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Spring Movement Ecology of Blanchard's Cricket Frog (*Acris blanchardi*) in Southwestern Wisconsin, USA

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Abstract.—**Blanchard's Cricket Frog (*Acris blanchardi*) uses seasonal movements as an important and often necessary survival strategy. The objectives of our research were to study spring cricket frog movements, habitat use, and life history to better inform management decisions for this state-listed endangered species. We also experimented with marking techniques. We used visual encounter surveys to investigate its ecology and phenology, and marking (e.g., toe-clipping) surveys and photographic identification to investigate individual and group movements. We documented movements from overwintering (e.g., rivers and streams) to breeding (e.g., wetlands and lakes) locations from mid-April to June in southwestern Wisconsin, USA. We did not always detect migrations away from overwintering sites on the river. Most female movements occurred after males had moved to breeding locations. Marking and photographing individuals was successful in verifying movement distances up to 662 m, suggesting that individual cricket frogs can be effectively identified over a one-month span by using this approach. Our results suggest that Blanchard's Cricket Frog spring movements in southwestern Wisconsin occur predominantly along waterbody corridors linking overwintering to breeding habitat. Conservation plans should incorporate use of these movement corridors into habitat management actions to enhance preservation of the species.**

Key Words.—conservation; life history; marking; migration

Introduction

Once an abundant species in the Upper Midwest of the U.S. (e.g., Iowa, Michigan, Minnesota, South Dakota, and Wisconsin), Blanchard's Cricket Frog (*Acris blanchardi)* has experienced declines in distribution and abundance, leading to a significant contraction of its northern and western historical range in the U.S. and Canada (e.g., Colorado: Hammerson and Livo 1999; Michigan: Lehtinen 2002; Minnesota: Oldfield and Moriarty 1994; Ontario: Oldham 1992; South Dakota: Burdick and Swanson 2010). Blanchard's Cricket Frog declines and range contraction in Wisconsin, USA, were first described in the late 1950s (Les 1979), with reports continuing into the late 1970s (Vogt 1981). The species was historically found throughout the southern half of Wisconsin, but following these declines, biologists were only able to verify a few remaining locations in southwestern Wisconsin (Jung 1993), leading the Wisconsin Department of Natural Resources (WDNR) to list the Blanchard's Cricket Frog as an endangered species in 1982 (https://dnr.wi.gov/files/PDF/pubs/er/ER001.pdf).

Known causes for these declines remain enigmatic; however, habitat alteration and fragmentation, pollution, and habitat succession from open to closed canopies have been described as potential causes (Lannoo 1998; Beasley et al. 2005; Irwin 2005). The chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*), has also been found on cricket frogs throughout the Upper Midwest (Steiner and Lehtinen 2008; Zippel and Tabaka 2008; Crawford et al. 2017). Although *Bd* has been found in Wisconsin, it has yet to be documented on Blanchard's Cricket Frogs in the state, a possible by-product of the minimal sampling efforts for the species (Sadinski et al. 2010; Standish et al. 2018). A 12–16 mo lifespan and high annual population turnover described in this species are problematic attributes that may exacerbate local and regional extirpations (Burkett 1984; McCallum et al. 2011). Increasing intensity and stochasticity of weather events linked with drought, flooding, and severe winters with limited snowpack (exacerbated by climate change) are additionally believed to contribute to this range retraction (Hay 1998; Irwin 2005; Badje et al. 2016).

Relatively few studies on Blanchard's Cricket Frog ecology have been published in the Upper Midwest (but see Johnson and Christiansen 1976; Gray 1983; McCallum and Trauth 2004; Swanson and Burdick 2010; Badje et al. 2016). As such, much information used to describe northern populations is derived from studies in southern latitudes, where wide ranging extirpations have not been observed (Pyburn 1958; Gray 1971; Burkett 1984; McCallum et al. 2011). In northern states, where ranges have receded, inquiries have focused on facets of life history that impact Blanchard's Cricket Frog survival and distribution, such as breeding and overwintering ecology (Gray 1983; Lehtinen and Skinner 2006; Burdick and Swanson 2010; Swanson and Burdick 2010; Badje et al. 2016).

Much of this research has focused on documenting where populations remain and defining the critical components of breeding and overwintering habitats that Blanchard's Cricket Frogs need to sustain viable and healthy populations. Breeding habitat in the Upper Midwest consists of permanent or semi-permanent water and is most often associated with open or semi-open canopy wetlands and waterbodies, including emergent marshes, wet prairies, fens, streams, river bottoms, and permanent ponds and lakes (Johnson and Christiansen 1976; Vogt 1981; Gray 1983). By contrast, Blanchard's Cricket Frog overwintering habitat has been documented primarily as cracks, crevices, and burrows (e.g., from crayfish and small mammals) on south-facing banks and adjacent uplands of streams and rivers, and on occasion, wetlands (Irwin et al. 1999; Swanson and Burdick 2010; Badje et al. 2016).

Since the 20th Century declines, movements (or more specifically, migrations, defined as movements to and from overwintering and breeding habitat) have received little research focus, although it is likely a critical component of Blanchard's Cricket Frog ecology in northern latitudes. The limited movement studies involving cricket frog marking techniques describe shorter movements showing affinities for shorelines in aquatic habitat, and occasionally, longer terrestrial migrations and/or one-way movements (e.g., dispersal events) in periods of rain and high humidity (Pyburn 1958; Gray 1983; Burkett 1984). Comprehensive movement studies that address phenology, ecology, habitat use, and movements of individuals between critical habitat in northern regions are lacking.

We assessed the movement phenology and patterns of the Blanchard's Cricket Frog in southwestern Wisconsin during spring of 2011. Our research objectives were to (1) increase knowledge of cricket frog movements and habitat use across the landscape, (2) obtain ecological data related to timing of spring movements, and (3) test different marking techniques for monitoring efficiency in northern populations. By increasing our knowledge of Blanchard's Cricket Frog movement ecology in Wisconsin, we can further learn about factors that affect their distribution, survival, and conservation at the edge of their range.

Materials and Methods

Study sites.—We conducted surveys at 10 locations to document breeding (e.g., wetlands and lakes) and overwintering (e.g., riverine) habitat for the Blanchard's Cricket Frog in the summer and fall of 2010 in Grant, Iowa, and Lafayette counties in southwestern Wisconsin (see Badje et al. 2016 for a review of habitat characteristics and township locations for all sites referenced herein). In spring 2011, we performed non-standardized visual encounter surveys (VES) at six of these locations (Sites 2, 3, 4, 6, 7, and 8) to obtain baseline ecological and phenological observations in the region. We additionally conducted individual (Sites 3 and 4) and batch-marking (Site 8) techniques to record more extensive movements between overwintering and breeding locations.

Visual encounter surveys (VES).—We conducted VES from 8 April 2011 to 1 June 2011 at all six study sites to detect seasonal movements between overwintering and breeding locations. We quickly determined that inland terrestrial searches were an ineffective use of time. We therefore consistently searched all shoreline habitats on a weekly basis that were adjacent to aquatic features within our study areas. We additionally recorded use of terrestrial microhabitats (e.g., bank type: gradual slope, sloughing, severe erosion, and riprap; sand and gravel bar; and nearby upland agricultural: pasture and cropland) and aquatic microhabitats (e.g., irrigation ditch, creek, river, ephemeral pond, wetland, and lake). The qualitative nature of the microhabitat data we recorded limited our ability to effectively assess habitat availability versus habitat selection. During site visits, we recorded individual Blanchard's Cricket Frog counts, snout-to-vent length (SVL; mm), weight (g), ambient air temperature (°C), wind speed (m/s), cloud cover (%), and relative humidity (%). We added male and female determinations in May based on maturation of male cricket frog vocal pouches (as occurs from April to early May in populations to the south in Illinois; Gray 1983). We calculated means, standard deviations, and range of values for weight and SVL of male and female Blanchard's Cricket Frogs processed in May 2011 (Table 1). We calculated sex ratios and grouped observations into aquatic habitat categories to document the sex-based differences in phenological movements from overwintering to breeding locations.

Batch-marking surveys.—We implemented a batch-marking approach without the use of photographs (described below) at Site 8 to determine whether individuals that overwintered near one another migrated to similar breeding locations. We compared this method to our individual marking technique with photographic assistance at Sites 3 and 4. Along a 2-km section of

Table 1. Means, standard deviations (SD), and range of values for snout-to-vent length (SVL; mm) and weight (g) for adult male and female Blanchard's Cricket Frogs (*Acris blanchardi*) sampled throughout May 2011 at Sites 3, 4, and 8 in Grant, Iowa, and Lafayette counties, Wisconsin, USA.

	SVL (mm)				Weight (g)			
Sex	Mean	SD	Range	n	Mean	SD	Range	n
Female	25.5	2.4	19.5–32.1	53	1.8	0.5	0.8–2.9	52
Male	24.4	1.9	19.6–28.1	107	1.4	0.4	0.4–2.3	106

river, we delineated seven transects of non-standardized lengths (approximately 100–200 m) known to be used by overwintering cricket frogs for batch-marking (Badje et al. 2016). We recorded geographic coordinates of the terminal segments of each transect with a Garmin GPS 76™ (Garmin, Olathe, Kansas, USA; ± 3 m accuracy per instruction manual).

On 9 May 2011, before any movements between habitats occurred, we processed and batch-marked 27 individuals within our seven transects. We recorded length (SVL), weight, and transect location data upon the first capture of an individual. We implemented a batch-marking toe-clip technique in which all captured individuals within a specific transect in the same day were given the same clip-code scheme. We clipped a single digit per individual, to limit the negative effects of two or more clipped digits. Prior to marking individuals, we disinfected a nail clipper with rubbing alcohol, and subsequently burned the clipper with a lighter, removing any remaining liquid. On subsequent surveys, after all marking activities were complete, we recorded geographic coordinates, sex, and clip-code scheme of any recaptured individuals.

We mapped and assessed the geographic coordinates of recaptured individual cricket frogs in a geographic information system (ArcMap 10; esri, Redlands, California, USA). For recaptured individuals, we determined minimum movement distance (i.e., start or end point, whichever was closer, of the transect the individual was batch-marked within from to its most distant recapture geographic coordinates), by using the ruler tool feature to obtain straight-line distance (m). To prevent the overestimation of movement distances, we assumed individuals moved in a straight line between their correlated geographic coordinates.

***Photograph-based individual marking surveys*.**— With the increasing occurrence of non-invasive photograph-based anuran capture-recapture studies (Kenyon et al. 2009; Del Lama et al. 2011), we used a photographic identification method (PIM) at Sites 3 and 4 in combination with a traditional marking approach (e.g., toe-clipping). Unlike our Site 8 batch-marking approach, which assessed metapopulation movements, we chose to record precise individual movements from overwintering to breeding locations at these two sites. Preceding movements of cricket frogs to breeding locations, we captured, marked, and processed all individuals within riparian overwintering areas (see Badje et al. 2016) between 28 April 2011 and 12 May 2011. We weighed, measured (SVL), and recorded initial geographic coordinates to all marked individuals. We also recorded aquatic habitat use (e.g., creek, river, ephemeral pond, marsh, and lake) of all captured individuals to document their aquatic habitat selection progression throughout spring. We followed Site 8 marking protocols for individual cricket frogs, with the exception that we used unique toe clips for each individual and did not correlate them with a transect. We then clipped one digit per individual on the front or hind foot, just above the first bone joint. We took photographs with a digital camera (model DSC W-70, Sony Corporation, Tokyo, Japan) of the dorsal and lateral views of each Blanchard's Cricket Frog. We associated these photographs with their respective toe-clip, and then assigned unique codes to all individuals (e.g., Site 3 = BH001; Site 4 = PK001).

During subsequent surveys, marking activities ceased and we walked all aquatic shorelines within Sites 3 and 4, searching for previously marked cricket frogs. Upon finding a clipped individual, we documented weight, length, sex, clip-code scheme, aquatic habitat, and geographic coordinates, and took photographs following initial capture protocols. We analyzed photographs on a high-resolution computer screen, comparing initially marked to recaptured individuals (Fig. 1). To efficiently identify individuals, we grouped them into study site and clip-code scheme. To search for matching individuals, we inspected and compared the location of similar sets of spots, bumps, and dorsal stripe, in addition to similar color schemes on the dorsal and lateral views. When a match was made, we gave recaptured individuals their corresponding individual code from the initial capture. We recorded recaptured individuals with an unconfirmed status if it appeared likely that there was a match, but the clarity of the initial or subsequent photograph was less than optimal for definitive matching. Once we reviewed all photographs of recaptured Blanchard's Cricket Frogs, we mapped geographic coordinates of individuals and analyzed their movements within the geographic information system. We calculated minimum movement distances from the furthest two geographic locations of individuals with the ruler tool feature to determine straight-line distance (m).

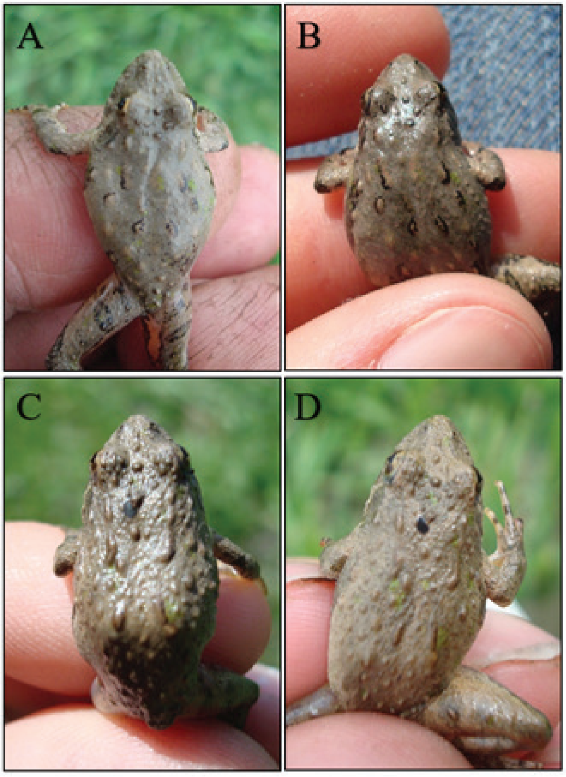

Figure 1. Dorsal photographs of two individual Blanchard's Cricket Frogs (*Acris blanchardi*) during a capture-recapture study in southwestern Wisconsin, USA. Individual PK011 images from (A) original capture date of 2 May 2011 and (B) final capture date of 20 May 2011. Individual BH028 images from (C) original capture date of 29 April 2011 and (D) final capture date of 6 May 2011. (A photographed by Andrew Badje and B-D by Tyler Brandt).

Results

Movement ecology.—On 8 April 2011, our initial site visit of the spring, we counted 57 Blanchard's Cricket Frogs along the stream at Site 3, indicating individuals had begun to emerge from their winter hibernacula. The first migrations to breeding habitat were on 12 April at Site 2, which represents the shortest documented distance (about 30 m) between overwintering and breeding locations of all our study locations. Subsequently and in phenological order for the year 2011, we observed initial occurrences at breeding locations on 18 April (Site 3), 25 April (Site 6), 12 May (Site 4), and 17 May (Site 8). Sites with shorter distances between overwintering and breeding locations exhibited earlier spring movements to breeding habitat.

Beginning 12 April, individual movements increased between overwintering and breeding habitats at Sites 2, 3, 4 and 8 (instances of confirmed migrations, as opposed to general movements). In mid-May the number of individuals found at wetlands (i.e., breeding sites) became larger than those at adjacent rivers (i.e., overwintering sites), as noted on 10 May (Site 2), 13 May (Site 3), 17 May (Site 8), and 20 May (Site 4). By the final week of May, capture ratios (e.g., river:wetland) reflected that most of the migration had occurred from the rivers to wetlands at Site 3 (13:108) and Site 4 (10:170). We could not confirm overwintering habitat at Site 6 in fall 2010, nor did we verify wetland specific breeding habitat at Site 7 in spring 2011, which limited our ability to determine the migration status of these populations. Of these two sites, we found only three individuals using breeding habitat at Site 6 by the end of surveys on 31 May, and we recorded no movements away from overwintering habitat at Site 7, whereas we continued to find cricket frogs within slow-moving sections of the river.

We were unable to determine whether April movements to breeding locations were made mostly or entirely by males as male vocal pouches in males had yet to become visually expressed. By mid-May, however, we recorded higher male abundance at breeding locations, and higher female abundance on river shorelines through VES. Male:female ratios of capture numbers at breeding locations were 60:17 at Site 3 (19 May), 15:1 at Site 4 (20 May), and 17:15 at Site 8 (24 May); at overwintering locations ratios were 2:13 at Site 3 (19 May) and 6:10 at Site 4 (20 May). We began to record higher numbers of both males and females on subsequent visits to Site 4 at breeding locations, with ratios of 58:10 (27 May) and 87:46 (1 June). At Site 4 males continued to migrate into breeding habitats into late-May and early June; however, during that same time period, females migrated at higher rates than males, beginning to lessen the earlier male dominated sex ratios at breeding sites. By the final week of our study low numbers of females and even fewer males remained in riverine habitat, with male:female ratios of 2:10 at Site 3 (26 May), 0:3 at Site 8 (30 May), and 1:4 at Site 4 (1 June).

Habitat use.—The available microhabitats within the river and stream floodplains of the six sites consisted of a shallow irrigation ditch, sand bars, gravel bars, mud flats, gradual sloping banks, banks with natural sloughing, steep banks with heavy erosion, and banks with recently installed riprap. Sites 4 and 8 each had a 20-m swath of riprap on the outer bends of riverbanks where severe erosion was a prior concern of the property owner. Throughout fall 2010 and spring 2011, we observed cricket frogs only on the peripheries of each segment of riprap. We made similar observations at Sites 4, 7, and 8, which featured highly eroded, steep sections of the outer bends of banks. Cricket frogs at our study sites also occurred adjacent to upland habitat, such as pastures of various grazing intensities as well as tilled and untilled agricultural fields, that could be traversed during overnight terrestrial movements following high humidity or precipitation events. Cricket frogs at our study sites used breeding habitats of various hydroperiods, which included seasonally flooded wetland scrapes and ephemeral ponds; restored wetlands; shallow, vegetated (e.g., *Equisetum* spp.) peripheries of an artificial lake; and slow-moving sections of creeks and rivers.

Marking techniques.—During batch-marking surveys at Site 8, we recaptured 29.6% (eight of 27) of the individuals marked from three of seven batch-marking transects. Of these eight individuals, we caught six different females on 17 May, 8 d post-marking, and all from within the transect they had originated. We also recaptured two males from two distinct river transects on 17 and 24 May, both having migrated to the nearest available wetland. We recorded the minimum movement distances of 260 and 390 m for these two males. We could not obtain minimum distances of movement for the six females because we recaptured all of them within their original transects.

We could not identify 15 of the individually marked and photographed cricket frogs (e.g., six from Site 3; nine from Site 4) due to poor photograph quality (e.g., glare, sun, and user error), which suppressed the efficacy of our recapture data. At Site 3, we recaptured 63.2% (24 of 38) of our marked individuals (Table 2).

Table 2. Photographic capture-recapture survey results in 2011 of Blanchard's Cricket Frog (*Acris blanchardi*) individual movements at Site 3 in Grant County, Wisconsin, USA. Data provided are individual frog identification code (Frog ID), sex (Male, Female, or Undocumented [-]), range of capture dates (month/day/year), number of recapture occurrences, days between first and last capture, straight-line distance (m) of the furthest two capture occurrences of an individual, and movement within aquatic habitat based on initial (1) and subsequent capture (2) results.

Frog ID	Sex	Range of Capture Dates	Recapture Occurrences	Days Between First and Last Captures	Distance (m)	Movement Within Aquatic Habitat
BH011	Male	29 April - 19 May	1	20	112	Creek to Ephemeral Pond (1)
BH013	Male	29 April - 26 May	2	27	233	Creek to Ephemeral Pond (1) Ephemeral Pond to Marsh (2)
BH017	Female	29 April - 26 May	2	27	127	Creek to Creek (1) Creek to Ephemeral Pond (2)
BH018	Male	29 April - 19 May	1	20	116	Creek to Ephemeral Pond (1)
BH019	Male	29 April - 13 May	1	14	35	Creek to Ephemeral Pond (1)
BH020	—	29 April - 6 May	1	7	4	Creek to Creek (1)
BH021	Male	29 April - 26 May	2	27	43	Creek to Ephemeral Pond (1)
BH023	Male	29 April - 26 May	2	27	135	Creek to Ephemeral Pond (1)
BH026	Female	29 April - 19 May	1	20	45	Creek to Ephemeral Pond (1)
BH027	Female	29 April - 26 May	2	27	93	Creek to Creek (1) Creek to Ephemeral Pond (2)
BH028	—	29 April - 6 May	1	7	8	Creek to Creek (1)
BH029	Female	29 April - 26 May	1	27	127	Creek to Ephemeral Pond (1)
BH030	Male	29 April - 19 May	1	20	208	Creek to Ephemeral Pond (1)
BH032	—	29 April - 19 May	1	20	249	Creek to Ephemeral Pond (1)
BH033	Male	29 April - 26 May	1	27	134	Creek to Ephemeral Pond (1)
BH034	Female	29 April - 26 May	1	27	115	Creek to Ephemeral Pond (1)
BH035	Female	29 April - 19 May	1	20	153	Creek to Ephemeral Pond (1)
BH036	Female	29 April - 19 May	1	20	123	Creek to Creek (1)
BH038	—	29 April - 6 May	1	7	41	Creek to Creek (1)
BH039	Female	29 April - 6 May	1	7	41	Creek to Creek (1)
BH040	Male	29 April - 26 May	1	27	181	Creek to Ephemeral Pond (1)
BH042	Male	29 April - 19 May	1	20	37	Creek to Creek (1)
BH043	Male	6 May - 26 May	2	20	122	Creek to Ephemeral Pond (1)
BH044	Female	6 May - 26 May	2	20	21	Creek to Creek (1) Creek to Ephemeral Pond (2)

Table 3. Photographic capture-recapture survey results in 2011 of Blanchard's Cricket Frog (*Acris blanchardi*) individual movements at Site 4 in Iowa County, Wisconsin, USA. Data provided are individual frog identification code (Frog ID), sex (Male, Female, or Undocumented [-]), range of capture dates (month, day, year), number of recapture occurrences, days between first and last capture, and straight-line distance (m) between the furthest two capture occurrences of an individual, and movement within aquatic habitat based on initial (1) and subsequent capture (2) results.

Frog ID	Sex	Range of Capture Dates	Recapture Occurrences	Days Between First and Last Captures	Distance (m)	Movement Within Aquatic Habitat
PK002	—	2 May - 12 May	1	10	41	River to River (1)
PK003	—	2 May - 12 May	1	10	45	River to River (1)
PK004	Female	2 May - 20 May	1	18	52	River to River (1)
PK005	Male	2 May - 27 May	1	25	438	River to Marsh (1)
PK011	Male	2 May - 20 May	1	18	28	River to River (1)
PK013	Female	2 May - 27 May	1	25	609	River to Marsh (1)
PK023	Male	2 May - 20 May	1	18	586	River to Marsh (1)
PK025	Male	2 May - 1 June	1	30	662	River to Marsh (1)
PK026	Male	2 May - 1 June	1	30	661	River to Marsh (1)
PK027	Male	12 May - 1 June	1	20	437	River to Marsh (1)
PK028	Female	12 May - 1 June	1	20	6	River to River (1)
PK029	Male	12 May - 1 June	2	20	541	River to River (1) River to Marsh (2)
PK035	Female	12 May - 1 June	1	20	606	River to Marsh (1)

By combining the minimum distances of movement for all recaptured individuals at Site 3, we were able to delineate a mean minimum distance of 100 ± (standard deviation) 70 m (range, 4–249 m; n = 24) for this population. We recaptured 28.9% (13 of 45) of marked individuals (Table 3) at Site 4 and were able to deduce a mean minimum distance of 360 ± 280 m (range, 6–662 m; n = 13) for this population as well.

Discussion

Movement ecology.—The tendency for anurans to migrate only if essential resources (e.g., overwintering, foraging, and breeding habitat) are spatially separated is well documented (Sinsch 1990). The shorter migration distances we recorded for the population at Site 3, a finding similar to those reported by Pyburn (1958), Gray (1983), and Burkett (1984), imply that on-site resources are more concentrated year-round at this site, compared to Site 4 and Site 8. Despite differences in mean movement distance between our sites, it appears that sites where we observed migration (e.g., river to wetland), all recaptured individuals eventually migrated to the nearest breeding wetland (when having a choice of two or more), therefore minimizing energy expenditure prior to breeding. It appears that the maximum movements of a few individuals (0.8 and 1.3 km) documented in Gray (1983) likely resulted in high energy expenditures and may be more representative of a colonization event. The variety of movement distances represented in our recapture results suggest the essential resources needed by Blanchard's Cricket Frog are site-specific, spatially separated, and seasonally discrete throughout the study sites.

Conspecific vocalizations, wetland scents, rain, mild-humid weather, orientation of the sun, moon, and stars, and the magnetic field of the earth are all used to some degree by anurans for orientation and migration (Pyburn 1958; Burkett 1984; Sinsch 1990). We documented delayed initial appearances of up to one month for Blanchard's Cricket Frog at breeding locations with longer migration routes (Sites 4 and 8) as compared to shorter routes (Sites 2 and 3). The delays in migration at Sites 4 and 8 may also allow for feeding near overwintering sites to accumulate the energy reserves needed for long distance movements, a hypothesis supported by the continual growth of cricket frogs throughout the months prior to the breeding season (Johnson and Christiansen 1976; Burkett 1984). Individuals may also benefit by staying near hibernacula longer into the spring to seek shelter from erratic fluctuations of temperatures in spring that occasionally bring late-season snow in Wisconsin. Sites exhibiting shorter movements, and earlier migrations, may provide further benefit to individuals by allowing for short back-and-forth movements from breeding to overwintering habitat in times of poor weather. These sites may also provide habitat where refugia are readily available throughout the year.

At Site 7 we did not observe a spring migration to the nearest potential breeding wetland (e.g., artificially made farm pond), which was located 0.8 km away and within the documented movement distances of the species (Gray 1983). We may have ended Site 7 surveys too early to document migrations to the farm pond or other breeding habitat. We suggest this may also be the case at Site 6, where we have documented annual breeding on the margins of a reservoir in previous monitoring studies (Wisconsin Department of Natural Resources, unpubl. data) but had yet to show a larger movement event upon our final site visit on 31 May 2011. Sites 6 and 7 also feature the deepest bodies of water in our study, making it feasible that movements are delayed longer at these sites until water temperatures reach thresholds needed for breeding.

Blanchard's Cricket Frog has been documented elsewhere breeding and laying egg masses on vegetation in calm channels, eddies, or backwaters of rivers (Gray et al. 2005), which may provide evidence that the species has the necessary year-round resources within the riparian corridor at Site 7. Therefore, long distance movements with high energy expenditures may be unnecessary here. Numerous call surveys documenting river-based breeding populations (i.e., absence of nearby wetland) of Blanchard's Cricket Frog suggests this habitat is found throughout southwestern Wisconsin (Rori Paloski, pers. obs.). Riparian areas inhabited and used as likely breeding locations (e.g., Site 7) have the further potential to connect metapopulations between wetlands, increase gene flow, and promote range expansion.

We were unable to determine sex upon the first observation of individuals at breeding locations, although it is thought that males at our study sites were the initial inhabitants (Pyburn 1958; Gray 1983). In mid-May, however, as we began to sex individuals, disparities in the ratio of males to females at breeding and overwintering locations became apparent (e.g., higher levels of males at breeding locations and more females at overwintering locations). Within one to two weeks (e.g., late-May), these differences became less pronounced, suggesting females chose to delay larger movements. Reasons for migratory postponement may in part be due to the development of eggs in females a short time after male chorusing begins (Johnson and Christiansen 1976) or waiting out the competition and aggression of males while the establishment of breeding territories ensues (Burmeister et al. 1999). Additionally, we documented the gradual movements of males and females throughout the study, which minimizes any support for a certain cue (e.g., rain event) to trigger a mass population or sex-specific movement event at our sites.

Marking techniques.—Non-photographic marking methods using various clip-code schemes have been successfully used on Blanchard's Cricket Frog movement, population, and survivorship studies (Pyburn 1958; Gray 1983; Lehtinen and MacDonald 2011). Our scheme at Site 8 most closely followed that of Burkett (1984), batch-marking individuals by day and transect. In comparison to the marking technique used at Sites 3 and 4, this batch-marking technique provided a more immediate result in identifying groups of individuals and their relative movements while in the field, as opposed to a later determination in an office setting. This approach may be preferable when research goals seek to minimize time, maximize efficiency, and are attempting to document broad movements of individuals to and from distinct habitats (e.g., river to wetland, wetland to wetland, wetland to river).

To lessen the invasiveness and potential negative effects of toe-clipping, photographing individuals is becoming a more widespread technique in anuran capture-recapture studies (Kenyon et al. 2009; Kelly 2010; Del Lama et al. 2011). Untested in Blanchard's Cricket Frog studies, we chose to experiment with the PIM in combination with a traditional toe-clipping method. Shortly after we completed marking, we found that individuals could be identified solely from photographs by matching the unique sequence of colors, spots, bumps, and dorsal stripe of individuals. During our study, the unique physical characteristics of an individual did not appear to change or disappear, which would make the method unreliable. A limiting factor for this approach is photograph quality.

The PIM we applied at Sites 3 and 4 proved successful in documenting migration of numerous individuals from 28 April 2011 to 1 June 2011. Toe-clipping reduced our time in identifying recaptured individuals in photographs because it allowed us to categorize and search through photographs of individuals representing the same site and clip-code, as opposed to reviewing all photographs of the originally marked individuals for a match. As pattern recognition computer software continues to advance (e.g., Wild.ID; Bolger et al. 2012), PIM may become more effective and less invasive than other marking techniques for capture-recapture studies. Although toe-clipping did not appear to be detrimental in our study, as demonstrated by the number of individuals we recaptured at Site 3, additional research is necessary to prove or disprove this. Future research comparing the survival rates of photographed-only, photographed and marked, and marked-only individual cricket frogs via a standardized capture-recapture study would lead to a better understanding of marking effects on individuals and populations, in addition to providing population estimates for a species in which such data is lacking.

Climate change implications.—Climate change is expected to increase weather stochasticity, influencing natural disaster (e.g., flooding and droughts) quantity and intensity throughout Wisconsin (Wisconsin Initiative on Climate Change Impacts 2011). Research on climate change suggests that northern populations of Blanchard's Cricket Frog are especially vulnerable to extreme weather, increased durations of adverse weather, disease, and reductions in body growth and reproduction (Lannoo 1998; McCallum 2010; Early and Sax 2011); however, Blanchard's Cricket Frog could benefit from a longer, warmer growing season, and subsequently see an expanded range in northern populations. As of 2017, cricket frogs have been recorded in many areas from which they were long considered extirpated on the northern edge of their range in southwestern Wisconsin (Wisconsin Department of Natural Resources, unpubl. data) and southeast Minnesota (Minnesota Department of Natural Resources 2015; Casper et al. 2017). Research focusing on the movements of cricket frogs can provide further insight on how adaptation may or may not occur in times of prolonged weather uncertainty. For northern populations of Blanchard's Cricket Frog to persist under adverse weather conditions, habitat function, connectivity, and diversity should be emphasized in conservation planning.

Conservation measures.—To improve the distribution and health of Blanchard's Cricket Frog populations in northern climates, the creation or maintenance of a diverse subset of interconnected and healthy aquatic and terrestrial habitats should be incorporated into management and conservation plans. Additionally, habitat should feature overwintering, migration, and breeding environments all within the movement and migration parameters published herein and elsewhere for this species to promote robust and self-sustaining populations and metapopulations. Wetland mitigation and restoration efforts benefitting cricket frogs should seek the placement of wetlands 0.25–1.0 km (maximum of 1.3 km) apart and within floodplains or nearby uplands where gaps in breeding habitat exist. Such strategies would use the best available science on movement ecology to protect the species throughout its annual life cycle and varied habitat use.

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