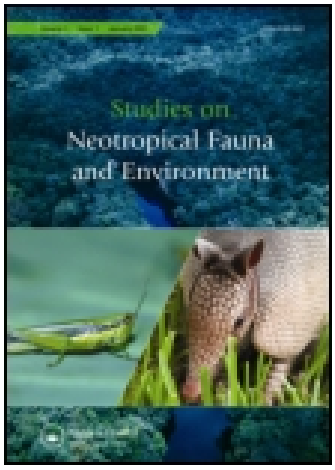

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Echolocation of the big red bat Lasiurus egregius (Chiroptera: Vespertilionidae) and first record from the Central Brazilian Amazon

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ORIGINAL ARTICLE

Echolocation of the big red bat *Lasiurus egregius* (Chiroptera: Vespertilionidae) and first record from the Central Brazilian Amazon

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Lasiurus egregius (Peters, 1870) is a rare Neotropical vespertilionid bat and virtually no data on its ecology and echolocation calls are currently available. We report the capture of four individuals in the Central Amazon, representing the first record for the region and a significant (> 800 km) expansion of the species' known range. Echolocation calls, recorded for the first time under natural conditions, were 1.5–8 ms in duration, and characterized by high mean bandwidth (18 kHz) and a mean frequency of maximum energy of 30 kHz.

Lasiurus egregius (Peters, 1870) é um morcego vespertilionídeo Neotropical cuja ecologia é praticamente desconhecida. Nós reportamos a captura de 4 indivíduos na Amazônia Central, representando o primeiro registo para a região e uma ampliação significativa (> 800 km) da distribuição conhecida para a espécie. Os pulsos de ecolocalização, gravados pela primeira vez em condições naturais, tiveram 1.5–8 ms de duração e foram caracterizados por uma alta frequência modulada (18 kHz) e frequência de máxima energia média de 30 kHz.

Keywords: Brazil; echolocation; *Lasiurini*; species distribution; acoustic identification

Introduction

The genus *Lasiurus* comprises 17 medium-sized to large vespertilionid bat species worldwide (Simmons 2005). Six of the nine species recorded in South America are known to occur in Brazil (Paglia et al. 2012). For the big red bat, *Lasiurus egregius*, so far there are only 19 species records from 12 localities across Central and South America (Figure 1). Due to the scarcity of records, the species' present IUCN conservation status is Data Deficient (Sampaio et al. 2008).

The genus *Lasiurus* is generally characterized by the presence of fur on the uropatagium (from proximal to distal parts) and a coloration that varies from yellowish to reddish (Gardner & Handley 2007). *Lasiurus egregius* has a distinctive reddish coloration, dorsally tricolored fur with dark bases, a yellowish middle band and reddish tips, while the ventral fur is bicolored with dark bases and reddish tips (Vieira 1942). Forearm length varies between 48 and 50 mm (Emmons & Feer 1997; Eisenberg & Redford 1999; Lim & Engstrom 2001) and the ears are generally wider than long (rhomboid), with a peculiar tragus (straight inner border and curved outer border). The wings are black and, although not mottled, paler areas are evident around the thumbs and phalanges. Close to the thumbs and on the dorsal part of the plagiopatagium (from the elbow to the metacarpal of the V finger), characteristic patches of fur can be found (Gledson & Wagner 2007). Virtually no data on the species' natural history are currently available (Miranda et al. 2011), morphometric data are scarce, and the echolocation calls of the species remain undescribed. Here, we report the first record of *L. egregius* for the Central Amazon, provide morphometric data to aid in species identification, and provide the first description of the species' echolocation calls.

Material and methods

Study area

Fieldwork was carried out at the Biological Dynamics of Forest Fragmentation Project (BDFFP; http://pdbff.inpa.gov.br) in the context of a larger project regarding the long-term effects of forest fragmentation on bat fauna. The BDFFP is located *c*.80 km

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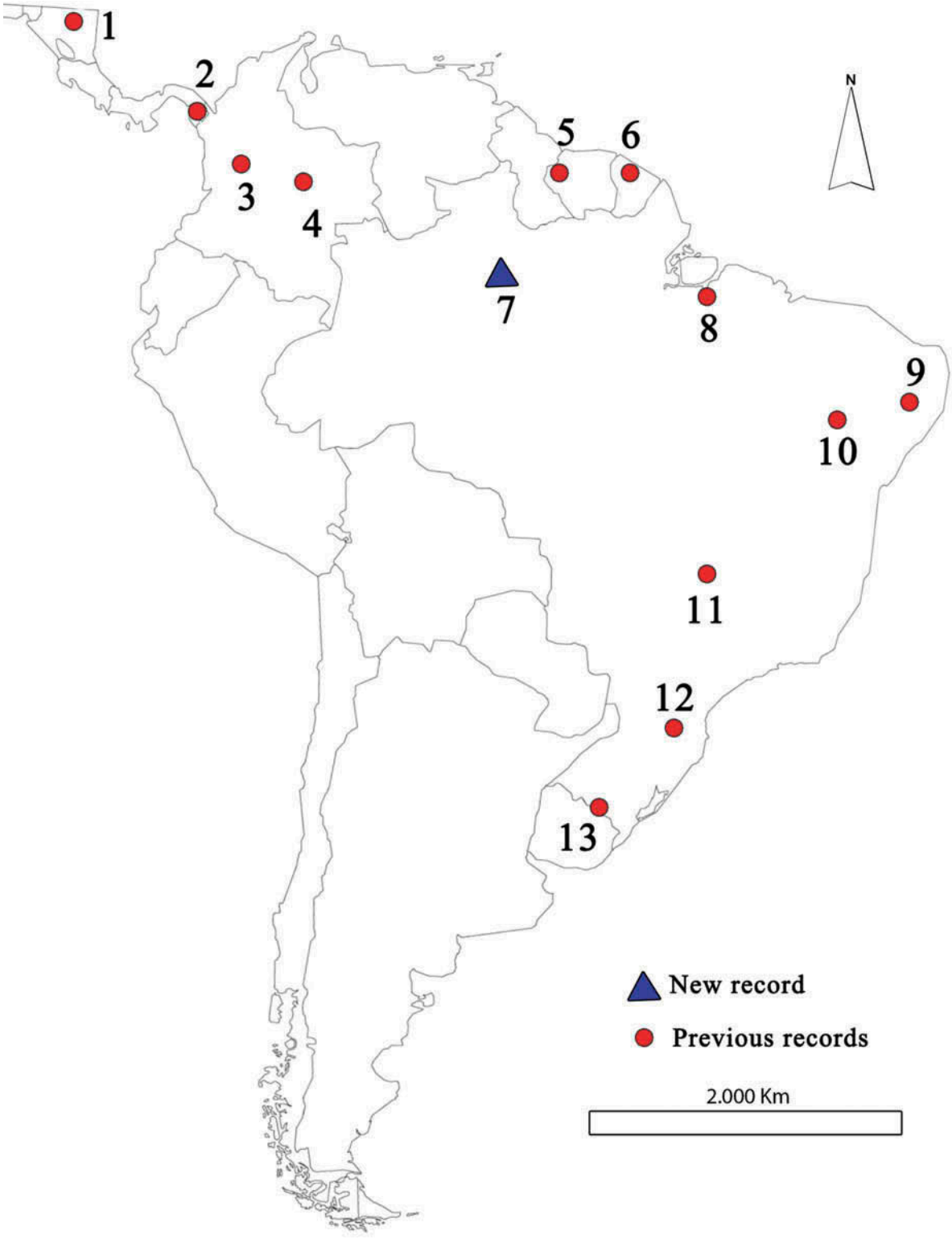

Figure 1. Distribution map of *L. egregius* showing all localities where the species has been recorded. Central America – Honduras: (1) Guayabo de Catacamas, Olancho (Mora 2012); Panamá: (2) Armilla Provincia de San Blás (Handley 1960). South America – Colombia: (3) Tolima (Bejarano-Bonilla et al. 2007); (4) unspecified location (Alberico et al. 2000); Suriname: (5) Bakhuis Bauxite Exploration Concession, Area 20 and 8 Recon Fly Camps (Lim 2009); French Guyana: (6) Sinnamary (Williams et al. 1990); Brazil: (7) Biological Dynamics of Forest Fragments Project, km 41 Reserve, Amazonas state (present study); (8) Área de Pesquisas Ecológicas do Guamá, Pará state (Kalko & Handley 2001); (9) Brejo da Madre de Deus municipality, Arara ranch, Pernambuco state (Silva 2007); (10) Reserva Biológica da Serra Negra, Pernambuco state (Sousa et al. 2004); (11) Uberlândia municipality, Minas Gerais state (Stutz et al. 2004); (12) Floresta Nacional de Três Barras, Santa Catarina state (Cherem & Pérez 1996); (13) Rivera, Rio Grande do Sul state (Giménez & Giannini 2011).

north of Manaus in the Central Amazon, Brazil (2°25′ S, 59°50′ W; elevation 30–125 m asl). The predominant vegetation in this region is lowland primary *terra firme* forest (Bierregaard et al. 1992).

Bat captures

In order to obtain echolocation calls for a reference call library for aerial insectivorous bats in the area, mist-netting was conducted at small lakes and streams, and potential roost sites were explored. We captured two post-lactating females of *L. egregius* on 14 October 2012, and one male and one female on 28 February 2013 at BDPFF's km 41 camp (2°26′55.5″ S, 59°46′14.2″ W; 100 m asl; Figure 1). The captures were made using one mist-net (12 × 2.5 m) set across a small pond (10 × 6 × 1 m), not covered with vegetation. Measurements from individuals were taken with a caliper to the nearest 0.1 mm. One of the four individuals was collected and deposited at the Mammal Collections of the Instituto Nacional de Pesquisas da Amazônia (INPA 6417).

Sound recordings

Echolocation call recordings were obtained under natural conditions from two females that were later captured, using a Pettersson D1000X detector (Uppsala Science Park Dag Hammarskjölds, Uppsala, Sweden) placed next to the mist-net. Upon the bat's impact the detector was activated using a 30 s pre-trigger (real time recording at 500 kHz sampling rate) to record the bat when it was flying prior to the capture. We used a sampling frequency of 250 kHz, with 16 bits/sample. For both spectrograms and power spectra, a customized 512 point fast Fourier transform with a Hanning window was used. To characterize echolocation calls, the following parameters were measured from the main harmonic of each pulse using Sonobat v3.1.1p (SonoBat, Arcata, CA, USA): peak frequency (kHz), the frequency containing most energy; bandwidth (kHz); start frequency (kHz); end frequency (kHz); and pulse duration (ms). To minimize measurement error and bias, we only measured those pulses from the recorded echolocation call sequences whose intensity was around 20 dB higher than background noise (n = 99).

Table 1. External and skull measurements (mm) and body mass (g) of three females and one male *Lasiurus egregius*. Skull measurements were taken from one specimen (collection number: INPA 6417).

	♀	♀	♀	♂	Mean	SD
Ear	13.7	15	14	13.7	14.1	0.6
Tragus	7.8	7.2	7.2	8.7	7.7	0.7
Forearm	48.2	48.8	47.6	47.4	48.0	0.6
Thumb	8.2	7.4	9.2	8.6	8.4	0.8
Tibia	25	25.3	24	25.5	25.0	0.7
Calcar	16	14.6	16.6	18.1	16.3	1.4
Hind foot	7.5	8.9	9.3	8.2	8.5	0.8
Tail	57.4	55.5	53.5	46.7	53.3	4.7
Body length	61.9	60	57.5	61.9	60.3	2.1
Wingspan	398.4	390.6	376	396.2	390.3	10.1
Body mass	15	16	14.8	11	14.2	2.2
Aspect ratio	7.79			8.48		
Wing loading (N m^{-2})	5.38			5.82		
Skull (with incisors)	16.8					
Skull (without incisors)	16.0					
Condyloincisive length	16.4					
Condylobasal length	16.1					
Condylocanine length	16.5					
Superior canine-molar	6.1					
Inferior canine-molar	7.1					
Maxillary toothrow	12.9					
Postorbital width	5.0					
Zygomatic width	11.8					
Palatal width at canines	6.4					
Braincase width	7.7					
Mastoid width	8.4					

Results

Our captures of *L. egregius* at the BDFFP represent the first record of the species for the Central Amazon, and a range expansion of 1260 km westward from Belém, Brazil, and 860 km southwestward from Bakhuis Bauxite Exploration Concession, Suriname, the closest previously known locations of occurrence (Figure 1). Measurements of external and cranial characteristics are given in Table 1, and the species' general appearance and distinctive morphological characteristics are illustrated in Figure 2. Echolocation calls of *L. egregius* generally consist of a modulated frequency (FM) component followed by a terminal part whose frequency is almost constant (quasi-constant-frequency or QCF) (Figure 3C). Peak frequency of echolocation calls averaged 30.2 kHz (with a range between 24.3 and 42.7); mean bandwidth was 18.4 kHz and calls produced were short to medium in duration (1.5–7.8 ms) (Table 2, Figure 3D). Start and end frequencies were 36.2–67.2 and 22.6–33.9 kHz, respectively, and harmonics were rarely recorded.

Discussion

Lasiurus egregius was first inaccurately considered endemic to Brazil (Koopman & McCracken 1998); however, later records from Suriname, Honduras, Panamá, French Guyana and Colombia indicated that the species is widespread in South and Central

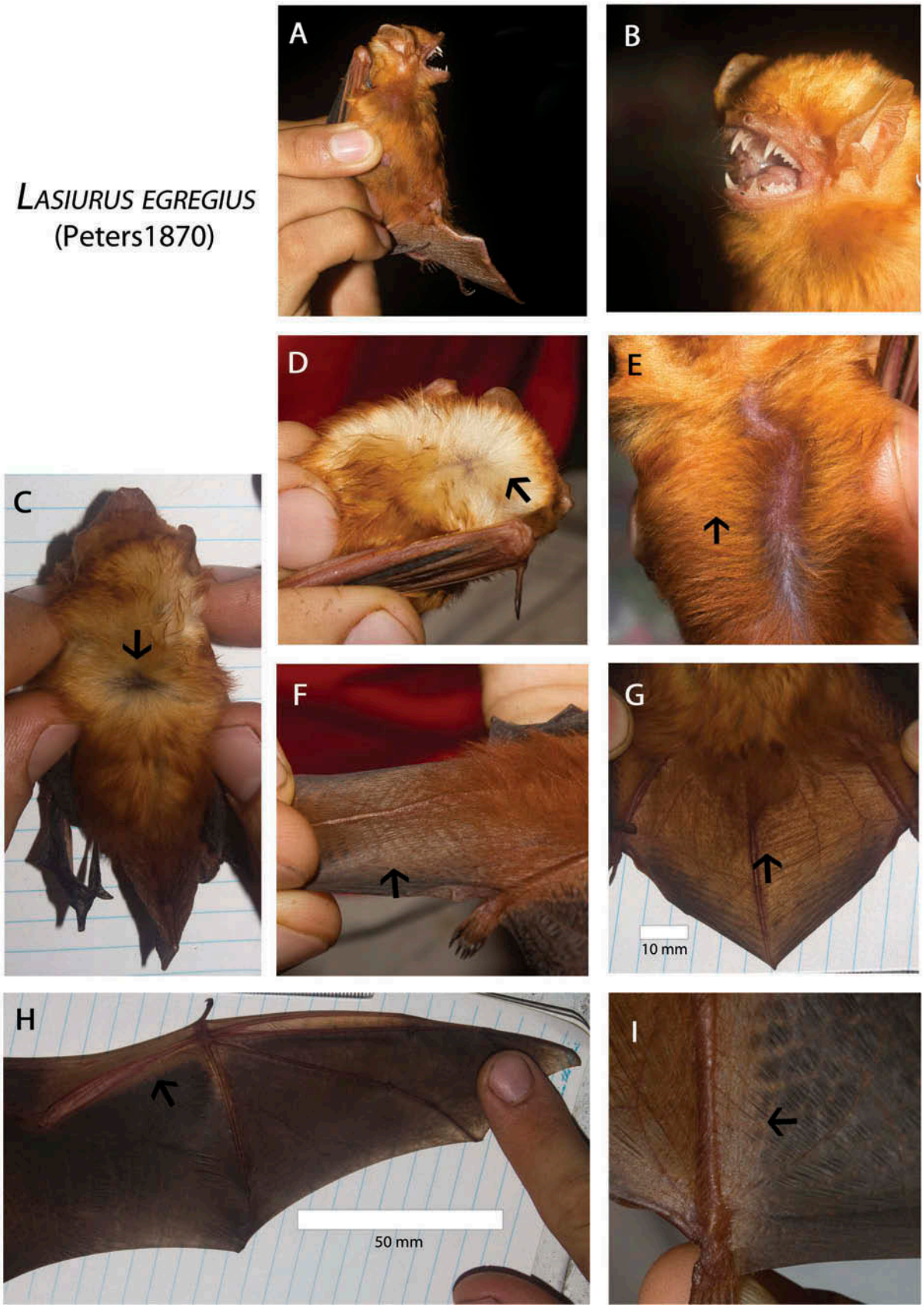

Figure 2. (Color online) Morphological characteristics of one *L. egregius* captured at the BDFFP, Central Amazonia, Brazil. A, side body view; B, rostrum; C, tricolored dorsal fur; D, tricolored fur between shoulders; E, ventrally bicolored fur; F–G, fur on the uropatagium; H, wings with brighter areas between phalanxes; I, brighter area next to the legs.

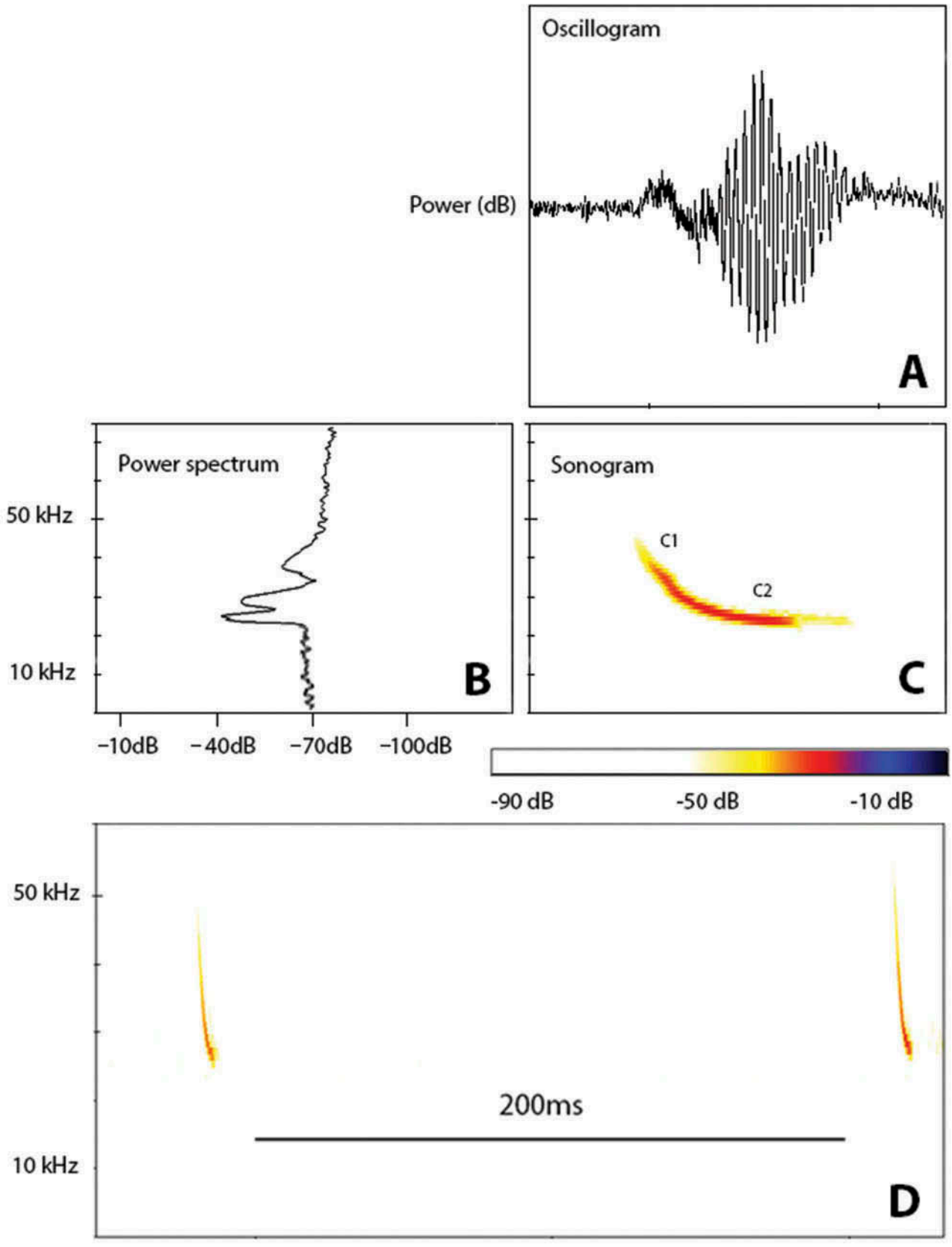

Figure 3. (Color online) Echolocation call of *L. egregius* while flying over a pond. A, oscillogram; B, power spectrum; C, spectrogram of an expanded pulse [C1: FM (modulated frequency) component; C2: QCF (quasi-constant-frequency) component]; D, spectrogram of a sequence of calls in a normally scaled image.

Table 2. Echolocation call characteristics for some species of the genus *Lasiurus* based on a literature review, and call characteristics of *L. egregius* recorded in this study.

Species	Main frequency (kHz)	Start frequency (kHz)	End frequency (kHz)	Duration (ms)	Country	Reference
Lasiurus cinereus semotus	30	42.1	24.9	8.7	Hawaii	Fullard (1989)
Lasiurus cinereus cinereus	20.1	27.7	18.3	9.8	Canada	Barclay et al. (1999)
Lasiurus cinereus cinereus	19.9	—	—	10.3	Canada	Barclay (1986)
Lasiurus cinereus cinereus	—	34	15	—	USA	O'Farrell et al. (2000)
Lasiurus borealis	37.5	—	—	—	Canada	Obrist & Wenstrup (1998)
Lasiurus intermedius	—	32.6	29.8	6.3	Mexico	Rydell et al. (2002)
Lasiurus ega	31	32.2	28.6	9.1	Mexico	Rydell et al. (2002)
Lasiurus blossevillii	42.5	—	—	8	USA	Pierson et al. (2006)
Lasiurus egregius	30.2 ± 3.5	45.4 ± 7.1	27.3 ± 1.9	4.8 ± 1.3	Brazil	Current study

America. Based on the records currently available, the species seems to cover a remarkable latitudinal (around 6000 km) and altitudinal (25–2900 m asl) range, and to use a diverse array of habitats, including *cerrado* (Stutz et al. 2004), rainforest (Kalko & Handley 2001), montane forest (Bejarano-Bonilla et al. 2007), swamp areas (Sousa et al. 2004), and secondary forest (Williams et al. 1990).

Due to good flight maneuverability and high sonar sensitivity, *L. egregius* is rarely captured with mist-nets, as many other Neotropical vespertilionids (O'Farrell & Gannon 1998; Ochoa et al. 2000; Rydell et al. 2002; Pech-Canche et al. 2011). In fact, despite a total capture effort of nearly 12684 mist-net hours at the BDFFP over the course of almost two years using both ground- and canopy-level mist nets, not a single individual of *L. egregius* was captured in continuous forest or forest fragments (authors' unpublished data). It is therefore important to note that the specimens here reported were captured over water bodies, which in rainforest generally tend to be less sampled than other habitats. Thus, we believe that *L. egregius* may turn out to be more common and widespread than the existing data suggest. The general paucity of detailed acoustic studies conducted in the Neotropics certainly also contributes to the lack of knowledge about this species.

As for other species of the genus, calls of *Lasiurus egregius* are characterized by single partially modulated pulses. In terms of pulse duration and frequency modulation the echolocation calls of *L. egregius* probably reflect an adaptation for flying in cluttered forest environments (Aldridge & Rautenbach 1987; Russo & Jones 2002). Relatively low aspect ratio and high wing loading also indicate that this bat species could be capable of foraging in dense forests (Norberg & Rayner 1987). Nevertheless, the presence of this species in more open habitats, such as swamps (Sousa et al. 2004) and grassland in the *cerrado* (Stutz et al. 2004) suggests that the species is not restricted to closed-canopy forests. When flying in such open habitats, or in open spaces above the canopy, *L. egregius* may use calls that are less frequency modulated than the ones that we recorded in the forest.

Although bats are known to slightly change the shape of their echolocation pulses when approaching a water surface (Jones & Rayner 1988), we consider that our recorded calls provide reliable information of the species' echolocation parameters under free flight conditions since they were not drinking water, but flying at some distance above the water surface. It is possible to identify many Neotropical vespertilionid bats using their echolocation parameters (Miller 2004). However, echolocation calls are known to vary remarkably not only among habitats, but also among geographic regions (Barclay et al. 1999). For confident species identification, it is therefore essential to compile reference calls from a broad range of geographic localities to reliably capture existing large-scale variation.

The western red bat, *L. blossevillii*, also present in our study area, can be distinguished from other species that overlap with it in peak frequency and that have a similar call shape, by an upturn at the end of the call (Pierson et al. 2006). Such details are more evident in the harmonics, as could be seen in some of our recordings of *L. egregius* where, however, this upturn seems not to be as pronounced as in *L. blossevillii.* More data and in-depth analyses are needed to determine whether this character is common in both species or even within the genus. For *L. ega* and *L. castaneus*, the other two species of *Lasiurus* present in the study area, reliable identification is still difficult (Rydell et al. 2002) given the lack of clear descriptions of their echolocation calls.

Our description of the echolocation calls of *L. egregius* provides a basis for the identification of the species in acoustic studies across its distribution range, and therefore has the potential to majorly contribute to a better knowledge of the ecology and

natural history of this bat species. However, other poorly studied species of *Lasiurus* have calls that are somewhat similar to those of *L. egregius* (Table 2), highlighting the need for further studies to develop reliable criteria for their acoustic discrimination.

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