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Accepted: 3 July 1995.

Journal of Herpetology, Vol. 29, No. 4, pp. 612-614, 1995

Timing of Reproduction and Metamorphosis in the Carolina Gopher Frog (*Rana capito capito*) in South Carolina

RAYMOND D. SEMLITSCH,[1] J. WHITFIELD GIBBONS,[2] AND TRACEY D. TUBERVILLE,[2] [1]*Division of Biological Sciences, University of Missouri, Columbia, Missouri 65211, USA and* [2]*University of Georgia, Savannah River Ecology Laboratory, P.O. Drawer E, Aiken, South Carolina 29802, USA.*

Because of recent concerns about the status of amphibian populations (Pechmann and Wilbur, 1994), any information on life history traits related to reproduction and juvenile recruitment can become crucial in making conservation decisions. This is especially true for the gopher frog, *Rana capito*, whose life history and population status is unknown in most parts of its range (Altig and Lohoefener, 1983). State surveys of herpetofauna have listed this species as uncommon, rare, or endangered for at least two decades (e.g., Mount, 1975; Martof et al., 1980; Dundee and Rossman, 1989; Johnson, 1987). At least two states, and perhaps others, have classified the species as threatened (e.g., in Florida by Moler, 1992; and in Alabama by Mount, 1986). During 1993 in South Carolina, verification of the presence of this species to the state's Heritage Trust Program was limited to a single observation (S. H. Bennett, pers. comm.). Its secretive nature, short breeding season, and small, patchy population distribution have all contributed to the lack of basic life history information about this anuran.

In an effort to increase our knowledge of this species, we have compiled data collected on activity patterns over the past 25 yr, including the timing of reproduction and metamorphosis of juveniles from various breeding sites on the Savannah River Site (SRS) in the Upper Atlantic Coastal Plain of South Carolina. A thorough description of the region, climate, and breeding sites mentioned in this report is given by Gibbons and Semlitsch (1991) or cited therein.

Rana capito adults have been collected at only seven (27%) of the ponds and Carolina bays effectively sampled on the SRS (41 sampling years). They have never been collected or heard at any large aquatic habitats such as the man-made reservior system of PAR Pond or at very ephemeral sites such as shallow roadside ditches and small borrow pits where other anuran species are often found (e.g., *Scaphiopus holbrooki, Bufo quercicus*). At breeding sites where they have been found, fewer than 10 adults have been collected in any year, despite continuous monitoring with drift fences and pitfall traps at these sites for multiple years as well as periodic night visits for visual and auditory observations (Table 1). In addition, their frequency of breeding among years at four well-studied sites is very low (Ellenton Bay 0.30, Rainbow Bay 0.06, Karen's Pond 0.67, and Risher Pond 0.40). Finally, we have observed no apparent change in these low frequencies of breeding or small population sizes over the past 25 yr.

The breeding season in most years lasted only a few days, and occurred between January and April. In 1982 at Flamingo Bay, the breeding season was more protracted and adults were found entering the site during two distinct periods, mid-February and again in mid-March. This was also observed at Karen's Pond in 1970 where one adult was found entering the pond as late as 2 April. The body size of collected adults ranged from 59.0-91.0 mm snout-vent length ($\bar{x} = 76.1 \pm 10.32$ mm SVL, N = 21; Table 1).

Metamorphosing juveniles were seldom found at sites, and they were even less frequent than the occurrence of breeding adults alone would suggest. During one year, emigrating juveniles (N = 50) were found in pitfall traps at the drift fence at Karen's Pond between 21 June and 10 July 1970 and averaged 36.7 $\pm$ 1.8 mm SVL. Metamorphosing juveniles (N = 46) were collected at a series of partial drift fences near Pond C between 18 June and 28 July 1971 ($\bar{x} = 41.0 \pm 2.9$ mm SVL). Also, metamorphosing juveniles were first captured emigrating from Flamingo Bay on 27 May 1982 and continued to leave through 12 July. In total, 25 metamorphs were captured leaving during

TABLE 1. A list of breeding sites, dates of collection, numbers of entering adults (M = male, F = female, U = sex not determined), and snout-vent length (mm) of *Rana capito* from South Carolina. * Pair found in amplexus. ** Includes all captures entering and exiting the pond.

Sites	Dates	Sex	Number of individuals	Snout-vent length (mm)
Bay 23	6 March 1982	M*	1	
		F*	1	
Ellenton Bay	18 February 1981	M	1	81.0
	17 January 1987	U	1	
	1 March 1987	U	1	
	30 January 1991	F	2	
	31 January 1991	F	1	
	1 February 1991	M	1	
Flamingo Bay	10 February 1982	M	2	
	16 February 1982	M	3	71.0, 84.0, 83.0
	17 February 1982	M	1	
		F	1	
	18 February 1982	M	1	
	11 March 1982	F	1	
	14 March 1982	F	1	
Karen's Pond**	30 January 1970	F	1	65.0
	3 February 1970	M	2	85.0, 84.0
	5 March 1970	U	1	69.0
	2 April 1970	U	3	59.0, 85.0
	6 April 1970	U	1	88.0
	5 January 1971	U	2	61.0, 78.0
	15 January 1971	U	2	65.0, 91.0
Rainbow Bay	14 February 1984	U	1	77.0
Risher Pond	18 March 1969	M	1	71.0
	19 March 1969	M	1	66.0
	25 January 1971	U	1	62.0
Sun Bay	23 February 1979	F	2	87.0, 87.0

that time and averaged 43.0 ± 2.9 mm SVL (N = 23). The metamorphosing juveniles from Flamingo Bay in 1982 could be used to estimate accurately the larval period in a natural pond. Using the average date of metamorphosis for the entire cohort (8 June ± 11.2 days) and the two adult breeding periods for that year (11–14 March; 10–18 February), we estimated a minimum and maximum larval period for the tadpoles of 87 and 113 days, respectively.

In summary, our data from one area of the Upper Coastal Plain of South Carolina indicate that *Rana capito:* (1) occurs in very small population sizes, (2) breeds infrequently among years at given sites, (3) typically has a short breeding period of less than two weeks, and (4) successfully recruits metamorphs into the adult population only rarely, despite the undisturbed nature of our study ponds and a typical larval period for ranid frogs. Considering that these data are from a limited region and that our study sites potentially represent populations on the periphery of this species' geographic range, there are several implications concerning conservation issues that can be made. We suggest that short-term surveys of breeding sites are unlikely to reveal the presence of breeding adults and their presence does not necessarily indicate successful reproduction or juvenile recruitment. Thus, state surveys would benefit from longer term monitoring programs of breeding adults but especially from surveys focusing on the detection of metamorphosing juveniles. In addition, if we can assume that *Rana capito* has a similar dispersal ability and longevity as other ranid frogs, we also suggest that it conforms to common criteria of species populations subject to rapid local extinction (i.e., small effective population size, high inbreeding potential, low reproductive rate). Although infrequent recruitment of juveniles by itself is less critical and certainly not uncommon for many pond-breeding amphibians (Pechmann et al., 1991; Semlitsch et al., 1995), other population characteristics for *Rana capito* indicate that it is truly in need of intensive study.

Acknowledgments.—We thank the many individuals who have checked drift fences over the last 25 years at SREL, especially D. Bennett, J. Caldwell, J. Greene, J. Pechmann, D. Scott, and L. Vitt. Thanks also to D. Nelson for kindly providing unpublished data from Pond C. The research and manuscript preparation was supported by U.S. Department of Energy Contract DE-AC09-76SR00-819 with the University of Georgia (SREL).

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Accepted: 4 July 1995.

Journal of Herpetology, Vol. 29, No. 4, pp. 614–616, 1995

Temporal Variation in Reproduction and Clutch Mortality of Leopard Frogs (*Rana utricularia*) in South Mississippi

J. SEAN DOODY AND J. E. YOUNG, *Dept. of Biological Sciences, Southeastern Louisiana University, SLU 814, Hammond, Louisiana 70402, USA.*

Amphibian reproductive events are often synchronized to the annual hydrological cycle of ponds (Semlitsch et al., 1993). Oviposition in amphibians is influenced by a variety of factors including water temperature (Howard, 1980), water depth (Crump, 1991), predation (Howard, 1978), and competition (see Semlitsch et al., 1993). In turn, the precise effect of these factors can be influenced by variation in the timing of oviposition. Harris (1980) showed that reproductive success of breeding *Ambystoma maculatum* varied significantly among waves of breeding activity within years.

Rana utricularia is known to breed in every month of the year in parts of its range (Mount, 1975; Dundee and Rossman, 1991), but is reported by Caldwell (1986) to have two primary breeding periods in some areas. Temporal variation in oviposition has not been rigorously examined for this species. One of us (JSD) has observed *R. utricularia* to oviposit most frequently in December, January, and February in Louisiana, the first breeding starting when ephemeral ponds begin to fill, as early as mid-November.

The goals of our study were to: (1) document variation in timing of oviposition, and (2) quantify temporal variation in reproductive success of *R. utricularia*. The latter objective was prompted by observations of egg mortality in the early-breeding animals. Additionally, as pond water levels dropped within one breeding event, we examined temporal variation in the range of water depths used by ovipositing females.

Glen's Pond is a small (20 × 30 m, maximum depth = approx. 1 m) ephemeral pond in Desoto National Forest in south Mississippi. The pond has an open canopy and is situated on a ridge in a longleaf pine stand. The pond has been monitored since 1987, during which time it has dried each summer, and has failed to fill in two of six winters (G. Johnson, pers. comm.). Active management (i.e., controlled burning) is now practiced at the site, in an effort to maintain appropriate breeding requirements of gopher frogs (*Rana capito*). Southern leopard frogs (*Rana utricularia*) are abundant at the site. Female leopard frogs oviposit as early as November with the advent of the rainy season, and breed until March (G. Johnson, pers. comm.).

Starting in November 1993, we counted freshly laid egg masses and mapped them according to their position in the pond. Twenty-eight visits were made thereafter, the last visit on 28 April 1994. Most surveys were during daylight hours; occasionally visits were made after dark in an attempt to make observations on mating behavior. A meterstick was installed in early November 1993 to monitor pool levels.

Time to desiccation of egg masses is defined as the median date of oviposition (within breeding events) to the day the last egg mass desiccated. Similarly, timing of mortality of tadpoles was determined from the median date of oviposition until the pond dried.

During the first breeding event, we measured oviposition site depths with vernier calipers and compared them to depths of random points in the pond. Random points were chosen by pacing transects and assigning random numbers to their intersections. Variation among water depths at egg masses was analyzed with single factor ANOVAs using Microsoft EXCEL software. Alpha level was 0.05 for all statistical tests.

We visited the pond 28 times between 8 November 1993 and 28 April 1994. Following rains, a total of 209 fresh egg masses were discovered during 11 surveys (Fig. 1). Three discrete breeding events occurred between 22 November and 13 March (Fig. 1), and were separated by 74 and 30 d, respectively. We found a few egg masses clustered together (egg masses touching), but the majority were deposited singly, regardless of oviposition date. Most clutches oviposited during the first two breeding events were aggregated in the same small area, with clutches from the third event aggregated within 6 m of that area. In a survey of one such aggregation, we found the mean distance between nearest masses to be 21 ± 8.2 cm. Most egg masses were attached to vegetation and their uppermost eggs were near the surface; when several days