Geoheritage (2020) 12: 42
https://doi.org/10.1007/s12371-020-00463-6

ORIGINAL ARTICLE

Impacts of Tourism-Led Constructions on Geoheritage Sites: the Case of Gilindire Cave

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Received: 29 August 2019 / Accepted: 30 April 2020 / Published online: 12 May 2020

Abstract

Geological heritage sites are of great importance both for better understanding of the formation of the earth and for transferring its memory to future generations. People's curiosity to access this information leads to tourism activity, in which caves constitute a significant place as sources of geotouristic attractions. In the case of Turkey, caves can also be considered as the major source of tourist attractions and thus economic gain providers for local communities. Focusing on the contribution of tourism to the economy, most local authorities allow tourism activity for the caves without adequate research. This leads to the construction of buildings for the needs of visitors and the installation of walking pathways, ladders, and luminaires inside the caves, which are in most cases harmful to cave ecosystems. Located on the Mediterranean coastline of Turkey, Gilindire Cave presents such a case. Unlike other caves in Turkey, it is among three caves that were found to occur in the Cambrian limestone caves literature. Thus, any data to be detected in this environment is of scientific importance. However, service buildings constructed in the upper elevation of the cave and visitor stairs and luminaires installed in the interior constitute major threats to accessing this valuable information. In this context, the study aims to examine the caves in the scope of geotourism and tourism-led constructions through the example of Gilindire Cave. As a result, the study underpins the importance of diligent investigation of cave ecosystems prior to any tourism-led activity and principles for the service structures to be built in such geoheritage sites.

Keywords Geoheritage · Geotourism · Cave · Gilindire Cave · Climate change

Introduction

Caves are cavities beneath the ground having kilometers of length and meters of depth and/or heights that are wide enough for a person to pass through. Caves are developed in soluble rocks and constitute a characteristic feature of carbonate, which is usually limestone, and non-carbonate rock such as basalt, sandstone, and formed by environmental effects such as dissolution, volcanic activity, or even the melting of glacial ice (Engel 2010). Caves are extreme ecosystems that are limited in nutrient with stable temperature, high humidity, and the only photosynthetic activity relies on light beam comes from the Entrance Zone. Caves are under the spotlight due to several reasons. Extreme and dark conditions of caves represent ideal ecosystems to study for many different branches such as biological, geological, environmental, and chemical studies. Also, the unique and not fully explored cave ecosystem provides an excellent opportunity for the discovery of novel microorganisms and biological by-products such as ethanol production, biotechnologically important and new enzymes, antibiotics, and even cancer treatments (Russell 1998; Gerday et al. 2000; Onaga 2001; Barton 2006; Baris 2009; Cavicchioli et al. 2011).

Around 40% of Turkey's lands are covered with rocks that are suitable for carbonate and sulphate karstification and the size of karstic areas is quite high when compared with European countries (MTA). Since all of these caves have not been studied, it is not possible to give a precise figure on the number of caves in Turkey, but it is estimated that approximately 35,000–40,000 caves can be found depending on the researches carried out in karstic areas. Most of these caves are located in the Western Turkey and Central Taurus Mountains (e.g., Muğla, Antalya, Isparta, Burdur, Konya, Karaman, İçel, and Adana).

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The first cave research was begun in 1964 by the Cave Research Association in Turkey. The Karst and Cave Research Unit, which was established in 1979 within the Department of Geological Studies of MTA, carries out most of the cave research today. So far, the number of caves documented and examined by all local and foreign cave groups is approximately 800. In terms of tourism diversity, caves constitute one of the important potentials in Turkey. The caves are used for the storage of products obtained from agriculture and animal husbandry by people for generations. They were used in the protection and maturation of products, in the storage of liquefied gas, natural gas, and fuel, as a shelter for military purposes, as well as in the production of Guano which is bat manure (Öcal and ve Özcan 2013; Arpacı et al. 2012). Caves are also used for tourism purposes as a branch of eco-tourism within the scope of alternative tourism (Külekçi and Ve Sezen 2018).

Gilindire Cave is located on the slopes of a steep seacoast, 7.5 km east of the Aydıncık town to the west of Mersin province of Turkey (Fig. 1). The total length of the cave is 560 m. Gilindir Cave is one of three caves that were found to occur in the Cambrian limestone caves literature in Turkey (Erdoğan et al. unpublished). Exhibiting polycyclic and polygenic formation characteristics, it therefore contains very different and rich cave formations (Erdoğan et al. unpublished). Speleothems of Gilindire cave can provide precisely dated paleoclimate records, and therefore it is very powerful lively archives for examining changes in climate variability and refines the picture obtained by other paleoclimate studies.

Gilindire Cave has a warm and humid atmosphere that does not change much during the summer and winter seasons. Since the entrance is narrow and flat, the average temperature of the cave is 25 °C and the absolute humidity is 80%. Different meteorological conditions were found in the fossilized part of the cave due to its proximity to the entrance and direct connection with the external environment. The temperature in this section is 30 °C and the humidity is 40%. There is no detailed study on the ecology of the cave. So far, there is information about bats that have not been identified on the basis of species only.

Within this background, this study is structured under four sections. Following the "Introduction" section, the second section provides an overview of Gilindire Cave and its significance as a representative of the last climate change in the Balkans. In the third section, the threats due to the tourism-led constructions and visitors are evaluated. In the

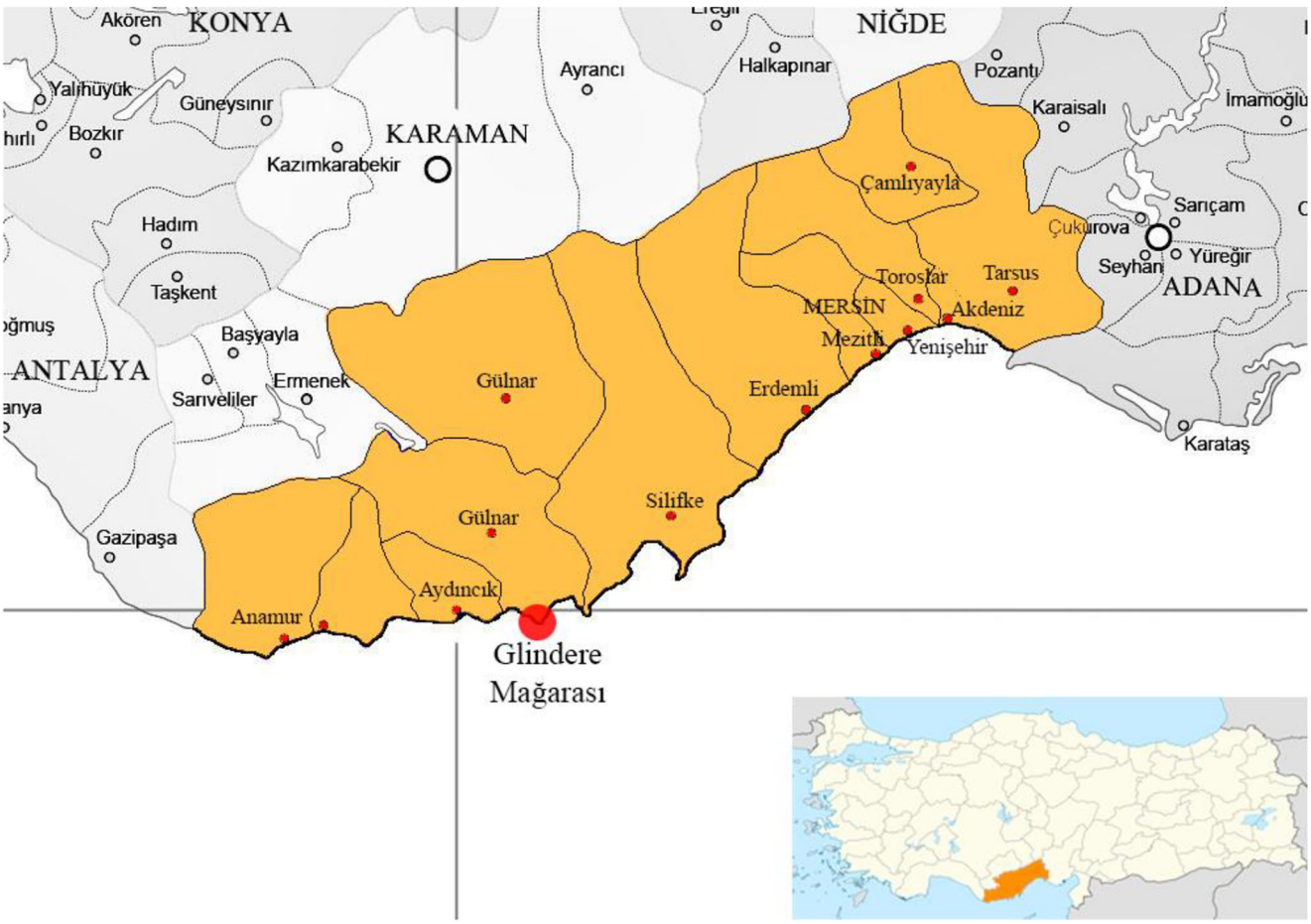

Fig. 1 Location map of Gilindire Cave

"Conclusion" section, the study underpins the importance of thorough investigation of the cave by considering different scientific disciplines prior to any tourism-led activity. It also suggests way to handle the problems emerged from the current constructions.

Gilindire Cave

The most extensive scientific study of the Gilindire Cave was conducted in 2000 by the Karst and Cave Research Unit of the General Directorate of MTA (Mineral Research & Exploration General Directorate). It consists of three separate parts that are connected to each other and formed in different periods. The entrance section, which consists of narrow galleries and prominent verticals, extends in the NNW-SSE direction, developed on the same direction fault line (Nazik et al. 2001). There is no dripstone formation in this section. On the other hand, the main gallery is the oldest part of the cave, which reaches 100 m in width and 18 m in height and extends between (0 m) + 22/− 28 m with respect to the entrance, is divided into many halls and rooms by large and thick dripstone columns (Nazik et al. 2001). The main gallery is connected to the third section of the cave by a large steep slope. This last section (Lake Hall), which is connected to a NE-SW fault, is the youngest part of Gilindire Cave and is covered with a large lake. The water level in Lake Hall, which is 140 m in length and 18–30 m in width and 35–40 in height, is at the same level with the sea at a depth of − 46 m according to the entrance of the cave (Fig. 2). The lake consists of two layers of water of different density, which contains brackish water up to − 10 m from the surface with sea water below. Numerous dripstones developed under and at the water level (Nazik et al. 2001). The formation of the cave and its scientific significance are provided in the following headings.

Formation of Cave

Gilindire Cave was developed during the Plio-Quaternary Period. The cave showed a period of development. The first part of the cave was developed in Tyrrhenian and the last part was developed during Last Glacial Period. Part of the section developed during the Last Glacial Period period was submerged (Nazik et al. 2001). During this period, the cave was flooded due to the rising sea. As a result of melting and wave erosion in the Tyrrhenian, two entrances were formed and the cave, which was passed to the vadose zone, opened to the outside and the formation of dripstones accelerated. In the last glaciation, when the sea level drops to − 90 m, geomorphological rejuvenation in the region was also observed and Gilindire Cave deepened in the weak zone on the fault and formed the Lake Hall—locally known as Mirror Lake as it reflects the stalactites in the cave interior (Fig. 3). At the same time, the fossil hall (Dripstone Hall) was suspended and reverse development began (Nazik et al. 2001). This new section, which had stalactites on its walls during its development, went down to − 93 m from the entrance.

After the last glacial period, as a result of the rising of the sea level, the flooding occurred both outside and inside the cave. As a result, the stalactites, which were formed during the vadose period in the Lake Hall, were submerged (Erdoğan et al. unpublished; Özşahin and Kaymaz 2015). Speleotems such as stalactites, stalagmites, and columns are common in the water at the bottom of the Lake Hall that is below the sea level zero as the last developing part of Gilindire Cave. It was deposited during the last glacial period, where the sea level of the cave formations was about 70 m lower than today, and then the rapid rise of the Mediterranean Sea by the melting of the glaciers at the end of last glacial period (11.700 years ago) and the formation of these formations were submerged.

Significance of Cave

Gilindire Cave was formed within the dolomite and limestone lithology of the Cambrian period. The most important feature that distinguishes this cave from the others is that it is the largest cave where the level changes in the Quaternary where the last climate change is experienced is the best in Balkans. In addition, it is also the only registration point in the Eastern Mediterranean for recent climate change. Because of all these features, this cave is regarded as a living laboratory by researchers.

The submerged formations in the Lake Hall of the Gilindire Cave are the living archives of the last glacial hydrological and climatic era. The cave is the only known point of detection of climate change in the eastern Mediterranean region east of Malta. The loss of this characteristic of the Gilindire Cave means the destruction of a very valuable scientific archive from 12,000 years ago. Turkey is home to thousands of different properties in different parts of the cave. Formations such as stalactites, stalagmites, columns, and flowstone are frequently encountered in the caves determined mainly by geological features and the precipitation regime. In addition to these, there are formations such as shower head, bottle brush, helicities (contradictory formations), and shelf-stone, which can only develop under unique hydrological climatological conditions. However, it is not always possible to see all these formations in the same cave. Gilindire Cave contains almost all the formations that can be encountered in a cave except for the endemic ones. In addition to stalactites, stalagmites, and columns, cave pearls, popcorn, dripstone pool, cork stalagmite, shower head, bottle brush, conulite, helicities (contradictory formation), pasta stalactites, and soda sticks are the best examples of formations (Fig. 4). Because of the richness of geomorphology of Gilindire Cave, the cave constitutes a unique laboratory for geologists and speleologists. Thus,

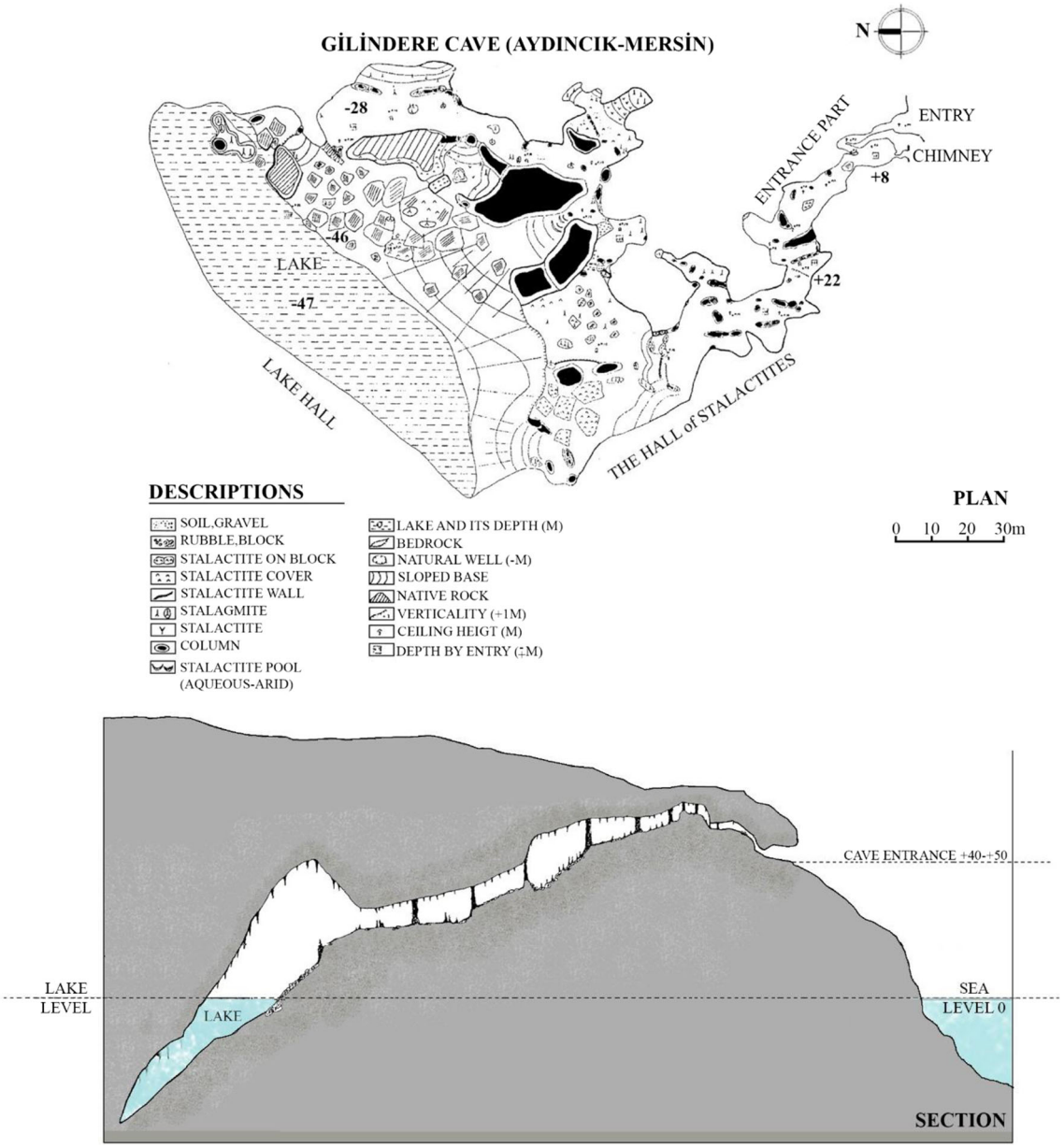

Fig. 2 Plan and section of Gilindire Cave (revised from Nazik et al. 2001)

when compared with the other caves in Turkey, it turns out to be a representative, rare, and unique sample.

Regarding the scientific value of Gilindire Cave, Lake Hall floor, the third and youngest part of the cave, is rich in formations like the rest of the cave. During the dives in Mirror Lake, base structures such as stalagmite and conulite were observed. The scientific significance of these formations originates from the period they were formed. These speleotems, which were formed during the glacial period, witnessed the last regional/global climate change and stored the hydrological, climatological, ecological, and microbiological data belonging to that period. As a result of the chemical-geochemical analysis of stalagmite samples taken from Mirror Lake base, climate data and atmospheric composition findings from that period can be obtained approximately 12,000 years ago. These findings will also allow paleoclimatic markers to shed light on current climate change discussions. Paleoclimate records are important to take action to global warming. Researchers have conducted many experiments to detect the last glacial period in the Middle East area (Frumkin 2000; Nazik et al. 2001; Rowe et al. 2012; Stockhecke et al. 2016; Carolin et al. 2019; Burstyn et al. 2019). Calcite speleothems provide an excellent datable isotopic record compared with other terrestrial places, since isotopic structure of calcite in vadose zone reacts rapidly to regional environmental changes (Burstyn et al. 2019). With this feature, Gilindire Cave is one of the points in the Eastern Mediterranean region, which has proven to be one of the "glacial period archive" (Nazik et al. 2001; Erdoğan et al. unpublished).

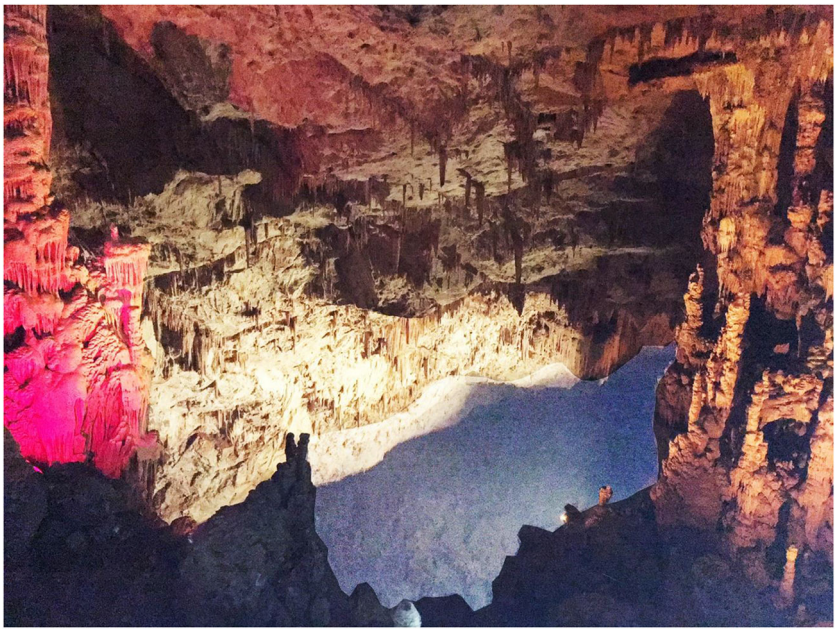

Fig. 3 Lake Hall (Mirror Lake)

Speleothems of Gilindire Cave hold climatic signatures of the very distant past. Since the cave was opened to tourism, there have been significant changes in the colors of the cave formations. Yet unpublished data by Aydin et al. presents the investigation of samples taken both from stalagmites and Mirror Lake. Considered as the first microbial study for Mirror Lake, it demonstrates that more than 40% of bacterial diversity were coming from unknown bacterial groups. These results are also tangible evidences that confirm the study of the cave scientifically in detail is an area worthy of study in terms of biotechnological, geological, and microbiological aspects. Since it has been best preserved in the lake hall for centuries, the study of discovery of new species, new antibiotics, new enzymes, and new products and/or secondary metabolites is important for the field of biotechnology. However, microbiological research on cave studies has been insufficient in Turkey.

Threats for Gilindire Cave

Gilindire Cave was protected by the General Directorate of Nature Conservation and National Parks at the end of 2013 with the status of Natural Monument within the scope of the

Fig. 4 Examples of cave formations

National Parks Law No. 2873 (Erdoğan et al. unpublished). With the financial support of Çukurova Development Agency for the purpose of opening up to tourism in 2011, the Ministry of Culture and Tourism and the Mersin local Governorship, in cooperation with the Ministry of Culture, Gilindire Cave is operated by the Aydıncık Municipality.

It is necessary to prevent the destruction of the ecosystem experienced in many tourist caves and to preserve the unique features of Gilindire Cave by emphasizing the use of the cave as a scientific laboratory and the importance of preserving this wonderful archive (Özşahin and Kaymaz 2014). For this reason, it is important that Gilindire Cave maintains its scientific quality and conveys it to visitors. It would be more appropriate for the cave to be considered as a training center and a scientific archive by assuming the role of a living laboratory where researchers can continue their work, related with Gilindire Cave.

Solid Waste Storage Area

In the Gilindire Cave Natural Monument, there is a solid waste landfill site belonging to Aydıncık Municipality. The pollution created by the solid waste landfill site is likely to reach the cave. Therefore, beyond the visual pollution, there is a serious contamination hazard for Gilindire Cave. Approximately 600 m of the pavement road leading from the main road to the cave, starting from the left side, scattered and uncontrolled glass wastes were stored. The area consists entirely of illegal solid waste landfill which does not belong to the Aydıncık Municipality.

Visitors

A concrete parking lot was built for visitors to the cave. The car park floor is covered with concrete approximately 15–20-cm thick. Visitor facilities and toilets are located on the vertical axis of the cave interior space (Fig. 5). Since the penetration of the underground will stop in the part of the cave ceiling which is located in this area, the development of the formations in this part of the cave will stop and possibly darkening will start.

In addition, the increase in the amount of tourists entering the cave increases the risk of carrying pathogenic microorganisms (Li et al. 2010; Roche and Guégan 2011). Scientists have performed a study to identify potential tourism hazards in caves and have reported that caves are a threat to visitors because of the possibility of unspecified and opportunistic microorganisms. It is also known that microorganisms living in this environment frequently cause respiratory system infections. For all these important health reasons, microbiological analysis of the cave environment is very crucial.

Visitor Usage Areas

With the support of the Çukurova Development Agency, the project known as "Aydin Lighting and Landscaping of Aynaligöl Cave of Aydincik District of Mersin Province" was supported under the Small Scale Infrastructure Projects Financial Support Program. The project was realized by the "Special Provincial Administration of Mersin Governorship." Within the scope of the project, interior and exterior lighting of the cave, walking paths (Fig. 6), and a parking lot were arranged and 3 small buildings were constructed.

As a result, it is obvious that no special attention was paid to the protection of the cave in any way during the applications such as electrification, armature placement, walkway arrangement, platform, and railing placement in the cave, which was made available for tourist use (Fig. 7).

All luminaires are units that emit heat and cause algae on the formations. In other words, artificial light poses a great danger to the cave ecosystem and threatens the life of macro- and micro-organisms adapted to living in the dark (Fig. 8). The results of this careless management have already started to manifest itself in the form of drying/darkening in the

Fig. 5 Buildings constructed for visitor needs on the cave

Fig. 6 Walking pathways both outside and inside the cave

formations around the luminaires. Almost all the connections between the luminaires and the line from the transformer pass through the open. Corrosion was observed in almost all metal railings (Fig. 7). It was determined by the diving teams that the chisel discs used during the construction of the metal platform at the end of the walkway were taken out of the cave and thrown into Mirror Lake.

Conclusions

The geological heritage sites are the geological formations that accommodate extraordinary scientific, educational, and esthetic values and have the potential for tourism development, as well as keeping records of the geological history of the earth. Developed in the last 30 years, geotourism is defined as a sustainable tourism approach which encourages people to experience these areas. The study explores the importance of caves as geological heritage sites, the necessary conditions for their protection, tourism opportunities, and the issues around the construction of service buildings through the evaluation of new constructions for tourism in the case study area. Since the cave is the only point of detection of global climate change in Balkans, every information obtained here is of great importance. Dive into Gilindire Caves can teach us about past and present climate changes.

Authorities should give special interest for management of cave. The relevant ministries, municipalities, governorate, and all relevant institutions, especially scientists, should work in a coordinated manner and ensure the protection of the cave (Table 1). These unique cave formations and living things in this environment should be studied for new products and information from new microorganisms by studying in detail both in terms of science and biotechnology. It is very important to preserve both the caves and their ecology. Cavers, scientists, and ministries should work together in a coordinated manner so that the arrangements in the cave should be designed to minimize the damage to the natural environment in the cave (Table 1). However, this is not the case for Gilindire Cave. Therefore, the cave should be temporarily

Fig. 7 Implementation details of metal constructions and electrification

Fig. 8 Luminaries inside the cave

closed to tourism and scientific studies should be focused on microbial diversity and the ecology of the cave should be studied in detail. They conduct geosite restoration action. Taken together, management of Gilindire Cave must include monitoring, controlling, and protecting increased public visitors (Table 1).

It is essential to preserve the geomorphological richness, ecosystem functions, and values of Gilindire Cave in its current state and without any harm to its natural environment. The damage that the cave has suffered during the tourism implementation project should be removed and precautions should be taken immediately. Gilindire Cave should not be considered as a recreational area for visitors. In accordance with the nature monument status of the cave, it would be more appropriate for local/foreign visitors to visit a place where caves, the importance of caves, and cave protection will be discussed, leaving the cave as a live laboratory to be used by researchers and others. All the buildings and the car parking

Table 1 Managerial concerns of Gilindire Cave

Managerial concerns	Suggestions
Conflicts that arise from the limits of responsibility of the public institutions	Related ministries and local administrations such as municipalities should work together and share responsibilities for the benefit of cave sustainable protection.
Insufficient funding for both conservation and research	Larger funding is necessary for detailed scientific research.
Lack of emergency precautions	Rescue and first aid training is essential for the cave guides and official staff.
Lack of basic scientific research on the cave and its ecology	Further research is required including geology, hydrology, ecology, speology, and paleoclimatic fields.
Uncontrolled access of visitors	Determination of the number of visitors to be allowed inside the cave.
Insufficient interpretive information	Visitors should be informed on uniqueness and singularity of the cave.
Use of inappropriate materials for pathways	New age materials should be preferred such as stainless steel, plastics like frp, and led lighting.
Improper lighting system design	Prefer to use led light, emergency lighting, and safe circuits. Backup power supply is essential.
Lack of cave environment maintenance and protection	Measures to minimize the impact of visitors on cave environment.
Lack of cave guides	Visitors should be directed by cave guides.
Improper location of improvements over the cave	Parking lots, buildings that correspond to the access over the cave should be removed.
Access and transport	Shuttle busses can be used of the transportation of the visitors.
Lack of future plans	Sustainable cave management plan should be prepared.

area that were constructed for tourism purposes should be removed since they are on the axis of the cave and thus harmful for the sustainability of the cave formation.

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