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Reproduction in the Wood Frog, Rana sylvatica (Anura: Ranidae), from Arkansas

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Hypogastura (Hypogastura) lima Christiansen and Bellinger
Hypogastura (Mitchellania) vulgaris Yosii
Hypogastura (Schoetella) albamaculata Scott
Neanura (Crossodonthina) serrata Folson
Neanura (Neanura) barberi (Handschin)
Neanura (Neanura) muscorum (Templeton)
Paranura anops Christiansen and Bellinger
Paranura caeca Folsom
Paranura colorata Mills
Paranura quadrilobata Hammer
Pseudachortus (Pseudachortus) complexus (MacGillvray)
Pseudachortus (Pseudachortus) sexatalis Macnama
Xenylla welchi Folsom

Family: Onychiuridae

Onychiurus (Onychiurus) ramosus Folsom
Onychiurus (Protophoria) armatus (Tullberg)
Onychiurus (Protophoria) pseudoarmatus Folsom
Onychiurus (Protophoria) uenoi Yosii
Onychiurus n. sp.
Tullbergia (Tullbergia) mala Christiansen and Bellinger

Family: Isotomidae

Folsomia candida Willem
Folsomia decaxtopthalma Ford
Folsomia fimetaria (Linnaeus)
Isotoma subviridis Folsom
Isotoma trispinata McGillivray
Isotoma viridis Bourlet
Isotomurus palustris Muller
Isotomiella minor Schuffer
Proisotoma (Appendisotoma) vesiculata Folsom
Tetracanthella ethelae complex Wray
Tetracanthella bellingeri Deharveng

Sinella (Sinella) avita Christiansen
Sinella (Sinella) barri Christiansen
Tomocerus (Pogonognathellus) bidentatus Folsom
Tomocerus (Plutomurus) brevimucronatus Denis
Tomocerus (Pogonognathellus) flavescens Tullberg
Tomocerus (Tomocerine) lamelliferus Mills
Tomocerus (Tomolonus) reductus (Mills)
Tomocerus (Tomocerus) vulgaris Tullberg
Tomocerus (Plutomurus) wilkeyi Christiansen
Willowsia bushi (Lubbock)
Willowsia nigromaculata (Lubbock)

Suborder: Symphypleona
Family: Sminthuridae

Dicyrtoma (Ptenothrix) atra (Linnaeus)
Dicyrtoma (Ptenothrix) castanea Snider
Dicyrtoma (Ptenothrix) quadrangularis, Mills
Neosminthurus bakeri, Snider
Sminthurides (Sminthurides) malagreni (Tullberg)
Sminthurides (Sminthurides) welcheseli Christiansen and Bellinger
Sminthurinus henshawi (Folsom)
Sminthurinus n. sp.
Sphyrotheca minnesotensis (Guthrie)

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REPRODUCTION IN THE WOOD FROG, *RANA SYLVATICA* (ANURA: RANIDAE), FROM ARKANSAS

The reproductive biology of the wood frog, *Rana sylvatica,* has received considerable scrutiny throughout much of its broad range in North America (see review in Davis and Folkerts, 1986). Interestingly, ever since the wood frog was first discovered in Arkansas over 50 years ago (Black, 1933, 1938), very little other than recent new county records (Cline and Tumlison, 1985; Plummer and Godwin, 1979; Robison and Douglas, 1977; Schuier *et al.,* 1972; Trauth *et al.,* 1987; Turnipseed, 1980, 1981) has been published on this species in the state. Within the Ozark Mountains of Arkansas (specifically the Boston Mountains and portions of the Springfield and Salem Plateaus), wood frogs have been found from Washington County in the west to Independence County in the east and from Baxter and Marion counties in the north to Pope County in the south. The Arkansas populations of *R. sylvatica* represent the southwesternmost extent of the species' range in North America; consequently, data on the reproductive biology of *R. sylvatica* in Arkansas can contribute to a better assessment of geographic and intraspecific variability in reproductive parameters (Berven, 1988; Berven and Gill, 1983) in this wide-ranging species. In the present study, we report on the breeding cycle in *R. sylvatica* from northcentral Arkansas.

From early February to late May, 1987 and 1988, breeding activity in *R. sylvatica* was monitored in Stone County; frequent visits to breeding sites in three other counties (Baxter, Marion, and Searcy) were also made. The primary study site consisted of two small farm ponds situated near each other (ca. 50 m apart). The surrounding habitat, located within the Sylamore Ranger District (SRD) of the Ozark-St. Francis National Forest, lies at an elevation of around 380 m and is geomorphically characterized by narrow, rounded ridges and steep, deeply-cut ravines. The forest type consists of a mixture of shortleaf pine and oak-hickory climax communities. We collected egg masses and adult and larval *R. sylvatica* from February to May, 1987, and egg masses and adults in February, 1988. Individual egg masses were placed in containers of 10% formalin, whereas adults were killed in a 20% chloretone solution and fixed in 10% formalin. Oviductal eggs within expanded ovisacs of females were excised and measured with an ocular micrometer to the nearest 0.01 mm using a dissecting microscope at a magnification of 10X. Ten eggs per ovisac were examined; 10 egg diameters from 10 randomly-selected egg masses were also measured as above. Eggs, larvae and adults were stored in 70% ethanol and deposited in the Arkansas State University Museum of Zoology. Statistical data (means) are accompanied by ± two standard errors.

Late winter precipitation coincided with the initiation of immigration to ponds and the so-called explosive breeding activity in *R. sylvatica.* We recorded a peak breeding period from early-to-late February, 1987, and from early February to the first week in March, 1988. The earliest male calling activity and deposition of egg masses were in two isolated SRD forest ponds on 7 February 1987; in 1988, the earliest calling and egg deposition in any pond were 1 February. At the primary study site, the first ampletic pairs were observed in pond #1 (chicken house pond),

and approximately 75 egg masses (mostly in communal ovipositional aggregates) were counted there on 11 February 1987. A 15 cm snowfall had occurred on 3 February, amplectic pairs were first observed in pond #2 (pasture pond). The earliest breeding at the chicken house pond and the pasture pond in 1988 was on 21 February. Amplectic pairs were observed for the last time in both ponds on 26 February 1987 and on 7 March 1988. Hatching of eggs occurred within a week or so after laying at the primary study site, and on 22 March 1987, tadpoles of ca. 22 mm in total length were collected in the pasture pond. This larval size roughly equates to an age of six weeks and is similar to a size-age growth pattern reported for Tennessee populations (Meeks and Nagel, 1973). Emerging froglets were collected around both ponds on 23 May 1987; therefore, the time interval from egg deposition to transformation is about 105 days.

Clutch size was determined by counting all eggs in 35 egg masses and in oviducts (ovisacs) of seven gravid females. Based upon counts from egg masses, clutch size varied from 510 to 1433 ($\overline{x}$ = 867.3 ± 63.5), whereas counts of oviductal eggs ranged from 645 to 1331 ($\overline{x}$ = 960.0 ± 201.9). By placing individual egg mass size into size classes (intervals of 100 eggs), the number of egg masses and clutches were 500 to 600 eggs (2 clutches), 600-700 (5), 700-800 (8), 800-900 (3), 900-1000 (9), 1000-1100 (5), 1100-1200 (2), and greater than 1200 (1). Gravid female *R. sylvatica* ranged from 60 to 70 mm in snout-vent length and, when matched with their clutch complement (in parentheses), were as follows: 60 (645), 60 (888), 62 (716), 65 (1241), 68 (1331), 70 (794), and 70 (1104). Females may oviposit all eggs within a single ovisac at one time (Davis and Folkerts, 1986); therefore, this may account for the variation in oviductal egg number among these females. A chi-square test revealed a significant difference (X^2 = 31.9; $P < 0.05$) in the number of oviductal eggs between left and right ovisacs. Although the total number of eggs per female appears to increase with body size, the causative factors attributing to variation in clutch size (e.g., body size, age, environmental parameters, nutritional state, and heredity) in Arkansas wood frogs remain unresolved.

The average clutch sizes (both methods) found for Arkansas *R. sylvatica* were similar to values reported for populations in more northern latitudes. For example, average clutch size (based upon egg mass size) was comparable to values in Virginia ($\overline{x}$ = 920; Berven, 1982) and Pennsylvania ($\overline{x}$ = 895; Seale, 1982), but was much greater than in the most southern populations in Alabama ($\overline{x}$ = 496; Davis and Folkerts, 1986) and Tennessee ($\overline{x}$ = 465; Meeks and Nagel, 1973). Moreover, clutch size in Arkansas averaged over 250 eggs more than the average for Missouri populations ($\overline{x}$ = 621; as reported for Johnson by Davis and Folkerts, 1986). Recently, Johnson (1987) reported a range (500 to 1000) closer to our findings.

Egg diameters of oviductal eggs in *R. sylvatica* varied from 1.7 to 2.4 mm ($\overline{x}$ = 1.92 ± 0.025; n = 100); this average value lies within the overall range of 1.6 to 2.9 mm for this species as summarized by Davis and Folkerts (1986). Diameters of laid eggs with expanded jelly envelopes ranged from 7.0 to 12.6 mm ($\overline{x}$ = 9.60 ± 0.379; n = 100) in our study. Arkansas wood frogs laid smaller eggs than in Alabama and Tennessee populations (Davis and Folkerts, 1986; Meeks and Nagel, 1973), but were similar in size to more northern populations (Berven, 1988).

Since the late 1960's, the U.S. Forest Service and the Arkansas Game and Fish Commission have constructed a large number of wildlife ponds in the SRD. Of the 39 ponds monitored in 1987, 74% contained wood frogs and/or eggs. Of 68 different ponds checked in 1987 and 1988, 72% had either frogs or egg masses present. Of 16 different ponds monitored both years, 10 (62.5%) had frogs and/or egg masses.

The ringed salamander, *Ambystoma annulatum*, and *R. sylvatica* were first recorded breeding syntopically during the present study (Trauth *et al.*, 1989). Other species found at these wildlife ponds were *Ambystoma maculatum* (spotted salamater), *Notophthalmus viridescens* (central newt), *Pseudacris crucifer* (spring peeper), and *Rana sphenocephala* (southern leopard frog). We witnessed interspecific competition for ovipositional sites in several ponds (especially evident between *R. sylvatica* and *A. maculatum*). In many small temporary ponds, these two species deposited their egg masses on top of one another forming several stratigraphic layers. By clustering egg masses, these two species may mutually gain a thermal advantage for developing larvae (Seale, 1982; Waldman and Ryan, 1983); however, this increased fitness via tolerance to cold temperatures may be neglected by the predatory nature of the adult and larval forms of the ecological associates (in particular, *N. viridescens* and *A. maculatum*, respectively; see Walters, 1975).

As reported previously in other populations of *R. sylvatica*, we found many egg masses completely infiltrated by the unicellular green alga, *Oophila amblystomatis*, a species commonly seen in *A. maculatum* egg masses. The relationship between algae and developing larvae remains mostly conjectural, although several studies have suggested a mutualistic arrangement. Several investigators have shown, in fact, that the alga may actually result in egg mortality. Gilbert (1942) summarized the early literature pertaining to this alga-amphibian egg phenomenon.

In conclusion, reproductive characteristics of *R. sylvatica* in Arkansas generally follow the pattern seen throughout this species' range. Wood frogs are explosive breeders and usually lay eggs in large communal aggregates in woodland ponds during the late winter. At many breeding sites, wood frogs compete with other winter-breeding salamanders and frogs for ovipositional locations within ponds. Hatching occurs rapidly, and transformation requires around 15 weeks, a span of time slightly longer than what is found in northern populations (Berven and Gill, 1983). Because the status of wood frogs in Arkansas has not, as yet, been adequately established (Smith *et al.*, 1984), future studies might consider addressing the interspecific relationships between wood frogs and their ecological associates. Information on interspecific predation could shed some light on survivorship rates and contribute new knowledge on this pond-breeding amphibian of the Ozarks.

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