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Reptile Use of Trails in the Phoenix Mountain Parks

Urbanization can be a source of habitat removal and degradation threatening some species of herpetofauna (Gibbons et al. 2000; Wolf et al. 2013). Species richness for amphibians and reptiles often declines in areas of high urbanization from loss of suitable habitat (McKinney 2008). However, within urban areas where natural habitats are preserved or protected, herpetofauna often persist (Hamer and McDonnell 2012). The ability to monitor impacts from human interactions on these protected areas can be essential for effective management (Goode et al. 1995).

Protected areas juxtaposed with urban areas can be popular for outdoor recreation and offer many social benefits to city residents. However, outdoor recreation such as hiking, mountain biking, and horseback riding can have both direct and indirect effects on wildlife and their habitats. For example, trail use can directly affect small animals by trampling or by disturbing refuges or breeding sites (Knight and Cole 1995). Indirect effects can alter habitat by compacting soils, introducing weeds, causing erosion, reducing vegetation or ground cover, or cause behavioral responses in wildlife by eliciting a flight response (Cole and Landres 1995). To ensure viable populations and communities, a better understanding of these recreational disturbances on wildlife is crucial.

Studying relationships between reptile abundance and diversity with recreational trails can benefit park managers by providing data on how trail usage and habitat characteristics may affect herpetofauna communities. We compared the reptile community and their habitats along multiuse trails and at off-trail sites. Our research objectives were to investigate how reptile abundance and diversity and habitat characteristics varied in relation to trails. We predicted that locations further away from trails would contain greater reptile abundance and diversity due to less human interaction and habitat modification.

Methods.—For our study, we chose McDowell (33.6952°N, 111.7348°W) and Usery (33.4791°N, 111.6191°W) Mountain Regional Parks, located in the Phoenix Metropolitan Area, Arizona, USA. These parks offer a model system to evaluate the effects of recreational trail use on reptile species. The two parks offer miles of multiuse trails for recreational activities, represent a large variety of plants and animals, and are surrounded by urban development within the Upper Sonoran Desert.

We performed surveys at each park along different trail conditions (high-use and low-use) and types (trail and off-trail). To select high-use and low-use trails, we consulted with park managers to identify trails that were popular with recreationalists and other trails with relatively low visitation rates. In each park, we established 40, 10 m × 20 m plots (N = 80). Of the 40 plots, 10 were high-use plots, 10 were low-use plots, and 20 were off-trail plots. The location of the first plot along trails was randomly selected and subsequent plots placed every 150 m. We placed off-trail plots 150 m perpendicular to trail plots and side was determined randomly. We took care to make sure no off-trail transect interested with other recreation trails within a park and were > 150 m from any other trail.

BEAU T. RUDD
HEATHER L. BATEMAN*
College of Letters & Sciences, Arizona State University at the Polytechnic campus, Mesa, Arizona 85212-6032, USA

** Corresponding author; e-mail: Heather.L.Bateman@asu.edu*

We quantified reptile abundance and diversity using visual encounter survey methods (McDiarmid et al. 2011). Two trained observers surveyed each plot once in July and once in August 2013 during morning hours (0600–1100 h) when reptiles are most commonly active (Brennan and Holycross 2009). Surveys were area-constrained and we exhaustively searched each plot under suitable debris, logs, and rocks while disturbing vegetation. We recorded all reptile observations by age class (hatchling or adult), location, and species.

Using similar methods to Banville and Bateman (2012), we measured habitat characteristics for each of the 80 plots (Table 1). We quantified percent ground cover (i.e., bare ground, cryptobiotic crust, litter, and woody debris), vegetation cover (i.e., cactus, shrub, succulent, and tree), and burrow density at 10 square-meter intervals. The measured intervals consisted of 10 alternating square-meter sub-plots along a randomly chosen 20 m length of the plot. Using point-intercept methods, we quantified proportion of cacti, shrubs, succulents, trees, and woody debris (> 1 cm in diameter). We measured, at randomly selected quarter-plot intervals (5 m × 10 m), percent cover of boulder, cobble, gravel, and sand, and at randomly selected half-plot intervals (5 m × 20 m) we counted perennial plant species.

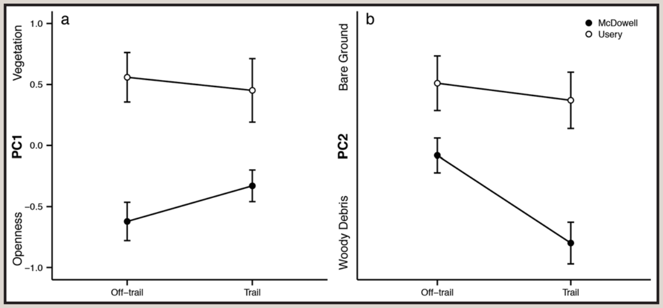

FIG. 1. Principle component factor values (PC1, PC2) depicting differences among park habitats in the Phoenix valley in central Arizona. PC1 values (a) are represented by the absence and presence of vegetation; cacti, shrubs, trees. PC2 values (b) are represented by the presence of woody debris and bare ground.

Table 1. Mean (± SE) of habitat variables along with principal components analysis factor correlation during summer 2013 at McDowell Mountain Park and Usery Mountain Park, central Arizona, USA.

	McDowell Mountain Park		Usery Mountain Park		
Variable	Off-trail (N = 20)	Trail (N = 20)	Off-trail (N = 20)	Trail (N = 20)	Component (correlation)
Bare ground (%)	76.0 ± 3.1	62.5 ± 3.6	65.0 ± 4.4	68.5 ± 3.7	2 (+)
Biotic crust (%)	0.4 ± 0.1	0.2 ± 0.1	1.0 ± 0.2	0.7 ± 0.1	5 (–)
Boulder (%)	–	–	3.5 ± 1.3	2.0 ± 1.0	1 (+)
Cobble (%)	0.7 ± 0.2	0.6 ± 0.1	8.8 ± 3.8	7.0 ± 2.6	2 (+)
Gravel (%)	78.3 ± 2.4	64.4 ± 4.1	77.9 ± 3.0	61.3 ± 5.7	3 (+)
Litter cover (%)	23.0 ± 3.0	36.0 ± 3.6	33.5 ± 4.1	31.0 ± 3.7	2 (–)
Sand (%)	18.2 ± 3.1	31.0 ± 3.4	8.1 ± 2.0	19.8 ± 2.8	4 (–)
Vegetation (%)	18.0 ± 2.4	12.1 ± 2.1	25.9 ± 2.8	27.2 ± 3.2	1 (+)
Number of burrows	0.2 ± 0.0	0.1 ± 0.0	0.3 ± 0.1	0.3 ± 0.1	3 (+)
Number of woody debris	0.2 ± 0.0	2.0 ± 0.5	0.1 ± 0.0	0.8 ± 0.3	2 (–)
Proportion of cacti, succulents	–	–	0.1 ± 0.0	–	1 (+)
Proportion of shrubs	0.2 ± 0.0	0.2 ± 0.0	0.3 ± 0.0	0.3 ± 0.1	1 (+)
Proportion of trees	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0	4 (+)
Vegetation species richness	4.7 ± 0.4	5.0 ± 0.5	7.1 ± 0.3	7.0 ± 0.6	1 (+)

Table 2. Presence of lizards as predicted by habitat characteristics (component, PC) from logistic regression in mountain parks from central Arizona. *Callisaurus draconoides* was negatively associated with PC2 (high amount of bare ground, lacking litter and woody debris) and found around areas containing woody debris.

Species	Correlation (+–)	Component	Statistic	Significance (accuracy)
Aspidoscelis tigris	NA	NA	$\chi^2 = 1.271$	P = 0.260 (53.8%)
Callisaurus draconoides	–	PC2	$\chi^2 = 11.203$	P = 0.004 (80.0%)
Uta stansburiana	NA	NA	$\chi^2 = 1.413$	P = 0.234 (75.0%)

We defined abundance as the greatest number of individuals per age class of each species detected during both surveys in each plot. We compared reptile abundance between parks using the Mann-Whitney U test and quantified reptile diversity using the Shannon index. We used Principle Component Analysis (PCA) to reduce habitat variables and summarize variation within plots. To determine differences in habitat, we used a two-way ANOVA to compare scores derived from the PCA between parks and trail type. To evaluate species-habitat relationships, we used logistic regression to correlate species' occurrences with derived PCA component scores. All analyses were conducted using SPSS Statistics (IBM Corp. version 22.0).

Results.—We recorded a total of 205 reptile observations consisting of 10 species with a Shannon's diversity index of 1.144. Species recorded at both parks include *Aspidoscelis tigris* (Tiger Whiptail), *Callisaurus draconoides* (Zebra-tailed Lizard), *Sceloporus magister* (Desert Spiny Lizard), and *Uta stansburiana* (Common Side-blotched Lizard). Species recorded only at McDowell Mountain Park include *Coleonyx variegatus* (Western Banded Gecko) and *Gambelia wislizenii* (Long-nosed Leopard Lizard). Species recorded only at Usery Mountain Park include *Cophosaurus texanus* (Greater Earless Lizard), *Crotalus atrox* (Western Diamond-backed Rattlesnake), *Masticophis flagellum* (Coachwhip), and *Urosaurus ornatus* (Ornate Tree Lizard). *Uta stansburiana* was the most common species at both parks, followed by *A. tigris*, and *C. draconoides* (58%, 23%, and 9% of abundance, respectively). We found *C. draconoides* (U = 666, P = 0.069) and *U. stansburiana* (U = 636, P = 0.102) in marginally greater abundances at trail locations compared with off-trail. However, overall reptile abundance was similar between parks (U = 678, P = 0.231), trail condition (U = 175, P = 0.490), and trail type (U = 763, P = 0.716); therefore, data were pooled for species-habitat analyses.

From the 14 habitat variables (Table 1), we identified five principle components that explained over 70% of the variation (eigenvalues > 1; PCA) in habitat among plots. Plots with high PC1 scores had high vegetation cover, proportions of cacti, shrubs, succulents, and a richness of vegetation species; plots with high PC2 scores had bare ground and lacked litter and woody debris; plots with high PC3 scores had gravel and a high density of burrows; plots with high PC4 scores had a high proportion of trees; and plots with high PC5 scores had few areas with cryptobiotic crust. PC1 values differed between parks ($F_{(1, 76)} = 26.771$, $P < 0.001$), were similar on and off trail ($F_{(1, 76)} = 0.104$, P = 0.748), and had no significant park x trail interaction ($F_{(1, 76)} = 0.762$, P = 0.386). Usery Mountain Park had greater amounts of vegetation than McDowell Mountain Park (Fig. 1a). PC2 values differed between parks ($F_{(1, 76)} = 20.240$, $P < 0.001$) and between on and off-trail ($F_{(1, 76)} = 4.809$, P = 0.031), but had no significant park x trail interaction ($F_{(1, 76)} = 2.178$, P = 0.144). McDowell Mountain Park had greater amounts of woody debris than Usery Mountain Park, with most woody debris located along trails (Fig. 1b). PC3 values differed on and off-trail ($F_{(1, 76)} = 7.106$, $P = 0.009$), with greater densities of burrows found off-trail.

Only the three most common species, representing 90% of abundance, were included in species-habitat analyses. Of the three species of lizards used in analyses, only *C. draconoides* had conclusive results. This species of lizard was negatively associated with PC2 (areas with high amount of bare ground, lacking litter and woody debris, Table 2).

Discussion.—Overall, we found that lizards did not avoid trails and some species may prefer areas with trails. For example, *C. draconoides* are known to occur in broad, sandy washes (Brennan and Holycross 2009), and this openness is imitated by the desert park trails. We observed twice as many *C. draconoides* at McDowell Mountain Park predominantly along trails where woody debris had been placed by managers. Lining trails with fallen trees and cacti was employed by park management to encourage users to stay on-trail. Modification of trails using woody debris may have contributed to habitat structure used by some lizard species. For example, we observed that *U. stansburiana* used the woody debris as perches. However, further study is needed to determine if reptiles utilizing trails are exposed to greater risks.

Some of the differences in habitat characteristic between the parks can be explained by a wildfire that burned McDowell Mountain Park in July 1995. Caused by lightning, this fire burned a large part of McDowell Mountain Park leaving areas void of large trees and cactus. This lower vegetation cover had no significant effects on reptile abundance and diversity between parks. However, the fire may be the source of woody debris that was placed along trails to keep recreationalists from going off-trail at McDowell Mountain Park (R. Hubbell, pers. comm. 2013); whereas, no woody debris was placed near trails at Usery Mountain Park.

Continuing to allow recreationalist an opportunity to enjoy county regional parks while protecting wildlife is a primary goal for park management (Taylor and Knight 2003). Our investigation of how reptiles respond to park trails allows greater insight for park managers. The research can contribute to effective management decisions for current and future parks. To support the conservation of wildlife and county regional park systems, we encourage further investigations of trails and possible impacts to biodiversity.

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