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Workshop Report

Current cave monitoring practices, their variation and recommendations for future improvement in Europe: A synopsis from the 6th EuroSpeleo Protection Symposium

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Abstract

This manuscript summarizes the outcomes of the 6th EuroSpeleo Protection Symposium. Special emphasis was laid on presenting and discussing monitoring activities under the umbrella of the Habitats Directive (EU Council Directive 92/43/EEC) for habitat type 8310 "Caves not open to the public" and the Emerald Network. The discussions revealed a high level of variation in the currently conducted underground monitoring activities: there is no uniform definition of what kind of underground environments the "cave" habitat should cover, how often a specific cave has to be monitored, and what parameters should be measured to evaluate the conservation status. The variation in spatial dimensions in national definitions of caves further affects the number of catalogued caves in a country and the number of caves to be monitored. Not always participants are aware of the complete national monitoring process and that data sets should be freely available or easily accessible. The discussions further showed an inherent dilemma between an anticipated uniform monitoring approach with a coherent assessment methodology and, on the contrary, the uniqueness of caves and subterranean biota to be assessed – combined with profound knowledge gaps and a lack of resources. Nevertheless, some good practices for future cave monitoring activities have been identified by the participants: (1) Cave

monitoring should focus on bio- and geodiversity elements alike; (2) Local communities should be involved, and formal agreements envisaged; (3) Caves must be understood as windows into the subterranean realm; (4) Touristic caves should not be excluded ad-hoc from regular monitoring; (5) New digital tools and open FAIR data infrastructures should be implemented; (6) Cave biomonitoring should focus on a large(r) biological diversity; and (7) DNA-based tools should be integrated. Finally, the importance of the 'forgotten' Recommendation No. 36 from the Bern Convention as a guiding legal European document was highlighted.

Keywords

cave monitoring, Habitats Directive, habitat type 8310, Emerald Network, Bern Convention, Recommendation 36

Date and place

26/ 10 - 30/10/2021; International Academy for Nature Conservation (INA), Isle of Vilm, Germany.

List of participants

Please refer to the complete list of authors. No differentiation is made between physical and virtual participants.

Introduction

This publication summarizes the outcomes of the 6th EuroSpeleo Protection Symposium entitled "*Assessing, monitoring and protecting cave biotopes and geotopes through Natura 2000 or similar programs in Europe*", held from 26th to 30th October 2021 at the International Academy for Nature Conservation (INA) on the Isle of Vilm (Germany). This hybrid event, jointly organized by the German Federal Agency for Nature Conservation (BfN) and the European Cave Protection Commission (ECPC) of the European Speleological Federation (FSE), gathered 45 participants from 22 countries (16 EU, 4 non-EU Europe, Australia and United States of America).

Aims of the workshop

A questionnaire was sent to the participants before the meeting, with the aim to generate a descriptive overview of the status quo of cave monitoring activities in the participating countries (Suppl. material 1). The questionnaire, as well as the symposium, had a strong focus on monitoring activities under the umbrella of the Habitats Directive (EU Council Directive 92/43/EEC) for habitat type 8310 "Caves not open to the public" and the Emerald

Network. To a lesser extent the topics of monitoring activities for individual cave-dwelling species of Annexes II and IV of the Habitats Directive (i.e., Microchiroptera, *Proteus anguinus*, *Speleomantes* spp., *Congeria* spp. and *Leptodirus hochenwartii*) or the habitat type 8330 "Submerged or partially submerged sea caves" were discussed.

Key outcomes and discussions

A high degree of variation in current cave monitoring practices

The participant's feedback received via the questionnaire revealed a high level of variation in the currently conducted underground monitoring activities. On the one hand, these differences result from the different framework conditions the Habitats Directive and the Emerald Network set for monitoring activities. Generally, Natura 2000 sites within the Habitats Directive are considered as the contribution of the EU member states to the global Emerald Network. However, as a more significant discrepancy, there is only a recommendation for reporting in the Emerald Network (e.g. H1 "Terrestrial underground caves, cave systems, passages and waterbodies"). In contrast, there is an obligation to report on and explicitly assess the conservation status of habitat types 8310/8330 as well as Annex species in the six-year reporting cycle of the Habitats Directive (Art. 17). On the other hand, the surveyed countries showed very strong discrepancies in terms of who carries out the monitoring activities (independent experts, speleological societies, research institutes, universities, museums, NGOs, bat specialists, national parks, ministries or regional administrations) and what resources can be relied on (financial, infrastructural, personnel, pool of knowledge). At site level the "Natura 2000" standard data form is harmonized with Emerald-site descriptions, however there is no explicit ruling how often this needs to be updated. Here the local degree of conservation should be reported. Moreover, there is no uniform definition of what kind of underground environments the “cave“ habitat should cover (Table 1), how often a specific cave has to be monitored (monthly to once each three years), and what parameters should be measured (fauna, flora[sic], abiotic parameters) to evaluate the conservation status. The variation in spatial dimensions in national definitions of caves further affects the number of catalogued caves in a country and the number of caves to be monitored. The survey results also showed that not all participants were aware of the complete national monitoring process and that data sets were not freely available or easily accessible. While in the EU the Natura 2000 implementation in the past largely focused on site selection and protection there is generally limited EU-guidance in monitoring systems (Ellwanger et al. 2018) and in some Member States these systems are still not fully established.

Table 1.

List of selected legal definitions of "a cave" for monitoring purposes.

Geographical coverage	Definition of a cave	Defined spatial criteria of a cave	Legal source
EU member states	Caves not open to the public, including their water bodies and streams, hosting specialised or high endemic species, or that are of paramount importance for the conservation of Annex II species (e.g. bats, amphibians)	Not defined	Interpretation Manual of European Union Habitats, version EUR 28
Bosnia and Herzegovina (Entity: Federation of BiH and Entity: Republic of Srpska)	Speleological objects are naturally formed underground cavities longer than 5 meters, that can be entered by man, and the dimensions of the entrance are less than the depth or length of object (caves, pits, abysses, estavels, etc.)	More than 5 m long; object can be entered by man, with dimensions of the entrance less than the depth or length of object	Zakon o zaštiti prirode („Službene novine Federacije BiH“, broj:66/13); and Zakon o zaštiti prirode (“Službeni glasnik Republike Srpske, broj:113/08)
Bulgaria	The cave is an underground cavity with a volume, big enough to fit a man	Big enough to fit a man	Source used in the speleology manual: Malcolm S. Field (2002) A Lexicon of Cave and Karst Terminology with Special Reference to EnvironmentalKarst Hydrology. Office of Research and Development,U.S. Environmental Protection Agency, Washington, DC
Croatia	Speleological objects/spaces are naturally formed underground spaces (caves, pits, abysses, estavelles, etc.), as well as their parts	Not defined	Point 46, paragraph 1, article 9 of the Nature protection act (Official Gazette, No. 80/2013, 15/2018, 14/2019 and 127/19)
Germany	Caves, including their waterbodies, are usually inhabited by specialized typical species (cavernicolous fauna), which may include rare local or regional endemics, restricted to one or a few cave systems. Semi-caves ("Balmen") are included if they have specific vegetation or fauna	Not defined	Legal source refers only to EU Habitats Directive itself, BNatSchG § 31-36 (Bundesnaturschutzgesetz, framework law) at National level, different implementations in the 16 Federal states with additional laws on nature conservation (Landesnaturschutzgesetze). See also Ssymank (in press)
Greece	Caves are not defined/ interpreted in Greece's legislation	Not defined	Not available

Geographical coverage	Definition of a cave	Defined spatial criteria of a cave	Legal source
Hungary	Cave is a natural cavity formed in the earth's crust, which exceeds the length of 2 meters along its longitudinal axis and - after the removal of its current or natural deposit - it is possible for a human to enter	More than 2 m long (longitudinal axis); broad enough to enter	1996. évi LIII. törvény a természet védelméről (Law on nature protection), Tvt. 23§
Italy	Both natural and artificial cavities are not defined/ interpreted in Italy's legislation. They are not protected at the origin but only by special laws on extractive activities, mineral waters, archaelogy and fine arts, or by parks, reserves and regional laws	Not defined	Underground mines stay under the dictates of the D.P.R. no. 128 of 09/04/1959 (Police regulations of mines and quarries, updated with Legislative Decree no. 624/96) while cavities of historical-archaeological interest or of particular geological singularity are protected by the Code of Cultural Heritage and Landscape (Legislative Decree 22.01.2004 no. 42)
Latvia	Natural or naturalised subterranean entity within bedrock or cemented Quaternary sediments more than 3 m long and broad enough to enter	More than 3 m long; broad enough to enter; length > width of the entrance	Page 12 in Eniņš (2004)
Luxembourg	Caves and semi-caves not used for tourism, including their water bodies. Requirements: 1) naturally formed underground cavity with a dark zone. 2) minimum size: cavities into which a person can enter, larger than 5m³, with a depth of at least 5m. 3) animal burrows are explicitly excluded	At least 5 m long; broad enough to enter; volume larger than 5m³	Monitoring sheet and national interpretation manual
Romania	The cave is a natural cavity formed in the earth's crust, wide and deep enough to allow a human to enter. By extension, the cave can be a system that can have more than one entrance and consists of several galleries, halls, wells and chimneys. The term also applies to the cavities defined above, which are partially or completely submerged or which have been opened by demolition or clearing	Wide and deep enough to allow a human to enter	Art. 43(3) from Governmental Emergency Ordinance 57/2007, approved by Law 49/2011

Conservation status of caves

Anecdotally, caves are just holes in the ground and maybe important for bats. And, they should be in generally good conservation status since nobody has access to them or it is physically too demanding to enter them. These typical misunderstandings are challenged by the fact(s) that caves are under strong human impact. Environmental pollution and sports, tourism and leisure activities are frequently identified as the main pressures and threats, which are often further intensified by illegal collections of cave-dwelling species and speleothems in some countries or specific caves (Prelovšek and Zupan Hajna 2011, Simičević 2017, Mammola 2018).

Trends of illegal cave-dwellers trade are particularly prominent in developing and transition countries, mostly due to ineffective local and regional management systems and insufficient interest in governing structures on this issue. In Dinaric Karst speleological objects, collecting and illegal trade mainly dates back to the 19th and early 20th centuries (Sket 2012). But unfortunately, the collection and illegal trade of mostly endangered, rare, and relict fauna, as well as of palaeontological remains (mostly *Ursus spelaeus)* still exists, e.g. in Bosnia and Herzegovina (Lukić Bilela and Jelić 2018), particularly in faunistic rich caves such as Vjetrenica or Megara (in Bjelašnica Mt.) known as one of the largest *U. spelaeus* finding sites in the Western Balkans (Lukić-Bilela et al. 2013).

Another severe problem, especially in Vjetrenica cave, was the sampling of numerous specimens within (already small) metapopulations of rare species. With or without a collecting permit, these negative examples have been observed even among well-known and established scientists, who are expected to have high ethical principles. Furthermore, obtaining permits is relatively simple and generally does not contain mechanisms to control the sampling methodology and/or number of samples, nor are fines imposed for non-compliance. Thus, transition countries often become a twilight zone for illegally collecting valuable samples, with holotypes often ending outside the home country. Furthermore, most of these countries are not signatories to the Nagoya Protocol, and have no impact to any benefit-sharing, while their subterranean biodiversity is directly threatened.

Based on the Habitats Directive 2013-2018 assessments (EEA Web Tool 2021), the evaluation of the conservation status of H8310 caves varies from country to country and between biogeographical regions, but usually falls in the categories FV (Favourable) and U1 (Unfavourable-Inadequate). However, many country reports highlighted that the monitoring data and evaluations relied on expert opinions with a very limited amount of systematically collected data available. This lack of a systematic data collection allows on the one hand a high degree of freedom in implementation procedures, and the authorities, institutions and individual persons to get involved in national cave monitoring activities, but on the other hand also creates a significant heterogeneity in the evaluation of the conservation status between countries. This shows that cave monitoring to a large extent relies on expert volunteers and their interests and, thus, is strongly dependent on motivated and skilled experts (e.g., speleologists, researchers, naturalists) as well as available resources. The lack of financial and infrastructural support by national public administrations also creates a risk of fluctuating expert knowledge for cave monitoring and

finally renders it extremely difficult to systematically collect, store and analyse data on a full scheme and long-term basis.

As a result, lacking adequate underlying data for monitoring can lead to erroneous conclusions regarding the conservation status of habitat 8310 or resident species, creating further inadequate conservation measures, or in case of a false favorable status, to no actions at all.

Prospects for future cave monitoring

Modern trends in conservation (speleo)biology prioritise the protection of endemic, relict or permanently endangered animal groups and their habitats, which necessitates an accurate assessment of the actual faunal inventory. Apart from being the basis for the preparation of Red Lists or Red Books of subterranean fauna, an adequate inventory is crucial for professionally guided monitoring activities of the often extremely vulnerable cave-dwelling organisms and subterranean ecosystems as a whole.

In line with a proposed conservation roadmap for the subterranean biome (Wynne et al. 2021), the symposium participants were guided by three basic questions: How to optimally monitor cave environments? How to evaluate the collected data? And finally, how to adequately define the conservation status of a cave? For the Habitats Directive, two principles of assessment are usually executed in parallel: loss or deterioration of the habitat and the distance to predefined favourable conservation status. The discussions showed an inherent dilemma between an anticipated uniform monitoring approach with a coherent assessment methodology and, on the contrary, the uniqueness of caves and subterranean biota to be assessed combined with profound knowledge gaps and a lack of resources. Nevertheless, seven good practices for future cave monitoring activities have been identified by the participants:

(1) *Cave monitoring should focus on bio- and geodiversity elements alike*

Caves harbour valuable bio- and geodiversity, and as such, both measures should be monitored and their entities protected. There was also a strong agreement that geodiversity elements guide biodiversity elements in underground environments and it is fundamental to secure them for effectively protecting cave-dwelling communities, which is in line with the recently adopted Resolution WCC-2020-Res-074-EN. An aspect that is intrinsically understood but not always explicitly formulated. Hence, a strong link between Life and Earth Sciences is needed to conduct monitoring activities, which often stays in contrast with established departmental and community structures. Goal-oriented integrative expert groups and networks should form, involving biologists, geologists, anthropologists, archaeologists, speleologists, speleodivers, and public administrations. A multidisciplinary community is needed to merge our understandings of caves being important sites of cultural heritage and endangered habitats of specific cave-dwelling communities (Wynne et al. 2021).

(2) *Local communities should be involved, and formal agreements envisaged*

Cave protection is a multi-layered process. The local community is physically, and often also emotionally, most closely involved. As such, local communities should be centrally involved in protecting caves, as no one can be more interested in protecting and improving their natural heritage (assets). This can be done e.g., by highlighting emblematic cave organisms (e.g., cave animal of the year; Vogel et al. 2017b) or fascinating speleothems and by active integration in the monitoring process, e.g. as conducted during the monitoring of special interest geological features at sites of special scientific interest (SSSI) in the UK. Training of local cavers in monitoring methods and conservation approaches (e.g., Romanian bat monitoring, Bücs et al. (2019)) can also create favorable conditions for active involvement in the future. Moreover, formal agreements for cave protection or memorandums of understanding should be aimed for, and a shared point-of-view of management plans developed by all stakeholders involved. A good example here originates from the Vjetrenica cave, as one of the faunistically richest caves in the world (Culver et al. 2021; Ozimec and Lucic 2009) with 219 species recorded (incl. 41 new for science) and being the reference site for the definition of a novel habitat type - the cave hygropetric (Sket 2004, Ozimec 2021). It has been declared a Protected Landscape and nominated for inscription on the UNESCO World Heritage List in 2021. This exceptional bio- and geodiversity also requires careful project management such as preparation of planning documents (strategy, program, and management plans), planning of future research but also financing and continuous work on promotion and education, with strong inclusion of the local community and the Municipality of Ravno, besides the governmental bodies. The cave is managed by the Public company "Vjetrenica", but the entire local community is directly or indirectly involved in cave protection and community prosperity. This includes working closely with speleologists, scientists from different fields of research, experts and business people. The local community is turning to sustainable tourism, sustainable agriculture and organic production to avoid toxic organophosphorus pesticides, supports scientific expeditions in the underground of Popovo polje (such as donations of local small business owners in food and other necessities). They also take an active part in different development projects in the Municipality of Ravno such as Vjetrenica infrastructure arrangement, revitalisation of the narrow railway and many other projects that directly contribute to sustainable tourism, agriculture and development. The local community supported the provision of space for the establishment of the Vjetrenica Biospeleological Museum, the first such museum in this part of Europe, and is actively working to create conditions for new development ideas that will enable further research in Vjeternica cave but all other caves in Popovo polje.

(3) *Caves must be understood as windows into the subterranean realm*

Caves allow humans to more or less easily enter underground environments, and to act in them. However, caves as an anthropocentric term must be understood and seen as windows into the subterranean realm (Mammola 2018). As such, monitoring activities within caves and the protection of a cave should be only the beginning of environmental protection, and it is of paramount importance to save the whole ecosystem by preserving

nearby aquifers and surface areas. The specific fauna of groundwater aquifers also has many local endemic species and their distribution is not linked to typical distribution patterns of above-ground biodiversity (Deharveng et al. 2009).

(4) *Touristic caves should not be excluded ad-hoc from regular monitoring*

The habitat type 8310 of the Habitats Directive excludes touristic caves from legal monitoring obligations. However, touristic caves are often the best-studied and understood underground environments in a country (Baradla Domica cave system in Hungary; Frasassi caves in Italy; Vjetrenica cave in Bosnia and Herzegovina; Grotte de Han in Belgium; Meziad cave in Romania) and harbour at least equally rich bio- and geodiversity elements compared to non-touristic caves (Culver and Sket 2002, Culver et al. 2021). Additionally, only small(er) parts of a touristic cave usually are open to the broader public with large(r) parts excluded from regular visits. Hence, the integration of touristic caves into regular monitoring activities seems logical, as there exists no valid scientific reason for their ad-hoc exclusion. At least, the non-touristic parts of caves open to the public could be considered as habitat type 8310. Many touristic caves play also an important role for bat species of Annexes II and IV of the Habitats Directive, and in this case monitoring of the bat species including their habitat is necessary anyway.

(5) *New digital tools and open FAIR data infrastructures should be implemented*

The FAIR principles of data management and stewardship should be followed to more effectively use and interconnect existing information, i.e. fostering the **F**indability, **A** ccessibility, **I**nteroperability, and **R**euse of digital assets (Wilkinson et al. 2016). Good examples for open (bio)speleological data e.g. comprise the CroSpeleo database from Croatia (Institute for Environment and Nature of the Ministry of Economy and Sustainable Development 2022), the Cave Fauna of Greece Database (Paragamian et al. 2018), the Database of Romanian cave invertebrates (Moldovan et al. 2020), the SubBIOCODE database from Bosnia and Herzegovina (SubBioLab 2022) and the Cave Biodiversity of Georgia database (Barjadze et al. 2019). Furthermore, new smart tools such as the German CaveLife app (Vogel et al. 2017a) for ecological assessments of underground environments can be utilised to ensure direct in-field digital data entry.

(6) *Cave biomonitoring should focus on a large(r) biological diversity*

The protection of the subterranean realm and fauna of a region always begins with the protection of certain caves and groups or organisms (Culver and Sket 2002). However, subterranean habitats are often only monitored for their suitability as an important hibernation and nursery place for bats. Furthermore, the listed subterranean non-microchiropteran species in Annexes II and IV of the Habitats Directive are eutroglobiont low-range endemics and of high conservation concern for very few European countries. The direct link to the monitoring of the more complex cave-dwelling fauna is not explicitly made, although the description of habitat type 8310 states that the "specialised fauna"

should be taken into account. It is a gap in the species Annexes of the Habitats Directive that at the time of their status nascendi several species groups were not considered, due to missing data and or understanding. However, many of these species are of European importance and fulfil all legal criteria of the Directive for their inclusion into the Annexes. Therefore, once an update of Annexes is foreseen in future, a systematic scan of overlooked taxa to include at least a few indicator species would help.

Underground habitats represent complex ecosystems, with specific trophic transfers and food-webs (Saccò et al. 2019, Zaenker et al. 2020, Premate et al. 2021). Yet, to understand and protect underground environments as habitats of taxonomically rich and seasonally variable communities (incl. members of the specialised cave fauna, seasonally cave-dwelling and epigean animal taxa, as well as bacteria, protists and fungi), future biodiversity monitoring should go beyond the current limited faunistic elements and selected eutroglobiont species. The huge spectrum of cavernicolous fauna should be taken as a major part of the typical species inventory of the cave habitat, intrinsically be monitored and assessed as a "structures and functions" parameter (which includes typical species) and thus be understood as obligatory part of the Habitat assessment of Cave habitat types 8310 and 8330. Typical species as such have to be reported as a list to the EU as part of the national reports every 6 years, however clear rules on how to integrate them into assessments are still missing.

(7) *DNA-based tools should be integrated*

Faunistic assessments of subterranean communities can widely benefit from more widespread implementation of DNA-based tools. The digital taxonomic knowledge deposited in DNA barcode reference libraries can be freely utilised, without the direct need or immediate availability of a morpho-taxonomic expert. Undeterminable developmental stages or complicated genders can be readily identified and members within cryptic species complexes, i.e. biological species currently taxonomically lumped under a single name, can be more precisely told apart, which is an often highlighted conservation concern for subterranean biota (Trontelj et al. 2009Delić et al. 2017, Fišer et al. 2018, Malard et al. 2018). Furthermore, environmental DNA (eDNA) approaches can help to improve the knowledge on endangered subterranean target species, especially in difficult to reach underground environments (Saccò et al. 2022). Specific eDNA-based assays have been developed e.g. for the Cave Salamander *Proteus anguinus* (Gorički et al. 2017, Vörös et al. 2017), the Alabama Cave Crayfish *Cambarus speleocoopi* (Boyd et al. 2020) and Hay's Spring Amphipod *Stygobromus hayi* and its more widespread congener *S. tenuis potomacus* (Niemiller et al. 2017). Finally, DNA or eDNA metabarcoding-based surveys can help to reach a more comprehensive understanding of the subterranean community in a given ecosystem, e.g., by increasing taxonomic resolution and including so far underrepresented taxa such as fungi, protists, diatoms, bacteria, cyanobacteria, algae and mosses (Sohlberg et al. 2015, Miettinen et al. 2015, Nawaz et al. 2018, Korbel et al. 2017, Pfendler et al. 2018, Alaoui-Sosse et al. 2021). Metabarcoding approaches have been also utilised to characterise the diets of bats (Galan et al. 2018) and to identify ancient rodent remains (Guimaraes et al. 2016).

Conclusion

Cave montoring practices are far from being standardised in Europe. On the one hand, this is due to the fact that variable resources and levels of support are available to the nations, and on the other hand, imposed by the fact that central parameters of cave monitoring are poorly described in the Directive 92/43/EEC and very poorly interpreted in the EU Habitat Interpretation Manual (e.g. definition of "cave", definition "not open to the public", term "specialised species", term "endemic species"). Although, and due to natural constraints, cave monitoring needs to have a certain level of national flexibility to account for the variation of bio- and geodiversity elements, some basic standardisation guidelines and open data repositories are needed to compare data across space and time.

The most important European legal document on the conservation of underground habitats is the Recommendation No. 36 (Bern Convention 1992). This recommendation dates back to 1992, asking the Member States to list underground invertebrates and underground habitats that need to be protected and to proceed with their legal protection. The initial documentation was provided by Christian Juberthie (1931-2019) and 24 distinguished speleobiologists from 20 European countries (Juberthie 1992). Unfortunately, the Recommendation remains unimplemented in the majority of Member States (Haslett 2007), and became widely forgotten in the European cave monitoring community. A first important step would be to revive the contents of the Recommendation No. 36, including criteria for selecting underground habitats of biological value and proposals for procedures of protection and management of underground habitats, in order to have a common denominator as a basis for future cave monitoring activities.

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Supplementary material

Suppl. material 1: Questionnaire for the 6th EuroSpeleo Protection Symposium 2022

doi

Authors: Jean-Claude Thies, European Cave Protection Commission (ECPC)
Data type: questionnaire
Brief description: *This questionnaire was mandatory for each applicant. It should yield important information about the Natura 2000 monitoring and conservation of cave habitats in the country of origin. The information derived was presented at the Symposium and was an important foundation for discussion*.
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