Herpetological Conservation and Biology 11(1):101–111.
Submitted: 12May 2014; Accepted: 17 March 2016; Published: 30 April 2016.

BLANCHARD'S CRICKET FROG *ACRIS BLANCHARDI* OVERWINTERING ECOLOGY IN SOUTHWESTERN WISCONSIN

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Abstract.—**Blanchard's Cricket Frogs (*Acris blanchardi*) were once considered among the most abundant frog species in southern Wisconsin, USA. Although historically documented in 31 counties, it is currently found in only a handful of these due to substantial population declines in the late 20th Century. Explanations for this dramatic reduction in numbers include environmental pollutants, climate change, and habitat loss. Unfortunately, a poor understanding of the basic ecology and natural history of this species hinders effective conservation. To achieve a more thorough understanding of overwintering ecology at the northern edge of their range, we surveyed 10 sites in southwestern Wisconsin in an effort to describe the hibernacula and pre-hibernation behavior of Blanchard's Cricket Frogs. We conducted transect and haphazard surveys to determine when most cricket frogs entered hibernacula and the type of hibernacula available (e.g., crayfish burrow, crack in stream banks). Of 385 possible hibernacula assessed, only 20 at four sites were occupied by Blanchard's Cricket Frogs. Most hibernation occurred in exposed cracks formed by the sloughing of river banks, but we observed partially individual frogs twice within small (1 cm diameter) burrows. Hibernating cricket frogs were never observed in large crayfish burrows, under grass, leaves, or logs, or burrowed in gravel banks, as observed elsewhere in their range. Communal hibernation was observed in 13 of the occupied hibernacula. Mean minimum hibernation depth for cricket frogs was 4.7 cm. Our results suggest that exposed, south-facing river banks are critical habitat, and effective Blanchard's Cricket Frog conservation in southern Wisconsin should protect such habitat near known populations.**

Key Words.—conservation; hibernacula; hibernation; microhabitat

INTRODUCTION

Blanchard's Cricket Frogs (*Acris blanchardi*) were once common throughout the Midwestern United States (reviewed by Gray et al. 2005), but have declined dramatically along the northern and western boundaries of their range, (Vogt 1981; Lannoo 1998; Lehtinen 2002; Gamble et al. 2008; Burdick and Swanson 2010). For example, this species was historically widespread in southern Wisconsin with confirmed records in 33 counties, but today persists in only nine (Wisconsin Department of Natural Resources, unpubl. data) and has been listed as a state endangered species since 1982. Explanations for why the Blanchard's Cricket Frog has declined include environmental pollutants, climate change, and habitat loss (Beasley et al. 2005; Lehtinen and Skinner 2006; McCallum 2010). Unfortunately, its ecology, including habitat requirements, is not well understood, which hinders appropriate conservation (McCallum et al. 2011).

Irwin (2005) suggested that a lack of suitable overwintering locations influences the distribution of this species across its northern and western range limits, and may be partially responsible for its recent decline. Blanchard's Cricket Frogs differ from some hylid species that hibernate terrestrially in that they cannot physiologically modify tissue glucose levels as a cryoprotectant (Swanson and Burdick 2010). Furthermore, they do not have the ability to avoid freezing by digging below the frost line (Irwin et al. 1999). They also cannot withstand inundation in anoxic water for more than 24 h nor in initially oxygenated water beyond 10 d (Irwin et al. 1999). Blanchard's Cricket Frogs therefore rely on other wildlife and natural environmental events to create suitable hibernacula, which limits the amount of potentially available hibernacula for this species. In Illinois they hibernate in shoreline cracks and crevices, under logs, and beneath onshore leaves (Garman 1892; Pope 1944; Gray 1971). In Ohio, Blanchard's Cricket Frogs have been found within gravel shorelines at burrow depths of 20–36 cm,

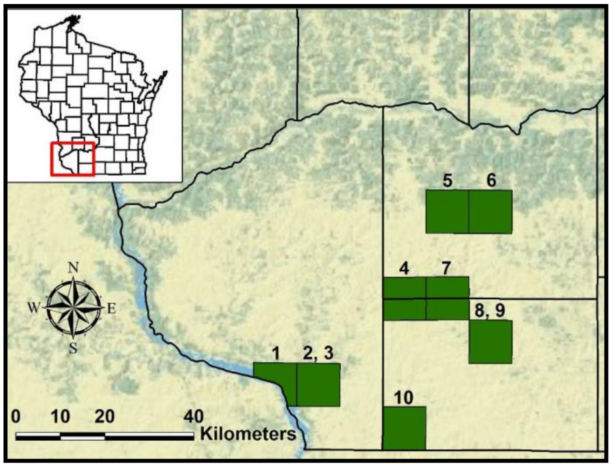

FIGURE 1. Study locations by township of Blanchard's Cricket Frog (*Acris blanchardi*) in southwestern Wisconsin, USA. Locations are listed by site identification numbers and are further described in Table 1. Locations are shown by township due to the legally designated endangered status of *Acris blanchardi* in Wisconsin.

and hibernating beneath onshore vegetation masses (Walker 1946). Swanson and Burdick (2010) reported that hibernating Blanchard's Cricket Frogs in South Dakota were most often observed in burrows and crevices along river banks that remained moist but did not freeze. They will also migrate substantial distances (i.e., 1.3 km) to find appropriate hibernacula (Gray 1983), which further exposes them to various sources of mortality.

Despite the importance of overwintering habitat (Irwin 2005), data on physical characteristics of hibernacula chosen by Blanchard's Cricket Frogs are particularly rare in the upper Midwest. Given that protection of suitable hibernacula can potentially influence persistence of this rare species in the northern portions of its range, an improved understanding of its overwintering ecology in the upper Midwest is essential for effective conservation. Due to the dearth of data available on this subject, the objectives of this study were to (1) identify and document Blanchard's Cricket Frog overwintering habitat and hibernacula in southwest Wisconsin; (2) compare the characteristics of occupied versus non-occupied hibernacula; and (3) observe pre-hibernation behavior, including identifying dates when most individuals were using hibernacula. This information will guide conservation and management for this imperiled species.

MATERIALS AND METHODS

Study sites.—Study sites were located in areas known to contain Blanchard's Cricket Frog populations in Grant, Iowa, and Lafayette counties in southwestern Wisconsin, USA (Fig. 1). We used geographic information systems (ArcMap 10; ESRI, Redlands, California, USA) to map locations of formerly occupied sites and subsequently visited study sites with favorable habitat including open or semi-open canopies with ponds, wetlands, and streams. We visited and assessed 13 potential study sites, selecting the 10 most favorable sites for hibernaculum surveys (Table 1).

Transect assessments.—Initial assessments of our survey sites included haphazard exploratory searches along wetland and pond shorelines and river banks to identify suitable locations for transect surveys. We established transect locations based on coarse assessments of Blanchard's Cricket Frog abundance and distribution at each site, and because they contained a diversity of habitat features (i.e., crayfish burrows and cracks on a variety of steep eroded banks, low-lying mud flats, and narrow benches caused by sloughing of the bank). We then established two 100 m transects, one on each bank of the river/stream, parallel to the edge of the water at each of our study sites.

Along their northern boundary, congregations of cricket frogs have been observed in late-fall and are described to immediately precede their entrance into nearby hibernacula (Swanson and Burdick 2010). We therefore conducted non time-constrained transect surveys from 19 October through 2 November 2010 to best overlap our survey efforts with those of prior overwintering studies. During surveys we identified all potential hibernacula along transects and investigated them for Blanchard's Cricket Frog occupancy. We completed transects for all 10 sites one time. Survey effort was dependent on the availability of potential hibernacula within transect boundaries, ranging from 2.6–5.2 h. We examined potential hibernacula for internal use of cricket frogs with the combination of a flashlight and a digital camera with fiber optic extension 1 m long and 1.5 cm in diameter (Ridgid 30063 Micro Explorer Inspection Camera; Ridge Tool Company, Elyria, Ohio, USA). We also incorporated the Stomping method (described in Gray 1971) for drawing cricket frogs from hibernacula. We repeated this technique by treading both subtly and heavily and also by pounding our feet on the ground near potential hibernacula.

We recorded a variety of microhabitat features for all hibernacula discovered within transect boundaries. We measured the maximum widths and lengths of all cracks and the diameters of burrow entrances with a caliper to the nearest 0.1 cm. Preceding the documentation of hibernaculum depth measurements, we waited until all visually detected cricket frogs had exited. Taking precautions not to excavate hibernating frogs or alter hibernaculum structure and microclimate, we then measured the depth of cracks and burrows. We did this by inserting a wooden dowel or a more maneuverable fiber optic extension cable, both with 1 cm markings,

TABLE 1. Descriptions of all Blanchard's Cricket Frog (*Acris blanchardi*) study locations with historical occurrences in Wisconsin, USA, grouped by county. For current occurrence, Y = Yes, N = No.

County	Site ID	Current Occurrence	Site Characteristics
Grant	1	Y	Valley with a small pond and stream feeding into the Mississippi River. Open to semi-open deciduous canopies.
	2	Y	Medium-sized river running through a valley featuring open, semi-open, and closed deciduous canopies. Seasonal flooding creates few ephemeral ponds within the river's floodplain.
	3	Y	Small creek meanders through a wide valley with open and semi-open deciduous canopies. Seasonal flooding replenishes nearby ephemeral ponds used for amphibian breeding.
Iowa	4	Y	A medium-sized river flows by a small creek leading to a restored wetland. Consists primarily of open canopies with minimal deciduous overhead cover.
	5	N	A small river flows through a wide, open canopy valley. Springs nearby replenish two ponds and adds additional flow to the river.
	6	Y	A manmade lake created by the construction of a dam over a small river. Features open to semi-open deciduous canopies, public beaches, and bays composed of emergent vegetation.
Lafayette	7	Y	A small river meanders through a wide, open canopy agricultural valley. Riparian areas have little to no vegetation buffer between nearby agricultural fields.
	8	Y	A medium-sized river meanders through a wide agricultural valley with two remediated wetlands within the floodplain. A complex of open, semi-open, and closed deciduous canopy exists within a small 10 m buffer zone from the river.
	9	Y	Situated within a large valley, a medium-sized river predominately runs through agricultural lands. Riparian areas consist of mostly closed canopies, but also contain semi-open and open deciduous canopies.
	10	Y	A small river flows through agricultural and pastured lands prior to its confluence with a much larger river. This location contains open canopies with highly eroded banks due to grazing. Further upstream, in less intensively-used pasture lands, semi-open deciduous canopies near less eroded banks can be found.

into the opening until it could be inserted no further. As a result of our discretionary approach, our conservative hibernaculum depth measurements represent minimum values of Blanchard's Cricket Frog hibernation depths.

We measured volumetric soil moisture percentages with a precision digital soil moisture meter with probe (0.1% accuracy; DSMM500; General Tools LLC, New York, New York, USA), which we inserted 18–21 cm below grade and as close to the potential hibernaculum as possible without structurally damaging it. Our digital moisture meter ranged in values of 0–50% with 0% representing xeric conditions and 50% demonstrated complete saturation of the surrounding soil. We also recorded soil temperature of each potential hibernaculum with a dial thermometer in the same manner as the soil moisture probe, but at a below grade depth of 5–8 cm. To avert disturbing the structure and internal microclimate of the active crevices, we took no soil measurements within each hibernaculum. We measured soil temperature and moisture in all potential hibernacula within transects from 19 October to 2 November 2010; thereafter, these variables were measured only for active hibernacula and at least once per week from 3 November through 3 December 2010. Afterwards, freezing of the topsoil and the accumulation of snow on hibernacula prevented us from obtaining further soil measurements.

We recorded bank aspect with a compass (Suunto Pro M-2 Baseplate Compass; Suunto, Vantaa, Finland). We categorized bank slope into two categories through coarse angle estimates in degrees of deviation from horizontal (i.e., 0–45° and 46–90°). We measured the distances between potential hibernaculum to the water level and to the vegetation line (cm). In addition to hibernacula measurements, we recorded site specific external weather parameters including ambient air temperature, maximum wind speed, and relative humidity.

Haphazard exploratory searching.—In early to mid-November, as daytime temperatures became cooler, Blanchard's Cricket Frogs were more likely to be within hibernacula or found above-ground a few meters from accessible hibernacula. On 3 November 2010, we reinstituted haphazard exploratory searching at locations outside of our transect boundaries to detect and characterize additional hibernacula. Once cricket frog congregations were identified, we investigated all potential hibernacula within a 5 m diameter to determine if they were also occupied. If visual confirmation of cricket frogs in hibernacula occurred, we recorded data in the same manner as in the transect surveys. We did not collect data on unoccupied hibernacula for this portion of the study.

By mid-November, we began to augment our occupied hibernacula parameters, obtained from both transect assessments and exploratory searching, with additional measurements. For each hibernaculum, we counted the number of individuals exiting in response to stomping; measured nearest distance from hibernaculum to the top of the bank (cm), to water (cm), and to vegetation (cm); estimated distance to the nearest human-modified habitat (m); and recorded substrate composition (mud, mud-sparse vegetation, mud-dense vegetation, and dense vegetation).

We recorded all sightings of Blanchard's Cricket Frogs above-ground to document the latest dates of activity and the associated microclimate parameters. When we believed that all cricket frogs were hibernating, we continued monitoring hibernacula until early December to detect seasonal changes in micro- and macrohabitats. Unconventional cricket frog hibernacula (i.e., beneath terrestrial leaf litter, debris, and logs, or in aquatic mud sediments) are little studied or reported throughout their range, (but see Garman 1892; Pope 1944; Walker 1946). Therefore, we surveyed these potential overwintering microhabitats to understand whether Blanchard's Cricket Frogs in Wisconsin select hibernacula other than burrows or crevices in river banks. Throughout November, before and after the ground froze, we opportunistically surveyed within a 20 m buffer from the river for cricket frogs preparing to hibernate under leaves, logs, and vegetation. Our weekly survey effort of 1–2 h was limited by the availability of such unconventional hibernacula within our designated search buffer. We also used a digital camera with a fiber optic extension in early December to search stream bottoms for cricket frogs above or within the mud.

To find additional hibernacula, we also monitored cricket frog movement near sunset as temperatures declined markedly in the month of November. Surveys began 1 h before sunset at locations where cricket frogs were located, but no previous hibernacula had yet been found. Human observers attempted to remain a sufficient distance to prevent influencing cricket frog behavior. Once a cricket frog entered a hibernaculum, we flagged the location, and collected data on macro- and microhabitat parameters in the same manner as other occupied hibernacula.

For both transect assessments and haphazard encounter surveys, we computed qualitative statistics for microhabitat parameters to compare occupied versus unoccupied hibernacula. Due to small sample size, we combined data on occupied hibernacula parameters from transects and encounter surveys, whereas we only used transect assessments for comparisons of unoccupied hibernacula characteristics. Further, we did not conduct comparative statistical analyses due to low sample size of occupied hibernacula.

RESULTS

Pre-hibernation behavior.—Field observations indicated that migrations to both upstream and downstream locations along lotic systems adjacent to documented breeding wetlands occurred in fall. By 11 October 2010, surveys of breeding wetlands indicated that most cricket frogs had left the known breeding wetlands and assembled along streams and rivers, in the vicinity of what would later be documented as overwintering habitat. At this time, a large proportion of the observed cricket frogs had congregated on open-canopy mud flats and gravel bars along streams or rivers (1–10 m in width), while the remaining individuals were found perched on adjacent banks. We estimated that these congregations were within approximately 0–50 m of the cricket frog hibernacula we document in the present study.

As daytime ambient air temperatures declined and cricket frogs became less active and harder to find, we gradually detected fewer frogs above ground and exiting hibernacula. On one occasion we observed individuals leaving crevices when ambient air temperature had dropped to 4.5° C. Our final Blanchard's Cricket Frog observations above ground occurred on 19 November 2010 (maximum ambient air temperature of 7.5° C). Thereafter, the lack of cricket frog observations above ground coincided with the freezing of the upper crust of the soil (determined by the inability to insert our thermometer into the frozen soil) and thus represented the onset of cricket frog hibernation.

Transect surveys.—Of the 370 potential hibernacula identified within transect boundaries (54 crevices or cracks on the river/stream banks and 316 small/large burrows), we observed (via walking or stomping) Blanchard's Cricket Frogs hibernating within five crevices. These active hibernacula possessed narrow openings, which were located on nearly level earthen overhangs that formed by the sloughing of river/stream banks due to natural erosion (Fig. 2). Mean width of the openings into occupied hibernacula (n = 5) was 1.6 cm (± 0.7 SD; range, 0.9–2.6 cm). Mean length of occupied

FIGURE 2. Blanchard's Cricket Frog (*Acris blanchardi*) emerging from a hibernaculum in Lafayette County, Wisconsin, USA. (Photographed by Tyler Brandt).

FIGURE 4. Typical overwintering microhabitat of Blanchard's Cricket Frog (*Acris blanchardi*) in southwest Wisconsin, USA. Hibernacula (i.e., cracks and crevices) were generally documented on near-level earthen benches formed by the sloughing of banks. (Photographed by Tyler Brandt).

hibernacula was 85.2 cm (± 18.1; range, 62–102 cm), and mean minimum hibernation depth was 7.6 cm (± 3.3; range, 4–12 cm). We did not observe cricket frogs in cracks with large openings or burrows along transects; however, we observed three Green Frogs (*Lithobates clamitans*), one Northern Leopard Frog (*Lithobates pipiens*), and one American Toad (*Anaxyrus americanus*) in crayfish burrows (mean diameter of burrow entrance 3.8 ± 1.1 cm]; mean minimum burrow depth of 17.6 ± 16.0 cm; Fig. 3).

Haphazard exploratory observations.—We discovered 15 additional crevice hibernacula via random searches at four of our study locations. By stomping, we were able to determine cricket frog numbers in occupied hibernacula ranged from one to 10 individuals. These hibernacula also occurred on over-hangs formed by the sloughing of stream banks (Fig. 4), and possessed a mosaic of mud, moss, short grasses, and broad-leaved herbaceous vegetation. We did not detect Blanchard's Cricket Frogs overwintering in any other potential microhabitat investigated (e.g., under grass, leaves, or logs, in large burrows, or in mud of stream beds). During non-constrained exploratory surveys conducted on-site prior to transect surveys, we found two cricket frogs in the entrances of small (1 cm diameter) burrows in late October (Fig. 5).

FIGURE 3. Northern Leopard Frog (*Lithobates pipiens*) observed in a crayfish burrow via fiber optic camera in Grant County, Wisconsin, USA. (Photographed by Andrew Badje).

FIGURE 5. A Blanchard's Cricket Frog (*Acris blanchardi*) near the entrance of a small burrow in late October in Grant County, Wisconsin, USA. We observed two such instances. We presume the cricket frogs observed selected these burrows as winter retreats. (Photographed by Andrew Badje).

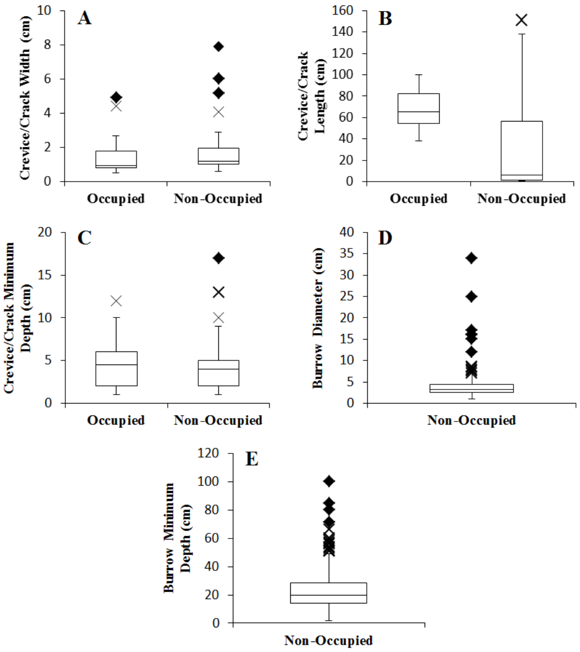

FIGURE 6. Crevice and burrow dimensions of hibernacula occupied and unoccupied by Blanchard’s Cricket Frogs. A: width of crevice at widest point; B: crevice length; C: minimum crevice depth from innermost measureable point; D: burrow opening diameter; E: minimum burrow depth from innermost measurable point. Horizontal line within each box represents the median, box limits represent the 25 and 75 percentiles (i.e., interquartile range, [IQ]), vertical lines represent the non-outlier ranges (i.e., values between the box limits and 1.5 × IQ), Xs indicate outliers (i.e., points between the non-outlier ranges and 3 × IQ), and diamonds indicate extreme outliers (i.e., points beyond the extreme outlier ranges).

Characteristics of hibernacula.—We recorded physical characteristics from the 20 occupied Blanchard’s Cricket Frog hibernacula identified during transect surveys and arbitrary searching in addition to the 365 unoccupied burrows and crevices documented within transects. Mean width of occupied crevices was 1.5 cm (± 1.2 SD; range, 0.5–4.9 cm; n = 19; Fig. 6A), while mean length was 68.1 cm (± 21.7; range, 38–100 cm; n = 7; Fig. 6B), and mean minimum hibernation depth was 4.7 cm (± 2.8; range, 1–12 cm; n = 20; Fig. 6C). Mean width of unoccupied crevices was 1.8 cm (± 1.4; range, 0.6–7.9 cm; n = 49; Fig. 6A), while mean length was 34.6 cm (± 42.1; range, 0.6–151 cm; n = 49; Fig. 6B), and mean minimum crevice depth was 4.4 cm (± 3.1; range, 1–17 cm; n = 49; Fig. 6C). Mean diameter of unoccupied burrows was 3.8 cm (± 2.9 SD; range, 1–34 cm; n = 316; Fig. 6D), and mean minimum burrow depth was 23.4 cm (± 13.6; range, 2–100 cm; n = 316; Fig. 6E).

We sampled various environmental factors related to soil in occupied crevices on 102 occasions (mean 5.1 samples per hibernacula). Mean percentage volumetric soil moisture in occupied hibernacula along transects was 32.0% (± 12.8; range, 20.2–47.1%; n = 5), but 25.6% in non-occupied crevices (± 12.0; range, 7.4–50%; n = 49), and 21.7% in non-occupied burrows (± 8.3; range, 0–50%; n = 310; Fig. 7A). Volumetric soil moisture percentage averaged 26.3% (± 7.6; range, 18–50%; n = 93; Fig. 7B) for all occupied crevices documented within transect assessments and exploratory searching. Transect assessments revealed mean soil temperature in occupied crevices of 8.9° C (± 0.8 SD; range, 7.5–9.5° C; n = 5), and 8.6° C in unoccupied crevices (± 3.6; range, 2–14° C; n = 49), but 9.6° C (± 3.0; range, 1–17° C; n = 310; Fig. 7C) for unoccupied burrows. Soil temperatures for occupied crevices averaged 3.5° C (± 3.4; range, -2 to 10° C; n = 77; Fig. 7D).

We did not find active hibernacula on north facing banks, but did record hibernacula on slopes that faced all directions from east to west (clockwise). We observed most hibernacula on banks with modest inclines from 0° to 45° with little vegetation in the immediate vicinity (Table 2). We also documented the distances between occupied hibernacula and relevant microhabitat parameters. Water was, on average, 73.2 cm (± 33.5; range, 30.5–121.9 cm; n = 20) from occupied crevices, and 116.1 cm (± 76.8; range, 15.2–518.2 cm; n = 49) from unoccupied crevices, and 87.3 cm (± 68.9; range, 0–457.2 cm; n = 310; Fig. 8A) from unoccupied burrows. Average distance to vegetation was 63.6 cm (± 56.9; range, 0–152.4 cm; n = 20) for occupied cracks, 87.5 cm (± 78.1; range, 0–304.8 cm; n = 49) for unoccupied cracks, and 76.2 cm (± 70.8; range, 0–274.3

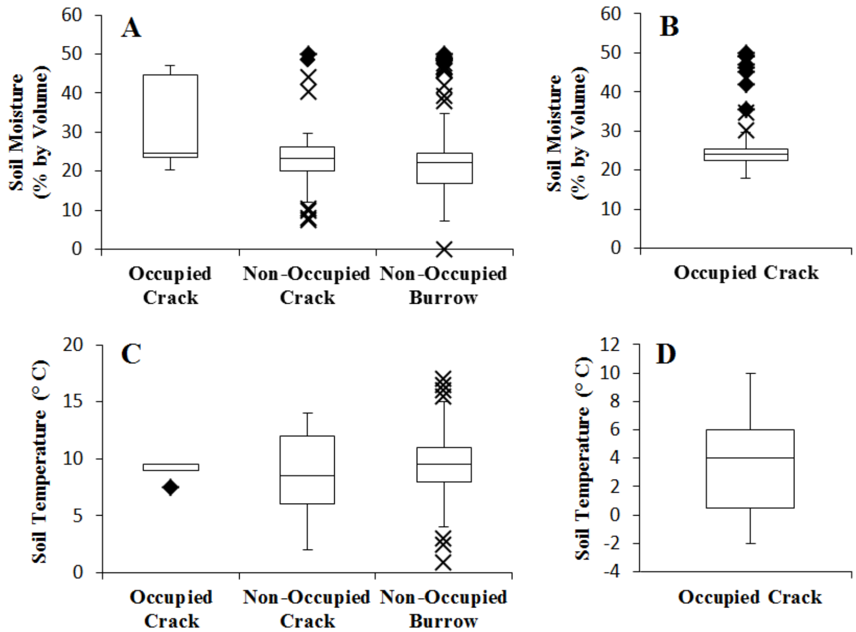

FIGURE 7. Soil characteristics of hibernacula occupied and unoccupied by Blanchard's Cricket Frog. A: volumetric soil moisture (0–50%) of occupied and unoccupied hibernacula within transects (documented from 19 October to 2 November 2010); B: volumetric soil moisture (0–50%) of all occupied hibernacula (recorded from 19 October to 3 December 2010); C: soil temperature (° C) of occupied and unoccupied hibernacula within transects (documented from 19 October to 2 November 2010); D: soil temperature (°C) of all occupied hibernacula (recorded from 19 October to 3 December 2010). Box plots as in Fig. 6.

cm; n = 310; Fig. 8B) in unoccupied burrows. Distance between occupied hibernacula and top of adjacent bank averaged 113.4 cm (± 53.4; range, 15.2–182.9 cm; n = 20; Fig. 8C). In addition, average distance between occupied hibernacula and nearest human-modified habitat (i.e., asphalt/gravel roads, all-terrain vehicle [ATV] trails, and agricultural fields) was 9.8 m (± 7.7 m; range, 0–25 m; n = 20; Fig. 8D).

DISCUSSION

Hibernaculum characteristics.—Surveys revealed that Blanchard's Cricket Frogs in southwestern Wisconsin often hibernate communally in narrow crevices within benches of sloughing soil along stream and river banks. Communal hibernation in cricket frogs has also been observed at gravel embankments in Arkansas (McCallum and Trauth 2003). Although on two occasions we found cricket frogs resting near the entrances to crayfish or small mammal burrows, we did not definitively observe them within such burrows. These findings are unlike what other researchers have described for northern populations of Blanchard's Cricket Frogs and Eastern Cricket Frogs (*Acris crepitans*; Swanson and Burdick 2010; Kenney et al. 2012). We also did not observe this species occupying other potential hibernacula (i.e., under logs, leaves, and vegetation masses) as found by studies from more southern localities (Garman 1892; Pope 1944; Walker 1946). Despite Eastern Cricket Frogs in New York using terrestrial hibernacula up to 140 m from aquatic habitat (Kenney et al. 2012), we did not examine potential overwintering habitat beyond 20 m from aquatic habitat.

In the northern periphery of distribution of this species, soil temperature within hibernacula is likely important to winter survival. Irwin et al. (1999) monitored a cricket frog hibernaculum at a depth of 2 cm in southern Ohio, and found that minimum soil temperature during winter was -0.5° C. In southeast South Dakota, Swanson and Burdick (2010) recorded soil temperatures in several hibernacula over a three year period and found that some never went below -0.6° C, while others dropped under -0.6° C for only 12 h. On the other hand, the authors found that soil temperature in other monitored hibernacula remained below the freezing point of body fluids (reaching a minimum of -5.0° C) for 42 h to 14 d. Our soil temperature readings

TABLE 2. Occurrence totals and proportions (%) of bank slope, bank aspect, and substrate for occupied Blanchard's Cricket Frog (*Acris blanchardi*) crack hibernacula (n = 20) and non-occupied cracks (n = 49) and burrows (n = 316) surveyed in Wisconsin, USA.

	Occurrence Totals			Proportion		
Variable	Occupied Cracks	Non-Occupied Cracks	Non-Occupied Burrows	Occupied Cracks	Non-Occupied Cracks	Non-Occupied Burrows
Bank Slope						
0–45°	19	21	95	95.0	42.0	30.1
46–90°	1	29	221	5.0	58.0	69.9
Bank Aspect						
N	0	15	40	0.0	30.0	12.7
NE	0	4	55	0.0	8.0	17.4
E	4	2	43	20.0	4.0	13.6
SE	2	1	15	10.0	2.0	4.7
S	1	14	36	5.0	28.0	11.4
SW	8	5	20	40.0	10.0	6.3
W	5	8	73	25.0	16.0	23.1
NW	0	1	34	0.0	2.0	10.8
Substrate						
Mud	5	-	-	25.0	-	-
Mud–Sparse Vegetation	14	-	-	70.0	-	-
Mud–Dense Vegetation	1	-	-	5.0	-	-
Dense Vegetation	0	-	-	0.0	-	-

are similar to a sub-set of those recorded from South Dakota: hibernacula located 5–8 cm below ground, were at or below -1° C on five separate dates during our winter survey period. Swanson and Burdick (2010) further found 80% of Blanchard’s Cricket Frogs to survive 6 h bouts of -1.5° C to -2.5° C, whereas all specimens died at 24 h exposures to the same temperatures. Such findings suggest the duration of exposure to below zero temperatures greatly influence cricket frog survival in hibernacula, and therefore could limit northern ranges and expansion.

The variation in documented hibernaculum soil temperatures and its relation to the freeze tolerances of cricket frogs (Irwin et al. 1999; Swanson and Burdick 2010), suggests that other factors influence successful hibernation. For example, it is plausible that soil moisture also has an important influence on winter survival. In Ohio, Irwin et al. (1999) described cricket frog hibernacula as being saturated with water. Our data indicates a preference for moderate soil moisture levels (mean of 26.3%), falling approximately halfway between xeric conditions and complete saturation. Although cricket frogs do not hibernate underwater (Irwin et al. 1999), partially saturated soils should afford some reprieve from desiccation and provide additional thermal buffering. As such, saturation of soils could reduce the likelihood that hibernacula will freeze and, thus, increase cricket frog winter survival.

It is also plausible that the slope aspect and sun exposure of chosen hibernacula play an important role in successful hibernation. In the northern hemisphere, south facing aspects generally tend to be warmer year round and receive more heat than north facing aspects (Blaustein et al. 1999). We observed that cricket frogs occupied more south-facing hibernacula in our study. As such, it is plausible that cricket frogs select these hibernacula because they experience increased solar and thermal input, which may keep winter temperatures within hibernacula at an acceptable level.

Cricket frogs in Wisconsin likely occupy other types of hibernacula located at greater distances from the edge of the water. Unfortunately, we did not implement surveys that would have detected these. Yet, the potential for such hibernacula should be considered in future cricket frog overwintering inquiries. More thorough surveys of potential hibernacula that investigate greater distances (i.e., ≥ 140 m) from aquatic habitat (on warm, sunny fall days) and at an increased number of habitats and sites throughout Wisconsin are warranted to better elucidate preferred hibernacula in the upper Midwest.

Climatic influences.—Latitude, and the associated climate, may explain recorded variation in the depth at which cricket frogs overwinter throughout their range. Irwin et al. (1999) reported hibernation depths at 3–10 cm in Ohio, while observed hibernacula depths in South Dakota are greater (i.e., 20–25 cm; Swanson and Burdick 2010). Kenney et al. (2012) also found Eastern Cricket Frogs hibernating within small animal burrows at depths of 5 cm to greater than 1.5 m in New York. Given that Blanchard’s Cricket Frog is an endangered species in Wisconsin, we were limited on how we could obtain precise hibernaculum depths, as we could not legally extract them from hibernacula in the winter

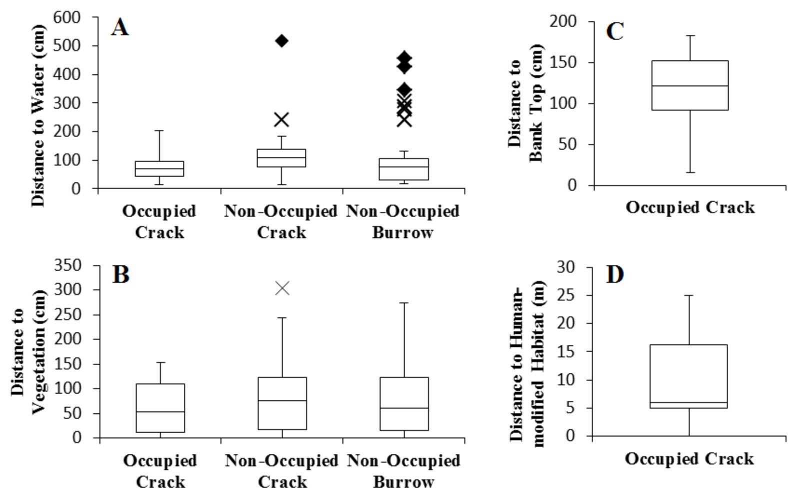

FIGURE 8. Distances to various microhabitat components for hibernacula occupied and not occupied by Blanchard's Cricket Frogs. A: hibernacula distance (cm) to water; B: hibernacula distance (cm) to vegetation; C: hibernacula distance (cm) to top of river bank; D: hibernacula distance (m) to nearest human-modified habitat. Box plots as in Fig. 6.

without damaging important habitat or causing them harm. Despite such precautions, the 1–12 cm minimum depth measurements obtained in Wisconsin were enough to document that this species hibernates at depths consistent with or greater than those reported in Ohio and, in some cases, New York.

Hibernaculum usage is also likely subject to climatic variation in rainfall between years. Crevices probably begin to form as soil moisture content declines during drier environmental conditions. Presumably, crevice depth is shallower in years with more rainfall, whereas in drier years, cracks with greater depths form. In years with more rainfall, populations of cricket frogs in northern latitudes could benefit from the additional thermal buffering properties of greater moisture to compensate for shallower crevices. When thermal buffering properties cannot compensate for shallow crevices in wet years, cricket frogs may more frequently use types of hibernacula other than those we documented. Further work on this subject is warranted.

Winter-to-winter variability may result in unstable environmental conditions over time, which could lead to less-suitable hibernating conditions for Blanchard's Cricket Frogs. For example, Irwin (2005) suggests that declines in higher latitude cricket frog populations were set into motion by severe drought in fall of 1976, followed by two extremely cold winters in 1976−1977 and 1977−1978. Prolonged drought may reduce soil moisture content, which would deepen the frost line and alter stable hibernacula characteristics (Irwin 2005). Although deeper cracks from a lack of rainfall may offset the thermal buffering provided by high soil moisture levels and other properties, when followed by winters that are particularly cold and lacking snowfall, hibernating cricket frogs could have been exposed to unusually dry and cold conditions within hibernacula that resulted in higher winter mortality. The effects of droughts and harsh winters on Blanchard's Cricket Frog populations can be further exacerbated by their naturally rapid population turnover rates (12–16 mo) and suggested semelparity (Burkett 1984; McCallum et al. 2011) or through the synergistic interactions of unknown stress-related factors.

Conservation measures.—Future long-term studies are required to assess the variation in winter conditions over time on the overwintering ecology of Blanchard's Cricket Frogs. Studies throughout the entire duration of hibernation are also needed to adequately describe successful hibernacula from ones that are used but not conducive to winter survival. To further achieve this, it is important to document the wide range, of overwintering microhabitat and conditions needed, such as depth of hibernation, soil moisture and temperature, bank aspect, and precipitation levels.

Blanchard's Cricket Frogs in South Dakota and Illinois have been observed in hibernacula on stream and river banks as early as mid-October and as late as early to mid-April (Gray 1971; Swanson and Burdick 2010). Studies of Eastern Cricket Frogs in New York have also described similar findings (Kenney et al. 2012). In areas with known cricket frog occurrences with suitable overwintering habitat (i.e., exposed banks), it would be beneficial to avoid or limit disturbance during hibernation. For example, scheduling maintenance activities associated with transmission lines, or other forms of infrastructure, to avoid possible hibernacula until after frogs have dispersed in the spring. A further extension to these dates would also account for migration to and from the area. In addition, best management practices (where plausible) should consider protecting such delicate overwintering habitat throughout the year. The loss of winter refugia could lead to local extirpations, being more pronounced in isolated or disjunct populations. Alterations of water levels (i.e., winter draw-downs) should also be considered carefully, as they may impact this species if moisture levels in hibernacula drop below normal.

Acknowledgments.—Partial funding was provided by the U.S. Fish and Wildlife Service under the State Wildlife Grants Program. Additional funding was provided by the Wisconsin Department of Natural Resources' Natural Heritage Conservation Program. Other support for this project came from the Natural Resources Conservation Service. We would like to thank the numerous private landowners and public officials for allowing property access and project support. Protocols followed that of the Institutional Animal Care and Use Committee (IACUC) guidelines set forth by the Herpetological Animal Care and Use Committee (HACC) of the American Society of Ichthyologists and Herpetologists (ASIH). The endorsement by the federal or state government is not implied through the use of a trademark name.

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