

BIOACOUSTICAL AND ETHO-ECOLOGICAL FEATURES IN AMPHIBIAN COMMUNITIES OF SOUTHERN CORDOBA PROVINCE (ARGENTINA)

NANCY E. SALAS; MARÍA V. ZAVATTIERI; ISMAEL E. DI TADA; ADOLFO L. MARTINO
AND MARÍA E. BRIDAROLLI

Ecología, Departamento de Ciencias Naturales, Universidad de Río Cuarto, (5800) Río Cuarto, Argentina.

RESUMEN: El conocimiento de las características del canto de los anfibios constituye un importante elemento para la identificación de las especies que puede ser empleado como herramienta para prácticas estandarizadas de monitoreo. En el presente trabajo se resaltan las diferencias eto-ecológicas más notables (hábitat de reproducción, sitio de canto, actividad estacional y diaria) de aquellas especies que integran las comunidades del sur de la Provincia Córdoba y se proporciona una clasificación de los cantos nupciales. La batracofauna del área de llanura del sur-este de la provincia de Córdoba está representada por 9 especies de leptodactílidos correspondientes a 5 géneros (*Leptodactylus gracilis*, *L. mystacinus*, *L. latinasus latinasus*, *L. ocellatus*, *Pleurodema tucumanum*, *Physalaemus biligonigerus*, *Odontophrynus americanus*, *Ceratophrys cranwelli* y *C. ornata*), 2 especies de bufónidos (*Bufo arenarum* y *B. fernandezae*) y un hílido (*Hyla pulchella pulchella*). Los registros acústicos obtenidos en el campo durante el período reproductivo fueron analizados a través de programas de análisis digital de sonido, comparándose los siguientes parámetros: frecuencia dominante, duración del canto, intervalo entre cantos; se realizaron además descripciones respecto del tipo de canto y su modulación. Se reconocieron tres tipos de cantos básicos según su duración, categoría que fue subdividida por la forma de la imagen oscilográfica. El resultado de este análisis establece que existen notables diferencias entre los cantos nupciales, principalmente a nivel de rangos de frecuencia dominante y duración de las emisiones. Esta partición del espacio sonoro representa un mecanismo de aislamiento reproductivo que minimiza la interacción entre especies simpátricas cuya reproducción muestra también un solapamiento temporal.

Palabras claves: anfibios, anuros, comunidades, bioacústica, cantos nupciales.

ABSTRACT: Knowledge of the characteristics of amphibian calls is essential for species identification, and may be used as a tool in standardized monitoring practices. In the present work, the most important etho-ecological differences (reproduction habitat, call site, daily and seasonal activity) of species that constitute the communities of southern Cordoba Province are indicated, and a classification of advertisement calls is provided. The anuran fauna of the plain area of the southern-central Córdoba Province is represented by 9 species of leptodactylids belonging to 5 genera (*Leptodactylus gracilis*, *L. mystacinus*, *L. latinasus latinasus*, *L. ocellatus*, *Pleurodema tucumanum*, *Physalaemus biligonigerus*, *Odontophrynus americanus*, *Ceratophrys cranwelli* and *C. ornata*), 2 species of bufonids (*Bufo arenarum* and *B. fernandezae*) and one hylid (*Hyla pulchella pulchella*). The acoustic records obtained in the field during the reproductive period were analyzed through a program of sound digital analysis comparing the following parameters: dominant frequency, call duration and interval between calls; descriptions regarding type of call and modulation were also made. Three types of basic calls were recognized based on duration; this category was sub-divided depending on the shape of the oscillographic image. Results of this analysis reveal marked differences between advertisement calls, mainly at the level of dominant frequency ranges and call duration. This partition of sound space represents a mechanism of mating isolation that minimizes the interaction between sympatric species that breed at the same time.

Key words: amphibians, anuran, communities, bioacoustics, advertisement calls.

Introduction

Specific composition of an amphibian community in a given area depends markedly on general constraints among which environmental variables and predation play a predominant role (Blair, 1972; Barbault, 1991). Furthermore, the structure and dynamics of communities are also the result of interactions within the same trophic level; for that reason, competition plays an essential role in its organization (Inger & Colwell, 1977; Johnson *et al.*, 1996). Considering spatial and temporal dimensions, the structure of the community should then respond to reducing those specific interactions (Duellman, 1967; Fouquette, 1960)

Community studies, within a particular taxonomic level can be made by analyzing differences between species with respect to morphological and ethological features. Among ethological features, the anuran call is considered a significant feature in intraspecific communication (Barrio, 1964c; Wells, 1977; Duellman & Trueb, 1986; Gerhardt, 1987) allowing the characterization of each species according to a basic acoustic structure (Simking & Ilchev, 1965; Gayou, 1984; Höglund & Robertson, 1988; Steinwarz & Schneider, 1991; Vasara *et al.*, 1991) whose evolutionary significance relates to the maintenance of mating isolation (Drewry & Rand, 1983). Furthermore, acoustic characteristics of anuran species of a given region can be used for censusing anurans (Zimmerman, 1994).

Numerous studies indicate that the reproductive sites of anuran species in a given area are generally partitioned in time and space, either with regard to calling sites (Crump, 1974 and 1982; Collins, 1975; Creuser & Whitford, 1976; Littlejohn, 1959; Bogert, 1960; Duellman, 1967; Duellman & Pyles, 1983; Dixon & Heyer, 1968; Chaning, 1976) or female oviposition sites (Crump, 1974 and 1982).

In addition, if spacial or temporal overlap occurs, that is, if they reproduce sympatrically

or synchronically, the species will show only minimal overlap (if any) in acoustic variables of their advertisement calls favoring specific recognition and reducing the interaction between species.

In our country, few studies describe and analyze the call of species that make up the anuran fauna and they are limited to the pioneering works of Barrio (1953; 1964a; 1964b; 1965a; 1965b; 1965c and 1980). Reports concerning the ecological characteristics and main acoustic parameters of anuran species present in the southern area of Córdoba Province can be found in Cei (1980 and 1987).

The anuran fauna of this region is represented by Leptodactylidae, Bufonidae and Hylidae. For information on call parameters of leptodactylid species, see Barrio (1964a and b; 1965a and b; 1966 and 1980), Straughan & Heyer (1976) and Salas & di Tada (1994). Barrio (1965c) and more recently Basso and Basso (1987) gave information on acoustic characteristics of *Hyla pulchella pulchella*. We are aware of no reference for the bufonid species present in the study area, *Bufo arenarum* and *B. fernandezae*, except for general characteristics of the call for the former in Barrio (1964c).

The aim of the present work is to highlight the most outstanding etho-ecological differences, and provide diagnostic information about advertisement calls of those species that make up the communities of anuran amphibians of the southern-central plain of Córdoba Province.

Materials and methods

Description of the study area. The study area is located between 3300 and 3400 south latitude and between 6300 and 6500 west longitude (Figure 1) in the southern-central area of Córdoba Province. Three geomorphological regions are distinguished: 1) the north and central part of the study area is a vasculated platform with coarse

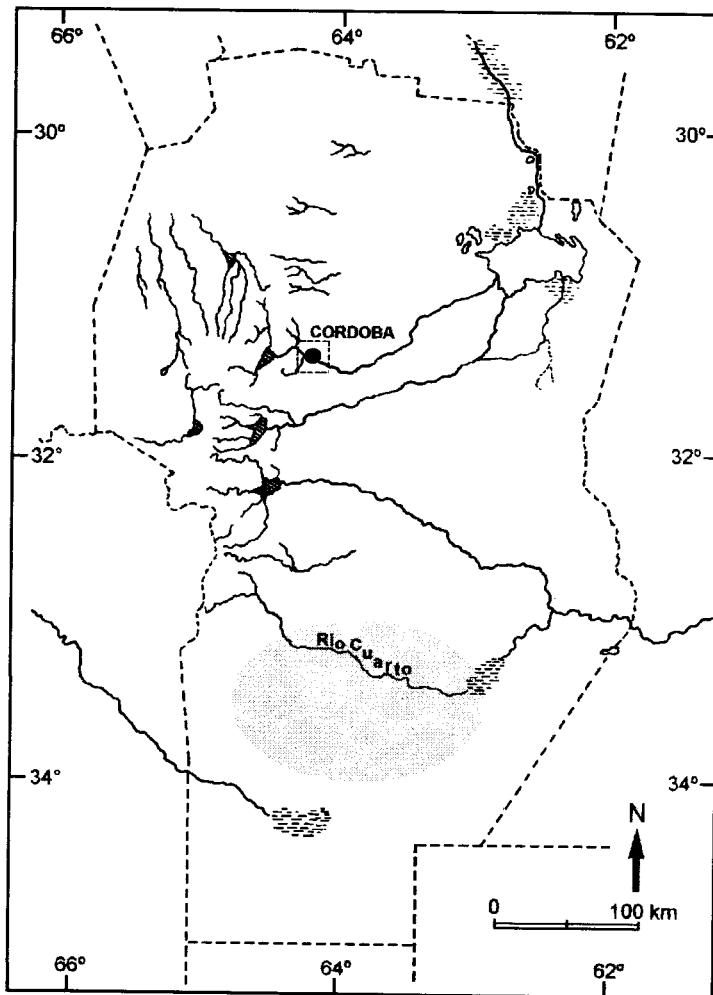


Figure 1. Geographic location of the study area (gray shadow) in south-central Córdoba Province, Argentina.

and permeable soils. In this region all the studied amphibians are present (12 species); 2) in the east, a flood plain distinguished by minimal altitude and reduced slopes, with abundant surface water courses and swamps. The amphibians present in this region are *Leptodactylus l. latinasus*, *L. gracilis*, *L. mystacinus*, *L. ocellatus*, *Physalaemus biligonigerus*, *Odontophrynus americanus*, *Bufo arenarum*, *B. fernadezae*, and *Hyla p. pulchella*; and 3) in the south-west, a dune plain with coarse, sandy and saline soils and well-developed dunes (Capitanelli, 1979b). In this

region are present *C. ornata*, *L. l. latinasus*, *P. biligonigerus*, *O. americanus*, and *B. arenarum*. With regard to the hydrology of the area, the active watershed of Río Cuarto or Conchancharagua river covers 1,450 km². The river-bed is 300 m wide, with an E direction and a NE diversion to the south of La Carlota, where swamplands and marshlands are formed as a consequence of the minimal slope. Seasonal variations are characterized by an increase of the river-bed in October-April and a considerable decrease from June to September, corresponding to

annual rainfall (Vázquez *et al.*, 1979).

The climate is mild-warm, subhumid in the east and semiarid in the south-east. Average temperatures reach 23.4°C in the summer, 5.8°C during the winter with frequent frosts in July. The annual average rainfall is 850 mm, with a period of maximum rain in October-March, and a period of minimum rain in April-September (Capitanelli, 1979a).

Finally, the province of Espinal ("District of Algarrobo"), the Pampa steppe and typical vegetation of swamplands and small lakes are phytogeographically represented in the area (Luti *et al.*, 1979).

Systematic list of species present in the area. The following classification was taken from di Tada *et al.* (1996a) and the presence of these species, considered by Bridarolli and di Tada (1994), was confirmed by capture, observation and call records. For each of these species, the main etho-ecological features: breeding habitat, call site, seasonal and daily activity, are described.

Order Anura Duméril, 1804

Suborder Neobatrachia Reig, 1958

Superfamily Bufonoidea Fitzinger, 1826

Family **Leptodactylidae** Werner, 1896

Subfamily Ceratophryinae Tschudi, 1838

Genus *Ceratophrys* Wied, 1824

1. *Ceratophrys cranwelli* Barrio, 1980
2. *Ceratophrys ornata* (Bell, 1843)

Subfamily Telmatobiinae Fitzinger, 1843

Genus *Odontophrynus* Reinhardt & Lutken, 1862

3. *Odontophrynus americanus* (Duméril & Bibron, 1841)
4. *Odontophrynus occidentalis* (Berg, 1896)

Subfamily Leptodactylinae Berg, 1896

Genus *Leptodactylus* Fitzinger, 1826

5. *Leptodactylus latinasus latinasus* Jiménez de la Espada, 1875
6. *Leptodactylus gracilis* (Duméril & Bi-

bron, 1841)

7. *Leptodactylus mystacinus* (Burmeister, 1861)

8. *Leptodactylus ocellatus* (Linnaeus, 1758)

Genus *Physalaemus* Fitzinger, 1826

9. *Physalaemus biligonigerus* (Cope, 1860)

Genus *Pleurodema* Tschudi, 1838

10. *Pleurodema tucumanum* Parker, 1927

Family **Bufonidae** Gray, 1825

Genus *Bufo* Laurenti, 1768

11. *Bufo arenarum* Hensel, 1867

12. *Bufo fernandezae* Gallardo, 1957

Family **Hylidae** Hallowell, 1857

Subfamily Hylinae Gray, 1825

Genus *Hyla* Laurenti, 1768

13. *Hyla pulchella pulchella* Duméril & Bibron, 1841

Analysis of acoustic records. Between 1991 and 1996, recordings of the advertisement calls of the above species were obtained from the beginning of the reproductive period (September) to mid-Autumn (May), at dusk and during the first hours of the night (07.00 to 12.00 pm). For bioacoustic recordings in the field, we used the instruments and techniques described by Salas and di Tada (1994) and di Tada *et al.* (1996b).

In the laboratory, the recording signals were digitalized and analyzed with software for digital sound acquisition and measurement (Canary, version 1.2, 1995). A total of 508 calls from 42 individuals (12 species) were analyzed. Using oscillograms, sonograms and spectrograms obtained for each species, calls were characterized by the following parameters, according to the terminology suggested by Heyer *et al.* (1990): the number of notes per call (NC), call duration (CD), interval between calls (IC), note duration (ND), interval between notes (IN) and dominant frequency (RDF: range of dominant frequency and DF: highest intensity-frequency).

Means and standard deviations were cal-

Species	Variable	DFR (Hz), DF (Hz)	CD (msec)	IC (msec)
<i>C. cranwelli</i>	2;13	1400-1900 (1695)	338.24 ± 19.27	1002.88 ± 544.78
<i>C. ornata</i>	1;13	1500-2500 (2000)	270.00 ± 7.57	1735.92 ± 440.84
<i>O. americanus</i>	5;37	900-1300 (1075)	368.16 ± 30.90	1433.48 ± 222.27
<i>L. l. latinasus</i>	5;74	2900-3500 (3220)	65.09 ± 3.26	337.00 ± 64.18
<i>L. gracilis</i> ¹	6;96	900-2200 (1808)	57.18 ± 1.74	267.42 ± 45.54
<i>L. mystacinus</i>	6;80	1900-2400 (2067)	43.30 ± 3.98	201.31 ± 29.03
<i>L. ocellatus</i>	1;58	80-680 (175)	308.84 ± 62.33	3616.74 ± 1538.26
<i>P. biligonigerus</i>	5;31	300-3300 (1750)	773.29 ± 92.01	3523.92 ± 1225.65
<i>P. tucumana</i>	2;35	2300-2700 (2500)	241.44 ± 23.13	365.71 ± 27.22
<i>B. arenarum</i>	3;17	950-1500 (1250)	4019.41 ± 1062.28	2307.50 ± 2583.90
<i>B. fernandezae</i>	2;31	2100-3200 (2400)	3858.45 ± 480.71	9408.57 ± 4446.60
<i>H. p. pulchella</i> ¹	2;23	2200-2600 (2300)	141.94 ± 26.47	465.37 ± 444.24

Table 1. Main acoustic parameters of anuran species of southern Córdoba Province obtained at air temperature from a range of 19 to 28°C (numbers in brackets means number of individuals and total number of calls analyzed). For the range of dominant frequency (RDF), the greatest intensity-frequency (DF) or amplitude peak employed for graphic representation is indicated in brackets. For temporal variables CD (msec) or IC (msec), the means and standard deviations are indicated.

(1) *Leptodactylus gracilis* and *Hyla pulchella pulchella*, show mating calls made up of two notes. For *L. gracilis*, although the notes are clearly distinguished on the oscillogram, they are not separated by an interval, and their average duration (ND) is 20.47 (1.25) msec for the first note and 32.78 (1.22) msec for the second note. Both notes in *H. p. pulchella* have a duration of 16.62 (7.11) msec and 39.14 (9.21) msec, but they are separated by an interval (IN) of 86.44 (20.93) msec.

culated for each temporal variable. The dominant frequency (DF) in relation to call duration (CD) was bidimensionally represented (Figure 3). From the latter characteristic, classification of advertisement calls of the species that make up the communities of southern Córdoba Province (Argentina) is provided.

Results

Etho-ecological features and call description. The main etho-ecological features obtained from samplings taken during five successive seasons (1991-1996) and from the literature (Barrio, 1953, 1964a, b and c; 1965a, b and c, 1966, 1980; Basso and Basso, 1987; Cej, 1980, 1987) are summarized, with a brief call description, for each species.

1. *Ceratophrys cranwelli*

Breeding Habitat: Temporary waters and permanent small lakes. Call site: In water, mud or open flooding sites. Seasonal activity: During spring rains. Daily activity: From dusk to dawn (occasional observations). Call description: Monotonous call, similar to a bass horn.

2. *Ceratophrys ornata*

Breeding Habitat: Temporary waters and permanent small lakes. Call site: In water, mud or open flooding sites. Seasonal activity: During spring rains. Daily activity: From dusk to dawn. Call description: Similar to *C. cranwelli* but shorter and higher-pitched.

3. *Odontophrynus americanus*

Breeding Habitat: Streams, small lakes and temporary ponds. Call site: Semi-sub-

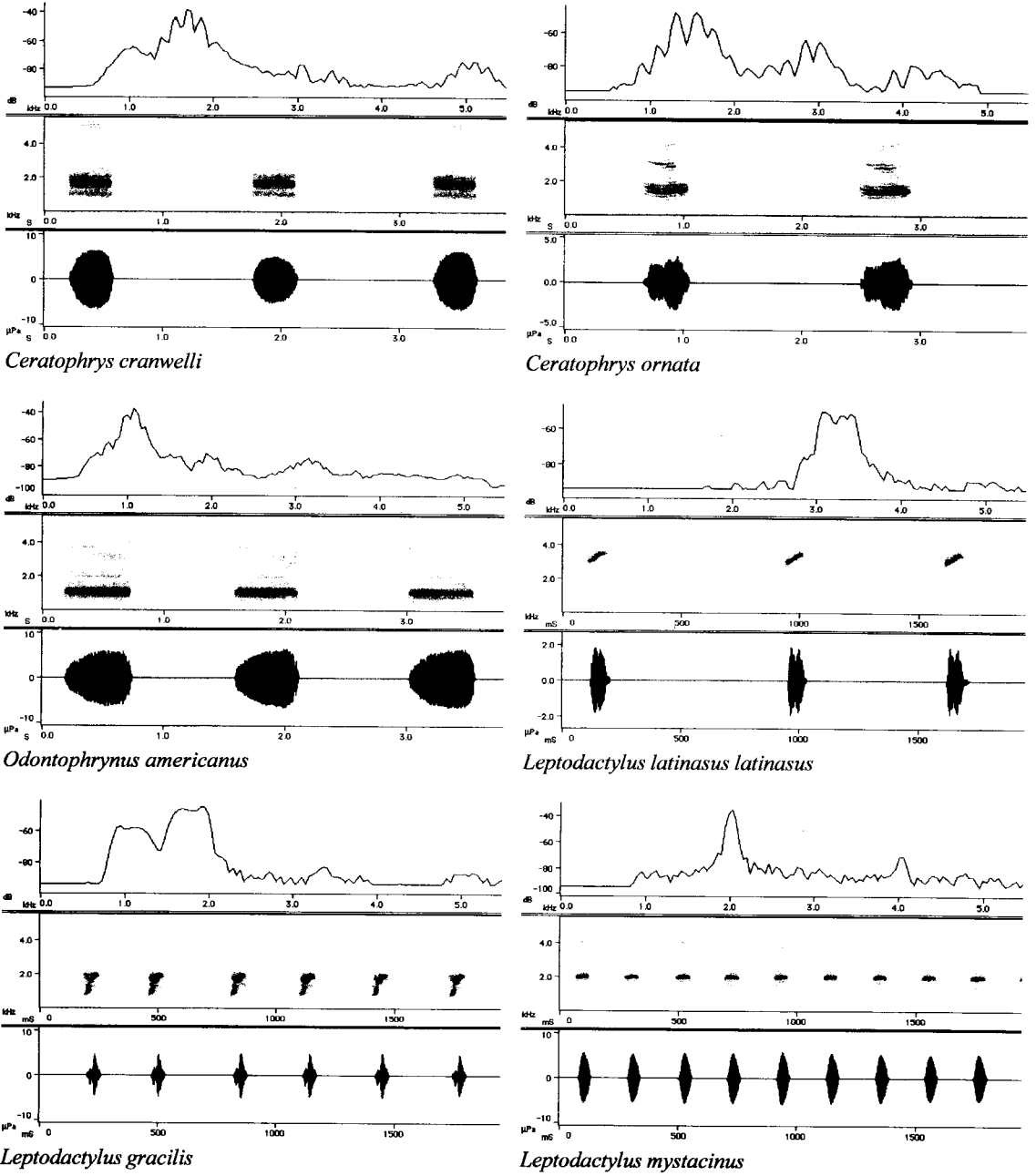


Figure 2. Spectrograms, sonograms and oscillograms for the twelve anuran species analyzed of southern-central Córdoba Province, Argentina.

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2. *Ceratophrys ornata*

Breeding Habitat: Temporary waters and permanent small lakes. Call site: In water, mud or open flooding sites. Seasonal activity: During spring rains. Daily activity: From dusk to dawn. Call description: Similar to *C. cranwelli* but shorter and higher-pitched.

3. *Odontophrynus americanus*

Breeding Habitat: Streams, small lakes and temporary ponds. Call site: Semi-sub-

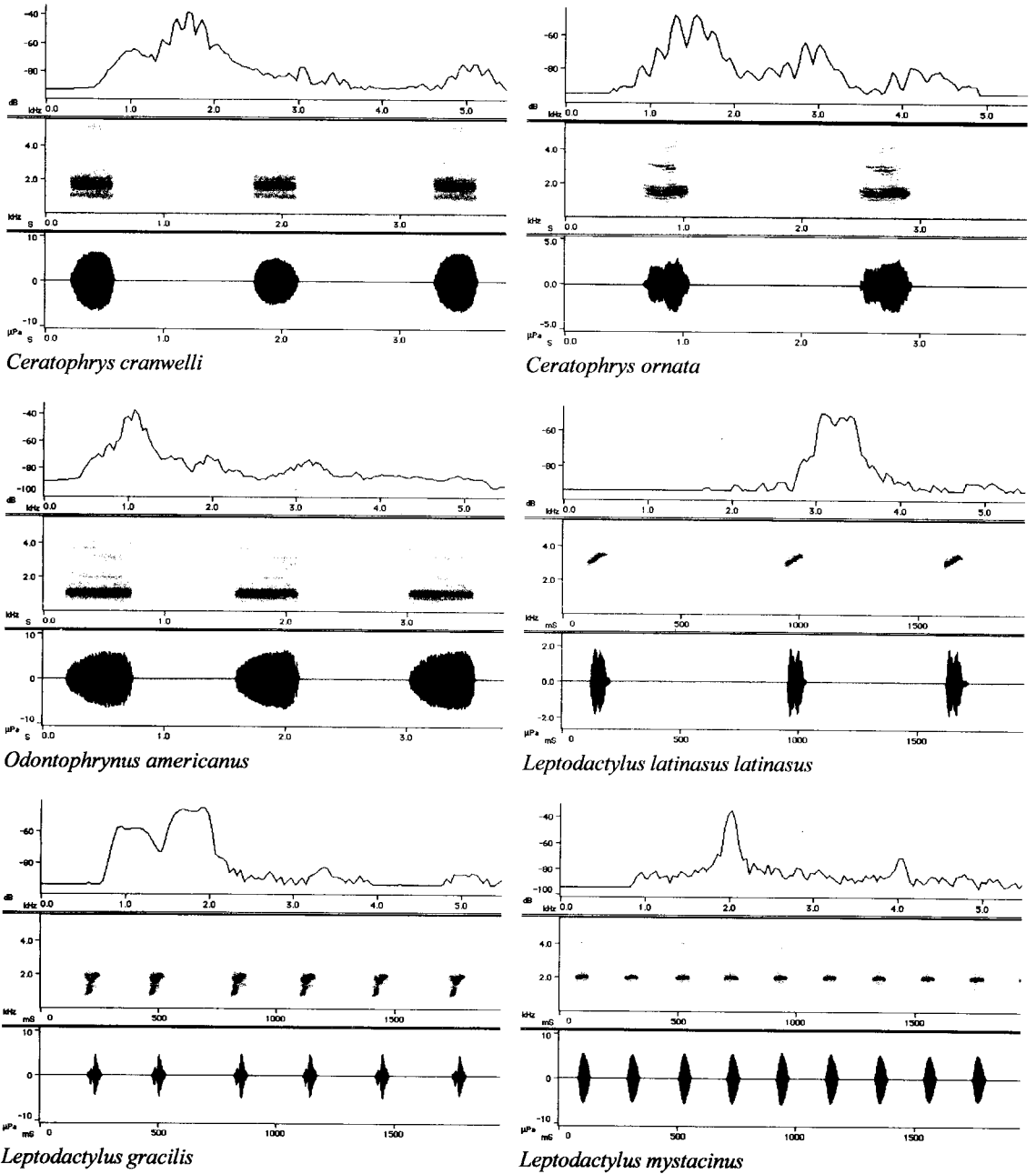


Figure 2. Spectrograms, sonograms and oscillograms for the twelve anuran species analyzed of southern-central Córdoba Province, Argentina.

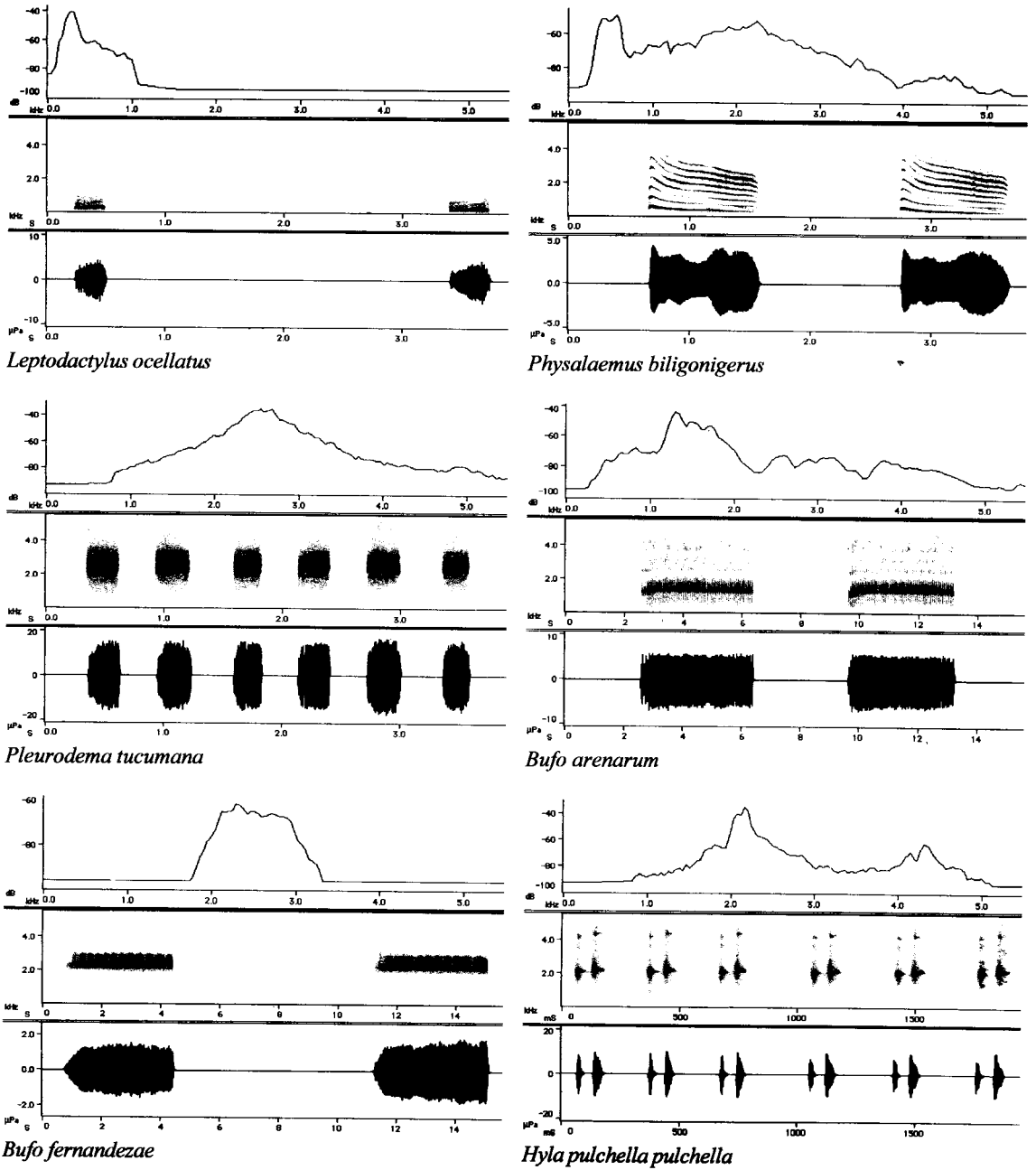


Figure 2 (cont.). Spectrograms, sonograms and oscillograms for the twelve anuran species analyzed of southern-central Córdoba Province, Argentina.

merged, in shelters or open spaces. Seasonal activity: During spring and summer. Daily activity: At night. Call description: Monotonous, low-pitched.

4. *Leptodactylus latinasus latinasus*

Breeding Habitat: Fossorial. Call site: Hidden under rocks, trunks or in cavities. Seasonal activity: Late spring, depending on availability of temporary water. Daily activity: Higher frequency from dusk to midnight. Call description: Short, metallic and high-pitched call.

5. *Leptodactylus gracilis*

Breeding Habitat: Fossorial. Call site: In cavities in the mud. Seasonal activity: Late spring. Daily activity: Higher frequency at dusk and the first hours in the night. Call description: Short, high-pitched call, similar to a water drop.

6. *Leptodactylus mystacinus*

Breeding Habitat: Fossorial. Call site: In cavities in the mud. Seasonal activity: Late spring. Daily activity: At night. Call description: Short, high-pitched call, similar to a whistle.

7. *Leptodactylus ocellatus*

Breeding Habitat: Streams and permanent small lakes. Call site: In water, on vegetation. Seasonal activity: From mid-spring to the end of summer. Daily activity: Mainly from dusk to dawn. Call description: Low-pitched call, similar to an eagle owl.

8. *Physalaemus biligonigerus*

Breeding Habitat: Swamplands and temporary ponds. Call site: In water, sitting on gramineous plants or floating. Seasonal activity: November-January, with a peak of activity at the beginning. Daily activity: At night and dawn. Call description: Call similar to a cat's miaowing.

9. *Pleurodema tucumanum*

Breeding Habitat: Permanent or tempo-

rary waters with a slight salinity. Call site: By edge of river. Seasonal activity: Regulated by rains, short cycles. Daily activity: Calling during the day and night. Call description: High-pitched call, similar to an insect's stridulation.

10. *Bufo arenarum*

Breeding Habitat: Streams, rivers, small lakes or dammed-up waters. Call site: By edge of river or semi-submerged. Seasonal activity: August-April, with peaks during spring rains. Daily activity: With higher frequency at dusk and night. Call description: Long, monotonous and pulsated call.

11. *Bufo fernandezae*

Breeding Habitat: Small lakes, ditches and temporary ponds. Call site: By edge of river side or semi-submerged. Seasonal activity: Depending on seasonal rains. Daily activity: With higher frequency at dusk and night. Call description: Long, monotonous call, similar to a cicada chorus.

12. *Hyla pulchella pulchella*

Breeding Habitat: Small lakes, ponds and streams. Call site: On the aquatic vegetation. Seasonal activity: October-May, with peaks at the end of the summer. Daily activity: From dusk to dawn. Call description: High-pitched, metallic and bipulsated call.

Results of the acoustic analysis for the all species: range of dominant frequency, greatest intensity frequency, call duration, and intervals between calls are shown in Table 1. The spectrograms, sonograms and oscillograms are shown in Figures 2. Based on our analysis, the following classification is provided for a simple diagnosis of advertisement calls based also on the shape of the oscillographic image. Although the presence of *Odontophrynus occidentalis* has been registered for the area (Ceï, 1980; di Tada *et al.* 1996), we were unable to localize any specimens for this study.

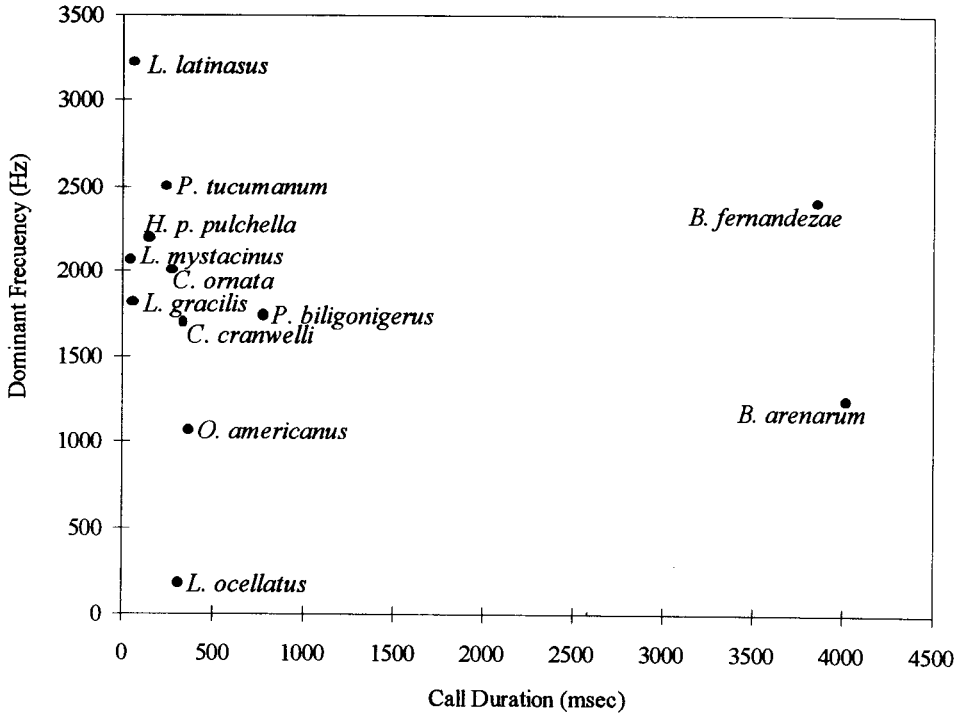


Figure 3. Bidimensional representation of the mean value of dominant frequency and call duration for the total number of anuran species present in south-central Córdoba Province.

- Short calls, duration 200 msec, triangular oscillograms (great amplitude-start and gradual extinction)
- Simple calls, without modulation *Leptodactylus mystacinus*
- Calls constituted by two notes, with modulation.
- With interval between notes. The first note is not modulated and with lower frequency than the second note..... *Hyla pulchella pulchella*
- Without interval between notes.
- Notes with similar amplitude and modulated frequency in both *Leptodactylus latinasus latinasus*
- The first note with a significantly lower amplitude than the second one, modulated frequency in both notes..... *Leptodactylus gracilis*
- Long calls, duration 200-1000 msec
- Oscillogram with an approximately oval shape. It starts with an increasing amplitude and decreases towards the end of the call with no abrupt changes.
- Oval oscillogram that starts and finishes with great amplitude..... *Pleurodema tucumanum*
- Oscillogram that starts and finishes gradually.
- Sonogram with a narrow range of dominant frequency (80-680 Hz) and very low *Leptodactylus ocellatus*
- Sonogram with a wide range of frequency (500-700 Hz)
- Low-pitched call, with average value of dominant frequency of 1075 Hz..... *Odontophrynus americanus*
- Average value of dominant frequency 1695 Hz..... *Ceratophrys cranwelli*
- Nonoval, approximately spindle-shaped oscillogram.
- Sonogram markedly modulated towards lower frequencies..... *Physalaemus biligonigerus*
- Sonogram without a marked modulation..... *Ceratophrys ornata*
- Very long calls, duration 1000 msec
- Call pulsed with well-defined pulse trains..... *Bufo arenarum*
- Oscillogram with irregular amplitude without trains of differentiating pulses..... *Bufo fernandezae*

Discussion and conclusions

Results obtained from the acoustic analysis for most of the species that constitute the communities of this area are compared with the limited number of specific references on these species with respect to the frequency or duration of their emissions (Barrio, 1964a and b; 1965a, b and c, 1966 and 1980; Straughan & Heyer, 1976; Cei, 1980, 1987; Basso and Basso, 1987), with the limitation of methodological, instrumental and geographical differences between those studies and the present one. No specific references for the *Bufo arenarum* and *B. fernandezae* calls were found.

In general, frequencies coincide with those recorded by these authors, even though we have only considered the range of dominant frequency (Table 1) for our results. With respect to temporal variables, the lack of coincidence can be explained in terms of the great influence of factors such as temperature that may affect call duration and interval between calls. In addition this information is not always available in the literature.

The species considered here show seasonal activity corresponding to that of spring and summer, with a higher or lower dependence on rainfalls depending on the species. Although the duration of daily activity may vary, during the early hours of the evening, mixed choirs of *Leptodactylus gracilis*, *L. l. latinasus*, *L. mystacinus*, *L. ocellatus*, *Physalaemus biligonigerus*, *Bufo arenarum* and *Odontophrynus americanus* are frequent. These species are often found together because of their distribution and abundance. Of the 12 species included here, *Leptodactylus gracilis*, *L. l. latinasus* and *L. mystacinus* differ considerably from the others in their microhabitat because their fossorial behavior. The other species coexist in the same breeding places using temporary and permanent water.

The three fossorial species *Leptodactylus l. latinasus*, *L. mystacinus* and *L. gracilis* avoid overlapping calls by having large differences

in dominant frequency (3000 Hz, 2022 Hz, 1673 Hz respectively). *L. ocellatus*, *Physalaemus biligonigerus*, *Bufo arenarum*, *Odontophrynus americanus*, *Ceratophrys ornata* and *Hyla p. pulchella*, coexist in the same locality, and their frequency ranges overlap partially (Table 1). However, there are differences in the dominant frequency values from 274 Hz (*L. ocellatus*) to 2100 Hz (*H. p. pulchella*) (Table 1).

Thus, according to the results obtained (Table 1, Figure 3), and those discussed by other authors, anuran species coexist by partitioning space and/or acoustic time (call frequency and duration) when the reproductive phenomenon implies spatial or temporal overlap, particularly for communities with a high diversity of species like southern-central Córdoba Province.

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