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A Survey of *Plethodon* sp. (Plethodontidae) Salamander Populations in Caves and Sinkholes at Fort Hood, Texas

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A Survey of *Plethodon* sp. (Plethodontidae) Salamander Populations in Caves and Sinkholes at Fort Hood, Texas

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Final Report

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Construction Engineering Research Laboratory
Champaign, IL 61826-9005

Under Work Unit Q681

ABSTRACT: Salamanders of the genus *Plethodon* occur in a variety of mesic woodland habitats. Recently, populations of an undescribed species have been discovered at Fort Hood, Texas. These populations are associated with features such as caves and sinkholes. Red imported fire ants (RIFA), *Solenopsis invicta* Buren, are thought to compete with cavernicoles for food and sometimes prey upon animals in the caves, but their impact at Fort Hood has not been closely examined.

This research documents (1) the presence/absence and abundance of *Plethodon* sp. at selected caves and sinkholes on Fort Hood and (2) the presence or absence of RIFA at features surveyed for *Plethodon* sp.

The data fail to demonstrate any meaningful relationship between either active RIFA mound counts or numbers of RIFA in bait traps and the presence/absence or abundance of *Plethodon* sp. Because RIFA can be overwhelming as a predator and difficult to control, management efforts should focus toward limiting the impacts of RIFA on sites where the salamander is known to occur. A more robust estimate of the population size for the salamander is needed. General size data suggest that the salamander population is normal and healthy.

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Conversion Factors

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

Preface

This study was conducted for Fort Hood Department of Public Works, Natural Resources Office under Reimbursable project Q681, "Provide Mammalian Predator Control at Surveyed Locations." The technical monitor was John Cornelius, AFZF-PW-ENV-NR

The work was performed under the direction of the Land and Heritage Conservation Branch (CN-C) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Michael L. Denight. This work was completed by Steven J. Taylor and Christopher A. Phillips of the Illinois Natural History Survey under contract No. DACA88-99-D-0002-14. The technical editor was Gloria J. Wienke, Information Technology Laboratory. Dr. Lucy A. Whalley is Chief, CEERD-CN-C, and Dr. John T. Bandy is Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John Morris III, EN and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

Salamanders of the genus *Plethodon* occur in a variety of mesic woodland habitats and are generally distributed throughout the eastern United States (Petranka 1998). Recently, populations of an undescribed species have been discovered at Fort Hood, Texas (Reddell 2001). These populations, associated with karst features such as caves and sinkholes, have been identified from 14 of the roughly 250 such features at Fort Hood (Reddell 2001). Red imported fire ants (RIFA), *Solenopsis invicta* Buren (Hymenoptera: Formicidae) have been listed as a serious threat to karst communities in Bexar County, Texas (USFWS 2000). RIFA are thought to compete with cavernicoles for food and at least occasionally prey upon animals in the caves (Elliott 1993), but the impact of RIFA on karst communities at Fort Hood (Bell and Coryell counties, Texas) has not been closely examined (Taylor 2001). Appendix A lists two literature sources that discuss the ecological relationships between *Plethodon* sp. salamanders and ants. It also lists literature sources and abstracts discussing the interactions of ants and other herptofauna.

Objectives

The objectives of this research are to (1) document the presence/absence and abundance of *Plethodon* sp. at selected karst features at Fort Hood, Texas; and (2) document the presence or absence of RIFA at features surveyed for *Plethodon* sp.

Approach

Visual surveys were conducted to estimate presence/absence and abundance of *Plethodon* sp. at Fort Hood Texas. Chapter 2 contains details of the salamander surveys. RIFA were surveyed at each feature using two methods. First, all active RIFA mounds within a 15-m radius of the feature were counted. Second, bait stations were deployed at each feature. Chapter 2 contains details and specifics of the RIFA surveys.

Mode of Technology Transfer

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 Methods

Plethodon sp. was surveyed using time- and area-constrained visual encounter survey (VES) methods (Heyer et al. 1994). This is "brute force" searching with time spent recorded to the nearest minute and area searched recorded with a text description and sketched on a map of the feature. This basic quantitative method allows for estimating presence/absence, relative abundance, and absolute abundance. All but 1 of the 14 karst features in which Reddell (2001) found *Plethodon* sp. was surveyed. The unsampled feature (BR's Secret Cave, Rocket River Cave System) is only a sight record (Reddell 2001). The Rocket River Cave System is in the live-fire area that was not accessible during this research. Thirty additional features were surveyed. Initially, the additional sites were chosen on the basis of how closely they seemed to fit the existing descriptions and maps of caves from which *Plethodon* sp. was already known. Selection was made in consultation with James Reddell, Marcelino Reyes, and others (Professional Communication: James R. Reddell, Curator of Invertebrate Zoology, Texas Memorial Museum, Austin, Texas, April 2002). Later visits were intended to help define the borders of the range of the species. This research focused on sites in the East Range, where we expected to have the most success finding additional salamander sites, even though karst features are broadly distributed across the base (Figure 1). We revisited four features (Coyote Den, Estes Cave, and Bear Springs East, and Bear Springs West) during the Spring and Summer, 2002, to determine if our ability to locate salamanders declined with increasing air temperatures and decreasing moisture levels. We chose Coyote Den Cave because it was a feature that was most likely to be affected by dry weather (the cave is shallow, with the entrance being a wide sinkhole). Estes Cave and Bear Springs (East and West) were chosen because we had previously encountered a large number of individuals at those sites and we thought they offered the best chance to encounter marked individuals and therefore test our marking methods. At all four features we found salamanders during both visits, suggesting that the absence of salamanders from many sites during previous trips did not merely reflect seasonal differences in climatic condition. The data for the second visits to Bear Springs and Estes Cave are not included in the analyses of RIFA/*Plethodon* sp. relationships because we did not collect RIFA data on the second visits. We did not record the time effort during the second visit to Estes Cave.

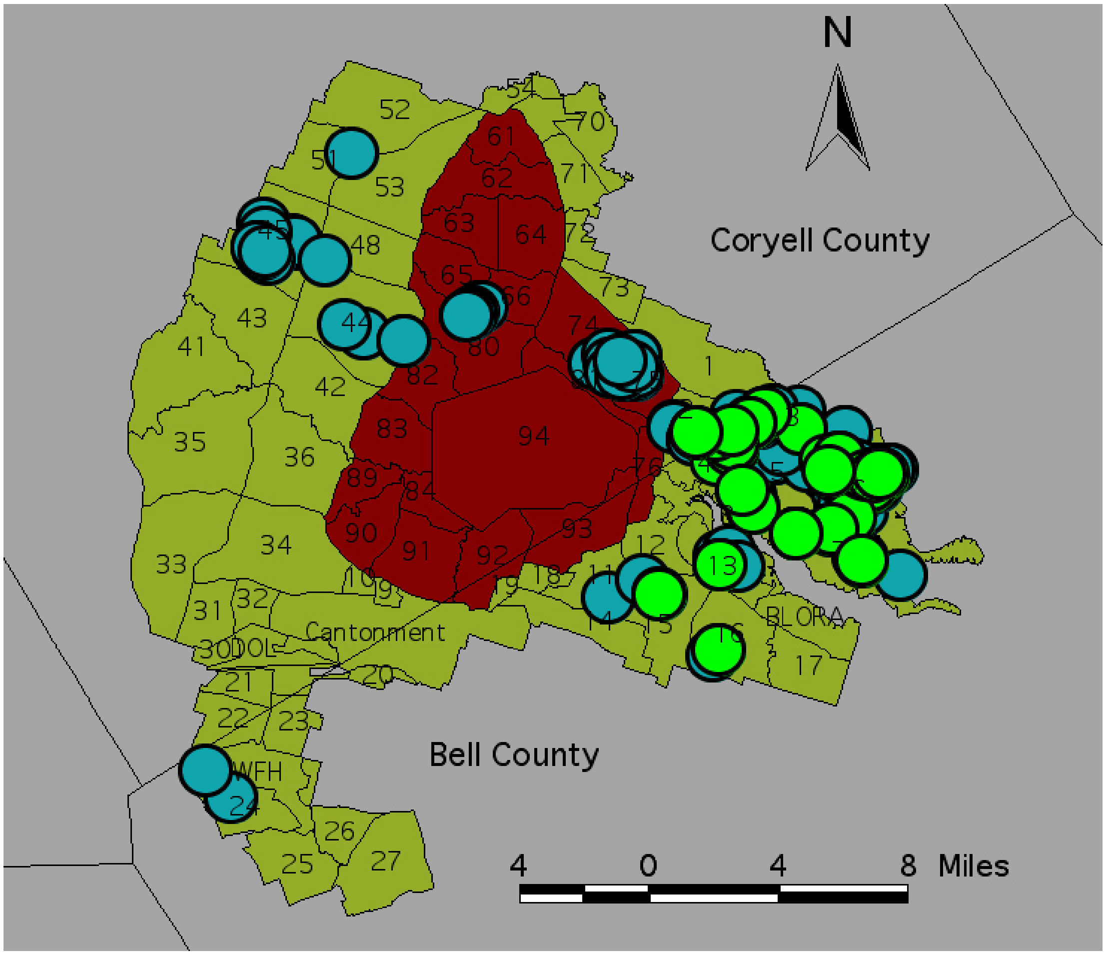


Figure 1. Distribution of karst features at Fort Hood, Texas.
Sampled features are indicated in bright green, unsampled features in blue. Live fire and impact areas are dark red.

Plethodon sp. encountered were weighed to the nearest 0.1 g using Pesola spring scales. Snout-vent length (SVL) and total length (ToTL) were recorded to the nearest 0.1 mm using digital calipers. Individuals over 25-mm SVL were marked by clipping one toe under the marking system of Medica et al. (1971; see also Figure 5B of Ferner 1979). At most features, the number one toe (outside toe of left front) was clipped. The exceptions are Violet Cave and Estes Cave where the number 8 toe (outside toe of right front) was clipped. All salamanders were released unharmed at the point of capture.

Other amphibians and reptiles encountered were recorded and photographed. Some individuals were euthanized and preserved according to our animal care protocol and were vouchered in the Amphibian and Reptile Collection at the Illinois Natural History Survey. See Appendix B for a list of amphibians and reptiles collected during this study.

RIFA were surveyed at each feature using two methods. First, all active RIFA mounds within a 15-m radius of the feature were counted (Figure 2). Second, five bait stations were deployed at each feature (Figure 3); one was 7.5 m from the feature in each of the four cardinal directions and one was inside of the feature. Each bait trap consisted of a 15-ml plastic tube with a piece of a canned sausage inside (following methods outlined in more detail in Taylor 2001). The traps were covered with a square of cardboard (for shade), and were left open for 20 minutes before being capped. Ethanol (70%) was added to the tubes to preserve the sample. The contents were sorted and ants identified in the lab. Soil temperature at 2 cm was recorded at each bait station using a digital thermometer probe. Air temperature, relative humidity, and wind speed were also recorded on the surface at each feature. Photographs were taken of each feature and of other amphibians and reptiles encountered. We examined the relationship between soil temperature and both of the RIFA indicators (mound counts and traps) and concluded that trap results were more temperature dependent; i.e., almost no traps contained RIFA at soil temperatures below 23^{o} C (Figure 3). Positive mound counts were obtained at soil temperatures as low as 7^{o} C (Figure 2). Therefore, we decided to use mound counts in the analysis of the relationship between presence of RIFA and *Plethodon* sp. We examined the relationship between the presence of RIFA and *Plethodon* sp. in two ways. First, we conducted a t-test (level of significance: $\alpha = 0.05$) on the mean number of active RIFA mounds at features with *Plethodon* sp. vs those with no *Plethodon* sp. Second, we ran a correlation analysis using number of active RIFA mounds and number of *Plethodon* sp. detected per unit effort.

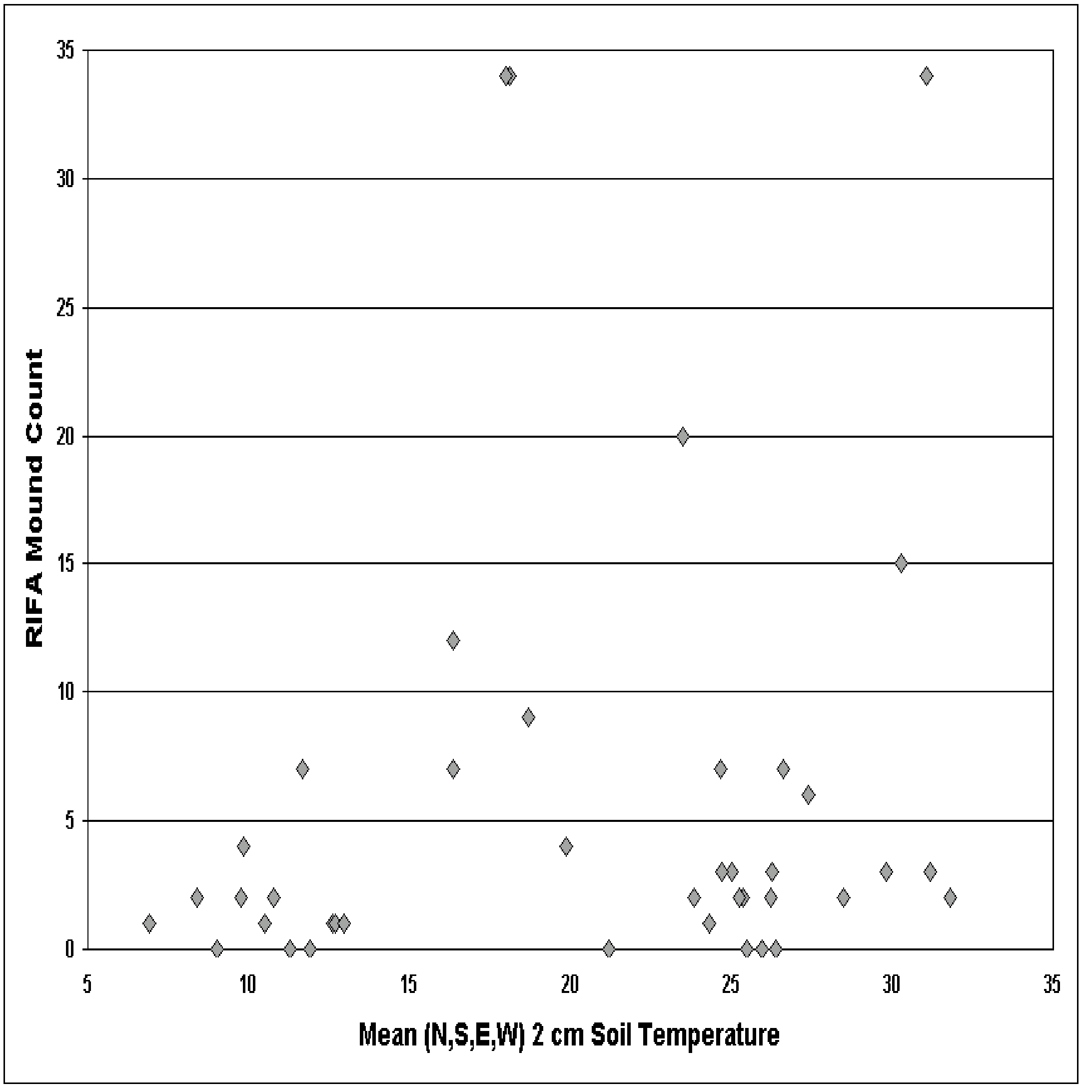


Figure 2. Active RIFA mound count (15-m radius of feature) in relation to soil temperature (°C) measured at 2-cm depth.

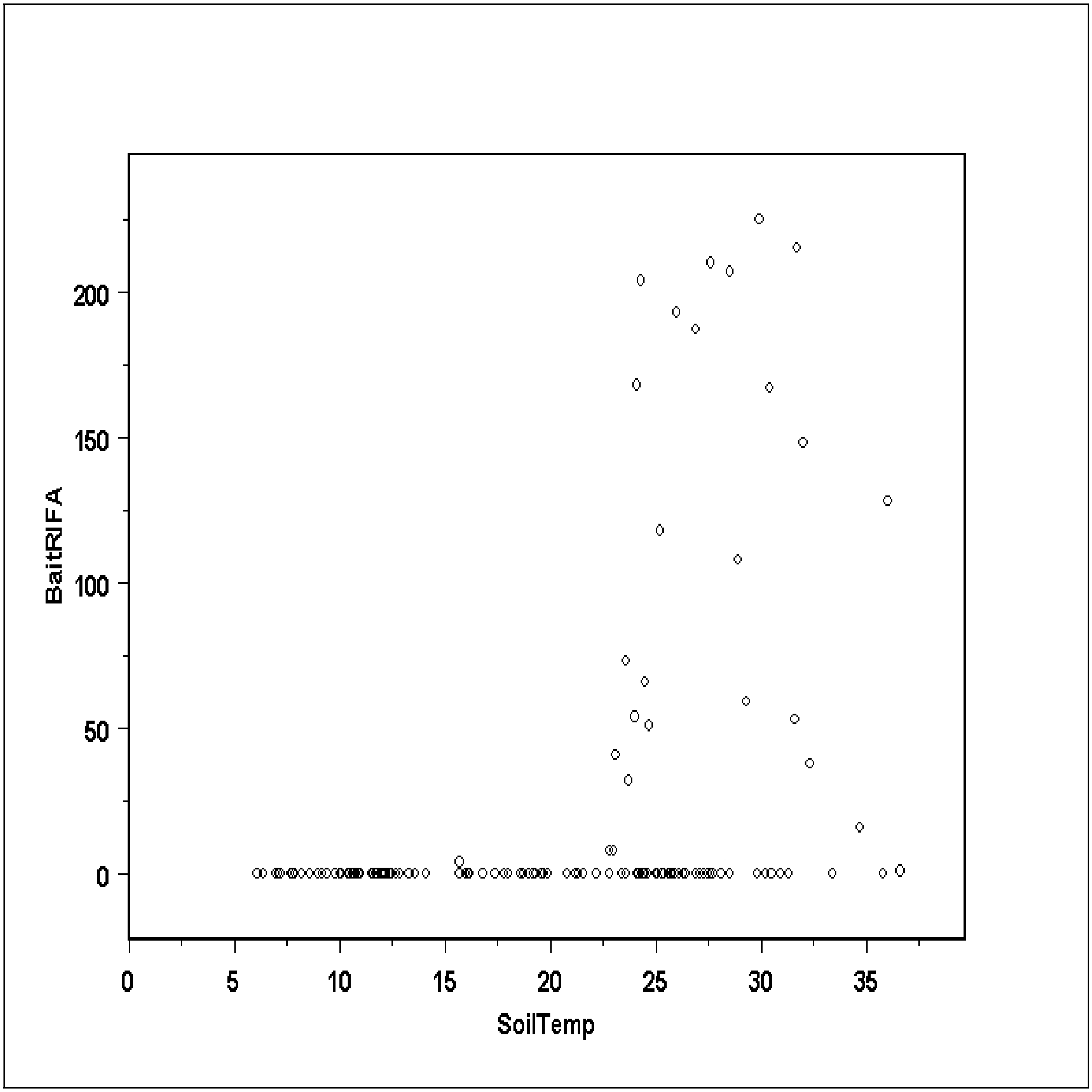


Figure 3. Abundance of RIFA in bait traps in relation to soil temperature (^oC) measured at 2-cm depth.

3 Results

We detected *Plethodon* sp. in 7 of the 13 features in which they were previously recorded (Table 1; Figures 4 and 5). We surveyed an additional 30 features and found *Plethodon* sp. at 3 of these (Table 1; Figure 4). The number of individuals encountered and the time spent searching at each feature are shown in Table 1. The means and ranges of SVL, ToTL, and mass are given in Table 2 and Figure 6.

Table 1. List of features with date visited and results of *Plethodon* sp. surveys. Features in bold are those that have previous records of *Plethodon* sp. (Reddell 2001).

Feature Name	Date Visited	Number *Plethodon* sp. Found (number marked)	Time Searched (man-hours)	Number *Plethodon*/ Time Searched
Big Crevice	7 February	0	0.65	0.00
Coyote Den Cave	7 February	2 (2)	0.67	2.99
Lucky Rock Cave	7 February	0	0.7	0.00
Treasure Cave	7 February	0	0.13	0.00
Peep in the Deep Cave	7 February	2 (2)	0.73	2.74
Lunch Counter Cave	7 February	0	0.32	0.00
Seven Cave	7 February	3 (3)	0.12	25.00
Buchanan Cave	8 February	0	0.47	0.00
Moffatt Pit Cave	8 February	2 (2)	0.28	7.14
Estes Cave	8 February	15 (10)	0.95	15.79
Violet Cave	9 February	6 (2)	0.4	15.00
Monkey Walk Cave #1	9 February	4 (3)	0.33	12.12
Monkey Walk Cave #2	9 February	0	0.28	0.00
Keilman Cave	9 February	0	0.43	0.00
Triple J Cave	9 February	0	0.42	0.00
Fools Cave	10 April	0	0.62	0.00
Forgotten Sink	10 April	0	0.13	0.00
Bear Springs East	10 April	4 (4)	0.08	50.00
Bear Springs West	10 April	7 (5)	0.2	35.00
Newby Cave	10 April	1 (1)	0.33	3.03

Feature Name	Date Visited	Number *Plethodon* sp. Found (number marked)	Time Searched (man-hours)	Number *Plethodon*/ Time Searched
Fern Falls Cave, Fern Falls Spring & Fern Falls Balcony Cave	11 April	0	0.92	0.00
Taylor's Branch Lower Spring	11 April	0	0.43	0.00
Skeeter Cave	12 April	0	0.28	0.00
Tres Dedos Cave	12 April	0	0.12	0.00
Runoff Cave	12 April	0	0.45	0.00
West Corral Sink	13 April	0	0.3	0.00
Toad Load Cave	13 April	0	0.18	0.00
Bear Springs East, 2nd visit	14 April	3 (2)	0.15	20
Bear Springs West, 2nd visit	14 April	8 (2)	0.5	16
Estes Cave, 2nd visit	14 April	19 (12)	*	*
Sink (F 7B-8)	4 June	0	0.06	0.00
Sink (F 7B-9)	4 June	0	0.05	0.00
Chimney Windows Cave	4 June	0	0.13	0.00
Hatchi's Hatchet Cave	4 June	0	0.08	0.00
Arroyo near Hatchi's Hatchet Cave	4 June	0	0.12	0.00
Loop Joint Cave	4 June	0	0.2	0.00
Coyote Den Cave, 2nd visit	5 June	2 (2)	0.5	4.00
Fecksome Cave	5 June	0	0.42	0.00
Gnarla Cave	5 June	0	0.43	0.00
Oh Boy Cave	5 June	0	0.15	0.00
Bumelia Well Cave	5 June	0	0.58	0.00
Price Pit Cave	6 June	0	0.17	0.00
Copperhead Cave	6 June	0	0.15	0.00
Copperhead Cave #2	6 June	0	0.18	0.00
Copperhead Spring Cave	6 June	0	0.1	0.00
Nolan Creek Cave	7 June	0	0.35	0.00
Spring F13 B2	7 June	0	0.15	0.00
* time effort not recorded.				

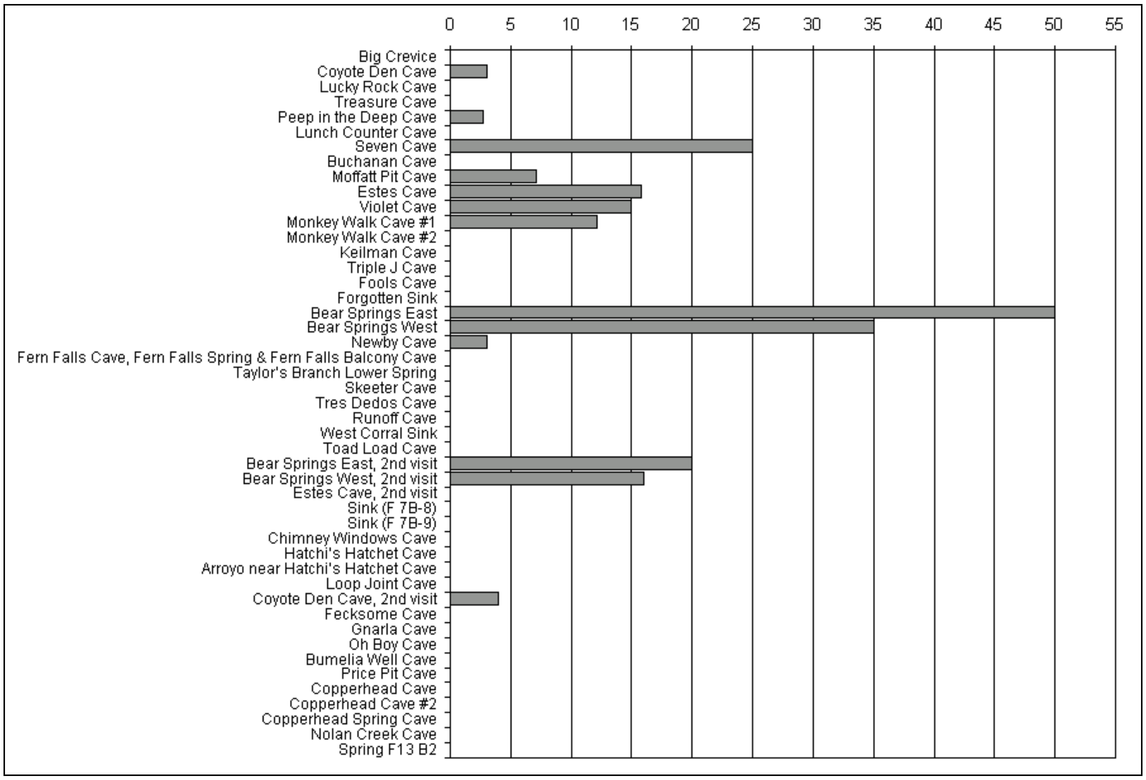


Figure 4. ***Plethodon*** **sp. encountered per unit effort for each feature surveyed.**

Features are sorted according to when they were surveyed (earliest at top). Time effort was not recorded on the second visit to Estes Cave.

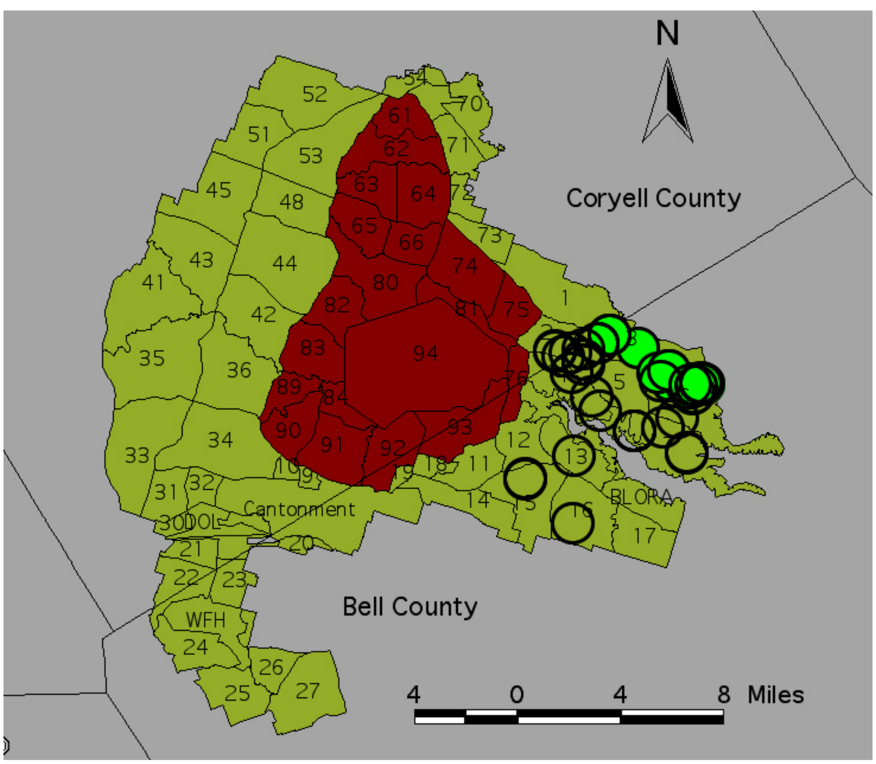
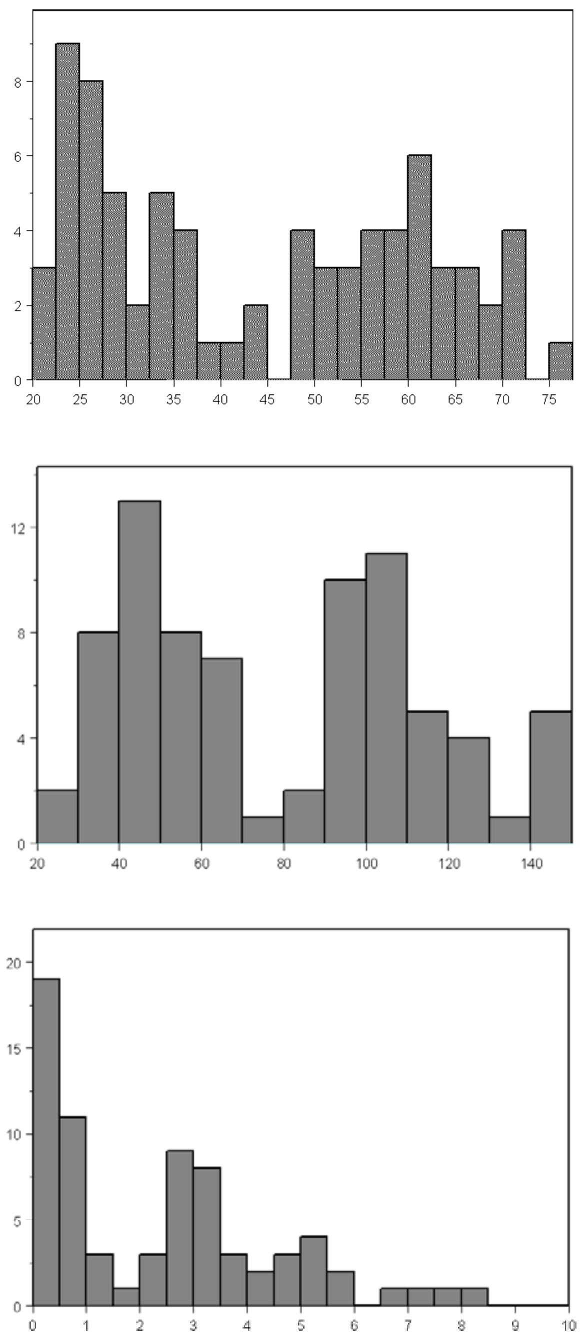


Figure 5. Sites at which ***Plethodon*** **sp. was confirmed in present study (circles filled with green) and those at which no** ***Plethodon*** **were found (open circles).**

Table 2. Means, variances, and ranges for SVL (mm), ToTL (mm) and Mass (g) of *Plethodon* sp.

Statistic	SVL	ToTL	Mass
Mean	44.28	77.59	2.32
Variance	294.01	1204.38	4.31
Range	21.1 – 75.3	25.4 – 143.7	0.1 – 8.0
Sample size (n)	78	78	73*

* Five individuals weighed less than 0.1 g each, the lower limit of our field scale.



A

B

C

Figure 6. Frequency histograms: (A) SVL (mm, N = 77); (B) ToTL (mm, N = 77) and (C) Mass (g, N = 72) for *Plethodon* sp. captured at Fort Hood, Texas.

There was no significant ($\alpha = 0.05$) difference in the number of active RIFA mounds between *Plethodon* and non-*Plethodon* features (two-tailed t-test, $t = -0.206$, $p = 0.84$, Figure 7). The correlation of active RIFA mounds and number of *Plethodon* sp. detected per unit effort was not significant ($r^2 = -0.0223$).

We encountered *Plethodon* sp. at all four features during the return visits, but we did not recapture any marked individuals.

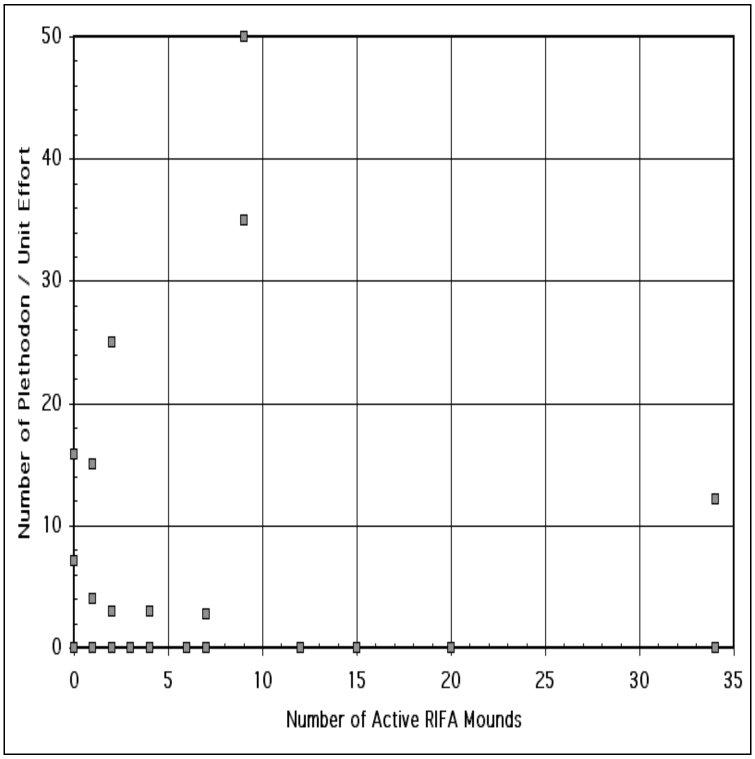


Figure 7. Relationship between number of active RIFA mounds within 15 m of feature and number of *Plethodon* sp. detected per unit effort.

4 Discussion

The data fail to demonstrate any meaningful relationship between either RIFA variable (active RIFA mound counts and numbers of RIFA in bait traps) and the presence/absence or abundance of *Plethodon* sp. The lack of a discernable relationship suggests either (1) that there is not a strong relationship between RIFA and *Plethodon* sp. or (2) that we are not able to detect such a relationship. However, *Solenopsis invicta* can be overwhelming as a predator and difficult to control. For these reasons, we feel that it would be prudent to focus some *Plethodon* sp. management efforts toward limiting the impacts of RIFA on sites where the salamander is known to occur. A relationship between RIFA abundance and *Plethodon* sp. population size may become more apparent when a robust estimate of population size is available for the salamander.

The four sites that were visited twice provide an opportunity to examine mark-recapture results. Because we did not recapture any marked individuals, we cannot estimate population size using any of the available models (e.g., Jolly-Seber, Schnabel, Schumacher and Eschmeyer; see Phillips et al. [2001] for a discussion and analysis of these methods), but the lack of recaptures also suggests the population is likely to be larger than the number of specimens recorded thus far. More intensive surveys including several visits per year over several years would be required before a robust estimate of population size could be derived (Phillips et al. 2001).

Finally, the size distribution of snout vent length (SVL) in Figure 6 suggests that the overall age structure of the Fort Hood *Plethodon* sp. may be normal and healthy. Using the date for *Plethodon glutinosus* from Florida (Highton 1956), the smallest individuals in Figure 6A would appear to be somewhere late in their first year of growth. Using the same data, individuals over 45 mm SVL would likely be sexually mature. We caution that the data for *P. glutinosus* may not reflect the biology of the Fort Hood species. Additional field measurements of SVL taken on a monthly basis over a 2-year period at sites where the species is fairly abundant (e.g., Bear Springs, Estes Cave) should provide a stronger foundation for understanding the life history and age class structure of this species.

A modest list of additional reptile and amphibian taxa was compiled during the present study (Appendix B). The list suggests that a more thorough survey of the herpetofauna of Fort Hood may yield additional taxa. Such a survey should focus on searches of multiple habitat types and include multiday field visits during various seasons (excluding winter) to maximize faunal diversity.

During bait trapping, several additional ant taxa were collected in bait traps. In addition, we observed, photographed, and collected another ant species, the Subterranean Army Ant (*Labidus coecus*), feeding on a cave cricket (*Ceuthophilus cunnicularis*) in one of the caves—this find may have management implications with regard to *Solenopsis invicta*. Texas is home to more than 190 ant species (O'Keefe et al. 2000), yet only about 20 ant species are known from Bell County, and only 7 from Coryell County. This suggests that a much more extensive search for various ant taxa should yield additional faunal diversity at Fort Hood. The diversity of ants, and other invertebrate taxa, is especially important in assessing the impact of RIFA on natural communities. RIFA is thought to generally have a negative impact on diversity and abundance of ants (e.g., Porter and Savignano 1990 and others, see Morrison 2002) and arthropod faunas in general (e.g., Vinson 1994), though recent work suggests this effect may lessen with time (Morrison 2002).

Acknowledgements

Jean Krejca and Jenn Mui provided invaluable help with fieldwork and many useful discussions. We thank Dr. Dave Hillis for assisting us in the field one day. We thank James Reddell and Marcelino Reyes for useful discussions and showing us an easier way to get to Estes Cave. We thank B. R. Jones for repeatedly trying to provide us with access to the Rocket River Cave System, even though we never managed to get the timing right. Finally, John Cornelius and Mike Denight also provided useful discussions and guidance.

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Appendix A: Literature Sources

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Crowell, R. L. 1981. Microhabitat selection and feeding ecology of troglophilic plethodontid salamanders in northwestern Arkansas. Ph.D. dissertation, University of Arkansas.

Little literature is available on the relationship of salamanders of the genus *Plethodon* and ants. However there is a more significant body of literature on the interactions of ants with other herpetofauna. This could be important if other reptile and amphibian species at Fort Hood are adversely affected by the invasion of the RIFA. We have included these citations and a few abstracts below.

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Anderson, M. T. and A. Mathis. 1999. "Diets of two sympatric neotropical salamanders, *Bolitoglossa mexicana* and *B. rufescens*, with notes on reproduction for *B. rufescens*." *Journal of Herpetology*. 33(4):601-607.

Abstract:
Life-history data were collected for the tropical salamanders *Bolitoglossa rufescens* and *B. mexicana* at a site in Veracruz, Mexico. Individuals of both species consumed a wide range of prey taxa, but ants (Hymenoptera: Formicidae) comprised a large proportion of the diets of both species. Niche breadth for *B. rufescens* was significantly narrower than *B. mexicana*, due, in part, to a stronger representation of ants in the diet (importance values for ants: *B. rufescens* = 0.480, *B. mexicana* = 0.343). We hypothesize that this difference in dietary breadth is due to differences in body size and, possibly, microhabitat; *B. rufescens* is smaller and strictly arboreal while the larger *B. mexicana* occupies both terrestrial and arboreal habitats. Diets also differed in size of prey; the larger species consumed significantly larger ant prey. Although there was substantial dietary overlap in terms of the taxa of prey consumed, niche separation based on size of prey may be important for these two species. Due to relatively low numbers of *B. mexicana* in the sample, reproductive data were collected only for *B. rufescens*. Developing follicles were visible in all female *B. rufescens*, but only six out of the 16 females had enlarged ova (minimum SVL of a female with enlarged ova = 24 mm). Because only two of the remaining females were smaller than 24 mm, we infer that most of the "non-gravid" females were sexually mature. Two out of 19 males in the sample were immature. Size sexual dimorphism is minimal for this species. The largest five individuals that were captured were females, but, overall, males and females were not significantly different in size.

Bellocq, M. I., K. Kloosterman, and S. M. Smith. 2000. "The diet of coexisting species of amphibians in Canadian jack pine forests." *Herpetological Journal* 10(2):63-68.

Abstract:
Diets of adults of amphibian species coexisting in the boreal forest are poorly understood. We quantified and compared the diets of adult amphibians from four jack pine (*Pinus banksiana*) forests in east-central Canada. Results showed that American toads (*Bufo americanus*) and northern redback salamanders (*Plethodon cinereus*) were predominantly ant-eaters; bluespotted salamanders (*Ambystoma laterale*) fed mainly on snails, beetles, and insect larvae; spring peepers (*Pseudacris crucifer*) took primarily spiders and wasps; and wood frogs (*Rana sylvatica*) took a variety of alternative prey and had the highest dietary diversity. Diets of these amphibians differed significantly among the species in all study sites. Discriminant analyses showed species separation based on food type, the variable representing the proportion of ants in stomach contents being the major contributor to the discriminant functions in all assemblages.

Caldwell, R. S. 1975. "Observations on the winter activity of the red-backed salamander *Plethodon cinereus* in Indiana USA." *Herpetologica* 31(1):21-22.

Camp, C. D. and L. L. Bozeman. 1981. "Foods of 2 species of *Plethodon* (Caudata: Plethodontidae) from Georgia and Alabama, USA." *Brimleyana* 0(6):163-166.

Abstract:
The stomachs of 34 *P. websteri* and 55 *P. serratus* from Georgia and Alabama were examined for food. Acarines and Collembola were major food items in stomachs of smaller *P. websteri*; ants were predominant in the stomachs of larger individuals. Ants were the dominant food item in the stomachs of *P. serratus*.

Cochran, P. A. 1998. "Early herpetological observations by a northeastern Wisconsin conservationist." *Bulletin of the Chicago Herpetological Society* 33(4) 73-74.

Notes:
Notophthalmus viridescens louisianensis, Bear Paw Lake(Wisconsin, Oconto County); Hibernating in ant hill, 1946 record; Records & observations by W. Fisk, 1944-1947.

Forester, D. C. 1979. "Observations of ant predation upon brooding salamanders." *Herpetological Review* 10(1):3-4.

Freed, P. S., and K. Neitman. 1988. "Notes on predation on the endangered Houston toad, *Bufo houstonensis*." *Texas Journal of Science* 40(4):454–456.

Summary:
In this paper, the authors report the first observation of predation on tadpoles of the Houston toad by two species of colubrid snakes, as well as predation on newly-metamorphosized toads by the red imported fire ant, *Solenopsis invicta*. The study was conducted in the spring of 1986 with toads that were released at the Attwater's Prarie Chicken National Wildlife Refuge in Colorado County, Texas.

Gunzburger, M. S. 1999. "Diet of the Red Hills Salamander *Phaeognathus hubrichti*." *Copeia* 199(2):523-525.

Abstract:
I examined the diet of *Phaeognathus hubrichti* using stomach contents of preserved specimens and fecal samples from live salamanders. Land snails (20%) and arthropods (68%), including ants, beetles, and spiders, were the most numerous prey items found. Diet composition may indicate how habitat quality affects foraging behavior of Red Hills salamanders.

Hall, R. J. 1976. "Summer foods of the salamander *Plethodon wehrlei* (Amphibia: Urodela: Plethodontidae)." *Journal of Herpetology* 10(2):129-131.

Abstract:
A large sample of feeding records was obtained for *P. wehrlei* in Pennsylvania [USA] for the summer. Weevils, insect larvae, centipedes, spiders, and orthopterans comprise the bulk of summer food. The most important single prey species is the introduced European strawberry weevil. Prey frequency varies ontogenetically and through the summer. Mites and ants are frequently eaten, but probably contribute little to the salamanders' energy intake.

Jensen, J. B. and M. R. Whiles. 2000. "Diets of sympatric *Plethodon petraeus* and *Plethodon glutinosus*." *Journal of the Elisha Mitchell Scientific Society* 116(3):245-250.

Abstract:
We examined the gut contents of sympatric *Plethodon petraeus* and *Plethodon glutinosus* collected from Pigeon Mountain, Georgia in 1992, 1998, and 1999. Although a wide variety of invertebrates was found in *P. petraeus* guts, ants and beetles were encountered most frequently. The diet of *P. glutinosus* was much more varied. Knowledge of these two species' diets may help us better understand their competitive foraging behaviors and guide habitat management and conservation decisions.

Lee, D. S. and A. W. Norden. 1973. "A food study of the green salamander *Aneides aeneus*." *Journal of Herpetology* 7(1):53-54.

Mitchell, J. C. and W. S. Woolcott. 1985. "Observations of the microdistribution, diet and predator-prey size relationships in the salamander *Plethodon cinereus* from the Virginia Piedmont (USA)." *Virginia Journal Of Science* 36(4):281-288.

Abstract:
Several aspects of the ecology of *Plethodon cinereus* from the central Virginia Piedmont were examined during 1980-1982. Unlike mountain populations in Virginia, which have higher red-back morph frequencies, lead-back morphs predominated in the Piedmont population. During the wet spring of 1980 *P. cinereus* were more abundant in the upland portion of the study area than in lower portions. During the drought-influenced spring of 1981 salamanders were more abundant in the lower portion of the area. The drought conditions probably caused this difference in microhabitat distribution. There were no significant differences in distribution of lead-back and red-back morphs for three soil components but red-back morphs preferred higher pH soils than leadback morphs. Both morphs preferred soils with less moisture than found in randomly selected control samples. Ants, collembola and mites were consumed most frequently by *P. cinereus* in two study sites. Proportions of prey types takenwere similar between sites. There was no significant correlation of prey size with salamander size. These latter two results suggest Piedmont *P. cinereus* forage randomly in the soil-leaf litter habitat.

Moulis, R. A. 1997. "Predation by the imported fire ant (Scoenopsis invicta) on Loggerhead Sea Turtle (*Caretta caretta*) nests on Wassaw National Wildlife Refuge, Georgia." *Chelonian Conservation and Biology* 2 (3):433-436.

Mount, R. H. 1981. "The red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae), as a possible serious predator on some native southeastern vertebrates: direct observations and subjective impressions." *Journal of Alabama Academy Sciences*. 52 (2):71-78.

Mount, R. H., S. E. Trauth and W. H. Mason. 1981. "Predation by the red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae), on eggs of the lizard *Cnemidophorus sexlineatus* (Squamata: Teiidae)." *Journal of Alabama Academy Sciences*. 52 (2):66-70.

Perez, M. V., M. J. Gil, and M. Lizana. 1990. "Food habits and trophic availability in the high mountain population of the spotted salamander from Spain (*Salamandra salamandra almanzoris*) (Caudata: Salamandridae)." *Folia Zoologica* 39(4):341-353.

Abstract:
We studied the diet of 133 specimens of *Salamandra salamandra almanzoris* from two sites in the Sierra de Gredos (province of Avila, Spain). The diet is basically insectivorous, consisting mainly of Coleoptera, Diptera and Formicidae. The food habits of this montane population differ notably from those in other areas within the Iberian Peninsula and Europe. We discuss our results in relation to the peculiar habitats which *Salamandra salamandra* occupies in Gredos, and the trophic availability of the arthropods in the environment.

Rayan, T. J. 1998. "Larval life history and abundance of a rare salamander, *Eurycea junaluska*." *Journal of Herpetology* 32(1):10-17.

Abstract:
The larval life history of *Eurycea junaluska* was studied in three southwestern North Carolina populations. Populations were sampled quarterly over a 13 mo period and size-class analyses were used to evaluate the pattern of larval growth and metamorphosis. Young of the year appeared in the late spring and experienced rapid growth through the first summer. Growth slowed in the second year and metamorphosis usually occured in the summer at about 25.5 mo post-hatching, although some data suggest that either 1 yr or 3 yr larval periods may be possible. The overall larval growth rate of *E. junaluska* is estimated at 1.27 mm/mo, much higher than in other stream-dwelling plethodontids. This species typically represents only about 10%

of the larval *Eurycea* community, with adults even less common. The relative scarcity of individuals and the significant distance between documented populations raises concern about long term population viability in the face of declines due to either natural or anthropogenic causes, or both.

Reagan, D. P. 1972. "Ecology And Distribution Of The Jemez Mountains salamander, *Plethodon neomexicanus*." *Copeia* 1972(3):486-492.

Roedel, M. O. and U. Braun. 1999. "Associations between anurans and ants in a West African savanna (Anura: Microhylidae, Hyperoliidae and Hymenoptera: Formicidae)." *Biotropica* 31(1): 178-183.

Rubin, D. 1969. "Food habits of *Plethodon longicrus*." *Herpetologica* 25(2):102-105.

Suarez, A. V. and T. J. Case. 2002. "Bottom-up effects on persistence of a specialist predator: ant invasions and horned lizards." *Ecological Applications* 12(1):291-298.

Torres, J. A. et al. 2000. "Ant and termite predation by the tropical blindsnake *Typhlops platycephalus*." *Insectes Sociaux* 47(1):1-6.

Whitaker, J. O., Jr. and D. C. Rubin. 1971. "Food Habits of *Plethodon jordani metcalfi* and *Plethodon jordani sherman* from North Carolina." *Herpetologica* 27(1):81-86.

Whitaker, J. O., Jr., C. Maser, R. M. Storm, and J. J. Beatty. 1986. "Food habits of clouded salamanders (*Aneides ferreus*) in Curry County, Oregon, (USA) (Amphibia: Caudata: Plethodontidae)." *Great Basin Naturalist* 46(2):228-240.

Abstract:
Stomach contents of 650 clouded salamanders (*Aneides ferreus*), collected monthly throughout the year from Curry County, Oregon, were examined. Samples from three age classes were involved: (1) 489 adults, (2) 131 juveniles, and (3) 30 hatchlings. Foods did not vary by sex, but did vary by age and by season. Hatchlings ate small items, particularly mites, springtails, flies, and small beetles. Juveniles fed mainly on flies, isopods (sowbugs), beetles, mites, and centipedes in winter; beetles, ants, and isopods in spring; ants and beetles in summer; and isopods, beetles, and ants in fall. Adults ate isopods and beetles as their major foods in winter, spring, and fall and isopods, ants, beetles, and earwigs in summer. Four species were exceedingly important as foods for these salamanders: an unidentified isopod, the snout beetle (*Trachyphloeus bifoveatus*), the European earwig (*Forficula auricularia*), and an ant (*Lasius alienus*).

Appendix B: List of Amphibians and Reptiles Collected at Fort Hood, Texas, During *Plethodon* sp. Surveys in 2002

Species	INHS number*	Date	Location	County	Comments
Cnemidophorus gularis	17873	6 February	Owl Creek	Coryell	Found dead
Scincella lateralis	18235	7 February	Treasure Cave	Bell	Found at bottom of first drop in cave
Pseudacris streckeri	17872	8 February	main rd.	Bell	Hopping across road next to a pud-dle
Rana berlandieri	17874	8 February	Estes Cave	Bell	Found in bottom of cave
Rana berlandieri	17875	8 February	Moffatt Pit Cave	Bell	Found in bottom of cave
Tantilla gracilis	18043	10 April	Lucky Rock Cave	Bell	
Acris crepitans	18022	10 April	Newby Cave	Bell	Found in bottom of cave
Acris crepitans	18023	10 April	Newby Cave	Bell	Found in bottom of cave
Bufo punctatus	18024	10 April	Newby Cave	Bell	Found in bottom of cave
Syrrhopus marnocki	18025	10 April	Newby Cave	Bell	Found in bottom of cave
Eumeces tetragrammus	18026	10 April	Newby Cave	Bell	
Eumeces tetragrammus	18027	10 April	Newby Cave	Bell	
Eumeces tetragrammus	18028	10 April	Newby Cave	Bell	

* Second column is the Illinois Natural History Survey accession number.

Species	INHS number*	Date	Location	County	Comments
Tantilla gracilis	18029	10 April	Newby Cave	Bell	
Acris crepitans	18030	10 April	Bear Spring	Bell	Found in bottom of cave
Acris crepitans	18031	10 April	Bear Spring	Bell	Found in bottom of cave
Salvadora grahamiae lineata	18037	11 April	Fort Hood	Bell	On road to Taylor Spring
Syrrhopus marnocki	18032	12 April	Skeeter Cave	Bell	Found in bottom of cave
Cophosaurus texanus	18033	12 April	Skeeter Cave	Bell	Under rock
Sceloporus olivaceus	18038	12 April	Fort Hood	Bell	Under rock on way up to training area
Leptotyphlops dulcis	18041	12 April	near Owl Creek cross-ing	Bell	Under rock
Leptotyphlops dulcis	18042	12 April	near Owl Creek cross-ing	Bell	Under rock
Bufo valliceps	18034	13 April	Toad Load	Bell	
Agkistrodon contortrix	18035	13 April	Toad Load	Bell	found dead at bot-tom of cave
Thamnophis proximus ru-brilineatus	18036	13 April	Fort Hood	Bell	Collected on road back from Nolan Creek Cave Spring
Storeria dekayi	18039	14 April	Estes Cave	Bell	
Micrurus fulvius tener	18040	14 April	Estes Cave	Bell	Found at bottom of first drop in cave
Graptemys pseu-dogeographica	18234	4 June	arroyo near Hatchi's Hatchet	Bell	Shell with decom-posing eggs and girdle bones
Cnemidophorus sexlineatus	18228	5 June	near Fecksome Cave	Bell	
Scincella lateralis	18230	5 June	Bumelia Well Cave	Bell	Found at bottom of first drop in cave
Scincella lateralis	18231	5 June	Bumelia Well Cave	Bell	Found at bottom of first drop in cave
Scincella lateralis	18232	5 June	Bumelia Well Cave	Bell	Found at bottom of first drop in cave
Scincella lateralis	18233	5 June	Bumelia Well Cave	Bell	Found in bottom of cave

[1]Second column is INHS accession number.

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14. ABSTRACT

ABSTRACT: Salamanders of the genus *Plethodon* occur in a variety of mesic woodland habitats. Recently, populations of an undescribed species have been discovered at Fort Hood, Texas. These populations are associated with features such as caves and sinkholes. Red imported fire ants (RIFA), *Solenopsis invicta* Buren, are thought to compete with cavernicoles for food and sometimes prey upon animals in the caves, but their impact at Fort Hood has not been closely examined.

This research documents (1) the presence/absence and abundance of *Plethodon* sp. at selected caves and sinkholes on Fort Hood and (2) the presence or absence of RIFA at features surveyed for *Plethodon* sp.

The data fail to demonstrate any meaningful relationship between either active RIFA mound counts or numbers of RIFA in bait traps and the presence/absence or abundance of *Plethodon* sp. Because RIFA can be overwhelming as a predator and difficult to control, management efforts should focus toward limiting the impacts of RIFA on sites where the salamander is known to occur. A more robust estimate of the population size for the salamander is needed. General size data suggest that the salamander population is normal and healthy.

15. SUBJECT TERMS
salamander, survey, natural resource management, caves, Plethodontidae, Fort Hood, TX

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