Final Report:

Prey of cave and surface populations of *Plethodon albagula* (Plethodontidae) at Fort Hood, Texas

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Cover Photograph: *Plethodon albagula* at Lunch Counter Cave (Bell County, Texas). This specimen shows the pattern of pigmentation most typical of specimens from the Tweedle Mountain area. Photo by Jean K. Krejca.

Plethodon albagula at Fort Hood (Bell and Coryell counties, Texas) was thought to represent an undescribed species (Reddell 2001). These salamanders are disjunct from the remainder of the distribution in Texas, and, along with a population in Williamson County, Texas, are genetically divergent from other *P. albagula* (Baird et al. 2006). These findings are of concern in natural resource management at Fort Hood, as the Fort Hood populations could still warrant species status, and narrowly endemic salamanders continue to receive attention from the U.S. Fish & Wildlife Service (e.g., USFWS 2007). In recent years, we have examined the seasonality, size classes, and habitat distribution of these salamanders at Fort Hood (Taylor et al. 2006, 2005b; Taylor and Phillips 2002).

Most of what is known about the biology of *Plethodon* species in the United States builds on the work of Highton (1956, 1962, 1995) and others (Highton and Larson 1979, Highton and Savage 1961, Highton et al. 1989). Few studies focus specifically on *Plethodon albagula*, with notable exceptions including work in the Ozarks by Briggler and Prather (2006) and Milanovich et al. (2006, 2007). The Ozark populations of *P. albagula*, however, are genetically quite different from the *P. albagula* found at Fort Hood (Baird et al. 2006) and differences in climate, habitat, and genetics all suggest that separate study of *P. albagula* at Fort Hood is warranted. Although a fair amount of information is available on the feeding habits of salamanders (e.g., Alavarado-Diaz et al. 2003; Altig and Brodie 1971; Bellocq et al. 2000; Denoel and Joly 2001; Felix and Pauley 2006; Gibbons et al. 2005; Jaeger 1972, 1980; Jaeger et al. 1995; Johnson and Wallace 2005; Maerz et al. 2005, 2006; Maglia 1996; Maglia and Pyles 1995; Matsui et al. 2003; Parker 1994; Placyk and Graves 2002; Schulert and Dicke 2002; Smith et al. 2004; and Steele and Brammer 2006), dominant prey varies considerably across taxa, and little is known about the feeding habits of *P. albagula* in Texas. This report presents new data on prey items of the Fort Hood populations of *P. albagula*.

Methods

Field Sampling

Between 1 February 2006 and 1 February 2007, we examined stomach contents of 93 *Plethodon albagula* captured at surface and cave sites in southeastern Fort Hood, Texas (Table 1, Figure 1). Beginning on 21 March 2006, we also used quadrats and visual counts of invertebrates to characterize the habitat and available food for salamanders.

Table 1. Summary of sites at which *Plethodon albagula* stomach contents were examined between 1 February 2006 and 1 February 2007 at Fort Hood, Texas.

Habitat	**Site**	**Sample dates**
Cave	Buchanan Cave	30 Jan 07
	Cowbell Cave	30 Jan 07
	Estes Cave	1 Feb 06, 21 Mar 06, 5 Jun 06
	Hackberry Cave	29 Jan 07
	Lunch Counter Cave	31 Jan 07
	Monkey Walk Cave No. 2	5 Dec 06
	Newby Cave	31 Jan 07
	Plethodon Cave	29 Jan 07
	Rainy Day Cave	30 Jan 07
	Tweedledee Cave	4 Dec 06
	Violet Cave	1 Feb 07
Surface	Bear Springs	2 Feb 06, 3 Feb 06, 4 Feb 06, 20 Mar 06, 6 Dec 06
	Estes Entrance Canyon (Lower Canyon)	22 Mar 06
	Estes Entrance Canyon (Upper Canyon)	22 Mar 06
	Estes N. Canyon	7 Dec 06, 8 Dec 06
	Estes S. Canyon Seep	21 Mar 06
	Seep near Bear Springs	6 Dec 06
	Side Canyon off Owl Creek	6 Dec 06
	Trib of Bear Creek, Dstrm of Bear Spgs	6 Dec 06

Figure 1. Distribution of locations of sites where salamanders were recovered for stomach contents analysis at Fort Hood, Bell and Coryell counties, Texas.

Salamander gut contents

Following the methods described by Legler and Sullivan (1979) as modified by Mahan and Johnson (2007), we used a stainless steel gavage feeding needle (18 Gauge, 50 mm, curved [www.finescience.com]) with a 10 ml syringe filled with spring water to irrigate the stomachs of anesthetized salamanders (Figures 2-4). MS222 (Ethyl 3-aminobenzoate, methanesulfonic acid salt, 98% [Acrōs Organics, Geel, Belgium]) was used to anesthetize the salamanders for this procedure; animals were placed in a fresh container of spring water until they recovered from anesthesia, and then were returned to the point of capture.

Invertebrate sampling

At sites where we flushed stomach contents from salamanders, we also inventoried the invertebrate biota within quadrats placed adjacent to each salamander collection location, both in cave and surface habitats.

A quadrat defining an area of 0.1 m^2 (0.316 x 0.316 m; as in Taylor et al. [2003]) was placed on the ground, and leaf litter depth was measure at 5 locations, near each corner and at center of quadrat. Leaf litter, twigs, and loose stones were then carefully searched by hand (Figure 5) and all taxa were identified to the lowest level feasible in the field. A subset of the biota was collected as vouchers and later confirmed through laboratory examination.

Because animals are readily available only in the winter months, especially in surface habitats, we did not examine seasonality in relation to prey items or habitats.

We analyzed the data to answer several basic questions:

1. What is the taxonomic composition of food items?

2. Is there a difference in gut contents between cave and surface populations of *Plethodon albagula* at Fort Hood, Texas?
    A. The number of food items in stomachs.
    B. The number of taxa in stomachs.

3. Is there a difference in food availability between cave and surface populations of *Plethodon albagula* at Fort Hood, Texas?
    A. The number of food items in quadrats
    B. The number of taxa in quadrats

4. Is stomach content taxa richness correlated to habitat taxa richness?

Figure 2. Number 18 curved gavage needle with salamander and gut contents (earthworm, etc.). The salamanders commonly swallow insects at least twice the diameter of the ball tip of the needle, and too small a tip increases risk of puncturing the wall of the esophagus/stomach. Bear Springs, February 2006.

Figure 3. Gavage needle inserted in salamader, with food items flushing out of its mouth into white pan. Photo by Crystal Le Boeuf, 20-22 March 2006, Bear Springs, Bell County, Fort Hood, Texas.

Figure 4. Steve Taylor inserting #18 Gavage needle in salamander (*Plethodon albagula*) just captured in Tweedle Dee Cave. Food items flushed out of its stomach are collected in the white pan, flushed into a whirl-pak bag with ethanol, and later examined in the laboratory. Photo by Charles Pekins, 4 December 2006, Bell County, Fort Hood, Texas.

Figure 5. The method for counting invertebrates in field surface quadrats (0.1 m^2). The researcher, Jean Krejca, has already removed much of the leaf litter from this sample site where a salamander was found in a surface canyon (December 2006). All invertebrates found in the quadrat are field-identified and tallied on the data sheet.

5. Does the abundance of prey items eaten by salamanders reflect the availability of taxa in the habitat?

6. Is the number of food items or taxa richness of salamander stomach contents correlated with the size of the salamander?

7. Are there any particularly notable taxa among the food items?

Statistical Analyses

To examine differences between cave and surface populations we compared the mean of the cave sites to the mean of the surface sites using the non-parametric Mann-Whitney test (Zar 1999), with the two-tailed null hypothesis that there was no difference between the mean number of food items and taxa in the stomachs of cave and surface salamanders. The same approach was used to examine possible differences in quadrat data.

To examine the correlation between stomach contents (both mean richness and number of food items) and availability in habitat, we plotted regression lines for all individual salamanders and evaluated r^2 values, with cave and surface habitats assessed separately. The same approach was used to examine possible correlations between stomach contents and salamander size.

To examine stomach content taxonomic distribution relative to taxonomic distribution of animals in quadrat counts, we summed data from all individual salamanders and hypothesized that the proportion of higher taxonomic groupings within salamander stomachs did not differ from their relative proportions in quadrat counts (H_0), using a χ^2 goodness-of-fit test with small taxonomic groups pooled (see Zar 1999), again separating cave and surface habitats.

For all statistical test, the level of significance was set *a priori* at α=0.05.

In addition to these statistical approaches, various bar charts and other graphics are used to give a sense of the nature of the datasets. We used presence-absence data for stomach content taxa from all sites to produce a phenogram of similarity using the UPGMA (Unweighted Pair Group Method with Arithmetic mean) clustering algorithm (average linkage cluster analysis; Sneath and Sokal 1973, SAS Institute 2001). Both SPSS 15.0 for Windows and SAS 9.1 for Windows were used for statistical analyses and graphing.

Results

Taxonomic composition of stomach contents

The salamanders contained a diverse selection of prey items, primarily, but not exclusively arthropods (Table 2). The relative abundance of the different taxa did not appear to be uniform either across major habitat types (cave, surface) or in taxonomic group representation. Certain taxonomic groups appeared to be more heavily represented in the stomach contents. Stratiomyid larvae (Diptera), ants (Formicidae), globular springtails (Collembola: Symphypleona), snails (Gastropoda: Planorbidae), mites (Arachnida: Araneae), and millipedes (Diplopoda) are the most common food items for salamanders from surface habitats (Figure 6), while cave crickets (Rhaphidophoridae, *Ceuthophilus* spp.), ants, and sciarid flies (Diptera: Sciaridae) are the most common for salamanders from cave habitats (Figure 7).

Habitat differences in quantity of stomach contents

The mean number of food items per stomach was less for salamanders from caves (n=11 sites) than for the surface (n=8 sites) (Mann-Whitney Test, U=4.00, p=0.001). The mean number of taxa per stomach was also less for salamanders from caves (n=11 sites) than for the surface (n=8 sites) (Mann-Whitney Test, U=5.50, p=0.001). These differences are evident by examination of box plots of the data (Figure 8), which also show that there is considerable variation among individuals.

A simple clustering of salamanders based on presence/absence of food items shows that there is a good deal of overlap between cave and surface salamander diets, although there is a strong tendency for cave-inhabiting salamanders to be more similar to one another than to surface salamanders in stomach contents (Figure 9).

Availability of food, cave and surface

The mean number of individual organisms found in visual quadrat surveys did not differ between cave (n=11 sites) and surface (n=5 sites) (Mann-Whitney Test, U=11.00, p=0.062). The mean number of taxa found in visual quadrat surveys did not differ between cave (n=11 sites) and surface (n=5 sites) (Mann-Whitney Test, U=12.50, p=0.089). In both cases, failure to detect a difference at the α=0.05 level of significance probably resulted from the small number of sampling sites that were included in the analysis, especially for surface habitats. Examination of box plots of the data (Figure 10), shows that there is considerable variation among individual quadrats, but that there is likely a real difference between the two habitat types, which might have been detected with larger sample size.

Table 2. Summary of taxa recovered from stomachs of *Plethodon albagula* captured at Fort Hood, Texas (1 February 2006 – 1 February 2007).

Phylum	Class	Order	Family	Genus/Species
Annelida?				
Annelida	Oligochaeta	Undetermined		
Chordata	Amphibia	Caudata	Plethodontidae	*Plethodon albagula*
Mollusca	Gastropoda	Undetermined		
		Basommatophora	Planorbidae	
		Stylommatophora	Lymnaeidae	
Arthropoda	Undetermined			
	Arachnida	Undetermined		
		Acari (undetermined)		
		Acari: Orabatoidea?		
		Araneae	Undetermined	
		Araneae		
		Araneomorphae	Undetermined	
			Araneidae	
			Lycosidae?	
			Lycosidae	*Pirata* sp.
			Tengellidae	
		Opiliones	Undetermined	
			Phalangodidae	*Texella* sp.
		Pseudoscorpiones		
	Chilopoda	Undetermined		
		Lithobiomorpha	Lithobiidae	
	Diplopoda	Undetermined		
		Julida?		
		Julida		
		Siphonophorida	Siphonophoridae	*Siphonophora* sp.
	Malacostraca	Isopoda	Asellidae	*Caecidotea* sp.
		Oniscoidea		
	Collembola	Undetermined		
		Entomobryomorpha	Undetermined	
			Entomobryidae?	
			Entomobryidae	Undetermined
				Sinella sp.
			Isotomidae?	
			Isotomidae	
			Oncopoduridae?	
			Tomoceridae	Undetermined
				Tomocerus sp.
		Poduromorpha	Undtermined	
			Poduridae	
		Symphypleona	Undetermined	

Table 2. Continued.

Phylum	Class	Order	Family	Genus/Species
	Insecta	Undetermined		
		Coleoptera	Undetermined	
			Cantharidae?	
			Cantharidae	sp. A
				sp. B
			Carabidae	*Rhadine reyesi*
				sp. A
				sp. B
				sp. C
			Chrysomelidae	*Zygogramma*? sp.
			Cryptophagidae	*Cryptophagus* sp.
			Curculionidae	
			Elateridae	
			Leiodidae	
			Nitidulidae	
			Scarabaeidae	sp. A
				sp. B
			Scarabaeinae	
			Scydmaenidae	
			Staphylinidae	sp. A
				sp. B
				sp. C
				sp. D
				Stenus sp.
		Dictyoptera: Blattaria		
		Diptera?		
		Diptera	Undetermined	
			Agromyzidae	
			Bibionidae	
			Ceratopogonidae	Undtermined
				Forcyipomyia? sSp.
			Ceratopogonidae	
			Chironomidae	
			Mycetophilidae	
			Phoridae	
			Psychodidae?	
			Psychodidae	
			Sciaridae?	
			Sciaridae	
			Stratiomyidae	Undtermined
				Allognosta sp.
				Euparyphus sp.
				Myxosargus? sp.
				Myxosargus sp.
				Nemotelus sp.
				Oxycera sp.
			Syrphidae?	
			Tipulidae	Undetermined
				Phalacrocera sp.
				Tipula sp.

Table 2. Continued.

Phylum	Class	Order	Family	Genus/Species
		Brachycera: Muscomorpha		
			Undetermined	
			Tephritidae?	
		Nematocera	Undetermined	
		Hemiptera		
		Heteroptera	Undetermined	
			Acanthosomatidae	
			Lygaeidae	
		Homoptera	Fulgoridae	
		Hymenoptera	Formicidae?	
			Formicidae	Undetermined
				Aphaenogaster sp.
				Labidus coecus
				Myrmecina americana
				Ponera prob. *pennsylvanica*
				Solenopsis invicta
				Solenopsis sp.
			Myrmicinae	
			Scelionidae	
		Lepidoptera	Noctuidae	
		Neuroptera	Chrysopidae	
		Orthoptera	Undetermined	
			Rhaphidophoridae	*Ceuthophilus* sp.
				Ceuthophilus cunnicularis
				Ceuthophilus secretus
		Thysanoptera		
		Terebrantia	Thripidae	
		Trichoptera		
Undetermined animal material				
Plant material				
	Undetermined			
	Woody undetermined			
	Vegetative undetermined			
Mixed plant and animal material				
Undetermined mineral material				
Undetermined material				

Figure 6. Stomach content taxa, and their frequency of occurrence, in salamanders found in surface habitats at Fort Hood, Texas.

Figure 7. Stomach content taxa, and their frequency of occurrence, in salamanders found in cave habitats at Fort Hood, Texas.

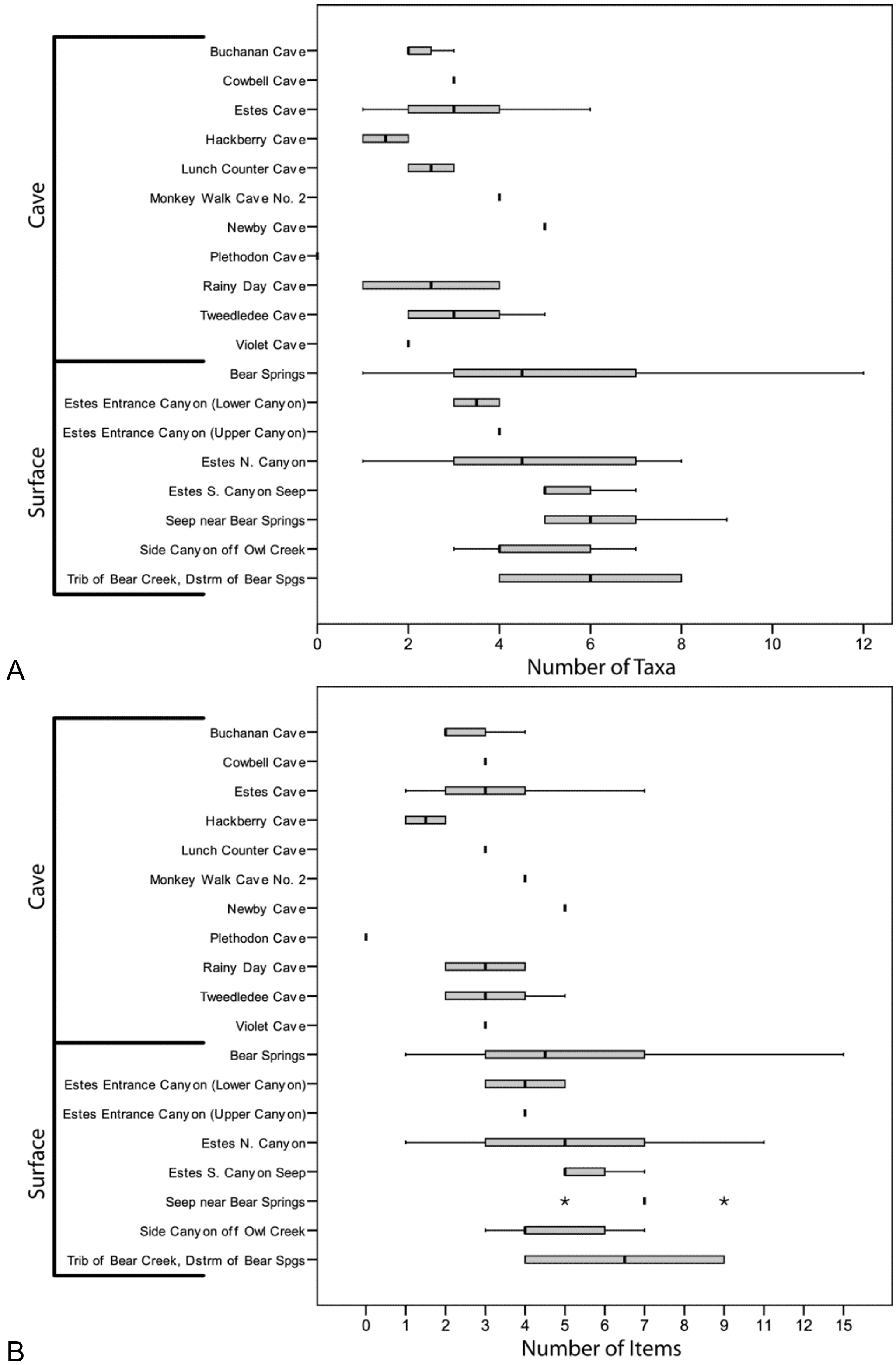


Figure 8. Box plots of number of taxa and number of food items from stomachs of 93 salamanders sampled from 19 sites at Fort Hood, Texas. A. Number of taxa. B. Number of food items.

Figure 9. Tree of similarity among salamanders on the basis of stomach contents (maximum taxonomic resolution: family) using average linkage cluster analysis.

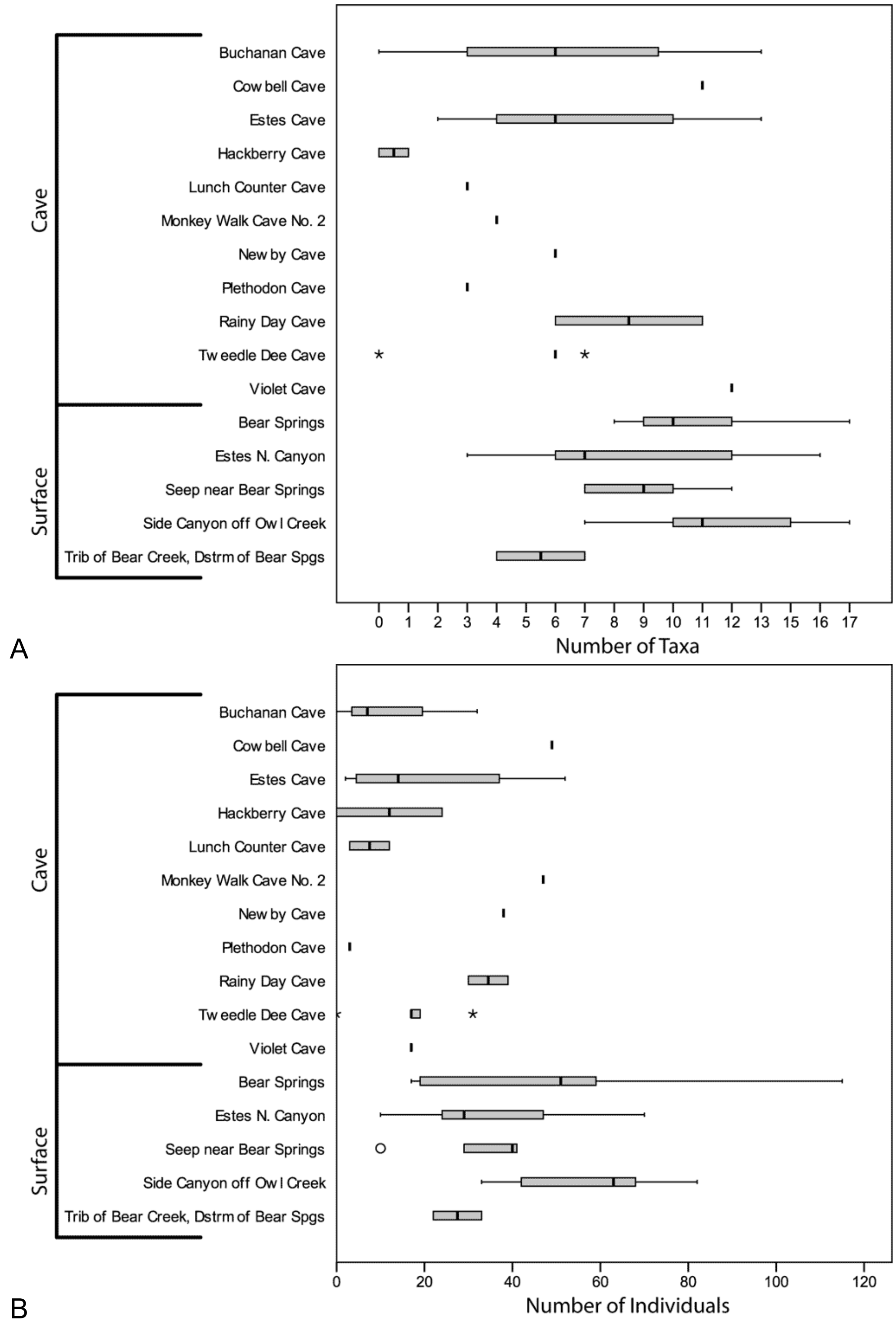


Figure 10. Box plots of number of taxa (A) and individual organisms (B) found in visual quadrat searches at 16 sites in Fort Hood, Texas.

Correlation between stomach contents and quadrat contents

The number of taxa in salamander stomachs was correlated with that in quadrats for caves (r^2=0.1601, p=0.0284, n=30) but not for surface habitats (r^2=0.0068, p=0.6836, n=27) (Figure 11). In addition, the total number of individual items found in salamander stomachs was correlated with the number of individuals found in quadrats for caves (r^2=0.2904, p=0.0021, n=30) but not for surface habitats (r^2=0.0011, p=0.8684, n=27) (Figure 12).

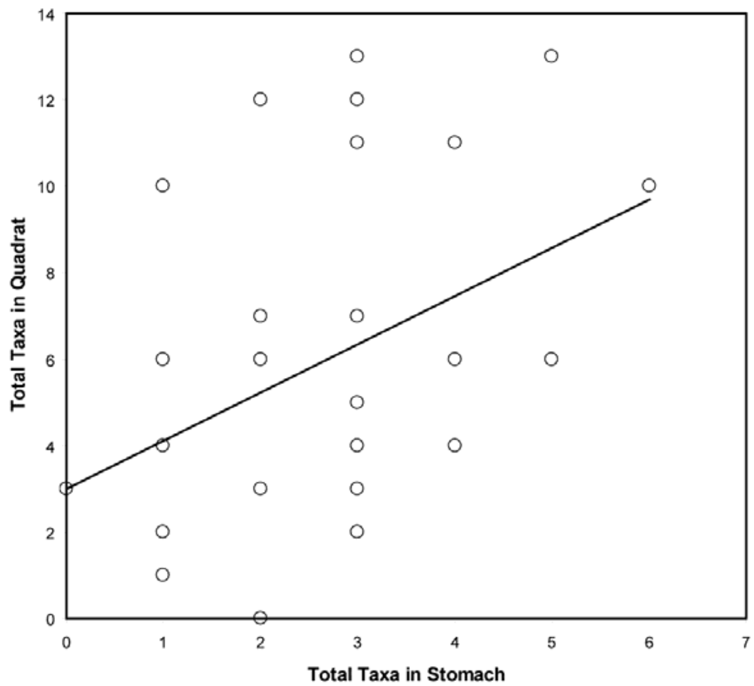
Does the proportion of prey items in salamander guts simply reflect availability?

We compared the taxonomic composition of visual quadrat census data to the taxonomic composition of salamander stomach contents using only those salamanders for which there was both stomach content and quadrat data (cave, n=30; surface, n=27). Taxonomic categories were pooled for both stomach content and quadrat census data, to a point which ensured that no χ^2 expected cell frequencies were less than 1.00, and no more than 20% of the expected cell frequencies were less than 5.00, for each χ^2 test (Cochran 1954, Roscoe and Byars 1971, Zar 1999). Categories which contained sufficient numbers of organisms to meet the above criteria were not pooled, and thus some pooled categories resulted in 'unnatural' groupings or organisms. The resultant five categories are:

- unclassified Arthropods, undetermined animals, *Plethodon*, & Annelida
- Gastropoda
- Collembola
- Insects
- Myriopods, Arachnids, & Crustaceans

For salamanders in caves, the proportions of prey items in these categories were different from the available proportions from quadrat data (χ^2 = 78.410, df=4, p<0.0001), and the same was true for salamanders found on the surface (χ^2 = 271.022, df=4, p<0.0001), indicating that salamanders do not simply eat in relationship to what is available (Figure 13).

Comparing quadrat data from cave and surface habitats using these five categories of pooled taxa showed that the proportion of prey items in the caves differed from what would be expected based on surface quadrat (χ^2 = 476.840, df=4, p<0.0001), indicating distinct differences in prey taxonomic composition between the two habitat types (Figure 14).



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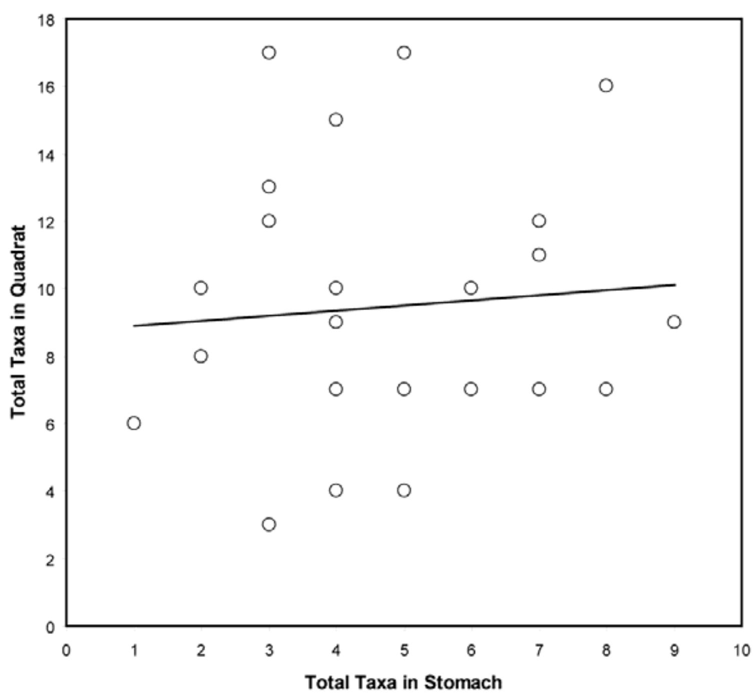
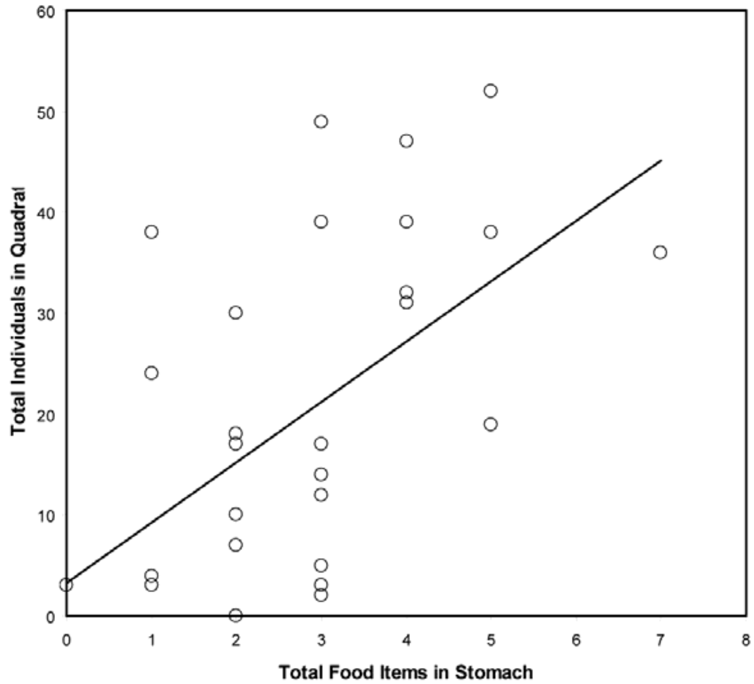


B

Figure 11. Correlation between number of taxa in quadrat counts and number of taxa in *Plethodon albagula* stomachs for cave (A, best fit line is Total Taxa in Quadrat = [1.1193 x Total Taxa in Stomach] + 2.9818) and surface (B, best fit line is Total Taxa in Quadrat = [0.1517 x Total Taxa in Stomach] + 8.7344) samples.



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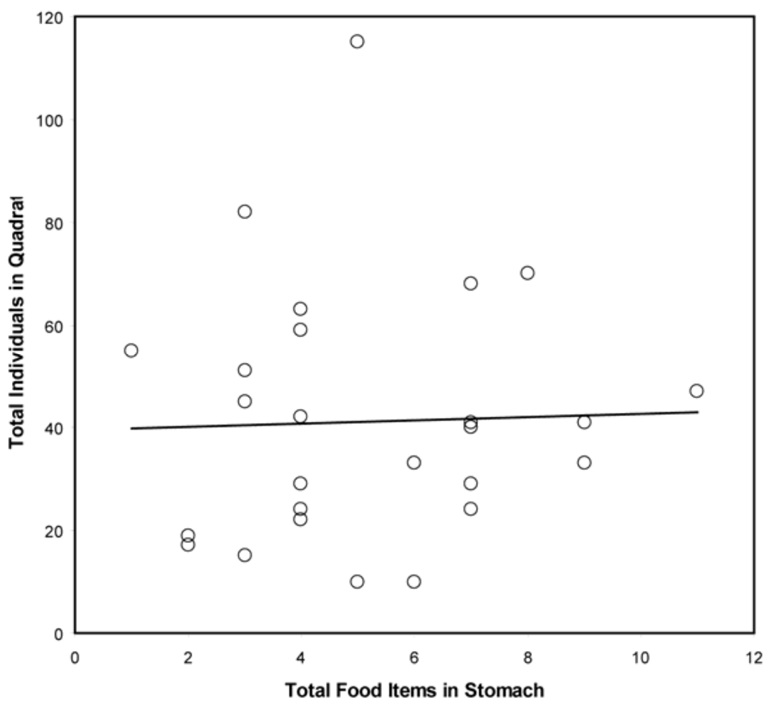


B

Figure 12. Correlation between number of food items in quadrat counts and number of items in *Plethodon albagula* stomachs for cave (A, best fit line is Total Individuals in Quadrat = [5.9688 x Total Food Items in Stomach] + 3.2883) and surface (B, best fit line is Total Individuals in Quadrat = [0.3273 x Total Food Items in Stomach] + 39.501) samples.

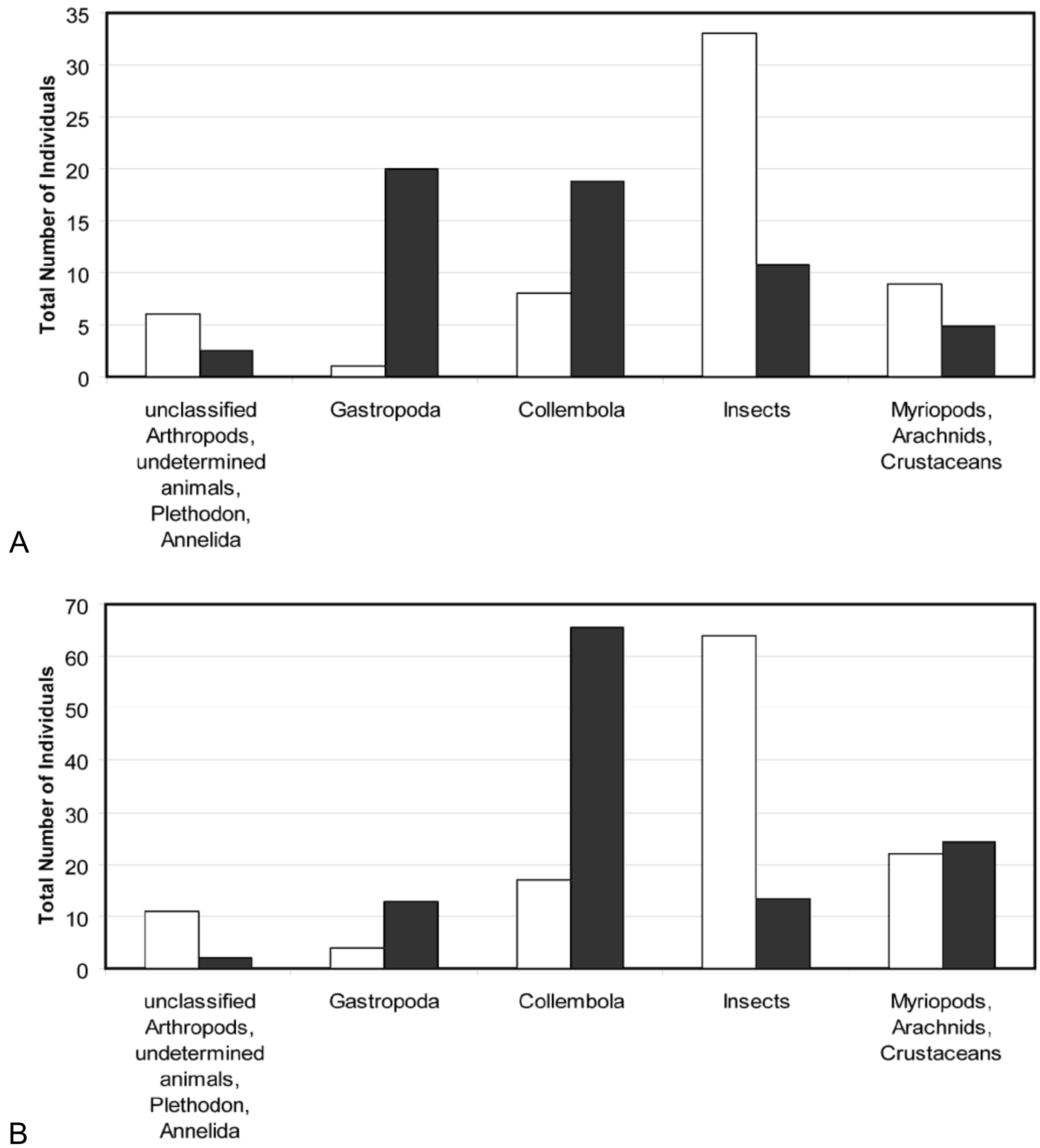


Figure 13. Categories of food items from stomachs of salamanders (white bars) compared with the expected proportions of the items based on visual quadrat counts (black bars). A. Salamanders in caves. B. Salamanders in surface habitats.

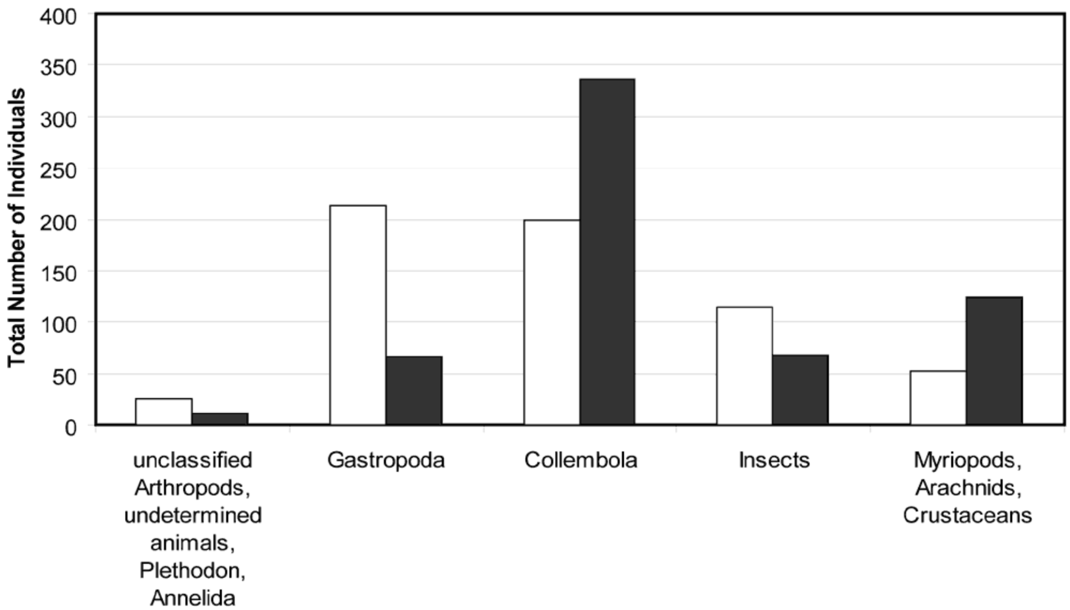


Figure 14. Categories of food items from in-cave quadrats (white bars) compared with the expected proportions of the items based on surface quadrat counts (black bars).

The proportions of the five categories of prey items in stomachs of salamanders from cave habitats did not differ from those of salamanders from surface habitats (χ^2 = 0.934, df=4, p= 0.9198) (Figure 15 A), a somewhat surprising result, which prompted us to re-run this analysis using not only the 57 salamanders with quadrat data, but all of the salamanders with stomach content data (cave, n=41; surface, n=52). This test yielded essentially the same result (χ^2 = 4.006, df=4, p= 0.4043) (Figure 15 B), and we can conclude that – at least at this coarse level of taxonomic resolution – the salamanders generally show preferences for specific groups of prey items, in spite of variable and disproportionate availability of the various prey taxa. In particular, the salamanders appear to have a preference for insects as prey.

However, the above finding does not mean there are no differences in prey items between surface and cave salamanders. Using the full dataset (93 salamanders: 41 cave, 52 surface), we examined the largest group of prey items, insects, more closely, breaking them into four groups for χ^2 analysis:

- Ants (Formicidae)
- Flies (Diptera)
- Beetles (Coleoptera)
- Other Insects

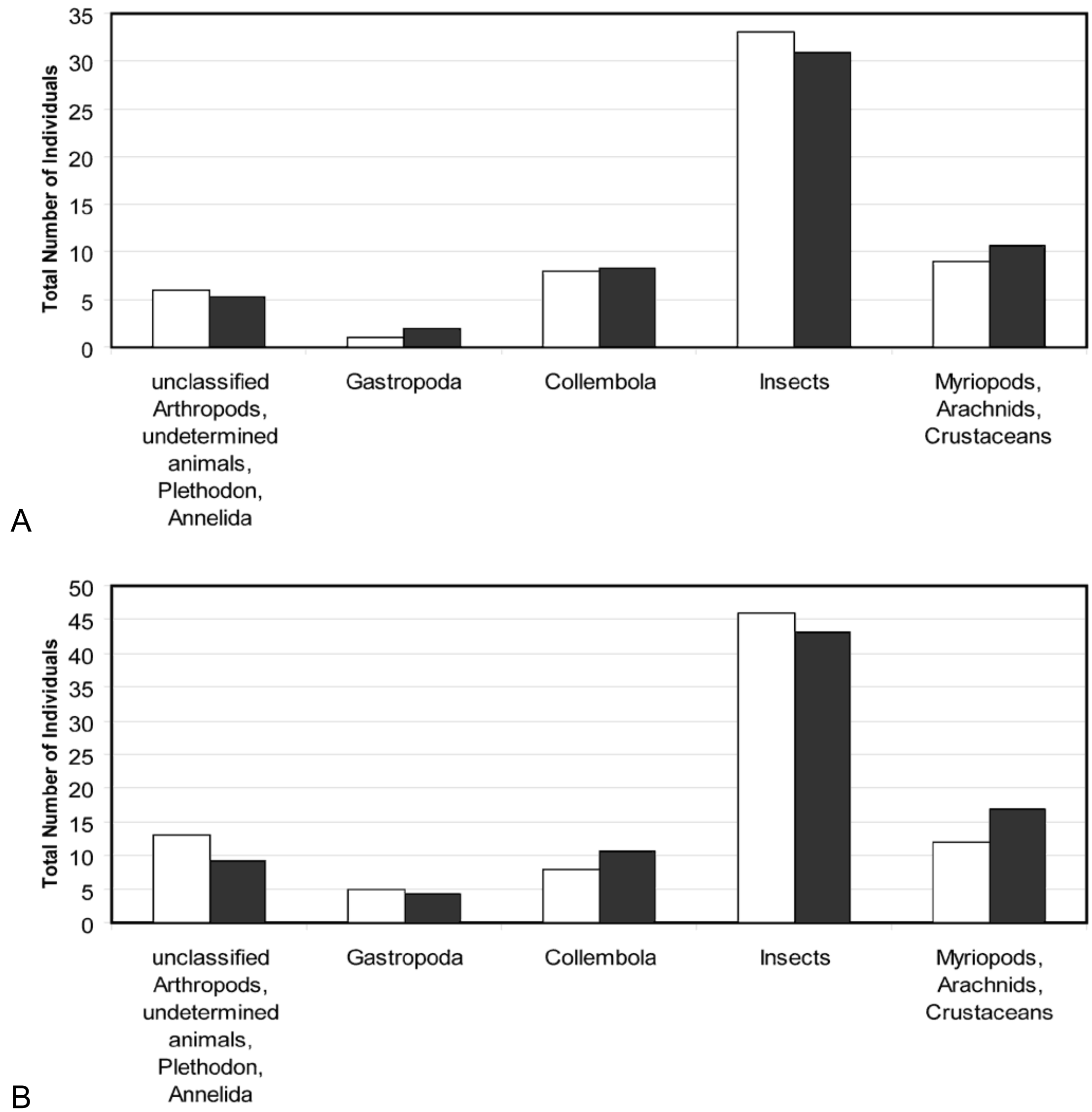


Figure 15. Categories of food items from stomachs of salamanders from caves (white bars) compared with the expected proportions of the items based on stomach contents of salamanders from surface habitats (black bars). A. Salamanders associated with quadrat data only (n=57). B. All salamanders in this study (n=93).

At this level of taxonomic resolution, the proportions of the four categories of prey items in stomachs of salamanders from cave habitats differed from what would be expected on the basis of analysis of stomach contents from salamanders from surface habitats (χ^2 = 76.802, df=3, p<0.0001) (Figure 16). It appears (Figures 6,7) that certain groups were notable in contributing to the observed differences, such as the higher numbers of larval Stratiomyidae (Diptera) in surface salamander stomachs, and the greater number of *Ceuthophilus* spp. (Orthoptera) in the stomachs of cave-inhabiting salamanders.

Salamander size in relation to abundance of prey

The number of individual items found in salamander stomachs was not correlated with snout-vent length for salamanders from caves (r^2=0.0005, p=0.8883, n=40) or from surface habitats (r^2=0.0216, p=0.2983, n=52) (Figure 17).

Notable prey items

Plethodon albagula prey included a variety of arthropods that are not readily obtained by generalized collecting techniques.

Several pseudoscorpions were recovered from salamander stomachs (Figure 18), but none appeared to be cave adapted. A harvestmen recovered from the stomach of a surface salamander appears to be a very infrequently encountered species, *Texella fendi* Ubick and Briggs (Figure 19), which has been reported from Chigiouxs' Cave at Fort Hood, and was described (Ubick and Briggs 1992) from specimens collected "beneath embedded limestone boulders" in Fayette

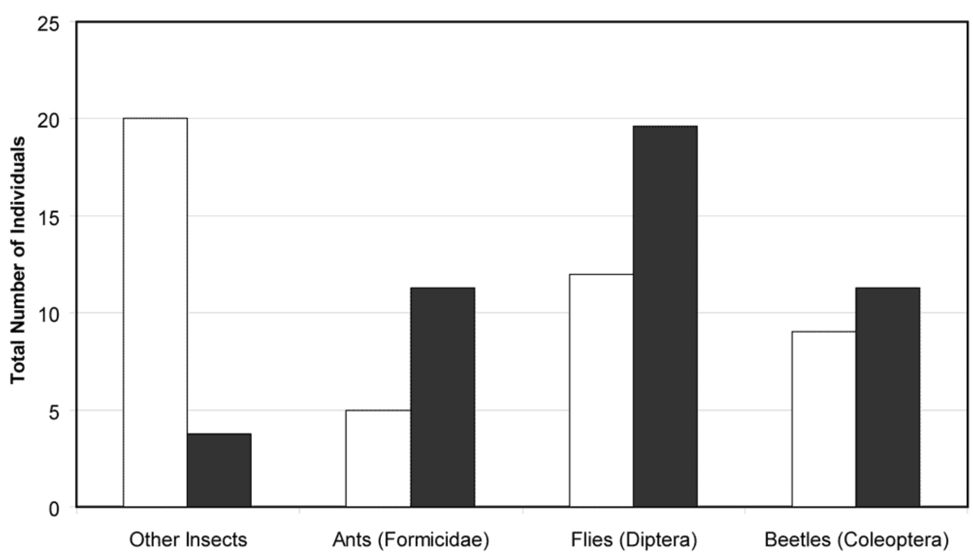
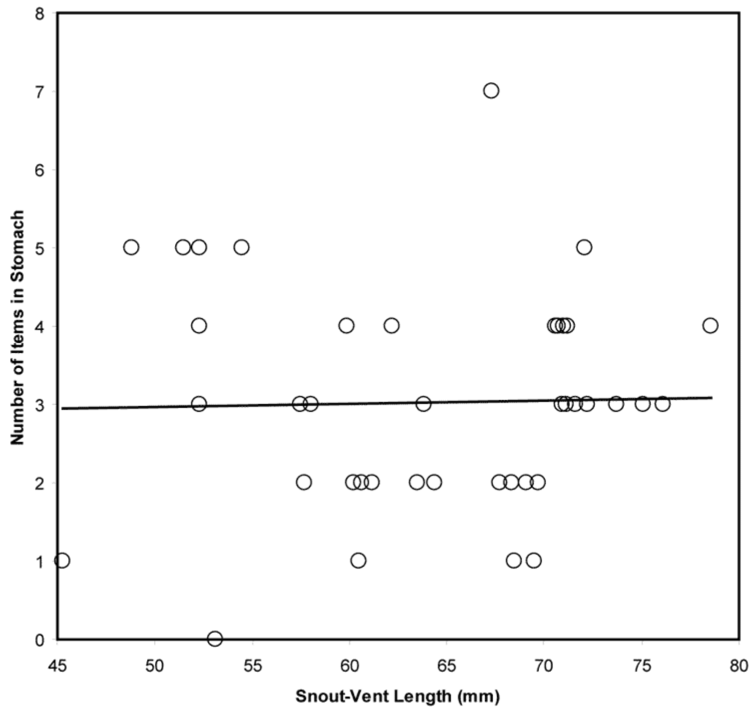


Figure 16. Categories of insects from stomachs of salamanders from caves (white bars) compared with the expected proportions of the items based on stomach contents of salamanders from surface habitats (black bars).



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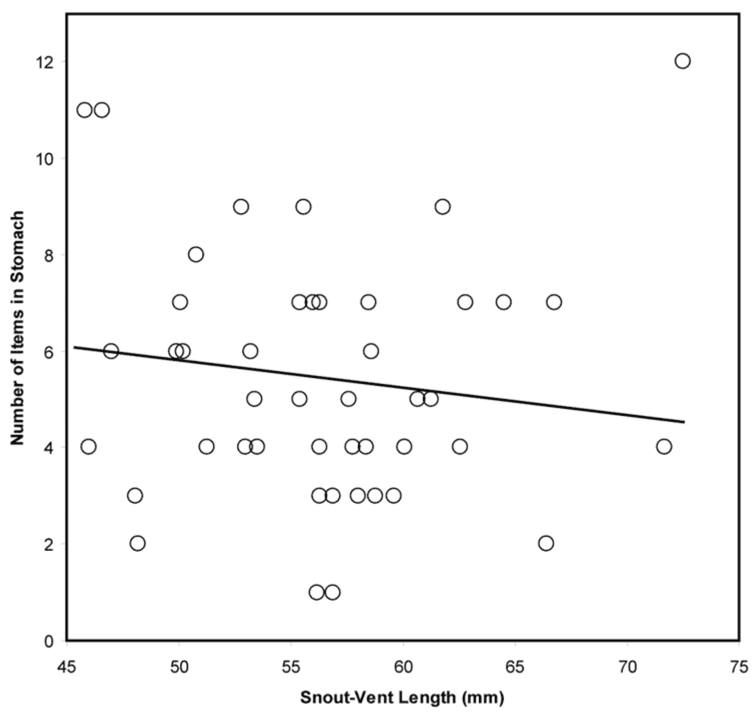

B

Figure 17. Correlation between snout-vent length and number of individual items in *Plethodon albagula* stomachs for cave (A, best fit line is Number of Items in Stomach = [0.0039xSnout-Vent Length] + 2.7757) and surface (B, best fit line is Number of Items in Stomach = [-0.0577x Snout-Vent Length] + 8.7041) samples.

Figure 18. Pseudoscorpion (Arachnida) (chelate palp has broken off body) from stomach of salamander found at Bear Springs. Scale = 1.0 mm.

Figure 19. *Texella* sp., probably *Texella fendi* Ubick & Briggs 1992 (Arachnida: Opiliones: Laniatores: Phalangodidae) from the stomach of a salamander found in surface leaflitter, Estes Cave North Canyon. A. Dorsal view. B. Ventral view of palps, showing spines. Scale = 0.5 mm.

County, Texas. Another specimen, possibly a new species, was reported by Reddell from Long Joint Sink, but was hand collected, not flushed from a salamander stomach. Thus it is possible the pictured (Figure 19) specimen we recovered is also undescribed.

Various spiders, including large Lycosids (Wolf Spiders) (Figure 20) were recovered from salamander stomachs. Large lithobiid centipedes (Figure 21) and various millipedes, primarily julid millipedes, were also recovered from salamander stomachs. The presence of lithobiid centipedes of of interest because a laboratory study by Anthony et al. (2007) demonstrated that there is competition between juviniles of another plethodontid salamander, *Plethodon cinereus*, and the centipedes *Lithobius forficatus,* an introduced species, and *Scolopocryptos sexspinosus*, a native species. They found that juvenile salamanders were excluded from cover objects by *S. sexspinosus*, and that the salamanders exhibited submissive behavior in response to both centipede species.

The infrequently collected genus *Siphonophora* sp. (Diplopoda: Siphonophorida: Siphonophoridae) was recovered from one salamander (Figure 22), and this specimen, along with others collected in Fort Hood caves by Reddell et al. are presently being examined by a taxonomic expert (Jason Bond, Department of Biology, East Carolina University, Greenville, North Carolina).

Figure 20. Lycosidae (Arachnida: Araneae) from the stomach of a salamander found at Bear Springs. Scale = 5.0 mm.

Figure 21. Centipede (Chilopoda: Lithobiomorpha: Lithobiidae) from stomach of salamander from Bear Springs, 20 March 2006. Scale = 1 cm.

Figure 22. *Siphonophora* sp. (Diplopoda: Siphonophorida: Siphonophoridae) from stomach of salamander found in Monkey Walk Cave. Scale = 1.0 mm.

Larval Stratiomyidae (Diptera), especially *Nemotelus* sp. (Figure 23), were common prey for surface salamanders. One salamander contained crane fly larvae of the genus *Phalacrocera* sp. Schiner, 1863 (Diptera: Tipulidae) (Figure 24). Although this genus cannot be identified to species level based on immatures, the specimens are still quite interesting. Dr. Chen W. Young (Carnegie Museum of Natural History) was sent this material to confirm the identification. He has stated that the "larvae differ from those of all the other crane flies in their habit of feeding on the leaves of various living bryophytic and spermatophytic plants, where they feed almost in the manner of certain lepidopterous caterpillars (Alexander, 1942)" and says "… *Phalacrocera* is either western or northeast in their known distribution. I wonder which species has ventured into Texas?" and "There are four species recorded for the Nearctic region and currently the most widely distributed species is *Phalacrocera tipulina*, but this could be the result from collecting bias" (Chen W. Young, personal communication, 15 August 2007).

A Silken Fungus Beetle of the genus *Cryptophagus* sp. (Coleoptera: Cryptophagidae) was recorded from a surface salamander (Figure 25). These small, fungus-feeding animals are poorly known taxonomically, and are found in

Figure 23. Larval *Nemotelus* sp. (Diptera: Stratiomyidae) from the stomach of a salamander found in the canyon between Bear Springs and Estes Cave. This taxon is one of the most commonly encountered prey items in the stomachs of the salamanders. Scale = 5.0 mm.

Figure 24. *Phalacrocera* sp. Schiner, 1863 (Diptera: Tipulidae) from the stomach of a salamander found in Estes Cave. Scale = 5.0 mm.

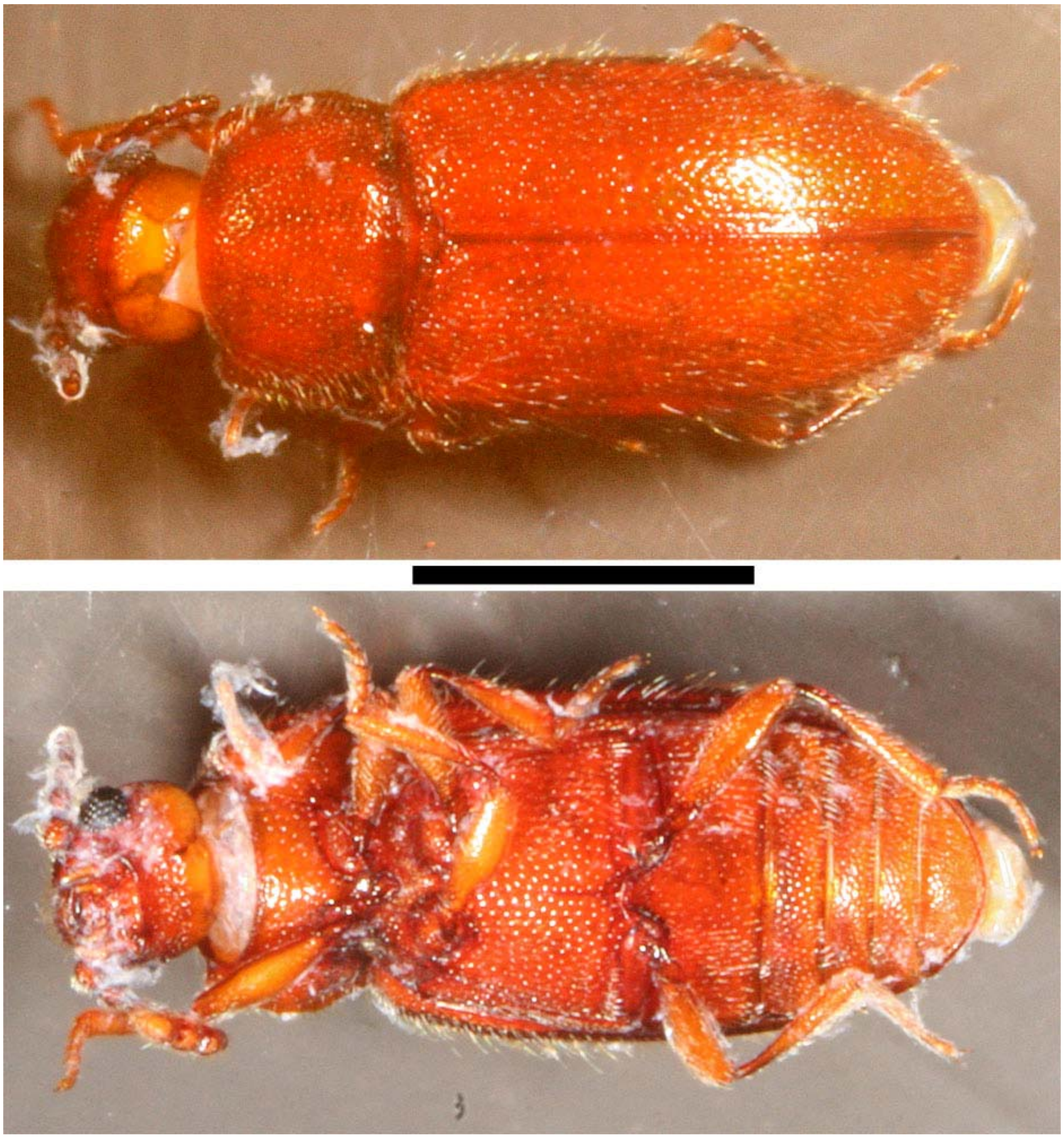

Figure 25. Silken Fungus Beetle, *Cryptophagus* sp. (Coleoptera: Cryptophagidae), from stomach of a salamander found in surface leaf litter. Scale=1.0 mm.

association with mold, fungus, leaf litter, and decaying wood. The North American species of the genus were last revised by Woodroffe and Combs (1961), many undescribed species likely exist.

Several ant (Hymenoptera: Formicidae) species were found in salamander stomachs. Notable among these is the Red Imported Fire Ant, *Solenopsis invicta*, recorded from seven salamanders, all but one of which were obtained in surface habitats. Other ants include common taxa such as *Aphaenogaster* sp., as well as less frequently encountered animals such as *Myrmcina* sp. (Figure 26) and *Ponera* prob. *pennsylvanica* Buckley, 1866 (Figure 27). The subterranean army ant, *Labidus coecus* (Latreille), 1802 was collected from the stomach of a cave-inhabiting salamander at Lunch Counter Cave. This is the only *Labidus* species recorded from Texas (O'Keefe et al. 2000), and we have recovered this ant from other caves at Fort Hood (Taylor and Phillips 2002), and elsewhere in Texas.

Cave-inhabiting *P. albagula* commonly contained cavernicoles, especially cave crickets. Both *Ceuthophilus secretus* and *Ceuthophilus cunnicularis* were recovered from stomach contents of these salamanders. One salamander contained both a cave cricket and a *Rhadine reyesi* (Coleoptera: Carabidae), along with the potentially undescribed *Siphonophora* sp. (Diplopoda) (Figure 28).

Figure 26. *Myrmcina* sp. (Hymenoptera: Formicidae) from stomach of salamander found at Bear Springs. Scale = 1.0 mm.

Figure 27. *Ponera* prob. *pennsylvanica* Buckley, 1866 (Hymenoptera: Formicidae) from stomach of salamander found at seep near Bear Springs. Scale = 1.0 mm.

Figure 28. Gut contents flushed from an adult salamander captured in Monkey Walk Cave No. 2, 5 December 2006. The sample contains an adult female *Ceuthophilus cunnicularis* (Orthoptera: Rhaphidophoridae, cave cricket), top, *Siphonophora* sp. (Diplopoda: Siphonophorida: Siphonophoridae), middle, and an adult *Rhadine reyesi* (Coleoptera: Carabidae), bottom, as well as mucus and other material. Smallest divisions on ruler are 1 mm.

Finally, at least one salamander's stomach contained the tip of another salamanders' tail (Figure 29). This finding is rather contrary to what we see in the scientific literature: Wise et al. (2004) demonstrated that behavioral interactions between *P. cinereus* individuals is influenced by tail autotomy, Sullivan et al. (2003) have examined avoidance behavior of *P. cinereus* in relation to injured and uninjured salamanders, and Hucko and Cupp (2001) studied the behavioral avoidance of chemicals from autotomized tails of conspecifics by the salamander *Plethodon richmondi*.

Discussion

Flushing stomachs of the salamanders was informative. We know from these data that the proportions of different food items found in salamander stomach is not proportional to what is available in their immediate surroundings, and that cave and surface populations differ in both available food and in food items found in their stomachs. Few prior studies have examined stomach contents of *Plethodon*, but our findings are generally consistent with those studies.

We did find some plant material in salamander stomachs. Some of this could have come from prey such as tipulid larvae, which are often packed full of algae, or from incidental vegetative material consumed when swallowing prey.

While we did not detect a difference in number of food items by salamander size, we did not measure prey volume or biomass, nor did we examine taxonomic distribution of prey by salamander size. Our study was also biased toward larger

Figure 29. The tip of a salamander (*Plethodon albagula*) tail flushed out of the stomach of another salamander. Tweedle Dee Cave, 4 December 2006. Photo by Jean K. Krejca. Smallest divisions on ruler are 1 mm.

individuals, as the smaller salamander size classes were too small for the gavage needle. In *P. cinereus*, prey size is related to body size (Maglia 1996), and we might expect similar differences in *P. albagula* at Fort Hood.

Knowledge gained in this study is useful in conserving the habitats in which the salamanders live – it is clearly important to maintain a diverse arthropod community to serve as prey for the salamanders. Maintaining plant and animal communities in their natural state is an obvious approach to ensuring the well being of the salamander populations.

Many factors affecting the maintenance of the Fort Hood *P. albagula* populations still warrant further study. The surface populations may be vulnerable to drying and warming associated with climate change – Jaeger (1972) found that in other plethodontid species, periods of aridity and a lack of moisture forced salamanders into localized areas, and stomachs during these dry periods contained fewer prey items. Observed differences in both stomach contents and prey availability between cave and surface populations of *P. albagula* at Fort Hood may have other implications as well. Maerz et al. (2006) found that *P. cinereus* in upland and lowland habitats in northeastern USA differed in prey size (based on stomach contents, but that they also differed in cranial morphology – could there be similar differences for cave and surface populations of *P. albagula* at Fort hood? Finally, territory defense has been shown to vary in intensity in relation to food quality in *P. cinereus* (Gabor and Jaeger 1999) – could there be a difference in territory defense strategies between cave and surface populations of *P. albagula* at Fort Hood? At Bear Springs, we have occasionally recorded the presence of ribbon snakes in or near *P. albagula* habitat, and on occasion, copperheads have been found in Estes Cave. It may be that these salamanders modify the foraging behavior in a manner that facilitates avoidance of snake predators (e.g., Madison et al. 1999, Murray and Jenkins 1999), and this predation risk likely differs between cave and surface environments.

Our study also points toward a role for *P. albagula* in structuring cave invertebrate communities. We observed several cases where salamanders consumed known cavernicoles such as the G1 endemic carabid beetle, *Rhadine reyesi* and the key (Taylor et al. 2005a) trogloxene *Ceuthophilus secretus*. Walton et al. (2006) demonstrated that another species, *Plethodon cinerius*, plays a role in structuring forest floor invertebrate communities in the northeastern United States by decreasing the densities of some invertebrate taxa, notably oribatid mites, pseudoscorpions, isopods and millipedes. In contrast, Rooney et al. (2000) found no significant effect of salamanders on arthropod abundance, but also found an increased abundance of springtails in the presence of salamanders (*P. cinereus*). Might *P. albagula* play a similar role in Fort Hood caves?

Summary

Stomach contents of *Plethodon albagula* captured at surface and cave sites in southeastern Fort Hood, Texas, were found to contain a wide variety of food items, including springtails, cave crickets, ants, and Diptera larvae. Food availability was quantified using quadrats and visual counts of invertebrates. Overall, relative proportions of stomach content tax in salamanders differed from the proportions available.

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