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Editorial

Global Patterns of Subterranean Biodiversity: A Continuing Quest

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The geographic pattern of the number of species in functional or phyletic groups is simultaneously highly derivative and fundamental to our understanding of community ecology. It is fundamental because the pattern of species richness (biodiversity) is one of the basic facts of macroecology that needs explanation. It is derivative because the pattern per se offers little in the explanation of the processes that dominate communities. Theories that explain regional and global patterns largely come from the MacArthur school of ecology beginning in the 1960s, including island biogeography theory [1], limiting similarity of competing species [2], as well as theories for the richness of tropical flora and fauna from Janzen and others [3]. The idea of studying species richness per se was further enshrined by the widespread use of the term "biodiversity" [4] and the availability of georeferenced large datasets, which were all made possible by the advent of data manipulation software, especially EXCEL^{TM}, and mapping software, especially ARCMAP^{TM}.

Biodiversity mapping for surface dwelling species at the continental and global scales has progressed at a rapid pace (e.g., [5]). Studies of subterranean biodiversity lagged behind [6] due to a variety of factors, mostly due to difficulty in collecting, namely the difficult nature of traversing caves and the rarity of many species. However, the expected pattern of subterranean biodiversity is implicit in early studies, especially in Jeannel's hypothesis that the Pleistocene, especially at the ice margins, was the primary driver of cave colonization [7]. Sket [8] was perhaps the first to make subterranean biodiversity the central focus with his article on the Dinaric karst of Italy, Slovenia, Croatia, Montenegro, Albania, and Serbia as a biodiversity hotspot. The European PASCALIS project (**P**rotocols for the **AS**sessment and **C**onservation of **A**quatic **L**ife **I**n the **S**ubsurface) marked the coming of age of the study of subterranean biodiversity and remains the most thorough study of subterranean biodiversity at a large scale [9,10]. While great strides have been made in our understanding of regional patterns of subterranean biodiversity, especially for Europe (see summaries [6,11]) and to a lesser extent in the United States [12,13], there has been little in the way of global analysis. This is largely because a much richer data set is available for Europe and the United States, allowing assessment of beta diversity.

The present collection of papers is a continuation of attempts to analyze global subterranean biodiversity patterns using hotspot caves. Recognizing that data outside Europe and North America was not extensive enough to analyze total diversity, accomplished by the sampling of a number of caves (in practice100 or more) to estimate alpha and beta diversity, Culver and Sket [14] suggested that especially species-rich caves might act as a surrogate

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for total diversity. They reported on 20 caves and wells, each with 20 or more obligate subterranean dwelling species, the total number known at the time. This list has undergone several iterations, the most recent being primarily the result of papers published in the first and second editions of "Subterranean Biodiversity" in the journal *Diversity.* Deharveng et al. [15] list a total of 28 sites with 25 or more species of subterranean limited species, and in recognition of the fact that aquatic and terrestrial hotspots only overlap in the Dinaric karst of southeast Europe and have different distributions, Năpăruş-Aljančič et al. [16] list 12 sites with 20 or more aquatic species and 17 with 20 or more terrestrial species.

The present special edition follows Năpăruş-Aljančič et al. in treating aquatic and terrestrial hotspots separately. We have also adjusted the criteria for inclusion in our list as follows: caves and other subterranean sites with 19 or more terrestrial or aquatic species. The cutoff is of course arbitrary and represents a balance between discriminating truly exceptional caves and having enough caves for geographic and statistical coverage. Deharveng et al. [15] discuss the challenges of using these data for an overview at length, and they also review the completeness of the geographical coverage. We will not repeat these caveats here except to point out that not all subterranean habitats are covered in this edition's papers and previous hotspot editions. Two omissions stand out. The deep soil is clearly a subterranean habitat, with constant darkness and species without eyes or pigment [17], but we have not attempted coverage. In fact, the specialized soil fauna is sometimes mistakenly assumed to be a cave fauna as a result of occasional specimens of soil fauna being found in caves [18]. It is not clear to us how diverse these deep soil specialists are. The second habitat we ignore is the underflow of rivers and streams—the hyporheic zone. The eyeless, depigmented denizens of the hyporheic can be quite species-rich. For example, Dole [19] reported 30 such species in a site in the Rhône River in France. A third habitat, epikarst, harbors a diverse array of species [20] but is typically sampled in caves and thus included in cave species lists.

The need for a third edition came as something as a surprise to us. However, the previous editions stimulated new work, and there were a few "leftovers" from the earlier editions. We take this opportunity to expand the aquatic and terrestrial lists to make them a more useful analytical tool. A longer list will also be useful in resolving the global pattern and its explanation. While the pattern of global hotspots of subterranean aquatic biodiversity is relatively clear, the terrestrial one is not [16], and these new records should clarify both the pattern and its causes.

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