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The distribution of bat species across the underground sites of Georgia

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Abstract

In Georgia, investigations of bat species using caves have been conducted since the beginning of the 20th century. However, robust knowledge is still largely unavailable, as only about 15% of the roughly 2,000 underground sites have been surveyed for bats. The primary objective of this article was to document the use of underground habitats by various bat species. To achieve this, we consolidated field observations with existing data from literature and assessed potential threats to these underground habitats, specifically focusing on caves that harbor significant bat colonies. In this study, we considered underground sites across Georgia where at least one bat species has been documented. In total, twenty out of the thirty bat species recorded in Georgia were found in these underground sites. We characterize the spatial distribution, elevational range, usage of underground habitat, and colony size for these species. These twenty species belong to three families and ten genera. Three of these species have conservation status on the Georgian Red List, and one species is on the Red List of Threatened Species, according to the International Union for Conservation of Nature (IUCN). We also report the spatial and elevational distribution of bat species richness and frequency of records in order to rectify conservation priorities in this important biodiversity hotspot.

Keywords

Caucasus, Chiroptera, Diversity, Distribution, underground

Introduction

Caves and other underground (also called subterranean) habitats, including man-made ones, are important roosting sites for many bat species. Underground habitats can be used by different bat species for regular roosting, reproduction, and/or hibernation and play a significant role in their life cycle (Dietz and Kiefer 2016). However, underground habitats are also under increasing anthropogenic pressure (such as touristic impact, habitat modification, light pollution etc.) that pose a threat to bat populations (Mitchell-Jones et al. 2007; Nanni et al. 2023). Thus, understanding spatial distribution of underground habitats and threats to them is essential for identifying urgent risks and developing comprehensive conservation strategies that include legal protection and community-based initiatives to safeguard these vital roosting sites.

The country of Georgia, as a part of the Caucasus and Irano-Anatolian biodiversity hotspots, is rich with habitat and landscape diversity (Mittermeier et al. 2011; Habel et al. 2019), including subterranean habitats. However, the study of Georgia's subterranean environment and its biodiversity, including bats, is still in its infancy (Mumladze et al. 2020). The first attempts to investigate the bat fauna of Georgia were initiated in the middle of the 19 century (e.g Nordmann 1840; Kolenati 1860) However, this research was sparse, and the sporadic data about bat species diversity and distribution were scattered in publications mainly in Russian and Georgian (e.g. Satunin 1896, 1903, 1908, 1912, 1913, 1915; Chkhikvishvili 1926; Ognev 1928; Kuzyakin 1950; Papava 1949, 1953, 1960; Janashvili 1953, 1963; Perov 1980, 1983). Unsurprisingly, publications related to bats in caves and other underground habitats were even rarer, with large time periods between publications (Fig. 1). By the 1980s, 13 bat species had been identified in Georgia from 71 subterranean sites.

More systematic studies of Georgian bats started at the end of the twentieth century. These included general publications on Georgian bats, which also provided information on bats in caves and other underground sites (Benda 2011; Bukhnikashvili 2004: Bukhnikashvili et al. 2004, 2009; Gazaryan 2005; Ghazaryan et al. 2006; Ivanitsky 2010, 2015, 2017; Smirnov et all 2016; Yavruyan et al. 2008; Natradze et al. 2023) albeit to a limited extent. The only sources specifically targeting bats in caves were limited to individual caves (Ivanitsky 2002; Imnadze et al. 2020).

These later works include 115 locations in Georgia but did not record any new species. In addition to these published reports, we collected bat data from more than 300 surveys over a 20-year period at 44 additional underground locations. While some of the data concerning Georgia's bat diversity and distribution were previously documented in the literature (Natradze et al. 2023). We now present findings in underground habitats for the first time in a readily accessible format. However, it is important to highlight that the availability of information on bat diversity and distribution in Georgia's subterranean environment remains severely limited, as most of our data was not published prior this study.

To provide a comprehensive overview of the diversity and distribution of bat species in Georgia's underground habitats, we compiled and analyzed all available data on

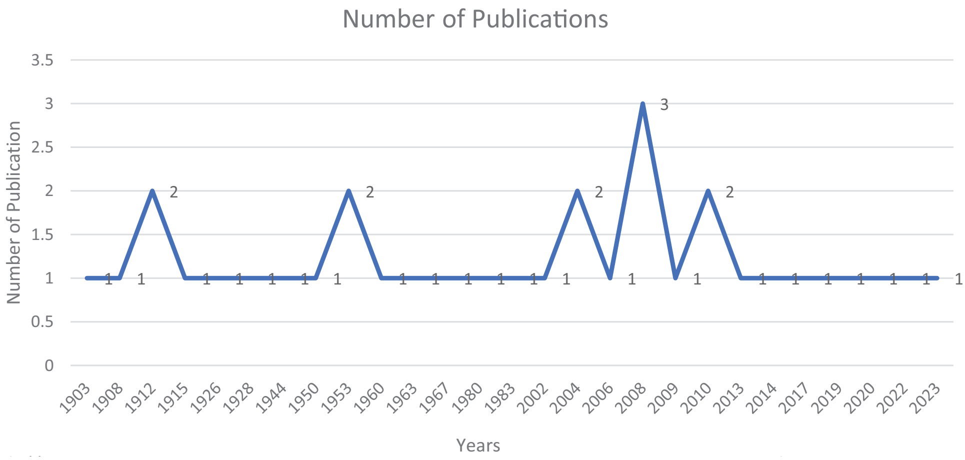

Figure 1. Number of publications with data on bats in underground habitats of Georgia, arranged by year.

bat records from these environments across the country. We characterized the spatial distribution, elevational range, and habitat use of the 20 bat species observed. This enhanced understanding of bat species distribution in Georgia is critical for conservation prioritization, particularly in light of the threats posed by anthropogenic pressures in this important biodiversity hotspot.

Materials and methods

Literature review

We gathered all known publications on Georgian bats, most of which are not available in English and/or through electronic databases of the scientific literature. Most of these publications are held in the scientific libraries of Georgian and Russian research institutions. We used the snowball survey method, where we began with a set of known references, including peer-reviewed, white, and gray literature, and traced back from there all additional references mentioned in this known set. Our known set began with materials from influential Georgian bat biologists prior to the 1970s. We included additional materials from a complete review of cataloged resources in our institute's academic library and other academic libraries within Georgia, as well as Georgian museums with bat collections. We visited relevant academic libraries and museums in Russia (e.g., the collection of the Zoological Institute of the Russian Academy of Science [Saint Petersburg]; the Zoological Museum of Moscow State University) and searched for references to bats in the Caucasus region. We also searched the European databases (GBIF, EUROBATS underground habitats database) and a compendium of Soviet publications (Chkhikvishvili 1926; Ognev 1928; Bobrinsky at al. 1944; Kuzyakin 1950; Janashvili 1953; Papava 1953, 1960; Janashvili 1963; Kipiani at al. 1966; Matsaberidze and Khotenovskii 1967; Perov 1980, 1983), for references to bats in the Caucasus region. Finally, we made use of our network of colleagues in the Caucasus region, Russia, and Europe to check our list of references for any additions. From the literature search, we recorded all reported instances of bats and included species, data, location, altitude, and coordinates. While exact coordinates for observations were often unavailable in older literature (i.e., prior to 1999), we georeferenced most of the sampling locations based on the names of the underground habitats.

Field data collection

Our surveys of caves and other subterranean sites were conducted from 1999 to 2024 during all seasons, resulting in more than 300 surveys across the country. In this paper, we report on 115 underground sites where bats were recorded. For each survey, we surveyed the underground sites for species presence. Additionally, during the swarming period, we mist-netted bats in front of the underground sites. Nets were constantly patrolled, and bats were removed immediately from the net and placed in bags where they remained calm while awaiting processing. We collected morphological measurements for species identification, according to Kuzyakin (1950) and Dietz (2016). After taking measurements, bats were released at the site of their capture. Bats were netted and handled under agreements #2722/01, 2302/01, R/057-21 issued by the Ministry of Environmental Protection and Agriculture of Georgia.

The sampling area covered all the major subterranean environments of Georgia. Natural caves are found mainly in karstic outcrops that cover 6.4% of the total area of Georgia (4,475 km^2). These caves are mostly found in western part of the country in the peripheral zone of the southern slope of the Caucasus and on the hilly zones north of the Colchis lowland (Ukleba 1981). In eastern Georgia, karstic outcrops are not fully developed and are present as limestone deposits where a few small grottos and crevices have formed. Overall, there are more than 1500 known karst and conglomerate caves in Georgia (Asanidze et al. 2017).

We also surveyed man-made subterranean sites. In western Georgia, these are mainly mines. The mine surveys were somewhat limited within the Chiatura municipality where abandoned manganese mines are unsafe to enter. In eastern Georgia, there are mainly man-made caves covered with built-in walls and small grottoes. These man-made caves are predominantly in the gorges of the Mtkvari (Kura), Iori, Khrami, Algeti and Mashavera rivers. They are formed in sandstone, while in other places they are made by widening volcanic caverns.

When bats were observed in colonies, we employed several methods to draw the rough estimate of the colony size. Due to difficulties associated with colony size estimates for bats (Kunz et al. 2009), for small and fully visible groups, we conducted direct counts of all individuals. In larger colonies, (where possible) individuals were counted for representative subgroups (i.e., subgroups delimited using the square light), and the total colony size was then estimated by multiplying the subgroup count by the estimated number of individuals. If the direct counts within subgroups were not possible (due to distance or danger of harassment) or for very large aggregations, sometimes consisting of multiple groups, we used photographic methods. When groups were too large to capture in a single image, multiple photographs were taken, and individuals were counted from the images.

Data analysis

In order to understand the association of each species with the subterranean habitat, we classified the lifestyle of bats into six categories based on literature descriptions and/or our field observations: (i) exclusively cave dwelling species, i.e. species that roost in caves only; (ii) mainly cave dwelling species, i.e. species that roost in caves, but can also use other types of underground habitats; (iii) partially cave dwelling species, i.e. species that mainly use trees as summer roosts but use caves and other subterranean habitats for wintering, mating or swarming; (iv) forest species, i.e. species that roost on trees but can use underground habitats for mating or cave entrances and crevices in the entrances of caves for temporary roosting; (v) species living in different types of crevices e.g. buildings, rocks, entrances of caves, joints of bridges; and (vi) species with no shelter preference, i.e. species with the widest spectrum of sheltering preferences.

We summarized and visualized the data using custom R code (R Core Team 2022). Location data were masked or aggregated to protect the location information of bats that may be endangered or harassed. We aggregated the data using a 50 × 50 km cell size as this size optimized the density of information for biologically meaningful visualization and was neither too dense nor too sparse.

Assessment of main threats to underground roosts

In addition to documenting the presence of bats, our surveys assessed potential threats to underground roosts at selected sites with colonies. We identified threats such as i) excessive disturbance, ii) destruction, alteration, or change in the use of habitat, and iii) light pollution, as highlighted in the studies by Mann et al. (2002), Mitchell-Jones et al. (2007), Voigt et al. (2018) and Kyheröinen et al. (2019). We quantified each threat on a scale from 1 to 3, where 1 represented low threat, 2 indicated medium threat, and 3 denoted high threat. Simultaneously, we evaluated the accessibility of each cave, assigning levels where 1 indicated hard access, 2 signified moderate access, and 3 denoted easy access. By calculating an average score for each site, combining threat and accessibility levels, we developed a comprehensive quantifier that enhanced our ability to assess the vulnerability of each site. This systematic quantification of both threats and accessibility transformed qualitative assessments into quantifiable data, crucial for comparing conditions across sites. This methodology enabled us to identify more vulnerable caves due to greater threats or easier access, guiding the development of precise conservation strategies and management practices. These assessments are pivotal in protecting these vital roosting areas, underscoring our commitment to converting subjective assessments into objective data for targeted conservation efforts.

Results

Species composition

Papers published from 1912 to 2010 recorded 13 bat species from 71 underground sites. Since 2010, we have added 44 underground sites and recorded a total of 20 species. Of these 20 species, one (*Rhinolophus blasii*) was recorded for the first time in the country; twelve species overlapped previously published reports, while the presence of previously recorded *R. mehelyi* could not be confirmed. In addition, six species that usually did not use underground habitats were unexpectedly recorded. Thus, at the time of writing, there were 331 records of 20 bat species from 115 sites in Georgia (Annex 1. Table 1).

During our surveys from 1999–2024, some bat species were recorded multiple times (Fig. 2). The most common species observed were *Rhinolophus ferrumequinum*, followed by *R. hipposideros*, *Miniopterus schreibersii*, *Myotis blythii*, and *R. euryale*. The species *R. ferrumequinum*, *M. blythii*, *R. euryale*, and *M. schreibersii* persist in significant numbers in specific cave habitats.

The most commonly encountered species included six primarily cave-dwelling species: *Rhinolophus ferrumequinum*, *R. hipposideros*, *R. euryale*, *Myotis blythii*, *M. emarginatus*, and *M. schreibersii*. Additionally, seven partially cave-dwelling species were recorded: *M. mystacinus*, *M. brandtii*, *M. daubentonii*, *M. nattereri*, *Barbastella barbastellus*, *Plecotus auritus*, and *P. macrobullaris*. Only one species, *R. blasii*, was found exclusively in caves (Fig. 3). We also recorded two forest species, *Myotis bechsteinii*, and *Nyctalus leisleri*; three species living in various types of crevices, *Hypsugo savii*, *Eptesicus serotinus*, and *Vespertilio murinus*. Finally, we recorded one species, *Pipistrellus pipistrellus*, which showed no clear roosting preference.

The results of species counts and records using the grid with 50 × 50 km cell size, which are illustrated in Suppl. material 1: map S1, provide insight into the distribution of these species across the surveyed areas. Counting species richness using a bar plot with 300-meter bands showed that the highest species diversity occurred in the 0–300 and 1200–1500 meters above sea level (m.a.s.l) elevation range, followed by the 600–900 m.a.s.l elevation range (Figs 4, 5). Spatial distribution maps for species are provided in Suppl. material 1: maps S2–S10.

Table 1. Threat Assessment Scores for Selected Bat Roosting Sites in Georgia.

#	Roost	Extensive disturbance	Destruction, maintenance or change of use	Light pollution	Accessibility	Average scores
1	Ghliana	3	3	2	3	2.75
2	Melouri	1	1	1	2	1.25
3	Samrtskhle Klde	2	3	1	2	1.75
4	Vardigora	1	1	1	3	1.5
5	Sakishore	1	1	1	2	1.25
6	Becho	1	1	1	2	1.25
7	Matkhoji Cave	2	1	1	2	1.5

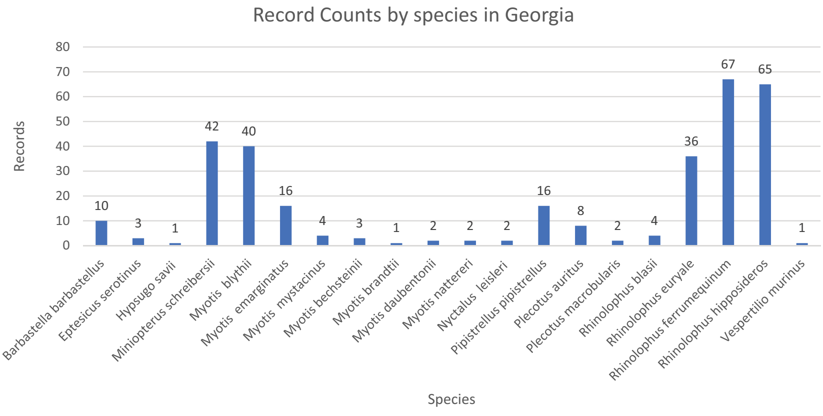

Figure 2. Number of records of Bat species in subterranean habitats.

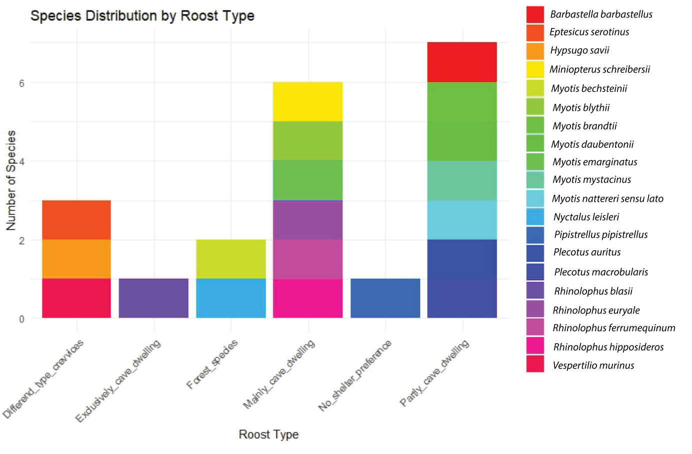

Figure 3. Cave associated species diversity in Georgia arranged according to habitat use.

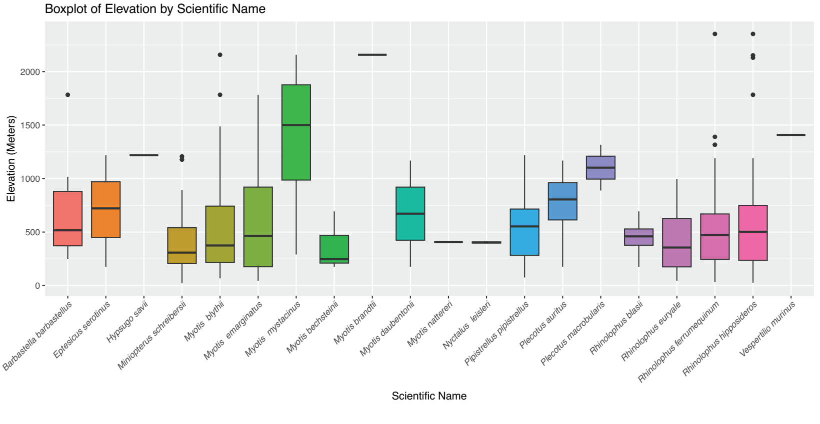

Figure 4. Species records by elevation.

Figure 5. Species richness by 300 meters bins.

The summary of threats affecting bat caves shows that Ghliana Cave and its colony are the most threatened, while the rest of the caves with colonies are moderately threatened by human disturbance (Table 1).

Discussion

We consistently recorded three (*Rhinolophus ferrumequinum*, *Myotis blythii*, *Miniopterus schreibersii*) species in the literature prior to 1999, as well as in our own surveys from 1999 to 2024, suggesting that the species richness has remained constant over time. We found that most of these species in underground environments are located in colonies of up to 1000 individuals. Our analysis highlights that the highest richness and diversity of bats in underground habitats of Georgia are localized in western Georgia, particularly within karstic outcrops. Notably, the highlighted grid areas emerged as locations with the highest species richness and number of records, underscoring their critical importance for bat conservation.

The most frequently encountered bat species, *Rhinolophus ferrumequinum*, *R. hipposideros*, *R. euryale*, *Myotis blythii*, and *Miniopterus schreibersii*, were assigned to the category of 'mainly cave dwelling species.' From these five species, *R. euryale* is included in the Red List of Georgia with the category Vulnerable (VU), and *M. schreibersii* is also designated VU on the IUCN Red List. All five of these species are included in the list of Emerald Network priority species (https://rm.coe.int/1680746afc), highlighting these locations as critical microhabitats for their survival. *R. blasii*, a species that roosts exclusively in caves (Dietz and Kiefer 2016), was recorded in Georgia for the first time in 2006, and since then it has been found in three other caves (Suppl. material 1: map S5). Notably, during our extensive surveys, we did not record *Rhinolophus mehelyi*, which should be considered as 'mainly cave-dwelling species', and was last recorded in 1964 (Matsaberidze, Khotenovskii 1967). Although we have not encountered this species, the possibility that it still occurs in the country cannot be conclusively ruled out, highlighting the need for continuous monitoring of these habitats.

In one of Georgia's largest nursery colonies, Ghliana Cave, a mixed maternity colony is present, with the number of species varying by year and season. The cave is annually inhabited by *Myotis blythii* and *Miniopterus schreibersii*. Additionally, in different years and seasons, it provides a roost site for *Rhinolophus ferrumequinum* and *R. euryale*. In some years, *M. emarginatus* has also joined this mixed colony. The population of the maternity colony fluctuates annually, ranging from 4,000 to 8,000 individuals (Campester 2019), reaching its peak in late July to early August.

Another of Georgia's most numerous nursery colonies is in the Samertskle Klde Cave, which also reaches 8,000 individuals or more in certain years, primarily consisting of *Myotis blythii* and *Miniopterus schreibersii.* Besides these nursery colonies, Sakishore Cave hosts the largest known wintering colony, with more than 1,000 *M. schreibersii*.

Based on our observations, various levels of threats affect underground habitats in Georgia. The results of the assessment enable us to identify specific risks and tailor conservation approaches to meet the unique needs of each site, thereby ensuring the protection of the most crucial habitats. The divergent threat levels observed at these key locations necessitate targeted management practices for the sustained protection of these essential bat populations. Our findings underscore the immediate need for customized conservation efforts for high-risk caves, such as Ghliana, and call for diligent monitoring due to their greater accessibility and moderate threat levels. The variation in threat severity across these sites highlights the necessity for specific protective actions and emphasizes the importance of continuous monitoring and adaptive management strategies.

Despite recent anthropogenic pressures, the outlook for bat biodiversity conservation in Georgia is encouraging: no species have been lost, and some species of concern remain locally abundant. However, of the important karstic areas that host bat diversity hotpots, only 18 caves or cave complexes are legally protected. These include the Imereti Caves Protected Area with protection status of several caves as natural monuments. Additionally, only two caves are listed as important by the Emerald Network (Emerald Network 2020), while two caves with Georgian protection status and two man-made caves are included in the database of the Agreement on the Conservation of Populations of European Bats (EUROBATS). Of the protected caves, only the Ghliana and Melouri caves host large bat colonies. From these, the Ghliana cave has the highest endangered score based on our estimates (Table 1) despite the fact that Georgian Ministry of Nature Protection and Agriculture developed a conservation action plan for Ghliana Cave in 2019 (Campester 2019).

Based on the existence of well-developed karstic areas, high frequency of encounter, high richness, and high diversity, we consider the Imereti, Samegrelo, and Apkhazeti regions of Georgia as the most important areas for bat conservation. Access in these regions is difficult due to the absence of roads and the high altitudes of some caves, which ensures some sort of de facto protection. However, such protection is not sufficient for conservational purposes, and only protection of underground sites with large colonies is not sufficient. Protective measures should also include surrounding habitats that are used by bat colonies as commuting routes and foraging grounds. We recommend that more conservation and research should be undertaken in the Imereti and Samegrelo regions to ensure bat protection. Also, we urge the establishment of conservation status for four more caves: Samertskhle Klde, Vardigora, Becho, and Sakishore. By protecting these caves, Georgia will contribute to the improvement of conservation status of *Rhinolophus euryale*, *Myotis blythii*, and *Miniopterus schreibersii.* While the current status of Georgian bat biodiversity is encouraging, more needs to be done to ensure protection in the face of anthropogenic threats. Long term monitoring of bat species in underground sites and analysis from a biodiversity perspective enhances our understanding of their natural history and distribution, thereby helping to prioritize conservation efforts.

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Supplementary material 1

Additional information

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Data type: pdf

Explanation note: **map S1.** The number of records and species found in each quadrat of Georgia. **maps S2–S10.** Species distribution Maps of records in underground habitats.

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