MICROHABITAT AFFINITY OF BLANCHARD'S CRICKET FROG (*ACRIS CREPITANS BLANCHARDI*) IN RURAL AND URBAN AREAS IN CENTRAL TEXAS

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ABSTRACT

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Habitats of small anurans are being encroached upon by land development in central Texas. Blanchard's cricket frog (*Acris crepitans blanchardi*) is a small frog occupying small streams in these areas of disturbance. I investigated microhabitat affinity of Blanchard's cricket frog to assess whether differences exist between urban and rural areas of central Texas. That is, I examined whether cricket frogs altered their use of microhabitats when in urban environments compared to rural. Vegetative and substrate characteristics and moisture profiles of microhabitats were quantitatively assessed and categorized using line intercept and quadrat methods. Morphological data were analyzed by principal component analysis to depict associations of morphological characteristics to microhabitat association. I collected 424 *Acris crepitans blanchardi* from May to December 2008 in 12 rural and 12 urban habitats along Barton Creek and Onion Creek watersheds. Chi-square goodness of fit test indicated microhabitat affinity by cricket frogs was influenced by moisture level and substrate type. There was no difference in the distribution of cricket frogs between urban and rural environments. Analyses of morphological characteristics by PCA indicated larger cricket frogs associated with areas of dense vegetation in the more arid rural locations. I did not find that the current level of human-induced disturbance has affected microhabitat use by Blanchard's cricket frogs; however, I would suggest a good management practice would be the establishment of a buffer zone in association with riparian habitats in central Texas.

I. INTRODUCTION

Recent documentation of a worldwide decline in several amphibian species has spurred ecological studies investigating their natural history (Blaustein and Olson 1991, Lannoo 1998, Knutson et al. 1999, Houlahan et al. 2000, Alford et al. 2001). Several possible causes of this decline have been identified such as UV radiation exposure, acidification, pollution, siltation of eggs, climate change, disease, and human-induced habitat fragmentation (Kats and Ferrer 2003, Davidson 2004, Daszak et al. 2005, Van Buskirk 2005, Blaustein and Bancroft 2007). With the case of human-induced habitat fragmentation, the influence of roads, cleared areas, electrical transmission lines, buildings and other man-made structures can isolate habitats and landscape features resulting in mosaics instead of a continuous and uniform habitat (Dickman 1987).

Anurans (frogs and toads) are one group of amphibians that have been the focus of study and concern. Unique adaptations allow anurans to cope with extreme conditions. They can thrive in habitats ranging from extremely moist conditions to a semi-desert environment (Deyrup 1964, Bentley 1966, Nevo 1973a). Anurans have been described as an ideal indicator of ecological changes due to their ability to thrive on both land and water (Krzysik 1998). Within these habitats, they function as primary consumers prior to adulthood and become more of a secondary consumer as adults (Brown 1974). With the surge of urbanization, however, anuran populations and micohabitats have been greatly affected by human influences.

Blanchard's cricket frog, *Acris crepitans blanchardi,* in particular, has become rare in recent years within some parts of its distribution and even extirpated in the extreme northern and northeastern portions of its range, particularly Colorado and Iowa (Lehtinen and Skinner 2006). The distribution of this species extends from lowlands and highlands of southern Canada southward into northern Mexico (Nevo 1973a, b). Blanchard's cricket frog is a small (approx. 2.5-4 cm length), warty-skinned member of the tree frog family (Hyalidae). Its most distinguishing features include a distinctive jagged stripe on the rear surface of its thigh, a dark triangle between the eyes, and a broad, light, dorsal stripe. Morphologically, these tiny, non-climbing hylids are described as having varying dorsal-color morphs (grey, red, green) with the dominant morph being grey (Pyburn 1961a and b, Nevo 1973a and b, Gray 1972). Some individuals may also be marked with green, reddish, or black spots or blotches on the back. The ventral surface is typically cream in coloration. The snout is generally blunt and pointed and there are two light bars that extend from the corner and edge of the jaw to the eye. On average, Blanchard's cricket frogs have snout-vent lengths of 21.5 mm (Neill 1950) with the maximum reported of 38 mm (Conant and Collins 1991). Males are smaller than females. A qualitative characteristic of the species is that the heel of an adpressed hind leg stretches beyond the snout.

Most research on cricket frog habitat selection has qualitatively described habitat characteristics (Smith et al. 2003). Although classified in the treefrog family, Blanchard's cricket frog spends no time in shrubs or trees. It prefers sunny, shallow water with ample vegetation on the banks and in the water, as found in marshes and along the edges of ponds or creeks (Conant and Collins 1991). In riverine habitats such as creeks, the species inhabits low gradient streams with pools, where as in lacustrine habitats, *Acris* select areas of shallow water. Cricket frogs are typically observed no more than 1 to 5 m from the nearest water source (Lannoo 1998). Within these zones, frogs occupy areas of exposed banks or sit on floating debris close to the edge. Due to respiratory requirements, Blanchard's cricket frogs select areas containing moist substrates within varying densities of vegetative cover (Gray and Brown 2005). In times of severe drought, cricket frogs take refuge in cracks of rocks or logs (Irwin et al. 1999).

Most studies of the ecology of Blanchard's cricket frogs do not address whether the frogs were sampled in an urban development or rural setting. The effects of urban development on wildlife, particularly anurans, have been well documented. Cousins (1982), Kunick (1982) and Dickman (1987) reported on anthropomorphic modifications of habitats both before and after urban expansion. These modifications, which included the creation of roads, buildings, cleared areas, and general human activities, ultimately lead to fragmentation in the anurans' habitats.

I investigated whether microhabitat affinity of *A. c. blanchardi* differs between and within rural and urban environments. Microhabitats are defined on a meter-by-meter scale. I assumed rural areas reflected natural patterns in the habits of Blanchards cricket frogs as a baseline for comparison with microhabitat selection observed in urban environments. These rural areas, such as ranch lands (or private properties no smaller than 3 ha), were primarily characterized as having little human disturbance (i.e., major roads, people traffic, and recreational properties), and few buildings/homes. The urban areas were classified by public access properties (i.e., recreational areas) with moderate to heavy human activity.

As a secondary objective, I analyzed associations between morphological variations and habitat selection of frogs through multivariate analysis (e.g., principal component analysis). I expected mean body size of Blanchards cricket frogs to be greater in rural environments that presumably are more arid. Larger cricket frogs have a much smaller surface to volume ratio that allows them to persist in xeric environments that smaller frogs may not be able to inhabit. In these environments smaller frogs are more prone to desiccation. My results would also provide further support to previous morphological studies relating to color variations such as Nevo (1973a, b), and Pyburn (1961a, b).

II. STUDY SITES

Two similar watersheds, Barton Creek and Onion Creek, were chosen as study sites because their riparian zones are becoming increasingly urbanized. The Barton Creek watershed stretches from Dripping Springs, Hays County (30°13' N, 98°11' W) east to Austin, Travis County (30°16' N, 97°46' W) and empties into Ladybird Lake (Colorado River in southwest Austin). This 310.8 km^2 watershed encompasses two zones within the Edwards Plateau (EP), a Contributing Zone (~ 290.1 km^2) and a Recharge Zone (~ 20.7 km^2). The Contributing Zone consists primarily of Glen Rose limestone and Terrace/alluvial deposits, and the Recharge Zone is dominated by Georgetown and Edwards limestones (Barker and Ardis 1996) (Fig. 1).

The Onion Creek watershed has headwaters in both Blanco and Hays counties and empties into the Colorado River in Travis County. The creek contains 906.5 km^2 of drainage and a drop of 277 m in elevation (0.25% drop) from its headwaters to mouth. This 121-km creek passes through two separate ecoregions; the Edwards Plateau (EP) and the Blackland Prairie (BP).

Throughout the entire limestone based EP portion of the watershed, deciduous and evergreen trees and shrubs dominate the riparian zone. Approximately 80% of the watershed is encompassed in the EP and is referred to as the Contributing Zone of the Edwards Aquifer.

Due to denser soil and less exposed limestone, the BP portion of the watershed is more diverse and contains better-developed riparian zones. This recharge zone of the aquifer begins east of IH-35 and encompasses 20% of the watershed (Fig. 1).

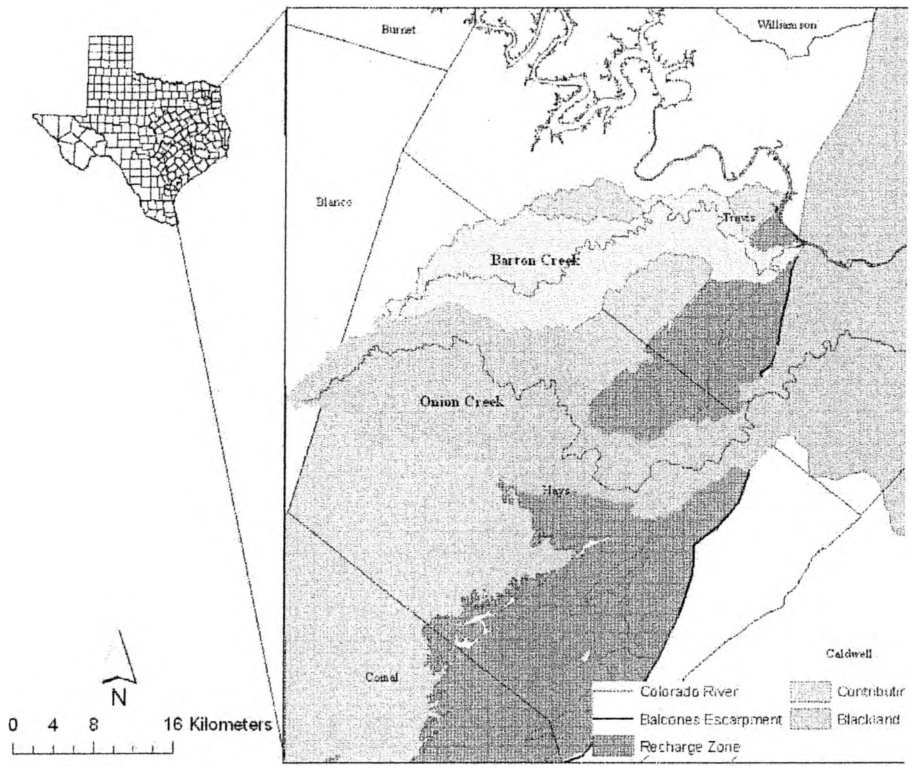


Figure 1. Map depicting overall study sites; Barton Creek watershed, and Onion Creek Watershed (Texas Commission on Environmental Quality 2009).

III. METHODS

Quadrats.---I randomly selected 24 quadrats (15 m x 4 m) in rural and urban areas (12 in each), adjacent to the stream and within each watershed, for a total of 48 quadrats. The 12 rural quadrats in Hays County occur within the Contributing Zones, and the 12 urban quadrats in Travis County occur within the Recharge Zone for both watersheds.

On the Barton Creek transect, 12 urban quadrats were located along the creek in the Lost Creek housing development (LC), located within the Recharge Zone of the aquifer. Hiking and biking trails of the Barton Creek Greenbelt pass along this portion of the creek, creating human and domesticated animal disturbance. This area is also identified as containing open areas of Glen Rose Limestone to lush grass with both sloping and steep banks. The 12 rural quadrats located at Alicia Diehl Ranch (AD) near the headwaters of Barton Creek, contains an ephemeral portion of the creek. Unlike the developed site of the creek, AD ranges from containing heavily to slightly vegetated areas, and contains a mixture of differing levels of Glen Rose Limestone and soil substrates. These transects are near United States Geological Survey (USGS) gages 08155200 and 08155240 (U.S. Geological Survey 2009).

Three Onion Creek transects were chosen for sampling sites. The 12 urban quadrats were located at a portion of the Onion Creek that passes through the Onion Creek Country Club (OC). This spring fed area is moderately disturbed by humans, and is fragmented by a 3-m wide road made for golf carts. The environment is classified as having a mixture of exposed Edwards Limestone and soil substrates.

The heavily vegetated Horseshoe Springs of Storm Ranch (SR) is a perennial tributary of Onion Creek in Hays County. Storm Ranch is moderately disturbed by cattle and has more bare soil than exposed Glen Rose Limestone. Bella Springs of Ragsdale Ranch (RR) is another perennial spring located on Onion Creek in Hays County. Exposed Glen Rose Limestone and low to moderate vegetation surrounds RR. Due to limited access on Onion Creek rural sites, 6 quadrats were chosen for Horseshoe Springs of Storm Ranch and 6 were selected on Bella Springs of Ragsdale Ranch. The Onion Creek transects were by USGS gages 08158700 and 08158827 (U.S. Geological Survey 2009).

Defining Microhabitats.---I established a 15 m x 4 m quadrat parallel to the edge of the creek with 1 m extending into the creek bed and 3 m into the riparian zone. Quadrats were spaced from 5 m to 50 m from each other. Flagging tape was placed at each corner of the quadrat at an approximately 2 m height, and coordinates of each flagged point were recorded using a Garmin eTrex Legend Cx GPS (Olathe, KS). Each point was reported as Universal Transverse Mercator (UTMs) in a database IV file (.dbf) using Microsoft Excel 2004 ®. To verify the location of each quadrat, the dbf was imported into ArcMap version 9.2.0 (Redlands, CA) on a 2002 CAPCOG true color aerial imagery.

I categorized microhabitats by the density of vegetative cover (i.e., grasses, shrubs, and trees) using the line intercept method (Canfield 1941). At each quadrat, I used two 15 m intercept lines (along the bank of the creek and 3 m into the riparian zone parallel to the initial line) to sample vegetative cover. The portion of the meter tape intercepted by vegetation either above or below defined vegetative cover. Percent vegetation was calculated by the sum of the vegetation, of both lines, divided by the total length measured by the lines (∑vegetation/30 m) for each quadrat at a site. Each quadrat was categorized based on the percent vegetative cover being low (0-33.9%), moderate (34-66.9%), or high (> 67%).

The same line intercept method was used in determining relative abundance of non-vegetative substrates. I classified non-vegetative substrates using the Wentworth substrate size scale: boulders (> 256 mm), cobble (64-256 mm), pebble (16-63.9 mm), gravel (2-15.9 mm), and sand and fines (0.1-1.9 mm) (Wentworth 1922). Relative proportion of each substrate type was calculated as the sum of each type, of both lines, divided by the total length measured by the lines (∑substrate type/30 m) for each quadrat at a site. Additional visual characteristics were also recorded (i.e., quadrats containing pools of water).

Data Collection.---Each quadrat was surveyed once per month (May-December 2008) by randomly selecting 4 quadrats without replacement using R version 2.6.1 for morning, afternoon, and evening sampling. I searched the surface of the ground and rocks, under debris, and within vegetation for at least 15 min at each quadrat. If no frogs were observed within 15 min, I recorded a 0. However, when frogs were observed, I continued sampling for a maximum of 30 min. I recorded the total frogs collected/observed in 30 min for that quadrat. I monitored weather conditions (relative humidity, open and shaded temperature, and wind velocity) using a Kestrel 3000 (Sylvan Lake, MI). I assumed frogs observed and/or collected were a random sample of the overall population.

I collected habitat data for each quadrat. I recorded the initial observed location (i.e., substrate) of each individual frog within the quadrat. I also collected data on additional microhabitat characteristics, such as ground moisture (wet or dry), quadrats containing pools or standing water, and recent signs of potential predators. I used Chi-square goodness of fit tests to determine, from calculated expected values, associations of frogs to habitat characteristics (i.e., urban and rural, microhabitats, substrates, moisture levels, and quadrats with pools versus no pools). Expected values were based on the proportion of the microhabitat type or quadrat characteristic. For example, if a given quadrat was 30% boulder then 30 out of 100 frogs were expected to be on boulder.

I captured frogs for morphological measurements by hand or dip nets and placed them in wet pillowcases for processing. Lengths were measured to the 0.1 mm using electronic digital calipers (Cen-Tech 6" Digital Caliper). The mass of each frog was taken with a field balance (DuraScale 50G, Phoenix, AZ) and reported to the nearest 10 mg. Measurements included: snout vent length (SVL: distance between the tip of the snout to the opening of the cloaca), length of left hind leg, length of left hind foot, body width at widest point, head width, interorbital distance, and vertebral stripe color and length (Nevo 1973b). Frogs were toe-clipped for mark-recapture analysis (Hero 1989) prior to release. Recaptures were noted but not reprocessed. A principal component analysis (PCA) was used to depict associations between habitat characteristics and morphology

Body width, mass, sex, head width, and vertebral stripe length were not used in the analyses because measurements of body width, head width, and vertebral stripe lengths were inconsistent. There was a relatively small sample size between males and females, and mass was not measured for every individual.

All activities were conducted in accordance with Texas State University–San Marcos IACUC approval #0819-0414-21 and state permit #SPR-0890-234.

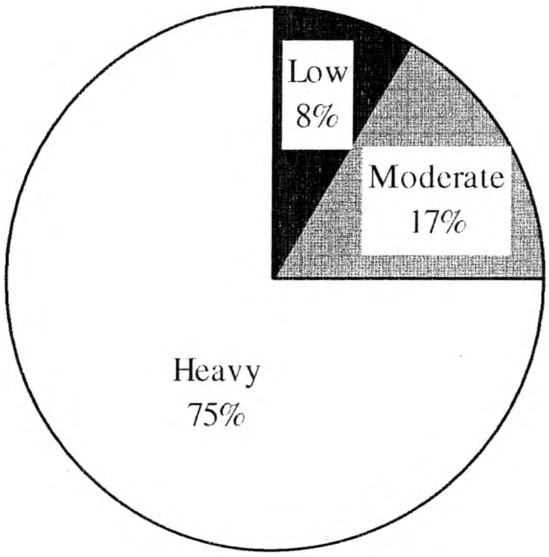
IV. RESULTS

From May to December 2008, a total of 424 individual frogs were observed and collected during 164 trap days (total effort time = 6,225 min); 65 of these days involved observing frogs (Table 1). On average I had the assistance of one additional observer and a maximum of 3 additional observers per collection day.

Table 1. Number of *Acris crepitans blanchardi* observations throughout the rural and urban study sites.

Location		Capture Days (n = 164)	Capture Days with Frogs (n = 65)	Frogs Observed (n = 424)
Rural		76	26	226
	Alicia Diehl Ranch	48	12	113
	Ragsdale Ranch	15	7	79
	Storm Ranch	13	7	34
Urban		88	39	198
	Lost Creek	60	18	47
	Onion Creek	28	21	151

Microhabitat Characteristics.---Among all quadrats, the rural contained a higher proportion of vegetation than the urban (50%, 38% respectively; Fig. 2). Substrates of sand and fines and cobble were dominant in rural quadrats; while, the urban predominately contained boulder, cobble, and pebble as the primary substrates (Fig. 3). I collected more cricket frogs at rural sites; 16 of 24 quadrats contained frogs (n = 226). Urban transects yielded cricket frogs at more quadrats (18 of 24) but fewer frogs overall (n = 198). During the period of observation, flow on Barton Creek varied from 0.001 m^3/s to 3.399 m^3/s and on Onion Creek from 0.000 m^3/s to < 6.230 m^3/s (Table 2).



a

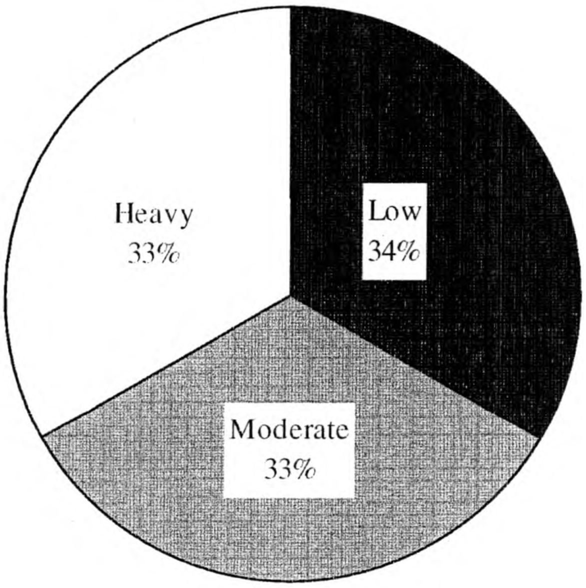


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Figure 2. Comparison of the percent of vegetation categories between the rural (a) and urban (b) quadrats. Values shown are means of the 24 rural and 24 urban quadrats.

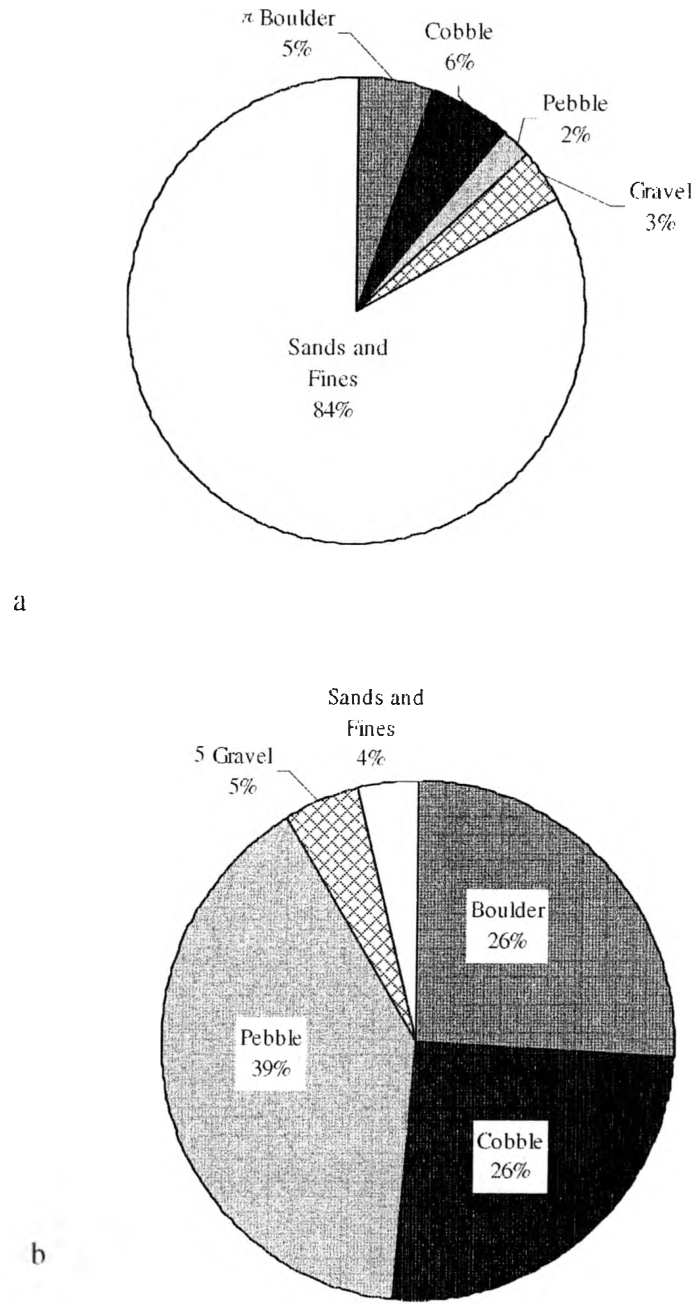


Figure 3. Comparison of the percent of substrate types at rural (a), and urban quadrats (b). Values shown are means of the 24 rural and 24 urban quadrats.

Table 2. Summary of flow conditions from May to December 2008.

USGS Site		Flow (m3/s)		
Number	Location	Mean	Min	Max
08155200	Barton Ck at SH 71 nr Oak Hill, TX	0 039	0.008	3.399
08155240	Barton Ck at Lost Ck Blvd nr Austin, TX	0.047	0 001	1 615
08158700	Onion Ck nr Driftwood, TX	0 008	0.000	< 0 425
08158827	Onion Ck at Twin Creeks Rd nr Manchaca, TX	0 002	0.000	< 6.230

Microhabitat.---A Chi square (χ^2) analysis goodness of fit test revealed no differences between cricket frogs associated with rural and urban sites ($\chi^2 = 1.85$, df = 1, $P = 0.17$; Fig. 4). With respect to microhabitats within the rural and urban sites, cricket frogs were associated with low vegetative cover; however, in terms of numbers observed in rural areas, high numbers of cricket frogs were observed in areas of heavy vegetation ($\chi^2_{rural} = 144.8$, $df_{rural} = 2$, P_{rural} ,< 0.001, $\chi^2_{urban} = 33.6$, $df_{urban} = 2$, $P_{urban} < 0.001$; Fig. 5a and b, respectively). Significant differences in substrate associations were observed within both rural and urban quadrats but a consistent pattern did not exist between the two ($\chi^2_{rural} = 88.9$, $df_{rural} = 4$, $P_{rural} < 0.001$, $\chi^2_{urban} = 41.6$, $df_{urban} = 4$, $P_{urban} < 0.001$; Fig. 6a and b, respectively).

When considering only substrate types (i.e., limestone and sand and fines), Blanchard's cricket frogs were positively associated with sand and fines and negatively associated with limestone ($\chi^2 = 67.3$, df = 1, $P < 0.001$; Fig. 7). Quadrats composed of a combination of moist areas and pools of water had a high abundance of Blanchard's cricket frogs ($\chi^2 = 346.2$, df = 3, $P < 0.001$; Fig. 8).

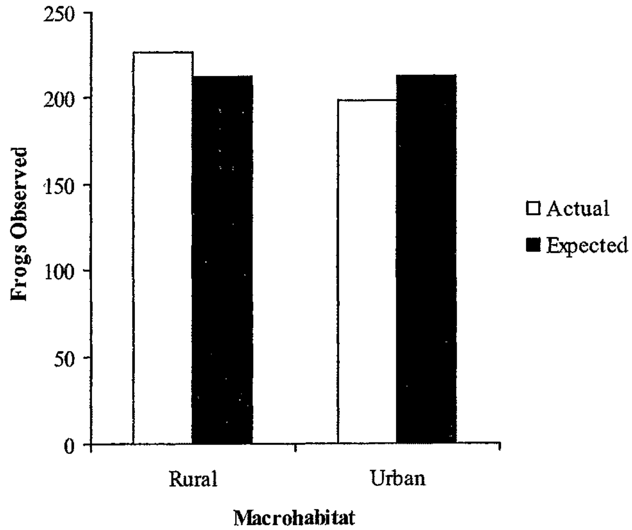


Figure 4. Comparison between number of Blanchard's cricket frogs (n = 424) observed in rural and urban quadrats.

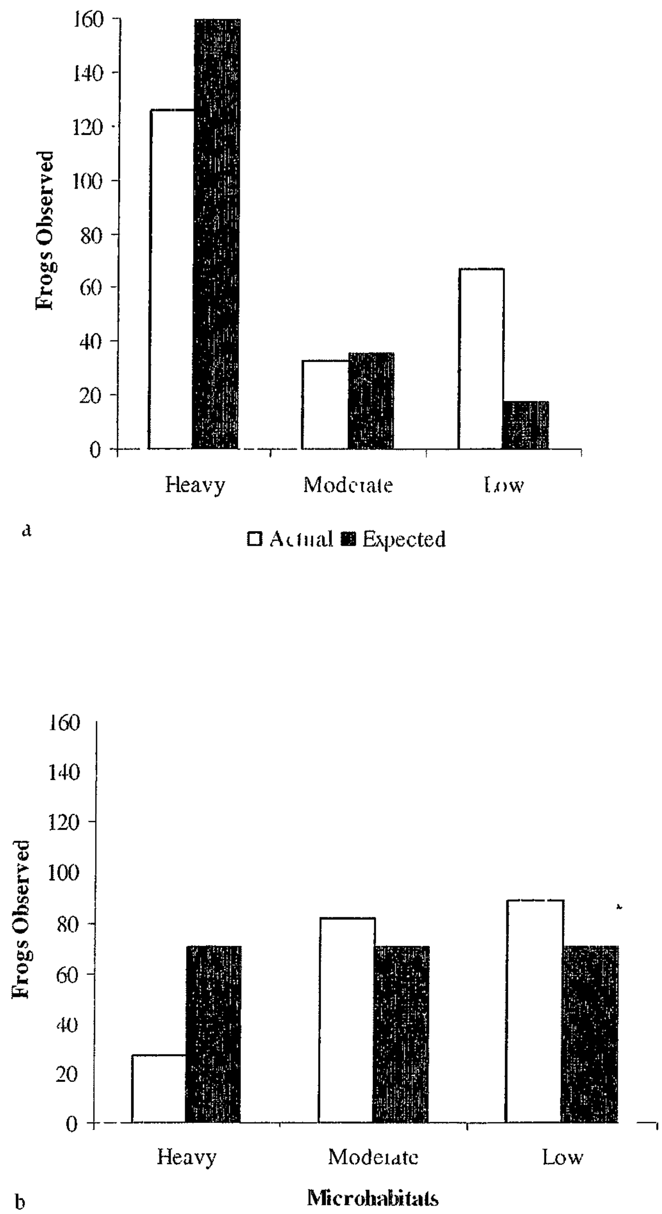
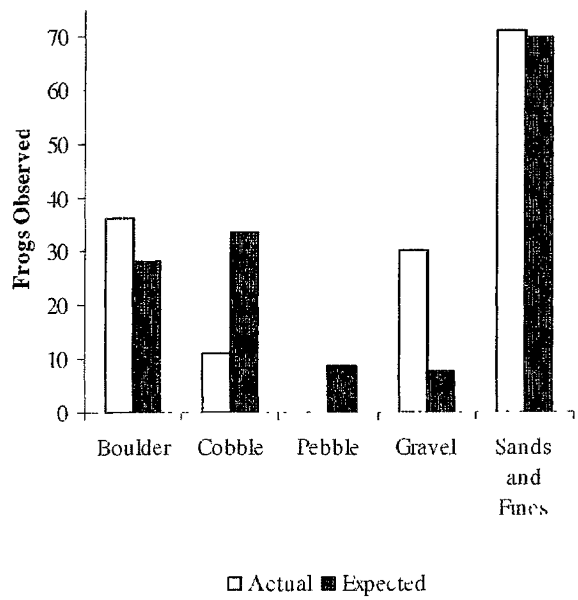


Figure 5. Comparison of the number of Blanchard's cricket frogs (n = 424) in microhabitats with heavy, moderate, or low densities of vegetation in rural (a) and urban (b) quadrats.



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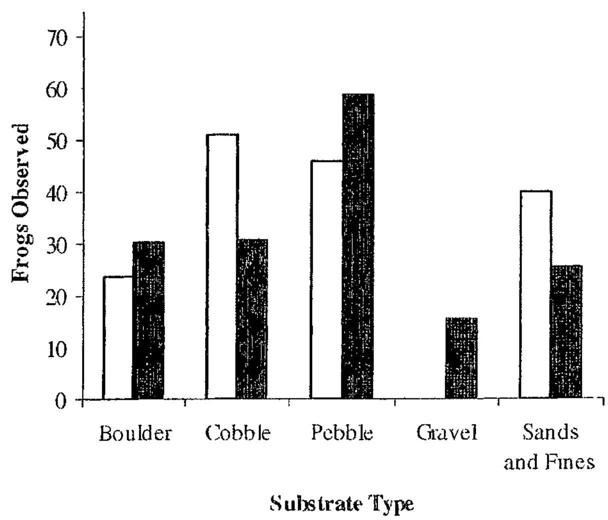

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Figure 6. Number of Blanchard's cricket frogs (n = 424) associated with different substrate types at rural (a) and urban (b) quadrats.

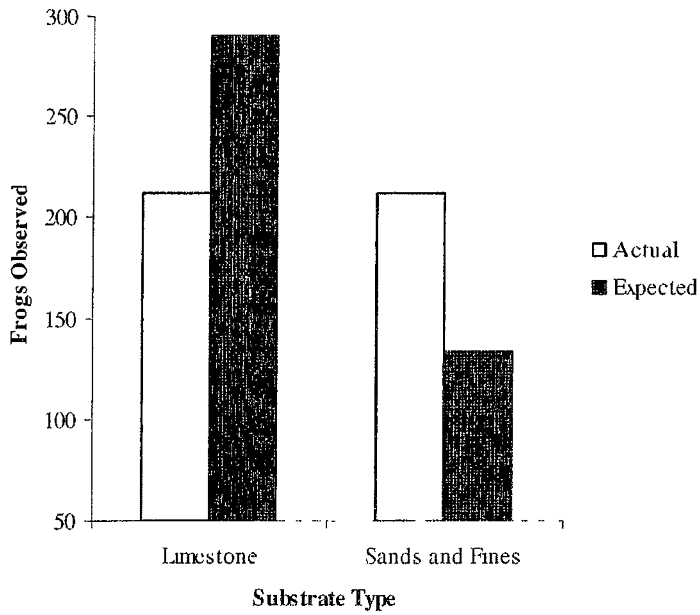

Figure 7. Comparison of the number of Blanchard's cricket frogs ($n = 424$) inhabiting limestone and sand and fines substrates within rural and urban quadrats.

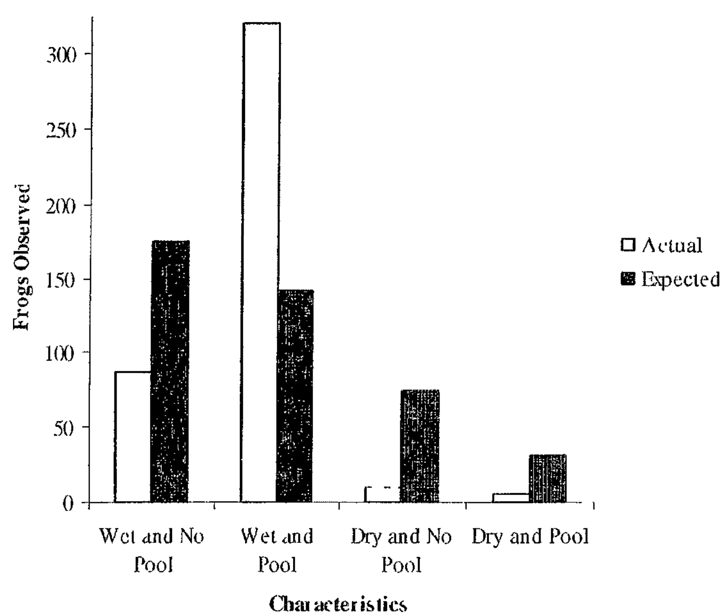

Figure 8. Number of Blanchard's cricket frogs ($n = 424$) inhabiting moist or dry microhabitats having pools of water or no pools.

Morphological Data.---The principal component analysis indicated a difference in morphological structures and microhabitat types for snout vent length (SVL), left foot length (LFL), left leg length (LLL), and interorbital distance (IOD) (Table 3). Also, vertebral stripe length and color, sex, and mass were left out due to a small sample size of red (52) and green (21) morphs and males (58) and females (127).

Table 3. Eigenvalues and variances explained by the morphological variables of collected Blanchard's cricket frogs (*n* = 424).

Variables	PC1	PC2	PC3	PC4
Snout-Vent Length (SVL)	-0.54*	-0.18	0.56	0.60
Left Leg Length (LLL)	-0.57*	---	0.26	-0.78
Left Foot Length (LFL)	-0.50*	-0.39	-0.76	0.14
Interorbital Distance (IOD)	-0.37	0.90**	-0.20	0.12
Proportion Variance	0.25	0.25	0.25	0.25
Cumulative Variance	0.25	0.50	0.75	1.00

PC1 and PC2 account for 50% of the variability and were used in the analysis.
* Variables are loaded on PC1
** Variables are loaded on PC2

In rural sites, without regards to sex, Blanchard's cricket frogs were larger than those in urban sites (Fig. 9). Those associated with areas of dense vegetation within the rural transects tended to be larger in SVL, LFL, LLL, and wider in IOD, than those in low to moderate vegetation (Fig. 10a). Within urban sites, frog morphology was consistent among levels of vegetation (Fig. 10b).

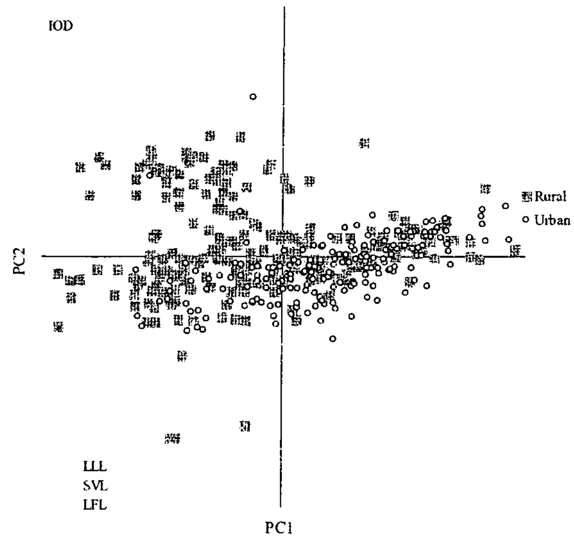

Figure 9. Morphological variations of Blanchard's cricket frogs between rural and urban sites. PC1 is represented by LLL, SVL, and LFL; and PC2 is represented by IOD. A pairwise comparison revealed correlations with SVL and LLL ($r = 0.84$); SVL and LFL ($r = 0.67$), and LLL and LFL ($r = 0.70$). There was no correlation between IOD and the other variables ($r < 0.50$).

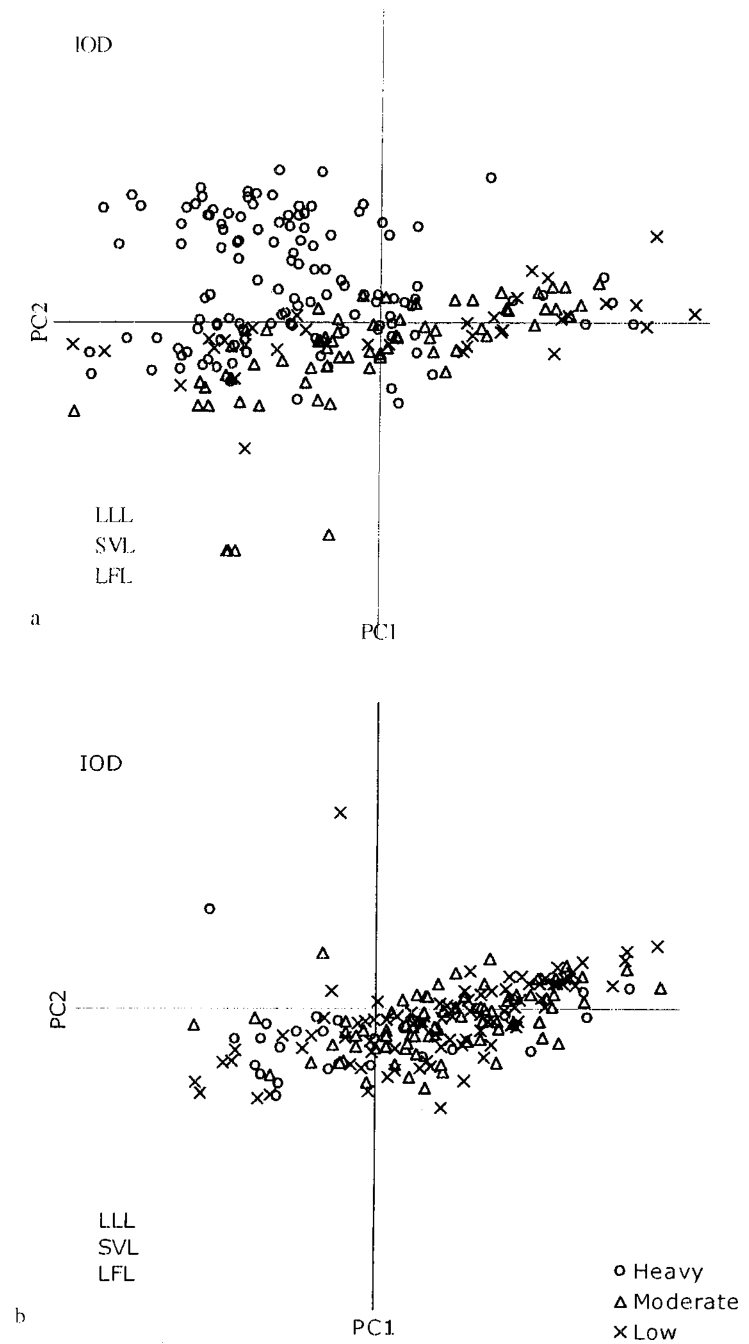

Figure 10. Associations among the morphological variables of Blanchard's cricket frogs and the microhabitat types of rural (a) and urban (b) sites(n=424). PC1 is represented by LLL, SVL, and LFL; and PC2 is represented by IOD.

V. DISCUSSION

Acris crepitans blanchardi inhabit a broad variety of habitat types that include human-disturbed areas (Gray and Brown 2005). My results indicated that Blanchard's cricket frogs were distributed uniformly in both rural and urban sites in my study area. These results also indicate that microhabitat affinity (association with low to moderate and avoidance of heavy vegetative cover) did not differ between rural and urban sites. Although frogs did not appear to select dense vegetation (e. g., observed abundance was less than expected), overall cricket frog abundance was greater in the dense vegetation. Affinity to substrate types differed between rural and urban sites. Cricket frogs in the rural sites tended to use boulder and gravel, while those in the urban sites tended to use cobble and sands and fines. Nevo (1973a, b) and Pyburn (1961a) reported similar microhabitat usage of cricket frogs in central Texas that included exposed areas of mud and mud/limestone substrates. In Missouri, *Acris crepitans* selected areas with a denser vegetative cover than expected (Smith et al. 2003). This difference compared to my results may be due to geographical and limnological (i.e., lotic/lentic, river/lake) variation in habitat structure between Texas and Missouri. That is, populations in Missouri may have adaptive preferences (or tolerances) for denser vegetation simply because it is more common there than in the more arid habitats of central Texas.

The number of frogs observed in association with water or moisture and the absence of water in at some sites may be related to the extreme drought that occurred during 2008 (Fig. 11). During such climatic events, anurans may disperse to the nearest water source (Anderson et al. 1999) or find shelter within moist cracks in the limestone banks or decaying logs (Irwin et al. 1999). The association with water was most evident in the breeding season from May-August. Cricket frogs were observed in greater abundance than expected ($n_{pools} = 158$) during this time.

Morphological Data.---Results from the PCA might provide further support to studies on surface to volume ratios and evaporative water loss by amphibians (Farrell and MacMahon 1969, Nevo 1973a, Smith et al. 2003). This might explain why slightly larger frogs occurred in the more arid rural environments. On the other hand, larger frogs in the dense vegetation within the rural environments could also represent older individuals; further studies would be needed to determine survivorship and age classes of frogs in these habitats.

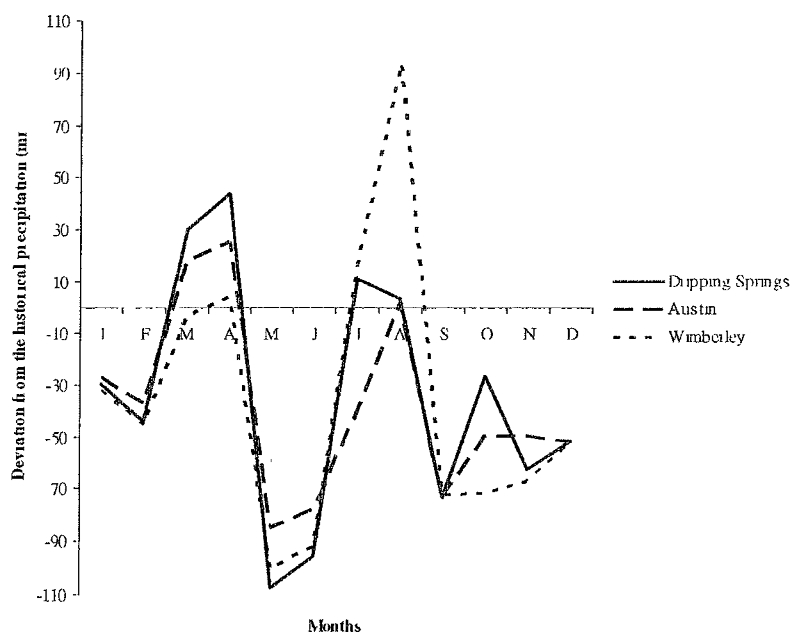

Figure 11. Precipitation data for Dripping Springs, Austin, and Wimberley for 2008 (U.S. National Climate Data Center 2009).

Future studies should continue to investigate quantitative analyses of habitat associations as well as morphology. These studies should include observations comparing geographical and limnological differences between varying degrees of human disturbance. They should also encompass correlations between water quality and morphological variations. With a better understanding of habitat association and adaptations we can carefully manage for the habitat of this species.

VI. MANAGEMENT IMPLICATIONS

Blanchard's cricket frogs have coped with the effects of minimal human disturbance that does not seriously alter microhabitats, as seen in my results. However, large-scale urban expanse could potentially lead to detrimental impacts on cricket frog populations. To mitigate this, state funded habitat programs such as the Virginia Department of Game and Inland Fisheries and Texas Parks and Wildlife Department's Backyard Habitat Program, have been implemented to encourage urban landowners to create habitats suitable for urban wildlife. My results indicate that cricket frogs will use a variety of substrate and vegetative types containing moisture. When these microhabitat characteristics are not present, urban landowners can provide them. Riparian zones of varying vegetative cover are essential for anuran survival. I recommend the application of a buffer zone to any water system. This is not only necessary for anurans, but also to increase erosion control and lead to better ecosystem management.

LITERATURE CITED

Alford, R. A., P. M. Dixon, and J. H. K. Pechmann. 2001. Ecology: global amphibian population declines. Nature 412: 499-500.

Anderson, A. M., D. A. Haukos, and J. T. Anderson. 1999. Habitat use by anurans emerging and breeding in playa wetlands. Wildlife Society Bulletin 27: 759-769.

Barker, R. A., and A. F. Ardis. 1996. Hydrogeologic framework of the Edwards–Trinity aquifer system, west-central Texas. U.S. Geological Survey Professional Paper 1421-B, 61.

Becker, C. G., C. R. Fonseca, C. F. Baptısta Haddad, R. F. Batista, and P. I. Prado. 2007. Habitat split and the global declıne of amphibians. Science 318: 1775-1777.

Bentley, P. J. 1966. Adaptations of amphibia to arid environments. Science 152: 619-623.

Blaustein, A. R., and D. H. Olsen. 1991. Declining amphıbians. Science 247: 1033-1034.

Blaustein, A. R., and B. A. Bancroft. 2007. Amphibian population declines: evolutionary considerations. Bioscience 57: 437-444.

Boone, M. D., and R. D. Semlitsch. 2001. Interactions of an insecticide with larval density and predation in experimental amphibian communities. Conservation Biology 15: 228-238.

Bradford, D. F., C. Swanson, and M. S. Gordon. 1992. Effects of low pH and aluminum on two declining species of amphibians in the Sierra Nevada, California. Journal of Herpetology 26: 369-377.

Bragg, A. N. 1940. Observations on the ecology and natural history of Anura. III. The ecologıcal distribution of Anura of Cleveland County, Oklahoma, including notes on the habits of several species. American Midland Naturalist 24(2): 322-335.

Brown, R. L. 1974. Diets and habitat preferences of selected anurans in southeast Arkansas. American Midland Naturalist 91(2): 468-473.

Canfield, R. H. 1941. Application of the line-intercept method in sampling range vegetation. Journal of Forestry 39: 388–394.

Conant, R., and J. T. Collins. 1991. A field guide to reptiles and amphibians: eastern and central North America. Third edition. Houghton Mifflin Company, Boston, Massachusetts.

Cousins, S. H. 1982. Species size distributions of birds and snails in an urban area. Urban Ecology (Ed. By R. Bornkamm, J.A. Lee & M.R.D. Seaward), pp. 99-109. Blackwell Scientific Publications, Oxford.

Davidson, C. 2004. Declining downward: amphibian population declines in California and historical pesticide use. Ecological Applications 14: 1892-1902.

Daszak, P., D. E. Scott, A. M. Kilpatrick, C. Faqqioni, J. W. Gibbons, and D. Porter. 2005. Amphibian population declines at Savannah River site are linked to climate, not chytridiomycosis. Ecology 86: 3232-3237.

Deyrup, I. J. 1964. Water balance and kidney. *In* J. A. Moore [ed.], Physiology of amphibia. Academic Press, New York and London.

Dickman, C. R. 1987. Habitat fragmentation and vertebrate species richness in an urban environment. Journal of Applied Ecology 24: 337-351.

Farrell, M. P., and I. A. MacMahon. 1969. An ecophysiological study of water economy in eight species of tree frogs (Hylidae). Herpetologica 25: 279-294.

Gray, R. H. 1971. Fall activity and overwintering in the cricket frog (*Acris crepitans*) in central Illinois. Copeia 1971: 748-750.

Gray, R. H. 1972. Metachrosis of the vertebral stripe in the cricket frog, *Acris crepitans*. American Midland Naturalist 87: 549-551.

Gray, R. H., and L. E. Brown. 2005. Decline of Northern Cricket Frogs (*Acris crepitans*). *In* M.J. Lannoo [ed.], Amphibian declines the conservation status of United States species. University of California Press, Berkeley. 47-54.

Hero, J. M. 1989. A simple code for toe clipping anurans. Herpetological Review 20: 66-67.

Houlahan, J. E., C. S. Findlay, R. R. Schmidt, A. H. Meyer, and S. L. Kuzaman. 2000. Quantitative evidence for global amphibian population declines. Nature 404: 752-755.

Irwin, J. T., J. P. Costanzo, and R. E. Lee. 1999. Terrestrial hibernaiton in the northern cricket frog, *Acris crepitans*. Canadian Journal of Zoology 77: 1240-1246.

Kats, L. B., and R. P. Ferrer. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distributions 9: 99-110.

Knutson, M. G., J. R. Sauer, D. A. Olsen, M. J. Mossman, L. M. Hemesath, and M. J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, U.S.A. Conservation Biology 13(6): 1437-1446.

Krzysik, A. J. 1998. Amphibians, ecosystems, and landscapes. *In* M.J. Lannoo [ed.], Status and conservations of Midwestern amphibians. University of Iowa Press, Iowa City. 31-41.

Kunick, W. 1982. Comparison of the flora of some cities of the Central European Lowlands. Urban Ecology. (Ed. By R. Bornkamm, J.A. Lee & M.R.D. Seaward), pp. 99-109. Blackwell Scientific Publications, Oxford.

Lannoo, M. J. 1994. Using species reintroductions to assist in determining whether amphibian declines are the result of current or historical factors. Meeting of the Central Division of the Declining Amphibian Populations Task Force, Indiana Dunes National Lakeshore. Unpublished abstract.

Lannoo, M. J. 1998. Status and conservation of midwestern amphibians. University of Iowa Press, Iowa City.

Lehtinen, R. M., and A. A Skinner. 2006. The enigmatic decline of Blanchard's cricket frog (*Acris crepitans blanchardi*): a test of the habitat acidification hypothesis. Copeia 2006(2): 159-167.

Mann, W., P. Dorn, and R. Brandl. 1991. Local distribution of amphibians: the importance of habitat fragmentation. Global Ecology and Biogeography Letters. 1(2): 36-41.

Neill, R. 1950. Taxonomy, nomenclature, and distribution of southeastern cricket frogs, genus *Acris*. American Midland Naturalist 43: 152-156.

Nevo, E. 1973a. Adaptive variation in size of cricket frogs. Ecology 54(6): 1271-1281.

Nevo, E. 1973b. Adaptive color polymorphism in cricket frogs. Evolution 27(3): 353-367.

Pyburn, W. R. 1961a. The inheritance and distribution of vertebral stripe color in the cricket frog. p. 235-261. In: Vertebrate speciation. W.F. Blair [ed.]. University of Texas Press, Austin.

Pyburn, W. R. 1961b. Inheritance of the green vertebral stripe in *Acris crepıcans*. Southwestern Naturalist 6: 164-167.

Smith, G. R., A. Todd, J. E. Rettig, and F. Nelson. 2003. Microhabitat selection by northern cricket frogs (*Acris crepitans*) along a west-central Missouri creek: field and experimental observations. Journal of Herpetology 37(2): 383-385.

Texas Commission on Environmental Quality. 2009. GIS data for the atlas of Texas surface waters. http://www.tceq.state.tx.us/gis/

U.S. Geological Survey. 2009. Texas water science center. http://tx.usgs.gov

U.S. National Climatic Data Center. 2009. http://www.ncdc.noaa.gov/oa/ncdc.html

Van Buskirk, J. 2005. Local and landscape influence on amphibian occurrence and abundance. Ecology 86: 1936-1947.

Wentworth, C. 1922. A scale of grade and class terms for clastic sediments. Journal of Geology 30: 377-392.

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