# UNDERWATER VOCALIZATION BY THE FOOTHILL YELLOW-LEGGED FROG (*RANA BOYLII*)

LAINE MacTAGUE, Department of Biology, Sonoma State University, 1801 East Cotati Avenue, Rohnert Park, CA 94928

PHILIP T. NORTHEN, Department of Biology, Sonoma State University, 1801 East Cotati Avenue, Rohnert Park, CA 94928

*1993 TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 29: 1-7*

*Abstract*: The foothill yellow-legged frog (*Rana boylii*) is a Species of Special Concern in California and a Category 2 Candidate for Federal listing. In April and May of 1991, in and along Santa Rosa Creek, Sonoma County, we used an aerial microphone and a hydrophone to obtain recordings of its vocalizations. Except for faint aerial calls given while a frog was clasped about the pectoral girdle by an investigator, the sounds were produced while the frogs were completely immersed in water. Representative tape recordings were analyzed by computer using the MacSpeech Lab II program. Five different vocalizations were identified: a short, unpulsed call; a short, pulsed call given when frogs were clasped by the investigator; pulsed calls of two intermediate lengths; and a long call in which groups of pulses are clustered into notes. The extensive vocabulary of the frog suggests that it may use vocalizations for a number of behavioral functions, such as advertisement of territory, vocal defense of territory, and attraction of mates. This previously-unreported phenomenon of underwater vocalization by *R. boylii* has at least three implications for management: (1) hydrophones could potentially be used in field censuses to enhance the detection abilities of surveyors during the breeding season; (2) phonic aspects of the phenotype should be used in conjunction with molecular, morphometric, and other traits in studies of geographic variation; and (3) habitat analyses should be done with an awareness that calling males may have requirements that differ from those of egg-laying females.

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The foothill yellow-legged frog (*Rana boylii*) is a member of the family Ranidae that historically occurred primarily in small to mid-sized streams of low to middle elevations in California and southwestern Oregon (Stebbins 1985; Zweifel 1955, 1968), with an isolated population in northern Baja California (Loomis 1965). Due to declines in the southern and central part of its range (Hayes and Jennings 1986, 1988), the species has been designated as a Species of Special Concern by the California Department of Fish and Game (Anonymous 1992) and as a Category 2 Candidate for Federal listing (Drewry 1991). Surveys for its presence are typically required by resource agencies in conjunction with land use permitting, and its habitat may be altered by management for other species (Fuller and Lind 1992).

Several verbal descriptions of the call of *R. boylii* exist in the literature. Stebbins (1985:86) provides this one: "Seldom heard. A guttural, grating sound on one pitch or with rising inflection, a single croak lasting 1/2 to 3/4 sec. Four or 5 croaks may be given in rapid series followed by a rattling sound, the entire sequence lasting about 2 1/2 secs." In his 1962 handbook, Stebbins (1962:340) identifies this description as one based on laboratory observations.

Zweifel (1955:215) heard two call types in the laboratory: a "...series of croaks given by males or females in response to attempted amplexus," and "a more protracted croak given occasionally by frogs unstimulated by contact with others." He also summarized information on field observations of others, stating that Richard Russell (pers. commun.) noted that the calls were similar to those of the leopard frog (*R. pipiens*) and, quoting Storer from Stebbins (1951:340) "Storer (MS) heard individuals croaking during the afternoon. The several males in a given area tended to join in voice for a few notes but lacked the synchronism common in a Pacific tree-toad [the Pacific treefrog (*Pseudacris regilla*)] chorus."

Despite these descriptions indicating that some considerable vocal repertoire exists in *R. boylii*, the experience of most field investigators, as connoted in Stebbins' use of "seldom heard" in the description above, is that the species is not often heard in the field (for example Amy Lind, pers. commun.). Mark R. Jennings reported, however, (pers. commun.) that Joseph R. Copp, Research Associate, Department of Herpetology, California Academy of Sciences, heard an extensive chorus under field conditions during a rainstorm in Santa Barbara County in 1958. Jennings has also heard vocalizations frequently in the laboratory (pers. commun.).

Licht (1969; see also Storm 1960 and Brown 1975) reported that male red-legged frogs (*R. aurora aurora*) in British Columbia call while completely submerged. We hypothesized that the same could be true of *R. boylii* as this species lacks vocal sacs like *R. a. aurora*, potentially aiding it in underwater vocalization (Hayes and Krempels 1986). By use of a hydrophone to obtain underwater recordings, we discovered that *R. boylii* does indeed call while submerged. One purpose of this paper is to provide a preliminary classification, sonographic depiction, and summary statistical description of these vocalizations. A

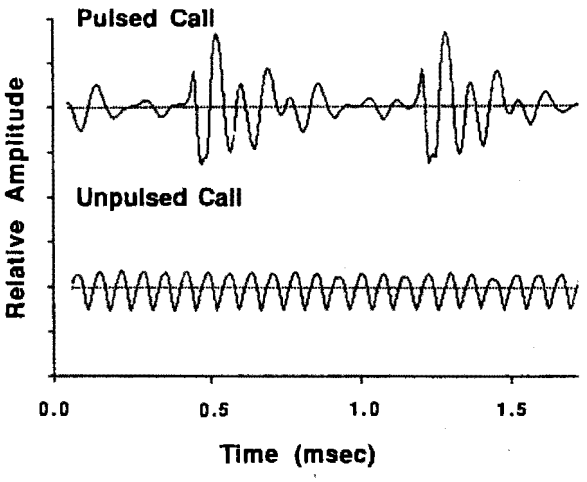


Fig. 1. Wave forms of segments of a pulsed and an unpulsed call of *Rana boylii*. For each call, positive sound pressure is depicted above the dashed line, negative pressure below, designated as "relative amplitude." Units are arbitrary, and are not necessarily the same for the two calls.

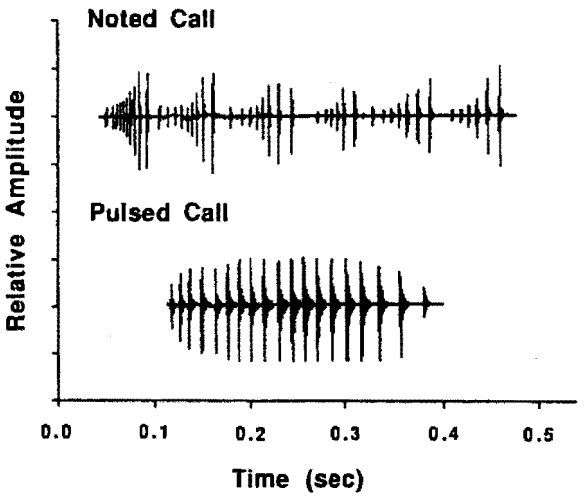


Fig. 2. Wave forms of segments of a pulsed and a noted call of *Rana boylii*. For each call, positive sound pressure is depicted above the dashed line, negative pressure below, designated as "relative amplitude." Units are arbitrary, and are not necessarily the same for the two calls.

second is to discuss the implications of underwater vocalization in this species for our understanding of its social behavior and of how the species can be conserved.

## STUDY AREA

Recordings were made from Santa Rosa Creek, Sonoma County, California, approximately 3.2 km upstream from State Highway 12 at an elevation of 200 m. This second-order section of the stream is typical of the *R. boylii* habitat described in Hayes and Jennings (1988), and consists of swift-flowing riffles that alternate with slower-flowing pools. Recordings were all from a single 4 m x 12 m pool bounded upstream and down by faster water. Depths ranged from 0.2-1 m. The channel in this pool was rock-based, with small boulders in the center of the pool and cobbles, gravel and sand in the shallow sections. At the study pool, Santa Rosa Creek was bounded on the north by steep, chaparral-covered slopes and on the south by a mixed-evergreen forest association dominated by bay (*Umbellularia californica*) and Douglas-fir (*Pseudotsuga menziesii*). The pool received full sunlight during midday of the study period, but was shaded during early morning and late afternoon by steep slopes on its south side.

## METHODS

Recordings were made between 1500 and 2400 hrs on April 19, and on May 1, 3, and 9, 1991, at water temperatures of 10-12°C. A Marantz PMD 430 stereophonic cassette recorder was used to tape record vocalizations. We recorded aerial calls through a Sony ECM 260F omnidirectional microphone, while a Deepsea Power and Light Sm-1000 hydrophone was used underwater.

Recording was centered under and around a large, half-submerged, 0.5 x 1.5-m rock in the shallow, downstream section of the study pool. The upstream edge of this rock overhung the creek bed by about 0.3 m, providing underwater cover. We were aware of 2-5 adult frogs in the area at most times.

Calls from representative tape segments were digitized at a rate of 20 KHz into the MacSpeech Lab II program (GW Instruments, Somerville, MA) on a Macintosh IIcx computer. This sampling rate allowed resolution of frequencies to 10 KHz, which encompassed the important portions of all calls. *Duration* was measured from the first to last portion of the call that was evident in a wide bandpass sonogram. *Dominant frequency* was measured as the peak of highest amplitude in a fast

Table 1. Characteristics of five types of calls of *Rana boylii* (see Fig. 3 for representative sonograms).

| | Squeak | Release | Short Croak | Long Croak | Rattle |
|---|---|---|---|---|---|
| N | 7 | 7 | 21 | 11 | 16 |
| % Pulsed | | | | | |
| Mean | 0 | 100 | 100 | 100 | 98.7 |
| St. Dev. | 0 | 0 | 0 | 0 | 4.11 |
| % Noted | | | | | |
| Mean | 0 | 0 | 0 | 0 | 96.7 |
| St. Dev. | 0 | 0 | 0 | 0 | 11.5 |
| Duration, sec | | | | | |
| Mean | 0.142 | 0.141 | 0.421 | 0.657 | 1.794 |
| St. Dev. | 0.021 | 0.017 | 0.055 | 0.051 | 0.572 |
| Dominant Frequency, KHz | | | | | |
| Mean | 1654 | 812 | 1157 | 1594 | 1138 |
| St. Dev. | 613 | 48 | 737 | 991 | 261 |
| Pulses/sec | | | | | |
| Mean | n.a. | 70.7 | 57.4 | 100.9 | 106.8 |
| St. Dev. | | 16.7 | 44.4 | 17.0 | 26.3 |
| Notes/sec | | | | | |
| Mean | n.a. | n.a. | n.a. | n.a. | 12.5 |
| St. Dev | | | | | 2.01 |
| Tuning, dB | | | | | |
| Mean | 35.7 | 16.1 | 19.7 | 12.3 | 16.3 |
| St. Dev. | 3.15 | 1.88 | 5.92 | 8.94 | 6.12 |

calls have most or all of their sound consisting of notes. As the call is given, the notes become successively longer and more slowly pulsed. The overall pulse rate within the notes is similar to that of the release calls, the more rapidly pulsed of the short croaks, and the long croaks.

## DISCUSSION

Underwater vocalization may be more common in ranid frogs than previously realized. In addition to *R. a. aurora* discussed above, Platz (1993) has discovered the phenomenon in *R. subaquavocalis*, a new species of the *R. pipiens* complex in Arizona.

The nature of the vocalizations produced by *R. boylii* are similar to those of other ranids (for example Mecham 1971, Schneider and Egiasarjan 1991), but a detailed comparison with calls of such species is beyond our purpose here. Except for the release call, we have chosen not to use call names that imply function until experimental data can be obtained.

Within *R. boylii* the squeak and rattle are distinctive call types, but the other three have overlapping qualities. Since our release calls represented one individual, and the others a small number of individuals, these intermediate-duration, pulsed calls without notes are best considered a graded series. Analysis of more individuals could show considerable overlap among them even though our cluster analysis separated them into distinct groups.

The description of the vocalizations of this species provided by Stebbins (1985) is consistent with our analysis. The failure of field observers to develop similar descriptions appears largely due to the fact that the frog sound does not conduct well from natural aquatic habitats into the air, and frogs are heard by ear only under specific

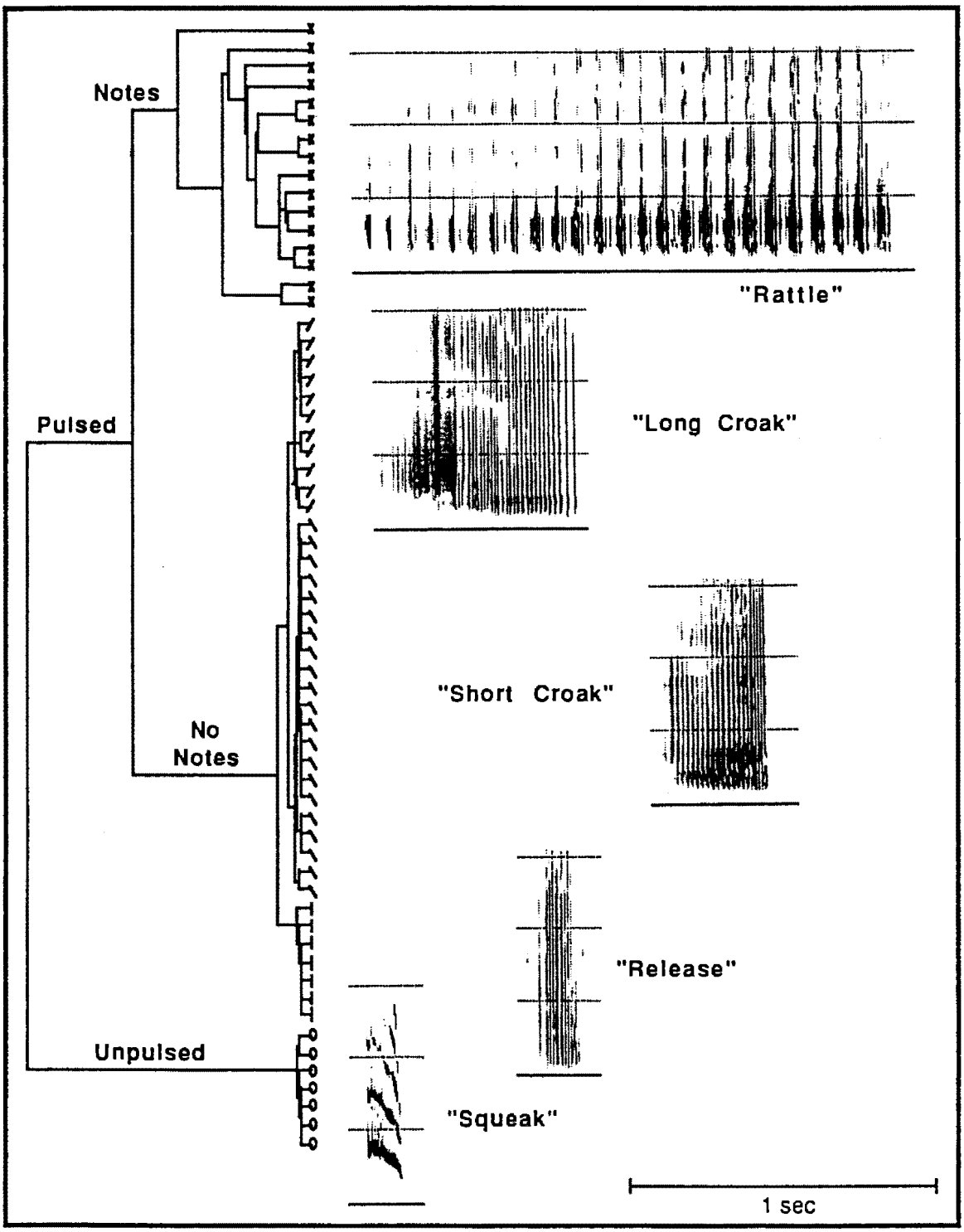


Fig. 3. Cluster diagram of five types of *Rana boylii* calls, based on duration, percent pulsed, and percent noted. A sonogram of a typical call of each type appears to the right of the associated set of points in the cluster diagram, which has been compressed horizontally and expanded vertically to allow space for the sonograms. Within sonograms, the vertical dimension is frequency with each dashed line representing 2 KHz. The horizontal dimension is time with a scale indicated by the "1 sec" bar. See Table 1 for numerical data.