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New data on the distribution and echolocation calls of Big Naked-backed Bat, *Pteronotus gymnonotus* (Wagner, 1843) (Chiroptera, Mormoopidae): northernmost records in Mexico

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Abstract. *Pteronotus gymnonotus* (Wagner, 1843) has its northernmost distribution records in southeastern Mexico, where it is classified as an endangered species. In this report we communicate two northernmost extralimital acoustic records of the species in the state of Veracruz, obtained in 2018 and 2022. The average constant frequency of echolocation calls of *P. gymnonotus* was 56.5 kHz in Boca Andrea and 53.88 kHz in Buena Vista. Acoustic detection surveys of the conspicuous echolocation calls of the species would help much in the detection of the species in roosts and foraging habitats.

Keywords. Acoustic surveys, cave-dwelling bats, endangered populations, insectivorous bats, threatened species

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Introduction

Big Naked-backed Bat, *Pteronotus gymnonotus* (Wagner, 1843), is a Neotropical, cave-roosting bat (Pavan and Tavares 2020). South of the Amazon, it is present in a latitudinally narrow band parallel to the southern margin of the Amazon basin. North of the Amazon, it is present from the northern margin of the Amazon basin through the Guianas region and the fringes of the evergreen forest on the southern Orinoco plains to the southeastern foothills of the western Andes and the surroundings of the Gulf of Maracaibo in Venezuela, the Caribbean coast of Colombia, and all of Central America (from Panama to southern Belize and Guatemala), and southeastern Mexico (Smith 1972; Hall 1981; Simmons 2005; Gardner 2008; Pavan and Tavares 2020).

Until recently, *P. gymnonotus* was known in Mexico only from a few records of single individuals: one from a historical locality in the Sierra de Los Tuxtlas (state of Veracruz) (Davis et al. 1964), which was the northernmost area of its known range; another from Yaxchilán, Chiapas (Alvarez-Castañeda and Alvarez 1991); and another from southern Tabasco (Ibáñez et al. 2000). An additional record of an individual in the state of Campeche (Guzmán-Soriano et al. 2013) has not been included yet in the distribution maps published to date (Rojas et al. 2018; Solari 2019; Wilson and Mittermeier 2019; Pavan and Tavares 2020) (Fig. 1). Recently, López-Wilchis et al. (2021) reported the capture of two males that were exiting from a cave near the village of Matías Romero Avendaño in the state of Oaxaca, considerably extending to the west the geographic range of this species (Fig. 1). An individual captured in Tehuantepec, Oaxaca, and described by (Goodwin 1958) as belonging to a new subspecies of *P. gymnonotus* (then known as *P. suapurensis calvus*) was later identified as *P. fulvus* (Smith 1972).

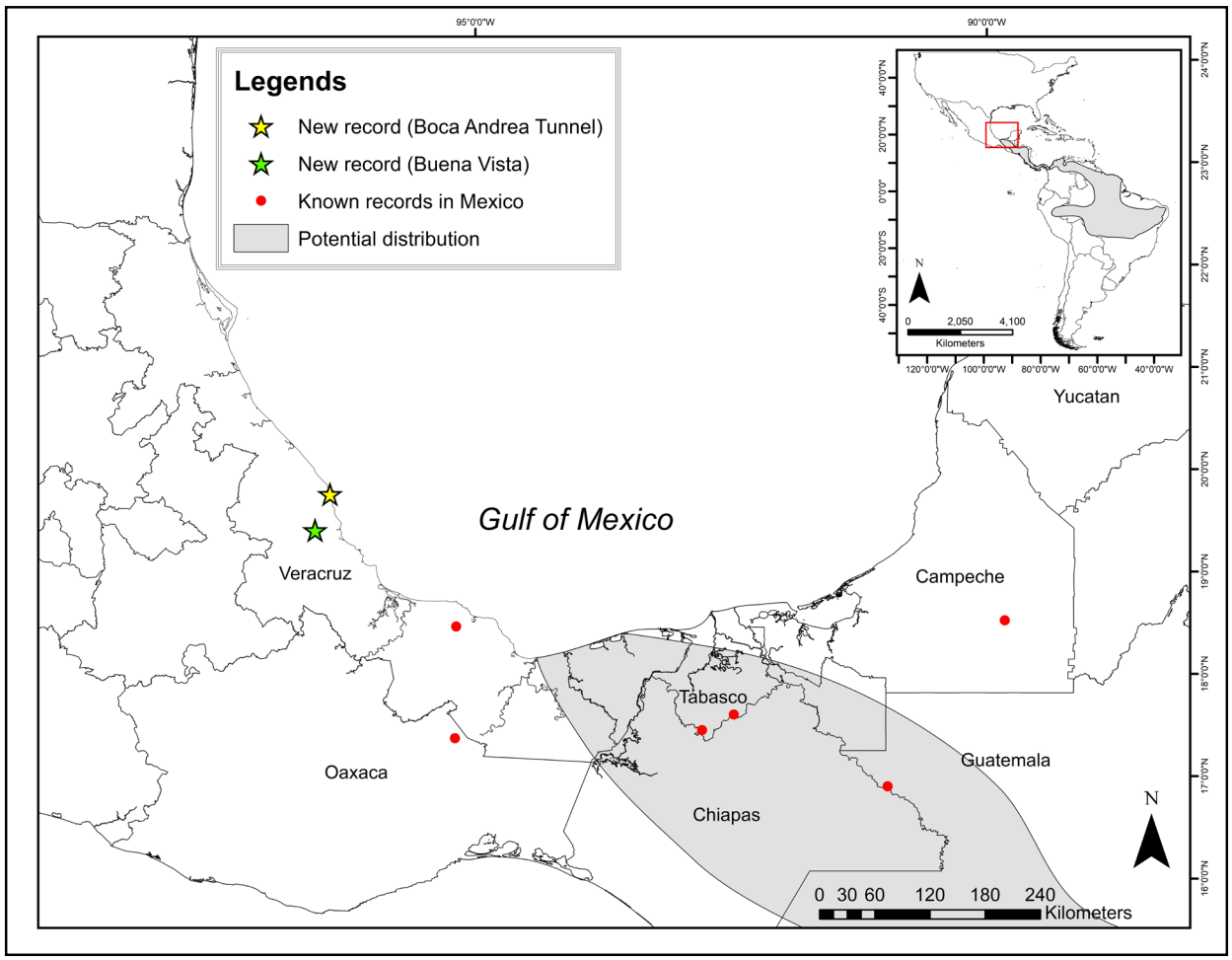

Figure 1. *Pteronotus gymnonotus.* New records locations, known records of occurrence and potential distribution. Grey area shows potential distribution according to Pavan and Tavares (2020).

Probably due to the paucity of records the species is listed under the category "Amenazada" (Threatened) in the current Mexican Official Norm NOM-059 on the Environmental Protection of the Native Wildlife (SEMARNAT 2010). To our knowledge, only two breeding colonies of *P. gymnonotus* are known at present in Mexico, one in the municipality of Macuspana (17°36′N, 092°28′W; Guillén-Servent and Ávila-Flores 2022) and another in the municipality of Tepijulapa (17°26′N, 092°46′W; López-Wilchis et al. 2021; Galindo-González and Guillén-Servent 2022), both in the southern state of Tabasco.

In this report we include two extralimital acoustic records from the center of the state of Veracruz, which constitute the new northernmost known localities of the species.

Methods

Study area and sampling. The acoustic records of *Pteronotus gymnonotus* were obtained at two localities in the state of Veracruz during other ecological studies. In October 2018, we recorded the echolocation sounds broadcasted by bats emerging from an underground tunnel near the town of Boca Andrea, Alto Lucero (Veracruz, Mexico; Fig. 1). The tunnel was excavated for a railway line, whose construction was aborted before completion, and, therefore, it has been abandoned for decades. The tunnel entrance is surrounded by remnants of palm forest and seasonally dry tropical deciduous forest, areas of cultivated grassland, pastures, and secondary forest. In February 2022, the echolocation sounds emitted by insectivorous bats were recorded in the area of Buena Vista, Emiliano Zapata (Veracruz, Mexico; Fig. 1). The site is in the valley of the Paso de la Milpa River, where original tropical deciduous forest vegetation remains on the slopes and the upper plateau. Narrow strips of subdeciduous tropical forest and riparian vegetation follow riverbanks, ravines, and creeks that running down the slopes from the plateau (INEGI 2016). The flat bottom of the valley is mostly occupied by pastures, fruit orchards, vegetable gardens, and herbaceous crops, although some patches of secondary and riparian vegetation remain (INEGI 2016). The valley is excavated on calcareous bedrock in which karstic activity has created abundant underground cavities with mouths often opening on the slopes. These caves are roosts of abundant colonies of cave-dwelling bats of the families Emballonuridae, Mormoopidae, Phyllostomidae, and Natalidae. For the taxonomy of the taxa mentioned in this note, we follow the latest version of the Integrated Taxonomic Information System (ITIS 2023).

Ultrasound recordings. In the Boca Andrea Tunnel, recordings were continuously made from the beginning of the emergence of the bats near sunset until three hours later using a Batlogger-M ultrasound detector (Elekon AG). The microphone was positioned laterally and about 8 m away from the central axis of the column of emerging bats. In Buena Vista, the recordings were made continuously from sunset to sunrise, with an AudioMoth v. 2.1 passive sound recorder (Hill et al. 2019). The recorder was placed 6 m above ground on a metal post to avoid echoes from the ground, at the edge of a patch of trees, with the microphone oriented horizontally towards an open area of grassland. This sampling point was part of a network of 129 recording points distributed in the area for monitoring the activity of insectivorous bats in the habitats. The detectors were programmed to sequentially record sound files in a waveform audio format (WAV), with a sampling rate of 312.5 kHz and a duration of 20 s for the first detector, and with a rate of 384 kHz and a duration of 10 s for the second detector.

Ultrasonic analysis. The recordings obtained were visually examined over the sonographic representation built using the BatSound Pro program v. 4.2 (Pettersson Electronick AB), with Fast Fourier Transformations (FFT) over "Hanning" Windows 512 points long and 97% overlap. The starting (FINI) and ending (FFIN) frequencies of the frequency modulated (FM) segment, and the duration of calls, were measured by manually positioning the frequency and time cursors over that sonographic display. Frequency of the constant element (CF) was measured on an accumulated Power Spectrum calculated over the total length of each call using "Hanning" windows 512 points long. The sounds belonging to *P. gymnonotus* were identified by comparison with the reference recordings obtained from released individuals in Cueva de Agua Blanca (Guillén-Servent unpubl. data, February 2005, August and September 2007) and Cueva de las Sardinas, Tabasco, Mexico (Guillén-Servent unpubl. data, May 2009), and based on the distinctive characteristics of frequency and temporal modulation, which allowed us to distinguish their sonograms from all other sympatric species (Griffin and Novick 1955; O'Farrell and Miller 1997; Smotherman and Guillén-Servent 2008; Mondragón-Cerón 2019).

Results

Pteronotus gymnonotus (Wagner, 1843)

New records. MEXICO – **Veracruz** • Alto Lucero, Boca Andrea; 19°45′N, 096°25′W; 31 m alt.; 12.X.2018; K.P Borges-Jesús and A. Guillén-Servent obs.; remnant palm groves and low deciduous forest, acoustic detector; WAV archive 16490620 • Emiliano Zapata, Buena Vista; 19°24′N, 096°34′W; 159 m alt.; 22.II.2022; K.P Borges-Jesús and A. Guillén-Servent obs.; pasture surrounded by mango crops and secondary outgrowth, acoustic detector; WAV archive AM19_20220222_185722.

Identification. The echolocation pulses of *Pteronotus gymnonotus* generally started with a very short (<1 ms) ascending frequency modulated (FM) element, followed by a central CF element of intermediate duration (~2–4 ms), and a final FM element with an asymptotically downward modulation of the frequency (Fig. 2). In recordings of emerging bats from the Boca Andrea Tunnel, we identified abundant echolocation calls from *Pteronotus fulvus* (Thomas, 1892), *P. psilotis* (Dobson, 1878), *P. mesoamericanus* Smith, 1972, *Mormoops megalophylla* (Peters, 1864), and a single call sequence from *P. gymnonotus*. This sequence was recorded at 19:27 GMT-5, 22.27 min after astronomical sunset. The sequence contained a total of nine pulses, which showed a very similar structure to that reported for the species mentioned in literature, with the initial frequency being 55.7 ± 0.60 kHz, that of the CF element being 56.5 ± 0.64 kHz, and the final frequency of the FM element being 45.8 ± 0.50 kHz. The average duration of the pulses was 4.54 ± 0.50 ms (Fig. 2).

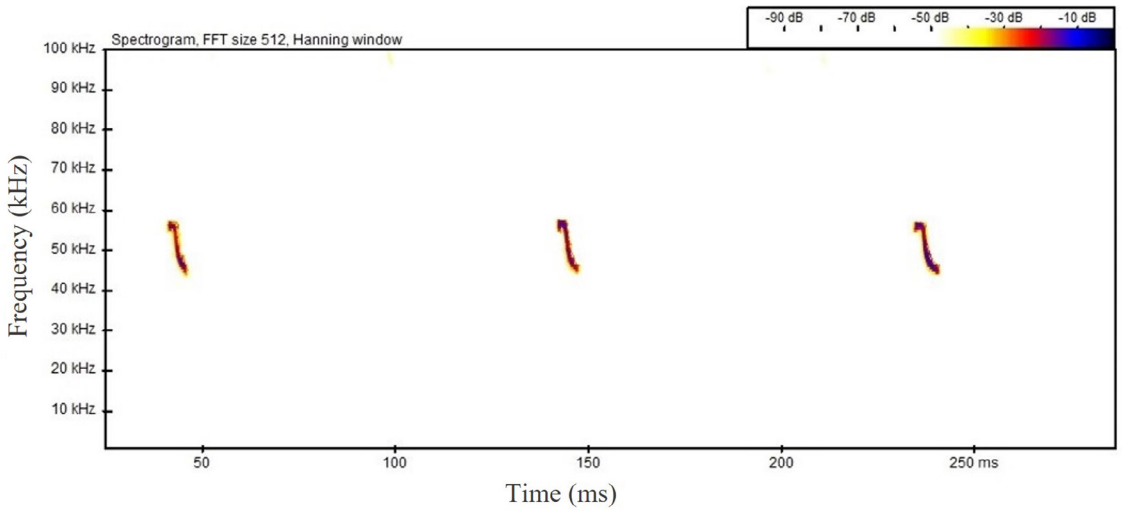

Figure 2. Sonogram of *Pteronotus gymnonotus* showing sequences of echolocation pulses recorded in the Boca Andrea Tunnel (Veracruz, Mexico).

In the Buena Vista recordings, we identified numerous sequences of echolocation calls from *P. fulvus*, and a single sequence from *P. gymnonotus*. This sequence was recorded at 18:57 GTM-5, 29.38 min after astronomical sunset. The sequence contained a total of 12 pulses, with the initial frequency being 52.98 ± 0.51 kHz, that of the CF element being 53.88 ± 0.49 kHz, and the final frequency of the FM element being 44.76 ± 0.18 kHz. The average duration of the pulses was 4.61 ± 0.41 ms.

Discussion

Records of *Pteronotus gymnonotus* are very scarce in Mexico, and most are limited to observations of isolated individuals, which has led some authors to consider the species to be of accidental occurrence in the country (Ibáñez et al. 2000). *Pteronotus gymnonotus* has a distribution generally associated with the margins of lowland humid tropical forests. However, the presence of this species in the dry forests of the Colombian Caribbean (Gardner 2008) suggests that temperature seasonality may influence its northern limit of distribution more than humidity or rainfall. All the previous records of this species in Mexico are from the margins of tropical rainforest areas. This type of vegetation has a limited potential distribution in Mexico, where it is almost restricted to the Gulf watershed, from southern San Luis Potosí to the coastal plains of Veracruz, Tabasco, and southern Yucatan Peninsula (Rzedowski 2006). Thus, it is expected that the natural distribution of *P. gymnonotus* in Mexico is less extensive than that of the other mormoopid bats present in the country (i.e., *P. mesoamericanus*, *P. fulvus*, *P. psilotis*, and *Mormoops megalophylla*).

The echolocation calls of species belonging to the family Mormoopidae are distinctive and easily recognizable, making their acoustic identification generally unambiguous (O'Farrell and Miller 1999; Macías et al. 2006). Like those of all mormoopid bats, the echolocation calls of *P. gymnonotus* are multiharmonic, with the second harmonic concentrating most of the energy, a weaker first harmonic or fundamental, and an even weaker, but still usually detectable third harmonic. In very intense calls captured at a short distance from the microphone, much weaker fourth and even fifth harmonics can be detected (Griffin and Novick 1955), but in echolocation calls recorded at lower intensity and with other bats present in the background (as in emergences from multispecies roost) often only the most intense second harmonic is detected (Smotherman and Guillén-Servent 2008).

The highest frequency (equivalent to the CF) of the most intense second harmonic of the echolocation calls of *P. gymnonotus* has been reported as averaging 60.0–61.3 kHz in populations from several localities in Brazil (Falcão and Pavan 2023). A peak frequency of 55 kHz was reported from Panamá (Surlykke and Kalko 2008) and of 54.8 kHz from French Guiana (Bataraud et al. 2013). Ibáñez et al. (2000) reported a CF of 55.2 kHz from a single individual recorded in Tabasco, southern Mexico. In the northernmost records (19°N) reported here, the CF ranges from 56.5 to 53.9 kHz. The scarcity of acoustic records makes it impossible to properly describe the putative geographical variation of the echolocation calls of *P. gymnonotus*, but it would seem that the southern populations broadcast calls at higher frequencies.

The Boca Andrea Tunnel was visited on several occasions before and after October 2018 without *P. gymnonotus* being detected. Other cave-dwelling localities in the region have been frequently sampled using the same methodology, without the detection of the species either (Borges-Jesús 2020). Calls of the species were not detected in any of the other ultrasound sampling units deployed in the different habitats in the Buena Vista area in two seasons (70 sensors in July 2021 and 129 sensors in February 2022). The paucity of records and the timing of the detections reported here, which were out of the reproductive season, suggest that the presence of the species in the region is occasional and probably corresponds to individuals dispersing from populations to the south. The climate of the region is remarkably seasonal in terms of temperature and precipitation, and its vegetation is dominated by seasonally very dry tropical deciduous forest (Moreno-Casasola 2006), which suggests that suitable habitats for this bat are not abundant in the area. In addition, the ecological niche models infer that the potential distribution of the species reaches its northern limit in Los Tuxtlas region, suggesting the absence of suitable habitat for the species further north (Rojas et al. 2018; CONABIO 2020) (Fig. 1). The closest locality where the species has been recorded is Cueva Laguna Encantada, located about 225 km further south in Los Tuxtlas Biosphere Reserve, but the record was a single male individual captured in December 1962 (Davis et al. 1964). The species has not been detected in other visits to this locality by several workers (Villa-Ramírez 1966; Guillén-Servent pers. obs., May 2015; López-Wilchis et al. 2021), which suggests that the species was rare and that it may have disappeared from the area. The reproductive colonies in the state of Tabasco are more than 500 km to the south (López-Wilchis et al. 2021; Galindo-González and Guillén-Servent 2022; Guillén-Servent and Ávila-Flores 2022), which makes it improbable that the bats detected in central Veracruz dispersed from these localities. The apparently occasional presence of the species in central Veracruz presented in this report suggests the existence of other populations of *P. gymnonotus* in humid tropical areas of the southern Gulf of Mexico, in the foothills of the Atlantic slope of Sierra Madre del Sur in Veracruz and Oaxaca, further north of the town of Matías Romero Avendaño where the species was recently reported (López-Wilchis et al. 2021), and near enough to allow dispersal this far north.

There is still scarce information on *P. gymnonotus* in Mexico and an absence of studies on its distribution and abundance. The geographical and ecologically

marginal location of the Mexican populations in the geographic distribution of this species, and the association of this species with an ecosystem of limited extent and a very high rate of deforestation in Mexico (Díaz-Gallegos et al. 2010), leads us to suspect the existence of threats to the persistence of *P. gymnonotus* in the country. Achieving adequate knowledge of the distribution and the status of the populations of *P. gymnonotus* in Mexico requires a dedicated and focused monitoring effort in the areas of southeastern Mexico, where distribution models indicate that there are suitable habitats for this species, and where the geological information indicates the possible existence of underground cavities that it can use as roosts. Given the specificity of the species' echolocation calls and its good detectability, acoustic detection surveys may be the most efficient tool to find its presence in foraging habitats and roosts that are home to important colonies.

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Authors' Contributions

Conceptualization: KPBJ, AGS, VJS. Acoustic data analysis: KPBJ. Funding acquisition: KPBJ. Resources: AGS, VJS. Writing – original draft: KPBJ, AGS. Writing – review and editing: KPBJ, AGS, VJS.

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