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Acoustic records of *Promops centralis* (Thomas, 1915) (Chiroptera, Molossidae) in corn agroecosystems of northwestern Mexico

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Abstract
The Big Crested Mastiff Bat, *Promops centralis* (Thomas, 1915), is widely distributed from Mexico to South America but has yet to be reported in the state of Sinaloa, Mexico. We collected 122 acoustic recordings of *P. centralis* from tropical dry forest and agroecosystems in Sinaloa and Sonora for two years (2015 and 2016). We documented a new record for *P. centralis* outside the known distribution area in northwestern Mexico. Our results reveal that the current *P. centralis* distribution needs to be reevaluated.

Keywords
Acoustic monitoring, Big Crested Mastiff Bat, Sinaloa, tropical dry forest.

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Introduction

The convergence of the Neotropical and Nearctic biogeographic regions in the state of Sinaloa, northwestern Mexico, is an important transitional zone for species distributions (Álvarez-Castañeda 2002; Sarukhán et al. 2009). This zone is reported as the most northern distribution limit of several bat (Chiroptera) species (Ceballos and Oliva 2005; Simmons 2005; Medellín et al. 2008). To date, 52 species of bats have been recorded in Sinaloa, of which 16% belong to the family Molossidae (Álvarez-Castañeda 2002; Hortelano-Moncada et al. 2016). This family is represented by insectivore bats that generally forage above the tree canopy in open spaces (Mora et al. 2004; Kalko et al. 2008; Jung et al. 2014: Arias-Aguilar et al. 2018). This flight behavior makes capture and documentation difficult using conventional bat surveying methods (mist nets and harp traps) and has potentially led to biased and incomplete knowledge of the actual distribution of many bat species (Peters et al. 2002; Berry et al. 2004).

The distribution of Big Crested Mastiff Bat, *Promops centralis* (Thomas, 1915) (Molossidae), ranges from Mexico to northern Argentina (Watkins et al. 1972; Birney et

al. 1974; Eisenberg 1989; Hall 1981; Urbano-Vidales et al. 1987; Sánchez-Cordero et al. 1993; Rojas-Martínez and Valiente-Banuet 1996; Arita 1997; Simmons and Voss 1998; Vidal and Martínez 2000; Simmons 2005; Ceballos et al. 2006; Eger 2008; Medellín et al. 2008; Sánchez and Magaña-Cota 2008; Pacheco et al. 2009; González and Arroyo-Cabrales 2013; González-Terrazas et al. 2016; Solari 2019). Despite its widespread distribution, *P. centralis* feeding and habitat preferences, flight patterns and roosting behavior are poorly understood making this species difficult to record (Hintze et al. 2019). There are few records of *P. centralis* and is considered an uncommon species (Ceballos and Miranda 2000).

Promops centralis is found in a variety of ecosystems including tropical rainforest, tropical dry forest, thorn forest, oak-pine forest (Téllez-Girón et al. 1997), agricultural landscapes (González-Terrazas et al. 2016), and urban areas (Jung and Kalko 2011), and is found in an elevational range from sea level to 1,800 m (Téllez-Girón 2005). Presently, the distribution of *P. centralis* in Mexico ranges from Jalisco along the Pacific coast, Veracruz in the Gulf of Mexico region, to the central and southeastern regions of the country, as well as the Yucatan Peninsula (Watkins et al. 1972; Rojas-Martínez and Valiente-Banuet 1996; Vidal and Martínez 2000; Alavez Tadeo et al. 2017). Notably, *P. centralis* has not been reported in the state of Sinaloa (located in northwest Mexico, adjoining with Sonora to the north, Chihuahua and Durango to the east and Nayarit to the south), although, it has been recorded at 1,300 km in the northern neighboring state of Sonora (González-Terrazas et al. 2016).

Despite biological diversity has been described for more than a century in the state of Sinaloa (Hortelano-Moncada et al. 2016) bat studies are scarce. Conventional survey methods and types of surveyed areas are mostly likely the contributing factors that limit the existence of bat species records. Acoustic monitoring, the use of sound recorder devices to register bat calls, along with conventional survey methods is becoming a regular practice in bat field biology. Acoustic monitoring permits species records of *P. centralis* and other difficult to study bat species, specifically insectivorous taxa that exhibit flight patterns not compatible with capture in mist nests or harp traps (O'Farrell et al. 1999; Jung and Kalko 2010, 2011; Jung et al. 2014; González-Terrazas et al. 2016; Dias-Silva et al. 2018).

We conducted our acoustic monitoring in combination with mist netting methods of the insectivorous bat community in corn plantations and in tropical dry forest (TDF) in Sinaloa and southern Sonora; according to González-Terrazas et al. (2016) recent record of the *P. centralis* can include these sites in its distribution. In this region, corn crops are reported as highly susceptible to insect pests (Hernández Juárez et al. 2016) and we hypothesize them might be attractive sites for *P. centralis* (Maine and Boyles 2015), as well as the tropical dry forest (Cué-Bär et al. 2006).

Methods

Study area. Bat surveys were conducted in corn plantations and tropical dry forest in February–October 2015 and August 2016. We studied nine sites with different types of corn plantations, irrigated year-round plantations and non-irrigated seasonal plantations. The irrigated sites were located in northern and central Sinaloa along the south side of the Fuerte River and in the Culiacán agricultural valley. The non-irrigated seasonal corn fields were located in the municipalities of Ahome and El Fuerte. The sites of the irrigated corn plantations were originally TDF. Nowadays water resources are more abundant, and the natural vegetation is limited to the barriers between irrigated channels and plots. In contrast, the seasonal corn plantations which are found in small open fragments on uneven terrain within the TDF landscape.

The surveys within TDF were conducted in three sites: Goode's thornscrub tortoise reserve (San Pablo property) in Reserva Monte Mojino, located in southeast Sonora; the Universidad Autónoma de Sinaloa protected area Nuestra Señora Mundo Natural (RENSMN), located in the central-eastern part of Sinaloa; and in the protected area of Meseta de Cacaxtla, along the southern coast of Sinaloa (Fig. 1). In northwestern Mexico, the TDF plant community is dominated by short trees and 70% of the vegetation is deciduous in the dry season. TDF extends from the coastal line to the foothills, where the conditions are warm, and semi dry with seasonal rainfall (Rzedowski 2006; Rzedowski and Calderón de Rzedowski 2013). TDF in southern Sonora site is characterized by riparian vegetation dominated by Sabine trees and has abundant water resources, whereas, TDF in the central part of Sinaloa is homogeneous in arboreal species composition and water resources are scarce. The TDF in the southern coastal site transitions from thornscrub, to mangroves and eventually to a sandy and rocky coastline.

Acoustic sampling. Insectivorous bat species were surveyed in all the sites at least once. We used mist-nets to survey and a passive ultrasound bat detector (SM2Bat+ detector, Wildlife Acoustics) to perform the acoustic recordings one night per site. The detectors were installed at 3 m height and at a 45° inclining angle in relation to the ground. Both methodologies began at 19:00 hours just before sunset (Table 1). The mist-net survey lasted for five hours and the bat detector devices recorded a total of eight hours.

Acoustic analysis. The bat detector device records sounds in "WAV" format which are analyzed using the specialized software SonoBat (v. 4.0.5) and Batsound Pro (v. 3.31 a). The intense and low frequency calls of Molossids are easily recorded, however we use a 192 kHz sampling rate. We proceed to analyze the calls manually, using the next call parameters measurements to characterize bat calls: 1000 ms by Window, 1024 FFT (fast Fourier transform)

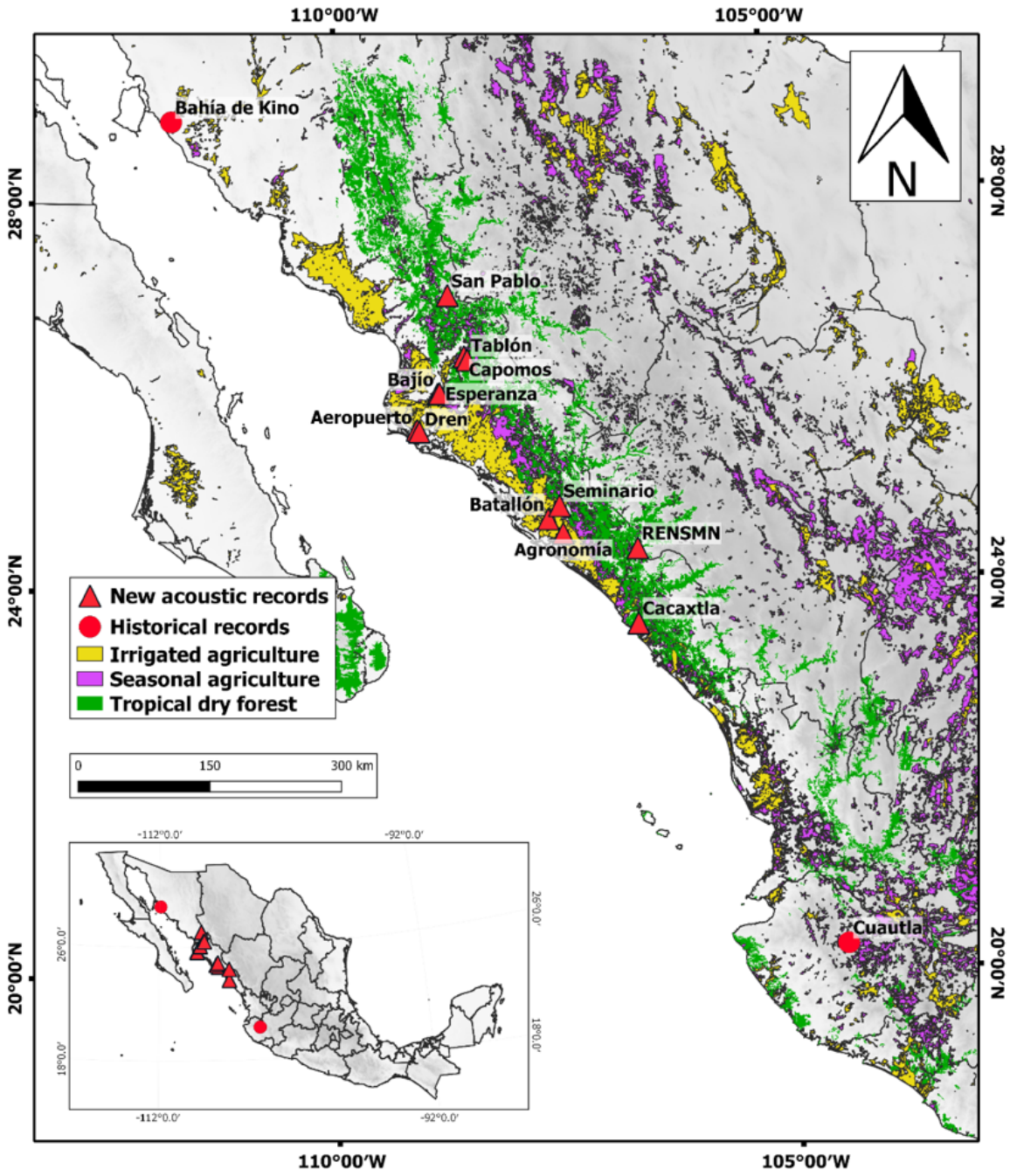

Figure 1. Habitat type of *Promops centralis* records in northwestern Mexico. The red triangles indicate the new records, and the red circle indicates the last known record from the Mexican Pacific slope including the most recent record from Sonora.

Size, Hamming FFT Window, 95 FFT Overlap. The measured variables were: start frequency (Fini, in kHz), final frequency (Ffin, in kHz), peak frequency (Fpeak, in kHz), high frequency (in kHz), low frequency (in kHz), mean frequency (in kHz), constant frequency (in kHz) and call duration (Dur, in ms), and interval between pulses (Inter, in ms), calculating the mean and standard deviation using the *jamovi* software v. 1.1 (The jamovi project 2019). As *Promops centralis* calls are highly characteristics, we use lower calls, where the start frequency is lower than the final frequency, to characterize them. As bat activity we considered minimum three calls as a sequence that shows a constant interval between each pulse (Fenton et al. 2004). The species identification consists in a comparison of our results, using the information and data available from Jung and Kalko (2011), Barataud et al. (2013), Jung et al. (2014), and González-Terrazas et al. (2016).

Results

We obtained 9,277 echolocation records from four families (Emballonuridae, Mormoopidae, Molossidae, and Vespertilionidae). We identified and analyzed 122 passes that contain 1,880 echolocation (searching) calls of the *Promops centralis*. The *P. centralis* search calls include ascendant and descendant structures which are formed by quasi-constant frequency (QCF) and modulated frequency (MF). The main diagnostic characteristic of this

Table 1. List of Sinaloa (Aeropuerto, Agronomía, Bajío, Capomos, Dren, Batallón, Esperanza, Cacaxtla, RENSM, Seminario and Tablón) and Sonora (Álamos) localities, dates, and habitat type of *Promops centralis* records.

Site	Date (dd/mm/yyyy)	Latitude	Longitude	Habitat
Sinaloa				
Aeropuerto	06/03/2016	25°40′12″N	109°04′18″W	Irrigated corn
Agronomía	06/02/2015	24°37′29″N	107°26′25″W	Irrigated corn
	23/02/2015	24°37′29″N	107°26′25″W	Irrigated corn
	06/03/2015.	24°37′29″N	107°26′25″W	Irrigated corn
Bajío	05/09/2015	26°02′17″N	108°49′59″W	Non -irrigated Seasonal corn
Batallón	21/02/2015	24°43′39″N	107°36′23″W	Irrigated corn
	08/03/2015	24°43′39″N	107°36′23″W	Irrigated corn
Cacaxtla	15/02/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
Capomos	20/09/2015	26°25′15″N	108°31′29″W	Non -irrigated Seasonal corn
Dren	22/032016	25°39′00″N	109°02′49″W	Irrigated corn
Esperanza	21/02/2016	26°02′36″N	108°48′34″W	Irrigated corn
RENSMN	14/02/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	27/02/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	28/03/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	24/06/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	31/07/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	30/09/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	05/09/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	31/07/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	01/10/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
	31/08/2015	24°24′15″N	106°36′31″W	Tropical Dry Forest
Seminario	22/02/2015	24°51′52″N	107°28′47″W	Irrigated corn
	07/03/2015	24°51′52″N	107°28′47″W	Irrigated corn
	20/03/2015	24°51′52″N	107°28′47″W	Irrigated corn
Tablón	17/10/2015	26°23′35″N	108°29′18″W	Non -irrigated Seasonal corn
Sonora				
Álamos	09/08/2016	27°03′15″N	108°42′06″W	Tropical Dry Forest

call is that the start frequency is lower than the final frequency (Table 2).

We report *P. centralis* records in 12 localities in northwestern Mexico in both corn plantations and TDF in the northern and central regions of Sinaloa and in the southern part of Sonora. The species records from the corn agricultural landscapes in northern and central Sinaloa were from nine locations within the three study sites; Aeropuerto, Dren, and Esperanza, located along the southern part of the Fuerte River in Ahome municipality; Bajio, Capomos, and Tablón located in the municipality of El Fuerte; lastly, Agronomía, El Batallón, and Seminario located in the Culiacán-Navolato agricultural valley. The TDF locations which report records of the species were from RENSMN and Cacaxtla in Sinaloa and Álamos in Sonora. We did not capture specimens in any of our mist netting efforts.

New records. MEXICO • 1 acoustic recording; Sinaloa, Ahome, Aeropuerto; 25°40′12″N, 109°04′18″W; 4 m a.s.l; 03 Mar. 2016; Alfredo Leal-Sandoval leg.; irrigated corn agroecosystem, ultrasound detector; AEROP_20160306_195534. • 1 acoustic recording; Sinaloa, Ahome, Dren; 25°39′00″N, 109°02′49″W; 6 m a.s.l; 22 March 2016; Alfredo Leal-Sandoval leg.; irrigated corn agroecosystem, ultrasound detector; WAV file: DREN_20160322_212742. • 3 acoustic recordings; Sinaloa, Ahome, Esperanza, 26°02′36″N, 108°48′34″W; 24 m a.s.l; 02 Feb. 2016; 18:51.40, 19:10.33, 20:06.57; Alfredo Leal-Sandoval leg.; irrigated corn agroecosystem, ultrasound detector; WAV files: ESPERANZA_20160221_185140, _20160221_191033, _20160221_200657. • 18 acoustic recordings; Sinaloa, El Fuerte, Bajio; 26°02′17″N, 108°49′59″W; 76 m a.s.l; 05 Sept. 2015; Alfredo Leal-Sandoval leg.; seasonal corn agroecosystem; ultrasound detector; WAV files: BAJIO-AGO_20150905_201231, _20150905_213252, _20150905_213320, _20150905_220502, _20150905_220604, _20150905_220630, _20150905_220727, _20150905_223019, _20150905_223040, _20150906_001442, _20150906_001530, _20150906_001558. _20150906_004132, _20150906_005409, _20150906_015919, _20150906_020003, _20150906_020105, _20150906_030913. • 1 acoustic recording; Sinaloa, El Fuerte, Capomos; 26°25′15″N, 108°31′29″W; 150 m

Table 2. Ascendant searching call parameters of *Promops centralis*. (Dur., duration; Inter, interval; Frmax, maximum frequency; Fmin, minimum frequency; Fpeak, peak frequency)

	Searching calls (n = 1880)				
	Dur (ms)	Inter (ms)	Frmax (kHZ)	Fmin (kHz)	Fpeak (kHz)
Mean	12	346	27.1	24.8	25.2
Standard deviation	8.3	101	4.07	3.3	0.534

a.s.l; 20 Sept. 2015; 01:38.06; Alfredo Leal-Sandoval leg.; seasonal corn agroecosystem; ultrasound detector; WAV file: RAFAE-SEP_20150920_013806. • 1 acoustic recording; Sinaloa, El Fuerte, Tablón; 26°23′35″N, 108°29′18″W; 150 m a.s.l; 17 Oct. 2015; Alfredo Leal-Sandoval leg.; seasonal corn agroecosystem; ultrasound detector; WAV file: TABLON_20151017_015001. • 17 acoustic recordings; Sinaloa, Culiacán, Agronomía; 24°37′29″N, 107°26′25″W; 20 m a.s.l; 02, 23 Feb., 06 Mar. 2015; Alfredo Leal-Sandoval leg.; native corn experimental crop, surrounded by irrigated agriculture, ultrasound detector; WAV files: P1_20150206_181732, _20150206_183621, _20150206_183652, _20150206_183707, _20150206_183716, _20150206_183941, _20150206_183944. AGONOMIA_20150223_ 184414, _20150223_194404, _20150223_202108, _20150223_203524, AGRO2_20150306_ 202912, 20150306_203256, _20150306_203355, AGRO2_20150306_203506, _20150306_203515, _20150306_203525. • 4 acoustic recordings; Sinaloa, Navolato, Batallón; 24°43′39″N; 107°36′23″W; 31 m a.s.l; 21 Feb., 08 Mar. 2015; Alfredo Leal-Sandoval leg.; irrigated corn agroecosystem, ultrasound detector; WAV files: RETES2_20150308_ 212406, _20150308_215558, RETETES_20150221_193143, _20150221_204919. • 13 acoustic recordings; Sinaloa, Culiacán, Seminario; 24°51′52″N, 107°28′47″W; 73 m a.s.l; 22 Feb., 07, 20 Mar. 2015; Alfredo Leal-Sandoval leg.; irrigated corn agroecosystem, ultrasound detector; WAV files: SEMI_20150222_201711, _20150222_203558, _20150222_210122, _20150222_212703, _20150222_213616, SEMI2_20150307_191442, _20150307_195119, _20150307_195510, _20150307_204121, _20150307_212031, _20150307_212058, _20150307_214104, SEMI32_20150320_214923. • 60 acoustic recordings; Sinaloa, Cosalá, RENSMN; 24°24′15″N, 106°36′31″W; 550 m a.s.l; 14, 27 Feb., 28 Mar., 24 Jun., 31 Jul., 31 Aug., 30 Sep., 01, 02 Oct., 26 Dec. 2015; Alfredo Leal-Sandoval leg.; Tropical Dry Forest remnants as the main vegetation, with its secondary vegetation transitions; ultrasound detector; WAV files: RNS_20150214_185830, 20150214_190617, REMNS_20150227_191237, 20150227_191440, 20150227_201821, ALBER2_20150328_211844, 20150328_211848, 20150328_214126, SENNO-005_20150624_020022, 20150624_020324, 20150624_020732, ALBER-6_20150731_011859, 20150731_012204, 20150731_012428, 20150731_012820, 20150731_013047, 20150731_013128, 20150731_013153, 20150731_013206, 20150731_021220, ALBER-AGO20150831_203539, 20150831_204013, 20150831_204932, 20150831_211248, 20150831_213104, 20150831_214349, 20150831_214432, 20150831_222528, 20150831_223026, RIPARIO_20150930_201004, 20150930_201303, 20150930_205804, 20150930_211604, 20150930_213201, 20150930_221247, 20150930_230212, 20150930_230531, GRANJA_20151001_203821, 20151001_203848, 20151001_204024, 20151001_204430, 20151001_204635, 20151001_204801, 20151001_204958, 20151001_205415, 20151001_210102, 20151001_211358, 20151001_211954, 20151001_222841, 20151001_225324, 20151001_225410, 20151001_231125, 20151001_232916, 20151001_233322, 20151001_234055, 20151001_235714, 20151002_000104, 20151002_001229, 20151002_002458, PROCEN_20151226_72909. • 2 acoustic recordings; Sinaloa, San Ignacio, Cacaxtla; 24°24′15″N, 106°36′31″W; 15 m a.s.l; 15 Feb. 2015; Alfredo Leal-Sandoval leg.; Tropical Dry Forest transition to coastal shrub and mangrove, with secondary vegetation transitions; ultrasound detector; WAV files: BARRAS_20150215_193310, 20150215_193753. • 1 acoustic recording; Sonora, Álamos, San Pablo; 27°03′15″N, 108°42′06″W; 530 m a.s.l; 09 Aug. 2016; Alfredo Leal-Sandoval leg.; a former cattle ranch turned to conserved natural site, dominated by Tropical Dry Forest and transition to riparian vegetation; ultrasound detector; WAV file: PROCEN_20160809_214011.

Identification. Members of the Molossidae family possess high plasticity in their searching calls (Mora et al. 2004; Gillam and McCracken 2007; Guillén-Servent and Ibáñez 2007; Gillam et al. 2009). To perform species identification we identified sound sequences, comparing our recordings to available echolocation data (Schnitzler and Kalko 2001; Jung and Kalko 2011). *Promops centralis* calls are highly characteristic and therefore we are confident that our recordings confirm species presence (Jung et al. 2014; González-Terrazas et al. 2016). The species calls are composed of QCF and MF ascendant calls where the start frequency is lower than the final frequency. Frequently we observed these ascendant calls were interspersed with higher decedent MF-QCF call, which did not overlap in the frequency range. The mean parameters of our records were: star frequency was 24.8 kHz ± 3.30, final frequency 27.1 kHz ± 4.07 and peak frequency 25.2 kHz ± 0.534. The mean duration of the calls was 12.0 ms ± 8.30 with 346 ms ± 101 intervals. Our record call measurements match previous records of the *P. centralis* described by Jung and Kalko (2011), Barataud et al. (2013), Jung et al. (2014), González-Terrazas et al. (2016), and Hintze et al. (2019) (Fig. 2; Table 2).

Discussion

Recent captures of Big Crested Mastiff Bat in the central part of Sonora (González-Terrazas et al. 2016) are remarkable records of this species in Mexico. Our records of *Promops centralis* are based on acoustic recording derivatives we extracted from our effort to describe insectivorous bat communities in Sinaloa and southern Sonora (Fig. 3), similar to what Hintze et al. (2019) performed when documenting the species range extension in northern Brazil. Our work provides clear evidence that corroborates a wider distribution of *P. centralis* in northwestern Mexico. Additionally, we document *P. centralis* presence in corn agricultural fields, which is a habitat that was not previously described for this species. Previous accounts in Mexico were limited to tropical dry forest (Sánchez-Cordero et al. 1993; Arita

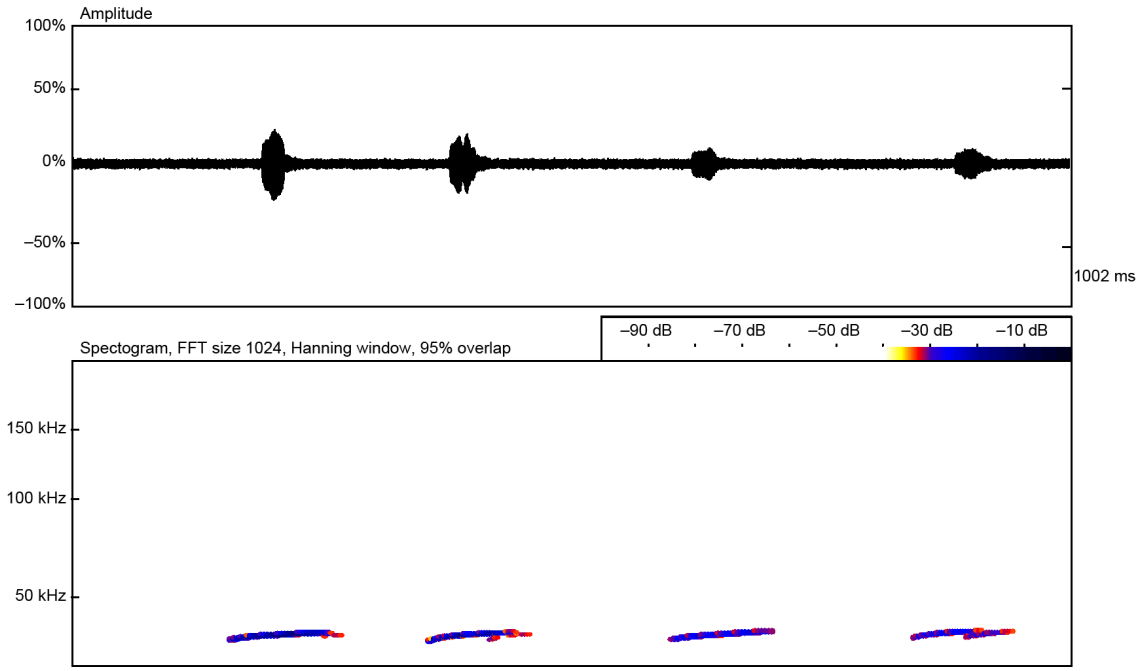

Figure 2. *Promops centralis* echolocation calls from a search sequence with ascendant modulation. Parameters: 1000 ms, FFT of 1024, Hamming window and 95% overlap (ALBER2_20150328_211848 Procen.wav).

1997; Téllez-Girón et al. 1997). Despite the descriptions of areas of likely habitat suggested by Ceballos et al. (2006), our findings corresponded to different habitats within Sinaloa.

Free-tailed bats (Molossidae) perform an important ecosystem services (Chang and Kareiva 1999; Symondson et al. 2002; Boyles et al. 2011; Clare et al. 2011; Kunz et al. 2011). The presence of bat species in agricultural landscapes can result in economic growth from the natural pest-control which would be of great benefit to farmers (Federico et al. 2008; Maine and Boyles 2015). Corn, the most important crop in Mexico (Palacios Velarde et al. 2008), it is planted year-round in many Sinaloa regions, and is vulnerable to pest's infestations (Hernández Juárez et al. 2016). We argue that cornfields could be essential habitats for feeding and water for the insectivorous bat community (Wickramasinghe et al. 2003; McCracken et al. 2008), as conversion of natural habitat as TDF to farm lands continues and more than the 40% of its coverture it is already lost (González-Medina et al. 2009).

Acoustic monitoring of presence of insectivorous bats in agroecosystems, in addition to its accuracy in identifying the presence of hard to capture bat species, allows us to indirectly describe the use of habitat (i.e., as areas that support a given diversity of bat species). We encourage the use of such methodological advances as they are likely to better support bat conservation efforts and habitat management.

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Authors Contributions

AL-S coordinated and obtained financial support and logistics of the fieldwork, and wrote the manuscript.

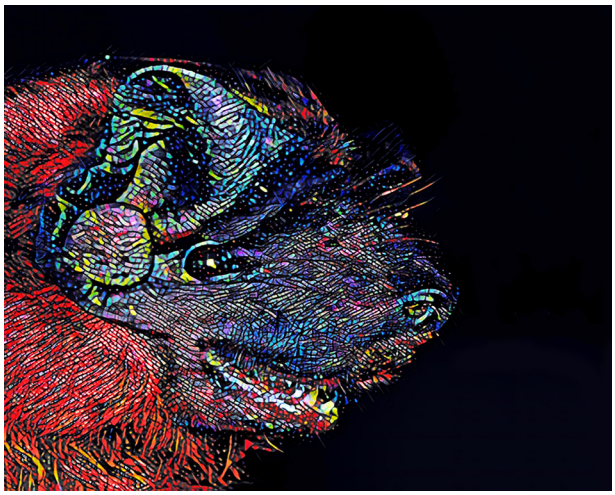

Figure 3. Big Crested Mastiff Bat, *Promops centralis* (Thomas, 1915), artistic representation. Illustration by H. Morales.

AT-V analyzed the acoustic data. GL-S contributed to the manuscript and helped in the submission. OOL-H provided reviews and comments during manuscript writing. PS-P, the Lab leader, provided contacts from farmers and facilities in the northern Sinaloa localities, and reviewed the manuscript. LL-H contributed to improvements in the manuscript, including the revision of English.

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