Bioacoustic analysis software as a tool for
amphibian identification in southwestern Costa Rica

A Thesis Presented
by
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ABSTRACT

The identification of anuran species has been enhanced by the use of programmable audio equipment and bioacoustic analysis software. This project utilized a Song Meter recorder to collect frog calls at the Pitzer College Firestone Center for Restoration Ecology and evaluated the recordings using Band Limited Energy detectors within Raven Pro sound analysis software. Processing the data led to the development of a set of simplified Raven Pro protocols. The results identified 8 frog species not previously documented on the Firestone species list: *Leptodactylus fragilis, Leptodactylus bolivianus, Hypsiboas rosenbergi, Scinax elaeochrous, Trachycephalus venulosus, Smilisca sordida, Smilisca sila,* and *Hyalinobatrachium valerioi.* To expand this study, monthly field recordings should be conducted at numerous areas, covering the extent of the Firestone reserve, to collect an expansive testing dataset and develop a more accurate anuran species list.
INTRODUCTION

Acoustic communication in frogs is one of the primary ways they make their presence known to each other. Animal communication plays an important role in sexual attraction, reproductive success, anti-predatory defense, and parental care (Bee et al., 2013; Carvalho et al., 2013). Frog calls and their properties can define mating communication and social organization (Duellman, 1967; Höbel, 2005; Schwartz, 1987). Each frog species has identifying call patterns, frequency ranges, and pulses (Heyer et al., 2003; Hilje and Aide, 2012; Höbel, 2014, Reichert, 2011). A number of types of calls have been identified, though more simply, most frog species make two types of calls: a distress call, made by both males and females, and an advertisement call, made predominately by males (Carvalho et al., 2013; Gerhardt, 1992; Schwartz, 1987; Yen and Fu, 2001).

Bioacoustic analysis is one of the most direct ways for humans to detect frogs, often at times when frogs are difficult to see (Brandes, 2008). Distinguishing frog species by their vocal communication characteristics is relevant to determining frog populations in a given area, and the use of programmable recorders and bioacoustic analysis software allows researchers to identify frog species (Duan et al., 2013; Towsey et al., 2012; Towsey et al., 2013). Also, analyzing auditory frog communication provides information about the anuran population, a vital bioindicator, relevant to the knowledge of all related species, dependent on the health and population numbers of those at the base of life (Smith et al., 2006; Yen and Fu, 2001). Information learned from acoustic analysis can tell humans about the biodiversity of habitats, and it can inform people about the impact of human activities on the plants and animals in an ecosystem (Yen and Fu). The use of autonomous recording equipment, also called automated recording system/s, to obtain frog-call data in the absence of human observers supplements classical morphological approaches to identifying species of frogs, thus providing better assessment about their taxonomy at the species level (Hutto and Stutzman, 2009; Tsuji-Nishikido et al., 2012; Yen and Fu). This study uses the Raven Pro software analyses of 2008 and 2014 Song Meter recordings of frogs at the Pitzer College
Firestone Center for Restoration Ecology in Barú, Costa Rica to update its list of anuran species by identifying previously undocumented species and confirming existing ones.

**STUDY AREA**

The Pitzer College Firestone Center for Restoration Ecology (FCRE) is a 150-acre nature reserve and field station located on the southwest coast of Costa Rica (Figure 1), adjacent to the 815-acre Hacienda-Barú Reserve (HB), near the town of Dominical. This part of Costa Rica lies within a tropical moist forest. There are four man-made ponds on the western region of the FCRE property that serve as habitats for numerous plants and animals and are the locations where the frog-call recordings were made (Figure 2).

![Figure 1. Pond sites at the Firestone Center for Restoration Ecology, Barú, Costa Rica. Audio recordings took place during the rainy seasons of 2008 and 2014. Area sizes of the ponds are (in m²): 644.97 (Duck Pond), 296.79 (Frog Pond), 974.06 (Basilisk Pond), 262.77 (Mudd Pond). Credit for map: Warren Roberts. Since the 1990s, FCRE has been a site of restoration and is now mainly secondary forest. The four ponds are located in the upper reaches of the property, averaging 281 meters above sea level. Two ponds, Basilisk and Mudd, lie within the bamboo forest on the reserve. Frog Pond and Duck Pond are situated in the secondary forest that borders the bamboo forest. According to Professor Donald McFarlane, the four ponds are fed by runoff from the highest part of the property (bamboo forest), via artificial swales. Mudd and Basilisk Ponds...](image-url)
overflow into the headwaters of North Creek, while Duck and Frog Ponds overflow into the headwaters of Terciopelo Creek. Being the most isolated of the four ponds, Mudd Pond becomes dehydrated during the dry season from December to April.

Figure 2. The four ponds on the FCRE property where test datasets were recorded. Clockwise from top left: Duck Pond, Frog Pond, Mudd Pond, Basilisk Pond. Photographed August 25-28, 2014.

METHODS & MATERIALS

A previous Pitzer College student recorded the testing dataset in June and July of 2008, and I recorded the August 2014 testing dataset. For the 2008 recordings, the Song Meter SM1 digital recorder, manufactured by Wildlife Acoustics, was set to record for two minutes every hour, between 6 PM and 4 AM. In 2014, I set the Song Meter to record a three-minute interval every hour, between 7 PM and 5 AM. For the 2014 field recordings, the Song Meter was moved to a new pond location each morning and placed low to the ground, usually wedged between the stalks of a bamboo plant, within 5 feet from the edge of each pond.
The settings of the Song Meter were as follows: sample rate = 16,000 samples/sec, channels = stereo, gain (left and right) = +42.0dB, compression = off.

The FCRE website contains an anuran species list, last updated in 2007, that documents 27 frog species at HB and 11 frog species at FCRE, which together span 29 unique anuran species (“Biodiversity: Amphibians,” 2007). The conflicting counts of identified frog species between the two neighboring reserves is due to the fact that HB enlisted a student to solely identify amphibians on their property. Of the total 29 known frog species inhabiting FCRE and HB, 22 sample recordings were obtained from these sources: Professor Donald McFarlane and amphibibiaweb.org; and through fonozoo.com, copyright permission was received from Adrián García-Rodriguez and William E. Duellman (Appendix C). Raven Pro version 1.5 for Mac OS X interactive sound analysis software from The Cornell Lab of Ornithology was used to examine the frog calls.

Within the Raven Pro software, a Band Limited Energy (BLE) detector was configured for each of the 22 sample recordings. The BLE detector uses the sample recording data to create an algorithm to identify the frog calls within the larger field recordings (Charif et al., 2010). I ran the 22 BLE detectors through all of the 220 two and three-minute field recordings using Raven’s BLE batch detection mode (Appendix B).

Two BLE detectors were configured for the each of the 22 sample calls. The first
batch detector run used the following parameters: minimum frequency – SD, maximum frequency + SD, minimum and maximum duration, and minimum separation. Because *Leptodactylus savagei* had a minimum frequency of zero hertz, its standard deviation was not subtracted. For the second batch detector run, I used the same duration and separation parameters, but shortened the frequency range to minimum frequency + SD and maximum frequency – SD (Figure 4). Two of the sampled anurans had frequency ranges that were beyond the scope of the Raven Pro Nyquist frequency limits: *Craugastor stejnegerianus* and *Sachatamia albomaculata*. Therefore, these frogs were omitted from testing. During the first BLE batch detector run, *Cochranella granulosa* was omitted for the same reason. According to *Raven 1.4 User’s Manual*, “The highest frequency that can be represented in a digitized signal without aliasing is called the Nyquist frequency, and is equal to half the frequency at which the signal was digitized.”

![Figure 4](image_url)

**Figure 4.** Frequency ranges of the sampled anurans used to configure BLE detectors. The larger range of *C. granulosa* (2528 – 26625 Hz) was omitted to better view the graph.

- **BLE detectors, first run:** min freq – SD; max freq + SD
- **BLE detectors, second run:** min freq + SD; max freq – SD

After running each BLE batch detector through a field recording, Raven Pro saves a selection table. Then by opening a field recording and its coinciding selection tables, each frog call
may be viewed with a label in the waveform and spectrogram views. For example, in
Figure 5 the following frog species can be seen: *Scinax elaechrous, Hypsiboas rosenbergi, Diasporus diastema, Oophaga granulifera, Dendropsophus microcephala, Smilisca sordida,*
and *Trachycephalus venulosa.*

![Figure 5](image)

**Figure 5.** Close-up of waveform (a) and spectrogram (b) views, from a field recording conducted at Frog Pond on August 27, 2014 from 12:00 AM – 12:03 AM, before and after BLE detector labeling. Images exported from Raven Pro v. 1.5.
RESULTS

Only results from the second BLE batch detector run were included in Table 1 because shorter frequency ranges rule out more false positives (Charif et al.). Anuran species were detected at all of the tested ponds. *Smilisca sila* was detected at only two ponds in 2008 and at three ponds in 2014, while *L. savagei* was detected at three ponds in 2008, but not at any of the ponds in 2014.

**Table 1.** Distribution of anuran species among the tested ponds at the Firestone Center for Restoration Ecology in 2008 and 2014. The ponds sampled were Duck Pond (DP), Frog Pond (FP), Basilisk Pond (BP), and Mudd Pond (MP). Only anuran species identified using bioacoustic analysis are documented here.

<table>
<thead>
<tr>
<th>Species</th>
<th>2008</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DP</td>
<td>FP</td>
</tr>
<tr>
<td><em>Diasporus diastema</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Leptodactylus fragilis</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Leptodactylus bolivianus</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Leptodactylus savagei</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Agalychnis callidryas</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Dendropsophus ebraccatus</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Dendropsophus microcephalus</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Hypsiboas rosenbergi</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Scinax elaeochrous</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Trachycephalus venulosus</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Smilisca phaeota</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Smilisca sordida</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Smilisca sila</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Oophaga granulifera</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Hyalinobatrachium valerioi</em></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

As of 2014, the HB website lists 31 known frog species inhabiting their property (“Reptiles & Amphibians,” 2014). From the 2008 and/or 2014 recordings, 15 species were identified at FCRE ponds using bioacoustic analysis software and 2 species were identified in photographs, for a total of 16 identified frogs (Table 2). *Lithobates vaillanti* and *Dendrobates auratus* were not detected in the 2008 or 2014 recordings, and a BLE detector could not be configured for *Craugastor bransfordii* because a sample call could not be obtained.
Table 2. The documented anuran species from HB’s 2014 species list, FCRE’s 2007 species list, and the identified frog species from FCRE in 2008 and 2014. *L. savagei was detected in recordings from 2008, but photographed on the trail between Duck Pond and Frog Pond in 2014. **R. marina was not detected in any recordings, but was photographed at Duck Pond and observed on numerous locations on the FCRE property (Appendix A).

<table>
<thead>
<tr>
<th>Species</th>
<th>HB 2014</th>
<th>FCRE 2007</th>
<th>FCRE 2008/2014</th>
</tr>
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<tr>
<td>Diasporus diastema</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Diasporus vocator</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craugastor transfordii</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Craugastor crassidigitus</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craugastor fitzingeri</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craugastor rugosus</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craugastor stejnegerianus</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pristimantis ridens</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leptodactylus fragilis</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Leptodactylus bolivianus</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Leptodactylus poecilochilus</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leptodactylus savagei</td>
<td>X</td>
<td>X</td>
<td>*</td>
</tr>
<tr>
<td>Lithobates vaillanti</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agalychnis callidryas</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Agalychnis spurrelli</td>
<td>X</td>
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</tr>
<tr>
<td>Dendropsophus ebraccatus</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Dendropsophus microcephalus</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hypsiboas rosenbergi</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Scinax elaeochrous</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Trachycephalus venulosus</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Smilisca phaeota</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Smilisca sordida</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Smilisca sila</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dendrobates auratus</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Oophaga granulifera</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Siverstoneia flotator</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhinella marina</td>
<td>X</td>
<td>X</td>
<td>**</td>
</tr>
<tr>
<td>Rhaebo haematiticus</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cochranella granulosa</td>
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<td></td>
</tr>
<tr>
<td>Espadarana prosoblepon</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyalinobatrachium valerioi</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sachatamia albomaculata</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teratobyla pulverata</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

Using sound analysis software allows a user to distinguish frog-species calls by visually analyzing the differences in the waveform or spectrogram views. The visual appearance of acoustic components displayed in the spectrogram view is a useful tool for identifying individual frog species. The BLE detector in Raven Pro can bypass background noise levels by using user-defined parameters to extract acoustic components of a larger dataset.

Bioacoustic sound analysis software alone, however, is not enough to determine anuran populations in a given area. This experiment used only field recordings from the ponds at FCRE, but there are frogs that inhabit locations other than the ponds. This could explain why *L. vaillanti* and *D. auratus* were identified in 2007, but were not detected in the 2008 and 2014 test datasets (Table 2). According to www.iucnredlist.org, *Rhaebo haematiticus*, a frog that is documented on the HB species list (Table 2), does not call. Therefore this species would not be identified using sound analysis software.

Figure 6. Clockwise from top left: Song Meter wedged in a bamboo plant August 28, 2014; recorder approximately 10’ away from original location on August 29, 2014; turtle found approximately 25’ from the recorder.

Some drawbacks in using computer software to identify species include: false positives, false negatives, small sample sizes, scarce sample calls, and misclassified sample
calls. During the recording at Mudd Pond, August 28-29, 2014, something moved the Song Meter approximately 10 feet from its original location. Listening to the recording, a tapping sound can be heard. It is my assumption that a turtle moved the recorder (Figure 6). The tapping sound was identified by the *H. rosenbergi* BLE detector, an example of a false positive.

The sample call of *H. rosenbergi* was an adequate recording, but other sample calls, like that of *Agalychnis callidryas*, were scarce (Appendix A). The recording of *A. callidryas* contains only two calls. Therefore, the standard deviation calculated for the minimum and maximum frequencies may not be as reliable as a more ample sample call. Also, the scarce call only allows for two call-duration measurements and one call-separation measurement.

Of the 29 known anuran species at HB and FCRE, 7 sample calls could not be obtained to configure more BLE detectors. A problem that arose in locating sample calls is that frog species are often taxonomically reclassified, but the recording labels are not updated. For example, during my research in the spring of 2014, I obtained a sample recording of *L. pentadactylus* (Smoky jungle frog) and it was not until September, when I cross-referenced all of the frog species names, that I realized *L. pentadactylus* had been reclassified as *L. savagei*. Therefore, to locate sample recordings, one must search by previous genus-species names as well as current names. Also, without much experience, it is difficult to know if a recorded sample call is a distress call, advertisement call, aggressive call, etc. Ideally, the sample calls would be well annotated; however, that is not always the case.

This study identified the following 8 anuran species that are not on the current FCRE species list: *Leptodactylus fragilis, Leptodactylus bolivianus, Hypsiboas rosenbergi, Scinax elaeochrous, Trachycephalus venulosus, Smilisca sordida, Smilisca sila*, and *Hyalinobatrachium valerioi*.

As technology improves, so will the identification of species by bioacoustic analysis. Wildlife Acoustics currently has a recorder that is capable of storing more than one terabyte
of data (up to 260 hours of sound recording) (Overview, 2014). A more economical approach to hardware would include building inexpensive field recorders (Barichivich, n.d.). Though the datasets from these recorders might not be as high-quality as “commercial” recordings, the costs would allow for multiple recorders to be used simultaneously at different locations. This method would have worked well for my study because I could have recorded the four ponds, in addition to other locations on the property, at the same time over four days, giving me more data to analyze.

After constructing the graph in Figure 4, I could see the possibility of acoustic niche competition in which individuals in vocal species “compete for the use of the sound resource for communication” (Villanueva-Rivera, 2014). The graph shows the frequency ranges of the sample frog calls used to configure the 22 BLE detectors. Though the frequency ranges overlap, each frog species has a defined frequency range parameter. If a frog species goes extinct, would another frog species evolve its call frequency range to take over the available acoustic niche? Acoustic niche competition is an ongoing field of study (Chek et al., 2003; Farina et al., 2011; Guyer and Donnelly, 2005; Krause, 1993) and acoustic competition is a possible future topic of study at FCRE that may explain why there are some frogs inhabiting Hacienda Barú that have not been identified at the Firestone Center for Restoration Ecology.

ACKNOWLEDGMENTS

I would like to thank: Professor Donald McFarlane for being my advisor and mentor, and allowing me the opportunity to research the wonderful world of frogs’ songs; Professor Elise Ferree for giving detailed advice on my drafts; family, friends, and Pitzer College for funding related to this work; my son Jackson Snyder for accompanying me on hikes to move the field recorder around the FCRE; Jean Gillingwaters for keeping me focused during the writing process and editing my thesis; and my partner Christian Snyder for listening to me go on and on about Band Limited Energy detectors and for all the emotional support I have required through these trying college years.
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reproductive isolation in frogs of the Leptodactylus pentadactylus species cluster (Amphibia,


Appendix A

Sample Anurans

All species names were cross-referenced on www.iucnredlist.org. Waveform/spectogram images and selection table data from Raven Pro version 1.5 for Mac OS X. If too numerous, only data for the first ten calls are included in the selection tables. Photographs by author unless noted.
Diasporus diastema
Family: Eleutherodactylidae
English name: Tink frog

<table>
<thead>
<tr>
<th>Selection</th>
<th>Begin Time (s)</th>
<th>End Time (s)</th>
<th>Low Freq (Hz)</th>
<th>High Freq (Hz)</th>
<th>Delta Time (s)</th>
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<td>0.283</td>
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<td>3815</td>
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<td>4.419</td>
<td>2884</td>
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<td>6.443</td>
<td>2884</td>
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Craugastor fitzingeri
Family: Craugastoridae
English name: Fitzinger’s rain frog

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<th>High Freq (Hz)</th>
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<td>4.290</td>
<td>1067</td>
<td>5335</td>
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</tr>
<tr>
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<td>1067</td>
<td>4649</td>
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<td>3</td>
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<td>22.014</td>
<td>1245</td>
<td>4979</td>
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</table>

Photograph by William Flaxington
www.calphotos.berkeley.edu
Craugastor stejnegerianus
Family: Craugastoridae
English name: Stejneger’s rain frog

Photograph by Todd Pierson
www.calphotos.berkeley.edu

<table>
<thead>
<tr>
<th>Selection</th>
<th>Begin Time (s)</th>
<th>End Time (s)</th>
<th>Low Freq (Hz)</th>
<th>High Freq (Hz)</th>
<th>Delta Time (s)</th>
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<td>4.677</td>
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<td>15595</td>
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Photograph by Todd Pierson
www.calphotos.berkeley.edu
Leptodactylus fragilis
Family: Leptodactylidae
English name: White-lipped frog

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Leptodactylus bolivianus
Family: Leptodactylidae
English name: Black-spotted frog

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**Leptodactylus savagei**
Family: Leptodactylidae
English name: Smoky jungle frog

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Lithobates vaillanti
Family: Ranidae
English name: Vaillant’s frog

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Photograph by Todd Pierson
www.calphotos.berkeley.edu
Rhinella marina
Family: Bufonidae
English name: Cane toad

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**Agalychnis callidryas**  
Family: Hylidae  
English name: Red-eyed treefrog

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**Dendropsophus ebraccatus**  
*Family: Hylidae*  
*English name: Hourglass treefrog*

![Image of Dendropsophus ebraccatus](image-url)

Selection | Begin Time (s) | End Time (s) | Low Freq (Hz) | High Freq (Hz) | Delta Time (s) |
---|---|---|---|---|---|
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2 | 0.476 | 0.611 | 2140 | 3535 | 0.136 |
3 | 0.762 | 0.964 | 2297 | 3790 | 0.202 |
5 | 1.052 | 1.202 | 2067 | 3675 | 0.150 |
6 | 1.438 | 1.602 | 2067 | 3560 | 0.165 |
7 | 1.634 | 1.794 | 2067 | 3560 | 0.161 |
7 | 6.530 | 6.767 | 47 | 837 | 0.236 |

Photograph by Tobias Eisenberg  
www.calphotos.berkeley.edu
Dendropsophus microcephalus
Family: Hylidae
English name: Small-headed treefrog

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Photograph by Esteban Alzate
www.calphotos.berkeley.edu
Hypsiboas rosenbergi
Family: Hylidae
English name: Rosenberg’s treefrog

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**Trachycephalus venulosa**  
Family: Hylidae  
*English name: Sticky latex treefrog*

![Image of Trachycephalus venulosa](image_url)

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Photograph by Santiago Ron  
[www.calphotos.berkeley.edu](http://www.calphotos.berkeley.edu)
Smilisca phaeota
Family: Hylidae
English name: Masked treefrog

Photograph by William Flaxington
www.calphotos.berkeley.edu

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**Smilisca sordida**

**Family:** Hylidae  
**English name:** Drabbed treefrog

![Graph showing sound waveform with highlighted frequency bands](image)

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Photograph by Tobias Eisenberg  
www.calphotos.berkeley.edu
*Smilisca sila*

Family: Hylidae

English name: Pug-nosed treefrog

![Sound Waveform](image)

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Photograph by Justin Touchon

www.biogeodb.stri.si.edu
Scinax elaeochrous
Family: Hylidae
English name: Green-boned treefrog

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Dendrobates auratus
Family: Dendrobatidae
English name: Black and green dart frog

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Photograph by Todd Pierson
www.calphotos.berkeley.edu
Oophaga granulifera
Family: Dendrobatidae
English name: Granular poison dart frog

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Hyalinobatrachium valerioi
Family: Centrolenidae
English name: Green glass frog

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Sachatamia albomaculata
Family: Centrolenidae
English name: Yellow-flecked glass frog

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Photograph by Justin Touchon
www.biogeodb.stri.si.edu
Cochranella granulosa
Family: Centrolenidae
English name: Granular glass frog

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Photograph by Tobias Eisenberg
www.calphotos.berkeley.edu
Appendix B

How to Configure Band Limited Energy Detectors in Raven Pro version 1.5 for Mac OS X
(A simplified guide)

For a more in-depth explanation of detectors, see Raven 1.4 User's Manual Chapter 10 (Detection).
1. In Raven Pro, open the sample sound file that you will use to configure the detector.

2. If necessary, adjust the brightness and contrast for the spectogram view so that the parts of the call that are of interest will be more visible, change the color scheme (this example uses “cool”), and zoom in or out within the spectogram and waveform views.

3. In the toolbar, click *Create Selection Mode* and *Commit Selections Immediately*.

4. In the spectogram window, draw rectangles around the areas of interest.
5. To change the color of the selection labels, go to *view > color scheme > edit* and change the inactive selection border and label colors to something that contrasts with the spectogram background. (See *Raven 1.4 User’s Manual Chapter 11. Customizing Raven.*)

6. If window views will be exported to another program, change the setting in preferences:

```markdown
# Image preferences

raven.ui.image.resolution.export=72  # change to 600
raven.ui.image.resolution.copy=72
```

7. There is a dot at the bottom of the spectogram window. Drag this up to see the selection table. Right click in the selection table area > *choose measurements* and add *Delta Time (s).* Save the selection table. The default location of the saved files can also be changed in preferences.
8. Import the selection table into Microsoft Excel or other spreadsheet program. Calculate minimum frequency - SD, maximum frequency + SD, and separation time between calls.

9. In Raven, make sure the spectogram window is active. Go to view > Interactive Detector... > Band Limited Energy Detector. Configure the detector using the calculated values from Excel, include the lowest and highest values of duration and the lowest value of separation. To test the detector, run it against its corresponding sample call. If necessary, adjust values until the detector successfully identifies the call(s) within the sample file. Once you have a working detector, rejoice! you have just gotten through the most difficult part. In the upper left-hand corner of the detector window, click Preset and save the detector. Repeat for each sample call.

10. Memory Management
    If the testing dataset is large, it is best to adjust the memory heap size so that Raven will not crash. Go to Window > Memory Manager (I chose a heap size of 5,000MB).

11. When you are ready to run your detectors through the field recordings, go to Tools > Detector > Batch Detector. Drop down the Detector menu and select Band Limited Energy Detector. Under Files, click Add. Select all the field recording sound files. Click Configure Detector, Click Presets and select a detector to run. You may also adjust the location where Raven will save the selection tables.

12. Raven saves every detector run as a selection table. If your dataset is large, you can scroll through the file names (Finder, on a Mac) and sort by file size. Any file size of 80 bytes is a selection table without any detected sounds. Move these files to a different folder so they don’t get in the way.
Appendix C

Copyright Permissions
Email correspondence between Adrían García Rodriguez and Anna Alquitela regarding copyright/permission to use frog call recordings:

From: Adrián García garciar.adrian@gmail.com
Subject: Re: Copyright permission for frog calls
Date: March 26, 2014 at 12:49 PM
To: Anna Alquitela msanna412@mac.com

Dear Anna,
Feel free to use my recordings. I would love to know what’s your project about, maybe I will help you with something else.

Adrián

2014-03-26 16:08 GMT-03:00 Anna Alquitela <msanna412@mac.com>:
Dear Mr. Garcia-Rodriguez:

I am writing to request permission to use your 2009 recording of Craugastor stejnegerianus (Fonozoo recording #8909) and your 2008 recording of Cochranella granulosa (Fonozoo recording #8908) for use in my senior thesis on bioacoustic analysis of Costa Rican frog calls.

Please let me know if there is a fee for using your work in this manner. I appreciate your assistance.

Sincerely,

Anna Alquitela
Student, Pitzer College
Claremont, California USA
msanna412@mac.com

Museo de Zoología y Laboratorio de Autómatas y Sistemas Inteligentes en Biodiversidad
Escuela de Biología, Universidad de Costa Rica
Tel (506) 2511-5966

Email correspondence between William Duellman and Anna Alquitela regarding copyright/permission to use frog call recordings:

From: Duellman, Wm E. duellman@ku.edu
Subject: Release of recording
Date: March 27, 2014 at 8:14 AM
To: Rafael Marquez rmarquez@mncn.csic.es
Cc: msanna412@mac.com

Dear Rafael:

Please send to Anna Alquitela (msanna412@mac.com) the recording of Hyalinobatrachium valerioi (Fonozoo recording #8125).

Mil gracias,

Bill
Dear Anna,

We have received the written consent about the recordings FZ Code: 8908-8909 and 8125. You can download the recordings from

http://pc161111.mncn.csic.es/~muu/Anna/

Please, let us know when you have downloaded it to remove it from the server.

I am enclosing the terms of use of the recordings, please you can sign it and send it to us.

If we can be of more help, please don’t hesitate to contact us back and consider for the future depositing a copy of the possible recordings you may obtain yourself during field work in the Fonoteca Zoológica for a more secure preservation and ease of use for other researchers.

Best wishes

Fonoteca Zoológica
Dept. de Biodiversidad y Biología Evolutiva
Museo Nacional de Ciencias Naturales (CSIC)
José Gutiérrez Abascal, 2
28006 Madrid
Spain

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fax +34 91 5645078

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