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CHORUSING PHENOLOGY AND HABITAT ASSOCIATIONS OF THE CRAWFISH FROG, *RANA AREOLATA* (ANURA: RANIDAE), IN KANSAS

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ABSTRACT—The chorusing phenology of the crawfish frog, *Rana areolata*, was monitored at a site in east-central Kansas from 1989 to 1993. Calling was initiated at temporary pools each spring following rainfall events with temperatures of ca. ≥13.0°C. Each year, peak chorusing spanned only 3 to 4 nights while some calling occurred periodically during a 22 to 55-d period in March to early May. Aural surveys of calling males conducted during peak chorusing periods in a 9-county area revealed that *R. areolata* remains locally common in areas of suitable habitat. The largest populations, as judged by calling activity, occurred in areas with large tracts of native tallgrass prairie, gentle terrain, and deep, clay soils. Few calling males were heard in areas with shallow soils or intensive agricultural development.

Rana areolata has a spotty distribution in the south-central United States (Conant and Collins, 1991). Typically occupying the burrows of crawfish or other animals, this secretive species rarely is encountered outside its brief spring breeding season (Barbour, 1971; Collins, 1993). Bragg (1953) studied the reproductive biology of *R. areolata* in eastern Oklahoma; other sources of information on the biology of this species are mostly anecdotal. The apparent rarity of *R. areolata* throughout its range, together with its fossorial habits, make it unique among the otherwise well studied North American ranids. It is listed as endangered or of conservation concern in five of the 12 states in which it occurs. In the southern tallgrass prairie region, populations have declined with the conversion of prairie to agriculture, and concerns about population losses have been raised (Platt et al., 1974; Johnson, 1987). The purpose of this study was to document the calling phenology, habitat preference, and status of *R. areolata* in eastern Kansas.

STUDY AREA—Studies were conducted in a nine-county area in east-central Kansas (Fig. 1). Part of the Osage Cuestas physiographic province, this area consists of gentle north-south-oriented ridges and valleys underlain by alternating layers of limestone and shale (Schoewe, 1949). Soils are mostly silt and clay loams and often have poorly drained clay subsoils. The average annual precipitation is 93 mm, of which nearly 70% falls between April and September (Sallee, 1977). The original vegetation was tallgrass prairie with forested areas restricted to river valleys and steeper slopes. The current land use is primarily agricultural. Flatter terrain is mostly under cultivation and areas with shallow soils and steeper slopes are planted to exotic grasses or maintained in native prairie for livestock grazing or hay production. Remaining tallgrass prairie occurs as scattered remnants in the eastern part of the study area and in progressively larger blocks to the west, due in large part to the increasing presence of shallow, rocky soils to the west.

MATERIALS AND METHODS—As a reference, chorusing was monitored at a site 3.2 km south of Welda in Anderson County. This area consists of gently rolling terrain along the divide between the Marais des Cygnes and Neosho watersheds and the land cover is mostly tallgrass prairie. Calling by *R. areolata* was monitored each year from 1989 to 1993 by one of us (WRB). In 1989, the date of first calling and the peak calling period were recorded. In 1990 to 1993, calling activity was monitored on a daily basis throughout the breeding season (late February to mid-May). Relative calling activity was recorded as *low* (few individuals calling, calls infrequent), *moderate* (few to moderate numbers of individuals calling, calls infrequent to regular), *high* (many individuals calling, moderate calling frequency), and *peak* (many individuals calling, calls a continuous "roar"). The volume spanned by these subjective categories appeared to more closely resemble a logarithmic, rather than a linear, scale. Breeding sites were checked periodically for the presence of egg

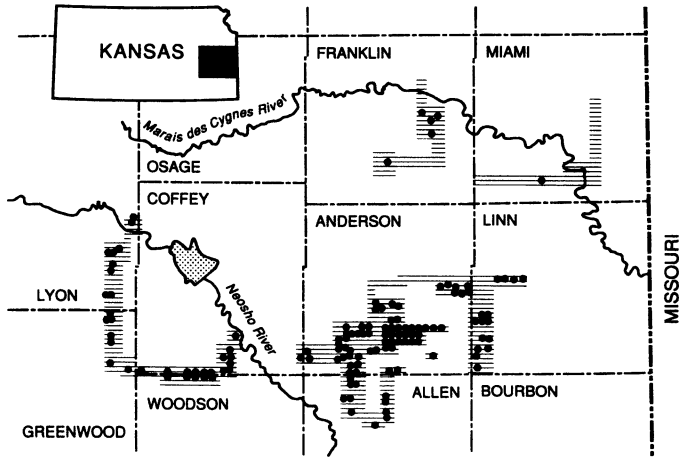

FIG. 1—Map of study area in east-central Kansas. Shaded areas show locations of aural surveys of calling *R. areolata*. Dots show locations of calling males from 1989 to 1993.

masses during and after the breeding season. Weather records (mean daily high and low temperatures and daily precipitation) were obtained for Garnett, Kansas (U.S. Department of Commerce, 1989–1993), located approximately 12 km north of the study area.

Aural surveys were conducted in the nine-county study area during peaks in chorusing each year, as judged by chorusing levels at the monitoring site near Welda. Survey routes were purposely selected in areas containing tracts of tallgrass prairie. We drove county roads between dusk and 2400 h, stopping at a minimum of 0.8-km intervals to listen for calling *R. areolata*. Under average weather conditions, calling males can be heard from a distance of approximately 0.8 km. Thus, an 0.8-km listening stop interval resulted in detection of most calling males and minimized the potential of counting the same individuals more than once. At each stop, the location and relative numbers of calling individuals were recorded on county maps. Because stops were brief (usually <3 minutes) and conducted by more than one individual, we did not attempt to distinguish four categories of calling activity as was done at the monitoring site. Instead, calling was recorded as *low* (calls periodic: 1 to 3 males actively chorusing or ≤10 males calling infrequently) or *high* (calls continuous: ≥4 males actively chrousing or >10 males calling infrequently). The low category used here for aural surveys encompasses the low and moderate categories of relative calling activity used at the monitoring site, and the high category used for aural surveys encompasses the high and peak categories at the monitoring site.

After three aural surveys conducted 11 to 12 March 1990 in Anderson, Allen, Linn, and Franklin counties, follow-up visits in July, 1990, were made to assess land cover. Along each route, land within 0.4 km of each listening stop was classified into the following categories: prairie hay meadow, prairie pasture, cropland, and non-native (brome or fescue) pasture. Land use immediately surrounding each chorus location also was recorded. For purposes of analysis, prairie hay meadow and prairie pasture were combined ("prairie") and cropland and nonnative pasture were combined ("cropland"). Each stop was categorized as being surrounded entirely by cropland within 0.4 km or as having prairie and cropland within 0.4 km. A prairie-only category was not used because few stops were surrounded entirely by prairie. A 2 × 2 chi-square test was used to test for an association between land use (i.e., entirely cropland, or prairie and cropland) and the presence or absence of calling frogs at stops.

RESULTS—*Chorusing Phenology*—Daily records of chorusing activity for 1990 to 1993 near Welda, Kansas, are shown in Figs. 2 to 5. In each year, initiation of the breeding season coincided with the first warm rains of the year. Temperatures of ≥13.0°C appeared necessary for active chorusing, although sporadic calling was noted at temperatures as low as 8.0°C. In 1990 and 1991, active calling first began following rains of <20 mm. In both these years, earlier rains had created moist soil conditions. Calling in 1992 was initiated during moderate (35 mm) rains on 4 to 5 March. In 1993, calling began with the arrival of warmer weather 5 days after the first rains in March. The length of the calling season (date of first calls to date of last calls) ranged from a low of 22 d (1993)

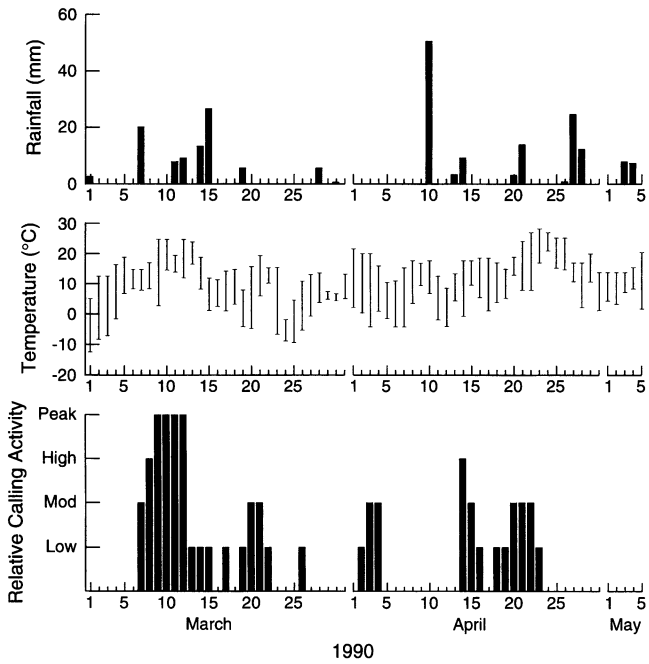

FIG. 2—Rainfall, daily maximum and minimum temperatures, and chorusing activity by *R. areolata* at a site near Welda, Kansas, in 1990.

to a high of 55 d (1992). Interestingly, the year with the fewest calling days (1993) had a wet spring following a wet winter that produced saturated soils and high water levels after late March.

Daily records of calling by *R. areolata* were not kept in 1989. However, a summary of calling activity during this year is provided here. After an unusually dry winter and early spring, 46 mm of rain fell on 28 March and an additional 29 mm of rain fell on 30–31 March. Mean daily high and low temperatures for the 29–31 March period were 20.5°C and 6.0°C. Calling males were first recorded on 29 March. Chorusing levels increased on subsequent nights and peaked during the week following 29 March. Calling then continued intermittently through most of April despite dry conditions. (Total April rainfall = 13 mm.)

Calling activity appeared to be dependent on air temperature, rainfall, and other environmental factors (Figs. 2 to 5). Cool temperatures often appeared to curtail or halt calling activity, especially early in the breeding season (e.g., 14–20 March 1990, 9–31 March 1992, 1–10 April 1993). Several days of warm (>15.0°C) weather often preceeded the first calling activity of the year, suggesting that low soil and water temperatures in late winter limit calling activity. Rainfall appeared to effect calling activity in two ways. First, rainy weather had a direct, stimulating effect on calling. Second, rainfall added water to breeding sites. Strong chorusing on nights without rain almost invariably occurred when breeding sites contained water from earlier rains (see especially 1990 and 1992; Figs. 2 and 4).

Chorusing activity peaked within a week of the start of the breeding season in all years except 1991 (Figs. 2 to 5). Peak chorusing levels also were characterized by short duration (4 d in 1990 and 1992, and 3 d in 1991 and 1993) and a tendency to occur on consecutive days once each spring. Only in 1993 did peak chorusing not occur on sequential days, and in this year cold weather arrived after one night of strong chorusing (Fig. 5). In 1991, conditions were unusually dry, and while chorusing was initiated after moderate rains in mid-April, chorusing did not peak until about 1 May when additional rains fell (35 mm on 25 to 30 April; Fig. 3) and breeding sites finally filled with water.

The daily timing of calling was variable. Call-

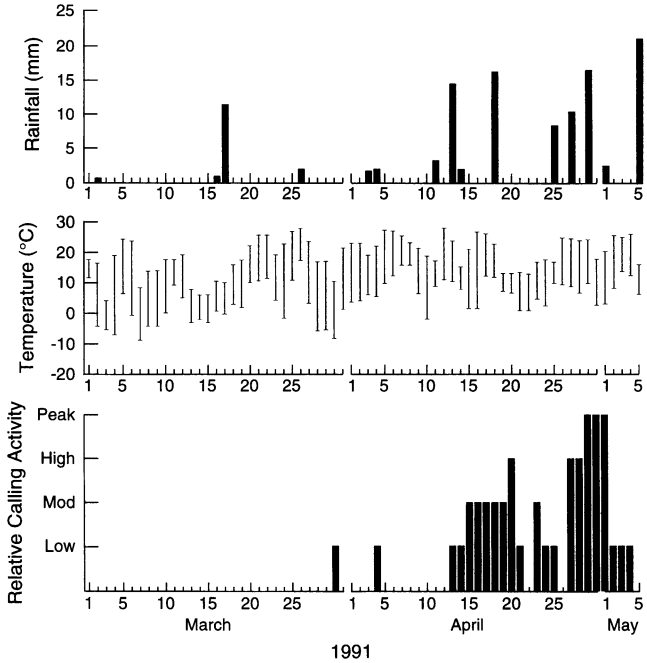

FIG. 3—Rainfall, daily maximum and minimum temperatures, and chorusing activity by *R. areolata* at a site near Welda, Kansas, in 1991.

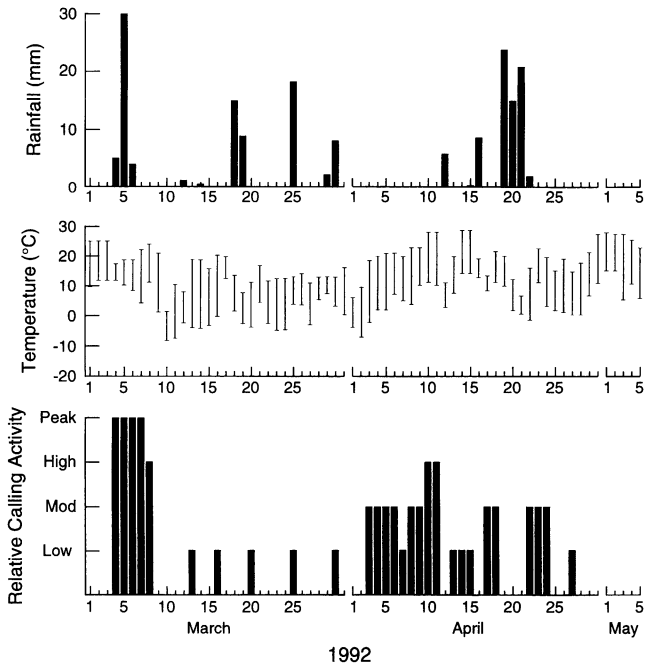

FIG. 4—Rainfall, daily maximum and minimum temperatures, and chorusing activity by *R. areolata* at a site near Welda, Kansas, in 1992.

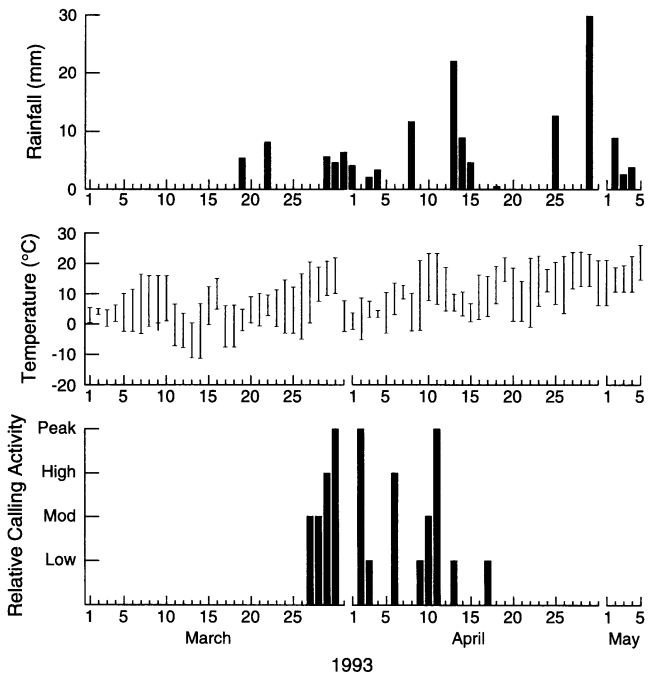

FIG. 5—Rainfall, daily maximum and minimum temperatures, and chorusing activity by *R. areolata* at a site near Welda, Kansas, in 1993.

ing seemed most frequent and most intense the first few hours after dusk. During periods of peak chorusing, calling continued all night. Under cloudy or rainy conditions, males occasionally called during daylight hours.

Several other anuran species were heard during monitoring of *R. areolata* at the Welda site. Frequent associates, in decreasing order of calling activity, were: western chorus frog (*Pseudacris triseriata*), plains leopard frog (*Rana blairi*), northern cricket frog (*Acris crepitans*), and American toad (*Bufo americanus*).

Breeding sites consisted of a variety of temporary, fishless bodies of water with grassy margins. Small stock ponds were the mostly widely available and frequently used sites for breeding. Natural breeding sites consisted mainly of prairie sloughs and depressions. One of us (WRB) recalls *R. areolata* often breeding in old bison wallows. Today, the few such wallows that remain have mostly silted in and do not hold water for extended time periods.

Egg Masses—At the monitoring site near Welda, egg masses of *R. areolata* were observed in breeding pools following periods of strong chorusing. Egg masses were observed on 13 April 1989 (ca. 100 egg masses found; eggs hatching), 28 March 1990 (31 egg masses found; eggs hatching), and 11 April to 1 May 1991 (egg masses few). Egg masses were typically 150 to 210 mm in diameter and were supported by vegetation in shallow water, generally 150 to 200 mm in depth. Frequently, egg masses were clustered within a pool. In one case, 22 egg masses were found in a 1-m^2 area of a larger pool.

Burrow Observations—On several occasions, individuals of *R. areolata* were observed in crayfish burrows. In each instance, frogs were observed looking out from the top of the burrow in response to strong vibrations made by tractors during haying operations or by people stomping near the burrow. Crayfish were not collected in this study, but the only crayfish species known that occurs outside permanent aquatic habitats in east-central Kansas is *Cambarus diogenes*. This large crayfish is common in prairie swales and other poorly-drained areas where it constructs burrows down to permanent water.

Aural Surveys—Results of aural surveys in nine east-central Kansas counties are shown in Fig. 1 and Table 1. Of 346 sections of land (896 km^2) checked for the presence of calling

TABLE 1—Results of aural surveys for *R. areolata* in east-central Kansas. Entries are the number of listening stops (see text for details).

Date	Counties	Calling activity			Total stops
		None	Low	High	
3-09-90	Anderson	0	31[1]		31
3-11-90	Anderson, Linn	22	15	20	57
3-12-90	Anderson, Allen	15	19	14	48
3-12-90	Franklin	33	7	1	41
4-18-91	Miami[2]	46	1	0	47
4-28-91	Anderson	4	22	6	32
5-01-91	Coffey, Woodson	15	6	8	29
3-07-92	Coffey, Woodson, Lyon, Greenwood	5	12	13	30
	Total	140	82	62	315

[1] Calling activity not recorded.
[2] Conditions marginal for calling.

males, frogs were heard in 134 sections. Accurately estimating numbers of calling males was difficult, given that the frequency and volume with which individuals called varied greatly with environmental conditions. At most listening stops where calling males were heard, the chorus contained less than 10 males at a single pond. Large choruses usually consisted of groups of males calling from several locations. We did not attempt to census the number of calling individuals at these large choruses, but the largest choruses, with calling males spread over 1 to 3 km^2 (such as at the monitoring site near Welda), may have contained several hundred adult males.

Geographic variation in the presence and activity levels of choruses were observed in the study area (Fig. 1 and Table 1). Numerous high-activity choruses were heard in the south-central part of the study area (Allen, Anderson, Coffey, and Woodson counties), whereas choruses were fewer and calling activity lower in the northern and western portions of the study area (Greenwood, Lyon, Franklin and Miami counties; Fig. 1). Two habitat characteristics, land cover type and topography, appear partly responsible for these differences. Areas with high calling activity tended to be native grasslands with low relief. Few frogs were detected on steeply sloping and shallow-soiled uplands. Much of the western portion of the study area consists of prairie on shallow-soiled uplands. Farther east, where more mesic, deep-soiled conditions prevail, much of the land is in cultivation and prairie is scarce.

Habitat Analyses—Land cover analyses following aural surveys at 128 listening stops in 1990 revealed that 74 of the stops had prairie within 0.4 km and 54 stops had only cropland within 0.4 km. Calling frogs were heard at 50 of the 128 stops, and all stops where frogs were heard were in prairie (44 stops) or within 0.4 km of prairie (6 stops) ($\chi^2 = 50.07$, $d.f. = 1$, $P < 0.001$). No *R. areolata* were heard in areas consisting exclusively of cropland or non-native grasslands. Prairies where frogs were found were being used for pasture, hay production, or were idle land. The range condition of these sites varied greatly, yet high-activity choruses were found both on high-quality prairies (Kansas Natural Heritage Inventory, unpublished data) and on poor-quality sites dominated by weedy native and exotic species (e.g., common ragweed, *Ambrosia artemisiifolia*; Japanese brome, *Bromus japonicus*; fescue, *Festuca* sp.; goldenrod, *Solidago* sp.).

DISCUSSION—*Breeding Phenology*—The onset of calling behavior in *R. areolata* appears to be triggered by a combination of appropriate moisture conditions and ambient temperature. This 5-yr study spanned unusually wet (1992 and 1993) and dry (1991) years, yet calling phenology seemed to follow similar climatic cues each year. Sufficient rainfall to saturate the soil and partially fill breeding pools and warm temperatures (usually ≥13.0°C) appears necessary to induce males to move from burrows to breeding sites and initiate calling. During years with average to wet soil moisture, calling was initiated after the first warm rains of the year. When soil moisture was unusually low, calling did not start until several rains had occurred. Once calling had begun in a year, additional rainfall or stormy weather stimulated calling behavior, but was not a prerequisite for calling. During each calling season, calling activity was episodic. Periods without calling were often attributable to cold weather or low water conditions. In fact, during the first half of the breeding season average temperatures (March mean daily maximum = 13.5°C, mean daily minimum = 0.5°C; Sallee, 1977) are marginal for calling.

Each year, a period of intense chorusing lasting for three or four nights took place. In all

but one year (1991), this chorusing peak occurred near the beginning of the calling season. The presence of numerous egg masses following some chorusing peaks documents that chorusing peaks are associated with strong breeding activity. We speculate that a disproportionately large amount of breeding each year coincides with these chorusing peaks and question how much, if any, breeding is associated with periods of non-peak calling.

The reproductive pattern in *R. areolata* appears well adapted to the southern tallgrass prairie environment where permanent surface water is scarce, summer droughts are common, and temporary water bodies hold water most reliably during the spring months. The early breeding season enables larvae to develop in temporary pools when they are most likely to hold water continuously for several months. Unlike xeric-adapted species, the period of water dependency in *R. areolata* is relatively long, approximately 75 d (Bragg, 1953). Delays in egg-laying expose larvae to increasing risk of summer drought. If egg deposition were to occur on 15 March (probably close to an average date), immature frogs would emerge from breeding pools in early June. June in eastern Kansas is, on average, the wettest month of the year. (Mean June precipiation at Garnett, Kansas = 146 mm [Sallee, 1973].) Alternatively, if breeding were postponed until 1 May, larval metamorphosis would not occur until mid-July, when the likelihood of temporary water bodies drying out during summer drought has increased considerably. In summary, as in many temperate amphibians, the timing of reproduction seems to be constrained in early spring by climactic conditions permitting breeding and in late spring/summer by the increasing risk of drought that can strand larvae.

Habitat Affiliations—Rana areolata occurs widely in east-central Kansas in an area where the pre-settlement vegetation was predominately tallgrass prairie (Küchler, 1974). Within this region, the presence of this species today is strongly correlated with areas of remnant tallgrass prairie or degraded native grasslands. Previous studies noted the association of the northern crawfish frog (*R. areolata circulosa*) with tallgrass prairie (e.g., Smith, 1934; Bragg, 1953; Johnson, 1987). However, *R. areolata circulosa* is also known to persist in areas where prairie has been converted to agricultural uses (Johnson, 1987; Karrow and Allen, in litt.; Busby, pers. obser.). While *R. areolata circulosa* may persist in areas following loss of the original prairie vegetation, this study indicates that the largest remaining populations, as judged by calling activity, occur where extensive tracts of prairie remain.

This study has several conservation implications. First, populations of *R. areolata* in Kansas are more widespread than previously believed. Formerly known from few sites in the state, the species was listed as threatened in Kansas. Evidence from this study indicates that this species remains locally common, and in areas with high quality habitat, may be the dominant ranid frog. However, little high quality habitat remains. Most of the best habitat—mesic prairie on level or gently rolling terrain—was converted to cropland shortly after European settlement. The few such areas that remain continue to be converted due to current market forces favoring cropland over pasture. Increasingly, *R. areolata* is restricted to marginal habitats such as non-native grasslands, prairie remnants surrounded by cropland, or rocky, shallow-soiled grasslands.

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