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Midsummer Ground Surface Activity Patterns of Western Toads (*Bufo boreas*) in Southeast Idaho

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While some behavioral aspects of Western Toads (*Bufo boreas*) have been documented (Campbell 1970; Carey 1978; Hailman 1984; Lilliwhite et al. 1973; Mullally 1958; Muths 2003; Muths and Corn 1997; Pimentel 1955), a great deal remains unknown. Toads are ectotherms that rely on environmental conditions to maintain body temperature and conserve water. Activity patterns appear to be critical in determining body temperature (Stevenson 1985), but the specific daily behaviors used by Western Toads for thermoregulation are not fully known. The greatest gap in our understanding of amphibians derives from how little is known about daily activity (Shoemaker 1992).

Conservation measures must incorporate aspects of amphibian ecology and behavior, such as habitat relationships and factors that affect their daily movements and other activities. The response of amphibian populations to landscape changes may range from negative (e.g., habitat fragmentation; Funk et al. 2004) to positive (e.g., fire; Hossack and Corn 2007). Thus, more detailed information on their daily behaviors may help us better anticipate the effects of landscape changes on amphibians.

We conducted a focal animal study with radiotelemetry to investigate and quantitatively characterize activity patterns, behavior, and microsite selection by Western Toads in southeastern Idaho. Whereas habitat selection has been studied in this area (Bartelt et al. 2004), we advance our understanding of this species' behavior by focusing on how time of day/night, environmental conditions, and habitat relate to activity. Our results may be particularly relevant to the species' conservation in this region because the Western Toad has experienced population declines within the Greater Yellowstone Ecosystem (Koch and Peterson 1995).

Methods.—Our study was conducted within the Greater Yellowstone Ecosystem at Stamp Meadows in the Targhee National Forest (UTM 471117 E, 4928908 N; elevation approx. 2000 m) in southeastern Idaho, USA. Stamp Meadows was a seasonally flooded meadow that contained a 13 ha pond, bordered by willows (*Salix*) and aspen (*Populus*), and surrounded by coniferous forest habitats (*Pinus*, *Picea*, and *Abies*) that had been modified by logging.

We studied the daily activity of 4 male (nuptial pads present) Western Toads (range 60–85 mm snout–urostyle length; 40–70 g). We used a plastic belt to secure a 1.85 g BD-2GT transmitter (Holohil Systems, Ltd., Carp, Ontario, Canada) to each toad, a method that appears not to affect toad behavior (Bartelt and Peterson 2000; Murray and Fuller 2000).

We used focal animal sampling and observed one toad at a time with continuous recording of all instances of behavior and time (Martin and Bateson 1993). We made observations from 17 July to 3 August 1995 and divided each 24 h day into 8 observation periods of 3 h (periods: 1 = 0000–0259 h, 2 = 0300–0559 h, 3 = 0600–0859 h, 4 = 0900–1159 h, 5 = 1200–1459 h, 6 = 1500–1759 h, 7 = 1800–2059 h, and 8 = 2100–2359 h). Periods 1, 2, and 8 included times of darkness and are described as night while other periods are described as day. Periods 4, 5, and 6 are specifically described as midday. We randomly selected 2 periods each day and randomly selected a toad to observe during each of these periods. We observed each toad for each 3 h observation period.

We located toads with a Telonics TR-2 receiver and H-type directional antenna (Telonics, Inc., Mesa, Arizona). The observer sat approximately 3 m away from the toad under a camouflage net to minimize toad disturbance. We made night observations with a red-filtered 3.8 V incandescent light and used diffuse light peripheral to the central beam to reduce light intensity (Buchanan 1993). To test the effects of our light on the toads, we changed position relative to toads on several occasions during nighttime observations and the light did not appear to change direction of travel or orientation of toads.

We measured ambient (the area encompassing the study site as a whole) and microsite (the area within 3 m of the toad) weather conditions. Terrestrial ambient air temperature 1 m above ground and relative humidity were recorded with a CR10 data logger (Campbell Scientific, Inc., Logan, Utah) and PCRC-11 humidity transducer (Phys-Chem Scientific Corp., New York, New York) (<3% error between 12 to 100% RH, <1% error between 25 to 94% RH) placed near the center of the study site. Ambient measurements were taken every second, then averaged for each observation period. Terrestrial microsite air temperature was recorded 1 m above ground in shade with a Schultheis rapid registering mercury thermometer (Miller and Weber, Inc., New York, New York) at the onset, termination, and periodically during each observation period, then averaged for each observation period. Aquatic microsite water temperature, 1 cm below the water surface, also was recorded when toads were located in an aquatic microsite.

We recorded the sequence and time of all activity (e.g., attempt to capture prey using a tongue strike (feeding strike), distance traveled, position change, direction change, vocalization, habitat change, interaction with other toads) during observation periods. A minute was considered active if any detectable activity, other than breathing, was observed. Distance traveled, a subcategory and more conservative measure of activity, was used for data analysis. Distance traveled was measured in body lengths and distance in cm was estimated based on the known snout–urostyle length of each study animal. Microsite habitats (e.g., terrestrial, aquatic, underground) used by toads also were recorded. When toads were underground, ground level active minutes and distance traveled were recorded as zero because toads could not be observed directly and were not exposed to ground level environmental conditions.

Independent variables were time (observation period), average temperature (terrestrial ambient, terrestrial microsite, and aquatic microsite) during the observation period, and average relative humidity during the observation period. Temperature was categorized for analysis (< 5°C, 5–9.9°C, 10–14.9°C, 15–19.9°C, and >19.9°C). Dependent variables were active minutes and distance traveled. We used one–way analysis of variance (ANOVA) to test for potential differences between independent and dependent variables. To examine for potential differences between microsite temperature and ambient temperature, we conducted a regression analysis with indicator variables for observation periods. To examine for a potential association between relative humidity and distance traveled, we conducted a linear regression analysis. Statistical analyses were performed using Stata 8.0 software (StataCorp 2004, College Station, Texas).

Results.—We made a total of 32 observations of the four toads over the 8 observation periods (Table 1). Individual toads were seldom observed for the same number of minutes for each observation period. This was usually due to the toad disappearing from view. Toads were active during all observation periods with peaks in activity during the midday and night (Fig. 1). Activity differed among observation periods ($F_{7, 24} = 2.4$, $P = 0.05$).

During the day, toads were located at terrestrial retreat microsites, where they moved short distances and frequently changed orientation or position while basking in the sunlight. At these microsites, toads were seen making feeding strikes (Table 1) at crawling insects such as ants, spiders, and beetles. Only once did we see a toad strike at a flying ant. Toads were observed to feed during all observation periods except at night during period 1.

At night, the four toads traveled up to 40 m during period 8 from terrestrial microsites to aquatic microsites where other toads were also observed (Fig. 2). We also observed toads returning to terrestrial microsites in the early morning during periods 2 and 3. Relatively shorter distances of movement (0–0.95 m) occurred during midday observation periods 4, 5, and 6. Distance traveled differed among observation periods ($F_{7, 24} = 3$, $P = 0.02$).

In addition to a relationship between distance traveled and observation period, distance traveled was significantly different among microsite temperature categories ($F_{4, 27} = 2.9$, $P = 0.04$). Toads traveled furthest when microsite air temperature was 5–9.9°C or 10–14.9°C, and traveled shorter distances when temperature exceeded 15.0°C (Fig. 3). Observation period and temperature are related and the relationship represents a sinusoidal pattern

TABLE 1. Observation periods and activities of four Western Toads radiotracked in southeastern Idaho, USA, in July and August 1995.

	Observation Period							
	1 (0000–0259)	2 (0300–0559)	3 (0600–0859)	4 (0900–1159)	5 (1200–1459)	6 (1500–1759)	7 (1800–2059)	8 (2100–2359)
Toad 1								
Observation minutes	173	133	156	170	28	143	16	112
Active minutes	41	16	13	47	11	3	4	70
Distance traveled (cm)	1050	340	2	0	0	0	1	3971
Feeding strikes	0	0	2	6	0	2	0	2
Toad 2								
Observation minutes	180	180	180	117	115	153	72	103
Active minutes	0	0	0	17	13	0	2	44
Distance traveled (cm)	0	0	0	82	0	0	0	995
Feeding strikes	0	0	0	0	0	0	0	7
Toad 3								
Observation minutes	166	157	146	123	167	164	157	156
Active minutes	3	72	3	18	9	42	4	52
Distance traveled (cm)	0	3720	0	3	0	7	5	765
Feeding strikes	0	2	1	6	1	0	1	2
Toad 4								
Observation minutes	180	180	187	136	180	166	96	148
Active minutes	0	0	71	23	52	37	12	97
Distance traveled (cm)	0	0	1846	10	65	0	45	4045
Feeding strikes	0	0	3	1	6	2	3	1
Total all toads								
Observation minutes	699	650	669	546	490	626	341	519
Active minutes	44	88	87	105	85	82	22	263
Distance traveled (cm)	1050	4060	1848	95	65	7	51	9776
Feeding strikes	0	2	6	13	7	4	4	12

(Fig. 4). Ideally, a multivariate analysis would be performed to evaluate the relative contributions of observation period and temperature to distance traveled, but the small sample size of this study prevents such analysis. However, distance traveled appears to be related more to observation period than temperature. For example, the average microsite temperatures during observation period 8 were category 2 (5–9.9°C) and 3 (10–14.9°C); and the average distance traveled during this period was 24.4 m. However, when the same average microsite temperature categories 2 and 3 occurred during other observation periods, the average distance traveled was only 7.9 m. This suggests that the longer distances traveled during observation period 8 were related in part to time of day rather than simply microsite temperature. Relative humidity also appears to contribute to distance traveled. For example, ambient relative humidity was significantly greater when toads traveled 9 m (88.3 ± 2.5% vs. 78.3 ± 2.4%; $t = 1.73$; P = 0.047).

Microsite temperature appears to be related to microsite habitat selection. Microsite air temperatures tended to be warmer than the surrounding terrestrial ambient air temperatures during periods 3, 4, 5, and 6 (Fig. 4) and were significantly warmer during midday periods 4 and 5 ($F_{1,14} = 7.6$, P = 0.02 and $F_{1,16} = 10.6$, P = 0.005, respectively). This suggests toads selected midday microsite habitat based at least in part on temperature. At night, ambient and microsite air temperatures were often near freezing. In these cold conditions, toads were found in warmer habitats, such as aquatic microsites. When toads were in aquatic microsites, water temperatures were up to 3°C warmer than terrestrial ambient air temperatures and 13°C warmer than terrestrial microsite air temperatures. In the later dates of the study, two toads traveled greater than 80 m from aquatic microsites and did not return to aquatic microsites at night. These two toads were located underground in a rodent hole and under a tree stump during cold nights. While driving to and from the study site at night on these cold nights, we also observed several toads in crouched positions on exposed dirt roads.

Vocalization was recorded on separate occasions for each toad, including occasions not provoked by contact with another animal. A toad was heard vocalizing while: 1) an ant was crawling on its head; 2) turning body orientation; 3) in an underground hole; and 4) in the process of digging in plant material. On two occasions at night, a toad vocalized when another toad attempted to amplex with it; upon vocalization, the other toad released its grasp and moved toward and clasped another nearby toad. On two other occasions at night, we heard three male toads, positioned at separate and distant (e.g., 50–70 m) points in the pond, repeatedly and sequentially vocalize.

Discussion.—We observed four male Western Toads during midsummer at high elevation in southeastern Idaho. We found them to be active during all observation periods with a peak in activity in the midday and early night. Despite being active in the midday, distance traveled was limited during midday. Distance traveled was furthest in the early night when toads traveled to warmer aquatic microsites. Our results are similar to Mullally (1958) who described the activity patterns of Western Toads, especially in the higher elevations, as primarily nocturnal with some diurnal activity. However, like other amphibians, activity patterns of Western Toads are not adequately described simply as diurnal, nocturnal, or crepuscular (Hailman 1984). Data from our study show behavior patterns and how variation in environmental conditions may affect toad biology.

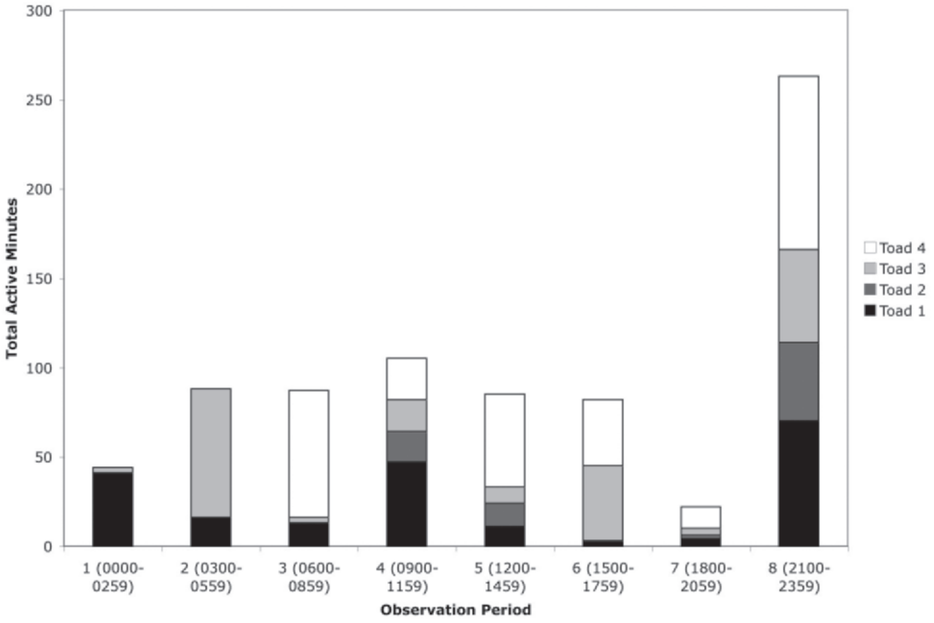

FIG. 1. Western Toad activity patterns were associated with observation period in southeastern Idaho, USA (ANOVA, P = 0.05).

We observed behavior patterns we believe were used to regulate body temperatures and water balance. The regulation of body temperature is primarily behavioral (Spotila et al. 1992) and the choices of times for daily activity appear to be the most critical behavior in determining body temperature (Stevenson 1985). During the day, each toad was located while basking in sunlight at a terrestrial retreat site. These microsites may have been selected, in part, due to their warmer temperatures relative to the surrounding habitat. Our observations that air temperatures of terrestrial retreat microsites were warmer than surrounding ambient air temperatures supports those of Campbell (1970), that toads basked in sunlight as a method to increase body temperature.

Distance traveled was furthest at night, consistent with the observations of other studies. Western Toads emerge and become active (including travel) at night (Mullally 1958; Pimentel 1955), during the hours of our observation period 8, 2100–2359 h (Hailman 1984). The toads may reduce water loss by traveling at these times when temperatures did not exceed 14.9°C and relative humidity generally did not drop below 78%. In addition, when < 80 m from an aquatic microsite, all four toads in our study were found to travel to an aquatic microsite at night. We suggest two reasons for the presence of toads in an aquatic microsite at night. First, during cold nights, the microsite water temperature was warmer than both ambient and terrestrial microsite air temperatures. Water is more thermally stable than many of the terrestrial microhabitats available to toads (Lillywhite 1970). The toads were, therefore, likely able to maintain a warmer body temperature by entering the aquatic microsite because an amphibian in water rarely experiences a body temperature more than 2°C different than the water (Spotila et al. 1992). Second, by entering the aquatic microsite, toads likely were able to regain, by absorption, any water lost during midday sun basking. Many amphibians move between aquatic and terrestrial microsites (Shoemaker 1992). *Bufo punctatus*, for example, has been described to have a pattern of behavior similar to the Western Toads we observed with up to 85 m of travel from its burrow to a small stream at night and returning to the same burrow early in the morning (McClanahan et al. 1994). Mullally (1956) also described Western Toads traveling to aquatic microsites

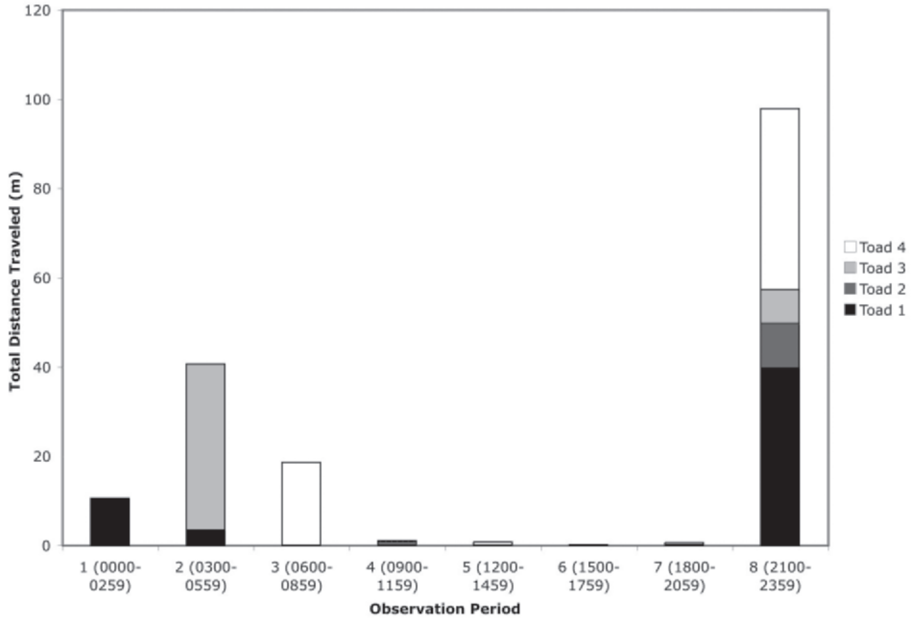

FIG. 2. Distance traveled by Western Toads was associated with observation period in southeastern Idaho, USA (ANOVA, P = 0.02).

in times of dry weather, probably to rehydrate.

Bartelt et al. (2004) observed Western Toads traveling 1.3 km from breeding sites in the late summer and these toads did not return to water. In the later dates of our study, two toads traveled from and were not found to return to aquatic microsites. These toads were located underground in a rodent hole and tree stump where they had no surface level activity. Limits on activity have been shown to be an important factor in water balance (Tracy 1976). Under moderate conditions of temperature and relative humidity, most amphibians cannot survive for more than a day in circulating air, because they quickly dehydrate (McClanahan et al. 1994). Retreating to cover likely reduces both evaporative water loss from midday basking and rehydration needs. Therefore, Western Toads without access to an aquatic microsite likely retreat from exposed sites during times of dryness, as we observed.

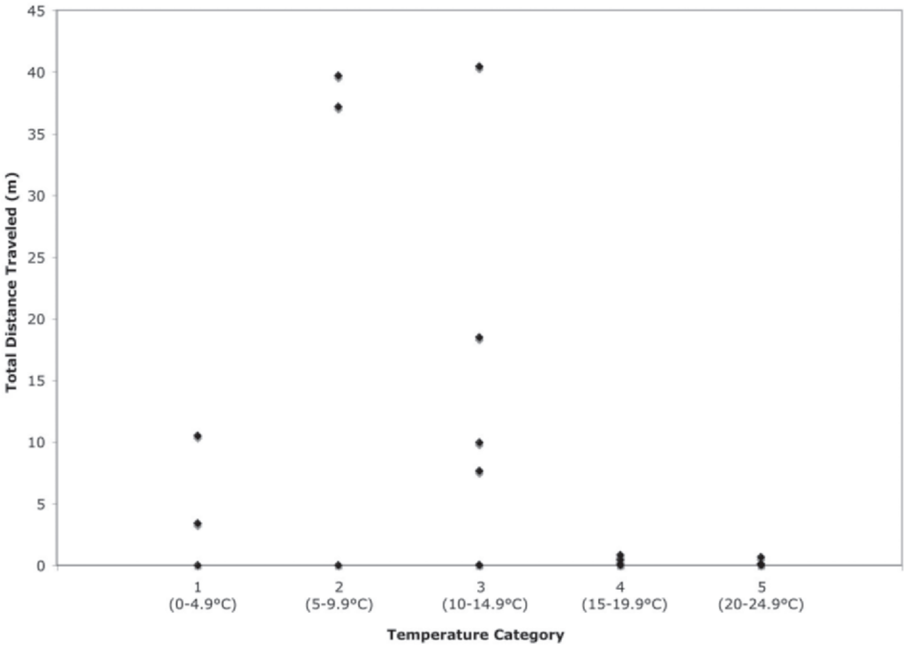

FIG. 3. Distance traveled by Western Toads was associated with microsite temperature category in southeastern Idaho, USA (ANOVA, P = 0.04).

In addition, we often found several non–telemetered toads on dry dirt roads at night. Mullally (1958) also found Western Toads on the road and Hailman (1984) discussed toads specifically seeking the road at night. The toads we found on roads were often in a crouched position, which maximized surface contact. Roads are not covered by vegetation and are exposed to radiant energy from the sun, which is stored and lost at the dirt surface. Typical of any system with storage and resistance, there is a time lag in heat flux out of dry soil (Campbell and Norman1998). The toads may crouch on the dry soil road to increase body temperature from this release of heat. Campbell (1970) and Carey (1978) proposed that toads increase temperature by conduction of heat from substrate. For toads on the road, mortality by vehicles may be a significant cause of death. We have previously reported the death by vehicle of a telemetered toad (Bartelt and Peterson 2000).

Mullally (1956) reports that male Western Toads vocalize only when provoked through contact with other animals such as when other males amplex them. In this situation, the clasped male vocalizes, whereupon the clasping male releases its hold. This interaction was observed and the presence of a radio-transmitter did not appear to inhibit or discourage other toads from clasping telemetered toads. We also found that toads vocalize at times when there is no contact by other animals, particularly at night when distant toads repeatedly called in sequence. The fact that vocalization was heard at times other than contact with other animals is interesting and may indicate that vocalization plays a larger role than that of communicating a release during amplexus or provocation.

The observations in our study represent a behavior sample of adult male free-living Western Toads. The activity and habitat use at different times and temperatures likely reflect thermal and water regulatory behavioral strategies. Though limited in sample size, our results demonstrate nocturnal peaks in travel with some level of activity present throughout the 24 h day, including a moderate diurnal component. Toads traveled over a narrow range of tem-

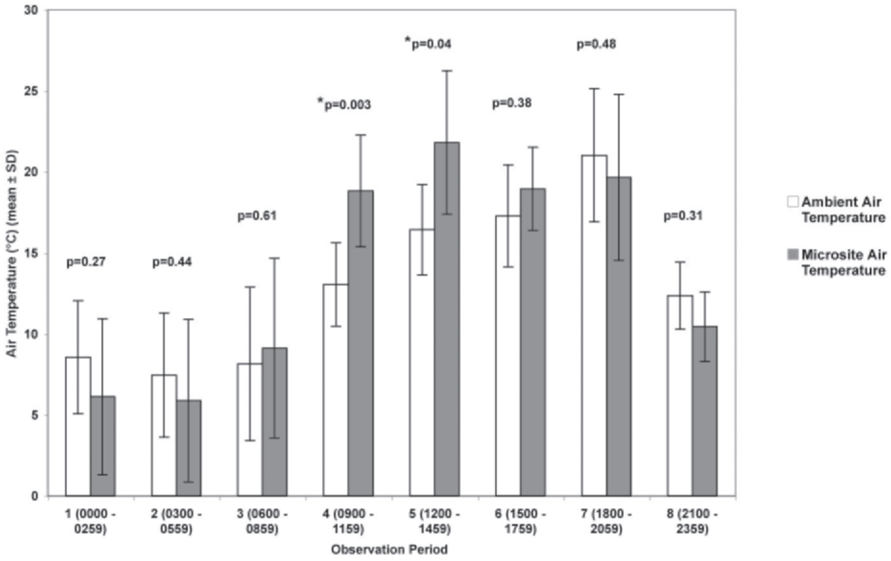

FIG. 4. Average microsite air temperature (°C at 1 m) where a Western Toad was located compared to ambient air temperature (°C at 1 m) during each observation period in southeastern Idaho, USA. Microsite air temperatures of the retreat sites selected by toads during periods 4 and 5 were warmer than ambient air temperatures.

peratures, and traveled longer distances during periods of high humidity. Toads were often found in aquatic microsites and on roads at night and at terrestrial retreat sites during the day.

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