Chapter 18
Human Impacts on Mexican Caves

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18.1 Distribution of Caves and Karst

Mexican caves were naturally formed in many different rocks: limestone, gypsum, sandstone, lava, and others. Our discussions of caves are arranged in broad regions: Northwest, Northeast, South, and the Yucatán Peninsula. Figure 18.1 shows an

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Fig. 18.1 The 2019 expedition to Nacimiento del Río Uluapan, Oaxaca, which involved technical cave diving and vertical caving by an international team. Photo by Adam Haydock

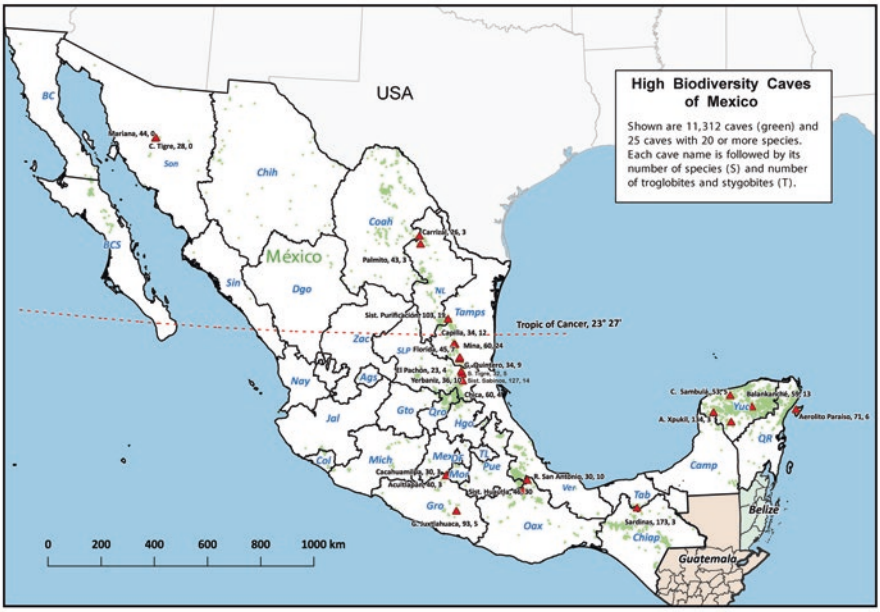

Fig. 18.2 Distributions of 11,312 known caves in Mexico (data courtesy of AMCS, Peter Sprouse). Twenty-five caves are shown having 20 to 40 species of troglobites and stygobites, but there are hundreds with rich and diverse animal communities. Besides invertebrates, bats are an important component of Mexican caves. By William R. Elliott

important resurgence cave, or nacimiento, currently being explored in Oaxaca.

Karst occurs across Mexico, and it is composed of landscapes formed by groundwater dissolution of limestone or gypsum rocks (Fig. 18.2). The Trans-Mexican

Volcanic Belt (Eje Volcánico Transversal) runs from Nayarit on the west coast to Veracruz on the Gulf coast. Lava caves are formed by drainage channels inside hot, flowing lava. Baja California contains rock shelters and littoral (shoreline) caves. All cave types may contain bats and interesting cave-adapted fauna. The AMCS (Association for Mexican Cave Studies) database contains nearly 12,000 cave locations, and the AMCS Index to Cave Maps of Mexico currently includes nearly 4000 maps (Elliott https://cavelife.info/maps/ and AMCS http://www.mexicancaves.org/maps/). Exploration and study of the caves attracts speleological groups from across México and the world. See UMAE https://umae.org/, the Unión Mexicana de Agrupaciones Espeleológicas. Numerous groups of speleologists can be found at those websites.

18.2 Biodiversity

Biodiversity is high in Mexican caves, with about 800 obligate cave species and many more associated with subterranean environments (Fig. 18.2). In this chapter, we refer to all cave-adapted forms as "troglobites," including terrestrial troglobites (troglobionts), and aquatic or marine stygobites (stygobionts) (Palacios-Vargas and Reddell 2013). Fourteen stygobitic fish species live in about 84 sites (Elliott 2018; Graham Proudlove pers. comm.). The other troglobites are invertebrates. Troglophiles are somewhat cave adapted but may occur in other habitats. Trogloxenes, like bats (Fig. 18.3) and cave crickets, come and go from the cave (Table 18.1).

Fig. 18.3 Distribution map which includes 351 bat caves and mines, some with large colonies, usually Tbra or "Mexican free-tailed bats," (common name in English, with a tail mostly free of the caudal membrane), or guano bat. Twenty-four caves have 9–15 bat species, 89 have 3–8, 132 have 1 or 2, and 105 are probable bat caves based on names like "murciélagos," "guano," "diablo," and "salitre" (saltpeter). Cueva San Francisco = Grutas de Zapaluta is included here as it may have 8–16 bat species. By William R. Elliott

Many of the species depend directly or indirectly on bat guano and other organic detritus or waterborne nutrients and detritus. These cave dwellers are scientifically interesting, and they provide evolutionarily significant insights into past climates, plate tectonics, and natural communities.

Terrestrial and some aquatic cave food chains often are based on bat guano from species roosting in different areas of the cave (Reddell 1981; Palacios-Vargas et al. 2011b, 2015; Hoffman et al. 1980, 1986, 2004; Elliott 2018). Cave bats include species that feed on insects, fruit, pollen, nectar, or blood (vampire bats). *Astyanax* cavefishes feed on floating bat guano (Elliott 2018). Collembola (springtails; Fig. 18.4) provide much of the base of the terrestrial food chains (Castaño-Meneses and Palacios-Vargas 2012), along with guano-dwelling mites, which include micropredators and those that feed on guano. More than 17 families and 180 species of Collembola have been recorded from Mexican caves, representing about 20% of the Collembola known from the country; this includes 12 families and 22 genera of troglobites (Palacios-Vargas et al. 2015). The food chain continues with millipedes, flies, moths, beetles, and many small arachnid predators.

Table 18.1 The top 25 general biodiversity caves in Mexico

Name	State	Municipio	Bat species	T	S	T/S	Risk
Sistema Huautla	Oaxaca	Huautla de Jiménez	2	30	48	0.63	2
Cueva de la Mina	Tamaulipas	Gómez Farías	2	24	60	0.40	1
Sistema Purificación	Tamaulipas	Hidalgo	2	19	103	0.18	1
Sistema de los Sabinos	San Luis Potosí	Ciudad Valles	4	14	127	0.11	2
Grutas de Balankanché	Yucatán	Tinum	7	13	59	0.22	2
Cueva de la Capilla	Tamaulipas	Gómez Farías	1	12	34	0.35	1
Cueva del Nacimiento del Río San Antonio	Oaxaca	Acatlán de Pérez Figueroa	1	10	30	0.33	1
Sótano de Yerbaniz	San Luis Potosí	Ciudad Valles	2	10	37	0.26	1
Grutas de Quintero	Tamaulipas	El Mante	13 (11)	9	34	0.26	5
Cueva de la Florida	Tamaulipas	Antiguo Morelos	8	7	45	0.16	1
Cueva Aerolito de Paraíso	Quintana Roo	Cozumel	?	6	71	0.08	1
Cenote Sambulá	Yucatán	Motul	?	5	53	0.09	4
Grutas de Juxtlahuaca	Guerrero	Quechultenango	8	5	93	0.05	2
Sótano del Tigre	San Luis Potosí	Ciudad Valles	1	5	32	0.16	1
Cueva Chica	San Luis Potosí	Ciudad Valles	6	4	60	0.07	3
Cueva de El Pachón	Tamaulipas	Antiguo Morelos	6	4	23	0.17	4
Actún Xpukil	Yucatán	Opichén	10	3	134	0.02	2
Cueva de las Sardinas	Tabasco	Tacotalpa	7	3	173	0.02	2
Gruta de Acuitlapán	Guerrero	Taxco de Alarcón	?	3	40	0.08	1
Gruta de Carrizal	Nuevo León	Lampazos de Naranjo	1	3	26	0.12	1
Gruta del Palmito	Nuevo León	Bustamante	0	3	43	0.07	2
Grutas de Cacahuamilpa	Guerrero	Pilcaya	7	3	30	0.10	3
Gruta Xtoloc	Yucatán	Tekax de Álvaro Obregón		2	86	0.02	1
Cueva de la Mariana	Sonora	San Miguel de Horcasitas	7	0	44		2
Cueva del Tigre	Sonora	San Miguel de Horcasitas	9	0	28		1

They are ranked in descending order for T = number of troglobites and stygobites. Another measure of general biodiversity is S = number of species. Some of these caves have many bat species or large bat colonies, but generally not. Risk means the likelihood of losing one or more species in the cave because of human activity; 1 is a natural cave, 2 had minor degradation, 3 and 4 are increasing levels of damage, 5 is severely impacted, gutted means a cave where life is absent. Risk was based on several factors: known loss of species, reduced bat populations, loss of habitat, level of human visitation, degree of human alteration, vandalism, etc.

Fig. 18.4 Collembola (springtails) provide much of the base of terrestrial food chains in caves. This *Pseudosinella* springtail is 1–2 mm long. Photo by Andy Murray

Few population estimates of cave invertebrates have been done in México, but these can be very large in bat caves. Osorio-Tafall (1943) studied the aquatic species in Cueva Chica, San Luis Potosí. Mitchell estimated a population of 11,000 ricinuleids (Arachnida) on guano in Cueva de la Florida, Tamaulipas (1970a). Mitchell (1970b) reported very large populations and densities of guanophiles in Fern Cave, Texas, associated with a large Mexican free-tailed, or guano bat, colony, similar to caves in Mexico. Palacios-Vargas (1983, 1988, 1993) conducted invertebrate surveys in many caves. Palacios-Vargas et al. (2011a, b) studied the ecologically rich Cueva de las Sardinas, Tabasco. Four different biotopes were studied over the course of a year: bat guano, litter, soil under chemoautotrophic bacteria colonies, and the control, plain soil without litter or guano. A total of 27,913 specimens of 169 species were collected. Guano had the highest densities recorded. Many reports by Palacios-Vargas et al. (1995, 2013, 2015) on cave invertebrate populations and by Calva (2017) in arid land caves are found in issues of *Mundos Subterráneos* (https://umae.org/mundos-subterraneos).

Endemism is relatively high among troglobites, with some taxa known only from one cave, or even a small part of one cave. In this study, we measured the endemism in a cave as the troglobite component, T/S, or fraction of troglobites (T) among all species (S) in the cave (Table 18.1). We also tabulated the number of bat species. Sistema Huautla, in mountainous Oaxaca, is the deepest cave in the Americas at 1560 m vertical relief, and it contains 48 species with at least 30 troglobites, a 63% troglobite component, the highest in México. Cueva de la Mina, in the tropical montane cloud forest of Tamaulipas, contains 60 species, 24 of which are obligate cave forms, nearly all terrestrial. An extremely different cave, Cenote Aerolito de Paraíso, Isla Cozumel, Quintana Roo, is submerged, most of it continuous with the Caribbean Sea. It hosts 71 species, 6 or which are stygobitic marine forms. All of these communities are vulnerable to disturbance. To date, some of the caves with high biodiversity have been impacted. Bat caves are disturbed by some visitors, but most severely by mining and human intervention, including harassment.

Table 18.2 The top 26 caves for bat diversity and abundance

Name	State	Municipio	Bat species	Tbra pop	Nmex pop	S	T	T/S	Total bats	Risk
Cueva Cerro Huatulco	Oaxaca	Santa María Huatulco	15						No census	1
Cueva Las Vegas	Puebla	Tenampulco	13		300				300	1
Grutas de Quintero	Tamaulipas	El Mante	13 (11)	100,00 1999		34	9	0.26	10,000	5
Cueva Cuaxilotla	Guerrero	Cuetzala del Progreso	12						>80,000	1
Aktún Loltún	Yucatan	Oxkutzcab	12						No census	2
Cueva El Salitre, Colima	Colima	Colima	11		>350				>350	1
Cueva El Salitre, Morelos	Morelos	Tlaltizapán	11							1
Cueva Los Laguitos	Chiapas	Tuxtla Gutiérrez	10		>10,000 [>1000]				100,000	1
Grutas Karmidas	Puebla	Zapotitlán de Méndez	10						No census	1
Mina Armadillo	Sonora	Alamos	10	Tbra	1000				1000	2
Mina La Aduana	Sonora	Alamos	10	Tbra	present before, absent 2010				No census	2
Actún Xpukil	Yucatán	Opichen	10		Present before, absent 2010	134	3	0.02	No census	2
Volcán de los Murciélagos	Campeche	Calakmul	9						3,000,000	2
Cueva La Fábrica	Colima	Coquimatlán	9						No census	1
Cueva Mina América	Morelos	Tlaquiltenango	9						No census	1
Cueva del Cerro	Morelos	Puente de Ixtla	9						No census	1
Cueva del Tigre	Sonora	San Miguel de Horcasitas	9	1,000,000	100	28	0	0	1,000,000	1
Mina Santo Domingo	Sonora	Alamos	9	Tbra	>500				>500	2
Cueva de Don Luis	Tabasco	Teapa	9						Big	1

(continued)

Table 18.2 (continued)

Name	State	Municipio	Bat species	Tbra pop	Nmex pop	S	T	T/S	Total bats	Risk
Cueva El Ojo de Agua	Tamaulipas	Gómez Farías	9		100				100	1
Cueva de El Abra	Tamaulipas	Antiguo Morelos	9	Large flights 1950s, now uncertain					Thousands	4
Cueva El Socavón	Veracruz	San Andrés Tuxtla	9		Present before, absent 2010				No census	1
Gruta Tzamnah	Yucatán	Tecoh	9						No census	1
Cueva San Francisco = Grutas de Zapaluta	Chiapas	La Trinitaria	8 (16?)	"Big"					"Big"	3
Grutas de Juxtlahuaca	Guerrero	Quechultenango	8		>1000	93	5	0.05	70,000	2
Cueva del Ídolo	Morelos	Jojutla	8							Gutted

See Table 18.3 for free-tailed bat caves) in Mexico. Another 18 caves contain 8 or 9 bat species, but most have not been censused. We assigned a risk value of 1 unless we had specific information. Tbra refers to *Tadarida brasiliensis*, Nmex refers to *Natalus mexicanus*; these are common cave bats, censused often. T = number of troglobites and stygobites. Another measure of general biodiversity is S = number of species

Table 18.3 (below) Details of 23 “free-tailed bat caves,” containing *T. brasiliensis mexicana,* which is important for control of agricultural pest insects

Name	State	Municipio	Bat species	Notes	Total bats	Risk
Cueva de Allende	Coahuila	Allende	1	Villa-R (1966)		1
Cueva de El Abra	Tamaulipas	Antiguo Morelos	9	Large exit flights 1950s, uncertain in 2020. Málaga Alba, Villa-R 1957: 560 Tbramex. Reddell (1965), thousands of dead bats. Torres-Flores and López-Wilchis (2010)		4
Cueva de la Boca	Nuevo León	Santiago	3	5–10 million before guano mining. Arita (1992): 5 million. Roemer (2003), winter 2002: 100,000. 2001: 2.5 million; 2021: 2 million. Villa-R (1966), Torres-Flores and López-Wilchis (2010): Nmex, Tbra	2,500,000	4
Cueva de la Chinacatera	Sinaloa	Angostura	4	Roemer (2003): Likely summer roost. Locals mined three hundred sacks of guano in 1999		2
Cueva de la Isla de Janitzio	Michoacán	Patzcuaro	1	Villa-R (1966). Small colony 1999, Roemer (2003). Now gutted of life.	<10	Gutted
Cueva de la Mariana	Sonora	San Miguel de Horcasitas	7	Calva (2017): 500,000.	500,000	2
Cueva de la Mula	Tamaulipas	Jaumave	3	Mollhagen (1971)		1
Cueva de las Torrecillas	Jalisco	Toliman	8	Ayala Téllez et al. (2018)	400	1

(continued)

Table 18.3 (continued)

Name	State	Municipio	Bat species	Notes	Total bats	Risk
Cueva del Guano	Durango	Lerdo	2	Map 1972, Roemer (2003): 53 Tbra 1999-12-12.	53	2
Cueva del Real	Jalisco	Tecaliltlán	5	Ayala Téllez et al. (2018). Except for *D. rotundus*, species were identified using echolocation calls. Low human disturbance	40	1
Cueva del Rincón de la Virgen	Nuevo León	García	1	Villa-R (1966), Roemer (2003): 10 + large guano deposit, 1999-12-10, summer roost for Tbra	10	1
Cueva del Tigre	Sonora	San Miguel de Horcasitas	9	Arita (1992): 9 bat species, very high abundance, 1 fragile species, a major free-tail colony. Torres-Flores and López-Wilchis (2010): Nmex, Chmex, Lniv, Mcal, Mmeg, Mvel, Pdav, Ppar, Tbra. 1000,000 Tbra, bats declined from 9 to 4 species from 1991 to 2017. Calva (2017)	1000,000	1
Cueva Higuerilla	Jalisco	Tecalitlán	2	Ayala Téllez et al. (2018). Human disturbance is low.	20 (echolation calls)	1
Cueva La España	Durango	Lerdo	1	11 specimens examined, Villa-R (1966)		1
Cueva San Francisco = Grutas de Zapaluta	Chiapas	La Trinitaria	8 (16?)	"big" colony of *Tadarida brasiliensis intermedia*, Villa-R (1966). Map at AMCS website	"big"	3

(continued)

Table 18.3 (continued)

Name	State	Municipio	Bat species	Notes	Total bats	Risk
Cuevas de Las Garrochas	Jalisco	Mixtlán	3	Roemer (2003): Banded Tbra from Carlsbad Caverns 1952-11-26. Tbra bones and odor 1999-12-21. No Tbra but Drot with young. Torres-Flores and López-Wilchis (2010): Nmex, Drot		1
Grutas de Quintero	Tamaulipas	El Mante	13 (11)	13 bat species max. Mollhagen (1971), 9 species. Reddell (1981). Arita (1992): 9 species, very high abundance, 1 fragile species. Roemer (2003): 10,000 Tbra 1999-12. Hernández-Vázquez (2005): 11 bat species. Torres-Flores and López-Wilchis (2010)	10,000	5
Las Cuevas	Baja Cal. Sur	Los Cabos	3	Torres-Flores and López-Wilchis (2010)		1
Mina Armadillo	Sonora	Alamos	10	Torres-Flores and López-Wilchis (2010)	1000	2
Mina La Aduana	Sonora	Alamos	10	Torres-Flores and López-Wilchis (2010)		2
Mina Santo Domingo	Sonora	Alamos	9	Torres-Flores and López-Wilchis (2010)	>500	2
Resumidero del Cerro Toxin	Jalisco	Toliman	4	Ayala Téllez et al. (2018)	300	1
Ventana Jabalí	San Luis Potosí	Ciudad Valles	1	Bonet (1953): guano mining. Mollhagen (1971)		2

See range maps in Villa-R. and Cockrum and Bradshaw. T = number of troglobites and stygobites. Another measure of general biodiversity is S = number of species. Only three caves have biodiversity scores to date: Mariana 3 S, 0 T; Tigre 28 S, 0 T; Quintero 34 S, 9 T, 0.26 T/S

Arita (1992, 1993, 1996, 1997) Arita and Vargas (1995), and Arita and Ortega (1998) studied the ecology and conservation of Mexican bats, especially in Yucatán. Arita developed a table, "Critical Caves for the Conservation of Mexican Cave Bats," in his 1992 dissertation, which listed 12 important caves with 9–12 bat species each. Since 1992, our knowledge has increased to 25 caves with 8–15 bat species each, detailed in Table 18.2. Nine of Arita's 12 bat caves are in our tables in this chapter, and the other 3 are in our GIS (geographic information system) and maps. It is important to document diversity and protect additional caves with multiple bat species and diverse invertebrate communities.

18.3 Human Impacts on Caves

Human impacts on caves are many, the main ones being disruption and killing of bats, mining, vandalism, trash dumping, overuse and degradation of cave environments, and contamination of groundwater. Palacios-Vargas (1995) proposed the inclusion of subterranean environments in ecological laws for the Mexican Government to protect caves and karst areas. Several authors have recommended conservation actions for individual caves.

Below is a descending list of impacts that have occurred at American and Mexican caves (Elliott 2000). These impacts are ranked on general frequency and severity, so they may vary in importance in the list depending on the region and cave type.

1. Destruction of caves by quarrying or inundation.
2. Unregulated, uncontrolled, and unsustainable mining of phosphates, guano, and other materials resulting in bat disturbance or extirpation.
3. Killing of multiple species of bats by locals or rabies control workers against vampire bats.
4. Disturbance of bats by cave visitors, mostly by tourists, but sometimes by cavers and scientists.
5. Alteration of entrances that affects access by wildlife or the cave environment itself.
6. Alteration or contamination of water inputs.
7. Pipeline breaks, dumping of toxic materials or medical waste.
8. General cave abuse, graffiti, trash, trampling, and breakage.
9. Some kinds of ecotourism cave development, environmental alteration, cave lint, algae growth (from artificial lights), loss of bats and troglobites.
10. Over-collecting by biologists (infrequent).
11. Infrequent visitation and unintended bat disturbance (harmful during critical times, such as birthing and nursery periods).

These impacts are ranked on frequency and severity, so some impacts may move up or down the list depending on the information available at any given time.

18.4 Review of Caves by Geographic Region

The international importance of Mexican cave biology is reflected in its large scientific literature, with more than 4200 papers, 123 cited here. There are more than 1000 papers on a single model species (i.e., *Astyanax mexicanus jordani* cavefishes) alone, and many papers and books on exploration, cave fauna, taxonomy, evolution, ultramorphology, genomics, cultural use of caves, geology, hydrology, and environmental problems.

Mexico has at least 139 species of bats, 60 of which occur in caves, with 36 reported in this chapter (Arita 1992; Ayala-Téllez et al. 2018). The largest impact reported on bats has been the mining of phosphates, nitrates, and guano (Elliott 2000). Some were mineralized deposits from bat guano and bones, but many affected caves had living bat colonies and fresh guano. In the past, federal rabies control workers killed vampire bats and sometimes other species living in the same caves (Elliott 2000). Guano mining in Ventana Jabalí, San Luis Potosí, and the need for protection of bat caves for agriculture were noted in 1953 by Federico Bonet, a prominent cave scientist. Population estimates of bats were difficult and imprecise until about 1980. Recurrent counts by experts of hibernating bats are now reliable. Large maternity colony emergences are more difficult to estimate, but there have been advances since 2000 in infrared videography for counting (Elliott 2008; Elliott et al. 2011). For the migratory Mexican free-tailed bat (*Tadarida brasiliensis mexicana*), it is important to identify and protect migratory routes and critical cave roosts in both the United States and Mexico (Wiederholt et al. 2013).

The following caves are detailed because of their high biodiversity or notable impacts. Other caves are listed in Tables 18.1 and 18.2. Many had documented human impacts, but some are important caves that have received little or no impact, but deserve additional protection.

18.4.1 Northwest Region

18.4.1.1 Cueva El Tigre and Cueva de La Mariana, Sonora

Both of these karstic caves are located between the towns of San Miguel de Horcasitas and Carbó in the central region of Sonora. They are located approximately 60 km NE of the capital, Hermosillo. Cueva El Tigre is 156 m long and 46 m vertical development. Cueva de la Mariana is 700 m long and 44 m deep (Calva 2017). The two caves were used for guano extraction. Landowners collected guano in winter, when bat populations decrease. Cueva El Tigre is still visited by the land owner to collect guano; however, guano extraction ceased in Cueva de la Mariana years ago.

Cueva El Tigre was explored in the 1960s. Despite the proximity between the caves, Cueva de la Mariana was not recorded by Sonora cavers until 2014. Cockrum

Fig. 18.5 *Myotis velifer*, the cave myotis, one of 60 bat species commonly found in Mexican caves. Photo by Rodrigo A. Medellín

and Bradshaw (1963) made several trips to Sonora as part of a bat-banding program. At Cueva El Tigre, they recorded 9 species, with 2 specimens of *Pteronotus mexicanus*, 32 *Pteronotus fulvus*, 19 *Mormoops megalophylla*, 18 *Macrotus californicus*, 1 *Choeronycteris mexicana*, 4 *Leptonycteris nivalis* (probably *L. yerbabuenae*), 4 *Natalus mexicanus*, 1 *Myotis velifer* (Fig. 18.5), and 10 *Tadarida brasiliensis*. *L. nivalis* is absent from the region, and there probably was a misidentification with its close relative *L. yerbabuenae*, which has been recorded in Cueva de la Mariana, and it is present in the region.

Arita (1993) compared Mexican bat caves, and he rated Cueva El Tigre as having high diversity and great bat abundance. Calva (2017) reported only four bat species corresponding to *T. brasiliensis*, *P. fulvus*, *N. mexicanu*s, and *M. californicus* in Cueva El Tigre. Calva recorded these four species in Cueva de la Mariana, plus three more: *Leptonycteris yerbabuenae*, *Myotis velifer*, and *Mormoops megalophylla.* The most abundant species was *T. brasiliensis* with an estimated population of more than one million individuals in Cueva El Tigre, and half a million in Cueva de la Mariana. Both caves are important because 50% of the species use them as maternity roosts. We have assigned a risk factor of 2 for Mariana and 1 for Tigre.

In his thesis, Calva (2017) collected and recorded invertebrates and other vertebrates in both caves. No troglobites were found. Despite the hot conditions inside both caves, 52 taxa were determined at least to generic level. In Cueva de la Mariana 43 species of invertebrates and vertebrates were recorded, whereas in Cueva El Tigre only 28 species were found. The two caves shared 19 species. For invertebrates, the unique groups were arthropods represented by centipedes, arachnids, and insects, and for vertebrates he recorded amphibians, reptiles, birds, and mammals.

18.4.2 Northeast Region

18.4.2.1 Cueva del Cañón El Buey, Coahuila

The cave is 20 m long and 8 m deep, and it is strongly affected by medical waste, including biologically infectious material such as syringes, photographed in 1996 at the bottom of a pit cave, Cueva (Pozo) del Cañón El Buey (Elliott 2000). We have assigned a risk factor of 5 for El Buey.

18.4.2.2 Toxic Sink, Coahuila

In July 1996, used drums of the insecticides, the organochlorine chlordane, and the organophosphate methamidophos were found and photographed in Toxic Sink, Coahuila, a pit cave (Elliott 2000). Both chemicals are highly toxic. We could not enter the cave and the fauna is unknown, but we have assigned a risk factor of 5 to Toxic Sink.

18.4.2.3 Cueva de la Boca, Nuevo León

The huge, 27 by 27 m entrance to Cueva de la Boca (Fig. 18.6) opens on the south side of Cañon Garrapatas, 1.5 km E of Santiago and Presa de La Boca. Cueva la Boca is a single chamber, 295 m long and 14–30 m wide. Near the entrance the ceiling is almost flat, but at the rear two large domes extend 152 m above the floor. A

Fig. 18.6 Cueva de la Boca, Nuevo León. The 27-m entrance is high on a ridge above Cañon Garrapatas. The cave now contains about 2 million *Tadarida brasiliensis*. Photo by Alejandro Gómez

30-m tower was formerly used for accessing and extracting phosphates from the walls. A jeep road was used to carry the rock and guano to the cave entrance, where an aerial tramway carried the ore in buckets across the canyon to the road below (Russell and Raines 1967).

Cueva La Boca is the focus of a major conservation effort to restore the colony of *Tadarida brasiliensis mexicana*, Mexican free-tailed bat or guano bat. It was estimated that 20 million bats formerly inhabited the cave, but 5 or 10 million is more likely. The colony is mostly *Tadarida brasiliensis mexicana*, but there is a small colony of *Mormoops megalophylla* and a seasonal colony of *Leptonycteris nivalis.* Unfortunately, because of human impacts, such as guano and phosphate extraction, uncontrolled tourism, pollution, and vandalism (bonfires, fireworks, etc.), the bat population was reduced to less than 100,000 in 1991, but it started increasing in 1994. The Program for Conservation of Bats in Mexico (PCMM) began working there in 1995 with a very active program on research, conservation, and environmental education (Medellín 2003; Medellín et al. 2004). They drafted a management plan for conservation of this cave, and provided it to a local organization in 1999. They obtained a mining permit to prevent future guano extraction and its disturbances. Medellín and his team continued research in the cave, and the colony recovered to about 2.5 million bats in 2001. The colony continued to grow in the next 5 years. Unfortunately, only a second fence was built in 2004, which was vandalized within months. Both fences are inadequate, and a video posted on YouTube on 22 March 2019 shows intruders entering the cave through holes in the fences. We assume that the bats are disturbed at times. The local organization continues to work sporadically in the area, but the Covid-19 pandemic has hindered efforts. The colony currently is about 2 million, an improvement, but we have rated the risk factor for La Boca at 4 because of frequent intruders.

18.4.2.4 Sistema Purificación, Tamaulipas

This large cave system includes 33 caves in a remote mountain region, the source for Río Purificación. Many years were required to explore and map the system. Purificación is the fourth longest cave in México at 94,889 m, the longest "dry" Mexican cave (mostly above water) and 11th deepest at 957 m. The cave, at 1916 m elevation, has 103 total species, 19 troglomorphic species (4 aquatic, 15 terrestrial), 2 aquatic and 46 terrestrial troglophiles (Reddell 1981, p. 20; Table 18.3). There are at least two bat species: unidentified insectivorous bats and *Desmodus rotundus*, the common vampire (Peter Sprouse and James Reddell, pers. comm.). The system receives massive floods during heavy rains, which flow out of the lower entrance to the Río Purificación. Access to the cave is available only to experienced speleologists, and we have rated the risk factor at 1.

18.4.2.5 Cueva de la Mina, Tamaulipas

Cueva de la Mina, at 1527 m elevation in the Sierra de Guatemala, has a small entrance, and is only 160 m long and 25 m deep. There is much flowstone over soil creep and roots reach down from the cloud forest. The cave has 60 species with 24 confirmed troglobites, for a troglobite component value of 40%. The cave was mapped in 1971 by Elliott and others from Texas Tech University. The cave is within the Reserva de la Biósfera El Cielo, hidden in the forest at about 1500 m asl (above sea level), near an abandoned logging road that is rarely traveled. It probably receives very few visitors (Reddell 1965, Reddell and Mitchell 1971b; Elliott 1973; Reddell and Elliott 1973b; Palacios-Vargas et al. 2015). Two species of bats were reported: *Anoura geoffroyi* and *Leptonycteris nivalis* (Mollhagen 1971). The most notable troglobite there is the endemic *Typhlochactas rhodesi*, the first blind scorpion discovered in México. For many years, Cueva de la Mina was the most biodiverse Mexican cave, but it is now number 2. Ecotourism in the area could affect this cave in the future, but we have rated the risk factor at 1 for now.

18.4.2.6 Cueva de la Capilla, Tamaulipas

This is a very biodiverse cave at high elevation (about 2100 m asl) with 34 species, including 12 troglobites, within the Reserva de la Biósfera El Cielo. Mapped in 1971 by Elliott et al., the cave is 250 m long and 22 m deep, with an entrance at each end. A bat collected here was lost, but it probably was *Corynorhinus mexicanus*. The cave is in an isolated area with very few visitors (Reddell and Mitchell 1971a, b; Elliott 1973; Reddell and Elliott 1973a, b; Palacios-Vargas et al. 2015). We have rated the risk factor at 1 for now.

18.4.2.7 Grutas de Quintero, Tamaulipas

Also called Cueva de Quintero, it is 1030 m long and 15 m in vertical relief. The cave is an old spring that was extensively mined and torn up for minerals since 1965; however, bat domes still exist and spring-fed rimstone pools remain at the far end. Russell and Raines (1967) described the cave in its better days as having a succession of travertine dams up to 3-m high filled with water, flowstone slopes, and large speleothems. They noted that foot traffic and some vandalism had marred the cave before the 12-m pit at 500 m from the entrance. Most of the scenic value of the cave has been destroyed since then.

Grutas de Quintero was listed as an “Important Cave for Conservation” (Arita 1992 and section below). Quintero is a cave of national importance, but it has suffered abuse for a long time. Figure 18.7 shows the damage to the cave from 1965 to 2007; formerly there were many pristine, travertine, or rimstone pools, but later most of the calcite crusts and speleothems were removed, and the pools were ruined and drained. Hernández-Vázquez (2005), noted 11 bat species and large amounts of

Fig. 18.7 Grutas de Quintero, the cave's condition in 1965 (left) compared to 2007 (right). The cave was extensively mined, destroying much habitat, and bats have been reduced. Photos by Francis Abernethy (left) and Peter Sprouse. Pictured are Jean Louis Lacaille Múzquiz (left) and Vince Massey

trash and vandalism; he recommended specific actions for the cave's restoration, management, and sustained use.

Quintero's general biodiversity is, or was, high (34 species, 9 troglobites). On 20 July 1983, Wilson et al. (1985) recorded three bat species: *Glossophaga soricina, Eptesicus fuscus miradorensis*, and a flight of about 100,000 *Tadarida brasiliensis mexicana*. In 1999, the cave contained only 10,000 *T. b. mexicana* (Roemer 2003). It is one of 24 sites for this species in Mexico. In 2005, Hernández-Vázquez netted 698 *T. b. mexicana* but made no population estimate.

The cave still is important as a diverse bat roost, with 13 species identified since 1971. Two of the species have not been reported since Mollhagen's 1971 survey of 9 bat species: *T. brasiliensis mexicana* (Fig. 18.8), *Artibeus jamaicensis*, *A. lituratus*, *Desmodus rotundus*, *Diphylla ecaudata*, *Eptesicus fuscus* (captured in small holes in the entrance vault*), Glossophaga soricina*, *Leptonycteris yerbabuenae*, *Micronycteris microtis*, *Mormoops megalophylla, Natalus mexicanus*, *Pteronotus mesoamericanus*, *P. psilotis*. The missing species are *Artibeus lituratus* and *Micronycteris microtis*.

Aquatic cave species include the cirolanid isopods *Speocirolana bolivari* and *S. pelaezi*, ostracod *Sphaeromicola cirolanae*, and mysid *Spelaeomysis quinterensis*. Terrestrial troglobites include the isopod *Brackenridgia bridgesi*, thysanuran *Anelpistina quinterensis*, schizomid *Sotanostenochrus mitchelli*, ricinuleid *Pseudocellus osorioi*, and pseudoscorpion *Paravachonium bolivari*.

Quintero has been the site of many studies, but there has been no long-term project to scientifically monitor the cave and conserve its resources (Jean Louis Lacaille

Fig. 18.8 A nursery colony of *Tadarida brasiliensis mexicana*. The babies are pink. A human disturbance may cause the mothers to drop their babies, but they cannot retrieve them from the floor. These bats control moths and other agricultural pests. Photo by Rodrigo A. Medellín

Múzquiz, pers. comm.). As a result, the cave has suffered, two bat species were lost, and habitat has been lost. We have assigned a risk factor of 5 to Quintero because of these documented losses and the continuing risk to the cave. This risk applies in three ways: biodiversity, bat biodiversity, and *T. b. mexicana* in particular. Quintero has the best documented losses of any Mexican cave, including a Master of Science thesis by Hernández-Vázquez (2005), and papers by Russell and Raines (1967), Mollhagen (1971), Elliott and Mitchell (1973), Reddell (1981), Wilson et al. (1985), Arita (1992), Roemer (2003), and Torres-Flores and López-Wilchis (2010).

18.4.2.8 Cueva de El Abra, Tamaulipas

This famous cave has a prominent, large entrance high above the Mexico 85 highway in the El Abra pass, south of Ciudad Mante. "Cave near Ojo de Agua" is a synonym for the cave, named for the village of El Abra (Ojo de Agua) 2 km SE. At 500 m long and 119 m deep, the cave has attracted countless visitors over many years. It was first explored to the bottom of its pit by Texas cavers in 1956. Málaga Alba and Bernardo Villa-R. collected bats in 1957. A skylight at the top of the hill also is a portal for up to 9 species of bats. In recent years, Jean Louis Lacaille Múzquiz (pers. comm.) and the Grupo Espeleológico Mante (GEM) from Ciudad Mante have removed graffiti and many bags of trash from the cave. There are warning signs placed by the local government, but there is no adequate safeguard against the continued abuse by visitors.

It is interesting that bats still use this cave, despite all the disturbance, but probably at a reduced number. The current bats are *Tadarida brasiliensis mexicana*, *Nyctinomops laticaudatus*, and *N. aurispinosus* from the cave (Málaga-Alba and Villa-R 1957; Torres-Flores and López-Wilchis 2010). Other species reported:

Artibeus jamaicensis, *Desmodus rotundus*, *Myotis nigricans*, *Glossophaga soricina*, *Pteronotus mesoamericanus*, *Natalus mexicanus*. Reddell (1965) reported, "Throughout the first section of the cave thousands of dead bats were seen on the floor during the most recent visit (27 January 1965) that were evidently the victims of some epidemic." We have assigned a risk value of 4 to this cave and its fauna, as the large flights of the 1950s no longer occur. A new bat census is needed.

18.4.2.9 Cueva de la Florida, Tamaulipas

Locally, Florida is called "Cueva Misantla," and a survey monument nearby called it "Mina la Florida." The elevation is 230 m asl. It is 1830 m long and 57 m deep. The cave apparently is an ancient resurgence similar to nearby Cueva de El Pachón, but now it is a dry cave with eight bat species and a rich invertebrate fauna, including a prolific population of two guano-dwelling ricinuleids, *Pseudocellus osorioi* and *P. pelaezi*. The map, lost since 1968, will be published by Elliott and Lacaille Múzquiz in 2021 or 2022. There are 45 total species with 7 troglobites. The ricinuleids were statistically estimated by Mitchell (1970a) in the left-hand tunnel, where there are copious guano deposits supporting a population of 11,000 *Pseudocellus osorioi* ricinuleids, and millipedes, schizomids, amblypygids, and other fauna. *P. pelaezi* is found more in the right-hand tunnel, Elliott Lacaille Múzquiz (2022).

Bat diversity, eight species: *Artibeus jamaicensis*, *Desmodus rotundus*, *Diphylla ecaudata*, *Glossophaga soricina*, *Mormoops megalophylla*, *Natalus mexicanus*, *Pteronotus mesoamericanus*, *P. psilotis* (Mollhagen 1971; Torres-Flores and López-Wilchis 2010; Elliott 2015a, 2018). The risk factor for Florida is 1 for now.

18.4.2.10 Cueva de El Pachón, Tamaulipas

Pachón is an important site for the study of *Astyanax* cavefishes (Fig. 18.9; Mitchell et al. 1977; Wilkens and Strecker 2017; Elliott 2018). The cave is 583 m long and 8 m deep. The cave has moderately high biodiversity and six bat species: *Artibeus jamaicensis*, *Desmodus rotundus*, *Diphylla ecaudata* (De la Torre 1954), *Glossophaga soricina*, *Natalus mexicanus*, *Pteronotus mesoamericanus* (Martin and Martin 1954).

In 1971, using a two-census, mark-recapture method involving a caudal fin clip (Lincoln Index), Mitchell et al. (1977) statistically estimated the Pachón population of cave *Astyanax* conservatively as $\hat{N} = 9781 \pm 8502$). In 2009, Reynoso et al. (2009) reported a new population estimate using a similar fin clip method in Pachón of $\hat{N} = 2750 \pm 1927$. The 2009 Pachón $\hat{N}$ is only 28% of the 1971 $\hat{N}$, but the confidence limits are wide in both cases. There has been a decline of cavefishes in Pachón, but it is difficult to say how large the decline was. Reynoso said, "We conclude that the scientific community should be concerned about the vulnerability of blind cave fish populations, since fishes are constantly extracted, or populations are manipulated for scientific purposes…." This conclusion was mainly for Pachón, which is often

Fig. 18.9 *Astyanax mexicanus jordani*, the cave *Astyanax* or Mexican cavefish, model system in evolutionary and genomics research. About 70–100 mm long. Photo by Jean Louis Lacaille Múzquiz

visited by scientists. The cavefishes of this cave ought to be censused again. We have set the risk factor for Pachón at 4 (Table 18.1).

18.4.2.11 Sistema de los Sabinos, San Luis Potosí

Sistema de los Sabinos contains three hydrologically connected caves: Cueva de Los Sabinos, Sótano del Arroyo, and Sótano de la Tinaja. The highest elevation is 320 m asl at Tinaja. The system is inhabited by the fish *Astyanax jordani*, (Hubbs & Innes 1936) and is 13,206 m long and 155 m deep. The cave receives large floods during the rainy season and drains to the Nacimiento del Río Choy.

Because of studies by scientists from México, USA, and Canada from 1942 to 1974, the three caves are known to contain 127 species, including 14 troglobites, 42% of the known cave species of the Sierra de El Abra region. More concentrated study of other large cave systems is needed, but it seems likely that the Sistema de Los Sabinos will remain the richest in cave biodiversity in the region because of the concentration of bats (in Sabinos and Tinaja) and flood detritus. Only nine species occur across all three caves; five are troglobites and four are troglophiles. Sabinos and Arroyo share 23 species, Arroyo and Tinaja share 8 species, and Sabinos and Tinaja share a different set of 9 species. The 14 troglobites range more widely in the system. Four bat species are known: *Balantiopteryx plicata*, *Desmodus rotundus*, *Diphylla ecaudata*, and *Glossophaga soricina* (Mollhagen 1971). The caves are still wild, but there is occasional disturbance of bats by ecotourists (Elliott 2018). We have set the risk factor for this system at 2.

18.4.2.12 Sótano de Yerbaniz, San Luis Potosí

Sótano de Yerbaniz is 2238 m long, 97 m deep, and has three levels below the entrance at 242 m asl. It has a large catchment area of 16 km^2 and it floods violently. Eyed *Astyanax* fish are sometimes found on levels 1 and 2, cavefishes on level 3.

The cave has a rich fauna of 37 species with 10 troglobites and at least 2 bat species. Surface fish and hybrids are sometimes found in shallow pools in the cave. A two-census, mark-recapture study estimated the total number of cavefishes at 8671 with 95% confidence limits 1810–15,534 (Mitchell et al. 1977; Elliott 2018). Food input is from flood debris, guano, and dying surface fish (Elliott 2014, 2015a, b, 2018).

Yerbaniz hosts the blind scorpion, *Sotanochactas elliotti*, in one damp gallery of the cave. Three trips found only three specimens total in that one passage. It is still considered the world's most troglomorphic (cave-adapted) scorpion. The cave schizomid, *Agastoschizomus lucifer*, also was discovered in the cave. Bats: *Desmodus rotundus*, and unidentified bats in the main roost over Level 3 lake. We consider the risk factor as 1 for Yerbaniz.

18.4.2.13 Sótano del Médico, San Luis Potosí

The cave is 10 m long and 37 m deep and is also known as Sótano Caracoles Médicos. The name of this cave near Tlamaya reflects the large amount of medical waste, including used syringes that had been dumped into it (Minton 1992). Although the fauna is poorly known, a risk factor of 5 is assigned.

18.4.3 South Region

18.4.3.1 Cave near Mezcala, Jalisco

In the mid-1990s, a colony of *Leptonycteris sp.* bats was killed or driven off by local people from an unnamed cave near Mezcala. The people probably went after the common vampire bat, *Desmodus rotundus*, which inhabits another cave nearby (Mario Sgro, pers. comm. in Elliott 2000). Although the fauna is poorly known, a risk factor of 4 is assigned.

18.4.3.2 Cueva de la Isla de Janitzio, Michoacán

The cave had a small colony of free-tailed bats. Villa-R (1966) examined two specimens of *T. b. mexicana* from Cueva de Janitzio. In December 2000, Roemer (2003) went there because bats banded from Carlsbad Cavern in the United States were found there before. We have reports that the cave has been gutted.

18.4.3.3 Three Bat Caves in Guerrero: Grutas de Cacahuamilpa, Cueva Cuaxilotla, and Grutas de Juxtlahuaca

Three large bat caves lie within 140 km of each other in northern and east central Guerrero: Grutas de Cacahuamilpa (7 bat species), Cueva Cuaxilotla (12), and Grutas de Juxtlahuaca (8). Cacahuamilpa is 1380 m long and 120 m deep. The subterranean stream of Río Chontalcoatlán runs below Cacahuamilpa and extends 6 km to exit at the famous Dos Bocas. Cuaxilotla is 1620 m long, but the depth was not mapped as the cave is relatively level. Grutas de Juxtlahuaca is a show cave, 5,099 m long, depth unmapped, but at least 60 m deep at the greatest ceiling height.

Cacahuamilpa has moderate biodiversity and high-human disturbance (7 bat species, 20,000 total bats, 3 troglobites, and 30 total species). In contrast, Juxtlahuaca has moderately high biodiversity and less human disturbance (8 bat species, 70,000 total bats, 5 troglobites, and 93 species). Of the three caves compared here, Cuaxilotla has the highest bat diversity and population and the lowest disturbance (12 bats, >80,000). This is the best existing dataset comparing human impacts on cave biodiversity in México. Details for each cave are given below.

Grutas de Cacahuamilpa, Guerrero

Cacahuamilpa is an historical show cave, used like Juxtlahuaca by the Olmec people, and later by the Chontal tribe for ceremonial purposes. The first biological investigation of this cave was conducted in 1866 by the Austrian Reverend, Dominik Bilimek, who accompanied Maximiliano of Habsburg on a cave visit. Bilimek (1867) reported 11 species with one troglobite, *Anelpistina* (ex *Lepisma*) *anophthalma*. The next important contribution to the fauna of this cave was that of the Mexican biologist, Alfonso L. Herrera (1891, 1911). Federico Bonet and Cándido Bolívar y Pieltain made an intensive study of cave fauna for 20 years. They began with a visit to Grutas de Cacahuamilpa in 1939, then in 1941 to Grutas de Juxtlahuaca. Bonet in 1962 studied Grutas de Acuitlapán (Guerrero), and from 1951 to 1963, he published several articles on his excursions to caves, and finally in 1971 on the paleontology of the Cacahuamilpa region. In 1969, the Accademia Nazionale dei Lincei of Italy sponsored the first Italian speleological expedition to Mexico, conducted by Valerio Sbordoni, Roberto Argano, and Vittorio Parisi. They visited 17 caves in several states, including the Cacahuamilpa region. Descriptions were published of a large number of new troglobitic and stygobitic species.

A Master of Science thesis by Galicia-Castillo (2004) of Cacahuamilpa, Cuaxilotla, and Juxtlahuaca found the following (translation):

1. The recorded number of bat species using the caves as day shelters was 4 species (7 species total) for Cacahuamilpa, 8 species for Juxtlahuaca, and 12 species for Cuaxilotla. In Juxtlahuaca and Cuaxilotla, one of these species is *Leptonycteris yerbabuenae*, which is a migratory species and very sensitive to disturbance. In Cacahuamilpa, three other species, *Artibeus jamaicensis*, *Sturnira parvidens*, and *Glossophaga soricina*, were observed using the cave as a night shelter only.
2. Bats avoid using roost sites that are frequented by humans.
3. Even if the roost sites are off the tour, this activity contributes to reducing the diversity of bats. The diversity and abundance of guanobious organisms appear to be correlated with the diversity and abundance of bats.

4. Intensity in tourist use negatively affects the diversity and abundance of bats. The type of management given to each of the caves has a decisive influence on the degree of effect on the species present.

Galicia-Castillo's final conclusion is translated as follows: "We found a clear tendency of bats to avoid using human-frequented sites as a roost site. A negative relationship was observed between the number of visitors each cave received and the diversity and abundance of bats that were recorded. There was also a direct relationship between the diversity and abundance of bats and the diversity and abundance of microarthropods. These results suggest that human presence in caves is a factor that negatively influences bat populations, causing an imbalance in the cave ecosystem, the food chain of which is initiated from bat guano."

The cave has been open to the public with trails and lights for many years. Cacahuamilpa has some 20,000 bats of 7 species (4 day-roosting and 3 night-roosting species) and is subjected to an extremely high level of tourist disturbance, with dynamiting decades ago, electric lights, concrete throughout much of the cave, and much vandalism due to poor surveillance.

Seven bats still occur in Cacahuamilpa (Galicia-Castillo 2004): *Balantiopteryx plicata*, *Pteronotus psilotis*, *Glossophaga soricina**, *Artibeus jamaicensis**, *Sturnira parvidens**, *Mormoops megalophylla*, *Pteronotus fulvus* (* = night roost).

The ricinuleid *Pseudocellus boneti* has been cited from Acuitlapán and Cacahuamilpa, and it has been used for important contributions of ultramorphology and oogenesis. Cacahuamilpa is moderately low in biodiversity with 3 troglobites and 30 total species. We have assigned Cacahuamilpa a risk factor of 3.

Cueva Cuaxilotla, Guerrero

Cuaxilotla by far has the lowest disturbance levels of the three Guerrero bat caves discussed here. It houses over 80,000 bats of 12 species (Galicia-Castillo 2004): *Macrotus waterhousii*, *Leptonycteris yerbabuenae*, *Anoura geoffroyi*, *Glossophaga soricina*, *Natalus mexicanus*, *Pteronotus fulvus*, *P. mesoamericanus*, *P. psilotis*, *Mormoops megalophylla*, *Artibeus jamaicensis*, *Desmodus rotundus*, *Balantiopteryx plicata.* The invertebrate fauna is not well known. We have assigned a risk factor of 1.

Grutas de Juxtlahuaca, Guerrero

An important cave with ancient Olmec features, this show cave also is well known. Juxtlahuaca and Aguachil have rhagidiid mites. The amblypygid (whip spider) *Paraphrynus mexicanus* has been cited in 5 caves from Guerrero; the biggest population occurs in Juxtlahuaca. Juxtlahuaca has moderately high biodiversity with 8 bat species, 5 troglobites, and a fauna of 93 species (Table 18.1).

Eight bats are recorded from Juxtlahuaca (Galicia-Castillo 2004): *Mormoops megalophylla*, *Pteronotus mesoamericanus*, *Natalus mexicanus*, *Glossophaga soricina*, *Leptonycteris yerbabuenae*, *P. fulvus*, *Macrotus waterhousii*, *Desmodus rotundus*, with a total population of about 70,000, varying seasonally.

The large population is likely due to a good level of management and surveillance conducted by the private owners, who have protected the cave for over 50 years. It has very restricted and controlled tourism under constant surveillance, and the number of visitors is a few hundred per month versus tens of thousands per month in Cacahuamilpa (Galicia-Castillo 2004). However, the constant use of the cave has resulted in the decrease of the invertebrate fauna (Palacios-Vargas et al. 1985; Galicia-Castillo 2004). We have assigned a risk factor of 2.

18.4.3.4 Cueva Las Vegas, Puebla, Municipio Tenampulco

Also known as Cueva de las Vega, Cueva de la Vega, and Cueva El Sapo. Not in AMCS databases, no map, but listed by Arita (1992): 13 species, highly abundant; (Avila-Flores and Medellín 2004; Torres-Flores and López-Wilchis 2010). A total of 13 bat species have been reported for this cave: *Natalus mexicanus*, *Artibeus lituratus*, *A. jamaicensis*, *Carollia perspicillata*, *Desmodus rotundus*, *Diphylla ecaudata*, *Glossophaga soricina*, *Leptonycteris nivalis* (IUCN endangered), *Mormoops megalophylla* (IUCN decreasing), *Myotis keaysi*, *M. nigricans*, *M. velifer*, *Pteronotus mesoamericanus* (IUCN 2021). We have assigned a risk factor of 1, because there are no accounts of bat losses to date.

18.4.3.5 Sistema Huautla, Oaxaca

Sistema Huautla is the deepest cave in the Americas at 1560 m, and the fifth longest in Mexico at 89,000 m. The system at Huautla de Jiménez has been explored and mapped by skilled speleologists since 1966. There are six major caves: Sótano de San Agustín, Sótano del Río Iglesia, La Grieta, Sótano de Agua de Carrizo, Li Nita, and Nita Nanta (top of the system at 1760 m asl). With at least 28 entrances, the system continues to be pushed to new depths and lengths by PESH (Proyecto Espeleológico Sistema Huautla), an international organization. There are long, deep sumps at the bottom, Sump 9.

The system contains 48 species with at least 30 troglobites, a 63% troglobite component, the highest in México (Oscar Francke, pers. comm.; Table 18.1). The troglobites include amblypygids, schizomids, scorpions, opilionids, spiders, millipedes, Collembola (springtails), and silverfish. In Li Nita, a new troglobitic scorpion of the genus *Typhlochactas* was collected in 2014. At least two species of bats occur, *Desmodus rotundus*, common vampire, is not far inside one of the three Sótano del Río Iglesia entrances; and a small group of other bats is not far inside the Sótano de San Agustín entrance. Three caves were impacted by local garbage and medical waste dumping, but that has ceased and the PESH cavers have begun a clean-up campaign (Cruz-López and Francke 2019; Krejca 2016; Mendoza and Franke 2018; Steele 2019). We have assigned a risk factor of 2.

18.4.3.6 Cueva del Nacimiento del Río San Antonio, Oaxaca

This large cave is a drainage network under a ridge at 90 m asl, the source of the Río San Antonio. There are 30 species with 10 troglobites, including the blind catfish, *Rhamdia reddelli*, and the small-eyed crayfish, *Procambarus oaxacae reddelli*. At least one unidentified bat species inhabits the cave, noted from guano.

The fauna of the cave is as follows: "A rich invertebrate cave fauna is associated with the catfish. Four species of troglobitic crustaceans inhabit the cave: *Potamalpheops stygicola* Hobbs (Decapoda: Alpheidae), *Macrobrachium villalobosi* Hobbs (Decapoda: Palaemonidae), *Procambarus (Austrocambarus) oaxacae reddelli* Hobbs (Decapoda: Cambaridae), and *Speleomysis olivae* Bowman (Mysidacea: Lepidomysidae). A specimen of the alpheid shrimp *Potamalpheops stygicola* was disgorged by a catfish upon preservation. The rarity of shrimps and mysids in pools containing catfish is doubtless related to predation by the fish on the crustaceans. The cave is also inhabited by a possibly troglobitic clam, which is abundant in various parts of the cave but awaits study. The terrestrial fauna is extremely abundant and includes troglobitic trichoniscid isopods, nicoletiid *Zygentoma*, millipedes, spiders, and opilionids." Northern Oaxaca's Municipio Acatlán de Pérez Figueroa has at least three blind catfish caves (Reddell 1981; Miller 1984; Mejía-Ortiz et al. (1997); Palacios-Vargas et al. 2015; Elliott 2020). We have assigned a risk factor of 1.

18.4.3.7 Cueva Cerro Huatulco, Oaxaca

Huatulco contains 15 species of bats, the highest confirmed count among Mexican caves. It lies at 450 m asl, surrounded by patches of tropical forest with medium-sized semideciduous trees, shade coffee plantations, and grasslands. Most bats were captured for a study of bat flies (Streblidae) using mist nets placed 20 m from the cave entrance. Despite the relevance of this cave, there is no map of it. A total of 732 individuals of all bats were captured, corresponding to the families Phyllostomidae (10 spp.), Mormoopidae (4 spp.), and Natalidae (1 sp.). About 53% of the bats carried 1 or more streblid species, totaling 1317 streblid specimens belonging to 24 species and 8 genera. 15 bat species: *Artibeus jamaicensis*, *Artibeus lituratus*, *Dermanura phaeotis*, *Dermanura tolteca*, *Dermanura watsoni*, *Carollia subrufa*, *Sturnira hondurensis*, *Desmodus rotundus*, *Glossophaga soricina*, *Leptonycteris yerbabuenae*, *Natalus mexicanus*, *Mormoops megalophylla*, *Pteronotus fulvus*, *Pteronotus mesoamericanus*, and *Pteronotus psilotis* (Tlapaya-Romero et al. 2019). We have assigned a risk factor of 1.

18.4.3.8 Cueva San Francisco, Chiapas

Cueva San Francisco near La Trinitaria is 1750 m long and 288 m deep; elevation is about 1500 m asl. The cave may have the highest number of bat species among Mexican caves, but not all are documented. Also called Cueva or Grutas de Zapaluta or La Trinitaria, it was reported by Villa-R (1966) as a *Tadarida brasiliensis intermedia* roost. It was recognized by Arita (1992) as a critical cave for the conservation of Mexican cave bats at 8 species (but without a list), with very high abundance, and 2 "fragile" species. Chávez and Horváth (2009) reported 7 resident species and claimed another 9 species (but did not list them), a possible total of 16 bat species. Known bats: *Pteronotus mesoamericanus*, *Artibeus jamaicensis*, *Artibeus lituratus*, *Glossophaga comissarissi*, *Desmodus rotundus*, *Tadarida brasiliensis intermedia.* The cave also hosts many interesting guanophiles and troglobites. In 2014, the cave was badly polluted, receiving a direct discharge of raw sewage from the nearby village (Oscar F. Francke, pers. comm.) We have assigned a risk factor of 3.

18.4.3.9 Cueva de las Sardinas, Tabasco

Called Cueva de Villa Luz by many, its original name in the literature is Cueva del Azufre and/or Cueva de las Sardinas locally. At an elevation of 72 m asl, the cave is 1987 m long and 23 m deep. With a total of 173 species, Sardinas has the highest richness among Mexican caves; 3 troglomorphic species, with 8 bat species: *Balantiopteryx plicata*, *Mormoops megalophylla*, *Pteronotus fulvus*, *Pteronotus gymnonotus*, *Pteronotus mesoamericanus*, *Pteronotus psilotis*, *Desmodus rotundus*, *Myotis nigricans*. It is now famous for its large population of partially cave-adapted *Poecilia mexicana* fishes, H_2S, sulfur-fixing bacteria, and "snotites" (microbially created, soft stalactites).

Troglobites: *Robustocheles* sp. (Rhagidiidae mite), *Dugesia* sp. (planarian), and *Poecilia mexicana* (cavefish; Torres-Flores and López-Wilchis 2010; Sánchez-Hernández and Romero-Almaraz 2011; Palacios-Vargas et al. 2011a, b; Northup and Jones 2011).

"La Pesca de la Sardina" is the annual, sacred ceremony in the cave by local Zoque Indians on Palm Sunday weekend. The fish are stunned with rotenone, contained in the ground-up bark of the Barbasco vine. The toxin inhibits the use of oxygen by tissues, causing the fish to become sluggish, and to cluster along the shallow edges of the stream, where they are scooped up. In 2001, about 20 kg of cave-adapted fish were caught and consumed in local dishes. The event seems to have only minor, short-term impacts on the cave and its rich biological community. The abundant energy of the cave's ecosystem and the dynamic nature of the ecology of the cave appear to make this exploitative event sustainable (Hose 2001). We have assigned a risk factor of 2.

18.4.4 *Yucatán Peninsula*

18.4.4.1 Volcán de los Murciélagos, Campeche

Nine bat species inhabit this extensive cave located in the public reserve of Balamkú, in the area of influence of the Reserva de la Biósfera de Calakmul, part of the ecosystem called La Selva Maya. Also called the Calakmul Bat Volcano, the cave is 670 m long and 117 m deep. The entrance is a deep funnel or sinkhole, followed by a steep slope down to about 120 m below the surface, where there is collapse area and breakdown pile. Another slope down comes to a high chamber, then another slope down to the nearly level bottom of the cave, about 450 m long, ending in a slope up to the ceiling (Rojo and Gheysens 2006; Arroyo-Cabrales et al. 2011; Vargas-Contreras et al. 2011, 2012).

El Volcán had perhaps 800,000–1000,000 bats in the early 2000s (Escalona-Segura et al. 2002, 2019). Bat emergences recorded with a camcorder in 2010–2011 lasted 30–45 min, and with a thermal camera 90 min, which suggests an estimated population over 3 million bats. In an unpublished chapter, Vargas-Contreras et al. (2011) reported that, "We observed cave visitors littering the surroundings. This cave can be used for tourism following some recommendations, establishing visitors' carrying capacity, and visiting after the reproductive season."

With a total bat diversity of 9 species, including the following trophic groups: insectivorous bats: *Mormoops megalophylla*, *Pteronotus mesoamericanus*, *P. fulvus*, *P. psilotis*, *P. gymnonotus*, *Natalus mexicanus*, *Myotis keaysi* and *Nyctinomops laticaudatus.* Nectivorous bats: *Glossophaga soricina* (Vargas-Contreras pers. comm.).

The cave contains some invertebrates: *Stenophysa* aquatic snails, *Mayaweckelia cenoticola* amphipods, and *Antricola mexicanus* soft ticks. Carbon-dioxide concentrations are dangerously high at 3–5%. The cave also harbors *Histoplasma capsulatum*, the fungal agent of histoplasmosis, a lung disease (Rojo and Gheysens 2006). Only qualified and safely equipped visitors should visit the cave's interior.

A large management plan was published in 2019, analyzing multiple aspects of the ecology and agroeconomy of the cave bats and the surrounding reserve (Escalona-Segura et al. 2019). We have assigned a risk factor of 2.

18.4.4.2 Cenote Sambulá, Yucatán

Also known as Cueva Sambulá and Cueva del Rancho Sambulá, this cenote is used for recreational purposes. The entrance is circular, about 5 m in diameter and 6 m deep. A slope with concrete steps supported by pillars leads to a large chamber with a concrete floor 10 m wide. Under the steps, the passage extends for about 20 m before ending in a series of low passages. In the opposite direction, the passage extends 15 m before meeting the flooded floor, which gradually becomes deeper, from 0.8 to 2 m. There is an excavated well with an extraction pump; 12 m beyond the pool ends and there are two low passages with a height of 1 m over a stretch of

10 m. The water temperature is between 26.7 and 27 °C and pH 6.5. (Barba-Macías, Palacios-Vargas 1998).

This is a cave with moderately high biodiversity, 53 species with 5 troglobites, but no bats, although they should be present. We set the risk factor at 4 based on the disturbed condition of the cave and loss of biodiversity.

18.4.4.3 Cueva de El Pochote, Yucatán

A pig farm (Agropecuaria Yucatán) was constructed above Cueva de El Pochote, which contained a unique cave fauna, including the cavefishes *Ogilbia pearsei* and *Ophisternon infernale*. The consequences of this action have not been reported in the literature. Only five caves contain both of these fishes. The cave also contains the isopod *Creaseriella anops* and the shrimps *Creaseria morleyi* and *Typhlatya pearsei*. Cenotes provide important habitat for stygobites and other species, such as the Morelet's crocodile, and provide drinking water for endangered mammals, such as the jaguar (Hall 1936). No studies of pollution effects on cave species of the Yucatán Peninsula have been published to date (Elliott 2000). Details about the cave's fauna are lacking, but we have set the risk factor at 2.

18.4.4.4 Cenote Dzitya, Yucatán

In Mérida, some wastewater is disposed of by deep-well injection, but its fate has not been traced. Pig farms and cattle ranches are another potential source of pollution, and use of fertilizers and pesticides threatens the karst groundwater in some areas. Solid waste is often dumped at the edges of towns or into dry caves. Cenote Dzitya, near Mérida, was contaminated by a nearby pig farm, according to water chemistry and algal data (Elliott 2000). Some cenotes in the Yucatán Peninsula are being cleaned by cavers and citizens, who are removing tires and trash (Sergio Grosjean and Roberto Rojo groups). Details about the cave's fauna are lacking, but we have set the risk factor at 2.

18.4.4.5 Grutas de Balankanché, Yucatán

Balankanché is an important cultural site as well as a high-biodiversity cave, with 59 species, 13 troglobites, and a diverse bat fauna with 7 species. The cave entrance is at 28 m asl, and the cave is 1400 m long and 15 m deep, with a trail about 500 m long through the main, dry passages. It is operated as an educational show cave in an archaeological zone. It is one of the few Mexican caves with two stygobitic fishes: *Ophisternon infernale* and *Typhliasina pearsei.* The aquatic fauna includes four troglobitic crustaceans: *Caecidotea* sp., *Antromysis cenotensis*, *Typhlatya pearsei*, and *Creaseria morleyi.* The terrestrial troglobite fauna includes a squamiferid isopod (*Trichorhina pearsei*), a trichoniscid isopod (*Cylindroniscus maya*), a pseudoscorpion (*Vachonium maya*), an amblypygid (*Paraphrynus chacmool*), an oonopid spider (*Oonops coecus*), a collembolan (*Troglopodetes maya*), and a gryllid cricket (*Tohila atelomma*). The cave is noted for a large population of the ricinuleid, *Pseudocellus pearsei*.

Even though the bat colonies are not large (Reddell 1977), three bat species were initially identified by Jones, Smith, and Genoways in 1973. Later Torres-Flores and López-Wilchis (2010) reported 7 bat species: *Natalus mexicanus*, *Artibeus jamaicensis*, *Desmodus rotundus*, *Glossophaga soricina*, *Mormoops megalophylla, Myotis keaysi*, and *Pteronotus mesoamericanus*. We have assigned a risk factor of 2 for Balankanché.

18.4.4.6 Cueva (Cenote) Aerolito de Paraíso, Isla Cozumel, and Other Systems, Quintana Roo

Many extensive, submerged, freshwater, and anchialine cave systems exist on the Caribbean coast of Quintana Roo. These world-class systems are actively explored by large numbers of serious cave divers and ecotourists. The longest is Sistema Sac Actún (+ the Dos Ojos system) at 371,958 m, the longest submerged cave in the world. Sistema Ox Bel Há is second at 271,026 m, and Sistema K'oox Baal (+Tux Kupaxa system) is third at 100,431 m (Minton 2020). Few of these cave systems have been well-studied biologically, and some of them are vulnerable to groundwater pollution from nearby tourist areas. A groundwater study by Kane and Lenczewski (2016) showed that the primary contaminants were bacteria, with high amounts of total coliform and *E. coli* fecal bacteria. Nutrient levels and metals were in low concentrations, and antibiotic tests produced negative results. Cavers and local citizens have embarked on trash removal and restoration projects at cenotes, sinkhole entrances to the systems (Fig. 18.10).

Sistema Aerolito or Cueva (Cenote) Aerolito de Paraíso (18,288 m long) is an anchialine cave on the west coast of Isla Cozumel, which connects to the Caribbean Sea and contains many unusual marine species. There are at least six stygobites of marine origin: *Copidaster cavernícola*, brittlestar; *Ophionereis* n. sp., brittlestar; Order Canalipalpata, an undescribed genus and species of polychaete worm is a possible stygobite; *Macrochaeta* is a possibly stygobitic polychaete worm; *Bahadzia bozanici*, hadziid amphipod; *Yagerocaris cozumel*, alpheid "snapping" shrimp (Pisanty et al. 2010; Frontana-Uribe and Solís-Weiss 2011; Ortiz and Cházaro-Olvera 2015; Ortiz and Winfield 2015, 2016). No remipedes or isopods are documented yet, but they would be expected based on similar caves. Threats to the cenote include groundwater pollution by land development and tourist facilities. We have assigned a risk factor of 1 for Aerolito.

Fig. 18.10 Trash removal by cavers and local citizens from Cenote Chancom, Yucatán. Photo by Sergio Grosjean-Avimerhi

Table 18.4 Summary of the risk values for 62 caves documented in this chapter

Risk	Caves
1	*36*
2	*16*
3	*3*
4	*4*
5	*3*
Gutted	*2*
Total	*64*

18.5 Conclusions and Recommendations

Mexico is superlative not only in the number of caves, but in their biodiversity and the scale of ecosystem services they provide. Knowledge of the fauna in Mexico's nearly 12,000 caves has increased greatly over 200 years. The fauna is still incompletely explored, but we have enough information to recommend strong conservation policies.

In 1995, Palacios-Vargas proposed adding the cave environment to the GEEPA Act, passed by the Mexican Congress in 1988 and amended in 2021 (El Congreso de los Estados Unidos Mexicanos, 2021), Article 55 establishes sanctuaries (reserves) for "grutas, cavernas, cenotes" and other natural features, but there are no specific penalties for causing harm, and cave fauna and bats are not mentioned.

In this chapter, we have specifically documented 64 caves (including 3 mines) in tables and text, but many thousands remain to be evaluated. Table 18.4

summarizes the risk values for the 64 sites, 28 (44%) of which present clear signals of human impact. Thirty-six caves have a risk value of 1 (a normal wild cave) and 16 have a mild risk of 2. Three caves have a moderate risk value of 3: Cueva Chica, Grutas de Cacahuamilpa, and Cueva San Francisco. A risk value of 4 was assigned to Cueva de la Boca, Cenote Sambulá, Cueva de El Abra, and Cueva de El Pachón because of species losses or threats. Grutas de Quintero lost two bat species, much aquatic habitat, and is at risk 5 of further damage to the cave and its rich fauna. In Coahuila, Cueva del Cañón El Buey and Toxic Sink were severely degraded with toxic trash and were rated at risk factor 5. Cueva del Ídolo, Morelos, and Cueva de la Isla de Janitzio, Michoacán, were gutted of life and may never recover their lost fauna.

Probably hundreds of Mexican caves have been impacted by humans. A similar trend has occurred in the USA (Elliott 2000). Disruption and destruction of bat roosts is the most damaging activity, but recent activities, including unregulated tourist use of caves, have strongly affected them.

About 800 obligate cave species are endemic to Mexican caves. The largest concentrations of wild mammals in Mexico are in caves, and the largest bat cave in the Neotropical biogeographic realm, the Volcán de los Murciélagos (Calakmul Bat Volcano), contains over 3 million bats. No other cave in the Neotropics has more bats.

In the Nearctic biogeographic realm, roughly including the northern half of Mexico, many caves are essential providers of ecosystem services. McCracken (1986) estimated that in the southwestern USA there might be 120–150 million Mexican free-tailed bats from spring to autumn. Although this may be an overestimate, it is likely that the Mexican states that border the USA have between 20 and 30 million *Tadarida brasiliensis*. This is an important resource for both nations (Russell et al. 2005, López-Hoffman et al. 2017).

Our data in Table 18.3 have 23 *T. brasiliensis* caves, with 12 having an aggregate of about 5 million bats. Many others host smaller colonies. Cave exploration is still preliminary across Mexico, but with our estimate of 20–30 million just in northern Mexico, bats consuming insects at the rate of 10 tons every night per million bats, would yield an ecosystem service that is in the order of magnitude reported by Lopez-Hoffman et al. (2017), Medellín (2009), Wiederholt et al. (2013, 2015, 2017), Federico et al. (2008), and Gándara et al. (2006). The order of magnitude goes from US $578,000 per year in the vicinity of Monterrey, Nuevo León, provided by Cueva de la Boca alone (Gándara et al. 2006), which is still at risk, to US $3.7 billion for the conterminous USA (Boyles et al. 2011). Furthermore, we know that *T. brasiliensis* moves far away from its roost caves each night, but even underestimating the area covered with a radius of only 50 km, the area of influence of 7850 km^2 around each cave (Medellín et al. 2017) yields an area of about 100,000 km^2 around the known *T. brasiliensis* caves.

18.6 Conservation Guidelines

Considering the losses that already occurred in at least 28 Mexican caves and mines, we recommend the following conservation guidelines that could be implemented at different levels of government:

1. Enact and enforce national legislation for caves (cavernas, cenotes, cuevas, grutas, sótanos) on private, state, and federal lands that prohibit vandalism, trash dumping and sewage discharges into caves, destruction and degradation of caves, and disturbance and killing of cave life, except the minimum sampling necessary for scientific study.
2. Prohibit mining of resources in all natural caves except under federal permits that ensure no disruption or harm to bats and other fauna, and only sustainable extraction of bat guano.
3. Prohibit disturbance, harassment, and killing of bats in caves and abandoned mines, which often contain bats beneficial to agriculture, except for precise, selective control of the Common Vampire Bat, *Desmodus rotundus.*
4. Establish a university institute to map and document Mexico's caves, abandoned mines, cave life, and cave-related geology, hydrology, and cultural resources, and to educate the public about the value of cave resources. The institute should work cooperatively with existing Mexican and international speleological groups, INEGI (Instituto Nacional de Estadística y Geografía), and other resource agencies. A repository of data and literature is needed, with a central, secure database. A geographic information system should be maintained in cooperation with existing speleological groups and INEGI.
5. Precise cave locations must be protected from general public view to avoid overuse or exploitation of caves by vandals. Protection of cave location data applies to the central cave database, INEGI, and other mapping agencies. Registered contributors and individuals with a valid need to know would be able to borrow limited cave location data for exploration, science, and conservation. Limited data may be available to those proposing possibly sustainable use of caves, which must be detailed in a written proposal. Data users would be encouraged to share new and corrected cave locations and data with the central database.
6. It is important to allow reasonable cave access to qualified explorers, scientists, conservationists, and cultural experts provided that they conform to conservation rules and laws for the caves and abandoned mines, and that they provide reports and data to the central database.
7. A new Federal initiative should create natural reserves (reservas naturales) to protect caves of all types, karst, volcanic caves, associated groundwater, and abandoned mines. Federal, state, and private funding should be sought for cave and bat conservation projects at all levels. Restoration of natural caves should be promoted. Traineeships should be offered at resource agencies to foster a new generation of cave and bat conservationists.

8. Steel cave gates should be built according to the best practices of the American Cave Conservation Association and their partners; see Elliott (2006, 2011) and Hildreth-Werker and Werker (2006). Cave gates are needed for a few caves and abandoned mines to prevent intruders from entering, but construction must be followed by a program of surveillance, inspection, and repair, as most gates are eventually broken or defeated by vandals.
9. Resource and mapping agencies should be included in these efforts and are encouraged to create new positions for cave specialists, biologists, and conservationists. Research and support projects dealing with cave life must be promoted and financially supported.
10. The operators of tourist (show) caves should write environmental plans to prevent, mitigate, or restore damage to their caves and fauna. The operators should set the maximum number of visitors and the proper season for use, especially when bats are present.

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