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SPECIES RICHNESS, DIVERSITY AND DISTRIBUTION OF AMPHIBIANS ALONG ELEVATIONAL GRADIENT ON MOUNTAIN AFADJATO, GHANA

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Abstract

In this study, the richness and distribution of amphibians were investigated with the use of systematic sampling method to determine amphibian species richness and distribution along the three levels of elevation. It was found out that, while richness and distribution varied significantly along elevational gradient, the diversity of species did not differ along the three levels of elevation. Furthermore, *Arthroleptis spp.* and *Phrynobatracus calcaratus* were found to be the most common and successful species that can live on Mountain Afadjato. In relation to amphibian abundance a negative relationship emerged between amphibian's species and litter levels along the three levels of elevation. The conclusion was that the higher the litter level the lesser the number of amphibians, thus amphibians at mount Afadjato eschewed higher litter levels.

Keywords: Amphibian, Elevation, Leaf litter, Afadjato, Ghana

Özet

Bu çalışmada amfibi tür çeşitliliği ve dağılımını incelemek üzere sistematik örnekleme yapılarak, amfibi türlerinin üç yükseltideki dağılımı incelenmiştir. Elde edilen bulgulara göre; tür zenginliği ve dağılımı yükselti boyunca anlamlı bir şekilde değişirken, tür çeşitliliğinin yükseltiye göre değişmediği tespit edilmiştir. Ayrıca *Arthroleptis spp.* ve *Phrynobatracus calcaratus* türlerinin Afadjato dağında en fazla yaygınlık gösteren ve yaşam rekabetinde üstünlük gösteren türler olduğu sonucuna varılmıştır. Yükselti boyunca ölü örtü seviyesi ile amfibi türlerinin yaygınlığı arasında negatif bir ilişki olduğu görülmüştür. Yükselti boyunca artış gösteren ölü örtü miktarına karşın amfibi tür sayısının azalması ile Afadjato dağında amfibilerin ölü örtünün fazla olduğu yerleri tercih etmediği sonucuna varılmıştır.

Anahtar kelimeler: Amfibi, Yükselti, Ölü örtü, Afadjato, Gana

INTRODUCTION

The general mechanisms responsible for the distribution of biodiversity can be explore and understood by the influence of altitudinal pattern on species richness and diversity (McCain, 2007). Information on biogeographically variation in species endemic richness is critical to understanding and conservation of biological diversity, and to develop rigorous conservation plans for a region (Fisher and Robertson 2002; Grytnes and Vetaas 2002; Fu et al. 2006).

Altitudinal gradients and the physical environment have been understood as prime factors that determine spatial and temporal distribution, abundance and richness patterns of organisms (Korner, 2000; Nagy & Grabherr, 2009). Countless studies have expounded a relationship between species richness and elevation in a variety of taxa in different geographic locations (Grau et al. 2007; McCain 2005; McCain, 2007). Altitudinal variability causes variation in climatic, biological and geographical conditions, which ultimately affect species richness patterns (Lomolino 2001; Rahbek 1995; Whittaker et al. 2001).

A common assumption underlying several large-scale ecological models is that species distributions are in equilibrium with contemporary climate; in other words, species are generally present in climatically suitable areas while being absent from unsuitable ones (Arau´ & Pearson 2005).This is because the diversity of animal and plant species on Earth is not uniformly distributed along latitudinal and altitudinal gradients and geographical gradients of diversity have long fascinated biogeographers and ecologists (Lomolino and Weiser 2001).

For many vertebrate assemblages in the tropics, the distribution patterns on elevational gradients are well documented. Studies on mammals (Patterson et al. 1989), birds (Rahbek 2001), as well as on amphibians and reptiles (Fauth et al. 2004) provide examples of how species composition, species richness, and abundance change with elevation both at local and regional scales.

However, investigating into the factors that regulate spatial variations in species richness has been one of the elemental questions in ecology for decades (MacArthur 1972, Currie 1991). A great number of studies have been conducted to explore the relationships between species richness and environment, but the knowledge of the cause of species richness variation remains poor. This is particularly true for herpetofaunas, which include amphibians and reptiles. Because both amphibian and reptile species richness are declining globally (Gibbons et al., 2000), there is urgency to understanding the relationships between herpetofaunas species richness and environmental factors. Buckley and Jetz (2007) examined the richness and environmental relationships for amphibians at the global scale. They concluded that the relationships vary between regions, suggesting that it is necessary to examine the amphibian-richness-environment relationship for individual regions separately.

The West African tropical rain forest ecosystem host about two- thirds of the earth's biodiversity however, little information is known about this rich biodiversity especially the factors that link species richness and distribution.

Ghana has a fascinating history of herpetological research beginning with the exportation of specimens to European countries during the 1800s (Hughes, 1988). The most comprehensive synopsis of the reptiles and amphibians of Ghana is a checklist of species compiled by Barry Hughes (1988), but this list is by no means definitive.

But most research to date has focused on providing vertebrate data for conservation assessment, and for many groups of invertebrates with the lack of even basic information in tropical ecosystems (Fisher and Robertson, 2002). Change is a constant process in ecosystems, driven by natural forces that include climate shifts, species movement, and ecological succession. Despite the clear understanding of the Afadjato Mountains as an important area for biodiversity conservation and biogeography (Bakarr et al., 2001), it is surprising that so little is known about the reptiles and amphibians of the area. To date there is little information documented on amphibian's species richness and distribution in the area except for Rödel et al. (2005) who studied herpetofauna at Kyabobo national park, over 100km north of Afadjato. This study aimed at exploring the relationship between elevational gradient on amphibians' species richness and distribution on mountain Afadjato. Specifically, the study was to determine the influence of elevational gradients on amphibian species richness and distribution; examine the density and diversity of amphibian species that occur at the various elevational levels of the mountain ecosystem and also examine how the abiotic environment such as litter levels influence amphibian abundance of the various levels along the mountain.The following hypotheses were tested: a. Species richness decreases monotonically with increasing elevation and b. Species richness peaks at mid-elevations.

MATERIAL AND METHODS

Study Area

Mountain Afadjato is part of Akwuapem-Togo range which constitutes the highest hills in Ghana with the Afadjato itself being the highest mountain in Ghana at 885m a.s.l. which runs in the northeast and southwest direction between the Volta River and the Ghana-Togo border (Ntiamoah-Baidu *et al.*, 2001). The mountain is located in the Agumatsa Range near the villages of Liate Wote and Gbledi, in the Volta Region of Ghana at the border with Togo. The hill lies within longitude 0°15'E and 0°45'E and latitude 6 ° 45'N and 7 ° 15'N and covers an area of 1172km² (Owusu, 2010). The general climatic conditions of the country characterized by bimodal rainfall and two dry seasons (Durand and Skubich, 1982) prevail in the area.

The name Afadjato comes from Avadzeto which means "to go to war against the bush".The mountain owes this name to the fact that it was covered by a certain plant which causes severe skin irritations. Hence, whenever farmers or hunters climbed the mountain, they were "at war" with the plants. The Ewes, however, did not have a written language for most of their history, so that the European colonizers called the mountain in the way they heard its name pronounced, namely Afadjato. The syllable "to" in Ewe language means "mountain", so that the correct name is not Mount Afadjato, but simply Afadjato.

Afadjato is shaped like a traditional yam mound and covered with luxuriant tropicalforest. Its area is well-known for its biodiversity richness. Researchers have recorded over 300 species of butterflies and 33 species of mammals. Mona and Spot-nosed monkeys are regular sights. Furthermore, BirdLife International has selected the site as one of the key Important Bird Areas in Ghana.

The mountain is endowed with two major waterfall- Wli and Tagbo waterfalls at the northern and southern borders respectively (Ntiamoah-Baidu *et al.*, 2001) and Fispool and Evans (2001) has declared the area as Important Bird Area (IBA). The geological underground comprises quartzite, shale and phyllite. Mean annual precipitation is 1650 mm (Frempong, 1995). These are Wli falls and Tagbo falls respectively. (Adam et al., 2006)

Wli Waterfall: This wonder is found at the northern part of the escarpment close to theTogo border. It is a steep slope with scattered forest remnants and plantations fast flowing mountain creek in the valley bordered by rain forest remnants (open areas with scattered lower trees heavily vegetated swamps fully exposed to sun.

Liate Wote Waterfall (Tagbo Fall): valley with fast running rocky creek, waterfall, cacao plantations and forest remnants; village, artificial pond, rice fields, surrounding of village resembles humid savanna. The nearby Tagbo Falls and Wli Falls (the highest in West Africa) are also considered tourist attractions.

Research Design

Using Global Positioning System (GPS), each transect, longitude, latitude, and elevation was measured. The area was segmented into three major levels according to the elevational heights as lower (200-400m asl), middle (400-600m asl) and upper (600m and above asl) respectively. Transects were

Table 1. Descriptions of stratified areas

LEVELS	ALTITUDE (asl)	DESCRIPTION
Lower Elevation	200m to 400m	Forested (90% intact) area with various lianas, saplings, tree species such as Wawa, odum etc. some degraded area are also found here.
Middle Elevation	400 to 600m	Made up of both closed and open forest and inhabited by various tree species and cassia,
Upper Elevation	600m and above	Open area made up of shrubs and grasses with heavy leaf litter. Plant species includes *Daniella spp.* , *Conbrentum spp.*, etc.

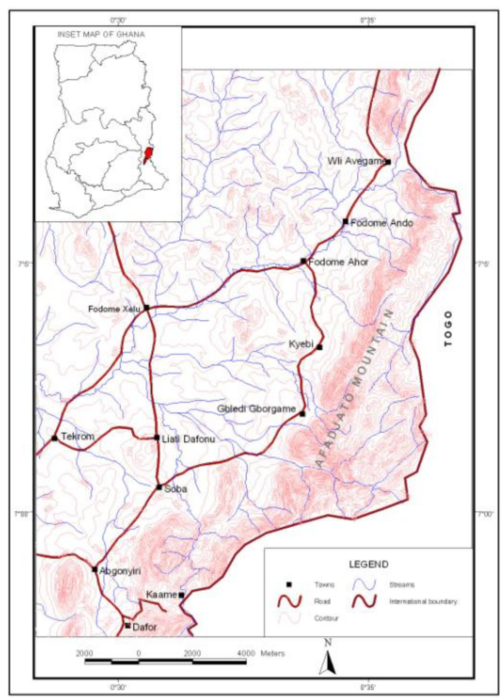

Figure 1: Map of Mount Afadjato.

perpendicular to the contours of the ridge and along transects, sample plots were established.

Subsequently, five transects were established at 2km from each other to serve as entry routes to the summit of the mountain. Each plot size was demarcated as 25m×20m and were established alternatively on both sides of the various transects.

Data Collection Procedure

Specimens were found by visual encounter surveys (Heyer et al. 1994; Rödel and Ernest, 2004). The visual encounter survey (VES) is widely used as a sampling method for reptiles and amphibians (Crump and Scott, 1994; Doan, 2003). In this method, one or more observers search a defined area for animals for a specified amount of time. Usually the number of individuals of a species counted is standardized by time or area searched (i.e., effort) to determine the relative abundance of the species. Supplemented with acoustic searching for frogs, turning rocks and logs, peeling bark, digging through leaf litter, and excavating burrows and termite mounds. All captured animals were released in the same habitat after being measured (snout-vent length) and photographed. Surveys were conducted during the day only to detect species. Mean litter levels were also measured in plots, in order to determine the possible relationship between volumes of ground litter to amphibian species richness along elevational gradients. To do this (6) mean litter depth were measured to the nearest 0.5 cm, 1 m in from each corner of the plot (Vonesh, 1988).

Data Analysis

The data was analyzed using Microsoft excel software 2007 and PAST (Hammer et al, 2001). The mean and Standard Deviation for each species calculated. The species richness and diversity were obtained for lower, middle and upper elevations along gradients. The shannon indices were used to determine species diversity at each level of altitude.

$$H' = -\sum_{i=1}^{R} p_i \ln p_i \qquad \text{............................} \quad (1)$$

Where ***Pi*** is the proportion of characters belonging to the ith type of letter in the string of interest. In ecology, ***Pi*** is often the proportion of individuals amphibians belonging to the ***i***th species in the dataset of interest.

Kruskal-Wallis test was used to determine the significance at (p=0.5) among the three elevational levels whilst Mann-Whitney test was to test the significance level between two elevational levels. Furthermore, correlation analysis was used to establish the relationship between litter levels and amphibian species richness and distribution at (p=0.5) this indices made the use of t-test at 95% confidence level.

RESULTS AND DISCUSSION

Amphibian Species Richness and Distribution Along Altitudinal Gradients

In total, 182 anurans were encountered. This was made up of ten (10) different species comprising of four families searched on transects across the various altitudinal level. From Table 2, it can be deduced that, the species abundance comprises *Arthroleptis species* which recorded the highest (53%) and were identified to be the most dominant speciesfound across every level of altitude; from lower to upper elevations. This was followed by *Phrynobatracus cf. calcaratus* (34%),*Bufo maculatus* (4%),*Hyperolius vindigulosus (2%),Leptopelis hyloides* (2%), *Armirana galamensis* (1%),*Bufo regularis* (1%),*Hyperolius torrentis* (1%)*,Leptopelis viridis* (1%)*, and* (1%)*Ptychadema oxyrhynclus. Arthroleptis species and Phrynobatracus calcaratus* were common across all elevational levels whilst *Bufo maculates,Bufo regularis, Armirana galamensis, Hyperolius vindigulosus* were identified only at the lower elevations.

With further reference to Table 2, a deduction can be made that, the lower level of the mountain recorded a total of 119 species, average amphibians abundance was (mean±5.9,SE= SD± 3.42 *n*=20), per ha; in the middle level, total species number recorded decreased to 41 with a mean of 2.05 (SD= 2.78, N=20); whilst the upper elevation recorded the least of 22 total species with mean of 1.1(SD=1.69, N=20) respectively.

The relative species indices also indicated that family Athroleleptidae dominates the area (53.3%), followed by family Ranidae (36%), Family Hyeroliidae (6%) and family Bufonidae (4.9%). Also, it can therefore be deduced that, species richness and abundance was higher at the lower elevation than the middle elevation and subsequently declined as changes in altitude occurred.

However, the family Bufonidae was totally absent at the upper altitude while less of members of the family Ranidae were encountered at lower and middle elevation but totally absent at the upper

Table 2. Species richness and distribution along elevational gradients of Mt. Afadjato.

Species Name	Lower Elevation	Middle Elevation	Upper Elevation	Overall
Family Arthroleptidae				
Arthroleptis spp.	58	24	15	97
Family Bufonidae				
Bufo maculatus	8	0	0	8
Bufo regularis	1	0	0	1
Family Hyperoliidae				
Hyperolius torrentis	1	1	0	2
Hyperolius vindigulosus	3	0	0	3
Leptopelis hyloides	3	1	0	4
Leptopelis viridis	1	1	0	2
Family Ranidae				
Armirana galamensis	1	0	0	1
Phrynobatracus calcaratus	41	14	7	62
Ptychadema oxyrhyclus	2	0	0	2
Grand Total	**119**	**41**	**22**	**182**

elevational level. This may be due to variations that were likely to have occurred in the environmental condition at various altitudinal gradients as supported by Khatiwada (2011).

Species Richness at the Various Elevational Gradients

This chapter reports on the amphibian species richness and distribution along elevational gradients of mount Afadjato (Table 2). The species richness varied significantly across the three elevational levels

(H=19.24,p< 0.01). At the lower level (200-400m a.s.l) the number of species encountered were higher than the middle elevation, 400-600m, a.s.l (U=80, P<0.01 p≤0.001227) but in contrast, there was no significant variation between the species richness of the middle and upper elevations, 600m and abovea.s.l (U=161.5, p≤0.304). A similar trend was observed for amphibian assemblages (Naniwadekar & Vasudevan, 2007).

Many herpetofaunal studies have shown a monotonic decline of species richness along elevational gradients on tropical mountains (Fauth et al. 1989; Gifford & Kozak 2011).This result contradicts to the hypothesis that, monotonic decline is the most common pattern of amphibian species richness and distribution and however supports the conclusion of Fu et al (2006) and Khatiwada (2011)who rejected that frog species richness has a monotonic decreasing relationship along the elevational gradient. Higher species richness at lower elevation sites may be due to more favorable climatic conditions for amphibian assemblages at lower elevations. This includes higher average temperatures, evapo-transpiration, productivity and precipitation, which are widely recognized as important for the spatial and temporal distribution pattern of amphibians (Buckley & Jetz, 2007)

Furthermore, the inhabiting *Arthroleptis* sp.and *Phrynobatracus calcaratus* were the most successful species that were habitable on the mountain (Table 2). A similar result was reported by Rödeland Cudjoe (in press).

At the middle elevation species such as Hyperolius torrentis, Leptopelis viridis were present but in smaller numbers than those found in at the lower elevations (Table 2). This might be due to continual changes in altitudinal gradient and individual species peculiar resource requirements produced by the habitat types. Thus landscape heterogeneityis a major factor responsible for the distribution and diversity of amphibians as observed by Monney et al.(2011).

Also at the lower elevation, species richness was higher in number than any other level of altitude

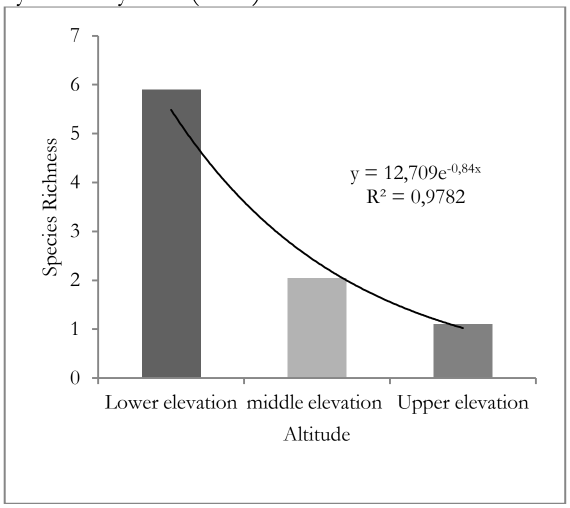

Figure 2. Mean number of species and their trend of distribution along the various levels of elevation

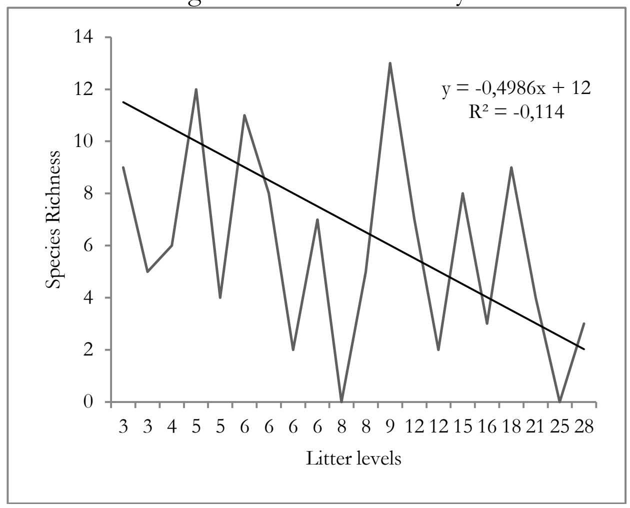

Figure 3 Relationship between litter levels and species richness at the lower elevation

(65%). At this level almost all species reported in Table 2 were present in higher quantities in term of numbers. Comparing to Khatiwada (2011) who reported higher species richness at lower elevation with subsequent declines of amphibian species richness long elevational gradients at both the middle and upper levels this dimension appeared to be the same.

According to the trend analysis, amphibian species richness at each level of elevation declined with increase in elevation at an exponential rate ($y=12.70e^{-0.84x}$) and this explains model explains about 98% of the trend as $R^2=0.978$ and is graphically presented in Figure 2.

Species Diversity at the Various Elevations

The Shannon indices were determined to represent the diversity of amphibians in the lower, middle and upper elevations. The diversity of amphibians found in the lower elevation was 2.763 (2.66, 2.87 at 95% CI), middle elevation 2.21(2.38, 2.78 95% CI) and upper elevation 2.051 (2.12, 2.62 95% CI). The diversity t-test also indicated a significant difference between the lower and middle elevation (t= 5.11,$p<0.01$) and lower and upper elevation (t= -5.27, $p<0.01$) but differs between middle and upper elevation (t= 1.22, $p\leq0.226$). The diversity indices suggest a very high diversity of amphibians at the lower elevational level than the middle and then peaks at the upper elevations. This indicates that, the maxima in diversity for frogs peaked at higher elevations. Similar patterns were also reported in plants (Grytnes and Vetaas, 2002)

Species turn over indices also indicated that whereas 28% of the species were commonly found between the lower and middle elevations, 33% were found to be common between the middle and upper elevations.

Litter Levels across the Various Altitudes

In this study, litter level was used as an environmental variability to justify the relationship between the several ecological components, species richness and distribution. The result revealed that difference of the depth of litter was statistically significant across the three levels of elevations (H*:* 16.9; P<0.01p=0.0023). Litter levels significantly varied between lower and middle elevation (U=88: P=0.026), lower and upper elevations (U=60.5: p=0.002), but was not significant between the middle and upper elevations (U=149.5: $P\leq0.176$)

Relationship Between Litter Levels and Amphibian Distribution

The mean litter were 10.8 (SD= 7.42, N=20), Middle elevation level mean was 20.7 (SD= 11.26, N=20) whilst upper elevation had mean 26 (SD=12.3, N=20), per ha. Litter levels between lower and middle were not the same (p≤0.002) but significantly the same between the middle and upper levels (p≤0.176). Litter levels also differ from lower and upper elevational levels. In comparing the three levels of elevation, there was a significant relationship between

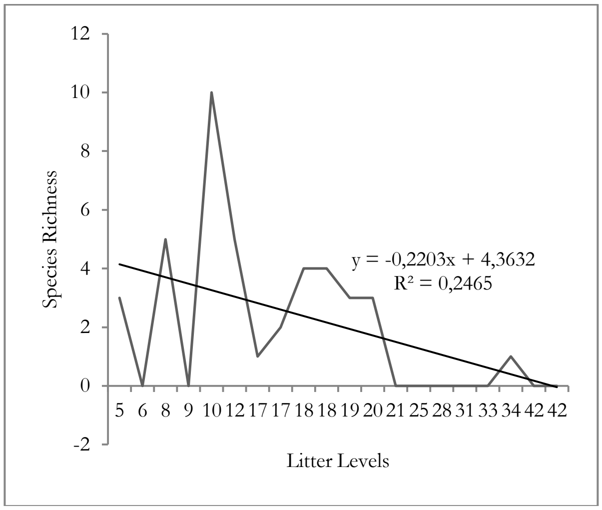

Figure 4. Relationship between litter levels and species richness at the middle elevation

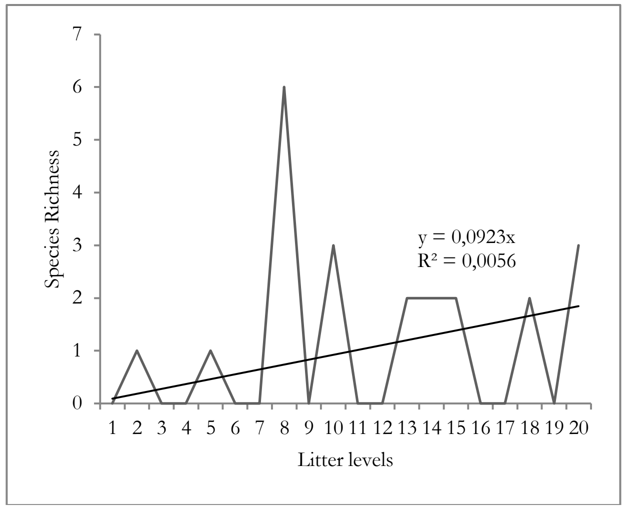

Figure 1. Relationship between litter levels and species richness at the upper elevation.

litters levels and amphibian species richness and distribution (H=16.91, P≤0.002).

Spearman correlation also indicated a negative relationship between the lower elevation and liter levels for the lower altitudes (r = -0.33207, P≤ 0.1526).The middle elevation also showed a negative relationship between litter levels and species richness (r =-0.52435, P≤0.017) but upper elevation identified a significant correlation (r = 0.24002, P ≤ 0.308). It can therefore be deduced that, litter levels on elevational gradient do not have any direct relationships with amphibian species richness or its distribution on higher elevations. This is because at the lower level where the habitats were mostly forested, litter levels were lower and hence higher amphibian species. On the other hand, at intermediate summits of the mountain, litters levels were higher; however few amphibian species were recorded. The leaf-litter of most tropical forests is believed to support a rich herpetofauna that may include frogs, salamanders, caecilians, lizards, snakes, amphisbaenas, and turtles. This study however contradicts to Scott (1976), Fauth *et al.* (1989), and Heinen (1992) who reported that litter depth correlate with herpetofaunal abundance and diversity.

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