Submerged Calling by Oregon Spotted Frogs (*Rana pretiosa*) Remote from Breeding Aggregations

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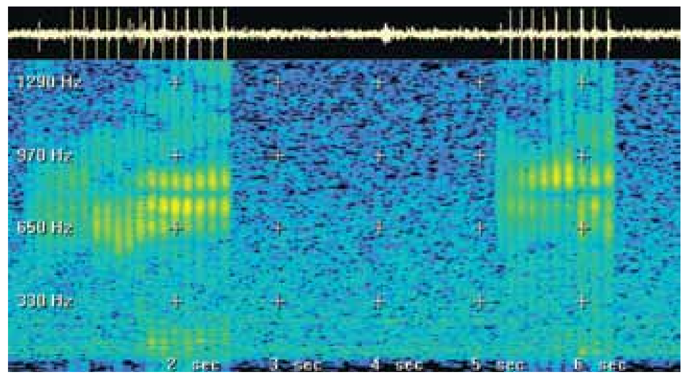
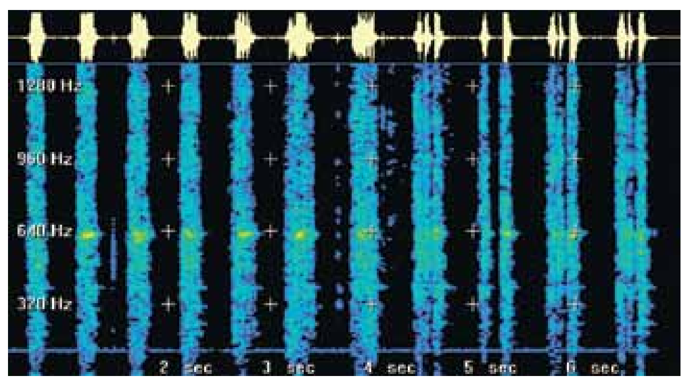
Frog calls, largely associated with reproduction (i.e., advertisement and release calls), have been the subject of much interest and study (Schiötz 1973, Rosen and Lemon 1974, Wells 1977, Fellers 1979, Duellman and Trueb 1986, Kelley 2004). Although we mostly hear frog calls and choruses coming from the surfaces of ponds, a number of species call while submerged. *Xenopus* and other pipids, all highly aquatic frogs, call while submerged (Elepfandt 1996, Christensen-Dalsgaard and Elepfandt 2004). Platz (1993) described a new species of leopard frog (*Rana subaquavocalis*; but see Goldberg et al. 2004) that exclusively emits mating calls while submerged that are inaudible at the surface. Ranids from the western United States, taxonomically distinct from their kin in the eastern U.S. (CNAH, 2009), have relatively weak calls that do not carry far from breeding locations. Several of these western ranids call both at the surface and while submerged when in or near breeding aggregations (Storm 1960, Licht 1969, Briggs 1986, MacTague and Northern 1993).

The Oregon Spotted Frog (*Rana pretiosa*) is a highly aquatic explosive breeder that overwinters under ice in much of its extant range and spawns soon after ice leaves the ponds (Hayes 1994). Eggs are deposited in communal aggregations of a few to sometimes more than a hundred egg masses. In the Sunriver area in central Oregon (elevation 1,320 m), breeding begins sometime between early March and early April, depending on conditions. Although the breeding season may last up to a month, breeding activity at individual oviposition sites typically spans a period of two to five days (pers. obs.). During breeding events, males gather at oviposition sites, calling actively at the surface with breeding taking place mostly during the day.

Recorded advertisement calls of *R. pretiosa* consist of a string of low "clucks" or knocks, emitted at a rate of 3–7/sec, with peak intensity between 600–900 Hz. Release calls, emitted by both males and females, were more of a single or double "squawk" given at a rate of 1–2 squawks/sec and with a frequency spectrum similar to advertisement calls. Release calls can be elicited almost any time by picking up a frog with the thumb and index fingers placed directly behind the forelimbs. Recordings of *R. pretiosa* advertisement and release calls at the Sunriver Nature Center are available at www.sunrivernaturecenter.org.



Sonogram of the male advertisement call of *Rana pretiosa*.



Sonogram of the release call of *Rana pretiosa*.

LUKE GALLOWAY

Adult Oregon Spotted Frog (*Rana pretiosa*).

Here, I report for the first time that *R. pretiosa* also calls actively from submerged locations tens to hundreds of meters away from and several days prior to the formation of breeding aggregations.

Methods

Sub-surface listening was conducted using a DolphinEAR™ hydrophone (model DE100-6-112), with a 6-m cable and preamp or DolphinEAR PRO hydrophone connected directly to a ZOOM H-4 digital recorder. Listening was conducted by casting the hydrophone from shore to the length of the 6-m cable, allowing it so sink, listening for 1 min, retrieving approximately 1 m, and listening again. Recordings were taken when good quality calling signals were detected.

Two sites were utilized for submerged calling surveys. Bullfrog Pond (BFP, 43°51'01"N x 121°26'50"W) is a 0.3-ha isolated (no hydrologic

Communal oviposition site showing ~18 newly laid egg masses adjacent to and on 12 egg masses laid several days earlier. Green algae are developing within older egg masses.

Author holding pre-amp and cable of a DolphinEAR hydrophone on the shore of Lake Aspen.

connections to nearby water bodies), excavated pond, somewhat irregular in shape, approximately 100 m long, and 10–25 m wide. Maximum depth is 2.5–3 m. Spring runoff raises the water level as much as 1 m, creating a shallow arm that extends up to 150 m from one end of the permanent portion of the pond. Breeding takes place in the distal portion of this temporary arm. The maximum distance from any point within the permanent pond to the oviposition site is approximately 200 m. Egg-mass counts over the past 10 years ranged from 21–200+ (median 24). Mark and recapture studies suggest only limited migration into or out of BFP (unpubl. pers. obs.). Oviposition generally takes place over 1–3 days.

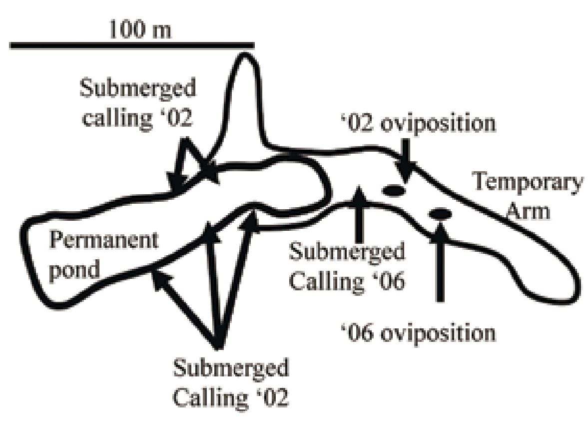
Lake Aspen (LA, 43°53'10"N x 121°26'47"W) is a 2.5-ha excavated pond with year-round connections to other water bodies, including the Deschutes River. Water levels are controlled by weirs and fluctuate by no more than 30 cm. A long-term mark and recapture study (unpubl. data) has documented that several hundred adult *R. pretiosa* move to LA in the fall to overwinter, entering via a shallow outlet channel. In March and April, frogs migrate out of LA to spawn at a communal oviposition site known as Duck Pond Marsh (DP, 43°53'28"N x 121°26'52"W) approximately 1 km away. At DP, egg masses are deposited in several collective clusters over an area of approximately 10 x 80 m. Spawning at DP spans 2–4 weeks, usually in bursts of 2–5 days at any one collective aggregation (unpubl. pers. obs.). Due to the larger size of LA, no attempt was made to systematically survey the entire shoreline. Instead, the hydrophone was deployed at locations along about 200 m of shoreline on either side of the outlet channel used by frogs to move to the oviposition site.

Results

BFP was ice-covered during surveys on 14 March 2002, except for open water at a seep at the south end. By 21 March, the spring thaw had provided numerous openings around the edges of the pond, although 5–8 cm of ice remained over much of the pond. The only sounds detected by hydrophone on 14 and 21 March were bubbles escaping from the ice. At approximately 1100 h on 28 March, advertisement calls of male *R. pretiosa* were detected at a depth of approximately 0.5 m near the edge of a patch of Cattails (*Typhus* sp.) within the permanent pond. Three males appeared to be calling at that location. Additional small groups of calling males were subsequently detected at four additional locations scattered around the perimeter of the pond. I found detectable calls only in a narrow zone 2–3 m from shore at depths of 0.5–1 m. Moving the hydrophone more than 2–3 m away from a calling individual was sufficient to lose the call because of sound attenuation. No frog calls were audible at the surface, and all frogs appeared to be concealed in submerged grass or sedge on the bottom. The weather on 28 March was cool (~12 °C) with a heavy overcast. I saw one frog at the surface of the pond during 2 h of surveying, a mature female that remained at the surface for approximately 5 min after detection, then submerged and was not seen again.

On 30 March, a high pressure weather system arrived, bringing warm sunny weather. On 31 March, a breeding aggregation of males formed at the historic breeding location and breeding commenced. A total of 21 egg masses were deposited over the course of approximately 24–36 h, with breeding completed some time on 1 April. Eighteen egg masses were clustered together, with three satellite masses deposited <3 m from the main aggregation. The distance from the breeding site to the various submerged calling locations was 80–150 m. During oviposition, 10–20 males were observed calling from the surface in the vicinity of the egg masses. Calling was audible up to 30 m away. Some males also were observed calling from the bottom in 10–15 cm of water, and their calls were audible but muffled. No calling was detected away from the breeding site on 30 March.

Hydrophone listening at BFP in 2003 and 2005 failed to detect any submerged calling prior to or remote from the formation of a surface aggregation and subsequent oviposition. At 1000 h on 15 March 2004, a single male was detected calling from a submerged position ~10 m from the eventual oviposition site. By 1330 h, several males had emerged at the oviposition site and were calling intermittently. That evening, from 2030–2130 h, all surface activity at the oviposition site had ceased, but a number of males were calling actively at the afternoon calling location and at two additional locations in the permanent portion of the pond approximately 80 m from



Schematic of Bullfrog Pond showing 2002 and 2006 locations of submerged calling and subsequent breeding.

the oviposition site. The following day, all detectable activity had shifted to the oviposition site and breeding commenced.

In 2006, ice remained on the ponds until late March and water stood at record high levels. On 3 April 2006, I detected several males calling from a 20-m zone in the middle section of the temporary arm of the pond. This calling zone was 20–40 m from the oviposition site used in prior years, and 40–60 m from the site that would be used in 2006. After dark, at 2100 h, several dozen males were detected calling at depths of 30–60 cm within this same narrow band, about 20 m long. Multiple calling males created a continuous chorus. At this time, no surface activity was detectable. From 1000–1130 h on 4 April, I detected submerged calling at this same location, but no more than two or three frogs were heard. No calling was detected from within the permanent pond. By 1400 h, a few males had surfaced and were calling near the historic oviposition site. On 5 April, surface activity had shifted about 20 m farther up the temporary arm and spawning commenced. Over the next three days, 46 egg masses were deposited in one major cluster and five satellite masses 2–5 m away.

Lake Aspen, a very different site, yielded somewhat different results. At 1130 h on 4 April 2002, one frog was detected calling about 4 m offshore near the pond outlet at a depth of about 1.5–2.0 m. Calling was sporadic, with pauses often lasting several minutes. A second individual was detected at a similar depth about 30 m to the west. No further calling was detected that year and no submerged calling was detected during several daytime surveys in 2006. At 1300 h on 28 March 2007, individual males were detected at two of six locations where the hydrophone was deployed. At 2100 h that evening, however, 1–3 males could be heard at four of six listening locations. At 1100 h the following day, a single frog was detected calling at one of the locations. These calling locations are approximately 1 km from the main oviposition site.

Discussion

Advertisement calls of male *Rana pretiosa,* a highly aquatic frog, were detected coming from submerged locations separated from oviposition sites by tens to hundreds of meters and sometimes preceding the formation of breeding aggregations by several days. Submerged calling activity was considerably greater after dark, even though most breeding activity occurs during the day. Once breeding aggregations formed at oviposition locations, males were detected only in the vicinity of the breeding aggregation, with calling restricted to the surface or at depths shallow enough for the calls to be audible above water.

Platz (1993) suggested four possible selective advantages for submerged calling: Avoiding predators, avoiding temperature extremes, extending the breeding and/or developmental season, and increasing sound transmission range. In central Oregon, the principal predators on *R. pretiosa* include Garter Snakes (*Thamnophis sirtalis*), Great Blue Herons (*Ardea herodias*), Mink (*Neovison* [=*Mustella*] *vison*), and Raccoons (*Procyon lotor*). Most of these predators are visual, daytime hunters. Calling while submerged, especially at night and at depths greater than 30 cm, would help *R. pretiosa* avoid these predators, except for raccoons.

In central Oregon and indeed throughout much of the range of *R. pretiosa,* temperatures on clear nights during the breeding season fall rapidly after sunset, and overnight temperatures from -10–-5 °C are common, although water temperatures a few centimeters below the surface typically remain at 8–14 °C. Submerged calling would thus avoid the cold temperatures at the surface. Increasing the larval developmental period is probably not important for *R. pretiosa* at Sunriver, where metamorphosis is normally completed in late July or August, but might be important at some high elevations sites where snow and ice can dramatically shorten the active season. Despite the density of water, submerged calling does not appear to increase sound transmission range at the depths and in the environment used by *R. pretiosa*. Ladich and Bass (2003) stated that "…in shallow waters, sound propagation is very much limited…." Indeed, I found submerged calling was often undetectable at distances greater than 1–3 m from the source when the frogs were hidden in submerged vegetation.

Many if not all of the species of *Rana* found in the western United States apparently call both at the surface and while submerged near breeding aggregations (Storm 1960, Licht 1969, Briggs 1986). This appears to be the first report of submerged calling by any of these species that is separated from breeding aggregations both spatially and temporally. Anecdotal reports place amplectic pairs of *R. pretiosa* at varying distances from breeding sites. However, whether remote pairing is simply opportunistic as frogs move toward breeding sites or if active mate selection may be taking place remotely from breeding sites and related to submerged calling is unclear. Several important questions remain to be answered. Is active mate selection taking place prior to arrival at breeding aggregations? If so, then what is the function of large aggregations of unpaired males found calling at the surface at oviposition sites? Conversely, if mate selection is principally accomplished in the breeding aggregations at oviposition sites, then what function does submerged calling serve? Does the presence of both surface and submerged calling in several species of western ranids suggest that this clade is evolutionarily in transition from one strategy toward the other or that competing selective pressures help maintain dual strategies? Do other western species that emit advertisement calls both at the surface and submerged (i.e., *R. cascadae*, *R. boylii*, and *R. luteiventris*) engage in submerged calling prior to and at some distance from the formation of breeding aggregations? Answering these questions will provide a better understanding of the ecology of this entire group of anurans.

LUKE GALLOWAY

Common Garter Snake (*Thamnophis sirtalis*) swallowing a Spotted Frog (*Rana pretiosa*).

Literature Cited

Briggs, J.L. 1987. Breeding biology of the Cascade Frog, *Rana cascadae,* with comparisons to *R. aurora* and *R. pretiosa. Copeia* 1987:241–245.

Christensen-Dalsgaard, J. and A. Elepfandt. 2004. Biophysics of underwater hearing in the Clawed Frog, *Xenopus laevis. Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology* 176:317–324.

CNAH (Center for North American Herpetology). 2009. Standard Common and Current Scientific Names (Frogs and Toads). www.cnah.org/nameslist.asp?id=3.

Duellman, W.E. and L. Trueb. 1986. *Biology of Amphibians*. McGraw-Hill, New York.

Elepfandt, A. 1996. Underwater acoustics and hearing in the Clawed Frog, *Xenopus*, pp. 177–191. In: R.C. Tinsley and H.R. Kobel (eds.), *The Biology of* Xenopus. Oxford University Press, New York.

Fellers, G.M. 1979. Aggression territoriality, and mating behaviour in North American treefrogs. *Animal Behaviour* 27:107–119.

Goldberg, C.S., K.J. Field, and M.J. Sredl. 2004. Mitochondrial DNA sequences do not support species status of the Ramsey Canyon Leopard Frog (*Rana subaquavocalis*). *Journal of Herpetology* 38:313–319.

Hayes, M.P. 1994. The Spotted Frog (*Rana pretiosa*) in Western Oregon. Part I. Technical Report 94-1-01. Oregon Department of Fish and Wildlife, Salem.

Kelley, D.B. 2004. Vocal communication in frogs. *Current Opinion in Neurobiology* 14:751–757.

Ladich, F. and A.H. Bass. 2003. Underwater sound generation and acoustic reception in fishes with some notes on frogs. In: S.P. Collin and N.J. Marshall (eds.), *Sensory Processing in Aquatic Environments*. Springer, New York.

Leonard, W.P., L. Hallock, and K.R. McAllister. 1997. *Rana pretiosa* (Oregon Spotted Frog). Behavior and reproduction. *Herpetological Review* 28:28.

Licht, L.E. 1969. Comparative breeding behavior of the Red-legged Frog (*Rana aurora aurora*) and the Western Spotted Frog (*Rana pretiosa pretiosa*) in southwestern British Columbia. *Canadian Journal of Zoology* 47:1287–1299.

MacTague, L. and P.T. Northern. 1993. Underwater vocalization by the Foothill Yellow-legged Frog (*Rana boylii*). *Transactions of the Western Section of the Wildlife Society* 29:1–7.

Platz, J.E. 1993. *Rana subaquavocalis*, a new species of Leopard Frog (*Rana pipiens* complex) from southeastern Arizona. *Journal of Herpetology* 27:154–162.

Rosen, M. and R.E. Lemon. 1974. The vocal behavior of Spring Peepers, *Hyla crucifer*. *Copeia* 1974:940–950.

Schiötz, A. 1973. Evolution of anuran mating calls: Ecological aspects, pp. 311–319. In: J.L. Vial (ed.), *Evolutionary Biology of the Anurans*. University of Missouri Press, Columbia.

Storm, R.M. 1960. Notes on the breeding biology of the Red-legged Frog (*Rana aurora*). *Herpetologica* 16:251–259.

Wells, K.D. 1977. The social behavior of anuran amphibians. *Animal Behaviour* 25:666–693.

Suburbanization of a Central Texas Herpetofauna

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Photographs by the author. All were taken at the study site.

Reptiles and amphibians were surveyed on the Balcones Escarpment in central Texas as the area was transformed into suburbia. Of four habitats, oak-juniper savanna was totally destroyed and a quarter of the adjacent oak-juniper woodland was eliminated, but two creeks and most deciduous riparian forest remained. Extirpation of 12 of 30 species (40%) included 55% of nine amphibian species, 50% of two turtles, 33% of six lizards, and 30% of 13 snakes. Herpetofaunal richness declined exponentially from 1965 to 1990 with increased house building, then stabilized through 2005 as building slowed and stopped. Species survival was related to use of cultural and remaining natural habitats, secretive behavior, and human interest.

Suburban development in Woodway (a suburb of Waco), McLennan County, Texas had begun in 1964, when I started a 46-year project to record the area's natural and unnatural herpetofaunal history (Gehlbach 2002). The 80-ha savanna was part of a ranch totally erased by suburbia during the study, and about 20% of adjacent woodland was lost. One earth-dammed stock pond was kept for fishing; the other was demolished by floods. Habitat protection was inadvertently affected by city building codes that saved forested ravines with steep slopes, creeks and their terraces, and by a planned-unit development's 6-ha private nature preserve of creek, forest, and woodland in 1984.

This study presents features of extirpation, survival, and general abundance of each species of amphibian and reptile and describes herpetofaunal change during the study site's suburban development. I hope it will stimulate other studies that support conservation and educational use of nature preserves in our ever-growing U.S. cities.

A mating pair of Cope's Gray Treefrogs (*Hyla chrysoscelis*).

Strecker's Chorus Frog (*Pseudacris streckeri*).