hotspots in karst landscapes by supporting specific functional group patterns of ant assemblages.

Although dolines may act as important microrefugia for many species, data on the functional diversity of their animal assemblages are scarce. We investigated the functional diversity (i.e., certain functional groups and functional traits) of ant assemblages in dolines and studied whether dolines surrounded by resource-poor environments (i.e., *Fagus sylvatica* forests) may function as safe havens for different kinds of ants. We found that dolines have the potential to maintain distinctive ant assemblages characterized by specific functional groups and traits that are rare in the surrounding habitats. Although continuous *Fagus sylvatica* cover in dolines had a detrimental impact on ant assemblages, grassland dolines surrounded by grasslands or *Fagus sylvatica* forests supported the presence of some specific functional groups and traits. These results suggest that conservation management needs to consider the influence of vegetation characteristics not only in dolines, but also on the surrounding plateau. We concluded that moderate grazing and/or mowing would be desirable in order to prevent shrub encroachment into grasslands to ensure optimal vegetation structure for ants in the long run. Therefore, proper management and conservation of these safe havens may mitigate the rate of biodiversity loss under global warming. We also concluded that there is a need to explore a wide variety of taxonomic groups and taxon-specific traits in parallel with the quality of the surrounding habitats when evaluating current and potential microrefugia.

Abiotic factors and arthropod taxa in dolines – *Bátori et al. 2022: Elementa: Science of the Anthropocene 10: 00084 (D1 paper).*

Microclimate, long term environmental stability and arthropod species: This is the first study illustrating a strong and concerted response of the distribution of five arthropod taxa from various trophic levels (spiders, woodlice, ants, ground beetles, and rove beetles) to topography and related microclimatic patterns in solution dolines.

We investigated the spatial patterns and species trait composition (moisture preference, body size, dispersal capacity, and feeding habit) of five groups of ground-dwelling arthropods – spiders, woodlice, ants, ground beetles, and rove beetles – in topographic depressions (i.e., "solution dolines" or "solution sinkholes") and on the surrounding plateau within a forested karst landscape and analyze the microhabitat conditions that affect these arthropod assemblages. We found that dolines have the capacity to maintain characteristic arthropod assemblages—including species that may be particularly vulnerable to climate change (e.g., species associated with moist habitats)—and thus, they may contribute to the landscape-scale biodiversity of karst landscapes. We also found that doline bottoms have the potential to maintain permanently moist conditions not only in spring and autumn but also during drier periods of the year. This ability of dolines may indicate the presence of potential hydrologic microrefugia. Furthermore, dolines displayed specific sets of species traits (e.g., more small-bodied spiders, more carnivorous ground beetles, and more rove beetles with high dispersal capacity occurred in dolines than on the plateau), highlighting that they may facilitate the persistence of some species and traits that are purged from the surrounding landscape. Future studies may reveal the long-term ecological consequences of different climatic and anthropogenic factors on the distribution and functional traits of arthropod taxa

within microrefugia and on the refugial capacity of these safe havens under a warming climate.

Degradation, species composition and vegetation patterns – ***Bátori et al. 2020: Biodiversity and Conservation 29: 503–525 (Q1 paper); Kiss et al. 2020: Acta Geographica Slovenica 60: 37–48 (Q2 paper); Aguilon et al. 2020: Biologia 75: 1529– 1535 (Q3 paper).***

Human disturbances and vegetation patterns: Local anthropogenic disturbances have had considerable impact on the species composition and vegetation structure of many dolines.

We investigated the conservation value of dolines in three European karst areas, where different levels and types of anthropogenic disturbances have been shaping the vegetation for centuries, using the number of plant species that are cool-adapted, moist-adapted and of high conservation importance (i.e. vulnerable species) as indicators. We found that anthropogenic disturbances generally have a negative impact, reducing the number of vulnerable species supported by dolines (e.g. dolines dominated by a high cover of *Calamagrostis epigejos*). However, more cool-adapted and moist-adapted species were found in some dolines planted with non-native *Picea abies* than in less disturbed dolines, indicating that anthropogenic disturbances can also have positive consequences for biodiversity. We concluded that anthropogenic disturbances alter the capacity of dolines to support vulnerable species, and that this will impact survival of species in landscapes under global warming. In this context, the effects of various disturbances on species composition and diversity need to be carefully considered to determine the best conservation and/or management options.

General framework for managing/maintaining doline microrefugia in forested karst landscapes – ***Bátori et al. 2021: Forest Ecology and Management 496: 119446 (D1 paper).***

Managing climate change microrefugia in karst landscapes: In our framework, we defined the seven steps that are considered important for managing/maintaining doline microrefugia in forested karst landscapes:

Step 1 – Define planning purpose and objectives

Maintain/increase the refugial capacity of doline microhabitats in forested karst landscapes and protect their climate change-vulnerable species; consider at least a 30–40 year planning cycle and 50–80 year climate projections.

Step 2 –Assess climate impacts and vulnerabilities

Consider macroclimatic drivers; increases in temperature and inter-annual precipitation variability; summer heat waves and drought; intense storms; vegetation shifts; changes in forestry policy and practices (e.g., preference for planting non-native warm-adapted tree species); changes in tourism-related effects (e.g., fire ignition, littering and trampling).

Step 3 – Review/revise conservation goals and objectives

Maintain sufficient number of cool and moist microhabitats (i.e. current and potential microrefugia) in dolines and their physical properties (e.g., rockiness, slope steepness and soil texture) to protect the biodiversity and critical ecosystem functions over the next 30–40 years (until the next planning cycle).

Step 4 – Identify and map key microrefugia features

Potential microrefugia features: environmental stability; high topographic complexity (e.g., diameter, depth, exposure, rockiness and slope angle); cool air pooling; high water retention capacity; microhabitats with a high number of climate change-vulnerable species; presence of highly divergent lineages.

Step 5 – Evaluate and prioritize refugial areas for specific management

Prioritize: large and/or deep dolines; high microhabitat diversity; high taxonomic diversity and species richness; high number of cool- and moist-adapted species (e.g., endemic and relict species); spatial and temporal overlap with other climate change-vulnerable species from different phyla.

Step 6 – Identify and implement priority actions to manage climate change microrefugia

Maintain old forests and natural forest dynamics in as many doline microrefugia as possible; protect surrounding forests; protect natural and semi-natural grassland patches among forest stands, support the rehabilitation of areas covered by young, dense and homogenous forests; assist colonization; implement close-to-nature forestry practices (e.g., continuous cover forestry); work together with local forest managers in order to obtain the best experience and to determine the most efficient solutions for all stakeholders.

Step 7 – Monitor the effectiveness of designated microrefugia, realign objectives and actions accordingly

Monitor: main microclimatic factors (temperature, soil moisture and light availability); habitat and microhabitat patterns; soil characteristics; indicator species; taxonomic diversity and species richness; human impacts.

Floristic composition and the 'geoecological' role of dolines – ***Erdős et al. 2018: Kitaibelia 197–206; Keveiné Bárány I. 2018: Karsztfejlődés 23: 163–185.***

Floristic data from dolines: We report the occurrence data of 44 vascular plant taxa collected at various localities in Hungary (also from dolines) during floristic, vegetation and ecological field surveys between 2016 and 2018. Of the species in the present article, 27 are protected or strictly protected. In the paper we focused on plants that are rare regionally or in the whole country, as well as on plants that occurred in unusual habitats.

'Geoecological' role of dolines: The ecological (environmental) system of the karst is very vulnerable, environmental impacts endanger the natural course of corrosion, the survival of individual habitats and the quality of non-renewable natural resources. The development of the dolines is governed by the integrated processes of geo-ecological factors (bedrock, climate, water, soil, vegetation, humans). Karst ecosystem services (drinking water supply, recreational utilization, timber production and carbon sequestration) are of great importance for humanity.

Palaearctic grasslands and dolines – ***Idoia et al. 2021: Journal of Vegetation Science 32: e13050 (Q1 paper).***

Data deposition: Our vegetation data from dolines (that were previously deposited in the GrassPlot database) were also used to characterise the Palaearctic grasslands and other open habitats.

The vegetation of karsts in Hungary – ***Bátori et al. 2022: Cave and karst systems of Hungary (book chapter)***

Detailed description about the vegetation of the Hungarian karst areas: We provided a review about the floristic composition, vegetation patterns, diversity patterns and threatening factors of the Hungarian karst areas (including dolines).

Datasets under analysis – climate, soil, doline size and slope aspect

Analyses of collected data (from the Aggtelek Karst area and Mecsek Mts) have been started in the last months in order to investigate the potential effects of macroclimate (Aggtelek: moderately cool and moderately humid, Mecsek: moderately warm and moderately humid), microclimate, soil, doline size (smaller and larger dolines) and slope aspect (e.g., S- and N-facing slopes) on doline vegetation. 2 m × 2 m plots from the different microhabitats of 24 dolines have been collected both in spring and summer. We will compare the vegetation–environment relationships in these dolines, and their capacity to provide potential microrefugia in the future. We plan to publish these results in Q1 journals.

Other results

In addition, we published 29 closely related papers in international journals (from these, 24 papers have been published in Q1 or D1 journals) in which different refuge areas (e.g., river embankment, burial mounds and forest edges) and potential microrefugia of the forest-steppe biome and karst areas had been investigated and discussed. As we used the experiences gained from the NKFIH K 124796 grant while we prepared these manuscripts (especially in the discussion), the grant identifier has been included in the sections Acknowledgements/Funding of these articles.

Conferences

Unfortunately, we could not attend all the conferences planned due to the COVID-19 pandemic and the subsequent lockdowns. However, we presented our results at the 6th European Congress of Conservation Biology, at the 12th Hungarian Ecological Conference, and at 13th Advances in Research on the Flora and Vegetation of the Carpato-Pannonian Region Conference.

Total IF collected during the project: 143,2

Publications from the results of the project (based on the MTMT database)

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- **Bátori Zoltán**, Gallé Róbert, Gallé-Szpisjak Nikolett, Császár Péter, Nagy Dávid D., Lőrinczi Gábor, Torma Attila, Tölgyesi Csaba, Maák István Elek, Frei Kata, et al.: Topographic depressions provide potential microrefugia for ground-dwelling arthropods, ELEMENTA-SCIENCE OF THE ANTHROPOCENE 10 : 1 Paper: 00084, 18 p. 2022
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