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Case Report

Protecting A Subterranean Ecosystem and Its Pleistocene Megafauna Fossils: A Case Study from Northeastern Mexico

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Introduction

Subterranean environments are fragile and often ignored. But disregard does not entail insignificance. Caves are valuable environments whose conditions support and preserve unique biological communities, geological formations, and important paleontological records. Like buried time capsules, fossil deposits in caverns have contributed significantly to the reconstruction of Pleistocene ecosystems and climatic conditions [1]. The karst region of the Sierra de El Abra in northeastern Mexico hosts numerous cave systems in its limestone-rich landscape. Housed within are the blind cavefish, *Astyanax mexicanus*; a fascinating organism that has served as a prime model for studying adaptations to these extreme environments [2]. *Astyanax* alone boasts almost 1,400 bibliographic entries. During an exploration of an undocumented cave, now the Sistema Calera cave, researchers discovered a rich assemblage of Late Pleistocene megafauna. Among the entombed were mammoths, bison, camelids, giant ground sloths, glyptodonts, and apex predators, such as *Smilodon* and dire wolf. But the cave may be affected by human activity beyond those that enter into it; exposing a vulnerability from its location on private, agricultural land [3. 4].

Materials & Methods

A multidisciplinary team explored and mapped Sistema Calera cave from 2022 to 2026. Approximately 1,324 meters of passages were surveyed, including narrow dry galleries and flooded sections. Fossil remains were documented and identified through comparative morphology. Excavations and documentation were conducted under INAH permits No. 401.1S.3-2024/138 and 401.1S.3-2025/147. Submerged passages were explored using a Remotely Operated Vehicle (ROV) equipped with cameras, lights, and a mechanical claw to retrieve fossils safely. Conservation strategy assessments were informed by field observations, landowner interviews, and regulatory consultation.

Results

Biological and paleontological significance

Sistema Calera is inhabited by a population of cave-adapted and surface- morphs of *Astyanax mexicanus*. Though the eyed and blind morphs are very distinct, their populations coexist and hybridize naturally. The cave also supports a large mysid shrimp *(Spelaeomysis quinterensis)* colony in submerged chambers. Over 750 fossils have been extracted from the depths and catalogued. These include mammoths, mastodons, camelids, bison, horses, deer, giant ground sloths, glyptodonts, dire wolves, saber-toothed cats, and short-faced bears. The cave is now considered one of the most significant deposits of Late Pleistocene relics in the Hustecan region of northern Mexico [4] (Figure 1,2).

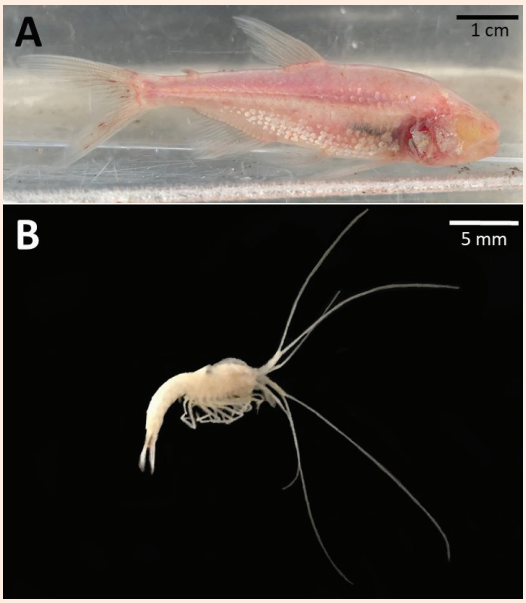

Figure 1: Cave-adapted organisms. A; Blind cave tetra (*Astyanax mexicanus*). B; Mysid shrimp (*Spelaeomysis quinterensis*).

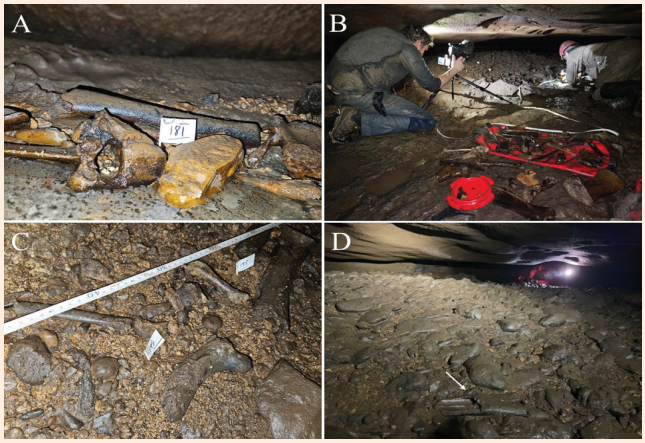

Figure 2: Over 750 fossils have been recorded from Sistema Calera cave, making it one of the most significant paleontological sites in the region. A; The vertebra of a bison; B; Detail photography and documentation of the fossils under trying conditions. C; Assortments of long bones highlighting the high density of remains. D; Ramón while doing the topography of this low-ceiling gallery. Arrow points at the metapodial of a camelid.

Conservation Efforts

First conservation attempt: private preserve and research station

The first conservation strategy was to establish a small private preserve. This required collaboration with the landowner of Sistema Calera. The idea was to create a modest field station near the cave entrance for visiting scientists to stay and conduct research. Occupants would contribute financially for lodging and access, generating a model to sustain the site for the landowner. Additional funding was expected to come from research grants and collaborations with academic institutions (Figure 3). This model aimed to combine scientific research with economic incentives for the landowner, thereby supporting both conservation and assisting local livelihoods. To raise awareness about the cave and its need for safeguarding, a documentary titled Crypt of the Megafauna was produced, describing the discovery, exploration, and conservation efforts. The film received the 'Best in Show' award at the 2024 National Speleological Society Convention and is available online: www.youtube.com/watch?v=71BLflbOsa8&t=2320s

Figure 3: Exceptionally well-preserved fossils recovered from the cave site. A; Mandible of a bison. B-C; Cranial remains of the short-faced bear Tremarctos floridanus. Researchers shown for scale and context.

However, this plan ultimately failed. The landowners, who were retired and required immediate financial resources, decided to sell the land to another rancher. The new buyer intended to use the property for agriculture and cattle farming. Lesson: Conservation planning must take into account the immediate economic realities faced by the local community. If a private landowner faces immediate financial pressures, they may have little choice but to sell or develop their land. When residents depend on natural resources for their livelihoods, they will understandably prioritize their day-to-day well-being over long-term conservation initiatives. Without alternative economic support or institutional backing, such preservation of environmentally significant sites becomes difficult. Effective strategies must therefore balance ecological protection while simultaneously offering economic stability for local stakeholders.

Second conservation attempt: non-profit land stewardship

After the land was sold, a second conservation strategy was developed based on the area's economic realities. In this strategy, the financial burden of conservation would not rely on a local campesino or landowner, who depends on using the land above the cave. Instead, we proposed that a non-profit organization assume responsibility for the site. Such an organization would not be subject to immediate economic pressures caused by weather variability or agricultural income, allowing decisions to prioritize long-term conservation goals. This model would also engage the local community through educational programs and incentives for sustainable land use. By aligning the interests of the locals with the researcher's objectives, both environmental protection and community well-being could be supported. The proposed strategy followed those used by the National Speleological Society (NSS) and many of its affiliated grotto clubs. In several cases, these organizations purchased small parcels of land containing cave entrances in order to protect them. The entrance to the Sistema Calera cave is a sudden vertical pit, that could be a liability to cattle in the area. Acquiring only the zone surrounding the entrance would minimize costs, secure access, and allow for fencing to prevent vandalism and loss of livestock (Figure 4).

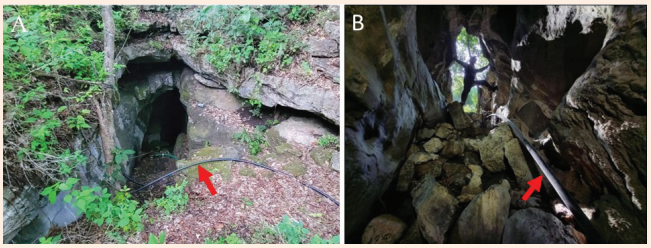

Figure 4: Entrance of the cave. A-B; The arrow indicates the location of a water pumping tube installed to remove water from the cave's interior, a practice that poses a threat to the conservation of the cave environment.

Initial discussions with the new owner were promising. However, the owner lives in a remote, mountainous region of rural Mexico, with limited infrastructure and no easy access to roads, electricity, or reliable telecommunications. Suddenly, digital communication with the campesino ceased for unknown reasons. Calls returned only a number not in service, and local contacts were unable to provide information concerning the owner's status or location. Without their help, the second strategy fell through.

Lesson: Effective strategies must account for potential communication breakdowns and include contingency measures to ensure continued stewardship. Remoteness and limited accessibility to landowners can critically impede conservation efforts.

Third conservation attempt: public education and museum outreach

The third conservation strategy focused on public awareness and support through outreach and education. The idea required cooperation with the local museum of Museo Regional Huasteco A. C., in the nearby city of Ciudad Valles. It involved creating an exhibit where some of the most compelling fossils would be displayed. This would highlight the scientific importance of the fossils and the need to protect the local cave environments. Such initiatives can help broaden recognition of subterranean ecosystems and may attract funding or institutional support for conservation.

This effort required working within the National Institute of Anthropology and History (Instituto Nacional de Anthropologia e Historia, INAH) rules, which mandates that fossil materials be deposited in the official repository of the Instituto de Geología at the Universidad Nacional Autónoma de México (UNAM). These requirements limit the ability to display original fossils in regional museum. Casts or replicas would be too costly to create in large numbers. As a result, the museum initiative could not be fully

implemented as originally envisioned until sponsorship can be found. A GoFundMe campaign was launched (www.gofundme.com/f/the-crypt-of-the-megafauna), and interviews were conducted with local news outlets, radio stations, and TV Azteca, one of the leading Mexican national television network (Figure 5,6).

Figure 5: The first local private landowner pictured alongside a researcher during initial discussions. Although the owner was initially enthusiastic about establishing a private preserve, urgent financial pressures ultimately compelled the sale of the land.

Figure 6: Paleontological section of the Museo Regional Huasteco A.C. Regulations prevented the transfer of fossils from the repository collection; therefore, an exhibition using replica casts will require external sponsorship to support their production and the exhibition design.

Lesson: Effective public outreach requires balancing regulatory constraints, resource availability, and early institutional coordination.

Discussion

The challenges at Sistema Calera cave illustrate potential issues in conserving cave ecosystems:

a) Economic pressures on landowners may override conservation goals unless alternative support is provided.
b) Remote locations complicate negotiation and ongoing management.
c) Regulatory frameworks, while necessary to protect natural resources, may unintentionally restrict public engagement and education.

Successful conservation requires strategies that integrate ecological protection, economic sustainability, community involvement, and institutional collaboration.

Conclusion

Sistema Calera cave contains a unique combination of subterranean biodiversity and Pleistocene megafauna fossils. Conservation efforts-including private preserves, non-profit stewardship, and museum outreach-have faced challenges from economic realities, remoteness, and regulations. Future protection will depend on external support, public awareness, and partnerships with institutions and non-profits. Sponsorship, funding, or community-supported initiatives will be critical to safeguarding this site for scientific study and education.

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