Acoustic identification of four species of bats (Order Chiroptera) in central Chile

Annia Rodríguez-San Pedro a & Javier A. Simonetti a

a Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile

Published online: 29 Jan 2013.

To cite this article: Annia Rodríguez-San Pedro & Javier A. Simonetti (2013): Acoustic identification of four species of bats (Order Chiroptera) in central Chile, Bioacoustics: The International Journal of Animal Sound and its Recording, 22:2, 165-172

To link to this article: http://dx.doi.org/10.1080/09524622.2013.763384

Please scroll down for article
Acoustic identification of four species of bats (Order Chiroptera) in central Chile

Annia Rodríguez-San Pedro* and Javier A. Simonetti

Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile

(Received 20 November 2012; final version received 28 December 2012)

Echolocation calls of four species of insectivorous bats of central Chile were recorded and characterized to determine vocal signatures that allow their identification in the field. Pulses of Tadarida brasiliensis were characterized by the highest duration and the lowest values for all frequencies, which do not overlap those of the remaining species. Tadarida emits narrowband, shallow frequency-modulated search calls. All three vespertilionid species studied (Histiotus montanus, Lasiurus varius and Myotis chiloensis) showed similar echolocation design to one another, consisting of a downward frequency modulation at the beginning of the signal followed by a narrowband quasi-constant frequency component; however, their calls differ by their spectral characteristics. Discriminant function analysis of six acoustic parameters (duration, initial frequency, slope frequency modulation, peak frequency, minimal and maximal frequencies) gave an overall classification of 87.4%, suggesting species could be correctly classified based on echolocation calls. Call duration and minimal frequency were the variables most important for species identification.

Keywords: echolocation calls; acoustic identification; discriminant function analysis; Vespertilionidae; Molossidae

Introduction

Aerial insectivorous bats have well-developed echolocation abilities, allowing them to detect and avoid mist-nets and, therefore, often go underrepresented in mist-netting studies (O’Farrell and Gannon 1999). Therefore, acoustic identification of insectivorous bat species based on the shape and pattern of their echolocation calls has become a successful tool to address differential habitat use and to infer patterns of activity and behaviour (Russo and Jones 2003; Estrada et al. 2004). However, this method is only effective if each sequence of calls recorded in the field can be unequivocally assigned to a given species.

Most of the Chilean bat species are associated with forested habitats (Galaz and Yáñez 2006), yet the area covered by temperate forest in central Chile has been reduced and fragmented due to agriculture and forest plantations (Echeverría et al. 2006). Landscape-level transformations could, therefore, affect bat populations in Chile. Defining appropriate conservation guidelines requires identifying habitat use, particularly when land-use changes are modifying habitat availability. Furthermore, despite the increasingly common use of bat detectors in studies of insectivorous bat activity (Law et al. 1999; Russo and Jones 2003; Estrada et al. 2004), the use of echolocation calls to conduct inventories of bats in Chile is currently hindered by a scant knowledge of the acoustic repertoire of most species. Within this framework, we aim to examine the characteristics...
of echolocation calls of four species of insectivorous bats occurring in central Chile, thereby facilitating acoustic inventories of bats and assessments of inter-specific variations in patterns of habitat use.

Of the four species studied, echolocation calls of *Myotis chiloensis* have been previously reported (Ossa et al. 2010), but their description was limited to only three acoustic parameters: call duration, terminal frequency and inter-pulse intervals (IPIs). In order to complement its acoustic characterization, a more detailed study of their sound emissions is presented here. Call design of *Tadarida brasiliensis* is well known from populations of the northern hemisphere (Simmons et al. 1978; Ratcliffe et al. 2004). Because geographic variation in echolocation calls has been reported for other species (Thomas et al. 1987), reference calls recorded for *T. brasiliensis* in a particular region may not be applicable elsewhere, so we offer a description of echolocation calls from Chilean populations. Finally, we present the first description of echolocation calls for *Histiotus montanus* and *Lasiurus varius*.

**Material and methods**

Bat captures and acoustic recordings were conducted at Tregualemu, on the coastal range of central Chile (35°59'00,7°S 72°46'00,6°W to 35°59'00,7°S 72°41'00,4°W), from January 2010 to October 2012. Echolocation calls of 16 *H. montanus*, 24 *L. varius* and 16 *M. chiloensis* were recorded from hand-released bats after capture using harp traps. All individual bats’ echolocation calls were recorded in the same habitat, a moderate-cluttered space over an open road (>4 m width) surrounded by low pine trees. Echolocation calls were recorded 5 m from the release point when no other bats were flying over the site. Echolocation calls of *T. brasiliensis* were recorded from 20 individuals foraging up to 10 m above ground level at least 50 m away from a known roost. Captured bats were identified in the hand following Galaz and Yáñez (2006).

Echolocation calls were recorded using an ultrasound bat-detector model D240X (Pettersson Elektronic AB, Upsala, Sweden) with a flat response characteristic between 10 and 120 kHz. The output of the bat detector was coupled to a digital recorder (M-Audio MicroTrack II) and operated in time-expanded mode. Time-expanded mode allows recording full-spectrum echolocation calls so that subsequent quantitative analysis of call structure may be carried out. Passes of echolocation calls were displayed simultaneously as spectrograms and oscillograms using BatSound 2.1 with a sampling rate of 44.1 kHz and a Hanning window. Spectrograms were made of consecutive fast Fourier transforms (FFTs) with a 99% overlap. For spectrograms and oscillograms, the time resolution was 0.1 ms. For spectrograms, the frequency resolution was 610 Hz. According to the duration of the call to be analysed (measured in the oscillogram), power spectra were calculated using FFTs obtained from 512 to 2048 data points.

From each individual, two to five pulses with good signal-to-noise ratio (peak intensity with more than 20 dB above noise level measured in the power spectrum) were chosen. No acoustic parameters were evaluated in pulses which did not meet these criteria. For each pulse, we manually measured the following parameters: (1) duration (time between start and end of a pulse, measured in ms in the oscillogram); (2) initial and (3) final frequencies (measured in the spectrogram); (4) slope of frequency modulation (difference in kHz between the initial and final frequencies of the call divided by the duration of the call); (5) peak frequency (frequency in kHz corresponding to the maximal intensity in the power spectrum); (6) maximal and (7) minimal frequencies (measured 20 dB below peak intensity in the power spectrum); (8) bandwidth (difference between maximal and minimal
frequencies). In each call sequence, we measured IPI from the beginning of a call to the start of next call. We used quadratic discriminant function analysis (DFA) to determine whether the four species could be separated in four independent groups (Russo and Jones 2002). Variables used in this analysis were call duration, final frequency, slope frequency modulation, peak frequency, maximal and minimal frequencies. Wilk’s $\lambda$ values were obtained with a multivariate analysis of variance (MANOVA) to test for statistical significance of DFA models. The standardized discriminant function coefficients were used to determine the contribution each variable made to the ability of DFA to classify calls. For each species, descriptive statistics (mean ± SE) were calculated. All tests were carried out with STATISTICA 8.0 (StatSoft, Inc. 2007).

Results

We analysed 62 calls from *T. brasiliensis*, 66 calls from *M. chiloensis*, 56 calls from *H. montanus* and 79 calls from *L. varius*. *T. brasiliensis* showed narrowband, shallow frequency-modulated (quasi-constant frequency) search calls with a single harmonic lasting 13 ms. Pulses were emitted with an average interval of $286.9 \pm 18.9$ ms (Figure 1, Table 1). *T. brasiliensis* echolocation calls exhibited the highest call duration and showed the lowest values for all frequency variables, which do not overlap with those of the vespertilionid species. *H. montanus*, *L. varius* and *M. chiloensis* emitted single harmonic search calls with a similar design consisting of a downward frequency modulation at the beginning of the signal followed by a narrowband quasi-constant frequency component. However, their calls differ in their spectral characteristics (Table 1). Search calls of *H. montanus* were characterized by durations shorter than 4 ms and bandwidth of 13 kHz. The minimal frequency was around 31 kHz. Pulses were emitted at intervals of $136.1 \pm 8.0$ ms (Figure 2, Table 1). Search calls emitted by *L. varius* showed intermediate acoustic parameters (Figure 3; Table 1) with pulses longer (5 ms) than those of *H. montanus*. The minimal frequency was around 37 kHz and the IPIs were averaged at $164.3 \pm 9.6$ ms. The calls broadcasted by *M. chiloensis* also consisted of short (<4 ms)

![Figure 1](image1.png)

**Figure 1.** Sonogram of echolocation calls of *T. brasiliensis* showing (a) a typical pulse sequence, (b) a single call, (c) a power spectrum of a typical echolocation call.
downward frequency-modulated signals sweeping down between 89 and 39 kHz with most energy at 47 kHz (Figure 4, Table 1).

Multivariate DFA of the six acoustic parameters gave an overall classification of 87.4% of the calls. MANOVA showed that the model was significant (Wilk’s $\lambda = 0.018$, $F = 125.64$, $p < 0.001$) and that 97.2% of the variation was explained by the first two discriminant functions. Search calls of individual bats could be assigned with accuracy to their groups (Figure 5, Table 2). Search calls emitted by *T. brasiliensis* were 100% of the time correctly identified and grouped separately of the rest of the species. Identification rates of calls of *H. montanus* were also high, with 98% of recorded calls correctly identified. However, search calls of *L. varius* and *M. chiloensis* overlap in several attributes, making their identification difficult. Of the six variables used in the DFA, the

![Figure 2](image)

Figure 2. Sonogram of echolocation calls of *H. montanus* showing (a) a typical pulse sequence, (b) a single call, (c) a power spectrum of a typical echolocation call.
most important for discriminating between species were call duration and minimal frequency (Table 3).

Discussion
We successfully described echolocation calls from four species and our discriminant analysis provided a high-identification performance, potentially offering a tool for future acoustic surveys in Chile.

Among the calls from Chilean bat we considered, those of *T. brasiliensis* could be unambiguously identified because of their narrow bandwidth, long duration and low final frequency. Despite claims of geographic variation as a factor influencing echolocation calls (e.g. Gillam and McCracken 2007), pulses emitted by *T. brasiliensis* in Chile are similar to those described for populations in the USA (Ratcliffe et al. 2004). Long, narrowband frequency-modulated signals emitted at long IPIs are well suited for the detection of weak echoes from small insects (Simmons and Stein 1980; Schnitzler and Kalko 2001). In addition, the longer these echolocation signals are, the better they encode target movements by carrying characteristic modulations in echo amplitude and frequency. Maximizing the range at which prey are detected will be particularly important

Table 2. DFAs of calls from four bats species in central Chile.

<table>
<thead>
<tr>
<th>Classified as</th>
<th>True group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>H. montanus</em></td>
</tr>
<tr>
<td><em>H. montanus</em></td>
<td>55</td>
</tr>
<tr>
<td><em>L. varius</em></td>
<td>1</td>
</tr>
<tr>
<td><em>M. chiloensis</em></td>
<td>0</td>
</tr>
<tr>
<td><em>T. brasiliensis</em></td>
<td>0</td>
</tr>
<tr>
<td><em>N total</em></td>
<td>56</td>
</tr>
<tr>
<td><em>% Correct</em></td>
<td>98.2</td>
</tr>
</tbody>
</table>

Note: Figures are the number and percentage of correctly classified echolocation calls.

Figure 3. Sonogram of echolocation calls of *L. varius* showing (a) a typical pulse sequence, (b) a single call, (c) a power spectrum of a typical echolocation call.
for fast flying bats such as *T. brasiliensis*, which hunt above forest canopy. The same echolocation call structure prevails in other molossids such as *Tadarida teniotis*, *Eumops glaucinus* and *Nyctinomops macrotis* (Russo and Jones 2002; Obrist et al. 2004; Mora and Torres 2008).

Echolocation call design of *M. chiloensis* described here is similar to that previously described in southern Chile, at a site 500 km away from Tregualemu (Ossa et al. 2010). *M. chiloensis* in southern Chile emit signals of short duration (2.1 ± 1.0 ms) with a final frequency of 43.4 ± 1.2 kHz and IPI of 77.5 ± 16.9 ms, which suggest no geographic variation in their echolocation calls.

The echolocation calls of *H. montanus* and *L. varius* consist mainly of single harmonic signals with a downward frequency-modulated segment followed by a quasi-constant

![Figure 4](image1.png)

**Figure 4.** Sonogram of echolocation calls of *M. chiloensis* showing (a) a typical pulse sequence, (b) a single call, (c) a power spectrum of a typical echolocation call.

![Figure 5](image2.png)

**Figure 5.** Results of a DFA used in the classification of the echolocation calls of *H. montanus* (triangles), *L. varius* (circles), *M. chiloensis* (cruces) and *T. brasiliensis* (rhombus) emitted during the search phase of their foraging behaviour.
frequency component. A steep FM sweep that precedes the narrowband component is better suited to localize and characterize background targets (Schnitzler and Kalko 2001). This call design is a general feature across the species of the family Vespertilionidae (Kalko and Schnitzler 1993; Siemers et al. 2001; Mora et al. 2005; Rodriguez and Mora 2006) which suggests that these bats perform two tasks while foraging. First, they search for insects near clutter, such as gaps and edges in the vegetation, and second they determine their position in space in relation to background targets (Schnitzler and Kalko 2001). Even *Myotis* sp. adopting a passive listening strategy to look for prey use such calls for orientation, yet call intensity may be reduced under such circumstances (e.g. Russo et al. 2007).

In our study, DFA provided a high-classification rate for the four species included in the analysis (87.4%; Table 2). Correct classification rates were similar or better than those of previous studies (Vaughan et al. 1997; Murray et al. 2001; Parsons and Jones 2000; Russo and Jones 2002). The four bat species in our study have calls with similar spectro-temporal designs, but have consistently different final frequency and call duration. These particular characteristics make them much easier to distinguish acoustically than the bats of Europe or North America, for example, where sympatric *Myotis* species have calls similar in structure but overlaps in spectral and temporal parameters, making them difficult to distinguish from one another (Parsons and Jones 2000; Vaughan et al. 1997). This result suggests that it should be possible to assess species-specific patterns of activity by bats in central Chile using acoustic monitoring alone. We hope this information will foster assessments of the consequences of the habitat transformation in central Chile upon its bat fauna.

**Acknowledgements**

We are grateful to Corporación Nacional Forestal VII Región and Forestal Masisa S.A. for granting permits to work on their states and to Luis Aguirre, Programa para la Conservación de los Murciélagos de Bolivia (PCMB) for the loan of bat detectors. We specially thank Yendery Cerda, Ronny Zúñiga and Fernando Campos for their help in the fieldwork. We are also grateful to Danny Rojas and two anonymous referees for their useful comments on this manuscript. This research has been partially supported by FONDECYT 1095046 and Programa Domeyko-Biodiversidad (Iniciativa Transversal 3), Universidad de Chile. A Rodríguez-San Pedro was supported by a doctoral fellowship from Comisión Nacional de Investigación Científica y Tecnológica (CONICYT), Chile.

Table 3. Relative importance of each call parameter in discriminating between the echolocation calls of the species by DFA.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Root 1</th>
<th>Root 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration (ms)</td>
<td>-0.59</td>
<td>-0.94</td>
</tr>
<tr>
<td>F-end (kHz)</td>
<td>0.41</td>
<td>-0.76</td>
</tr>
<tr>
<td>Slope (kHz/ms)</td>
<td>0.01</td>
<td>-0.41</td>
</tr>
<tr>
<td>Peak frequency (kHz)</td>
<td>-0.31</td>
<td>0.07</td>
</tr>
<tr>
<td>Maximal frequency (kHz)</td>
<td>0.04</td>
<td>0.28</td>
</tr>
<tr>
<td>Minimal frequency (kHz)</td>
<td>0.57</td>
<td>-0.12</td>
</tr>
</tbody>
</table>

Note: Higher standardized coefficients suggest higher discrimination power for a particular variable.
References


