Mammoth Cave National Park

2025 Conservation Outlook Assessment

SITE INFORMATION

Country: United States of America (USA)
Inscribed in: 1981
Criteria: (vii) (viii) (x)

Mammoth Cave National Park, located in the state of Kentucky, has the world's largest network of natural caves and underground passageways, which are characteristic examples of limestone formations. The park and its underground network of more than 560 surveyed km of passageways are home to a varied flora and fauna, including a number of endangered species. © UNESCO

SUMMARY

2025 Conservation Outlook

Finalised on 11 Oct 2025

GOOD WITH SOME CONCERNS

Overall, the conservation outlook for the Mammoth Cave National Park World Heritage site is good with some concerns. The park has especially benefited by the removal of Lock and Dam 6 in 2017, which previously flooded portions of the cave system unnaturally. The current condition of the World Heritage values is generally stable, whilst there remain existential threats to the values of the site, the protection and management standards are very high and intervention measures are mostly effective in combatting these threats. There are concerns that levels of air and water pollution are increasing and impacting detrimentally on the geological and biological values of the site as well as damage to the karst formations of the site by visitors, however appropriate management responses are in place showing some signs of improvement in air quality. Of particular concern is the significant reduction of bat populations from the white-nose fungal disease introduced into the site, which may prove difficult to overcome. Nearly 80% of the cave-limited fauna is of conservation concern, many of which are at an elevated risk of extinction because of small ranges, few occurrences, and several potential threats. Climate change and its impacts increasing temperatures and increased storms frequency may impact the integrity of the site's OUV, however the impact is difficult to accurately predict.

FULL ASSESSMENT

Description of values

Values

World Heritage values

▶ **Superlative examples of natural features in limestone karst terrain.** **Criterion:(vii)**

The park protects the longest cave system in the world and more than 400 other caves, with huge chambers, vertical shafts, stalagmites and stalactites, splendid forms of beautiful gypsum flowers, delicate gypsum needles, rare mirabilite flowers and other natural features that are all superlative examples of their type. No other known cave system in the world offers a greater variety of sulfate minerals (State Party of the USA, 1980; 2006; IUCN, 1981; World Heritage Committee, 2018).

▶ **The world's largest network of natural limestone caves and underground passages.** **Criterion:(viii)**

The 100 million-year old karst landscape presents nearly every type of cave formation known. Its huge and complex network of cave passages provides a clear, complete and accessible record of the world's geomorphic and climatic changes. The land surface has all of the classic features of a karst drainage system - a vast recharge area, complex network of underground conduits, sink holes, cracks, fissures, and underground rivers and springs (State Party of the USA, 1980; 2006; IUCN, 1981; World Heritage Committee, 2018).

▶ **The richest known cave biota.** **Criterion:(x)**

The property has the greatest diversity of known cave biota numbering over 130 species, of which 49 species of cave-limited fauna with 32 troglobionts (terrestrial animals adapted to living entirely in caves) and 17 stygobionts (aquatic troglobionts, i.e organisms that are specialized for living in subterranean ground waters). Seven species are endemic to the Mammoth Cave System and other small caves in Mammoth Cave National Park (Niemiller et al., 2021).

Other important biodiversity values

▶ **Diverse vegetation and abundant wildlife.**

Terrestrial vertebrates include 43 species of mammals, 207 birds, 37 reptiles and 27 amphibians. The temperate deciduous oak-hickory forest community includes 84 tree varieties, 28 shrubs and vines, 29 types of ferns, 209 wildflowers, 67 species of algae, 27 species of fungi and 7 species of bryophyte. (State Party of the USA, 1980; 2006; IUCN, 1981; World Heritage Committee, 2018).

Assessment information

Threats

Current Threats **Low Threat**

The threats to the site are diverse and of varying degrees of severity, however effective management actions have reduced the overall threat level. Low levels of threat come from damage by visitors and ecosystem modification, especially suppression of wildfires and flooding of natural underground water systems due to storm water drainage from surrounding residential and industrial areas. The most serious

threats are from neighbouring coal-fired power plants that cause air and groundwater pollution, and from the incidence of the deadly white-nose fungal disease affecting the bat population. The park authorities are addressing air pollution at the site and as a result, have seen some improvements in air quality in recent years. However, there is existing and potential future groundwater contamination from human and animal waste production, agricultural land runoff and urban storm water discharge, because the majority of groundwater recharge area for Mammoth Cave lies beyond park boundaries. Although the impact from climate change on key attributes is unclear, precipitation, the frequency and intensity of severe thunderstorms, and extreme precipitation events are all projected to increase at the park and may have potentially future impacts on water quality. In addition, increased soil erosion from heavy rainfall events may increase turbidity and reduce dissolved oxygen levels during those events. Soil eroded from the surface may be deposited in the active cave network impacting on passage morphology.

▶ **Fire & Fire Management** — **Low Threat**

(Wildfire)

Inside site, extent of threat not known
Outside site

Wildfires are imprinted on patterns of vegetation development. Most fires are from arson, careless smoking and campfires, but there are some lightning fires. The authorities include fire suppression among fire management measures. Prescribed fires are considered unlikely to affect nationally protected species or critical habitats in the World Heritage site (NPS, 2001; NPS, 2009; Olsen et al., 2005; NPS, 2021a). However, prescribed fires can also cause changes in habitat use dynamics such as in bats (NPS, 2021a). Storm water drainage wells in neighbouring areas are causing sinkhole flooding and ground collapse (May et al., 2005). Fire also has impacts on recharge which in turn can impact on speleothems (IUCN Consultation, 2020). The ongoing implementation of the park's 2019 fire management plan should ensure long-term beneficial impacts on park vegetation by reducing non-native plant species; enhancing the diversity, structure, composition, and integrity of fire-dependent vegetation communities; and reducing the potential for larger intense wildfires (NPS, 2019b).

▶ **Pathogens** — **High Threat**

(White-nose fungal disease)

Inside site, widespread(15-50%)
Outside site

Other invasive species names

White-nose fungus (Pseudogymnoascus destructans)

In 2013, the White-nose fungal disease resulted in a major die-off of bats native to the park, including all seven species, three of which were already listed as endangered. This has resulted in shifts in foraging assemblages (Thalken et al., 2018) which may have further ecological consequences. A response plan includes access restrictions, decontamination requirements for all activities, surveillance and monitoring, and outreach and education (NPS, 2010; NPS, 2011; NPS, 2019a; NPS, 2023) for which additional funding has been made available (IUCN Consultation, 2020).

▶ **Oil & Gas exploration/development** — **High Threat**

(Groundwater infiltration of contaminants)

Inside site, widespread(15-50%)
Outside site

There is existing and potential future groundwater contamination from human and animal waste production, agricultural land runoff and urban storm water discharge, because the majority of groundwater recharge area for Mammoth Cave lies beyond park boundaries (NPS, 2019a; Niemiller et al., 2021; NPS, 2024a). In addition, three major transportation corridors traverse the cave's recharge basin, so that any spills or other release of contaminants is quickly washed into the karst aquifer.

▶ **Recreational Activities** — **Low Threat**

(Damage by visitors)

Inside site, extent of threat not known

Damage by tourists such as graffiti, vandalism, and removal of cave formations continues to be a threat to the limestone karst features in the caves (NPS, 2019a). Visitation throughout the cave has caused and continues to cause both inadvertent and deliberate damage to speleothems and other cave features. Some speleothems are extremely fragile. In one example of protecting a cave feature, park staff installed a grate around fragile speleothems located immediately adjacent to the trail on the Frozen Niagara route to prevent damage. Human presence in the cave results in the deposition of a small

amount of detritus consisting of hair, skin cells, and lint from clothing. Human travel then stirs up fine sediments that settle onto adjacent cave surfaces. This redistributed dust can build up over time and affect cave aesthetics and damage delicate speleothems (NPS, 2024a).

▶ Invasive Non-Native/ Alien Species

Low Threat

(Lamp flora establishment)

Inside site, localised(<5%)

Lamp flora which would not otherwise occur in the caves has established itself in many damp areas of the cave that are electrically lit (NPS, 2019a), posing a threat to the cave biota and potentially carrying impacts on the evolution and formation of the natural cave features (IUCN Consultation, 2020). Where applicable, old lighting in algae-prone sections of the cave would continue to be replaced with advanced lighting intended to limit the growth of lamp flora (NPS, 2019a).

▶ Air-borne Pollutants

Low Threat

(Air pollution)

Inside site, widespread(15-50%)
Outside site

The location of the World Heritage site is downwind of many sources of air pollution, including power plants, urban areas, and industry in Kentucky and Tennessee (NPS, 2019c; NPS, 2021a). The park authorities are addressing air pollution at the site and as a result, had seen some improvements in air quality in recent years (NPS, 2021a), but the implications of any national air pollution policy changes will need to be closely observed. Several coal-fired plants in the vicinity have been taken out of service in recent years, but the area already contained 40 operating power plants. Plants produce huge quantities of carbon dioxide, sulfur dioxide, nitrogen and mercury. Some bats have up to 10x the mercury level considered safe for people, ozone pollution is considerably above levels known to harm plant life, and particulate matter causing hazy skies reduces vision for scenic viewing. Air monitoring is conducted by a number of monitoring facilities in and around the NP, with the National Park Service’s Air Resources Division overseeing the national air resource management program for the NPS.

▶ Changes in Precipitation & Hydrological Regime

Data Deficient

(Severe weather)

Inside site, extent of threat not known
Outside site

Severe storms result in flooding, causing damage to trails, campsites and roads, and requiring emergency funding (May et al., 2005; NPS, 2003; NPS, 2006). Increasingly severe storms result in flooding, both at the surface and subsurface levels, which may also have impacts on stygobites from increased sediment (IUCN Consultation, 2020). Overall precipitation, the frequency and intensity of severe thunderstorms, and extreme precipitation events are all projected to increase at the park and may have potentially future impacts on water quality, likely leading to an increase in the number of spikes in E. coli levels (NPS 2024a). In addition, increased soil erosion from heavy rainfall events may increase turbidity and reduce dissolved oxygen levels during those events (NPS, 2024a). Soil eroded from the surface may be deposited in the active cave network impacting on passage morphology. Accumulation in the phreas can divert flow and reactivate relict passages. The overall impact from this threat on the site's values remains data deficient.

Potential Threats

Low Threat

Pollution from neighbouring industrial developments, and its possible impact on natural values of the site, is of major future concern to stygobiota. Climate change is an additional potential threat through more frequent severe storms and an increase in temperatures, potentially affecting the highly sensitive stygobiota and fragile limestone karst features. US national parks are facing challenges from government changes which impact staff numbers and funding for operational and management needs, further enhanced by increasing climate change impacts. This creates uncertainty regarding the medium-term impact on sustainable finance for essential management activities.

▶ Commercial & Industrial Areas

Data Deficient

(Neighbouring industrial developments)

Inside site, scattered(5-15%)
Outside site

Pollution, especially of groundwater, from neighbouring commercial, residential, and industrial developments, and their possible impact on natural values of the site, are of major future concern, particularly to stygobites (IUCN Consultation, 2020; NPS, 2021a). Groundwater pollution may also adversely impact on speleothems and case passage morphology.

▶ **Changes in Temperature Regimes** — **High Threat**

(Increasing temperatures)

Inside site, extent of threat not known
Outside site

A high potential exists for future impacts on cave and karst resources from climate change (NPS, 2024a). While caves are semi-closed systems that buffer fluctuations in air temperature, over longer periods, they reflect mean annual surface temperature in temperate areas. Due to the “chimney” effect at Mammoth Cave, changes in temperature, particularly in winter months, may affect airflow through the cave. The changes in temperature due to climate change can be problematic because caves are home to organisms that exhibit low tolerance to climatic perturbations and may have little adaptive capacity due to their evolution in a stable environment. Furthermore, changes to temperature and airflow may also impact on the growth of speleothems.

▶ **Recreation & Tourism Areas** — **Very Low Threat**

(Development of new trails)

Inside site, extent of threat not known
Outside site

The use of new trails and facilities could cause adverse soil impacts, including erosion and rutting, which would impact cave drainages (NPS, 2024a).

▶ **Recreational Activities** — **Very Low Threat**

(Potential air tour operator)

Outside site

There is a potential for an air tour operator to open a business outside of the national park. While tours over the park are not expected, nearby air traffic might impact the park's soundscape (State Party of the US, 2024).

▶ **Residential Areas, Commercial & Industrial Areas** — **Low Threat**

(Residential and commercial development)

Outside site

Both new and existing industrial development in the groundwater recharge basin, outside park boundaries, has the potential to impact water quality and cave biota (IUCN Consultation, 2020).

▶ **Removing/Reducing Human Management** — **High Threat**

(Changes in staff capacity and funding)

Inside site, throughout(>50%)
Outside site

US national parks are facing challenges from government changes which impact staff numbers and funding for operational and management needs, further enhanced by increasing climate change impacts (e.g. Matza, 2025; Rosenblat, 2025). This creates uncertainty regarding the medium-term impact on sustainable finance for essential management activities.

Overall assessment of threats — Low Threat

The threats to the site are diverse and of varying degrees of severity, however effective management actions have reduced the overall threat level. Low level threats come from ecosystem modification, especially suppression of wildfires, damage to the caves by visitors and flooding of natural underground water systems due to storm water drainage from surrounding residential and industrial areas. More serious threats come from neighbouring coal-fired power plants that cause air and groundwater pollution, where impacts will be largely felt by stygobites and there may be some smaller impacts on the dissolution process. Furthermore, changes to temperature and airflow may also impact on the growth of speleothems. Changes in air circulation and the quantity and quality of recharge can threaten sulfate minerals through various mechanisms. The incidence of the deadly white-nose fungal

disease affecting the bat population is of high concern. The most significant potential threat is from increased air and water pollution due to ongoing development in surrounding areas outside the park, as well as increasing temperatures and storm frequency due to climate change.

Protection and management

Assessing Protection and Management

▶ **Involvement of stakeholders and rightsholders, including indigenous peoples and local communities, in decision-making processes** — **Highly Effective**

Stakeholder and local community support for the park is excellent. Park management is supported by a number of organisations representing a wide range of stakeholders including NGOs such as Friends of Mammoth Cave National Park (IUCN, 1981; NPS, 2009a; State Party of the USA, 1980; Friends of Mammoth Cave National Park, 2019), research organisations such as the Cave Research Foundation, National Speleological Society as well as local, state and federal institutions (IUCN Consultation, 2020). The public is regularly invited to provide comments to draft plans and assessments. For example, the Long Range Interpretative Plan (NPS, 2022) has been developed in consultation with a variety of stakeholders including park's affiliated Native American tribes (NPS, 2022a) and the Land and Rivers Trails Management Plan Environmental Assessment (NPS, 2024) was available for review and comments, questions on the park planning process were answered during two public meetings.

▶ **Legal framework** — **Highly Effective**

The World Heritage site is Federal and publicly owned land subject to Federal and State protection laws (State Party of the USA, 1980; IUCN, 1981).

▶ **Governance arrangements** — **Highly Effective**

The United States Government owns Mammoth Cave National Park. It is managed by the National Park Service, a federal agency. As an entity of the government of the United States of America, the National Park Service is an agency within the Department of the Interior. Mammoth Cave National Park is operated and managed under the authority of national government, which has "exclusive federal jurisdiction" over all lands within the park (State Party of the US, 2024).

▶ **Integration into local, regional and national planning systems (including sea/landscape connectivity)** — **Mostly Effective**

Park land use is well co-ordinated with other State land and resource uses (IUCN, 1981; State Party of the USA, 1980). Whilst there are some concerns regarding industrial development outside the site, the development priorities are completed in accordance with applicable laws. Mammoth Cave National Park was recognized by a number of additional designations, including National Water Trail (NPS, 2022b) and Dark Sky Park designations (Barren River Area Development District, 2019; NPS, 2021d).

▶ **Boundaries** — **Mostly Effective**

The boundaries of the World Heritage site are well defined. However, most current and potential threats to the values of the site arise outside park boundaries, and largely beyond NPS control.

▶ **Overlapping international designations** — **Data Deficient**

Mammoth Cave National Park is the core area of the Mammoth Cave Biosphere Region, a part of the UNESCO Man and the Biosphere (MAB) Programme. Mammoth Cave National Park, the Barren River Area Development District, and Western Kentucky University have signed a cooperative agreement to promote conservation of water resources and biodiversity, economic development for healthy people and a healthy economy, and support for research and education (NPS, 2022b). However the extent to

which the management between the WH site and the BR is well coordinated could not be determined.

▶ Implementation of World Heritage Committee decisions and recommendations

Data Deficient

There have been no requests to the State Party from the World Heritage Committee in recent years. The committee adopted a retrospective statement of outstanding universal value for the site based on improvements

▶ Climate action

Mostly Effective

Although in-depth analysis of the effects of climate change on park natural resources was outside the scope of the assessment, the Natural Resource Condition Assessment (NPS, 2021a) provides condition analyses and data sets findings which can assist strategic park resource planning and useful for park-level climate-change studies and planning efforts. The Cultural Landscape Report (NOPS, 2021b) addresses potential impacts of climate change, recognizing that the ways in which increased severity and intensity of storms and temperatures and rainfall pattern fluctuations may affect the cave, its resources, and visitors will be important information to be used in planning for the future, as archaeological resources are anticipated to be particularly impacted by climate change.

▶ Management plan and overall management system

Highly Effective

The management system is well formulated through an excellent Foundation Document, and a 2019 Cave and Karst Management Plan along with several subsidiary plans such as a business plan, water resources plan, fire management plan, trail management plan etc. (NPS, 2003; NPS, 2006; NPS, 2007; NPS, 2011; NPS, 2019a; 2019b; State Party of the USA, 1980). A Cultural Landscape Report has been developed to address the impact of additional access upgrades and other management concerns associated with the Mammoth Cave Historic District (NPS, 2021b). A Long Range Interpretative Plan has been developed in 2022, designed to guide park managers for the following 5-7 years (NPS, 2022a).

▶ Law enforcement

Mostly Effective

Protection of park resources is largely provided by the park's ranger staff, but supplemented by reciprocal enforcement agreements with local agencies. According to the last Periodic Reporting, there is acceptable capacity to enforce legislation and regulation in the World Heritage property but some deficiencies of enforcement remain (State Party of the US, 2024).

▶ Sustainable finance

Some Concern

The 2014 Foundation Document reports that historical levels of funding were reduced by 30% in recent years. The park geologist, hydrologist, anthropologist and botanist positions have been left vacant in the past, there is currently no information whether these have been subsequently filled. Some needed research is supplemented with a master cooperative agreement with a nearby university. However, in 2020, the park received funding to begin the preparation of a Resource Stewardship Strategy (RSS) (IUCN Consultation, 2020) to identify key issues in the management, which may address this issue. According to the last periodic reporting, governmental funding represent more than two thirds of the parks financial resources, with the remaining third covered by individual visitor charges and commercial activities (State Party of the US, 2024). The available budget is acceptable but could be further improved to fully meet the management needs (State Party of the US, 2024). The NPS website for the park reports a budget of approximately $6.7 million, concessions and commercial services, a safety program, all while cooperating with park partners and local communities where visitors spend an estimated $48.1 million each year (NPS, 2022). The current level of budget is unclear, however US national parks are facing challenges from government changes which impact staff numbers and funding for operational and management needs, further enhanced by increasing climate change impacts (e.g. Matza, 2025; Rosenblat, 2025). This creates uncertainty regarding the medium-term impact on sustainable finance for essential management activities.

▶ Staff capacity, training and development

Some Concern

According to the latest periodic report, human resources partly meet the management needs of the World Heritage property (State Party of the US, 2024). The NPS website for the park reports that there are around 150 NPS employees to manage 52,830 acres. The staff are highly professional and well trained. The absence of key personnel, including a park geologist and hydrologist, has been a concern in the past and it is not clear whether this has been resolved. Furthermore, there have been reports of staff cuts with at least 20 positions cut from the interpretation and visitor resources division and potentially other divisions also affected (Parham, 2025).

► Education and interpretation programmes — Mostly Effective

The site has an excellent visitor centre and learning centre (NPS, 2003; NPS, 2010). The Mammoth Cave National Park's Environmental Education program has developed camps that focus on water/hydrology, nature/cave exploration, and fire. Each year the rangers connect with over 65,000 students through this program (Mammoth Cave National Park, 2024). There are a range of activities, including in-classroom programs, field trips, distance learning and professional development. In 2021, Mammoth Cave National Park's Environmental Education program was awarded the Southeast Regional Excellence in Education Award from the National Park Service. This award is the highest recognition presented to a NPS team for outstanding contributions to the profession of education, and recognizes innovation and adaptation within education program planning, development, and implementation (NPS, 2022b). Reports of positions cut from the interpretation and visitor resources division are of some concern but require further investigation to determine whether this has impacted on the overall effectiveness of education and interpretation programmes (Parham, 2022).

► Tourism and visitation management — Highly Effective

The annual number of tourists visiting the site is approximately 550,000, with 80% taking a guided cave tour. A Long Range Interpretative Plan has been developed in 2022, designed to guide park managers for the following 5-7 years (NPS, 2022a). Aim of the Plan is to guide the expansion and refinement of interpretive operations at Mammoth Cave National Park with specific focus on developing strategy to: 1) Improve accessibility for visitors with differing ability levels; 2) Make park experiences more inclusive to serve diverse audiences; 3) Ensure the park's lasting relevance to next generation audiences with technology; 4) Expand opportunities to provide surface interpretation and visitor services; 5) Enhance opportunities for volunteer engagement. In 2024, a Comprehensive Land and River Trail Management Plan update was published (NPS, 2024). A number of trail improvement project have been implemented. In 2019, rehabilitation of two miles of Cave Trail along the Grand Avenue Route began have been rehabilitatedto improve visitor services and also enhance resource protection (IUCN Consultation, 2020). The Heritage Trail Rehabilitation Project which will improve the trail's visual profile, enhance the visitor experience, and maintain wheelchair accessibility while reducing the park's annual maintenance requirements, started in January 2025 and is expected to be completed in September 2025 (NPS, 2025).

► Sustainable use — Data Deficient

According to the Statement of OUV for the World Heritage site, a portion of the site has development (roads, visitor facilities, park operational and administrative infrastructure), but most of the area remains undeveloped in a natural zone.

► Monitoring — Highly Effective

Comprehensive monitoring program for ecological indicators, water and air quality, cave environment, fire and visitor use, among others (May et al., 2005; Watson, 2005; NPS, 2006; NPS, 2007; NPS, 2009; NPS, 2011; 2019a; 2019b; NPS, 2021a). However, more recent monitoring reports could not be found. Ongoing monitoring is being carried out following the removal of lock and dam #6 following initial ecological assessments of the affected waterways (Compton et al., 2017). Mammoth Cave now also hosts a seismic monitoring station, which has been incorporated into the real-time earthquake monitoring conducted by KGS as part of the Kentucky Seismic and Strong-Motion Network. With offices housed at Mammoth Cave park headquarters, the Cumberland Piedmont Inventory and Monitoring Program is one of thirty two National Park Service I&M Networks across the country established to facilitate collaboration, information sharing, and economies of scale in natural resource monitoring.

▶ Research — Highly Effective

Strong research program involving park scientists and domestic and international researchers. Research results are applied to management intervention (MCNP, 2013). New paleontological research started in 2019 has identified at least 70 species of ancient fish and two new species of ancient sharks located inside Mammoth Cave (NPS, 2024b).

▶ Effectiveness of management system and governance in addressing threats outside the site — Highly Effective

The management system is implemented well through sufficiently resourced staff, guided by a comprehensive set of management plans (NPS, 2003; NPS, 2006; NPS, 2007; NPS, 2011; 2019a; 2019b; State Party of the USA, 1980). In FY 2020, the park received funding to begin the preparation of a Resource Stewardship Strategy (RSS). Since then, the RRS evaluates the major components of the park's fundamental resources that must be protected into the future, including a comprehensive strategic plan for achieving and maintaining targets in conserving these resources over time (IUCN Consultation, 2020; NPS, 2021c). Additional funding has also been received in recent years for a variety of management activities related to White-nose Syndrome in bats.

▶ Effectiveness of management system and governance in addressing threats inside the site — Some Concern

There is good communication and collaboration with outside agencies, especially through NPS participation in the Mammoth Cave Area Biosphere Region Advisory Council, which is a partnership with the surrounding Barren River Area Development District and Western Kentucky University (IUCN Consultation, 2020), with cross-sectoral engagement in conservation of Mammoth Cave and most development priorities completed in accordance with applicable laws which, while less strenuous than other states, still provide some protection (NPCA, 2013; NPS, 2003; NPS, 2009a; State Party of the USA, 1980; IUCN Consultation, 2020). However, the site continues to face threats from a variety of development that has potential for impacts (i.e. opening of an air tour operator business), accidental leaks from a variety of sources, antiquated septic systems, etc. As such, continued vigilance in protecting Mammoth Cave with both existing and new development is required to ensure that development outside the site does not negatively impact the sites values.

Overall assessment of protection and management — Mostly Effective

Generally, the protection and management of the World Heritage site is of a high standard and mostly effective. There is strong legal protection at State and Federal level, the site is under public ownership and the stakeholder support is good. The park has suffered some reductions in terms of staff and finance, but management intervention is guided by a series of comprehensive and widely consulted management plans. Monitoring, research, interpretation and education are exemplary. Of greatest importance for managers is the need to remain vigilant over possible negative impacts from urban, industrial and resource development activities outside the site that have the potential to increase above current levels.

▶ Good practice examples

In 2009, Mammoth Cave National Park entered its first sister park agreement with the help of the NPS Office of International Affairs. The park uses sister park relationships to exchange research and best management practices for the preservation of cave resources and the development of sustainable human communities within karst landscapes (NPS, 2022b). Mammoth Cave National Park is Sister Park with Shilin Stone Forest National Park, part of the South China Karst World Heritage Site, Škocjan Caves Regional Park, both World Heritage Site And Biosphere Reserve, and Puerto Princesa Subterranean River National Park, World Heritage site and part of the Palawan International Biosphere Reserve.

State and trend of values

Assessing the current state and trend of values

World Heritage values

▶ **Superlative examples of natural features in limestone karst terrain.**

Low Concern
Trend:Data Deficient

The general state and trend in scenic and aesthetic values are good, but concerns surround human disturbance and vandalism to some karst landforms and the incidence of atmospheric haze from pollution affecting scenic viewing and visitor enjoyment (AP, 2006; May et al., 2005; MCNP, 2013; NPS, 2007; NPS, 2009; State Party of the USA, 2002; NPS, 2019a; NPS, 2021a).

▶ **The world's largest network of natural limestone caves and underground passages.**

Low Concern
Trend:Data Deficient

The state and trend of the karst geological values can be assessed as generally of low concern. While there are concerns about modification to natural water flows and deterioration in water quality, the park achieved a major goal in 2017 with the removal of Lock and Dam 6 on the Green River, re-establishing natural flow on 10 miles of river in the park and significantly reducing cave flooding. (AP, 2006; May et al., 2005; MCNP, 2013; NPS, 2007; NPS, 2009; State Party of the USA, 2002). Threats from neighbouring coal-fired power plants that cause air and groundwater pollution may impact stygobites and there may be some smaller impacts on the dissolution process. Furthermore, changes to temperature and airflow may also impact on the growth of speleothems. Changes in air circulation and the quantity and quality of recharge can threaten sulfate minerals through various mechanisms (Huang et al. 2023).

▶ **The richest known cave biota.**

High Concern
Trend:Deteriorating

The Mammoth Cave system is home to 49 species, with 32 troglobionts and 17 stygobionts. Seven species are endemic to the Mammoth Cave System and other small caves in Mammoth Cave National Park. The Mammoth Cave System is the type locality for 33 cave-limited species. The exceptional diversity at Mammoth Cave is likely related to several factors, such as the high dispersal potential of cave fauna associated with expansive karst exposures, high surface productivity, and a long history of exploration and study. Nearly 80% of the cave-limited fauna is of conservation concern, many of which are at an elevated risk of extinction because of small ranges, few occurrences, and several potential threats (Niemiller et al. 2021), including climate change and habitat loss, but the most common are threats to water quality.

Of major concern to management is the relatively recent introduction of the deadly white-nose fungal disease (or white-nosed syndrome, WNS), which has destroyed much of the bat population in the World Heritage site (NPS, 2021; NPS, 2010; NPS, 2011; NPS, 2014). Mammoth Cave National Park is home to a total of 13 species of bats, three of which are are listed on the federal endangered species list. These species include the Indiana bat, the gray bat, and the northern long-eared bat. Around 2005, Indiana bat populations seemed to be stabilizing, but the arrival of WNS to North America exacerbated species mortality rates. Since this time Indiana bats have been killed in large numbers by WNS, populations have again fallen dramatically, and they are critically endangered. In 2019, the NPS led teams that documented about 350,000 gray bats hibernating in a cave located in the park. In the 70s, populations of gray bats were concentrated to a few caves in the United States and disturbance of those sites was leading to lower numbers. This led to the species being listed as endangered. Fortunately, since they were listed, almost all of these critical sites have been protected, which has led to increased population numbers. Gray bats have been fortunate that they have not been significantly impacted by WNS. Their increasing numbers has been a success of the Endangered Species Act. In contrast, the number of northern long-eared bats captured or seen during bat surveys has decreased by over 99%. This species was once the most common bat surveyed in the park during summer, now it is very rare to see one.

Unfortunately, the 99% decrease seen in the park from WNS, is very similar to what is seen in other parts of the species' range where WNS occurs (NPS, 2023).

Summary of the Values

▶ **Assessment of the current state and trend of World Heritage values** — **Low Concern** / **Trend: Data Deficient**

Overall, the current state of World Heritage values in the site is of low concern however there is a lack of data to determine the current trends of the key attributes related to the geological values. The integrity of the site has improved significantly since inscription due to a number of management interventions. Whilst issues remain around air and water pollution impacts, these are addressed in the comprehensive management plans. Continued die-off of a majority of seven native bats species due to white-nose fungal disease is another concern, which could even eliminate some species, including populations of the three species already listed as endangered. Furthermore, nearly 80% of the cave-limited fauna is of conservation concern, many of which are at an elevated risk of extinction because of small ranges, few occurrences, and several potential threats.

▶ **Assessment of the current state and trend of other important biodiversity values** — **Low Concern** / **Trend: Stable**

Biodiversity values are generally not seriously threatened. However, some concern remains around White Nose Syndrome in bat species, amongst other low level concerns about the impacts on plant life from air pollution, caused by neighbouring coal-fired power stations, and deterioration in water quality from external pollution sources affecting aquatic biota.

Additional information

Benefits

Understanding Benefits

▶ **Importance for research, Contribution to education**

The World Heritage site is of great research interest to the international scientific community and through hosting visitors makes a major contribution to geological interpretation and education.

▶ **Outdoor recreation and tourism**

Mammoth Cave National Park is a major tourist destination, with benefits flowing to local and regional tourist operators and other related commercial enterprises.

▶ **History and tradition**

Significant archaeological resources and historical sites have been identified, recovered, recorded and/or curated in the site.

Summary of benefits

The Mammoth Cave National Park World Heritage site not only protects a karst landscape of outstanding universal value, it also makes a significant contribution to geological science through research and education, and to cultural protection and promotion, while providing economic benefits from tourism.

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