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Taxonomic Status of *Bufo simus* O. Schmidt, 1857 (Anura: Bufonidae)

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Abstract.—The taxonomic status of *Bufo simus* Schmidt, 1857, is reviewed. Comparisons of the lectotype with members of different species groups of South American *Bufo*, reveal that *B. simus* is a junior synonym of *Bufo spinulosus* Wiegmann.

Based on a sample of small, juvenile toads obtained by the Polish commercial botanist and collector Josef Warsewicz, Schmidt (1857) described *Bufo simus*, purportedly from "Río Chiriqui, near Boca del Toro" (Panama). Günther (1901) applied this name to some populations of Mexican *Bufo*, an action followed by several subsequent authors (Kellog, 1932; Smith and Taylor, 1948). Firschein (1950) did not share this opinion, stated that those Mexican populations corresponded to *Bufo occidentalis* Camerano and considered *Bufo simus* to be a nomen dubium. Taylor (1951) identified an adult toad collected by Helen T. Gaige in Boquete, Panama, as the adult form of *B. simus* and also discarded its identity with any Mexican toad population. Simultaneously, Dunn and Stuart (1951) suggested that the type locality of *B. simus* might be wrong, because the material obtained by Warsewicz had erroneous original data.

Savage (1972) examined Taylor's adult specimen, and designated it as the holotype of a new species, *Bufo peripatetes*. Upon examination of some of the syntypes of *B. simus*, Savage (1972), pointed out that the species definitely was not from Middle America and suggested that, most probably, it originated from Peru or Bolivia, countries also visited by Warsewicz. Savage (1972) concluded: "The name *Bufo simus* cannot be firmly associated with any South American toad population at this time. To expedite comparison and final allocation of the name, the British Museum example, BM 1947.2.21.18, is hereby designated the lectotype of *Bufo simus* O. Schmidt, 1857. It can be anticipated that future comparisons of the lectotype with *Bufo* from Peru and Bolivia by workers familiar with these forms will make final allocation of the name possible. Suffice it is to say that the name cannot be used for any North or Central American toad and should be struck from lists of the amphibian fauna of the region."

Other similar cases of species collected by Warsewicz and described by Schmidt with erroneous type localities in Panama have been already addressed. Savage (1969) realized that *Bufo veraguensis* Schmidt was a senior synonym of *Bufo ockendeni* Boulenger, from Peru and Bolivia; Duellman and De la Riva (1999) rediscovered *Gastrotheca splendens* (Schmidt) in Bolivia (originally described from "Panama" as *Hyla splendens*). However, despite Savage's (1972) conclusion, to the best of my knowledge, no herpetologist familiar with South American toads has addressed properly the case of the species inquirenda *B. simus*. In contrast, numerous taxonomic studies of South American species of *Bufo* took place during the last decades, and most of them overlooked the existence of the *B. simus* problem, which might have lead the situation to greater taxonomic confusion (see De la Riva et al., 2000). The only exception is the recent description of a new species of toad from Peru by Duellman and Schulte (1992).

Materials and Methods

Museum specimens were examined under stereomicroscope and measured to the nearest 0.1 mm with digital calipers. Museum abbreviations are BM, Natural History Museum, London; CBF, Colección Boliviana de Fauna, La Paz; KU, Natural History Museum, the University of Kansas, Lawrence; and MNCN, Museo Nacional de Ciencias Naturales, Madrid.

Results and Discussion

The lectotype of *B. simus* (BM 1947.2.21.18), like all the specimens in the type series (nine specimens deposited in five different museums, according to Savage [1970]), is a recently metamorphosed juvenile, 15.5 mm in SVL (Fig. 1). Based on the comparison of *B. simus* with juveniles of species in groups of South American *Bufo* with representatives in Peru and Bolivia, *B. simus* can readily be shown not to be a member of the *Bufo granulosus*, *Bufo guttatus*, *Bufo marinus*, or *Bufo typhonius* groups. Members of the *B. granulosus* group have a characteristic array of cranial crests (Gallardo, 1965) absent in *B. simus*. Members of the *B. gutattus* group have dorsal skin smooth, in contrast with the warty skin of *B. simus*. The differences between *B. simus* and *B. marinus* were pointed out by Savage (1972), and all of them apply to the other species of the *B. marinus* group in the central Andean countries: *Bufo arenarum* Hensel (Bolivia), *Bufo poeppigii* Tschudi (Peru and Bolivia), and *Bufo schneideri* Werner (= *Bufo paracnemis* Lutz; Bolivia); additionally, the parotoids of *B. simus* are small and rounded, in contrast with the large, elongated parotoids of those species (see De la Riva, 2002). Members of the *B. typhonius* group have cranial crests, pointed snout, and a bony knob at the angle of the jaw, characters absent in *B. simus*.

Comparisons of *B. simus* with the *Bufo veraguensis* group as a whole are more complicated, for characters in this group show remarkable interspecific variation (see Duellman and Schulte, 1992). At present, the Bolivian-Peruvian fauna of the *B. veraguensis* group is composed by the species *Bufo amboroensis* Harvey and Smith, *Bufo arborescandens* Duellman and Schlute, *Bufo chavin* Lehr, Köhler, Aguilar, and Ponce, *Bufo fissipes* Boulenger, *Bufo inca* Stejneger, *Bufo justinianoi* Harvey

FIG. 1. Lectotype of *Bufo simus* Schmidt, 1857 (BM 1947.2.21.18); SVL = 15.5 mm.

and Smith, *Bufo nesiotes* Duellman and Toft, *Bufo quechua* Gallardo, and *B. veraguensis* Schmidt.

Duellman and Schulte (1992) provided a key for the species then included in the *B. veraguensis* group and, more recently, Pramuk and Kadivar (2003) provided a key for most *Bufo* of the Peruvian Andes. Both keys and the examination of specimens at hand show that *B. simus* can be distinguished from *B. fissipes*, *B. inca*, *B. justinianoi*, *B. quechua*, and *B. veraguensis* by the absence of cranial crests (although it has been generally admitted that *B. fissipes* lacks cranial crests [e. g., Duellman and Schulte, 1992; Lehr et al., 2001], a recent report on this species [Köhler, 2000], indicates that canthal, supraorbital, and supratympanic crests are present). From *nesiotes*, *B. simus* differs by having a row of enlarged dorsolateral tubercles and first finger longer than second; this latter character also distinguishes it from *B. arborescandens*. Contrary to *B. chavin*, *B. simus* lacks cranial crests and enlarged glands on tibia and forearms. Finally, *B. simus* differs from *B. amboroensis* by, among other features, having toes only partially webbed, instead of fully webbed. In summary, *B. simus* is conspecific with no species in the *B. veraguensis* group as it is currently delimited.

The only species group that remains to be considered in relation to *B. simus* is the *Bufo spinulosus* group. In a recent account of the Peruvian and Ecuadorian species in this group, Pramuk and Kadivar (2003) recognized seven species: *Bufo amabilis* Pramuk and Kadivar, *Bufo arequipensis* Vellard, *Bufo cophotis* Boulenger, *Bufo corynetes* Duellman and Ochoa, *Bufo limensis* Werner, *Bufo spinulosus* Wiegmann, and *Bufo vellardi* Leviton and Duellman. Pramuk and Kadivar (2003) overlooked the important contribution by Córdova (1999), in which, based on cytogenetics, *B. arequipensis* was placed in the synonymy of *B. spinulosus*. *Bufo arequipensis* was described by Vellard (1959) as a subspecies of *B. spinulosus*, and the two forms, impossible to distinguish (C. Aguilar, pers. comm.), had been already considered synonyms by several authors (Gorham, 1974; Rodríguez, 1995).

To ascertain the taxonomic status of *B. simus* in relation to the *B. spinulosus* group, I have used the key provided by Pramuk and Kadivar (2003) and compared the lectotype of *B. simus* with fresh specimens of *Bufo* spp. from the CBF, MNCN, and KU (see Appendix 1). *Bufo corynetes* and *Bufo cophotis* have longitudinal series of enlarged glands on dorsum, which are absent in *B. simus*. The parotoid glands of *B. simus* are rounded, in opposition to the elongated and triangular or subtriangular glands of *B. amabilis*, *B. limensis*, and *B. vellardi*. *Bufo simus* is in all respects similar to *B. spinulosus*. Adult specimens of *B. spinulosus* have a small, depressed tympanum, with tympanic annulus not distinct (Pramuk and Kadivar, 2003). Unfortunately, tympanic characters are often not observable in recently metamorphosed anurans (see Etherington, 1988). This delayed development of the outer ear apparatus in postmetamorphic stages seems to be common in bufonids; I have examined juveniles of other species (e.g., *B. major*, *B. marinus*), which have tympanum as adults, and they lack a tympanum while small juveniles. This is the case in the lectotype of *B. simus* too.

Comparisons of the lectotype of *B. simus* with Bolivian and Peruvian juveniles of *B. spinulosus* of similar size (for example, CBF 00065 from Lahuachaca [Department of La Paz, Bolivia, 17°23′S/67°40′W] and MNCN 41986 from Yura [Department of Arequipa, Peru, 16°12′S/71°42′W]) show that both specimens are similar in all respects, including the absence of tympanum. Recently collected specimens have darker coloration, which most probably is a consequence of the much longer time the lectotype of *B. simus* has been in preservative. In the most complete description of the species, Schmidt (1858) pointed out that there was color variation in the sample studied, some small specimens being almost black; interestingly, he stated that the tip digits were yellow and there were yellow blotches on hands and feet. Duellman and Ochoa (1991) considered this coloration in hands and feet of juveniles and metamorphs to be a diagnostic feature of all the members of the *B. spinulosus* group. *Bufo spinulosus* is a common species in the altiplano and puna from northern Peru to at least 43°S in Argentina and Chile (Cei, 1972; Pramuk and Kadivar, 2003). Juveniles of this species are often found in large numbers; the yellow or orange areas on hands and feet are always noticeable. Thus, careful reading of Schmidt's paper by someone familiar with Andean *Bufo* would have securely led to the clarification of the status of *B. simus* much earlier. Based on all the previous arguments, I formally propose that *B. simus* O. Schmidt, 1857, be considered a junior synonym of *B. spinulosus* Wiegmann, 1834.

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Appendix 1

Material Examined.—*Bufo amboroensis*: BOLIVIA: Cochabamba: Río Chua Khocha, La Siberia (MNCN

41987). *Bufo arborescandens*: PERU: Amazonas: 5 km N Mendoza, 06°18′S/77°27′W, 2400 m (KU 209394, 209395, holotype). *Bufo chavin*: PERU: Huánuco: Palma Pampa, 09°53′14″S/75°53′21″W, 3010 m (MTKD D 44318). *Bufo cophotis*: PERU: Cajamarca: S. slope Abra Quilsh, 26 km NNW Cajamarca, 3500 m (KU 196626; KU 211711); 55 km N Cajamarca, 3600 m (KU 211733); S. slope Abra Comulica, 20 km NE Encanada, 3520 m (KU 211741). *Bufo corynetes*: PERU: Cuzco: Abra Málaga, 50 km NW Ollantaytambo, 13°09′S/72°20′W, 3780 m (KU 173229, holotype); San Luis, 13°09′S/72°21′, 3200 m (KU 212554). *Bufo fissipes*: PERU: Puno: Santo Domingo, Carabaya (BM 1947.2.20.64, holotype). *Bufo nesiotes*: PERU: Huánuco: Laguna, W. slope of Serranía de Sira, 1280 m (KU 154920, holotype). *Bufo quechua*: BOLIVIA: Cochabamba. Tablasmontes (MNCN 41988). *Bufo spinulosus*: BOLIVIA: La Paz: road Quime - Inquisivi, 16°55′49″S/67°09′24″W, 3594 m (MNCN 41989); road Charazani - Curva 15°08′06″S/69°02′03″W, 3700 m (MNCN 41990); Lahuachaca, 17°23′S/67°40′W (CBF 00065). PERU: Arequipa: Yura (MNCN 41986). *Bufo veraguensis*: BOLIVIA: Serranía Bellavista, 15°42′13″S/67°29′15″W, 1450 m (MNCN 41991).

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Versatility of Habitat Use in Three Sympatric Species of Plethodontid Salamanders

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Abstract.—*Eurycea cirrigera*, a relatively small species that occurs in the Allegheny Mountains, appears to fill in the gaps along the aquatic-terrestrial gradient that are left by two sympatric salamander species; the terrestrial *Plethodon cinereus* and semiaquatic *Desmognathus fuscus*. To better understand the local distribution of these three species we tested the hypothesis that *E. cirrigera* is better able to utilize a variety of microhabitats than *P. cinereus* or *D. fuscus*. In field enclosures change in mass in relation to initial mass, as a proxy of fitness, was compared for each species, in three different habitats (stream, stream bank, and forest) over time. Independent of species the stream habitat showed a significant negative effect on the fitness of all individuals. Additionally, *E. cirrigera* showed significantly higher fitness than *P. cinereus* over all three treatments. The mean fitness of *D. fuscus* was intermediate, but not significantly different than *P. cinereus* or *E. cirrigera*. These results suggest that, in the absence of predation and competition, *E. cirrigera* is not negatively affected by being a generalist.

Coexistence of similar species is one of the most important questions in ecology. Niche theory states that competitive, sympatric species must have different resource needs (MacArthur and Levins, 1967), and has been invoked to explain the distribution of plethodontid salamanders (Southerland, 1986a,b). Competition and predation have also been supported as important factors affecting the distribution of plethodontids along a stream to terrestrial gradient (Hairston, 1949, 1951, 1980, 1986; Beachy, 1993, 1997). However, these salamanders also have important resource needs in terms of hydration (Grover, 1996, 2000; Grover and Wilbur, 2002) and diet (Hairston, 1949) that have not been examined in as much detail.

The southeastern United States is the most species-rich area of the world in terms of salamanders (Petranka, 1998). At an elevation of 1160 m, the Mountain Lake Biological Station (MLBS) in southwestern Virginia has seven species (four genera) of plethodontid salamanders. The majority of these species can be found living at least macrosympatrically along most stream environments. Hairston proposed that plethodontid species decrease in size as they become more terrestrial due to competitive interactions (Hairston, 1949) or predation by larger species (Hairston, 1980, 1986, 1987) that push the smaller species away from the optimal, stream, habitat. At the MLBS, Grover (1996, 2000) found a direct relationship between body size and dehydration/rehydration rates. His data offer an alternative explanation for the fact that larger plethodontid species (*Desmognathus quadramaculatus* and *Desmognathus monticola*) are found in streams, whereas a smaller species, *Plethodon cinereus*, occupies more terrestrial areas.

Both forest and stream portions of this gradient have been studied extensively (e.g., Jaeger et al., 1998; Lancaster and Jaeger, 1995; Southerland, 1986a,b,c,d; Kleeberger, 1984). The stream to forest ecotone, however, has not been examined in as much detail, leaving a gap in our understanding of relationships within this gradient (but see Grover and Wilbur, 2002). This study focused on three plethodontid species that can be found within the ecotone: *Plethodon cinereus*,

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TABLE 1. Number of individuals recaptured after 21 days for each species, (*Desmognathus fuscus*, *Eurycea cirrigera*, and *Plethodon cinereus*) in each habitat (stream, stream bank, and forest). Initial counts were all 10.

Habitat	*D. fuscus*	*E. cirrigera*	*P. cinereus*
Stream	9	9	6
Bank	9	9	10
Forest	10	8	7

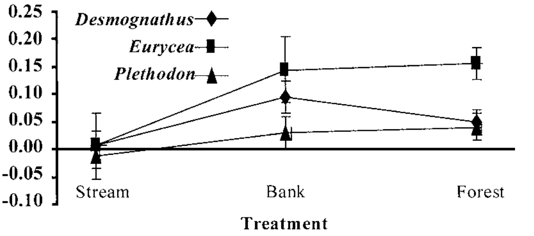

FIG. 1. Performance of *Desmognathus fuscus*, *Eurycea cirrigera*, and *Plethodon cinereus* in the stream, bank, and forest habitat simulations. Performance is measured as the change in mass over 21 days, divided by the initial mass.

a completely terrestrial salamander, *Desmognathus fuscus*, an aquatic specialist, and *Eurycea cirrigera*, a species bound to water for reproduction but also found throughout the stream-forest gradient as adults. From previous studies we know that desiccation resistance (Grover, 1996, 2000), foraging needs (Hairston 1949), and competition (Beachy, 1986; Hairston, 1949, 1951) play important roles in the distribution of salamanders along these gradients.

In this study, we examined one factor affecting the distribution of a species, versatility of habitat use, which may account for the way *E. cirrigera* is seemingly able to coexist with other salamanders and use the ecotone. It may be the case that *E. cirrigera* is able to fill in gaps left open when other species are absent. To test the hypothesis that *E. cirrigera* is a more versatile species, in the sense that it is able to more effectively use a variety of habitats, we measured the size-specific change in mass of *E. cirrigera* in three different habitats over time and compared these data to two more specialized species, *D. fuscus* and *P. cinereus*. If there is a cost to being a generalist, one would expect *E. cirrigera* to have intermediate fitness in all habitats and *D. fuscus* and *P. cinereus* to have the highest fitness in the habitat in which they most often occur in nature.

MATERIALS AND METHODS

This study was conducted in and around the Spring Stream cattle bunks at Sartain Branch, south of the Mountain Lake Biological Station, Virginia (37°22′32″N, 80°31′20″W, elevation 1160 m), and extended through June and July 2002. The focal section of stream in this study is a small, shallow portion located approximately 10 m downstream of the spring source. Heavy cover of *Rhododendron maximum* encompasses the immediate study area, resulting in a shady, moist environment. The surrounding forest is a high elevation mixed deciduous forest dominated by Northern Red Oak, *Quercus rubra*.

To test the versatility of the three species, different habitat zones (stream, bank and forest floor) were simulated in 90 0.65 $\times$ 0.42 m plastic bins, covered by window screening to prevent colonization by terrestrial invertebrates. A layer of gravel lined the bottom of each bin. Soil was placed on top of the gravel for the bank and forest simulations only. A cover object, a rock for the stream and bank simulations and a log for the forest simulations, was added to each bin. Also, using a shovel, a 0.03 m deep 0.21 $\times$ 0.07 m volume of substrate was taken from the top layer of substrate adjacent to each bin and placed inside the bin in order to supply macroinvertebrates as food for the salamanders. PVC piping and plastic tubing were used to plumb water from the spring through the stream habitat bins. Each bin was then placed in its respective area in the field. Stream simulation bins were placed in cattle bunks (3.35 m long, 0.69 m wide, and 0.63 m deep) located within the stream itself, and elevated to avoid chemical contamination from bin to bin. Bank simulation bins were placed directly on the slope of the bank just above the water's edge. Forest simulation bins were placed approximately 3 m from the stream edge.

A 3 $\times$ 3 factorial design with 10 randomized blocks was used for this experiment. Each of the three species was crossed with each of three habitat zones (forest floor, stream bank and stream). Blocks were arranged spatially and temporally so that all of the treatments within a block were located along the same portion of stream and the animals were added to the bins on the same day. *Eurycea cirrigera*, *P. cinereus*, and *D. fuscus* were collected daily for one week from James River drainage tributaries. Each salamander was placed individually in a randomly chosen bin, and blocks were set up to run as soon as enough individuals were collected (three individuals per species, nine total), so that holding time was minimized (always less than two days). All individuals remained in their designated bins for 21 days. Mass, snout–vent length, and tail length of each individual were measured, using a digital scale and digital calipers, before and at the conclusion of the experiment. A ratio of change in mass to initial mass

TABLE 2. ANOVA results for the change in mass/initial mass data. Change in mass is the difference in mass from the beginning of the experiment to the end of the experiment. Species include *Desmognathus fuscus*, *Eurycea cirrigera*, and *Plethodon cinereus*. Treatments include stream, stream bank, and forest.

	df	Mean	*F*	*P*
MODEL	17	0.027	2.87	0.001
BLOCK	9	0.024	2.16	0.016
SPECIES	2	0.063	6.72	0.002
TREATMENT	2	0.059	6.32	0.003
SPECIES $\times$ TREATMENT	4	0.008	0.86	0.492

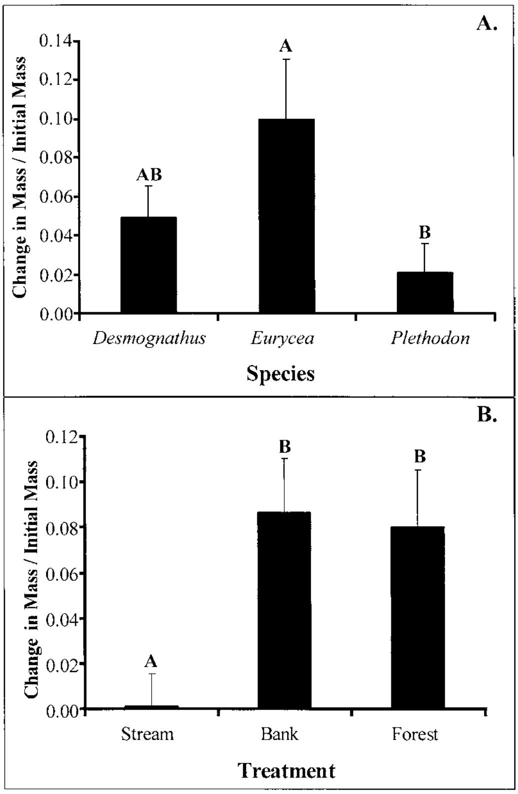

FIG. 2. (A) Species performance, independent of habitat treatment for *Desmognathus fuscus*, *Eurycea cirrigera*, and *Plethodon cinereus*. (B) Treatment performance, independent of species, in the stream, bank, and forest habitat simulations. Differing letters depicts significant differences.

was used as a measure of condition, so that size variation across species and individuals could be taken into account. Because escape did occur, an incomplete block ANOVA was incorporated, and escape data were analyzed using a Chi-square test. The latter indicated that escapes occurred randomly across species (χ^2 = 0.92, P = 0.92, df = 4; Table 1).

RESULTS

After accounting for the block effect, the species-treatment interaction was not significant (Table 2, Fig. 1). However, both species and treatment effects were significant (Table 2). A posthoc Scheffe test (α = 0.05) determined that *E. cirrigera* had a significantly higher gain in mass than *P. cinereus* when all three habitat treatments were combined (Fig. 2). An additional Scheffe test (α = 0.05) determined that all individuals (regardless of species) within the stream treatment gained significantly less mass than individuals in either the bank or forest treatments (Fig. 2).

DISCUSSION

This study demonstrates that without the influence of competition and predation, individual condition of salamanders varied by both habitat and species. *Eurycea cirrigera*, a habitat generalist, gained significantly more mass than *P. cinereus*, the terrestrial specialist, over all three habitat treatments. This trend was also found when *E. cirrigera* was compared to *D. fuscus*, although the difference was not significant. These results support previous work by Southerland (1986c), reinforcing the idea that an intermediate species is most versatile in its use of habitats. The results from the stream treatment data indicate that all individuals had poor fitness in the stream habitat regardless of species, including *D. fuscus*, an aquatic specialist, suggesting that the aquatic setup may not have been biologically appropriate.

Previous studies on the distribution of plethodontid salamanders along a gradient from the stream to the forest have focused on competition (Southerland, 1986d) and predation (Hairston, 1986; Jaeger et al., 1998). Those studies that did examine habitat versatility addressed the question through choice experiments (e.g., Southerland, 1986a,d) and found that competition has a significant effect on choice of habitat by an individual or species. For this study, we removed effects of competition and predation so that performance alone, in terms of size-specific change in mass, could be examined when individuals were restricted to three simulated natural habitats. Additionally, we did not give salamanders a choice of habitat so that we could examine ability to acclimate to an environment even if it was not a preferred habitat. We found that *E. cirrigera* is best able to acclimate to a variety of habitats and pays little cost to being a generalist.

In nature, predation and competition may play large roles in determining the distribution of *E. cirrigera*, and possibly inhibit an individual's ability to thrive in habitats when more specialized species are present. Unfortunately, effects of predation and competition on distribution of *Eurycea* remain largely unknown. Beachy (1997) demonstrated that *Eurycea wilderae* experienced differential growth rates when exposed to different levels of predation by *Desmognathus quadramaculatus* in the larval stage. Little else is known about effects of competition and predation on this genus. Additional work with *E. cirrigera* is needed to test its ability to compete with and avoid predation from sympatric species and how these interactions might affect habitat distribution.

The unexpectedly poor performance results of all individuals within the stream habitat suggest that all of these species may not forage in the stream environment. Poor performance in the stream environment is expected for *P. cinereus*, since it is a terrestrial specialist. However the poor performance results from the other two species, especially *D. fuscus*, is interesting since *D. fuscus* is an aquatic specialist and *E. cirrigera* is partially bound to the water (Petranka, 1998). The cold, highly oxygenated water of Appalachian streams may provide good habitat for respiration and hydration for lungless plethodontid salamanders but may offer few foraging opportunities. Gut content analyses of all three species has shown that the majority of their diet includes terrestrial invertebrates, such as spiders, worms, flies, and beetles (Jaeger, 1972; Sites, 1978). Hairston (1949) found through gut content analysis that desmognathines ate a larger proportion of terrestrial prey than would be expected from the habitats where they are normally encountered. Aquatic species may use the aquatic environment for respiration and hydration and conduct the majority of their foraging in more terrestrial environments. In support of this, Southerland (1986a,d) showed that when given the choice, desmognathine salamanders spent a large portion of their time in terrestrial environments. The high change in mass of *D. fuscus* in the bank environment suggests that these aquatic salamanders need both the terrestrial and aquatic habitats.

Constraining plethodontid salamanders to a single simulated microhabitat type is common in experimentation (Beachy, 1994, 1997; Bernardo, 1994; Wiltenmuth, 1997). Artificial constriction of a habitat type may hinder ability of salamanders to forage under experimental conditions. In our experiment, we intentionally constrained salamanders in specific habitat types, to test effects of these habitats on animals. Our results suggest that future ecological experiments involving aquatic or semiaquatic plethodontid salamanders should include a stream to terrestrial gradient to better mimic their natural environment.

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