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## Postbreeding Movement and Habitat Use of the Plateau Brown Frog, *Rana kukunoris*, in a High-Elevation Wetland

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**ABSTRACT.**—We studied the movement patterns and habitat selection of 33 radio-tagged Plateau Brown Frogs (*Rana kukunoris*) in the Zoige Alpine Wetland in southeastern Qinghai-Tibet plateau. Our goals were to (1) understand postbreeding movement patterns of *R. kukunoris*; (2) describe microhabitat use, with special reference to use of small mammal burrows; (3) test for movement pattern and microhabitat use differences between sexes and between seasons; and (4) provide a preliminary description of overwintering sites. We found no differences in movement patterns between sexes in *R. kukunoris*, however, directional movement trends differed between habitats. Male and female *R. kukunoris* showed similar microhabitat selection with regard to air temperature, relative humidity, and vegetation height. Although males used mammal burrows more frequently than females at one study site, BaiHua, both sexes used these microhabitats frequently during their movements. Overwintering sites of *R. kukunoris* were characterized by year-round flowing water. Results from this study will assist in making decisions about conservation and land protection for this species.

Montane amphibians face a variety of extinction threats. In addition to the most pressing threats facing most amphibians, habitat loss and degradation, some populations have declined enigmatically in apparently pristine environments (Stuart et al., 2004; Cushman, 2006). One of the difficulties in protecting amphibians is that many species require a variety of habitat types to complete their life cycle, and failure to conserve any one of these habitats can result in local extirpation (Becker et al., 2007). Detailed knowledge of the habitat use and movement patterns of amphibians is needed for effective conservation planning. With an understanding of critical habitats and the spatial context in which amphibians occur, better decisions can be made for land protection and acquisition (e.g., Fellers and Kleeman, 2007). For example, with explicit knowledge of the composition and arrangement of preferred overwintering, breeding, and summer habitats of Wood Frogs (*Lithobates sylvaticus*), it was apparent that much less habitat area would require protection than perceived through traditional core habitat models (Baldwin et al., 2006).

Sinsch (1990) suggested that habitats must provide four major resources for the annual activities of anurans: reproduction, nutrition acquisition, hibernation, and aestivation. In some circumstances, these resources may be located in the same habitat patch, and anurans need not consume energy resources to migrate (Pilliod et al., 2002). For many temperate anurans, however, some or all of those resources are spatially separated, thereby requiring seasonal migrations among different habitat patches (Sinsch, 1988; Pilliod et al., 2002; Muths, 2003), in particular for the use of resources that are critical to the survival of an animal and can only be found in specific habitat patches, such as overwintering sites at high altitudes or latitudes (Dunning et al., 1992; Matthews and Pope, 1999; Pilliod et al., 2002). Microhabitats such as vegetation or mammal burrows with proper temperature and relative humidity are important in harsh environments to allow amphibians to maintain suitable body temperatures and prevent predation during their terrestrial movements (Spieler and Linsenmair, 1998; Trenham, 2001; Johnson et al., 2008).

The Plateau Brown Frog, (*Rana kukunoris*) is endemic to the Qinghai-Tibet plateau of western China where it breeds in a variety of habitats including streams, ponds, and fens (Zhang,

1999; Xie et al., 2000). In autumn, 90% of the population of *R. kukunoris* in the Zoige Alpine Wetland is located in a 51-m radius core area surrounding ephemeral water bodies where they preferred microhabitats with 5.1–10 cm high vegetation and either yak feces or small mammal burrows (Dai et al., 2005a,b). The species has experienced recent declines in site occupancy and relative abundance in the Zoige wetland for reasons unknown (Fellers et al., 2003). The Zoige wetland is one of China's largest and is a complex of various high-elevation wetland types that contribute to the Yellow River watershed (Yan and Wu, 2005). The Zoige wetland is a fragile ecosystem. It is undergoing a succession from wetlands to wet meadows, to sandy meadows, and finally to sand dunes. The deterioration is accompanied by a loss of wetland functions and biodiversity as well as increasing air temperatures (Yong et al., 2003) and is apparently related to increased grazing pressure and extraction of groundwater, as well as wetland ditching and draining (Yan and Wu, 2005). As *R. kukunoris* is an important part of the unique biodiversity of this area, movement and habitat selection information are needed to make management decisions.

We used radiotelemetry to monitor Plateau Brown Frogs at two sites within the Zoige wetland to meet the following objectives: (1) understand postbreeding movement patterns of *R. kukunoris*; (2) describe microhabitat use, with special reference to use of small mammal burrows; (3) test for movement pattern and microhabitat use differences between sexes and among seasons; and (4) provide a preliminary description of overwintering sites.

### MATERIALS AND METHODS

**Study Area.**—We conducted our research in the Zoige (Rouergai) National Wetland Nature Reserve (ZNWNR) in northern Sichuan Province, China. This reserve is located near the eastern edge of the Qinghai-Tibet Plateau at elevations between 3,400 m and 3,700 m. The mean annual temperature 4 km away in the city of Zoige was 0.7°C with a maximum air temperature of 10.7°C in July and a minimum air temperature of -10.7°C in January (Bai et al., 1996). Mean annual rainfall was 656.8 mm. The study area falls within the Zoige Basin and includes a wetland complex of wet meadows, ponds, brooks, and marshes surrounded by low hills and meadows. The

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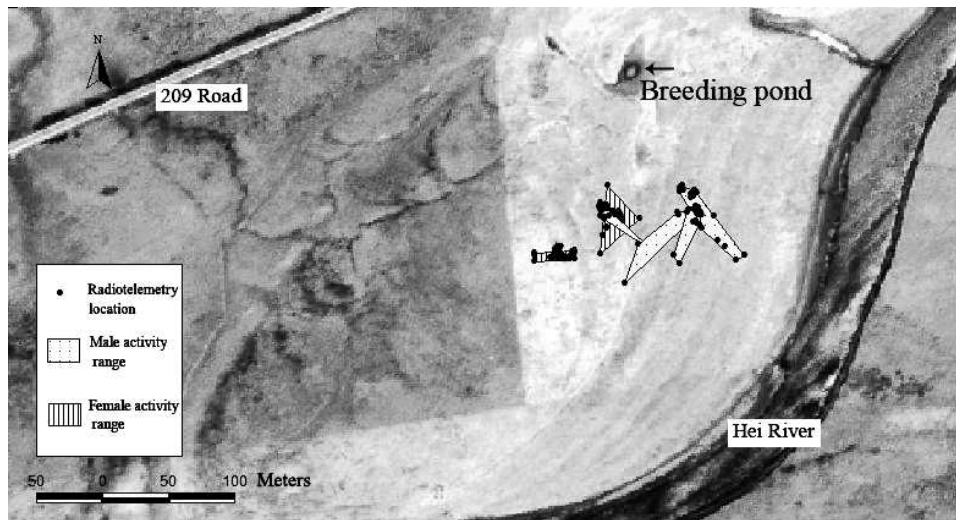


FIG. 1. Activity range of male and female Plateau Brown Frog *Rana kukunoris* during early season at BaiHua in the Zoige National Wetlands Nature Reserve, Sichuan, China, 2006.

interspersed meadows are used by Tibetan pastoralists for grazing of yaks and sheep. The Zoige Basin is considered to be of global significance for wetland biodiversity conservation and is home to such endangered species as the black-necked crane, *Grus nigricollis* (Yan and Wu, 2005). The area is inhabited by three species of amphibians endemic to the Qinghai-Tibet Plateau; *Bufo minshanicus*, *Nanorana pleskii*, and *R. kukunoris* (Zhang, 1999).

We used two sites for our study of *R. kukunoris*. The first site, BaiHua ( $33^{\circ}35'29''\text{N}$ ,  $102^{\circ}54'53''\text{E}$ ; elevation 3,430 m), was a circular pond that had a surface area of  $\sim 0.25$  ha and was  $<1$  m in depth; the site was situated within meadows north of the Hei River and dried most years by the end of the summer (Figs. 1, 2). We observed breeding and successful metamorphosis of *R. kukunoris* from the pond. The second site, JunQu ( $33^{\circ}36'02''\text{N}$ ,  $102^{\circ}56'25''\text{E}$ ; elevation 3,440 m), was located approximately 3 km southwest of BaiHua and was a 2–3-m wide spring-fed brook that ran through meadows. Plateau Brown Frogs bred along the length of the brook within the study site (Figs. 3, 4). BaiHua and JunQu were used as study sites for *R. kukunoris* that are representative breeding habitats available in Zoige. Vegetation surrounding both sites was dominated by *Pedicu-*

*laris oederi*, *Polygonum viviparum*, *Potentilla anserine*, *Leontopodium* spp., and *Agrostis sibirica*.

**Radiotelemetry and Data Collection.**—We captured frogs by hand, determined sex based on enlarged nuptial pads of males, and measured their snout-vent length (SVL) to the nearest millimeter and mass to the nearest gram using dial calipers and Pesola spring scales, respectively. Radio transmitters (Holohil model BD-2, 0.96-g, battery life 42 days for frogs SVL 48–60 mm; model PD-2, 2.4-g, battery life 90 days for frogs SVL  $>60$  mm) were attached via an elastic-cord waist band (see Rittenhouse and Semlitsch, 2007). Frogs were released at point of capture. Total mass of transmitters was  $<10\%$  of frogs' body mass (Richards et al., 1994). We relocated frogs daily using a three-element Yagi antenna and a model Merlin 12 receiver (Custom Electronics of Urbana Inc., IL) and examined frogs every two days for abrasions and to adjust belt tightness. We tracked seven frogs (3♀, 4♂) at BaiHua for an average of  $15.8 \pm 0.3$  days from 8–23 July 2006 and nine frogs (5♀, 4♂) for  $8.7 \pm 0.5$  days from 20–28 September 2006. We tracked 10 frogs (5♀, 5♂) at JunQu for  $17.4 \pm 3.5$  days from 20 May to 21 June 2007 and seven frogs (4♀, 3♂) for  $18.7 \pm 2.1$  days from 12 October to 2 November 2007. In the Zoige wetlands, *R. kukunoris* breed in

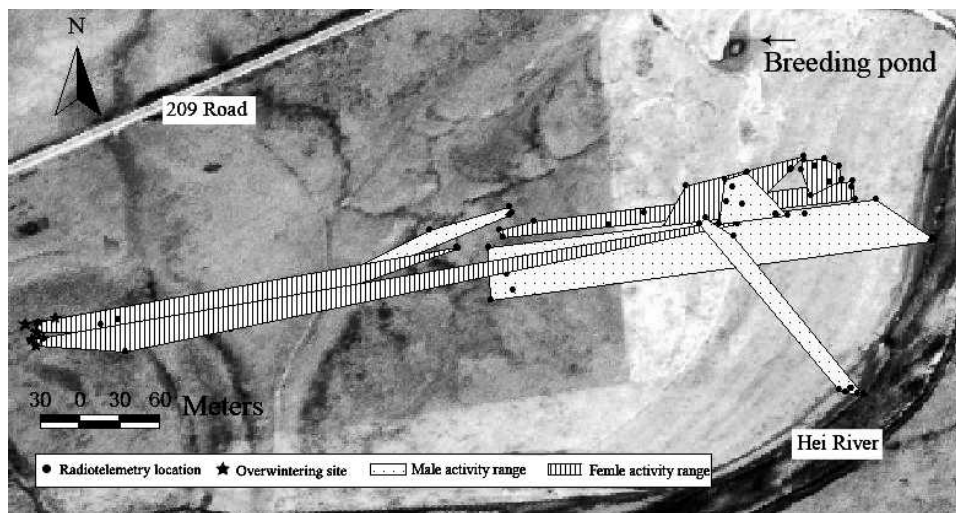


FIG. 2. Activity range of male and female Plateau Brown Frog *Rana kukunoris* during late season at BaiHua in the Zoige National Wetlands Nature Reserve, Sichuan, China, 2006.



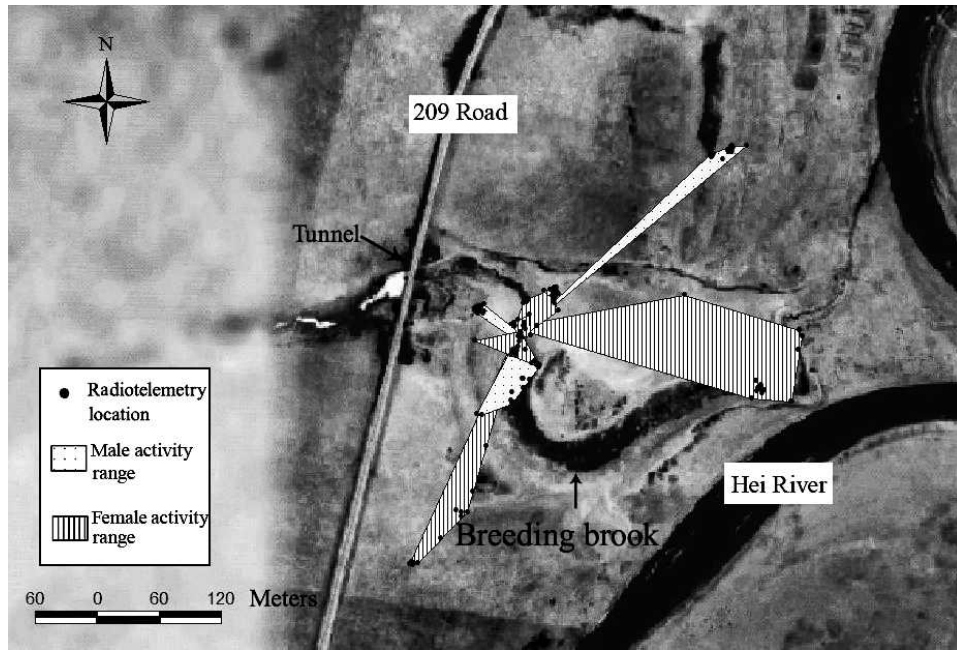


FIG. 3. Activity range of male and female Plateau Brown Frog *Rana kukunoris* during early season at JunQu in the Zoige National Wetlands Nature Reserve, Sichuan, China, 2007.

April and early May and then forage in grasslands until early to mid-September when they begin migrating to overwintering sites once nighttime temperatures drop below freezing (Qi et al., 2007a,b). Based on this information, we categorized May to July as the early season and September to November as the late season. Seasons differed slightly between years because of differences in weather. Upon relocating a frog, we used a handheld GPS unit (Garmin Etrex) to record their position in UTM coordinates. We collected habitat measurements at frog locations and random locations that were paired with frog locations. A random location was chosen based on a random compass bearing (0–360°) and distance (0–50 m) from frog location and marked with a flag at the ground surface (Faccio, 2003). We measured air temperature and relative humidity at the ground surface within 20 cm from the frog with a digital

max/min thermohygrometer (Goldensun Electronic Technology Co., LTD, model HTC-609) at all frog locations and at random locations at JunQu. We measured vegetation height using a tape measure from the soil surface to the tip of the highest vegetation at all frog locations at BaiHua, during the early season at JunQu, and at random locations during the early season at JunQu. We measured water depth with a tape measure from the water surface to the substrate and counted the number of conspecifics within a 1-m<sup>2</sup> area at frog and random locations during the late season in JunQu. We also noted whether frogs were inside of a mammal (Plateau Pika, *Ochotona curzoniae*; Long-tailed Dwarf Hamster, *Cricetulus longicaudatus*; or Plateau Zokor, *Myospalax baileyi*) burrow upon relocation. Daily precipitation data were obtained from the Zoige Meteorological Stations 2 km away from BaiHua.

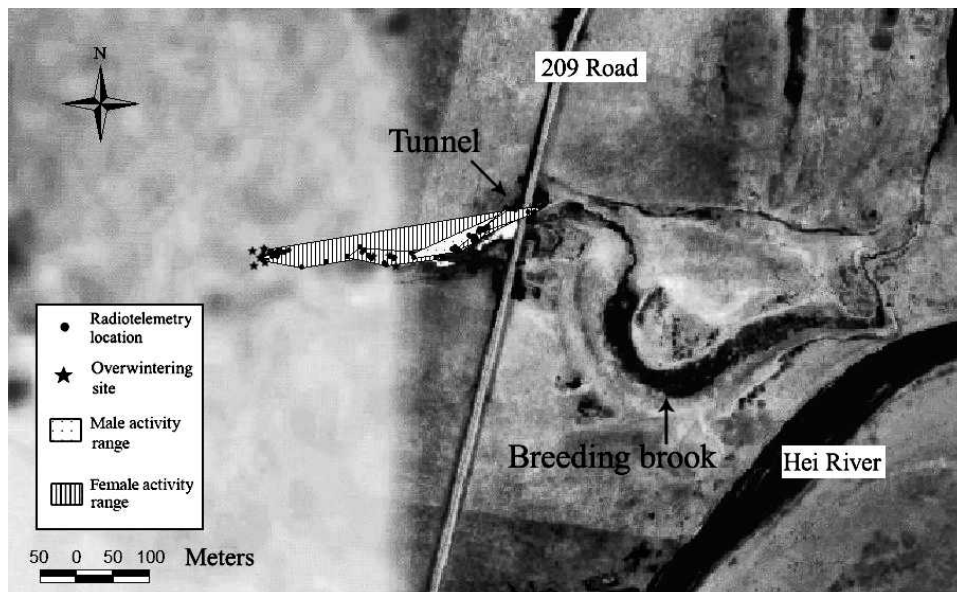


FIG. 4. Activity range of male and female Plateau Brown Frog *Rana kukunoris* during late season at JunQu in the Zoige National Wetlands Nature Reserve, Sichuan, China, 2007.

TABLE 1. Results of three-way analysis of covariance (ANCOVA) testing the effects of site, season, and sex as main factors and snout-vent length (SVL) as a covariate on three movement parameters for *Rana kukunoris* at BaiHua and JunQu in the Zoige National Wetland Nature Reserve, Sichuan, China 2006–07. Values given are  $F_{1,24}$  values.

Effects in ANCOVA	Activity range area (m <sup>2</sup> )	Average daily distance (m)	Distance from release (m)
Site	0.61	1.15	0.14
Season	4.35*	18.52**	3.54
Sex	0.03	0.046	0.16
Site × season	9.30**	22.86**	4.63*
Site × sex	2.37	0.42	1.60
Season × sex	0.97	0.93	3.29
Site × season × sex	0.72	<0.01	<0.01

\*  $P < 0.05$ , \*\*  $P < 0.001$ .

Tracked frogs that were located under the ground surface and remained at the site without changing location for more than three successive days in the late season were considered to have started their hibernation (Ra et al., 2008).

**Data Analysis.**—We entered frog locations into ArcGIS 9.1 and used them to calculate estimates of movement parameters using Hawth's Tools (www.spatial ecology.com), a plug-in for ArcGIS. We used all locations for a given frog within each tracking period and the 100% minimum convex polygon method to calculate activity range area. We also calculated average daily distance moved and net distance moved from release point for each frog within each tracking period. To obtain the average daily movement distance for all frogs, first we summed the distance of all frogs on a given day and then divided it by the number of frogs. We used circular statistics (Zar, 1999) to test for linearity of movements within each tracking period and interpreted significant linearity as evidence of directed movement.

Individual frogs were used as the sampling unit for all statistical tests. When issues with nonnormality (Kolmogorov-Smirnov  $P < 0.05$ ) or heteroscedasticity (Levene's test  $P < 0.05$ ) could not be rectified with transformations, we used nonparametric statistical tests. We used a full-factorial three-way analysis of covariance with site, sex, and season as main factors and SVL as a covariate to test for differences in activity range area, average daily distance moved, and distance moved from release point. We compared activity range area, average daily distance moved, and distance moved from release point between early and late seasons at both sites using independent-samples  $t$ -tests. We compared air temperature at frog locations between sexes using a Mann-Whitney  $U$ -test and compared relative humidity, vegetation height, number of conspecifics, and water depth between sexes using independent-sample  $t$ -tests. To explore microhabitat preferences, we used paired-sample  $t$ -tests to compare average air temperature, relative humidity, vegetation height, number of conspecifics, and water depth between frog locations and random locations at JunQu

during seasons for which data were available. Because of differences in data collection protocols, we could test for seasonal differences in frog and random air temperature and relative humidity only at JunQu; we accomplished these comparisons using independent-samples  $t$ -tests. We used contingency table analysis to test the hypotheses that sex was independent of use of burrow and nonburrow habitats at both sites combined and separately. A Spearman correlation analysis was used to determine the correlation between the average daily movement distance for all frogs and rainfall. We reported mean with standard error and considered statistical test significant when  $P < 0.05$  unless otherwise noted. We used Bonferroni corrections to adjust family-wise type I error rates for gender-related comparisons of microhabitats and frog versus random microhabitat comparisons (adjusted  $P$ -value = 0.01) and for seasonal comparisons of frog and random microhabitats (adjusted  $P$ -value = 0.013).

## RESULTS

**Movement Patterns.**—We found no differences between sites or sexes for activity range area, average daily distance, or distance moved from release point (Table 1). Both activity range area and average daily distance moved were higher during the late season ( $4,112 \pm 1,302$  m<sup>2</sup> and  $40.18 \pm 10.14$  m, respectively) than during the early season ( $3,294 \pm 1,273$  m<sup>2</sup> and  $11.88 \pm 1.93$  m, respectively; Table 1). We found no significant site × sex, season × sex, or site × season × sex interactions for activity range area, average daily distance moved, or distance moved from release point (Table 1). We found a significant site × season interaction for activity range area, average daily distance moved and distance moved from release point (Table 1). Activity range area, average daily distance moved, and distance moved from release point were all higher in the late season than in the early season at BaiHua, whereas we detected no seasonal differences in any movement parameters at JunQu (Table 2). We found no significant correlation between average daily movement distance for all frogs and rainfall during either early or late seasons at BaiHua or JunQu ( $r = 0-0.34$ ,  $P > 0.21$ ; Fig. 5). Of all individuals tracked, 33% of males and 50% of females showed directed movement trends. During the early season at BaiHua, 14% of frogs showed directed movement trends ( $Z = 1.17$ ,  $P < 0.05$ ), whereas 78% of the frogs in the late season showed directed movement trends ( $Z = 1.35-5.02$ ,  $P < 0.05$ ). At JunQu, 30% of frogs during the early season showed directed movement trends ( $Z = 1.08-3.61$ ,  $P < 0.05$ ), whereas during the late season 43% of tracked frogs showed directed movement trends ( $Z = 0.37-4.1$ ,  $P < 0.05$ ).

**Habitat Use.**—Male and female microhabitats did not differ in terms of air temperature (Mann-Whitney  $U = 131$ ,  $P = 0.87$ ), relative humidity ( $t_{31} = 0.41$ ,  $P = 0.69$ ), vegetation height ( $t_{24} = -0.31$ ,  $P = 0.76$ ), number of conspecifics ( $t_5 = 0.06$ ,  $P = 0.96$ ), or water depth ( $t_5 = 1.00$ ,  $P = 0.36$ ). Neither air temperature nor

TABLE 2. Seasonal comparison of movement parameters ( $\bar{x} \pm SE$ ) for *Rana kukunoris* at BaiHua and JunQu in the Zoige National Wetland Nature Reserve, Sichuan, China 2006–07. Results of independent samples  $t$ -test comparisons are shown with  $P$ -values.

	Season		$t$ -value	df	$P$ -value
	Early	Late			
<b>BaiHua</b>					
Activity range area (m <sup>2</sup> )	448 ± 114	5,508 ± 1,998	-4.73	14	<0.001
Average daily distance (m)	7.1 ± 1.19	61.4 ± 14.50	-6.60	14	<0.001
Distance from release (m)	29.2 ± 7.64	138.5 ± 39.20	-3.23	14	0.006
<b>JunQu</b>					
Activity range area (m <sup>2</sup> )	4,279 ± 2,355	2,317 ± 1,375	0.79	15	0.44
Average daily distance (m)	15.2 ± 2.76	12.8 ± 3.03	0.63	15	0.54
Distance from release (m)	105.6 ± 38.40	72.1 ± 30.50	0.19	15	0.85

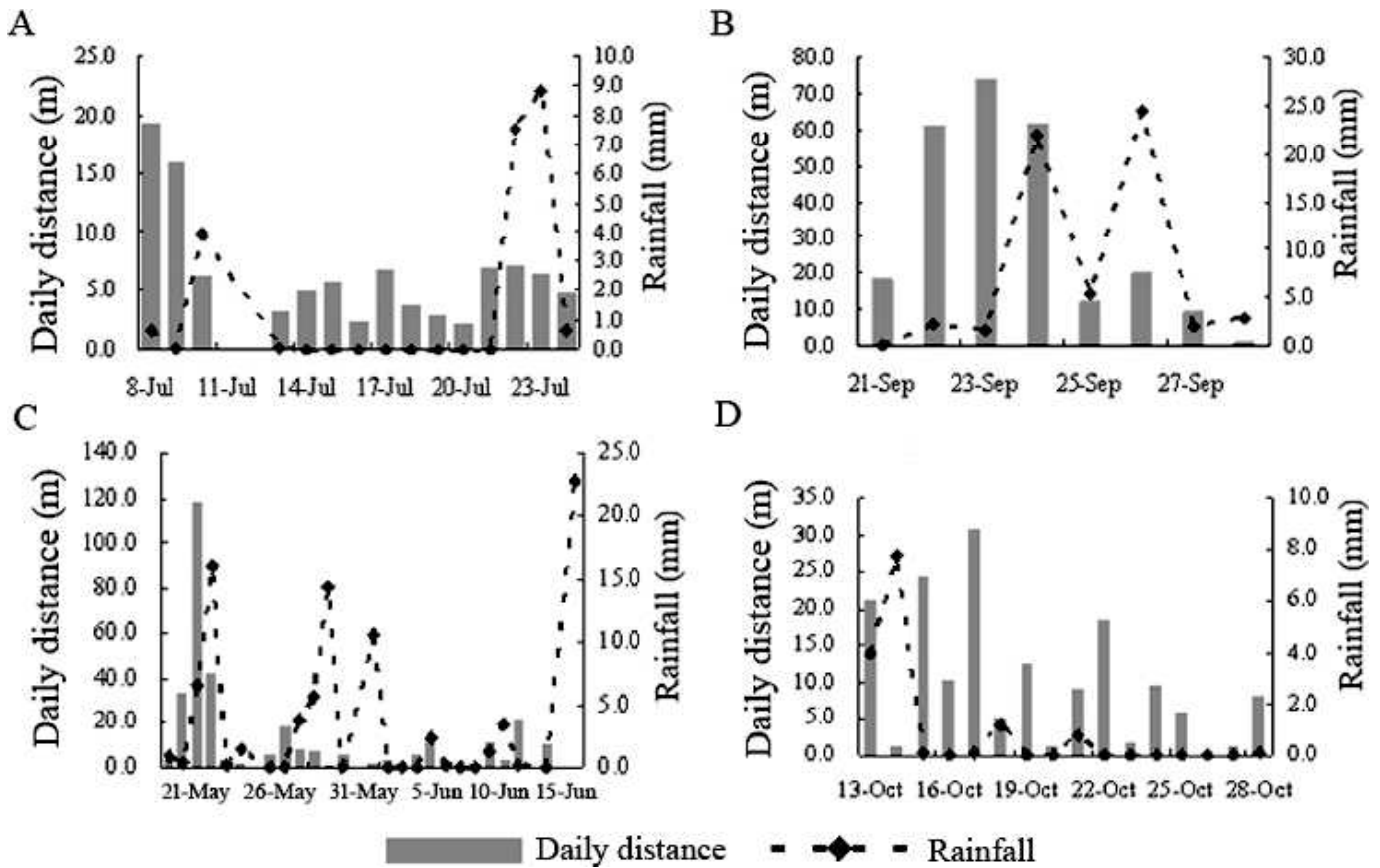


FIG. 5. Average daily movement distance and rainfall during (A) early season at BaiHua, (B) late season at BaiHua, (C) early season at JunQu, and (D) late season at JunQu of Plateau Brown Frog *Rana kukunoris* in the Zoige National Wetlands Nature Reserve, Sichuan, China, 2006–07.

vegetation height differed between frog and random locations. Relative humidity, water depth, and the number of conspecifics were all higher at microhabitats used by frogs than random locations (Table 3). Relative humidity did not differ between seasons ( $t_{15} = -0.45$ ,  $P = 0.66$ ) at random locations but was higher in the late season ( $93.6 \pm 9.20$  SD) than in the early season ( $72.9 \pm 9.84$  SD;  $t_{15} = -4.38$ ,  $P = 0.001$ ) at frog locations. Air temperature was higher in the early season at random and frog locations ( $15.8 \pm 6.82$ ,  $15.3 \pm 5.89$ , respectively) than the late season ( $6.4 \pm 3.05$ ,  $6.4 \pm 3.33$ , respectively) ( $t_{15} = 11.53$ ,  $P = 0.001$ ,  $t_{15} = 14.19$ ,  $P = 0.001$ , respectively). At BaiHua males used burrow habitats more often (25%) than females (10%;  $\chi^2 = 5.45$ ,  $df = 1$ ,  $P = 0.02$ ). At JunQu, males and females used burrows in the similar proportion (25% and 18%, respectively;  $\chi^2 = 1.08$ ,  $df = 1$ ,  $P = 0.30$ ). We observed seven microsites where *R. kukunoris* overwintered, all at JunQu (Fig. 4). Frogs that we tracked during the late season at BaiHua moved away from the study site and arrived at a nearby spring-fed deep pool. Their transmitter batteries subsequently died, and we presume that they overwintered there (Fig. 2). In addition to a small spring-fed stream where two frogs overwintered at JunQu, the study site contained a spring-fed wetland pool where four frogs overwin-

tered; both habitats contained flowing water year-round. One frog entered a small stone cavity and remained there inactive for more than two weeks. This cavity was more than 2-m deep and might connect to the water table.

#### DISCUSSION

We found no differences in movement patterns between sexes in *R. kukunoris*. This finding is consistent with movement patterns of *Bufo calamita*, *Leptodactylus labyrinthicus*, and *Rana draytonii* (Miaud et al., 2000; Tozetti and Toledo, 2005; Fellers and Kleeman, 2007). Other studies on frog movement patterns showed that female frogs move farther than males during the postbreeding period (Pilliod et al., 2002; Muths, 2003; Bartelt et al., 2004; Johnson et al., 2007). Several reasons have been proposed to explain female-biased movements. Site fidelity may give males a competitive advantage when females arrive to breed in the spring. Different energetic requirements associated with reproduction may require females to travel farther for foraging, and larger body sizes may allow females to do so (Turner, 1958; Sinsch, 1992; Bartelt et al., 2004). The reason movement patterns do not differ between sexes of *R. kukunoris* is

TABLE 3. Relative humidity, air temperature, vegetation height, water depth, and number of conspecific ( $\bar{x} \pm SE$ ) Plateau Brown Frogs (*Rana kukunoris*) at microhabitats of radio-tagged frog and at random locations, Zoige National Wetland Nature Reserve, Sichuan, China, 2007. Results of paired *t*-test comparison of frog versus random locations are shown with *P*-values.

Variable	N	Frog	Random	Paired- <i>t</i>	<i>P</i>
Relative humidity (%)	24	81.5 $\pm$ 3.40	66.3 $\pm$ 1.48	3.24	<0.001
Air temperature (°C)	24	11.6 $\pm$ 1.13	11.9 $\pm$ 1.19	-1.61	0.299
Vegetation height (cm)	16	6.0 $\pm$ 0.54	5.2 $\pm$ 0.45	2.21	0.028
Water depth (cm)	7	20.4 $\pm$ 4.98	1.3 $\pm$ 0.27	3.78	0.009
Conspecifics (# individuals)	7	12.7 $\pm$ 1.95	1.8 $\pm$ 0.64	5.77	<0.001



unknown, but the lack of difference may be related to the lack of sexual size dimorphism in this species (Fei et al., 2009).

We found evidence of late-season migratory behavior at one of our sites (BaiHua) but not the other (JunQu). Sites with specific characteristics (especially adequate dissolved oxygen and water that does not freeze) are used by frogs during overwintering, especially in harsh environments that experience long winters (Lamoureux and Madison, 1999; Holenweg and Reyer, 2000; Pilliod et al., 2002; Lemckert, 2004). These habitats are often spatially separate from the breeding or foraging habitats used by a species. Before the onset of winter, *Rana muscosa* moved to areas of flowing or deep water that did not freeze (Matthews and Pope, 1999). *Lithobates clamitans* made movements during autumn to areas of flowing water in streams and seeps to overwinter (Lamoureux and Madison, 1999) and *Rana luteiventris* moved to sites that provided thermal buffering (Bull and Hayes, 2001). In Zoige high-elevation wetlands, winters last for more than six months each year; thus proper overwintering sites are critical for the survival of *R. kukunoris*. Frogs at BaiHua migrated from around a temporary pool that dries by the end of the summer and is, therefore, unsuitable for overwintering; we assume the frogs moved to nearby springs with constantly flowing water to overwinter. At JunQu, in contrast, adequate overwintering habitats, such as partially frozen ponds, backwaters, and seeps, were present within the study site and, therefore, frogs did not need to consume energy resources to migrate.

Suitable microhabitats allow amphibians to conserve water and heat during terrestrial movements and are, thus, a critical aspect of amphibian ecology (Wygoda, 1984, 1989). Heterogeneous landscapes, structural differences in cover types among vegetative patches and differing movement patterns between sexes may lead to different microhabitat selection patterns between sexes. Female Western Toads (*Bufo boreas*) used terrestrial habitats extensively and were selective of certain cover types, whereas males traveled shorter distances and stayed nearer to the pond (Bartelt et al., 2004). The male and female *R. kukunoris* that we tracked showed similar patterns of movement and microhabitat use with regards to air temperature, relative humidity, and vegetation height.

The increased abundance of *R. kukunoris* we observed at microsites used by tracked frogs was likely related to an overall preference by the species for small aquatic water bodies embedded within pasture habitats. This assertion is reinforced by the increase in water depth we observed at frog sites compared to random sites; this increase is caused by a preponderance of water depths of zero at random sites. Such water bodies allow amphibians to rehydrate periodically and to escape short-term temperature extremes. Possibly because of this, the spatial distribution of frogs is often correlated with presence of water sites (Lamoureux and Madison, 1999; Hodgkinson, 2001; Jakob et al., 2003). Montane populations of *Rana temporaria* in Spain also preferentially use small puddles, at least partially to escape low nighttime temperatures (Vences et al., 2000).

Decreasing air temperature during late seasons may be a cue leading *R. kukunoris* to use moister microhabitats than during early seasons. Both Northern Leopard Frogs (*Lithobates pipiens*) and Wood Frogs (*Lithobates sylvaticus*) shift preferences to more moist microhabitats in cold temperatures. *Lithobates pipiens* prefers water over land only during cold temperatures, and likewise *L. sylvaticus* prefers to be under rather than on leaf litter during colder temperatures (Licht, 1991). Lower air temperatures at frog locations during the late season compared to early season may indicate a limit to thermoregulatory behaviors during fall in these montane frog populations. Other research has commented on the difficulty of maintaining optimal body temperatures at high elevations (e.g., Vences et al., 2000).

Although male *R. kukunoris* used mammal burrows more frequently than females at BaiHua, both sexes frequently used these microhabitats during their movements. Several individ-

ual frogs used burrows during approximately 70% of relocations. Other amphibian species, notably salamanders, are known to use mammal burrows (Madison and Farrand, 1998; Hasumi et al., 2009). Microhabitats within mammal burrows offer respite in dry or cold climates; soil temperature and humidity are both higher in areas with burrows of the plateau pika, a species found at our study sites (Smith and Foggin, 1999). Plateau Pikas are known to be a keystone species and their burrows provide important nesting and hiding sites for several species of birds and lizards (Smith and Foggin, 1999). These burrows were also used by *Bufo minshanicus* at our study sites (YQ and ZF, pers. obs.). The reason mammal burrow use differs between sexes of *R. kukunoris* at BaiHua, but does not differ at JunQu, needs more research.

Because our results suggest that this species uses or prefers ephemeral water bodies and small mammal burrows and has specific requirements for overwintering sites, we suggest that some practices used in the ZNWNR likely affect populations of *R. kukunoris*. The Zoige wetland region has been an important rangeland for nomadic yak, sheep, and horse herders for thousands of years (Miller, 1999). More recently, however the number of livestock is increasingly oversized (Yang, 1999). Excessive grazing can affect not only the community structure of vegetation, influencing microhabitat selection and thermoregulatory behavior during terrestrial migration of frogs (Kiehl et al., 1996; Eccard et al., 2000; Hayes and Holl, 2003) but also threaten small waterbodies used for reproduction and overwintering by *R. kukunoris* through the actions of trampling and erosion (YQ, pers. obs.). Efforts are underway in ZNWNR to encourage the downsizing of yak and sheep herds (Z. Ming, pers. comm.). There is a perception in ZNWNR that pika populations threaten the productivity of the rangeland and, therefore, the government poisons the animals (Z. Ming, pers. comm.). However, the extirpation of pikas and other small mammals would likely negatively affect *R. kukunoris* through the elimination of an important microhabitat—the mammals' burrows. How this affects frogs is unclear. At high densities, and more often on overgrazed ranges, pika can affect vegetation structure, thereby potentially degrading frog habitat (Smith and Foggin, 1999). There is little evidence, however, that the poisoning of pikas helps to restore rangelands, and the most effective way to keep pika populations in check is to lessen grazing pressure (Smith and Foggin, 1999). An integrated management plan that incorporates the needs of local cultures and scientific information on the requirements of local diversity will help to maintain this unique and biodiversity ecosystem.

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