



Editorial

# Cave Communities: From the Surface Border to the Deep Darkness

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**Abstract:** The discipline of subterranean biology has provided us incredible information on the diversity, ecology and evolution of species living in different typologies of subterranean habitats. However, a general lack of information on the relationships between cave species still exists, leaving uncertainty regarding the dynamics that hold together cave communities and the roles of specific organisms (from the least to the most adapted species) for the community, as well as the entire ecosystem. This Special Issue aims to stimulate and gather studies which are focusing on cave communities belonging to all different typologies of subterranean habitats, with the overarching goal to corroborate the key role of the subterranean biology in ecological and evolutionary studies.

**Keywords:** cave biology; subterranean habitats; vertebrates; invertebrates; community dynamics; biospeleology; hypogean; conservation; biodiversity; troglobite; troglophile; troglone

## Introduction

The study of subterranean habitats (i.e., all natural and artificial subterranean voids and groundwater suitable for human exploration; [1]) and their related fauna is a discipline that is intriguing scientists from many points of view [2–5], and its broad interest is testified by the large number of published researches, see [6–10]. Subterranean environments are of special importance for diversity as they often host a highly specialized fauna, with unique, unusual and sometimes even bizarre morphological, behavioural and ecological adaptations [11,12].

The peculiar ecological features characterising the subterranean habitats are probably one of the most important causes of the astounding diversity occurring there [12,13]. One of the most evident is the absence of light, as the solar radiation does not go beyond a few meters from the entrance (i.e., the connection with the surface), preventing organisms dependant on light, such as plants, from settling. [8,14]. Consequently, without the presence of these important primary producers, a general paucity of organic matter occurs within subterranean habitats, and the resident species mostly depend on allochthonous inputs [8]. Another consequence of the shelter from the sunlight and climatic fluctuations, is an increase of the stability of the subterranean microclimate, especially in the deepest parts [15,16].

Cave-dwelling species need to cope with the particular environmental conditions occurring in subterranean habitats, and to do that, they show a specific set of behavioural, physiological and morphological features [17–20]. Such features are generally considered as the result of species adaptation to the peculiar local ecological conditions [21–23]; however, several researches are documenting that

also other processes, such as neutral mutation or genetic drift, may represent alternative important factors [24–26]. Cave species are generally classified based on both the presence of specific adaptations to subterranean habitats and their ability to complete their life cycle there [12,27], although sometimes such classification may be too strict [10,28]. The most adapted species are the troglobionts: they often show evident adaptations (e.g., reduction of eyes and pigmentation, elongation of appendages) and only reproduce in subterranean habitats. Troglaphiles are a species that are able to reproduce in both subterranean and surface habitats, and show some adaptations to cave life. Troglaxenes are occasional visitors in caves and only reproduce in surface habitats. Although the wide contribution on the knowledge of cave-adapted species, researchers often overlooked troglaxenes in their studies [29–31], thus limiting the information on the potential effects that these transient species may have on cave communities and the overall ecosystem [32–34]. Cave animals often occupy specific areas of the subterranean habitats, the less adapted being closer to the connection with surface, and the most adapted in the deepest parts [8,30,35,36]. Consequently, different cave communities can occur [16,37–39], each one characterised by distinct diversity and dynamics, with species holding different ecological roles [33,40–43], and often with blurred borders.

This Special Issue of Diversity aims to explore the relationships among cave-dwelling species, considering not only troglobionts, but all the organisms occurring from the entrance to the deepest sectors, a topic which is still poorly explored. Our goal is to stimulate and collect new research focused on multiple cave species [37,44], or on the ecological role that single species have for the local ecosystem [31,45]. For example, considering the ecological gradient occurring from the cave entrance to the deepest areas (light, microclimatic variability and food availability vs. darkness, microclimatic stability and food scarcity; [27]), species occupy areas according to their preference [46–49], and consequently form different communities characterised by specific intrinsic dynamics [30,43,50,51]. Studying the relationships between species within cave communities will not only let us understand how species interact (e.g., competition, mutualism, prey–predator interactions), but will also allow us to determine their ecological importance for the entire subterranean ecosystem. Indeed, species from the communities inhabiting the areas close to the cave entrance are likely to have a key role in supporting the overall subterranean habitat, as they are able to transfer new organic matter from surface habitats to the subterranean one [42,43,45,52,53]. Consequently, some of the species from deep cave areas (if not entire communities) are strongly dependant on the operations of shallowest communities [42,54].

From a geological point of view, several types of subterranean environments exist (e.g., natural and artificial caves, shallow subterranean environments sensu [7], small fissures and interstices, etc.) and each one can host a unique set of organisms, from bacteria and fungi to invertebrate and vertebrate species, that are often geographically restricted and numerically rare [55–57]. Improving the knowledge on subterranean communities will allow an increase in the effectiveness of conservation plans towards single cave species as well as the entire ecosystem [56,58,59]. Indeed, conservation plans towards key species will have a cascade of positive effects on the entire ecosystem [60,61]. Furthermore, understanding the role of cave communities and the relationships occurring between species with different levels of adaptation can allow us to predict the potential effects due to subterranean biodiversity loss, as cave species (especially stenoendemic ones) are highly sensitive to multiple factors, such as environmental changes, pathogen spread, invasion of alien species and even poaching [62–66].

Since its beginning, subterranean biology has been characterised by two main branches, one related to taxonomic investigations of subterranean organisms [2,8], and the other considering caves as a powerful natural laboratories to perform evolutionary, ecological and behavioural studies on selected model species [27,67,68]. The study of subterranean diversity has the potential to lead the advances of modern science and solve some of the current scientific challenges [27]. We hope that this Special Issue could provide new insights of broad interest, and develop a new hypothesis to test and highlight the role of the subterranean biology as one of the leading disciplines in ecology and evolution.

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