INVESTIGATING ENERGY FLOW PATHWAYS THROUGH A HEADWATER TOP PREDATOR: FOOD WEBS, PREY AVAILABILITY AND INDIVIDUAL VARIATION

by

AMY ELAINE TRICE

(Under the Direction of Amy D. Rosemond)

ABSTRACT

Little is known about the trophic ecology of headwater stream salamanders beyond basic diet snapshots. These important predators likely drive numerous ecosystem functions. During a two-year study period, I investigated the seasonal changes and species-specific differences in three distinct headwater stream salamander species (*Desmognathus quadramaculatus, Desmognathus ocoee* and *Eurycea cirrigera).* Through the application of stable isotopes, mixing models, gut content analysis, and biomass estimates of both salamanders and their prey, I provided an evaluation of headwater stream spatial and temporal variation, as well as the trophic ecology of salamanders, within the headwaters of the Etowah River watershed.

INDEX WORDS: Biomass, Carbon isotope, $\delta^{13}C$, $\delta^{15}N$, *Desmognathus ocoee, Desmognathus quadramaculatus*, Etowah River, *Eurycea cirrigera*, Headwater stream, Nitrogen isotope, Macroinvertebrate, Mixing model, Salamander, Seasonal, Trophic

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DEDICATION

I dedicate this work to my grandparents, Hartford and Neva, who taught me at a young age to appreciate the wonderful streams of South Georgia. The memories that lie within will never be lost. I am forever grateful for their loving spirit.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

PREFACE

Food webs inherently encompass both energy flow pathways and the interactions among trophic groups. Headwater stream ecosystems, in particular, are influenced in complex ways by both in situ production and allochthonous terrestrial inputs. Community assemblages, in our case macroinvertebrates and salamanders, utilize these energy resources differently within the stream ecosystem. Knowledge of larval salamanders' ecological role within stream ecosystems is lacking (Register et al. 2006) with even less known about their influence on energy flow both within stream and as a terrestrial subsidy. As land use begins to alter both energy subsides, shifts in food webs are likely depending on the degree or extent of alteration. The importance of food webs and understanding energy flow dynamics of top predators before land alterations occur is the overarching focus of this dissertation.

The research presented here was originally premised to assess the effects of low impact development on headwater stream food webs, centered on larval salamanders. Baseline pre-development data is presented here. Through this research larval salamander species were investigated with more depth, analyzing individual variation in isotopic composition. In the pages that follow I identify the importance of salamanders in headwater stream ecosystems, estimate their prey biomass through within stream and diet sampling and define how one species in particular may alter our interpretation of isotopic values for top predators. Generally, we highlight the importance of these underappreciated predators and more broadly, implications for headwater stream ecosystems in terms of habitat alteration and conservation of salamanders.

CONSERVATION AND ECOLOGY OF SALAMANDERS

Salamanders are declining globally mainly as a result of anthropogenic habitat loss (Dodd and Smith 2003). These declines likely have unknown consequences to ecosystem processes (Davic and Welsh 2004, Petranka et al. 1993, Whiles et al. 2006). Moreover, limited information exists on the trophic ecology and energy transfers (Register et al. 2006) of this dominant headwater stream vertebrate. The southern Appalachians encompass high diversity of salamander fauna (Petranka and Smith 2005, Hairston 1987) with biomass estimates in forests often exceeding all other vertebrates combined (Petranka and Murray 2001). Due to their high diversity and biomass, conservation of salamanders is of considerable importance. What is more, is very few studies have provided evidence for their ecological significance as many populations diminish (Milanovich 2010, Whiles et al. 2006).

Salamanders of the family Plethodontidae are the focus of this research. The family Plethodontidae is lungless with both semi-aquatic and terrestrial forms. The semi-aquatic forms (e.g., most species of *Desmognathus* and all of *Eurycea*, *Pseudotriton*, and *Gyrinophilus*) are diverse within the Appalachian highlands (Petranka 1998). These semi-aquatic species possess biphasic life histories with larval periods ranging from five months – four years depending on species (Petranka 1998). Integrating across terrestrial aquatic linkages, these biphasic species serve as important predators within stream ecosystems and serve as important prey items as they metamorphose into the terrestrial ecosystem (Miller et al. 2007) making preservation of both stream and riparian habitats vital to Plethodontidae conservation (Crawford et al. 2007).

ANALYTICAL APPROACHES

I used several analytical approaches aimed at: 1) quantifying the primary prey sources of salamanders, 2) quantifying salamander biomass and 3) quantifying salamander prey biomass.

To quantify the primary prey sources for salamanders, diet analyses were coupled with both stable isotopes and mixing models. Diet analysis of salamanders provided a snapshot of present energy resources. Stable isotopes, which integrate incorporation of prey items into tissue over time, are useful in that they provide a measure of what carbon and nitrogen sources are assimilated, rather than simply consumed. The stable isotope of nitrogen (^{15}N) measures trophic structure of the consumer while the isotope of carbon (^{13}C) provides information on what energy resources are being used. Studies examining stable isotopes at or near natural abundance levels are reported as delta (δ), a value given in parts per thousand or per mil. Delta values are not absolute isotope abundances but differences between sample readings and widely used natural abundance standards which are considered δ = zero (e.g. atmospheric air for N, at $\%^{15}N = 0.3663033$; Pee Dee Belemnite for C, at $\%^{13}C = 1.1112328$). A hierarchical Bayesian mixing model, incorporating measured stable isotope values, was also used to predict prey composition in terms of functional feeding groups of individual's salamander species isotopic composition. The model estimated variability in diet both spatially (stream scale) and temporally (season).

Different approaches were used to quantify the biomass of salamanders and macroinvertebrate prey. Salamander biomass was evaluated using leaf litter bags and dip netting. Repeated counts were used to estimate capture probability for each species across all four sites. Macroinvertebrate biomass was measured using core and surber sampling techniques to investigate both pool and riffle habitats.

OVERVIEW OF REMAINING CHAPTERS

The first research objective, addressed in Chapter 2, was to determine energy flow pathways via prey utilization by salamanders in headwater streams. I quantified four, seasonal headwater stream food webs near Jasper, GA, USA, (34° 44' N 84° 22' W) to obtain descriptions of trophic structure prior to land use alteration. Studies that have quantified energy flow in headwater stream ecosystems have found them highly dependent on allochthonous carbon from the surrounding forest (Hall et al. 2000, Wallace et al. 1997). Changes in watershed land use are predicted to reduce dependence on allochthonous sources of carbon and increase dependence on *in situ* production (England and Rosemond 2004). This may occur through both reductions in forested land cover and associated detritus and increased autochthonous production due to increased nutrient loading or light availability. I hypothesized shifts in $\delta^{13}C$ and $\delta^{15}N$ of salamander predators and macroinvertebrate prey due to spatial and temporal drivers. To assess prey utilization by salamanders I used a combination of stable isotope analysis, a hierarchical Bayesian model and gut content analyses of salamanders. Stream community composition may also affect food web interactions so measurements of seasonal variation in predators (salamanders and macroinvertebrates) and primary consumers (macroinvertebrates) relative biomass are also incorporated into Chapter 2.

The second research objective was to analyze individual isotopic (*Eurycea cirrigera*, *Desmognathus ocoee* and *Desmognathus quadramaculatus*) and diet (*Eurycea cirrigera* and *Desmognathus quadramaculatus*) variation of salamanders with regards to body size (Chapter 3). I observed individual salamander isotopic values to incorporate a great deal of variability; therefore, body size was investigated as a potential cause of variability. The same headwater streams that I quantified contribution of prey types to salamanders were also used to investigate patterns in body size. Comparisons in $\delta^{15}N$ vs. body size were also evaluated at the Coweeta Long-term Ecological Research Site (LTER) Otto, NC. I hypothesized individual variation may alter our interpretation of salamander energy sources. To assess this individual variation I used measures of isotopic composition and gut content analysis. I compared isotopes of two species of salamanders to snout-vent length (SVL). After observing a decreasing trend of $\delta^{15}N$ with SVL in *Desmognathus quadramaculatus*, I used gut content analysis to help inform this trend. Potential maternal effects on isotopic composition were also investigated.

Chapter 4 (Conclusion) synthesizes the results from Chapters 2-3.

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CHAPTER 2

SEASONAL PATTERNS IN ENERGY FLOW AND PREY UTILIZATION BY HEADWATER STREAM SALAMANDERS IN THE SOUTHEASTERN U.S.A.[1]

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ABSTRACT

The southern Appalachian region harbors an extraordinary diversity of salamanders, but is also an area of rapid development and associated conversion of forested land to other uses. To inform conservation efforts of herpetofauna in this region, we quantified sources of energy flow to headwater stream salamanders and determined seasonal patterns in salamander biomass and the prey resources they depended on. We used individual-based stable isotopic mixing models of salamanders, combined with gut content analyses, to determine patterns of prey utilization and tested whether those patterns changed seasonally (spring, summer, fall) in four headwater streams. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopic signatures of all three species of salamanders (*Desmognathus ocoee, Desmognathus quadramaculatus, and Eurycea cirrigera*) were intermediate between multiple basal resource signatures and occupied the top trophic levels in all seasons. Dominant prey resources changed slightly seasonally: predatory macroinvertebrates (predators), dominated summer diets, predators and scrapers dominated in spring and predators and collector-gatherers dominated in fall. Mixing model results were roughly consistent with gut contents, but showed greater reliance on macroinvertebrate predators. Both salamander species analyzed for gut contents (*D. quadramaculatus* and *E. cirrigera*) utilized a wide variety of prey (up to 52 total unique taxa between the two species), but there was little overlap in the macroinvertebrate taxa that dominated diets between the two species. Macroinvertebrate predator and collector-gatherer biomass was highest in pool habitats, and scraper biomass was highest in riffles, indicating that both habitats are necessary for production of food resources supporting salamander populations. Thus, conservation of diverse in-stream habitats as well as diverse basal resources are likely critical to maintain populations of salamanders in similar headwater streams.

KEYWORDS: Biomass, Carbon, Nitrogen, Isotope, $\delta^{13}C$, $\delta^{15}N$, Headwater stream, Macroinvertebrate, Mixing model, Salamander, Seasonal, Trophic

INTRODUCTION

Stream-dwelling amphibians are highly threatened globally with watershed clear cutting, disease, habitat degradation, acid mine draining, acid deposition and sedimentation contributing to declines (Aber et al. 2000, Dodd and Smith 2003, Stuart et al. 2004). Specifically, 29% of identified salamander species in the United States have a conservation status of imperiled or critically imperiled in at least part of their range (Davic and Welsh 2004) likely due to habitat modification (Dodd and Smith 2003). Petranka et al. (1993) estimated losses of salamanders in clearcut national forests of western North Carolina to be in the millions. The southern Appalachian region harbors an extraordinary diversity of salamanders, which are most abundant in headwater streams and associated riparian ecosystems (Petranka 1998). Salamanders of the family Plethodontidae, in particular, serve as important predators in these headwater streams and become important prey as they metamorphose and migrate into the terrestrial system (Miller et al. 2007). Despite their dominance in vertebrate biomass of eastern North American forests (Burton and Likens 1975), we know very little of their ecological roles in aquatic food webs (but see Milanovich 2010 and Davic and Welsh 2004), on which they rely during development.

Larval salamanders are the top predators in the fishless streams they occupy and their growth rates and mass per area have been shown to be bottom-up limited. Studies have demonstrated that supplementation of prey increased growth rates of *Ambystoma texanum* (Ambystomatidae) larvae in a central Kentucky stream, indicating bottom-up control of salamander growth rates by production of macroinvertebrates (Petranka 1984). Other resources, by affecting prey production, likewise may limit salamander growth rates, production or mass. Wallace et al. (1997, 1999) reported reduced abundance, biomass and production of a larval salamander population, presumably due to reductions in prey, when detrital litter inputs were excluded for three years compared to a reference stream. Johnson and Wallace (2005) focused on *Eurycea wilderae* as part of this experimental manipulation and found both reduced growth rate and fewer prey items per gut compared to *E. wilderae* in the non-litter excluded, reference stream. In a resource addition study, Johnson et al. (2006) found that nutrient addition, presumably by stimulating production of stream invertebrates, resulted in greater growth rates of *E. wilderae.* Together, these studies show strong connections between watershed-derived resources and bottom-up control of salamander growth rates via responses in prey.

Although identification of sources of prey supporting stream salamanders is necessary to establish their essential resource base, few studies have identified specific prey or energy resources for larval salamanders (but see Burton 1976, Davic 1983, Davic 1991, Johnson and Wallace 2005). Of those studies that have used diet analyses, metamorphosed individuals incorporate a high percentage of terrestrial prey in their diets (Hairston 1987), whereas, larvae that inhabit streams or ponds almost exclusively ingest aquatic prey (Davic 1991). Stable isotopic analysis integrates carbon incorporation from multiple sources, and these analyses have focused almost entirely on cave dwelling salamanders (Fenolio et al. 2006) or on threatened anurans (frogs) in tropical upland streams indicating their importance as major consumers (Whiles et al. 2006). In this study, we used both diet and stable isotope analyses to determine probable dominant food resources for larval stream salamanders. Patterns in seasons and habitat (pools or riffles) essential for production of prey were also identified. Specifically, we used high resolution (individual based) stable isotope analyses coupled with gut content analyses to determine patterns in energy flow and prey resource utilization by salamanders in four headwater streams. We compared findings from stable isotope mixing models (from three seasons) and gut contents (from two seasons) to assess congruence of results between these approaches.

The salamander species we analyzed (*D. quadramaculatus*, *D. ocoee* and *E. cirrigera*) are known to possess a biphasic life history with emergence generally occurring in summer months (Petranka 1998). Headwater deciduous streams are strongly affected by heavy summer shading, autumn inputs of allochthonous detritus, spring autochthonous production and associated seasonal patterns in macroinvertebrate production (Webster et al. 2006). In this study, we tested for seasonal (and habitat-specific) patterns in macroinvertebrate biomass and patterns in salamander biomass. Using the information based on the resources identified as important to salamanders (above), we describe patterns in seasons and habitat essential for production of prey critical to maintenance of salamander populations in southeastern headwater streams.

METHODS

Four study streams were used as replicates to determine patterns in salamander prey utilization and to determine seasonal patterns in salamander and prey biomass. All streams were in heavily forested watersheds and are second-order headwater tributaries to the Etowah River. Located in the Blue Ridge region of north Georgia near Jasper, GA, USA, (34° 44’ N 84° 22’ W) the streams are typical of cold-water Appalachian mountain streams. Study sites were within the Dawson Forest Wildlife Management Area and Potts Mountain, GA. Nutrient concentrations in all streams were low and displayed little variation between streams (Table 2.1).

MACROINVERTEBRATE BIOMASS – Taxonomic composition and biomass of macroinvertebrates were determined from samples based on seasonal energy inputs (November 18-21 2008 – fall, March 24-30 2009 – spring, July 22 2009 – summer), assuming these patterns occur seasonally. Pools and riffles were analyzed in a 100 m reach of each stream. Five riffles at each stream were sampled using a Surber sampler (250 µm mesh; 0.09 m^2 sampling area) and hand scrubbing rocks for three minutes. Five pools were also sampled at each stream with a stovepipe corer (0.04 m^2). The top 10 cm of sediment was removed and elutriated in the field by rinsing through a 250 µm sieve (Roy et al. 2003). Samples were returned to the lab on ice and preserved in 70% ethanol. All large macroinvertebrates (i.e. >1mm) were hand-picked using a dissecting scope at 10X magnification. If necessary, small macroinvertebrates (i.e. <1mm) were sub sampled and hand-picked. Chironomids were identified as Tanypodinae or non-Tanypodinae and non-insects identified to order. Macroinvertebrate insect larvae were identified to genus using standard taxonomic keys (Merritt et al. 2007, Wiggins 1977). Individuals were then measured to the nearest 0.5 mm and biomass measured as ash-free dry mass (AFDM) quantified using genus-specific length-mass regressions (Benke et al. 1999).

SALAMANDER BIOMASS – We used a repeated sampling design accounting for imperfect detection to estimate salamander biomass. A combination of leaf litter bags and dip netting were employed (sensu Chalmers and Droege 2002, Peterman et al. 2008b, Nowakowski and Maerz 2009) from April 2008 – November 2008 (prior to macroinvertebrate biomass sampling which began November 2008). Leaf litter bags (55 x 25 cm made with 1.3 cm^2 mesh) were filled with deciduous litter from the surrounding forest and spaced 10 m apart in the wetted portion of the 100 m stream channel and allowed to soak for 72 hours. On each of three consecutive days, litter bags were sampled by quickly lifting the bag from the stream and placing it in a container of stream water. Bags were agitated and rinsed with stream water to dislodge larval salamanders. Salamanders were identified, counted and measured (snout-vent length, SVL).

We used a simple abundance estimation corrected for estimated occupancy assuming incomplete detection (MacKenzie et al. 2002). Repeated counts were used to estimate capture probability for each species across all four sites. We then used the mean number of individuals per occupied litter bag among the three consecutive sample dates divided by capture probability to estimate mean abundance of occupied litter bags. We estimated the proportion of litter bags occupied by estimating detection probability using a model where detection could vary among sites, during the three-day sampling process, and by site and season. We multiplied the proportion of litter bags occupied by the number of total number of litter bags (n = 10) and multiplied by the estimated mean abundance to generate our mean abundance. We regressed wet mass on SVL for each species to establish species-specific length mass regressions that were used to estimate AFDM. We converted AFDM estimates to estimates of species-specific biomass per season per species measured as mg AFDM m^{-2}. Estimates of capture probability, detection probability and occupancy were generated through program MARK (MARK, 2004 Version 4.2).

It should be noted that because our sampling effort lacked individual capture histories and limited sampling effort within seasons was insufficient to estimate temporary emigration. Studies of adult (Bailey et al. 2004) and larval (Perofsky, unpublished honors thesis) plethodontids indicate that temporary emigration is high (>85%), suggesting that only 15% of the population is available for sampling at any time. Therefore, our estimates of abundance and biomass really represent short-term surface estimates, and not total population abundance or biomass estimates. However, if we assume that temporary emigration rates are similar among sites and habitats, then our surface population estimates are sufficient for comparing seasonal and site differences in biomass. "Super-population" estimates would require correcting for temporary emigration, and are likely to be on the range of an order of magnitude higher than the values we report (Bailey et al. 2004).

STABLE ISOTOPIC SIGNATURES OF CARBON AND NITROGEN – Samples for stable isotopes were collected for a variety of basal food resources, macroinvertebrate taxa and salamander taxa. Samples were collected over the same seasonal periods as macroinvertebrate biomass. For data analyses, streams were used as replicates and means of sample types were determined by each stream and season. Basal resource samples consisted of n=5 per stream for fine particulate organic matter (FPOM, < 1 mm, > 0.7 μm), biofilm (hard substrate algae and soft substrate algae, n=10 per stream), n=3 coarse particulate organic matter (CPOM > 1mm) per stream, and n=2 seston per stream, for a total of 80 samples per sampling date for basal resources. FPOM was obtained by disturbing the streambed and sifting organic matter through a 1mm sieve. Samples were then filtered onto 0.7 μm filters, oven-dried at 60°C and ground. CPOM samples consisted of grab samples of terrestrial derived leaf litter collected randomly within stream at three sites, oven-dried at 60°C and ground for isotopic analysis. Seston samples were collected upstream and downstream of the 100m sampling reach in three, 1-L Nalgene bottles (6L) and lyophilized. A Loeb sampler (modified after Loeb 1981) was used to obtain biofilms, ten samples were taken in each stream, five hard substrate and five soft substrate. 20 ml of each were lyophilized for stable isotope analyses.

Ten numerically dominant macroinvertebrate taxa (varied in functional feeding group (FFG) and family) and salamanders (*Eurycea spp., Desmognathus quadramaculatus, Desmognathus ocoee*) were sampled for each stream during each season. Macroinvertebrate specimens for stable isotopes were collected during the 2008-2009 seasonal sampling for biomass. Specimens were sorted by hand for all macroinvertebrate taxa present. After collections, macroinvertebrates were identified to lowest taxonomic level using standard taxonomic keys (Merritt et al. 2007, Wiggins 1977). Specimens were frozen, later guts removed before being dried and ground for stable isotope analysis. Salamander specimens were collected at night (each season after biomass samples were collected), when larvae are most active, using an aquarium dip net (1 mm mesh) and headlamp by turning over rocks and leaf litter within the stream (Johnson and Wallace 2005). Salamanders were immediately euthanized with a 0.5% solution of Tricaine methanesulfonate (MS-222) buffered with sodium bicarbonate. Immediately after euthanasia, salamanders were rinsed with deionized water, tails placed in vials and placed immediately on ice for stable isotope analysis, with the remaining body preserved in Kahle's solution in the field to preserve gut contents. All isotopic samples were homogenized and weighed in tin capsules. Samples were then combusted in a Carlo Erba (Milan, Italy) NA 1500 CHN analyzer coupled to a Finnigan Delta C mass spectrometer (Thermo Electron Corp., Waltham, MA, U.S.A.) as a continuous flow system at the Odum School of Ecology Analytical Lab, University of Georgia. A laboratory working standard (bovine liver and poplar leaves) was placed every 12 samples. Isotope ratios are expressed as $\delta^{13}C$ or $\delta^{15}N$ (with units of permil). Delta values are not absolute isotope abundances but differences between sample readings and one or another of the widely used natural abundance standards which are considered delta = zero (atmospheric air for N, At $\%^{15}N = 0.3663033$; Pee Dee Belemnite for C, At $\%^{13}C = 1.1112328$).

SALAMADNER DIET ANALYSIS – Diet analysis was performed on *D. quadramaculatus* (n=45) and *E. cirrigera* (n=43) individuals comprised from both March (spring) and July (summer) of 2009. Each animal's SVL from the tip of the snout to the posterior portion of the vent was measured to the nearest mm. In the laboratory, guts were removed under a stereo microscope and contents teased out. Insect taxa were identified to genus when possible except for Chironomidae, which were identified as either non-Tanypodinae or Tanypodinae. Non-insect taxa were identified to order. All prey items were measured to the nearest millimeter using an ocular micrometer (Johnson and Wallace 2005). Prey biomass (AFDM) was estimated using established length-mass or head width-mass regressions (Sample et al.1993; Benke et al. 1999; Sabo et al. 2002).

DATA ANALYSES – Isotopic composition ($\delta^{15}N$ and $\delta^{13}C$) was investigated to discern differences in season (fall, spring, summer) and species, FFG or basal resources overall using a multivariate analysis (MANOVA). Effects of season on $\delta^{15}N$ or $\delta^{13}C$ were run separately for salamander species, FFG or basal resources on season were analyzed using ANOVA. Isotopic signatures of carbon and nitrogen were response variables and stream served as a blocking factor. An interaction effect of species, FFG or basal* season was also included.

Gut contents were also analyzed with MANOVA testing the effects of salamander species and season on % collector, % predator, % scraper and % shredder found within salamander guts. Both MANOVA tests used proc glm at $\alpha = 0.05$. ANOVA and MANOVA were run in SAS® Version 9.2 (SAS Institute Inc., Carey, NC, USA).

To predict prey composition in terms of functional feeding group isotopic composition of individual salamander, a novel hierarchical Bayesian mixing model designed by Semmens et al. (2009) was used The model (http://conserver.iugo cafe.org/user/eric.ward/Bayesian%20SI%20mixing%20models) incorporates multiple sources of uncertainty, while allowing for mean and variance parameters to be incorporated into the model framework to account for uncertainty in source isotope values (Moore and Semmens 2008). This modeling approach is unique in that it both estimates the composition of each salamanders' diet but also the variation in diet among particular portions of the population (Semmens et al. 2009). I used the model to estimate variability in diet composition among both spatial (stream) and temporal scales (season). The proportional contribution of each prey item to salamander isotopic composition was evaluated using MixSIR run in the program R (R 2.10.1, R Development Core Team 2010) and JAGS (Semmens et al. 2009). To assess the variation in trophic relationships among salamander species among seasons, individual salamander isotopes were analyzed for each season and average percent contribution of each functional feeding group found for each species. Individual salamander $\delta^{13}C$ values were corrected for lipid content based on C:N (Post et al. 2007). Individual isotopic values of macroinvertebrates were combined to obtain average functional feeding group prey values for each season. The isotopic fractionation values for $\delta^{13}C$ and $\delta^{15}N$ were set at 2.43 ± 0.25 and 1.67 ± 0.12 (Schiesari, Werner, Kling 2009, Whiles et al. 2006 and Maerz, unpublished data), respectively, based on previous tests for shifting with amphibians. Using uninformative priors, the MixSIR model ran for 8×10^4 iterations, resulting in convergence on posterior source contributions of the different functional feeding group prey items of the diet of individual salamander species (Moore and Semmens 2008). *D. quadramaculatus* exhibits a range of values according to body size (SVL), so only individuals greater than 20 mm SVL were averaged for both the mixing model and bi-plots (see Chapter 3). Results of the model are presented as mean and standard deviation.

Macroinvertebrate FFG biomass was examined using 2-way Analysis of Variance (ANOVA) to discern differences among seasons (spring, summer, fall) and among substrates (pool, riffle) for each of the four FFG (collectors, predators, scrapers, shredders) separately. We used 2-way ANOVA to detect differences in salamander biomass seasonally blocking by stream.

Interactions of season (spring, summer, fall) and species (*D. quadramaculatus*, *D. ocoee*, *E. cirrigera*) were also investigated to test for an effect on salamander biomass. All ANOVA statistics were performed using SAS® Version 9.2 (SAS Institute Inc., Cary, NC, USA).

RESULTS

SEASONAL PATTERNS IN STABLE ISOTOPIC SIGNATURES OF BASAL RESOURCES AND MACROINVERTEBRATE CONSUMERS – Dominant salamander species (*D. quadramaculatus*, *D. ocoee* and *E. cirrigera*) had higher trophic positions than macroinvertebrates (Figure 2.1). Salamanders' signatures of both $\delta^{15}N$ and $\delta^{13}C$ differed overall (Wilks' $\lambda = 0.58$, $F_{4,34} = 2.58$, $p = 0.05$) but were not significantly different for $\delta^{15}N$ among species or season (Table 2.2). The $\delta^{15}N$ values of consumers were enriched relative to mean values of the dominant primary producers, with the exception of biofilm, which contained high $\delta^{15}N$ values (Figure 2.1). FFG isotopes (both $\delta^{15}N$ and $\delta^{13}C$) differed significantly overall (Wilks' $\lambda = 0.13$, $F_{6,54} = 16.45$, $p < 0.0001$) and $\delta^{15}N$ values were significantly different among FFG ($p < 0.001$, Table 2.2). Macroinvertebrate predators ($\delta^{15}N$ approximately 2.0 $\%_o$ for all three seasons) were slightly below salamanders in $\delta^{15}N$ values (Figure 2.1). Isotopic signatures both $\delta^{15}N$ and $\delta^{13}C$ of the dominant organic carbon sources were clearly distinguished (Wilks' $\lambda = 0.02$, $F_{6,64} = 64$, $p < 0.001$) and seasonally different (Wilks' $\lambda = 0.63$, $F_{6,64} = 4.10$, $p = 0.005$). $\delta^{15}N$ values were different among basal resource type ($p < 0.001$) and among seasons ($p < 0.05$). $\delta^{15}N$ values increased from basal resources to primary consumers, macroinvertebrate predators and top predator salamanders in accordance with FFG descriptions as well as observed and known diet analysis. CPOM (approximately -3.0 $\%_o$ for all three seasons) differed from both FPOM (1.1$\%_o$ spring, -0.5 $\%_o$ summer and 0.2 $\%_o$ fall) and seston ($\delta^{15}N$ 0.6 $\%_o$ for spring and summer and -0.6 ‰ fall) in $\delta^{15}N$ (Table 2.2). CPOM was depleted in $\delta^{15}N$ relative to FPOM and seston. We observed depleted $\delta^{15}N$ values of CPOM compared to signatures of biofilm as well.

Carbon isotopic signatures differed among salamander species ($p = 0.03$, Table 2.2). FFG were significantly different from one another with respect to $\delta^{13}C$ ($p < 0.001$) with shredders being different from all other FFG. $\delta^{13}C$ of basal resources were significantly different among resources ($p < 0.001$). CPOM values were within expected ranges of terrestrial derived carbon (-28.7 – - 29.5‰) and were significantly different from FPOM and seston (Table 2.2). Carbon isotopic signatures of seston were variable ranging from -21.8 – -25.9‰. Isotopic signatures of individual salamander and macroinvertebrate species as well as basal resources can be found in Appendix 2.1.

EVIDENCE FOR MACROINVERTEBRATE PREY UTILIZATION BY SALAMANDERS USING STABLE ISOTOPE MIXING MODEL RESULT – Based on model results, salamanders derive most of their tissue from the predator functional feeding group (Table 2.3). Specifically, model results indicated predators dominated *D. ocoee* energy sources through all seasons; however, scrapers dominated in spring (49%) and 34% of the assimilated prey was composed of collectors in fall. *D. quadramaculatus* energy sources also were composed almost exclusively of predators in spring and summer (99%) however in fall a shift to 51% collectors and 40% predators occurred with model predictions. *E. cirrigera* mixing model results indicated 54% predator composition and 41% scraper composition in spring and *E. cirrigera* shifting to be incorporate more prey items into composition in fall with 16% collectors, 67% predators and 13% shredders. It should be noted that these are mean values from individual salamander isotopic model results. The complete model results can be found in Appendix 2.2.

SALAMANDER DIET ANALYSES– The model output generally predicted a greater assimilation of % predators contributing to isotopic composition within tissues compared to predator biomass found in guts, although predators comprised a large proportion of guts (except for *E. cirrigera* in the summer) (Table 2.3). Gut content of *D. quadramaculatus* also had a high % biomass of collectors not expressed in the model. *E. cirrigera* gut content incorporated a wider variety of unique prey compared to *D. quadramaculatus*, which was generally supported by the model. However, some discrepancies did exist, especially as more collector FFG occurred in guts of both *D. quadramaculatus* and *E. cirrigera* than were expressed in the model. Both *D. quadramaculatus* and *E. cirrigera* contained a number of unique prey items exclusive to each taxon (Table 2.4). Individual *D. quadramaculatus* and *E. cirrigera* species differed among % FFG consumed (Wilks' $\lambda = 0.82$, $F_{4,72} = 3.75$, $p = 0.0080$) and among season (Wilks' $\lambda = 0.85$, $F_{4,72} = 3.09$, $p = 0.021$) overall within gut content. Significant differences among species were found for % collector ($p = 0.013$) and % predator ($p=0.0007$). Seasonal differences existed in % scraper consumed ($p= 0.02$) and were marginally significant for % shredder ($p = 0.06$).

PATTERNS IN MACROINVERTEBRATE BIOMASS – Macroinvertebrate biomass varied markedly among seasons ($p = 0.0001$) and between habitats ($p = 0.02$) of pools and riffles (Table 2.5). Total biomass was peaked in spring with pools harboring the greatest biomass differing from all other seasons and substrate (Figure 2.2).

Standing stock biomass of important prey resources to salamanders was examined in more detail to investigate seasonal relationships. Collectors were significantly different between substrates ($p=0.02$) and among season ($p=0.02$) driven by the high biomass of spring pools (Figure 2.2). Scrapers varied between substrates ($p < 0.001$) being found almost exclusively in riffle habitats and among seasons ($p = 0.002$). Collector FFG biomass was dominated by

Diplectrona sp. (Trichoptera: Hydropsychidae), *Serratella* sp. (Ephemeroptera: Ephemerellidae) and *Parapsyche* sp. (Trichoptera: Hydropsychidae). Pools were dominated almost exclusively by the collector biomass of *Hexagenia* sp. (Ephemeroptera: Ephemeridae). The predator FFG consisted of high biomass estimates of *Arigomphus* sp. (Odonata: Gomphidae), *Hexatoma sp.* (Diptera: Limoniidae) and *Ceratopogon* sp. (Diptera). *Psilotreta* sp. (Trichoptera: Odontoceridae) dominated scraper biomass almost exclusively in riffle habitat, whereas *Hydatophylax* sp. (Trichoptera: Limnephilidae) and *Tipula* sp. (Diptera: Tipulidae) dominated shredder biomass.

PATTERNS IN SALAMANDER BIOMASS – Salamander biomass, in contrast to macroinvertebrate biomass, peaked in spring and summer. A significant interaction between season and species ($p=0.043$, Table 2.5) was observed. Biomass was similar among *D. ocoee* and *E. cirrigera* (Figure 2.3) among seasons with *D. ocoee* exhibiting slightly higher mean biomass across seasons compared to *E. cirrigera*. *D. quadramaculatus* exhibited the highest mean biomass in both spring and summer. It should be noted that we are currently evaluating the best way to model and present salamander biomass data for publication, as there are numerous estimates incorporated into these values. This is not to say that the dominant species and seasonal trends will be different, however absolute biomass values may alter for publication.

DISCUSSION

Salamanders are top predators in the headwater streams we sampled and utilize a diversity of prey resources. Prey groups, specifically collectors, predators and scrapers, rely on a variety of carbon resources and exhibit high biomass in a diversity of habitats (collectors dominated in pools, while scrapers dominated in riffle habitats). Allochthonous carbon from terrestrial sources was identified as a particularly important basal resource supporting salamanders, as basal carbon signatures of CPOM and FPOM were aligned with collectors and predators (in fall and spring), which were both important prey items for salamanders. Diet analyses confirmed larval salamanders were feeding almost exclusively on aquatic prey. Furthermore, the reliance on aquatic prey indicates salamanders are both important predators and likely controlled from the bottom-up in these systems via prey production. Macroinvertebrate biomass was highest in spring, suggesting production in that season is particularly important for larval salamander production.

Our data show that salamanders were highest trophically where macroinvertebrate predators were slightly below salamanders in $\delta^{15}N$ values and did not show seasonal differences (Figure 2.1). Although macroinvertebrate predators were averaged to obtain a predator FFG signature, it should be noted that in some instances macroinvertebrate predators exhibited $\delta^{15}N$ values similar to salamanders especially *Hexatoma* (Diptera: Limoniidae), *Gomphus* (Odonata: Gomphidae) and *Ceratopogon* (Diptera) (Trice, unpublished data). Basal resources were variable in their $\delta^{13}C$ and $\delta^{15}N$ signatures. Seston signatures were enriched compared to CPOM and FPOM, indicating a less depleted carbon source. The trophic position of all macroinvertebrate functional feeding groups, however, was more consistent with CPOM and FPOM food resource as $\delta^{15}N$ values for both seston and biofilm were higher than primary consumer groups. Variability observed by scrapers is likely explained by diverse food sources in diets, although scrapers depend primarily on autochthonous production they often ingest FPOM and animals (Cummins and Klug 1979).

Salamander gut content analyses were consistent with measured salamander isotopic signatures. Guts were composed of macroinvertebrate prey items (mainly collectors and predators for *D. quadramaculatus*), supporting the idea that salamanders are top predators in headwater streams. However, *D. quadramaculatus* did contain two *D. ocoee* larvae in two instances (Trice, unpublished data). Gut content analyses and mixing models, applied simultaneously, are valuable in understanding food web interactions, as isotopic signatures alone make teasing apart specific feeding relationships rather difficult. Mixing model results allowed an interpretation of stable isotope data in terms of our salamander predators, feeding on potential prey resources (collectors, predators, scrapers, shredders). These results generally estimated a greater reliance of % predators isotopic composition compared with biomass of predators found in guts (Table 2.3). Yet, *D. quadramaculatus* diets from gut analyses had a high biomass of collectors and predators, although collectors were not expressed within model output, whereas, *E. cirrigera* diets from gut content included a wider range of prey including collectors, predators and shredders in spring, which the model predicted. Disparities likely exist with mixing model results and gut content as gut content provides only a snapshot of consumer foraging preferences at present. Essentially, prey items that are consumed by an organism may not be assimilated into tissue (Mihuc and del Toetz 1994). The mixing model, however, measures stable isotope integration of carbon and nitrogen into consumer tissue over time. Salamander species are likely selectively feeding or at the least consuming individual prey from sources, which are more abundant in the stream as these prey items would be encountered more frequently. The majority of gut biomass of both species was collectors and predators, which also dominated within stream biomass.

Caveats inherent with all mixing models may also affect our model output and should be addressed. For example, species-specific shifting values are lacking overall for salamanders and may alter model output, due to lack of precise estimates. We used best available shifting values known for amphibians, in our case frogs (Schiesari, Werner, Kling 2009, Whiles et al. 2006 and Maerz, unpublished data). Specific values are needed for Plethodontidae as incorporating incorrect shifting values into the model could overestimate or underestimate prey contribution. Furthermore, the lack of source isotopic distinctiveness is of concern. Discrimination of sources is easier when you have divergent energy sources within the food web. Incorporating gut content analyses into detrital food web studies is, therefore, vital particularly in instances where shifting values and feeding relationships are unknown, as the case with salamanders. It is important to note that the Bayesian framework is a large advance in stable isotope mixing models allowing the user to incorporate individual isotopic data, providing increased biological relevance as organisms are known to exhibit intraspecific diet variability (Semmens et al. 2009).

Macroinvertebrate biomass was highest in spring presumably due to life history characteristics of maroinvertebrate populations. This trend is likely due to utilization of large late fall inputs of detrital carbon in the form of leaf litter and a response by the macroinvertebrate community, since high levels of biomass are often associated with a continuous and reliable source of energy (Huryn and Wallace 2000), in this case terrestrial carbon. Biomass may also be high during spring because losses due to emergence have not yet occurred. In fact, community emergence in temperate zones tends to peak in early summer and declines by late summer (Baxter et al. 2005, Sweeny and Vannote 1982, Sabo and Power 2002). Total biomass was higher in spring with pools harboring greater biomass. Salamanders relied on the FFGs of collectors, predators and scrapers. Collector biomass comprised the largest component of biomass peaking in spring with pools harboring the highest biomass. Predator biomass was similar across seasons likely providing a stable prey source for salamanders. Scrapers were a small component of biomass peaking in spring riffles. These patterns indicate both riffle and pool habitats are vital for salamander energy inputs, while spring is an important time for prey production.

While prey biomass peaked in spring, salamander predator biomass peaked in spring and summer. Fall exhibited reduced biomass, however, for all three species (Figure 2.3). Davic (1983) reported larvae (*Desmognathus* and *Eurycea*) total biomass ranging from 7.8 g/m^2 in June to 6.1 g/m^2 in October, following similar trends from our study of reduced fall biomass. Our research also supports other studies which have observed minimal variation within salamander guilds in other spring-fed streams (Davic 1983) and noted population estimates remained relatively stable among years in northeastern forested stream (Burton and Likens 1975). As mentioned earlier, our biomass estimates are lower than those of some studies (Peterman et al. 2008, Johnson and Wallace 2005) as values represent short-term surface estimates rather than total population estimates. While differences existed in biomass among species and season, *D. quadramaculatus* contained the highest biomass in spring and summer overall. Due to the life history of salamanders, we likely sampled before metamorphosis. This is observed by high biomass in spring and summer with fall exhibiting low biomass estimates, as many of the large individuals have presumably migrated into the surrounding riparian zone.

The importance of salamanders for stream food webs and function is likely both direct and indirect. Through predatory effects, salamanders may decrease prey density and biomass therefore shifting invertebrate community composition and likely slowing detrital processing (Davic 1983) potentially dampening the release of fine particulate organic matter to downstream communities (Davic and Welsh 2004). Decreased detrital processing in stream could exhibit positive effects for the invertebrate community as these pulsed resources (leaf litter) are likely available for longer periods. Salamanders are also integrating patchy prey items within the system as they are utilizing prey resources from different habitats. The two most common species analyzed for gut content analyses (*D. quadramaculatus* and *E. cirrigera*) were found to occupy similar trophic levels but fed on different prey items. These species therefore are not ecologically redundant. A great deal of reliance on detrital resources was noted for prey items, therefore, implications to prey resources in the form of riparian habitat alteration could directly impact salamanders by severing energy connections. Studies have demonstrated reduced abundance, biomass and production of larval salamanders (Wallace et al. 1997, 1999) with detrital exclusion while the effect of decreased growth rate has also been established (Johnson and Wallace 2005). These habitat modifications will further disrupt salamander ecological function (see Milanovich 2010). It is predicated that depending on the prey negatively affected, one salamander species likely will be impacted more than others.

Headwater stream ecosystems face continued pressure from habitat alteration, watershed development and stream burial (Elmore and Kaushal 2008) while amphibians are declining globally (Whiles et al. 2006). The results of this study highlight the importance of using both isotopes and gut content analysis to answer questions about where salamanders derive their energy. Without understanding natural causes of variation among salamander species, it is difficult to isolate anthropogenic effects of severing prey availability and energy connections from salamanders. As we continue to alter the landscape, these studies will be even more pressing especially in the southern Appalachian region, which harbors much of the world's global diversity of salamanders. Our study adds information on the trophic structure and energy sources of these unique predators with hopes of informing conservation of both within stream habitat and the surrounding riparian zone.

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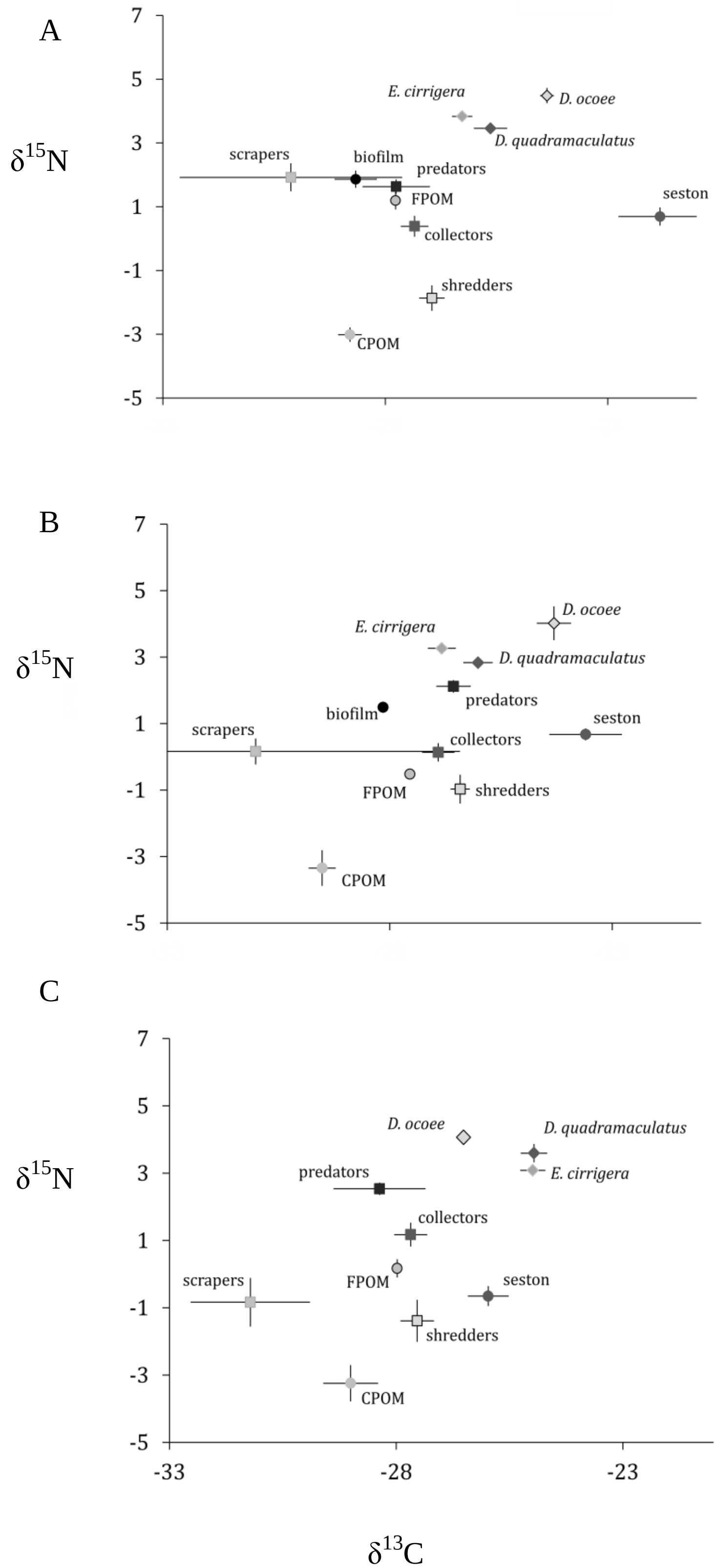

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scrapers
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D. ocoee
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D. quadramaculatus
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D. quadramaculatus
predators
E. cirrigera
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Figure 2.1. $\delta^{13}C$ and $\delta^{15}N$ values of salamander species (*Desmognathus quadramaculatus*, *Desmognathus ocoee* and *Eurycea cirrigera*) macroinvertebrate functional feeding groups (collectors, predators, scrapers, shredders) and basal resources (CPOM, seston, leaf litter and FPOM). A) spring 2009, B) summer 2009 and C) fall 2008. Mean incorporates signatures over all streams for the appropriate category per season (see Appendix 1 for detailed signatures and replicate number). Error bars reflect mean ± SE. CPOM is coarse particulate organic matter. FPOM denotes fine particulate organic matter.

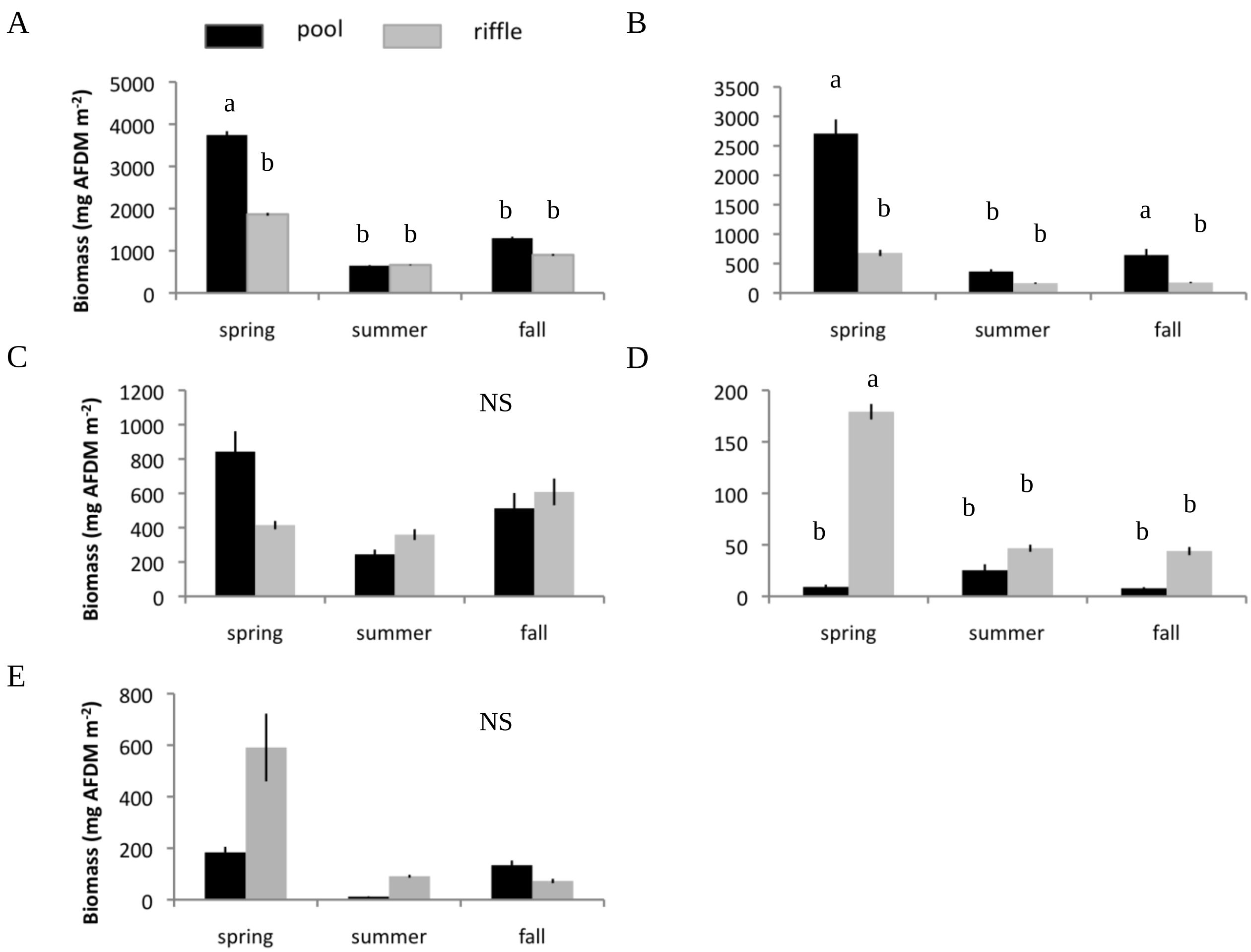

Figure 2.2. Pool and riffle habitat biomass (mean of four headwater streams) denoted as A) total biomass, B) collector-gatherer biomass, C) predator biomass, D) scraper biomass and E) shredder biomass. Biomass is expressed as mg AFDM m^{-2} across three seasons (spring, summer and fall). Note differences in scale between biomass estimates. AFDM is ash-free dry mass. Means for categories with the same letter are not statistically different (Tukey-Kramer, $p < 0.05$).

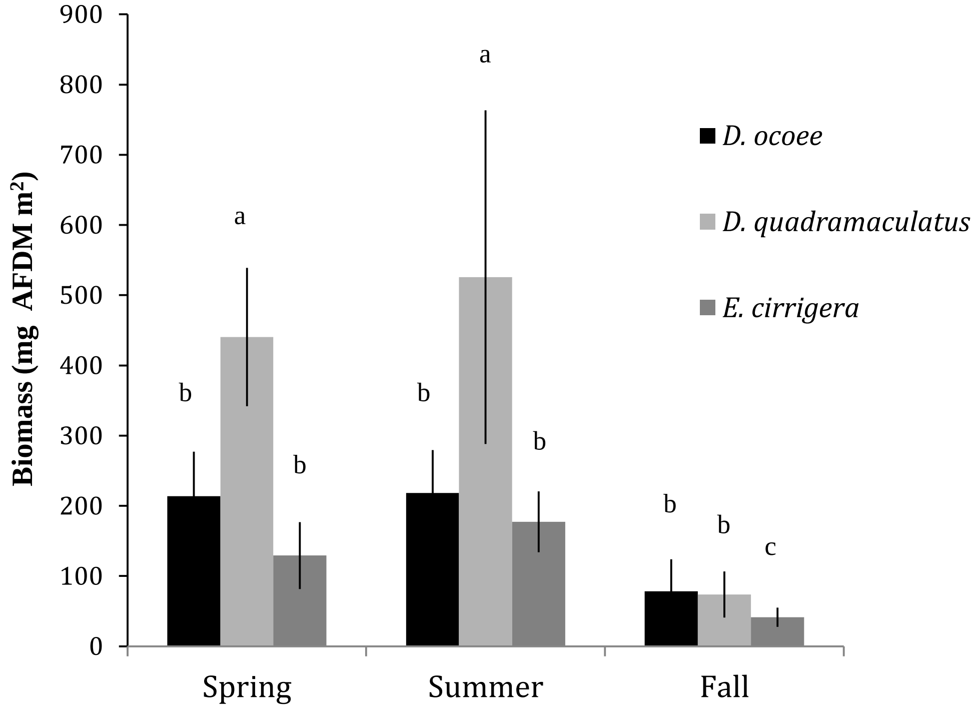

Figure 2.3. Salamander biomass (means ± SE from four headwater streams) across three seasons (spring, summer and fall) of the three dominant species guilds measured as mg AFDM m^{-2}. Biomass estimates were calculated from mark-recapture data used to generate abundance values from an occupancy model. AFDM is ash-free dry mass. Means for categories with the same letter are not statistically different (Tukey-Kramer, $p < 0.05$). Count data is presented in Appendix 2.3.

Table 2.1. Site characteristics of the four headwater streams investigated. Mean active channel width (m) and mean pebble size (mm). Nutrients NO_3-N, NH_4-N, PO_4-P, total nitrogen and total phosphorus are reported as μg/L. Standard deviation for each category denoted in parenthesis. Nutrients were sampled monthly from July 2008 – February 2009, with means derived from approximately n = 41 samples.

Stream	Active channel width (m)	Pebble size (mm)	NO_3-N	NH_4-N	PO_4-P	TN	TP
1	1.92 (0.488)	62 (99)	7.0 (8.0)	44.3 (38.0)	0.9 (2.0)	186.2 (332.0)	10.2 (13.0)
2	2.992 (0.728)	57 (77)	11.0 (9.0)	71.0 (111.0)	3.6 (3.0)	180.0 (190.0)	10.9 (9.0)
3	1.7698 (0.451)	33 (53)	10.5 (14.0)	38.1 (45.0)	0.2 (0.0)	130.0 (35.0)	9.8 (12.0)
4	2.027 (0.356)	45 (69)	18.6 (9.0)	36.4 (32.0)	1.1 (3.0)	236.7 (98.0)	9.5 (10.0)

Table 2.2. ANOVA results for salamander species (*Desmognathus quadramaculatus*, *Desmognathus ocoee* and *Eurycea cirrigera*), FFG (collector, predator, scraper and shredder) and basal resources (CPOM, seston, leaf litter, biofilm and FPOM). Response models for A) $\delta^{15}N$ and B) $\delta^{13}C$ testing differences $\delta^{15}N$ or $\delta^{13}C$ in among seasons (spring, summer, fall) and blocking for stream (n=4). Response models include an interaction effect of species, FFG or basal resources*season blocking for stream. Post-ANOVA tests were included for significant effects. Categories with the same letter are not statistically different (Tukey-Kramer, $p < 0.05$). Letters in panel A also indicate highest to lowest in trophic position. Whereas, letters in panel B are from depleted to enriched in carbon signatures. Symbols denote significance: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

A

Category	F	df	P
Salamander species			
$\delta^{15}N$			
species	2.83	2,25	NS
season	0.70	2,25	NS
species*season	0.72	4,25	NS
stream	0.08	3,25	NS
FFG			
$\delta^{15}N$			
FFG	17.38	3,37	***
season	0.16	2,37	NS
FFG*season	1.36	6,37	NS
stream	2.98	3,37	0.05
Post-ANOVA FFG			
collector	b		
predator	a		
scraper	a,b		
shredder	c		
Basal resources			
$\delta^{15}N$			
basal	98.54	3,41	***
season	5.08	2,41	*
basal*season	1.55	5,41	NS
stream	4.63	3,41	*
Post-ANOVA basal			
FPOM	a		
CPOM	b		
seston	a		
Post-ANOVA season			
spring	a		
summer	a,b		
fall	b		

B

Category	F	df	P
Salamander species			
$\delta^{13}C$			
species	4.33	2,25	*
season	0.53	2,25	NS
species*season	4.98	4,25	**
stream	10.42	3,25	***
Post-ANOVA			
species*season			
Quad – spring	a,b		
Quad – summer	a,b		
Quad – fall	a,b		
Ocoee – spring	b		
Ocoee – summer	a,b		
Ocoee – fall	a		
Eury – spring	a		
Eury – summer	a		
Eury – fall	a,b		
FFG			
$\delta^{13}C$			
FFG	1.57	3,37	NS
season	0.10	2,37	NS
FFG*season	0.71	6,37	NS
stream	1.18	3,37	NS
Basal resources			
$\delta^{13}C$			
basal	50.49	3,41	***
season	3.10	2,41	NS
basal*season	1.35	5,41	NS
stream	0.28	3,41	NS
Post-ANOVA basal			
FPOM	b		
CPOM	a		
seston	c		

Table 2.3. Proportion of prey items contributing to carbon and nitrogen stable isotopes of salamander species seasonally (spring, summer and fall), using MixSIR. Proportion biomass within stream and gut content of salamander species are included for each prey item. *C* collector, *P* predator, *SC* scraper and *SH* shredder. Mixing model results are listed as % ± SD.

Season	FFG	% Biomass	*Desmognathus ocoee*		*Desmognathus quadramaculatus*		*Eurycea cirrigera*	
			% mixing model	% gut content	% mixing model	% gut content	% mixing model	% gut content
Spring	C	60.4	0.16 ± 0.47	--	0.26 ± 1.15	22.76	3.28 ± 4.13	32.47
	P	22.42	50.60 ± 48.99	--	99.30 ± 1.29	57.49	54.70 ± 13.92	40.16
	Sc	3.36	49.23 ± 49.09	--	0.42 ± 0.74	14.4	41.56 ± 14.05	0
	Sh	35.2	0.00 ± 0.01	--	0.01 ± 0.02	5.34	0.46 ± 0.89	27.36
Summer	C	40.55	3.06 ± 6.04	--	0.06 ± 0.21	63.98	3.31 ± 3.87	50.25
	P	46.1	93.84 ± 7.56	--	99.37 ± 1.11	24.28	72.04 ± 7.88	0.67
	Sc	5.5	2.16 ± 3.65	--	0.55 ± 1.06	8.17	23.72 ± 7.66	46.99
	Sh	7.86	0.94 ± 2.44	--	0.02 ± 0.06	1.86	0.93 ± 1.68	2.09
Fall	C	37.33	34.98 ± 27.38	--	51.20 ± 29.04	--	16.81 ± 13.94	--
	P	50.93	56.60 ± 25.65	--	40.60 ± 25.71	--	67.46 ± 11.27	--
	Sc	2.35	2.62 ± 4.26	--	2.20 ± 3.57	--	2.68 ± 4.08	--
	Sh	9.39	5.81 ± 5.65	--	6.00 ± 5.80	--	13.05 ± 9.08	--

Table 2.4. Prey taxa incorporating > 1.5% biomass of *Desmognathus quadramaculatus* and *Eurycea cirrigera* (spring and summer). N denotes the number found in all guts of the species. Total dry mass is total biomass measured as mg AFDM.

D. quadramaculatus				*E. cirrigera*			
Prey taxa	N	total dry mass (mg AFDM)	% dry mass/total dry mass	Prey taxa	N	total dry mass (mg AFDM)	% dry mass/total dry mass
Aquatic Prey				Aquatic Prey			
COLLECTORS				**COLLECTOR**			
Ephemeroptera				Ephemeroptera			
Isonychidae sp.	1	2.18	3.58	*Baetis* sp.	3	3.44	14.50
Paraleptophlebia sp.	14	3.27	5.36	*Paraleptophlebia* sp.	13	3.43	14.45
Trichoptera sp.				Trichoptera			
Diplectrona sp.	5	8.14	13.37	*Diplectrona* sp.	3	1.32	5.55
Dolophilodes sp.	5	0.96	1.58	Diptera			
Wormalidae sp.	2	3.02	4.97	Nontanypodinae	36	1.21	5.11
PREDATORS				**PREDATORS**			
Odonata				Diptera			
Calopterygida sp.	1	1.22	2.00	Tanypodinae	4	4.01	16.89
Diptera				**SCRAPERS**			
Ceratapogon	10	1.78	2.92	Ephemeroptera			
Tanypodinae	14	1.13	1.86	*Macaffertium* sp.	1	2.48	10.43
Plecoptera				*Stenonema*	4	0.88	3.70
Isoperla sp.	7	9.63	15.80	Trichoptera			
Sweltsa sp.	1	1.50	2.46	*Psilotreta* sp.	3	2.05	8.63
SCRAPERS				**SHREDDERS**			
Ephemeroptera				Diptera			
Maccaffertium sp.	4	1.69	2.78	*Tipula* sp.	2	2.77	11.67
Stenonema femoratum	4	2.23	3.67				
Terrestrial							
Ant (Camponotus pennsylvanicus)	5	1.20	1.98				
Coleoptera	2	10.15	16.67				

Table 2.5. ANOVA results for total macroinvertebrate biomass and FFG biomass (collectors, predators, scrapers and shredders) testing differences in season and substrate. An interaction effect of season and substrate blocking for stream (n=4) was tested on total macroinvertebrate biomass. Salamander biomass ANOVA results testing differences in species (*Desmognathus quadramaculatus*, *Desmognathus ocoee* and *Eurycea cirrigera* or season (spring, summer and fall). An interaction effect of season and species were analyzed on salamander biomass data per stream using stream (n=4) as a block effect. Symbols denote significance: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Category	F	df	P
Total biomass			
season	10.24	2,78	***
substrate	4.89	1,78	*
season*substrate	3.05	2,78	0.05
stream	1.14	3,78	NS
Collector			
season	4.96	2,23	*
substrate	6.65	1,23	*
season*substrate	2.65	2,23	NS
stream	1.44	3,23	NS
Predator			
season	0.79	2,23	NS
substrate	0.41	1,23	NS
season*substrate	0.76	2,23	NS
stream	1.29	3,23	NS
Scraper			
season	9.12	2,23	**
substrate	27.82	1,23	***
season*substrate	11.84	2,23	***
stream	1.89	3,23	NS
Shredders			
season	1.64	2,23	NS
substrate	0.41	1,23	NS
season*substrate	0.50	2,23	NS
stream	1.37	3,23	NS
Salamander biomass			
species	11.96	2,19	***
season	7.41	2,19	**
season*species	3.37	4,19	*
stream	3.25	3,19	*

Appendix 2.1. $\delta^{15}N$ and $\delta^{13}C$ values from all four headwater streams. Values include individual salamander and macroinvertebrate species, as well as basal resources. Year collected, season and stream are also represented. Spring and Summer 2008 were not included in any of the analysis discussed but are listed for reference only.

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Desmognathus monticola	3.20	-25.54	2009	Summer	Blackwell	Reference
Desmognathus monticola	2.23	-23.41	2009	Summer	Blackwell	Reference
Desmognathus monticola	2.39	-24.15	2009	Summer	Blackwell	Reference
Desmognathus monticola	3.07	-24.40	2009	Summer	Blackwell	Treatment
Desmognathus monticola	2.42	-24.97	2009	Summer	Blackwell	Treatment
Desmognathus monticola	4.16	-23.78	2009	Summer	Blackwell	Treatment
Desmognathus monticola	3.48	-24.63	2009	Summer	Blackwell	Treatment
Desmognathus monticola	3.30	-24.85	2009	Summer	Blackwell	Treatment
Desmognathus monticola	2.73	-25.14	2009	Summer	Blackwell	Treatment
Desmognathus monticola	3.35	-24.42	2009	Summer	Blackwell	Treatment
Desmognathus monticola	1.90	-25.40	2009	Summer	Yellow	Treatment
Desmognathus monticola	3.42	-26.25	2009	Summer	Yellow	Treatment
Desmognathus monticola	0.64	-24.50	2009	Summer	Yellow	Treatment
Desmognathus monticula	3.56	-24.33	2008	Fall	Blackwell	Treatment
Desmognathus ocoee	5.07	-23.61	2009	Summer	Blackwell	Reference
Desmognathus ocoee	4.58	-23.73	2009	Summer	Blackwell	Reference
Desmognathus ocoee	3.65	-25.22	2009	Summer	Blackwell	Reference
Desmognathus ocoee	2.77	-24.67	2009	Summer	Blackwell	Reference
Desmognathus ocoee	5.38	-24.36	2009	Spring	Blackwell	Reference
Desmognathus ocoee	5.72	-24.64	2009	Spring	Blackwell	Reference
Desmognathus ocoee	4.62	-25.51	2009	Spring	Blackwell	Reference
Desmognathus ocoee	5.40	-25.22	2009	Spring	Blackwell	Reference
Desmognathus ocoee	5.11	-23.46	2009	Spring	Blackwell	Reference
Desmognathus ocoee	4.70	-24.85	2009	Spring	Blackwell	Reference
Desmognathus ocoee	4.54	-23.91	2009	Spring	Blackwell	Reference
Desmognathus ocoee	5.01	-24.05	2009	Spring	Blackwell	Reference
Desmognathus ocoee	4.24	-25.19	2009	Spring	Blackwell	Reference
Desmognathus ocoee	5.42	-23.98	2009	Spring	Blackwell	Treatment
Desmognathus ocoee	5.60	-23.41	2009	Spring	Blackwell	Treatment
Desmognathus ocoee	4.58	-23.45	2009	Spring	Blackwell	Treatment
Desmognathus ocoee	1.98	-25.04	2009	Spring	Yellow	Reference
Desmognathus ocoee	2.38	-24.27	2009	Spring	Yellow	Reference
Desmognathus ocoee	3.99	-23.94	2009	Spring	Yellow	Reference
Desmognathus ocoee	4.23	-24.19	2009	Spring	Yellow	Reference
Desmognathus ocoee	4.22	-24.10	2009	Spring	Yellow	Reference
Desmognathus ocoee	3.59	-25.07	2009	Spring	Yellow	Treatment

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Desmognathus ocoee	3.96	-26.55	2008	Fall	Yellow	Reference
Desmognathus ocoee	4.17	-26.49	2008	Fall	Yellow	Treatment
Desmognathus quadramaculatus	5.69	-23.31	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.54	-25.79	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.62	-25.17	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.73	-25.72	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.58	-25.22	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.88	-26.07	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.75	-25.98	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.57	-25.91	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.91	-24.65	2009	Summer	Yellow	Treatment
Desmognathus quadramaculatus	5.77	-25.83	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.63	-25.62	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.55	-25.07	2009	Summer	Yellow	Treatment
Desmognathus quadramaculatus	6.43	-25.54	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.20	-25.10	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.49	-26.04	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.70	-25.71	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.77	-25.67	2009	Summer	Yellow	Reference
Desmognathus quadramaculatus	5.51	-25.64	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.43	-25.03	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.63	-25.46	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.38	-24.80	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	5.58	-25.43	2009	Summer	Yellow	Treatment
Desmognathus quadramaculatus	4.29	-23.89	2009	Summer	Yellow	Treatment
Desmognathus quadramaculatus	3.19	-25.35	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	3.55	-24.52	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	3.47	-24.43	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	3.24	-25.02	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	2.80	-25.20	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	3.03	-25.57	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	2.64	-26.36	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	2.63	-26.04	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	2.99	-25.67	2009	Summer	Blackwell	Reference
Desmognathus quadramaculatus	2.88	-25.45	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	2.51	-26.19	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	3.40	-28.68	2009	Summer	Yellow	Treatment
Desmognathus quadramaculatus	2.60	-25.28	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	2.85	-25.73	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	2.84	-28.67	2009	Summer	Yellow	Treatment
Desmognathus quadramaculatus	2.45	-25.65	2009	Summer	Blackwell	Treatment
Desmognathus quadramaculatus	2.18	-26.31	2009	Summer	Yellow	Treatment
Desmognathus quadramaculatus	4.32	-24.48	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	3.88	-23.85	2009	Spring	Yellow	Treatment
Desmognathus quadramaculatus	4.84	-24.48	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	4.45	-24.08	2009	Spring	Yellow	Treatment
Desmognathus quadramaculatus	3.61	-24.59	2009	Spring	Yellow	Treatment
Desmognathus quadramaculatus	4.87	-24.76	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	4.95	-24.85	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	4.44	-25.44	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	6.32	-23.65	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	5.36	-24.55	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	4.05	-24.84	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	4.66	-24.41	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	4.47	-24.76	2009	Spring	Blackwell	Reference

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Desmognathus quadramaculatus	4.11	-25.58	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	3.97	-24.93	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	3.09	-24.96	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	3.77	-24.57	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	3.86	-28.01	2009	Spring	Yellow	Treatment
Desmognathus quadramaculatus	3.89	-24.61	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	3.67	-26.24	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	3.04	-24.54	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	3.40	-25.45	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	2.66	-25.27	2009	Spring	Blackwell	Reference
Desmognathus quadramaculatus	2.53	-23.57	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	3.46	-24.96	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	3.66	-27.33	2009	Spring	Yellow	Treatment
Desmognathus quadramaculatus	3.06	-25.47	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	3.92	-29.52	2009	Spring	Yellow	Treatment
Desmognathus quadramaculatus	3.25	-25.18	2009	Spring	Blackwell	Treatment
Desmognathus quadramaculatus	5.11	-24.43	2008	Fall	Blackwell	Reference
Desmognathus quadramaculatus	3.22	-24.73	2008	Fall	Blackwell	Reference
Desmognathus quadramaculatus	3.20	-24.62	2008	Fall	Blackwell	Reference
Desmognathus quadramaculatus	3.64	-24.86	2008	Fall	Blackwell	Treatment
Desmognathus quadramaculatus	3.18	-24.56	2008	Fall	Blackwell	Treatment
Desmognathus quadramaculatus	3.78	-26.67	2008	Fall	Yellow	Treatment
Desmognathus quadramaculatus	3.01	-24.87	2008	Fall	Yellow	Treatment
Eurycea cirrigera	2.58	-24.32	2009	Summer	Blackwell	Reference
Eurycea cirrigera	2.57	-24.78	2009	Summer	Blackwell	Reference
Eurycea cirrigera	4.09	-24.80	2009	Summer	Blackwell	Reference
Eurycea cirrigera	2.62	-24.46	2009	Summer	Blackwell	Reference
Eurycea cirrigera	3.17	-27.69	2009	Summer	Blackwell	Reference
Eurycea cirrigera	2.70	-24.05	2009	Summer	Blackwell	Reference
Eurycea cirrigera	2.92	-27.38	2009	Summer	Yellow	Reference
Eurycea cirrigera	2.54	-27.40	2009	Summer	Yellow	Reference
Eurycea cirrigera	2.08	-27.93	2009	Summer	Yellow	Reference
Eurycea cirrigera	2.66	-25.11	2009	Summer	Yellow	Reference
Eurycea cirrigera	3.31	-26.65	2009	Summer	Yellow	Treatment
Eurycea cirrigera	4.28	-29.42	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.91	-27.90	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.58	-27.85	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.63	-26.51	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.96	-28.15	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.39	-27.10	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.68	-26.84	2009	Summer	Yellow	Treatment
Eurycea cirrigera	2.85	-26.02	2009	Summer	Yellow	Treatment
Eurycea cirrigera	2.44	-28.37	2009	Summer	Yellow	Treatment
Eurycea cirrigera	4.11	-28.17	2009	Summer	Yellow	Treatment
Eurycea cirrigera	4.06	-27.61	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.56	-29.02	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.62	-26.41	2009	Summer	Yellow	Treatment
Eurycea cirrigera	3.04	-25.27	2009	Spring	Blackwell	Reference
Eurycea cirrigera	3.31	-27.69	2009	Spring	Blackwell	Reference
Eurycea cirrigera	4.12	-25.24	2009	Spring	Blackwell	Reference
Eurycea cirrigera	3.14	-25.22	2009	Spring	Blackwell	Reference
Eurycea cirrigera	3.72	-25.48	2009	Spring	Blackwell	Treatment
Eurycea cirrigera	3.81	-24.59	2009	Spring	Blackwell	Treatment
Eurycea cirrigera	5.08	-24.52	2009	Spring	Blackwell	Treatment
Eurycea cirrigera	3.60	-24.78	2009	Spring	Blackwell	Treatment

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Eurycea cirrigera	4.01	-25.32	2009	Spring	Blackwell	Treatment
Eurycea cirrigera	3.59	-28.23	2009	Spring	Yellow	Treatment
Eurycea cirrigera	4.33	-27.17	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.42	-26.61	2009	Spring	Yellow	Treatment
Eurycea cirrigera	4.44	-26.57	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.67	-28.57	2009	Spring	Yellow	Treatment
Eurycea cirrigera	4.56	-27.07	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.84	-26.76	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.77	-26.46	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.67	-26.60	2009	Spring	Yellow	Treatment
Eurycea cirrigera	2.97	-26.29	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.70	-26.09	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.81	-26.43	2009	Spring	Yellow	Treatment
Eurycea cirrigera	4.27	-26.87	2009	Spring	Yellow	Treatment
Eurycea cirrigera	4.31	-26.51	2009	Spring	Yellow	Treatment
Eurycea cirrigera	3.08	-24.34	2008	Fall	Blackwell	Reference
Eurycea cirrigera	2.35	-24.55	2008	Fall	Blackwell	Reference
Eurycea cirrigera	3.20	-24.62	2008	Fall	Blackwell	Reference
Eurycea cirrigera	3.10	-25.36	2008	Fall	Blackwell	Treatment
Eurycea cirrigera	3.15	-24.65	2008	Fall	Blackwell	Treatment
Eurycea cirrigera	3.40	-24.15	2008	Fall	Blackwell	Treatment
Eurycea cirrigera	3.05	-26.00	2008	Fall	Yellow	Treatment
Eurycea cirrigera	3.35	-26.26	2008	Fall	Yellow	Treatment
Gyrinophilus spp.	4.54	-25.35	2009	Spring	Blackwell	Treatment
Gyrinophilus spp.	4.99	-23.36	2009	Spring	Blackwell	Treatment
Gyrinophilus spp.	4.98	-23.49	2009	Spring	Blackwell	Treatment
Pseudotrition spp.	4.20	-25.07	2009	Spring	Blackwell	Treatment
Pseudotrition spp.	4.16	-27.05	2009	Spring	Yellow	Treatment
Pseudotrition spp.	2.74	-27.68	2009	Spring	Yellow	Treatment
Pseudotrition spp.	4.51	-27.74	2009	Spring	Yellow	Treatment
Acroneuria	3.25	-25.59	2008	Summer	Blackwell	Reference
Arctopsyche	1.87	-26.53	2008	Summer	Blackwell	Treatment
Ceratopogon	3.08	-26.91	2008	Summer	Blackwell	Treatment
Cheumatopsyche	2.04	-26.14	2008	Summer	Blackwell	Reference
Cordulegaster	2.56	-25.43	2008	Summer	Blackwell	Reference
Cordulegaster	2.17	-26.00	2008	Summer	Blackwell	Treatment
Cordulegaster	4.87	-30.74	2008	Summer	Yellow	Treatment
Dicranota	4.27	-25.04	2008	Summer	Blackwell	Reference
Diplectrona	0.30	-26.39	2008	Summer	Blackwell	Reference
Diplectrona	0.17	-25.94	2008	Summer	Blackwell	Treatment
Gomphus	3.38	-25.00	2008	Summer	Blackwell	Reference
Gomphus	2.30	-25.63	2008	Summer	Blackwell	Treatment
Gomphus	5.81	-29.66	2008	Summer	Yellow	Treatment
Hexagenia	-0.79	-26.97	2008	Summer	Blackwell	Reference
Hexagenia	0.23	-26.48	2008	Summer	Blackwell	Treatment
Hexatoma	3.67	-24.70	2008	Summer	Blackwell	Treatment
Hexatoma	4.94	-26.76	2008	Summer	Yellow	Treatment
Isonychia	1.97	-26.16	2008	Summer	Blackwell	Reference
Isonychia	1.68	-29.09	2008	Summer	Yellow	Treatment
Non-tanypodinae	0.71	-28.84	2008	Summer	Blackwell	Treatment
Non-tanypodinae	3.00	-25.62	2008	Summer	Blackwell	Reference
Phylocentropus	-7.44	-73.18	2008	Summer	Blackwell	Reference
Phylocentropus	-1.17	-63.99	2008	Summer	Blackwell	Treatment
Rhyacophila	4.30	-25.10	2008	Summer	Blackwell	Reference
Sialis	2.40	-30.77	2008	Summer	Yellow	Treatment

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Stenonema	0.71	-26.35	2008	Summer	Blackwell	Treatment
Tanypodinae	2.27	-26.91	2008	Summer	Blackwell	Treatment
Tipula	-1.52	-25.93	2008	Summer	Blackwell	Reference
Tipula	-1.41	-26.43	2008	Summer	Blackwell	Treatment
Tipula	0.05	-26.56	2008	Summer	Yellow	Treatment
Acroneuria	3.29	-25.94	2008	Spring	Blackwell	Treatment
Attaneuria	3.11	-25.67	2008	Spring	Blackwell	Treatment
Calopteryx	1.27	-27.33	2008	Spring	Yellow	Reference
Ceratopogon	3.39	-27.12	2008	Spring	Blackwell	Reference
Ceratopogon	2.65	-27.50	2008	Spring	Blackwell	Treatment
Ceratopogon	3.58	-29.90	2008	Spring	Yellow	Treatment
Cheumatopsyche	1.02	-29.14	2008	Spring	Yellow	Reference
Chironomidae	1.74	-27.42	2008	Spring	Blackwell	Treatment
Chironomidae	0.85	-26.89	2008	Spring	Yellow	Reference
Cordulegaster	1.93	-27.17	2008	Spring	Blackwell	Reference
Dicranota	3.62	-41.80	2008	Spring	Yellow	Treatment
Diplectrona	0.47	-25.94	2008	Spring	Blackwell	Reference
Diplectrona	2.39	-28.09	2008	Spring	Yellow	Treatment
Ectopria	-0.12	-31.49	2008	Spring	Blackwell	Reference
Ephemera	1.50	-25.42	2008	Spring	Blackwell	Treatment
Gomphus	4.89	-28.37	2008	Spring	Yellow	Treatment
Hexagenia	1.14	-26.56	2008	Spring	Blackwell	Reference
Hexagenia	0.74	-26.24	2008	Spring	Blackwell	Treatment
Hexagenia	2.44	-28.51	2008	Spring	Yellow	Treatment
Hexagenia	0.08	-26.27	2008	Spring	Yellow	Reference
Hexatoma	3.75	-24.87	2008	Spring	Blackwell	Reference
Hexatoma	-0.98	-25.87	2008	Spring	Blackwell	Treatment
Hexatoma	3.54	-27.37	2008	Spring	Yellow	Treatment
Hexatoma	2.30	-26.00	2008	Spring	Yellow	Reference
Isoperla	0.06	-32.71	2008	Spring	Blackwell	Reference
Isoperla	3.39	-35.97	2008	Spring	Yellow	Treatment
Isoperla	0.70	-27.64	2008	Spring	Yellow	Reference
Leptocerus	1.51	-25.04	2008	Spring	Yellow	Reference
Neophylax	-0.04	-32.93	2008	Spring	Blackwell	Reference
Non-tanypodinae	1.58	-26.57	2008	Spring	Blackwell	Reference
Non-tanypodinae	3.20	-29.77	2008	Spring	Yellow	Treatment
Paranyctiophylax	4.91	-31.08	2008	Spring	Yellow	Treatment
Parapsyche	2.26	-26.68	2008	Spring	Blackwell	Reference
Phylocentropus	-8.32	-67.72	2008	Spring	Blackwell	Treatment
Psilotreta	0.89	-29.59	2008	Spring	Blackwell	Reference
Pycnopsyche	-5.52	-25.59	2008	Spring	Yellow	Reference
Rhyacophila	4.78	-32.38	2008	Spring	Yellow	Treatment
Rhyacophila	1.16	-26.15	2008	Spring	Yellow	Reference
Simulidae	2.17	-41.80	2008	Spring	Yellow	Treatment
Stenonema	0.88	-27.01	2008	Spring	Blackwell	Reference
Stenonema	1.73	-26.89	2008	Spring	Blackwell	Treatment
Stenonema	-0.39	-29.59	2008	Spring	Yellow	Reference
Tallaperla	-2.03	-27.59	2008	Spring	Blackwell	Treatment
Tanypodinae	3.54	-26.91	2008	Spring	Blackwell	Reference
Tanypodinae	2.94	-27.97	2008	Spring	Yellow	Treatment
Tipula	-0.40	-28.64	2008	Spring	Yellow	Treatment
Aeshnidae	1.98	-26.15	2008	Fall	Blackwell	Reference
Arigomphus	1.82	-25.58	2008	Fall	Blackwell	Reference
Arigomphus	2.33	-25.56	2008	Fall	Blackwell	Treatment
Beloneuria	2.66	-25.62	2008	Fall	Blackwell	Reference

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Ceratopogon	3.84	-41.79	2008	Fall	Yellow	Treatment
Ceratopogon	1.45	-31.03	2008	Fall	Blackwell	Treatment
Cordulegaster	1.86	-26.34	2008	Fall	Yellow	Reference
Diplectrona	2.49	-29.06	2008	Fall	Yellow	Treatment
Diplectrona	-0.77	-26.71	2008	Fall	Blackwell	Reference
Diplectrona	-0.55	-27.01	2008	Fall	Blackwell	Treatment
Dixa	2.22	-26.45	2008	Fall	Yellow	Treatment
Dixa	-1.19	-26.14	2008	Fall	Blackwell	Reference
Dixa	0.01	-26.79	2008	Fall	Blackwell	Treatment
Ectopria	-1.56	-29.90	2008	Fall	Yellow	Reference
Elmidae (adult)	0.66	-29.71	2008	Fall	Blackwell	Treatment
Gomphus	2.82	-30.21	2008	Fall	Yellow	Treatment
Hexagenia	1.28	-30.91	2008	Fall	Yellow	Treatment
Hexagenia	0.48	-27.08	2008	Fall	Blackwell	Treatment
Hexatoma	2.54	-29.24	2008	Fall	Yellow	Reference
Hexatoma	3.21	-28.46	2008	Fall	Yellow	Treatment
Hexatoma (a)	2.70	-30.43	2008	Fall	Blackwell	Treatment
Hexatoma (b)	2.79	-26.58	2008	Fall	Blackwell	Reference
Hydatophylax	-2.15	-25.87	2008	Fall	Blackwell	Reference
Hydropsyche	2.22	-28.13	2008	Fall	Blackwell	Treatment
Isoperla	3.59	-25.72	2008	Fall	Blackwell	Treatment
Leptophlebia	3.19	-28.49	2008	Fall	Yellow	Treatment
Nigronia	2.13	-25.38	2008	Fall	Yellow	Reference
Non-tanypodinae	3.04	-28.35	2008	Fall	Yellow	Treatment
Non-tanypodinae	1.75	-27.67	2008	Fall	Blackwell	Treatment
Oligochaete	1.06	-26.16	2008	Fall	Blackwell	Reference
Optiseruus	-0.11	-32.53	2008	Fall	Blackwell	Reference
Parapsyche	1.72	-26.55	2008	Fall	Blackwell	Treatment
Phylocentropus	-9.69	-73.82	2008	Fall	Blackwell	Reference
Phylocentropus	-9.67	-77.70	2008	Fall	Blackwell	Treatment
Pycnopsyche	-2.69	-27.36	2008	Fall	Yellow	Treatment
Rhyacophila	1.39	-27.54	2008	Fall	Blackwell	Reference
Tallaperla	-1.31	-27.05	2008	Fall	Blackwell	Reference
Tallaperla	0.94	-27.95	2008	Fall	Blackwell	Treatment
Tanypodinae	3.46	-28.24	2008	Fall	Yellow	Treatment
Tipula	-1.73	-27.79	2008	Fall	Yellow	Treatment
Aeshnidae	2.17	-27.42	2009	Summer	Blackwell	Reference
Arctopsyche	1.26	-26.22	2009	Summer	Blackwell	Reference
Arigomphus	2.15	-30.46	2009	Summer	Yellow	Treatment
Arigomphus	2.79	-25.02	2009	Summer	Blackwell	Treatment
Arigomphus	2.42	-25.53	2009	Summer	Blackwell	Reference
Ceratopogon	0.89	-26.43	2009	Summer	Yellow	Treatment
Ceratopogon	3.49	-24.55	2009	Summer	Blackwell	Reference
Cordulegaster	2.01	-25.53	2009	Summer	Yellow	Reference
Cordulegaster	2.61	-27.99	2009	Summer	Yellow	Treatment
Cordulegaster	1.79	-27.07	2009	Summer	Blackwell	Reference
Dicranota	1.27	-30.88	2009	Summer	Blackwell	Reference
Diplectrona	-0.48	-26.90	2009	Summer	Yellow	Reference
Diplectrona	-0.79	-26.91	2009	Summer	Blackwell	Treatment
Diplectrona	-0.18	-26.36	2009	Summer	Blackwell	Reference
Dixa	1.17	-25.36	2009	Summer	Blackwell	Treatment
Ectopria	-0.23	-35.60	2009	Summer	Blackwell	Treatment
Hexagenia	-1.65	-26.76	2009	Summer	Yellow	Reference
Hexagenia	0.79	-28.27	2009	Summer	Yellow	Treatment
Hexagenia	-0.23	-26.32	2009	Summer	Blackwell	Reference

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Hexatoma	3.96	-26.78	2009	Summer	Yellow	Treatment
Hexatoma	2.08	-25.62	2009	Summer	Blackwell	Treatment
Hexatoma (a)	0.57	-24.53	2009	Summer	Blackwell	Reference
Hexatoma (b)	2.20	-25.70	2009	Summer	Blackwell	Reference
Hydatopylax	-2.02	-27.37	2009	Summer	Yellow	Reference
Lepidostoma	-0.85	-26.85	2009	Summer	Yellow	Reference
Lepidostoma	-1.00	-25.82	2009	Summer	Blackwell	Reference
Nigronia	2.40	-25.28	2009	Summer	Blackwell	Reference
Non-tanypodinae	0.44	-26.79	2009	Summer	Yellow	Reference
Non-tanypodinae	-0.01	-30.08	2009	Summer	Yellow	Treatment
Non-tanypodinae	1.69	-27.38	2009	Summer	Blackwell	Reference
Oligochaete	-0.38	-25.57	2009	Summer	Yellow	Reference
Phylocentropus	-7.62	-65.98	2009	Summer	Blackwell	Treatment
Psilotreta	0.55	-26.42	2009	Summer	Blackwell	Treatment
Rhyacophila	2.50	-25.91	2009	Summer	Blackwell	Reference
Sialis	0.53	-25.49	2009	Summer	Yellow	Reference
Tabanus	2.53	-28.79	2009	Summer	Yellow	Treatment
Tallaperla	0.04	-26.60	2009	Summer	Blackwell	Reference
Tanypodinae	2.64	-27.87	2009	Summer	Yellow	Treatment
Tanypodinae	1.08	-25.61	2009	Summer	Yellow	Reference
Tanypodinae	2.44	-25.45	2009	Summer	Blackwell	Reference
Tipula	-2.08	-26.39	2009	Summer	Blackwell	Treatment
Anchytarsus	0.18	-25.12	2009	Spring	Yellow	Reference
Anisocentropus	-1.61	-28.44	2009	Spring	Blackwell	Reference
Arigomphus	2.61	-25.38	2009	Spring	Blackwell	Reference
Beloneuria	3.13	-26.30	2009	Spring	Blackwell	Reference
Ceratopogon	2.34	-27.15	2009	Spring	Blackwell	Reference
Ceratopogon	1.66	-26.91	2009	Spring	Yellow	Treatment
Ceratopogon	1.79	-26.65	2009	Spring	Blackwell	Treatment
Collembola	-4.65	-26.26	2009	Spring	Yellow	Reference
Cordulegaster	1.08	-28.27	2009	Spring	Yellow	Treatment
Cordulegaster	1.81	-27.49	2009	Spring	Blackwell	Reference
Dicranota	1.90	-26.65	2009	Spring	Blackwell	Treatment
Diplectrona	-1.01	-27.32	2009	Spring	Blackwell	Reference
Diplectrona	1.02	-29.26	2009	Spring	Yellow	Treatment
Diplectrona	0.00	-26.06	2009	Spring	Blackwell	Treatment
Dixa	0.58	-27.34	2009	Spring	Yellow	Treatment
Dixa	-0.61	-26.57	2009	Spring	Yellow	Reference
Dromogomphus	3.09	-27.80	2009	Spring	Yellow	Treatment
Dromogomphus	0.48	-40.59	2009	Spring	Blackwell	Treatment
Eccoptura	2.00	-26.29	2009	Spring	Blackwell	Reference
Eccoptura	2.29	-29.00	2009	Spring	Yellow	Treatment
Ephemera	0.96	-26.10	2009	Spring	Blackwell	Treatment
Ephemera (forked)	1.59	-30.60	2009	Spring	Yellow	Treatment
Heteroplectron	-0.49	-26.90	2009	Spring	Blackwell	Treatment
Hexagenia	1.62	-28.92	2009	Spring	Yellow	Treatment
Hexatoma	2.33	-26.56	2009	Spring	Blackwell	Reference
Hexatoma	2.34	-25.21	2009	Spring	Blackwell	Treatment
Hexatoma (a)	1.08	-25.27	2009	Spring	Yellow	Reference
Hydatophylax	-4.94	-27.05	2009	Spring	Blackwell	Treatment
Hydropsyche	1.51	-26.44	2009	Spring	Blackwell	Treatment
Lepidoptera	-4.20	-24.69	2009	Spring	Yellow	Reference
Lepidostoma	-2.47	-26.41	2009	Spring	Blackwell	Treatment
Maccaffertium	0.68	-27.76	2009	Spring	Blackwell	Reference
Mayfly	-0.84	-26.65	2009	Spring	Yellow	Reference

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Nigronia	1.23	-25.69	2009	Spring	Blackwell	Reference
Nigronia	0.36	-25.19	2009	Spring	Yellow	Reference
Non-tanypodinae	0.77	-30.17	2009	Spring	Blackwell	Reference
Non-tanypodinae	1.39	-27.70	2009	Spring	Yellow	Treatment
Non-tanypodinae	0.77	-27.07	2009	Spring	Yellow	Reference
Non-tanypodinae	-0.03	-27.37	2009	Spring	Blackwell	Treatment
Oligochaete	0.24	-26.13	2009	Spring	Yellow	Treatment
Oligochaete	1.65	-25.62	2009	Spring	Blackwell	Treatment
Oligochaete	-0.66	-26.19	2009	Spring	Yellow	Reference
Parapsyche	1.86	-27.41	2009	Spring	Blackwell	Treatment
Phylocentropus	-10.15	-71.70	2009	Spring	Blackwell	Reference
Phylocentropus	-5.96	-63.16	2009	Spring	Blackwell	Treatment
Pseudolimno	1.27	-26.52	2009	Spring	Yellow	Treatment
Pteronarcys	-0.35	-27.75	2009	Spring	Blackwell	Treatment
Pycnopsyche	-2.88	-26.96	2009	Spring	Yellow	Reference
Pycnopsyche	-2.28	-26.83	2009	Spring	Blackwell	Treatment
Rhyacophila	3.41	-37.66	2009	Spring	Yellow	Treatment
Rhyacophila	-1.19	-26.52	2009	Spring	Yellow	Reference
Rhyacophila	2.16	-26.88	2009	Spring	Blackwell	Reference
Simulidae	-0.42	-27.44	2009	Spring	Yellow	Reference
Simulidae	1.17	-26.89	2009	Spring	Blackwell	Treatment
Stenonema (truncated gills)	2.73	-37.44	2009	Spring	Yellow	Treatment
Tabanus	2.32	-27.07	2009	Spring	Blackwell	Reference
Tallaperla	-0.84	-27.92	2009	Spring	Blackwell	Treatment
Tallaperla	-1.23	-28.29	2009	Spring	Blackwell	Reference
Tanypodinae	1.37	-26.73	2009	Spring	Blackwell	Reference
Tanypodinae	2.34	-30.73	2009	Spring	Yellow	Treatment
Tanypodinae	-0.76	-26.75	2009	Spring	Yellow	Reference
Tanypodinae	0.94	-26.21	2009	Spring	Blackwell	Treatment
Tipula	-0.50	-26.38	2009	Spring	Yellow	Treatment
Tipula	-2.71	-27.24	2009	Spring	Yellow	Reference
Tipula	-1.81	-27.36	2009	Spring	Blackwell	Reference
Biofilm	1.22	-28.32	2009	Summer	Yellow	Treatment
Biofilm	1.89	-27.89	2009	Summer	Yellow	Treatment
Biofilm	3.11	-28.14	2009	Summer	Yellow	Treatment
Biofilm	1.13	-28.54	2009	Summer	Yellow	Treatment
Biofilm	2.44	-28.46	2009	Summer	Yellow	Treatment
Biofilm	2.34	-28.34	2009	Summer	Yellow	Treatment
Biofilm	0.60	-28.42	2009	Summer	Yellow	Treatment
Biofilm	1.86	-28.71	2009	Summer	Yellow	Treatment
Biofilm	0.20	-28.29	2009	Summer	Yellow	Treatment
Biofilm	0.86	-28.35	2009	Summer	Yellow	Reference
Biofilm	1.60	-28.18	2009	Summer	Yellow	Reference
Biofilm	0.71	-28.76	2009	Summer	Yellow	Reference
Biofilm	1.31	-28.67	2009	Summer	Yellow	Reference
Biofilm	1.71	-28.33	2009	Summer	Yellow	Reference
Biofilm	0.79	-28.67	2009	Summer	Yellow	Reference
Biofilm	0.21	-28.77	2009	Summer	Yellow	Reference
Biofilm	-0.17	-28.43	2009	Summer	Yellow	Reference
Biofilm	1.64	-27.64	2009	Summer	Blackwell	Treatment
Biofilm	0.86	-27.56	2009	Summer	Blackwell	Treatment
Biofilm	2.22	-27.61	2009	Summer	Blackwell	Treatment
Biofilm	0.20	-28.09	2009	Summer	Blackwell	Treatment
Biofilm	1.75	-27.62	2009	Summer	Blackwell	Treatment

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Biofilm	1.15	-27.85	2009	Summer	Blackwell	Treatment
Biofilm	2.36	-28.56	2009	Summer	Blackwell	Treatment
Biofilm	0.51	-28.00	2009	Summer	Blackwell	Treatment
Biofilm	0.91	-27.71	2009	Summer	Blackwell	Reference
Biofilm	4.04	-27.09	2009	Summer	Blackwell	Reference
Biofilm	1.33	-27.12	2009	Summer	Blackwell	Reference
Biofilm	3.10	-27.54	2009	Summer	Blackwell	Reference
Biofilm	2.11	-27.10	2009	Summer	Blackwell	Reference
Biofilm	2.11	-27.71	2009	Summer	Blackwell	Reference
Biofilm	1.58	-30.26	2009	Summer	Blackwell	Reference
Biofilm	4.23	-29.01	2009	Spring	Yellow	Treatment
Biofilm	2.38	-27.92	2009	Spring	Yellow	Treatment
Biofilm	2.96	-28.66	2009	Spring	Yellow	Treatment
Biofilm	3.60	-28.01	2009	Spring	Yellow	Treatment
Biofilm	2.54	-28.56	2009	Spring	Yellow	Treatment
Biofilm	2.05	-28.40	2009	Spring	Yellow	Treatment
Biofilm	2.79	-27.69	2009	Spring	Yellow	Treatment
Biofilm	5.73	-27.91	2009	Spring	Yellow	Treatment
Biofilm	1.63	-29.57	2009	Spring	Yellow	Treatment
Biofilm	1.75	-28.23	2009	Spring	Yellow	Treatment
Biofilm	0.63	-28.95	2009	Spring	Yellow	Reference
Biofilm	0.33	-27.52	2009	Spring	Yellow	Reference
Biofilm	-1.10	-28.67	2009	Spring	Yellow	Reference
Biofilm	-0.37	-28.24	2009	Spring	Yellow	Reference
Biofilm	1.06	-28.46	2009	Spring	Yellow	Reference
Biofilm	1.27	-28.01	2009	Spring	Yellow	Reference
Biofilm	-0.07	-28.79	2009	Spring	Yellow	Reference
Biofilm	1.36	-27.72	2009	Spring	Yellow	Reference
Biofilm	0.25	-28.77	2009	Spring	Yellow	Reference
Biofilm	2.00	-27.85	2009	Spring	Yellow	Reference
Biofilm	2.46	-28.35	2009	Spring	Blackwell	Treatment
Biofilm	2.30	-27.76	2009	Spring	Blackwell	Treatment
Biofilm	0.99	-27.74	2009	Spring	Blackwell	Treatment
Biofilm	1.72	-27.92	2009	Spring	Blackwell	Treatment
Biofilm	-0.28	-27.24	2009	Spring	Blackwell	Treatment
Biofilm	1.43	-42.37	2009	Spring	Blackwell	Reference
Biofilm	4.23	-30.66	2009	Spring	Blackwell	Reference
Biofilm	1.99	-26.98	2009	Spring	Blackwell	Reference
Biofilm	3.38	-27.14	2009	Spring	Blackwell	Reference
Biofilm	2.87	-27.66	2009	Spring	Blackwell	Reference
Biofilm	1.66	-27.93	2009	Spring	Blackwell	Reference
FPOM	-0.76	-27.85	2008	Summer	Blackwell	Treatment
FPOM	-0.83	-27.91	2008	Summer	Blackwell	Treatment
FPOM	-0.82	-27.97	2008	Summer	Blackwell	Treatment
FPOM	-0.15	-27.82	2008	Summer	Blackwell	Treatment
FPOM	0.36	-27.45	2008	Summer	Blackwell	Reference
FPOM	1.49	-27.40	2008	Summer	Blackwell	Reference
FPOM	-0.31	-27.57	2008	Summer	Yellow	Treatment
FPOM	-0.94	-27.78	2008	Summer	Yellow	Reference
FPOM	-1.04	-28.18	2008	Summer	Yellow	Reference
FPOM	-0.07	-28.23	2008	Summer	Yellow	Reference
FPOM	-0.25	-28.31	2008	Summer	Yellow	Reference
FPOM	-0.27	-28.21	2008	Summer	Yellow	Reference
FPOM	0.80	-29.01	2008	Summer	Yellow	Treatment

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
FPOM	0.52	-28.23	2008	Summer	Yellow	Treatment
FPOM	0.84	-28.37	2008	Summer	Yellow	Treatment
FPOM	0.47	-28.25	2008	Summer	Yellow	Treatment
FPOM	0.30	-28.06	2008	Summer	Blackwell	Treatment
FPOM	0.29	-27.95	2008	Summer	Blackwell	Treatment
FPOM	1.12	-27.61	2008	Summer	Blackwell	Reference
FPOM	0.83	-27.60	2008	Summer	Blackwell	Reference
FPOM	1.68	-27.34	2008	Summer	Blackwell	Reference
FPOM	-0.76	-26.40	2009	Summer	Yellow	Reference
FPOM	-1.90	-27.73	2009	Summer	Yellow	Reference
FPOM	-1.89	-27.47	2009	Summer	Yellow	Reference
FPOM	-1.06	-27.88	2009	Summer	Yellow	Reference
FPOM	-1.00	-27.15	2009	Summer	Yellow	Reference
FPOM	0.30	-27.17	2009	Summer	Yellow	Reference
FPOM	-1.15	-27.29	2009	Summer	Yellow	Reference
FPOM	-0.04	-27.66	2009	Summer	Blackwell	Reference
FPOM	-0.27	-27.27	2009	Summer	Blackwell	Reference
FPOM	0.15	-27.91	2009	Summer	Blackwell	Reference
FPOM	-0.03	-27.25	2009	Summer	Blackwell	Reference
FPOM	0.14	-27.75	2009	Summer	Blackwell	Reference
FPOM	-0.09	-27.44	2009	Summer	Blackwell	Treatment
FPOM	0.19	-27.47	2009	Summer	Blackwell	Treatment
FPOM	-0.03	-27.39	2009	Summer	Blackwell	Treatment
FPOM	0.13	-27.42	2009	Summer	Blackwell	Treatment
FPOM	-0.12	-27.65	2009	Summer	Blackwell	Treatment
FPOM	-1.17	-28.26	2009	Summer	Yellow	Reference
FPOM	-1.15	-28.24	2009	Summer	Yellow	Treatment
FPOM	-0.68	-28.09	2009	Summer	Yellow	Treatment
FPOM	0.55	-27.71	2008	Spring	Blackwell	Reference
FPOM	0.51	-27.86	2008	Spring	Blackwell	Treatment
FPOM	0.39	-27.97	2008	Spring	Blackwell	Treatment
FPOM	0.22	-27.87	2008	Spring	Blackwell	Treatment
FPOM	-0.99	-28.17	2008	Spring	Yellow	Reference
FPOM	1.17	-27.52	2008	Spring	Blackwell	Reference
FPOM	2.14	-27.05	2009	Spring	Blackwell	Reference
FPOM	2.52	-26.87	2009	Spring	Blackwell	Treatment
FPOM	-1.35	-28.15	2009	Spring	Blackwell	Treatment
FPOM	0.67	-27.32	2009	Spring	Yellow	Reference
FPOM	1.99	-27.63	2009	Spring	Yellow	Reference
FPOM	4.88	-27.65	2009	Spring	Yellow	Reference
FPOM	1.31	-27.45	2009	Spring	Yellow	Reference
FPOM	1.22	-27.45	2009	Spring	Yellow	Reference
FPOM	-0.37	-28.53	2009	Spring	Yellow	Reference
FPOM	-1.91	-28.76	2009	Spring	Yellow	Reference
FPOM	2.53	-27.24	2009	Spring	Yellow	Treatment
FPOM	2.33	-27.31	2009	Spring	Yellow	Treatment
FPOM	1.71	-27.61	2009	Spring	Blackwell	Reference
FPOM	2.19	-27.27	2009	Spring	Blackwell	Reference
FPOM	0.70	-27.90	2009	Spring	Blackwell	Treatment
FPOM	1.01	-27.87	2009	Spring	Blackwell	Treatment
FPOM	-1.10	-28.52	2009	Spring	Yellow	Reference
FPOM	-0.51	-28.22	2009	Spring	Yellow	Reference
FPOM	1.52	-28.11	2009	Spring	Yellow	Treatment
FPOM	1.01	-28.00	2009	Spring	Yellow	Treatment
FPOM	0.84	-28.31	2009	Spring	Yellow	Treatment

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
FPOM	1.21	-27.92	2009	Spring	Yellow	Treatment
FPOM	0.92	-27.82	2009	Spring	Blackwell	Reference
FPOM	1.45	-27.96	2009	Spring	Yellow	Treatment
FPOM	3.00	-27.26	2009	Spring	Blackwell	Treatment
FPOM	1.10	-27.87	2009	Spring	Blackwell	Reference
FPOM	0.64	-27.73	2008	Fall	Blackwell	Treatment
FPOM	3.12	-27.73	2008	Fall	Blackwell	Reference
FPOM	-0.03	-27.56	2008	Fall	Blackwell	Treatment
FPOM	-0.88	-28.06	2008	Fall	Blackwell	Treatment
FPOM	0.26	-27.65	2008	Fall	Blackwell	Treatment
FPOM	0.13	-27.96	2008	Fall	Blackwell	Reference
FPOM	-0.97	-28.24	2008	Fall	Yellow	Reference
FPOM	0.86	-28.41	2008	Fall	Yellow	Treatment
FPOM	-0.66	-28.26	2008	Fall	Yellow	Treatment
FPOM	-0.31	-28.57	2008	Fall	Yellow	Treatment
FPOM	0.79	-27.98	2008	Fall	Yellow	Treatment
FPOM	-0.79	-28.07	2008	Fall	Yellow	Treatment
FPOM	-0.28	-27.95	2008	Fall	Yellow	Reference
FPOM	-2.15	-28.54	2008	Fall	Yellow	Reference
FPOM	-0.46	-28.14	2008	Fall	Yellow	Reference
FPOM	0.16	-28.17	2008	Fall	Yellow	Reference
FPOM	1.27	-27.28	2008	Fall	Blackwell	Reference
FPOM	1.45	-27.31	2008	Fall	Blackwell	Reference
Leaf Litter	-2.35	-27.80	2008	Summer	Blackwell	Treatment
Leaf Litter	-1.18	-27.46	2008	Summer	Blackwell	Reference
Leaf Litter	-2.73	-28.49	2008	Summer	Yellow	Reference
Leaf Litter	-3.80	-28.85	2008	Summer	Yellow	Treatment
Leaf Litter	-2.51	-28.99	2009	Summer	Blackwell	Reference
Leaf Litter	-4.75	-30.40	2009	Summer	Blackwell	Treatment
Leaf Litter	-2.50	-29.39	2009	Summer	Yellow	Reference
Leaf Litter	-3.63	-29.29	2009	Summer	Yellow	Treatment
Leaf Litter	-1.79	-27.14	2008	Spring	Blackwell	Treatment
Leaf Litter	-2.05	-27.82	2008	Spring	Blackwell	Reference
Leaf Litter	-2.54	-29.33	2008	Spring	Yellow	Treatment
Leaf Litter	-3.13	-28.40	2008	Spring	Yellow	Reference
Leaf Litter	-3.39	-28.61	2009	Spring	Blackwell	Reference
Leaf Litter	-3.30	-28.17	2009	Spring	Blackwell	Treatment
Leaf Litter	-2.97	-28.98	2009	Spring	Yellow	Treatment
Leaf Litter	-2.38	-29.42	2009	Spring	Yellow	Reference
Leaf Litter	-3.46	-30.13	2008	Fall	Blackwell	Treatment
Leaf Litter	-2.22	-28.05	2008	Fall	Blackwell	Reference
Leaf Litter	-4.06	-28.83	2008	Fall	Yellow	Treatment
Seston	0.65	-28.37	2008	Summer	Yellow	Treatment
Seston	-0.27	-23.60	2009	Summer	Yellow	Reference
Seston	1.33	-20.83	2009	Summer	Yellow	Treatment
Seston	1.30	-22.10	2009	Summer	Yellow	Treatment
Seston	0.35	-23.99	2009	Summer	Blackwell	Reference
Seston	0.72	-24.66	2009	Summer	Blackwell	Reference
Seston	0.74	-26.09	2009	Summer	Blackwell	Treatment
Seston	0.56	-23.92	2009	Summer	Blackwell	Treatment
Seston	-1.69	-28.14	2008	Spring	Yellow	Reference
Seston	-0.40	-28.61	2008	Spring	Blackwell	Treatment
Seston	-0.12	-27.87	2008	Spring	Blackwell	Reference
Seston	-0.05	-19.59	2009	Spring	Yellow	Reference
Seston	-0.03	-22.00	2009	Spring	Yellow	Reference

Category	$\delta^{15}N$	$\delta^{13}C$	Year	Season	Stream	
Seston	1.29	-18.03	2009	Spring	Yellow	Treatment
Seston	1.81	-18.88	2009	Spring	Yellow	Treatment
Seston	0.65	-22.97	2009	Spring	Blackwell	Reference
Seston	-0.44	-24.45	2009	Spring	Blackwell	Reference
Seston	1.51	-24.34	2009	Spring	Blackwell	Treatment
Seston	0.81	-24.36	2009	Spring	Blackwell	Treatment
Seston	0.65	-26.94	2008	Fall	Yellow	Reference
Seston	-0.75	-26.94	2008	Fall	Yellow	Reference
Seston	-2.00	-24.39	2008	Fall	Yellow	Treatment
Seston	-1.54	-24.23	2008	Fall	Yellow	Treatment
Seston	0.04	-25.51	2008	Fall	Blackwell	Reference
Seston	-0.60	-25.81	2008	Fall	Blackwell	Reference
Seston	-0.30	-27.89	2008	Fall	Blackwell	Treatment
Seston	-0.72	-26.06	2008	Fall	Blackwell	Treatment

Appendix 2.2. Mixing model results of percent prey items composing individual salamander species isotopic composition. Listed are individual species, season sampled, FFG prey items (collectors, predators, scrapers, shredders) and isotope values ($\delta^{15}N$ and $\delta^{13}C$) for individual salamanders.

species	season	collectors	predators	scrapers	shredders	$\delta^{15}N$	$\delta^{13}C$
Desmognathus ocoee	spring	0.00160194	0.506002	0.492369083	2.69533E-05	5.38	-24.36
Desmognathus ocoee	spring	0.001560474	0.5061188	0.492293533	2.72339E-05	5.72	-24.64
Desmognathus ocoee	spring	0.001620109	0.5059825	0.492371023	2.63806E-05	4.62	-25.51
Desmognathus ocoee	spring	0.001680858	0.5059181	0.492374742	2.63268E-05	5.40	-25.22
Desmognathus ocoee	spring	0.00159178	0.5061346	0.492246607	2.6974E-05	5.11	-23.46
Desmognathus ocoee	spring	0.001603034	0.5060347	0.492335362	2.69295E-05	4.70	-24.85
Desmognathus ocoee	spring	0.001701378	0.5060053	0.492266821	2.6523E-05	4.54	-23.91
Desmognathus ocoee	spring	0.00163133	0.5060167	0.492324427	2.75915E-05	5.01	-24.05
Desmognathus ocoee	spring	0.001632122	0.505937	0.492404621	2.62758E-05	4.24	-25.19
Desmognathus ocoee	spring	0.001588291	0.5061741	0.492210865	2.67683E-05	5.42	-23.98
Desmognathus ocoee	spring	0.001557655	0.5061154	0.492300136	2.68129E-05	5.60	-23.41
Desmognathus ocoee	spring	0.001647214	0.506072	0.492254143	2.66561E-05	4.58	-23.45
Desmognathus ocoee	spring	0.00173071	0.5059281	0.49231362	2.76119E-05	1.98	-25.04
Desmognathus ocoee	spring	0.001692792	0.5058719	0.492406989	2.83542E-05	2.38	-24.27
Desmognathus ocoee	spring	0.001671556	0.5059893	0.492312106	2.70805E-05	3.99	-23.94
Desmognathus ocoee	spring	0.001632583	0.5060187	0.492323161	2.55075E-05	4.23	-24.19
Desmognathus ocoee	spring	0.001649408	0.5060278	0.492296341	2.64317E-05	4.22	-24.10

species	season	collectors	predators	scrapers	shredders	δ^{15}N	δ^{13}C
Desmognathus quadramaculatus	spring	0.00174062	0.5058812	0.492351393	2.67685E-05	3.59	-25.07
Desmognathus quadramaculatus	spring	0.002714697	0.9929225	0.004243467	0.000119322	3.40	-25.45
Desmognathus quadramaculatus	spring	0.002591074	0.9930478	0.004241663	0.00011945	4.44	-25.44
Desmognathus quadramaculatus	spring	0.002671113	0.9929908	0.004220113	0.000117966	4.47	-24.76
Desmognathus quadramaculatus	spring	0.002640434	0.9930936	0.004147114	0.000118833	4.05	-24.84
Desmognathus quadramaculatus	spring	0.002780967	0.9928465	0.004253781	0.000118736	3.09	-24.96
Desmognathus quadramaculatus	spring	0.002601561	0.9929736	0.004304479	0.000120317	4.11	-25.58
Desmognathus quadramaculatus	spring	0.00280765	0.9927758	0.004295298	0.000121232	2.66	-25.27
Desmognathus quadramaculatus	spring	0.002607845	0.9930784	0.004194983	0.000118751	4.32	-24.48
Desmognathus quadramaculatus	spring	0.002670391	0.9930337	0.004176251	0.000119694	3.97	-24.93
Desmognathus quadramaculatus	spring	0.002537035	0.9931712	0.004172326	0.000119442	4.84	-24.48
Desmognathus quadramaculatus	spring	0.002753412	0.9929199	0.004207032	0.000119611	2.53	-23.57
Desmognathus quadramaculatus	spring	0.00273158	0.9929006	0.004247958	0.000119874	3.04	-24.54
Desmognathus quadramaculatus	spring	0.002681713	0.9929809	0.004218008	0.000119383	3.25	-25.18
Desmognathus quadramaculatus	spring	0.002475851	0.9932996	0.004107659	0.000116902	5.36	-24.55
Desmognathus quadramaculatus	spring	0.002710725	0.9929258	0.00424405	0.000119401	3.06	-25.47
Desmognathus quadramaculatus	spring	0.002646444	0.9930136	0.004219427	0.000120543	3.46	-24.96
Desmognathus quadramaculatus	spring	0.002702805	0.9929874	0.004190985	0.000118786	3.89	-24.61
Desmognathus quadramaculatus	spring	0.002526099	0.9931192	0.004233139	0.000121565	4.87	-24.76
Desmognathus quadramaculatus	spring	0.002313964	0.9933591	0.004207099	0.000119806	6.32	-23.65
Desmognathus quadramaculatus	spring	0.002470172	0.9931669	0.004244574	0.000118382	4.66	-24.41
Desmognathus quadramaculatus	spring	0.002700308	0.9929533	0.004227876	0.000118483	3.77	-24.57
Desmognathus quadramaculatus	spring	0.002606262	0.9930946	0.004179925	0.000119256	4.95	-24.85
Desmognathus quadramaculatus	spring	0.002624864	0.9930524	0.004199909	0.000122783	3.67	-26.24
Desmognathus quadramaculatus	spring	0.002767357	0.9928842	0.004228102	0.000120311	3.86	-28.01
Desmognathus quadramaculatus	spring	0.002691342	0.9928803	0.004307671	0.000120681	3.92	-29.52
Desmognathus quadramaculatus	spring	0.002715255	0.9929705	0.004195669	0.00011861	3.61	-24.59
Desmognathus quadramaculatus	spring	0.002617995	0.9929989	0.004261993	0.000121091	3.66	-27.33
Desmognathus quadramaculatus	spring	0.00263738	0.9930461	0.004197036	0.000119487	3.88	-23.85
Eurycea cirrigera	spring	0.002527948	0.993182	0.004171591	0.000118463	4.45	-24.08

species	season	collectors	predators	scrapers	shredders	$\delta^{15}N$	$\delta^{13}C$
Eurycea cirrigera	spring	0.032955857	0.5510904	0.411347108	0.004606598	3.04	-25.27
Eurycea cirrigera	spring	0.032992351	0.5428469	0.419419248	0.004741499	3.31	-27.69
Eurycea cirrigera	spring	0.03297235	0.5510472	0.411455045	0.004525394	4.12	-25.24
Eurycea cirrigera	spring	0.033918851	0.5489086	0.412475969	0.004696624	3.14	-25.22
Eurycea cirrigera	spring	0.032710639	0.5493971	0.413270047	0.004622202	3.72	-25.48
Eurycea cirrigera	spring	0.032959481	0.5457218	0.416655687	0.004663049	3.81	-24.59
Eurycea cirrigera	spring	0.032341963	0.5634515	0.399966532	0.004239972	5.08	-24.52
Eurycea cirrigera	spring	0.032886118	0.5478844	0.414676009	0.004553455	3.60	-24.78
Eurycea cirrigera	spring	0.032955611	0.5489742	0.413590592	0.004479608	4.01	-25.32
Eurycea cirrigera	spring	0.032680392	0.5407737	0.422001836	0.004544034	3.59	-28.23
Eurycea cirrigera	spring	0.032606192	0.5455464	0.417375419	0.004472036	4.33	-27.17
Eurycea cirrigera	spring	0.032457432	0.5451705	0.417755891	0.004616188	3.42	-26.61
Eurycea cirrigera	spring	0.032725721	0.5465875	0.416171141	0.004515645	4.44	-26.57
Eurycea cirrigera	spring	0.032453369	0.5404888	0.422518308	0.004539521	3.67	-28.57
Eurycea cirrigera	spring	0.032405299	0.5482713	0.414880617	0.004442771	4.56	-27.07
Eurycea cirrigera	spring	0.032890674	0.5435345	0.418995538	0.004579279	3.84	-26.76
Eurycea cirrigera	spring	0.03324904	0.5452071	0.416864721	0.004679129	3.77	-26.46
Eurycea cirrigera	spring	0.03297073	0.5464015	0.415998923	0.004628859	3.67	-26.60
Eurycea cirrigera	spring	0.033235518	0.5461149	0.415950636	0.004698953	2.97	-26.29
Eurycea cirrigera	spring	0.032716375	0.5448897	0.417720072	0.00467382	3.70	-26.09
Eurycea cirrigera	spring	0.033137142	0.5443267	0.417944662	0.004591535	3.81	-26.43
Eurycea cirrigera	spring	0.032498395	0.5469957	0.416059328	0.004446603	4.27	-26.87
Gyrinophilus	spring	0.032506069	0.5479172	0.415096582	0.004480173	4.31	-26.51
Gyrinophilus	spring	0.001776353	0.787739	0.199086695	0.011398	4.54	-25.35
Gyrinophilus	spring	0.001690692	0.7871654	0.199892744	0.01125114	4.99	-23.36
Pseudotrition	spring	0.001762043	0.7872512	0.199716228	0.01127054	4.98	-23.49
Pseudotriton	spring	0.124018892	0.1267904	0.745406456	0.003784275	4.20	-25.07
Pseudotriton	spring	0.126006221	0.1269524	0.743048625	0.003992799	4.16	-27.05
Pseudotriton	spring	0.127682997	0.1279041	0.739422151	0.00499071	2.74	-27.68
Desmognathus monticola	spring	0.125992707	0.1279261	0.742314258	0.00376692	4.51	-27.74

species	season	collectors	predators	scrapers	shredders	$\delta^{15}N$	$\delta^{13}C$
Desmognathus monticola	summer	0.451813227	0.5186341	0.012836916	0.016715771	3.20	-25.54
Desmognathus monticola	summer	0.471661317	0.496879	0.014472204	0.016987516	2.23	-23.41
Desmognathus monticola	summer	0.472721506	0.4961245	0.013965409	0.017188628	2.39	-24.15
Desmognathus monticola	summer	0.456158313	0.5138394	0.013394509	0.016607746	3.07	-24.40
Desmognathus monticola	summer	0.475928091	0.4931507	0.013584821	0.017336387	2.42	-24.97
Desmognathus monticola	summer	0.423148832	0.5472789	0.013196096	0.016376172	4.16	-23.78
Desmognathus monticola	summer	0.446453954	0.5233043	0.013267627	0.016974119	3.48	-24.63
Desmognathus monticola	summer	0.451549052	0.5188169	0.012705209	0.01692887	3.30	-24.85
Desmognathus monticola	summer	0.46861881	0.5013771	0.013146279	0.016857853	2.73	-25.14
Desmognathus monticola	summer	0.447641584	0.5219041	0.013599696	0.016854624	3.35	-24.42
Desmognathus monticola	summer	0.448256216	0.5218859	0.013120368	0.016737541	3.48	-24.63
Desmognathus monticola	summer	0.45030063	0.5199006	0.012852069	0.016946703	3.30	-24.85
Desmognathus monticola	summer	0.466492588	0.5032872	0.013374822	0.016845406	2.73	-25.14
Desmognathus monticola	summer	0.448655337	0.521118	0.013599414	0.016627215	3.35	-24.42
Desmognathus monticola	summer	0.529767346	0.4401125	0.01279999	0.017320114	0.64	-24.50
Desmognathus monticola	summer	0.492184119	0.4771803	0.013298812	0.017336779	1.90	-25.40
Desmognathus monticola	summer	0.442226889	0.5284019	0.012547093	0.016824134	3.42	-26.25
Desmognathus ocoee	summer	0.441508287	0.528516	0.012784665	0.017191071	3.42	-26.25
Desmognathus ocoee	summer	0.027679047	0.9427532	0.02056656	0.009001223	5.07	-23.61
Desmognathus ocoee	summer	0.029149684	0.9408849	0.020742834	0.009222603	4.58	-23.73
Desmognathus ocoee	summer	0.031495856	0.9365578	0.022408505	0.009537848	3.65	-25.22
Desmognathus quadramaculatus	summer	0.034211959	0.9332988	0.022494118	0.009995116	2.77	-24.67
Desmognathus quadramaculatus	summer	0.000612345	0.9937857	0.005380917	0.000221039	5.51	-25.64
Desmognathus quadramaculatus	summer	0.000603921	0.9938747	0.005302342	0.000219031	6.43	-25.54
Desmognathus quadramaculatus	summer	0.000596662	0.9938038	0.005380747	0.000218757	5.63	-25.46
Desmognathus quadramaculatus	summer	0.000613772	0.9936286	0.005527272	0.000230346	3.03	-25.57
Desmognathus quadramaculatus	summer	0.000621176	0.99373	0.005415798	0.000233075	5.38	-24.80
Desmognathus quadramaculatus	summer	0.000618315	0.9937689	0.005382981	0.000229849	5.20	-25.10
Desmognathus quadramaculatus	summer	0.000613085	0.9935906	0.005569234	0.000227074	5.43	-25.03
Desmognathus quadramaculatus	summer	0.000620343	0.993475	0.005676816	0.000227845	2.99	-25.67

species	season	collectors	predators	scrapers	shredders	$\delta^{15}N$	$\delta^{13}C$
Desmognathus quadramaculatus	summer	0.000610761	0.9934887	0.005674584	0.000225982	2.64	-26.36
Desmognathus quadramaculatus	summer	0.000611542	0.9936916	0.005478134	0.000218679	5.49	-26.04
Desmognathus quadramaculatus	summer	0.00058647	0.9937574	0.005432382	0.000223736	5.57	-25.91
Desmognathus quadramaculatus	summer	0.000609569	0.9934992	0.005663027	0.000228218	3.19	-25.35
Desmognathus quadramaculatus	summer	0.000622065	0.9935425	0.005606694	0.000228762	3.47	-24.43
Desmognathus quadramaculatus	summer	0.000637757	0.993602	0.005536237	0.000223973	3.55	-24.52
Desmognathus quadramaculatus	summer	0.000624877	0.9935351	0.005616236	0.000223742	2.45	-25.65
Desmognathus quadramaculatus	summer	0.000614659	0.9936314	0.005537002	0.000216936	2.60	-25.28
Desmognathus quadramaculatus	summer	0.000628886	0.9935223	0.005626573	0.000222242	2.88	-25.45
Desmognathus quadramaculatus	summer	0.000602623	0.9935743	0.005595607	0.000227457	2.63	-26.04
Desmognathus quadramaculatus	summer	0.000621574	0.9937128	0.005425218	0.00024045	2.85	-25.73
Desmognathus quadramaculatus	summer	0.000632038	0.9935555	0.005585571	0.00022694	3.24	-25.02
Desmognathus quadramaculatus	summer	0.000607046	0.9934201	0.005745433	0.000227446	2.58	-25.86
Desmognathus quadramaculatus	summer	0.000615135	0.9935899	0.005559928	0.000235026	2.80	-25.20
Desmognathus quadramaculatus	summer	0.000621658	0.9936951	0.005464214	0.000219	3.90	-25.39
Desmognathus quadramaculatus	summer	0.000607461	0.9937635	0.005408704	0.000220323	5.77	-25.83
Desmognathus quadramaculatus	summer	0.000601778	0.9938074	0.005365619	0.000225203	5.88	-26.07
Desmognathus quadramaculatus	summer	0.000603864	0.99376	0.005398516	0.000237581	5.75	-25.98
Desmognathus quadramaculatus	summer	0.000607588	0.9937689	0.00539765	0.000225814	5.73	-25.72
Desmognathus quadramaculatus	summer	0.000598306	0.9936789	0.005495987	0.000226852	5.77	-25.67
Desmognathus quadramaculatus	summer	0.000616933	0.9937853	0.005383236	0.000214526	5.63	-25.62
Desmognathus quadramaculatus	summer	0.000632725	0.9935965	0.005555523	0.000215267	5.54	-25.79
Desmognathus quadramaculatus	summer	0.000619065	0.9937604	0.005401245	0.000219247	5.62	-25.17
Desmognathus quadramaculatus	summer	0.000619128	0.9937596	0.005394089	0.000227158	5.91	-24.65
Desmognathus quadramaculatus	summer	0.000620009	0.9934836	0.005665869	0.000230517	4.29	-23.89
Desmognathus quadramaculatus	summer	0.000603887	0.9935557	0.005614788	0.000225598	5.55	-25.07
Desmognathus quadramaculatus	summer	0.000613735	0.9937807	0.00538259	0.000222989	5.58	-25.43
Desmognathus quadramaculatus	summer	0.000628002	0.9935661	0.005578548	0.00022732	2.18	-26.31
Desmognathus quadramaculatus	summer	0.000619125	0.9938298	0.005327444	0.000223661	2.84	-28.67
Desmognathus quadramaculatus	summer	0.000624306	0.9936771	0.005476273	0.000222319	3.40	-27.85

species	season	collectors	predators	scrapers	shredders	$\delta^{15}N$	$\delta^{13}C$
Eurycea cirrigera	summer	0.000612847	0.9935617	0.005595717	0.000229701	3.40	-28.68
Eurycea cirrigera	summer	0.000623514	0.9933722	0.005776784	0.000227481	2.58	-24.32
Eurycea cirrigera	summer	0.036284326	0.6655766	0.288040058	0.010099006	2.57	-24.78
Eurycea cirrigera	summer	0.033058725	0.7198071	0.237848764	0.009285413	4.09	-24.80
Eurycea cirrigera	summer	0.035683751	0.6750878	0.279193861	0.010034631	2.62	-24.46
Eurycea cirrigera	summer	0.034927664	0.7127067	0.242557239	0.009808405	3.17	-27.69
Eurycea cirrigera	summer	0.036127211	0.6675163	0.286168527	0.010187991	2.70	-24.05
Eurycea cirrigera	summer	0.03570835	0.6810926	0.273172076	0.010026979	2.66	-25.11
Eurycea cirrigera	summer	0.03587214	0.6953196	0.258477354	0.010330871	2.44	-28.37
Eurycea cirrigera	summer	0.034070994	0.716568	0.239821164	0.009539803	4.11	-28.17
Eurycea cirrigera	summer	0.033561897	0.7316204	0.225355068	0.009462604	4.06	-27.61
Eurycea cirrigera	summer	0.035382043	0.7159588	0.239112496	0.009546652	3.56	-29.02
Eurycea cirrigera	summer	0.034615894	0.7159447	0.239982781	0.00945667	3.62	-26.41
Eurycea cirrigera	summer	0.035228369	0.7099866	0.245123517	0.009661477	3.31	-26.65
Eurycea cirrigera	summer	0.033229544	0.7363894	0.221085783	0.009295298	4.28	-29.42
Eurycea cirrigera	summer	0.033901488	0.7286848	0.227690852	0.009722898	3.91	-27.90
Eurycea cirrigera	summer	0.034208589	0.7213998	0.234751887	0.009639765	3.58	-27.85
Eurycea cirrigera	summer	0.034089208	0.7196056	0.236639387	0.009665848	3.63	-26.51
Eurycea cirrigera	summer	0.033164205	0.7322598	0.225122738	0.009453305	3.96	-28.15
Eurycea cirrigera	summer	0.034202527	0.7091372	0.246850143	0.009810144	3.39	-27.10
Eurycea cirrigera	summer	0.034491511	0.712001	0.24402252	0.009484986	3.68	-26.84
Eurycea cirrigera	summer	0.035625138	0.6953364	0.259030663	0.010007838	2.85	-26.02
Desmognathus monticola	summer	0.035056226	0.6930487	0.261981717	0.009913328	2.85	-26.02
Desmognathus ocoee	fall	0.357676	0.5276955	0.03098926	0.08363918	3.56	-24.33
Desmognathus ocoee	fall	0.3489691	0.5667701	0.02631021	0.05795065	3.96	-26.55
Desmognathus ocoee	fall	0.3481448	0.5694675	0.02569441	0.05669327	4.17	-26.49
Desmognathus quadramaculatus	fall	0.3521819	0.5617369	0.02646034	0.05962087	3.70	-24.66
Desmognathus quadramaculatus	fall	0.5130302	0.415105	0.01920084	0.05266403	5.11	-24.43
Desmognathus quadramaculatus	fall	0.5129444	0.4025125	0.02259684	0.06194629	3.22	-24.73
Desmognathus quadramaculatus	fall	0.5128333	0.4027471	0.02247803	0.06194157	3.20	-24.62

species	season	collectors	predators	scrapers	shredders	$\delta^{15}N$	$\delta^{13}C$
Desmognathus quadramaculatus	fall	0.5103105	0.4082094	0.02188396	0.05959609	3.64	-24.86
Desmognathus quadramaculatus	fall	0.5131815	0.4023245	0.02261252	0.06188143	3.18	-24.56
Desmognathus quadramaculatus	fall	0.5058788	0.4133219	0.02196724	0.05883204	3.78	-26.67
Eurycea cirrigera	fall	0.5156666	0.3980913	0.02304541	0.0631967	3.01	-24.87
Eurycea cirrigera	fall	0.1643329	0.6803491	0.0264231	0.1288949	3.08	-24.34
Eurycea cirrigera	fall	0.1774833	0.6499704	0.02857807	0.14396827	2.35	-24.55
Eurycea cirrigera	fall	0.1644427	0.6818904	0.02621512	0.12745183	3.20	-24.62
Eurycea cirrigera	fall	0.1696341	0.6720443	0.02704639	0.13127521	3.10	-25.36
Eurycea cirrigera	fall	0.1647164	0.680874	0.02648297	0.12792667	3.15	-24.65
Eurycea cirrigera	fall	0.1595284	0.6923167	0.02544737	0.12270746	3.40	-24.15
Eurycea cirrigera	fall	0.174166	0.6648087	0.02754886	0.13347641	3.05	-26.00
Eurycea cirrigera	fall	0.1703158	0.6744717	0.02668475	0.12852781	3.35	-26.26

Appendix 2.3. Count data of salamander species from four headwater streams using leaf litter bags and dip nets form April 2008-November 2008. Data includes stream and trap number, salamanders species, date, snout-vent length (mm), total length (mm), mass (g wet weight) and age. Age categories are: larvae (L), young of year (YOY), reaching metamorophosis (recMet), metamorphing (M), juvenile (Juv) and adult (A).

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	1	*Eurycea cirrigera*	8-Apr-08			0.091	L
Blackwell	Reference	1	*Desmognathus quadramaculatus*	8-Apr-08			0.16	L
Blackwell	Reference	1	*Desmognathus quadramaculatus*	8-Apr-08			0.153	L
Blackwell	Reference	1	*Eurycea cirrigera*	8-Apr-08			0.113	L
Blackwell	Reference	3	*Eurycea cirrigera*	8-Apr-08			0.142	L
Blackwell	Reference	3	*Eurycea cirrigera*	8-Apr-08			0.105	L
Blackwell	Reference	3	*Eurycea cirrigera*	8-Apr-08			0.104	L
Blackwell	Reference	3	*Eurycea cirrigera*	8-Apr-08			0.159	L
Blackwell	Reference	3	*Desmognathus ocoee*	8-Apr-08			0.079	L
Blackwell	Reference	3	*Eurycea cirrigera*	8-Apr-08			0.158	L
Blackwell	Reference	3	*Eurycea cirrigera*	8-Apr-08			0.166	L
Blackwell	Reference	5	*Eurycea cirrigera*	8-Apr-08			0.089	L
Blackwell	Reference	7	*Desmognathus quadramaculatus*	8-Apr-08			0.38	L
Blackwell	Reference	7	*Desmognathus quadramaculatus*	8-Apr-08			0.418	L
Blackwell	Reference	7	*Eurycea cirrigera*	8-Apr-08			0.106	L
Blackwell	Reference	9	*Desmognathus ocoee*	8-Apr-08			0.982	L
Blackwell	Reference	9	*Desmognathus quadramaculatus*	8-Apr-08			0.461	L
Blackwell	Reference	9	*Desmognathus quadramaculatus*	8-Apr-08			0.37	L
Blackwell	Reference	9	*Eurycea cirrigera*	8-Apr-08			0.147	L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	8-Apr-08			0.187	L
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	8-Apr-08			0.257	L
Blackwell	Treatment	7	*Desmognathus ocoee*	8-Apr-08			0.184	M
Blackwell	Treatment	9	*Eurycea cirrigera*	8-Apr-08			0.128	L
Blackwell	Treatment	9	*Eurycea cirrigera*	8-Apr-08			0.132	L
Blackwell	Treatment	9	*Gyrinophilus porphyriticus*	8-Apr-08			0.065	L
Blackwell	Reference	1	*Eurycea cirrigera*	9-Apr-08			0.185	L
Blackwell	Reference	3	*Eurycea cirrigera*	9-Apr-08			0.188	L
Blackwell	Reference	3	*Eurycea cirrigera*	9-Apr-08			0.054	L
Blackwell	Reference	5	*Desmognathus quadramaculatus*	9-Apr-08			0.334	L
Blackwell	Treatment	1	*Desmognathus ocoee*	9-Apr-08			0.013	L
Blackwell	Treatment	3	*Eurycea cirrigera*	9-Apr-08			0.079	L
Blackwell	Treatment	5	*Eurycea cirrigera*	9-Apr-08			0.156	L
Blackwell	Treatment	9	*Eurycea cirrigera*	9-Apr-08			0.187	L
Blackwell	Reference	1	*Eurycea cirrigera*	10-Apr-08			0.13	
Blackwell	Reference	2	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	2	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	2	*Desmognathus ocoee*	10-Apr-08				recMet
Blackwell	Reference	2	*Desmognathus quadramaculatus*	10-Apr-08				L
Blackwell	Reference	3	*Eurycea cirrigera*	10-Apr-08			0.192	L
Blackwell	Reference	3	*Eurycea cirrigera*	10-Apr-08			0.125	L
Blackwell	Reference	4	*Desmognathus ocoee*	10-Apr-08				recMet
Blackwell	Reference	4	*Desmognathus ocoee*	10-Apr-08				recMet
Blackwell	Reference	4	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	4	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	5	*Desmognathus quadramaculatus*	10-Apr-08			0.202	L
Blackwell	Reference	5	*Eurycea cirrigera*	10-Apr-08			0.262	L
Blackwell	Reference	5	*Desmognathus ocoee*	10-Apr-08			0.088	L
Blackwell	Reference	6	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	6	*Gyrinophilus porphyriticus*	10-Apr-08				L
Blackwell	Reference	7	*Desmognathus quadramaculatus*	10-Apr-08			0.247	L
Blackwell	Reference	8	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	8	*Eurycea cirrigera*	10-Apr-08				L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	8	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	9	*Eurycea cirrigera*	10-Apr-08			0.056	L
Blackwell	Reference	10	*Desmognathus ocoee*	10-Apr-08				L
Blackwell	Reference	10	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	10	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	10	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	10	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Reference	10	*Desmognathus quadramaculatus*	10-Apr-08				L
Blackwell	Treatment	1	*Eurycea cirrigera*	10-Apr-08			0.172	L
Blackwell	Treatment	2	*Gyrinophilus porphyriticus*	10-Apr-08				L
Blackwell	Treatment	3	*Eurycea cirrigera*	10-Apr-08			0.143	L
Blackwell	Treatment	4	*Desmognathus quadramaculatus*	10-Apr-08				L
Blackwell	Treatment	4	*Gyrinophilus porphyriticus*	10-Apr-08				L
Blackwell	Treatment	4	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Treatment	6	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	10-Apr-08			0.245	L
Blackwell	Treatment	7	*Desmognathus ocoee*	10-Apr-08			0.093	L
Blackwell	Treatment	8	*Gyrinophilus porphyriticus*	10-Apr-08				L
Blackwell	Treatment	8	*Gyrinophilus porphyriticus*	10-Apr-08				L
Blackwell	Treatment	8	*Gyrinophilus porphyriticus*	10-Apr-08				L
Blackwell	Treatment	9	*Eurycea cirrigera*	10-Apr-08			0.187	L
Blackwell	Treatment	10	*Eurycea cirrigera*	10-Apr-08				L
Blackwell	Treatment	10	*Eurycea cirrigera*	10-Apr-08				L
Yellow	Reference	1	*Desmognathus quadramaculatus*	16-Apr-08			0.821	L
Yellow	Reference	3	*Desmognathus quadramaculatus*	16-Apr-08			0.979	L
Yellow	Reference	3	*Eurycea cirrigera*	16-Apr-08			0.46	L
Yellow	Reference	5	*Eurycea cirrigera*	16-Apr-08			0.421	L
Yellow	Reference	5	*Eurycea cirrigera*	16-Apr-08			0.457	L
Yellow	Reference	7	*Eurycea cirrigera*	16-Apr-08			0.125	L
Yellow	Reference	7	*Eurycea cirrigera*	16-Apr-08			0.266	L
Yellow	Reference	9	*Desmognathus quadramaculatus*	16-Apr-08			1.109	L
Yellow	Reference	9	*Eurycea cirrigera*	16-Apr-08			2.43	L
Yellow	Reference	9	*Eurycea cirrigera*	16-Apr-08			0.24	L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Treatment	3	*Desmognathus quadramaculatus*	16-Apr-08				L
Yellow	Treatment	7	*Gyrinophilus porphyriticus*	16-Apr-08			0.093	L
Yellow	Treatment	7	*Desmognathus quadramaculatus*	16-Apr-08			0.227	L
Yellow	Treatment	9	*Gyrinophilus porphyriticus*	16-Apr-08			0.085	L
Yellow	Treatment	9	*Eurycea cirrigera*	16-Apr-08			0.227	L
Yellow	Reference	1	*Desmognathus quadramaculatus*	17-Apr-08				L
Yellow	Reference	3	*Desmognathus quadramaculatus*	17-Apr-08			0.47	L
Yellow	Reference	3	*Desmognathus quadramaculatus*	17-Apr-08			0.67	L
Yellow	Reference	7	*Eurycea cirrigera*	17-Apr-08			1.25	L
Yellow	Reference	7	*Desmognathus quadramaculatus*	17-Apr-08			0.325	L
Yellow	Reference	7	*Desmognathus quadramaculatus*	17-Apr-08			0.11	L
Yellow	Reference	9	*Desmognathus quadramaculatus*	17-Apr-08			0.296	L
Yellow	Treatment	3	*Desmognathus quadramaculatus*	17-Apr-08			2.24	L
Yellow	Reference	5	*Eurycea cirrigera*	18-Apr-08			0.415	L
Yellow	Reference	7	*Eurycea cirrigera*	18-Apr-08			0.301	L
Yellow	Reference	7	*Eurycea cirrigera*	18-Apr-08			0.46	L
Yellow	Reference	7	*Eurycea cirrigera*	18-Apr-08				L
Yellow	Treatment	3	*Eurycea cirrigera*	18-Apr-08			0.225	
Yellow	Treatment	3	*Desmognathus quadramaculatus*	18-Apr-08			0.83	
Yellow	Treatment	5	*Desmognathus quadramaculatus*	18-Apr-08			0.088	
Blackwell	Reference	1	*Desmognathus ocoee*	7-May-08	14	16	0.12	L
Blackwell	Reference	3	*Gyrinophilus porphyriticus*	7-May-08	18	33	0.16	L
Blackwell	Reference	5	*Eurycea cirrigera*	7-May-08	25	50		L
Blackwell	Reference	7	*Desmognathus quadramaculatus*	7-May-08	20	40	0.32	L
Blackwell	Reference	7	*Desmognathus quadramaculatus*	7-May-08	20	38	0.32	L
Blackwell	Reference	9	*Desmognathus quadramaculatus*	7-May-08	37	43	1.47	L
Blackwell	Reference	9	*Eurycea cirrigera*	7-May-08	15	30	0.2	L
Blackwell	Treatment	1	*Eurycea cirrigera*	7-May-08	21	37	0.19	L
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	7-May-08	23	38	0.45	
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	7-May-08	21	41	0.32	
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	7-May-08				
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	7-May-08				
Blackwell	Treatment	9	*Gyrinophilus porphyriticus*	7-May-08	63	95	3.4	

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Treatment	9	*Pseudotriton spp.*	7-May-08	32	54	0.63	
Blackwell	Treatment	9	*Desmognathus ocoee*	7-May-08	28	53	0.39	
Blackwell	Treatment	9	*Eurycea cirrigera*	7-May-08	20	35	0.28	
Yellow	Reference	7	*Eurycea cirrigera*	7-May-08	27	50	0.54	
Yellow	Treatment	1	*Eurycea cirrigera*	7-May-08	25	45	0.45	
Yellow	Treatment	3	*Eurycea cirrigera*	7-May-08	34	68	0.7	
Yellow	Treatment	3	*Eurycea cirrigera*	7-May-08	21	48	0.46	
Yellow	Treatment	5	*Desmognathus ocoee*	7-May-08	14	22		
Yellow	Treatment	5	*Gyrinophilus porphyriticus*	7-May-08	15	25	0.2	
Yellow	Treatment	7	*Desmognathus monticola*	7-May-08	50	85	2.95	
Yellow	Treatment	7	*Desmognathus quadramaculatus*	7-May-08	22	32	0.029	
Yellow	Treatment	9	*Eurycea cirrigera*	7-May-08	25	48	0.45	
Blackwell	Reference	3	*Gyrinophilus porphyriticus*	8-May-08	47	84	2.24	
Blackwell	Reference	3	*Gyrinophilus porphyriticus*	8-May-08	15	30	0.19	
Blackwell	Reference	3	*Eurycea cirrigera*	8-May-08	19	30	0.2	
Blackwell	Reference	3	*Eurycea cirrigera*	8-May-08	8	15	0.01	
Blackwell	Reference	3	*Eurycea cirrigera*	8-May-08	8	15	0.01	
Blackwell	Reference	3	*Eurycea cirrigera*	8-May-08	17	35	0.27	
Blackwell	Reference	5	*Desmognathus ocoee*	8-May-08	12	23	0.14	
Blackwell	Reference	7	*Desmognathus quadramaculatus*	8-May-08	20	37	0.31	
Blackwell	Reference	7	*Desmognathus quadramaculatus*	8-May-08	21	42	0.41	
Blackwell	Reference	9	*Eurycea cirrigera*	8-May-08	9	17	0.01	
Blackwell	Treatment	1	*Eurycea cirrigera*	8-May-08	16	35	0.22	
Blackwell	Treatment	1	*Eurycea cirrigera*	8-May-08	20	37	0.23	
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	8-May-08	19	40	0.32	
Blackwell	Treatment	5	*Eurycea cirrigera*	8-May-08	16	30	0.18	
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	8-May-08	30	60	0.91	
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	8-May-08	15	28	0.18	
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	8-May-08	75	35	0.08	
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	8-May-08	65	30	1.33	
Blackwell	Treatment	9	*Eurycea cirrigera*	8-May-08	18	35	0.24	
Yellow	Reference	1	*Desmognathus ocoee*	8-May-08	40	78	1.41	
Yellow	Reference	3	*Desmognathus ocoee*	8-May-08	40	80	1.68	

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Reference	3	*Desmognathus ocoee*	8-May-08	45	87	1.9	
Yellow	Reference	3	*Desmognathus monticola*	8-May-08				L
Yellow	Reference	5	*Pseudotriton spp.*	8-May-08	22	35	0.26	
Yellow	Treatment	3	*Gyrinophilus porphyriticus*	8-May-08	21	42	0.22	
Yellow	Treatment	5	*Gyrinophilus porphyriticus*	8-May-08	34	55	1	
Yellow	Treatment	5	*Gyrinophilus porphyriticus*	8-May-08	20	30	0.21	
Yellow	Treatment	5	*Eurycea cirrigera*	8-May-08	8	15	0.1	
Blackwell	Reference	1	*Eurycea cirrigera*	9-May-08	15	28	0.1	
Blackwell	Reference	1	*Eurycea cirrigera*	9-May-08	10	16	0.06	YOY
Blackwell	Reference	1	*Eurycea cirrigera*	9-May-08	16	30	0.15	
Blackwell	Reference	3	*Eurycea cirrigera*	9-May-08	16	27	0.17	
Blackwell	Reference	3	*Eurycea cirrigera*	9-May-08	7	15	0.01	YOY
Blackwell	Reference	3	*Eurycea cirrigera*	9-May-08	16	33	0.21	
Blackwell	Reference	3	*Eurycea cirrigera*	9-May-08	9	16	0.03	YOY
Blackwell	Reference	3	*Eurycea cirrigera*	9-May-08	9	16	0.02	YOY
Blackwell	Reference	3	*Eurycea cirrigera*	9-May-08	15	28	0.3	
Blackwell	Reference	5	*Eurycea cirrigera*	9-May-08	9	17	0.04	YOY
Blackwell	Reference	7	*Desmognathus ocoee*	9-May-08	20	37	0.28	
Blackwell	Reference	9	*Eurycea cirrigera*	9-May-08	18	33	0.18	
Blackwell	Reference	9	*Gyrinophilus porphyriticus*	9-May-08	14	25	0.07	
Blackwell	Reference	9	*Eurycea cirrigera*	9-May-08	9	18	0.03	YOY
Blackwell	Reference	9	*Eurycea cirrigera*	9-May-08	8	16	0.03	YOY
Blackwell	Treatment	5	*Desmognathus quadramaculatus*	9-May-08	24	43	0.61	L
Blackwell	Treatment	5	*Eurycea cirrigera*	9-May-08	16	28	0.17	
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	9-May-08	16	31	0.15	
Blackwell	Treatment	9	*Desmognathus quadramaculatus*	9-May-08	31	54	0.8	L
Yellow	Reference	3	*Eurycea cirrigera*	9-May-08	32	68		L
Yellow	Reference	5	*Desmognathus ocoee*	9-May-08	38	90		recMet
Yellow	Reference	5	*Eurycea cirrigera*	9-May-08	26	45		J
Yellow	Reference	9	*Eurycea cirrigera*	9-May-08	21	42		J
Yellow	Treatment	1	*Eurycea cirrigera*	9-May-08	21	20	0.24	L
Yellow	Treatment	3	*Eurycea cirrigera*	9-May-08	20	47	0.34	L
Yellow	Treatment	3	*Eurycea cirrigera*	9-May-08	8	13	0.03	YOY

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Treatment	3	*Eurycea cirrigera*	9-May-08	7	15	0.04	YOY
Yellow	Treatment	3	*Eurycea cirrigera*	9-May-08	9	16	0.03	YOY
Yellow	Treatment	5	*Pseudotriton spp.*	9-May-08	18	35		L
Yellow	Treatment	5	*Gyrinophilus porphyriticus*	9-May-08	17	36		L
Yellow	Treatment	7	*Eurycea cirrigera*	9-May-08	7	15		YOY
Yellow	Treatment	7	*Gyrinophilus porphyriticus*	9-May-08	14	28		L
Yellow	Treatment	7	*Desmognathus ocoee*	9-May-08	14	28		
Blackwell	Reference	1	*Eurycea cirrigera*	2-Jun-08	12	15	0.04	recMet
Blackwell	Reference	1	*Eurycea cirrigera*	2-Jun-08	12	21	0.02	recMet
Blackwell	Reference	1	*Desmognathus quadramaculatus*	2-Jun-08	21	34	0.13	L
Blackwell	Reference	2	*Desmognathus ocoee*	2-Jun-08	18	32	0.11	recMet
Blackwell	Reference	2	*Desmognathus ocoee*	2-Jun-08	31	48	0.27	Juv.
Blackwell	Reference	2	*Desmognathus ocoee*	2-Jun-08	18	22	0.09	recMet
Blackwell	Reference	2	*Desmognathus ocoee*	2-Jun-08	18	35	0.11	recMet
Blackwell	Reference	2	*Eurycea cirrigera*	2-Jun-08	19	36	0.1	L
Blackwell	Reference	2	*Desmognathus ocoee*	2-Jun-08	17	35	0.11	recMet
Blackwell	Reference	2	*Desmognathus ocoee*	2-Jun-08	18	35	0.13	recMet
Blackwell	Reference	2	*Desmognathus ocoee*	2-Jun-08	18	34	0.17	recMet
Blackwell	Reference	2	*Eurycea cirrigera*	2-Jun-08	12	19	0.02	YOY
Blackwell	Reference	2	*Eurycea cirrigera*	2-Jun-08	12	18	0.03	YOY
Blackwell	Reference	2	*Eurycea cirrigera*	2-Jun-08	13	21	0.02	YOY
Blackwell	Reference	2	*Gyrinophilus porphyriticus*	2-Jun-08	18	32	0.1	L
Blackwell	Reference	2	*Eurycea cirrigera*	2-Jun-08	9	13	0.04	recMet
Blackwell	Reference	2	*Eurycea cirrigera*	2-Jun-08	12	18	0.04	recMet
Blackwell	Reference	2	*Eurycea cirrigera*	2-Jun-08	12	18	0.06	recMet
Blackwell	Reference	3	*Desmognathus ocoee*	2-Jun-08	15	28	0.11	Juv.
Blackwell	Reference	3	*Eurycea cirrigera*	2-Jun-08	22	43	0.17	Juv.
Blackwell	Reference	3	*Desmognathus ocoee*	2-Jun-08	18	31	0.09	recMet
Blackwell	Reference	4	*Desmognathus ocoee*	2-Jun-08	18	39	0.08	recMet
Blackwell	Reference	4	*Desmognathus ocoee*	2-Jun-08	15	28	0.07	recMet
Blackwell	Reference	4	*Eurycea cirrigera*	2-Jun-08	21	37	0.39	L
Blackwell	Reference	4	*Desmognathus monticola*	2-Jun-08	19	37	0.13	recMet
Blackwell	Reference	5	*Desmognathus quadramaculatus*	2-Jun-08	23	40	2.62	L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	5	*Desmognathus ocoee*	2-Jun-08	18	26	0.16	recMet
Blackwell	Reference	5	*Desmognathus monticola*	2-Jun-08	27	53	0.39	Juv.
Blackwell	Reference	5	*Desmognathus ocoee*	2-Jun-08	17	32	0.12	recMet
Blackwell	Reference	6	*Desmognathus ocoee*	2-Jun-08	17	29	0.12	recMet
Blackwell	Reference	6	*Desmognathus ocoee*	2-Jun-08	19	38	0.18	recMet
Blackwell	Reference	6	*Eurycea cirrigera*	2-Jun-08	13	19	0.02	YOY
Blackwell	Reference	6	*Desmognathus ocoee*	2-Jun-08	16	27	0.09	recMet
Blackwell	Reference	7	*Desmognathus ocoee*	2-Jun-08	16	24	0.08	recMet
Blackwell	Reference	7	*Desmognathus quadramaculatus*	2-Jun-08	23	37	0.41	L
Blackwell	Reference	7	*Desmognathus ocoee*	2-Jun-08	17	29	0.12	recMet
Blackwell	Reference	7	*Desmognathus ocoee*	2-Jun-08	18	34	0.46	recMet
Blackwell	Reference	7	*Eurycea cirrigera*	2-Jun-08	10	15	0.02	YOY
Blackwell	Reference	7	*Eurycea cirrigera*	2-Jun-08	11	16	0.03	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	24	44	0.25	L
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	10	15	0.02	YOY
Blackwell	Reference	8	*Desmognathus ocoee*	2-Jun-08	17	29	0.11	recMet
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	19	37	0.17	L
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	20	38	0.18	recMet
Blackwell	Reference	8	*Desmognathus ocoee*	2-Jun-08	17	32	0.16	recMet
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	10	16	0.02	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	9	15	0.02	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	10	16	0.02	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08	11	17	0.04	YOY
Blackwell	Reference	9	*Desmognathus monticola*	2-Jun-08	20	35	0.2	Juv.
Blackwell	Reference	9	*Eurycea cirrigera*	2-Jun-08	20	37	0.15	L
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08	23	38	0.19	L
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08	22	38	0.18	L
Blackwell	Reference	10	*Desmognathus ocoee*	2-Jun-08	19	32	0.17	recMet
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08	20	38	0.17	recMet
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08				YOY

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Reference	10	*Desmognathus quadramaculatus*	2-Jun-08	31	56	1.09	L
Blackwell	Reference	10	*Desmognathus quadramaculatus*	2-Jun-08	35	52	0.78	L
Blackwell	Reference	10	*Desmognathus ocoee*	2-Jun-08	33	54	0.65	recMet
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	2-Jun-08				L
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	2-Jun-08				L
Blackwell	Treatment	1	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	1	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	1	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	2	*Gyrinophilus porphyriticus*	2-Jun-08	19	34	0.14	L
Blackwell	Treatment	3	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	3	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	3	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	2-Jun-08				L
Blackwell	Treatment	3	*Gyrinophilus porphyriticus*	2-Jun-08				L
Blackwell	Treatment	4	*Gyrinophilus porphyriticus*	2-Jun-08	45	57	1.46	L
Blackwell	Treatment	4	*Desmognathus quadramaculatus*	2-Jun-08	20	31	0.25	L
Blackwell	Treatment	4	*Desmognathus quadramaculatus*	2-Jun-08	21	30		L
Blackwell	Treatment	4	*Desmognathus ocoee*	2-Jun-08	18	35	0.12	recMet
Blackwell	Treatment	5	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	5	*Eurycea cirrigera*	2-Jun-08				L
Blackwell	Treatment	8	*Eurycea cirrigera*	2-Jun-08	25	50	0.29	Juv.
Blackwell	Treatment	8	*Eurycea cirrigera*	2-Jun-08	17	30	0.11	L
Blackwell	Treatment	9	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Treatment	9	*Eurycea cirrigera*	2-Jun-08				L
Blackwell	Treatment	9	*Desmognathus ocoee*	2-Jun-08				recMet
Blackwell	Treatment	10	*Eurycea cirrigera*	2-Jun-08	18	42	0.24	Juv.
Blackwell	Treatment	10	*Eurycea cirrigera*	2-Jun-08	8	15	0.01	YOY
Blackwell	Reference	1	*Desmognathus quadramaculatus*	3-Jun-08	34	52	1.26	L
Blackwell	Reference	2	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Reference	2	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Reference	2	*Pseudotriton ruber*	3-Jun-08				L
Blackwell	Reference	2	*Desmognathus ocoee*	3-Jun-08				recMet

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	3	*Gyrinophilus porphyriticus*	3-Jun-08	22	40	0.35	L
Blackwell	Reference	3	*Desmognathus ocoee*	3-Jun-08	16	27	0.1	recMet
Blackwell	Reference	4	*Desmognathus ocoee*	3-Jun-08				Juv.
Blackwell	Reference	4	*Desmognathus ocoee*	3-Jun-08				Juv.
Blackwell	Reference	4	*Desmognathus ocoee*	3-Jun-08				Juv.
Blackwell	Reference	4	*Desmognathus ocoee*	3-Jun-08				Juv.
Blackwell	Reference	4	*Eurycea cirrigera*	3-Jun-08				L
Blackwell	Reference	4	*Eurycea cirrigera*	3-Jun-08				L
Blackwell	Reference	4	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Reference	2	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Reference	2	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Reference	2	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Reference	2	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Reference	2	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Reference	2	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Reference	5	*Desmognathus ocoee*	3-Jun-08	18	37	0.4	recMet
Blackwell	Reference	6	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Reference	6	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Reference	7	*Eurycea cirrigera*	3-Jun-08	10	15	0.01	YOY
Blackwell	Reference	7	*Eurycea cirrigera*	3-Jun-08	11	16	0.02	YOY
Blackwell	Reference	7	*Eurycea cirrigera*	3-Jun-08	12	15	0.02	YOY
Blackwell	Reference	7	*Desmognathus ocoee*	3-Jun-08	16	30	0.18	YOY
Blackwell	Reference	7	*Desmognathus quadramaculatus*	3-Jun-08	30	53	0.69	L
Blackwell	Reference	9	*Desmognathus ocoee*	3-Jun-08	15	30	0.14	recMet
Blackwell	Reference	9	*Eurycea cirrigera*	3-Jun-08	18	39	0.34	L
Blackwell	Reference	10	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Reference	10	*Desmognathus quadramaculatus*	3-Jun-08				recMet
Blackwell	Reference	10	*Eurycea cirrigera*	3-Jun-08				L
Blackwell	Reference	10	*Eurycea cirrigera*	3-Jun-08				L
Blackwell	Reference	10	*Eurycea cirrigera*	3-Jun-08				L
Blackwell	Reference	10	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Reference	10	*Desmognathus ocoee*	3-Jun-08				recMet
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	3-Jun-08	25	44	0.39	L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	3-Jun-08	27	45	0.35	L
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	3-Jun-08	23	35	0.31	L
Blackwell	Treatment	1	*Eurycea cirrigera*	3-Jun-08	10	14	0.02	YOY
Blackwell	Treatment	1	*Eurycea cirrigera*	3-Jun-08	25	48	0.29	L
Blackwell	Treatment	1	*Desmognathus ocoee*	3-Jun-08	21	37	0.2	recMet
Blackwell	Treatment	2	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Treatment	2	*Gyrinophilus porphyriticus*	3-Jun-08				L
Blackwell	Treatment	3	*Eurycea cirrigera*	3-Jun-08	20	27	0.34	recMet
Blackwell	Treatment	4	*Desmognathus quadramaculatus*	3-Jun-08				L
Blackwell	Treatment	4	*Eurycea cirrigera*	3-Jun-08				YOY
Blackwell	Treatment	5	*Eurycea cirrigera*	3-Jun-08	9	13	0.01	YOY
Blackwell	Treatment	6	*Desmognathus ocoee*	3-Jun-08				J
Blackwell	Treatment	6	*Eurycea cirrigera*	3-Jun-08				J
Blackwell	Treatment	8	*Eurycea cirrigera*	3-Jun-08				recMet
Blackwell	Treatment	9	*Eurycea cirrigera*	3-Jun-08	23	42	0.22	recMet
Blackwell	Treatment	9	*Eurycea cirrigera*	3-Jun-08	22	44	0.26	recMet
Blackwell	Treatment	10	*Eurycea cirrigera*	3-Jun-08				L
Blackwell	Reference	1	*Eurycea cirrigera*	4-Jun-08				L
Blackwell	Reference	2	*Desmognathus ocoee*	4-Jun-08	29	50	0.46	recMet
Blackwell	Reference	2	*Desmognathus ocoee*	4-Jun-08	20	34	0.15	recMet
Blackwell	Reference	2	*Gyrinophilus porphyriticus*	4-Jun-08	17	32	0.13	L
Blackwell	Reference	3	*Desmognathus ocoee*	4-Jun-08				Juv.
Blackwell	Reference	3	*Gyrinophilus porphyriticus*	4-Jun-08				L
Blackwell	Reference	4	*Desmognathus ocoee*	4-Jun-08	22	39	0.28	Juv.
Blackwell	Reference	4	*Eurycea cirrigera*	4-Jun-08	21	38	0.21	L
Blackwell	Reference	4	*Eurycea cirrigera*	4-Jun-08	10	14	0.2	YOY
Blackwell	Reference	4	*Desmognathus ocoee*	4-Jun-08	24	38	0.29	recMet
Blackwell	Reference	5	*Desmognathus ocoee*	4-Jun-08				recMet
Blackwell	Reference	7	*Eurycea cirrigera*	4-Jun-08				YOY
Blackwell	Reference	7	*Eurycea cirrigera*	4-Jun-08				YOY
Blackwell	Reference	7	*Eurycea cirrigera*	4-Jun-08				YOY
Blackwell	Reference	7	*Desmognathus ocoee*	4-Jun-08				recMet
Blackwell	Reference	7	*Desmognathus ocoee*	4-Jun-08				recMet

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	8	*Eurycea cirrigera*	4-Jun-08	22	42	0.25	L
Blackwell	Reference	8	*Eurycea cirrigera*	4-Jun-08	12	16	0.01	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	4-Jun-08	10	16	0.01	YOY
Blackwell	Reference	8	*Desmognathus ocoee*	4-Jun-08	20	33	0.34	Juv.
Blackwell	Reference	8	*Eurycea cirrigera*	4-Jun-08	20	35	0.13	L
Blackwell	Reference	9	*Desmognathus ocoee*	4-Jun-08				Juv.
Blackwell	Reference	9	*Eurycea cirrigera*	4-Jun-08				L
Blackwell	Reference	10	*Eurycea cirrigera*	4-Jun-08	20	38	0.18	L
Blackwell	Reference	10	*Desmognathus ocoee*	4-Jun-08	18	34	0.13	recMet
Blackwell	Reference	10	*Desmognathus ocoee*	4-Jun-08	18	38	0.17	recMet
Blackwell	Reference	10	*Eurycea cirrigera*	4-Jun-08	10	15	0.01	YOY
Blackwell	Reference	10	*Desmognathus ocoee*	4-Jun-08	15	31	0.13	recMet
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	4-Jun-08	33	53	0.97	J
Blackwell	Treatment	1	*Eurycea cirrigera*	4-Jun-08				YOY
Blackwell	Treatment	1	*Eurycea cirrigera*	4-Jun-08				YOY
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	4-Jun-08				L
Blackwell	Treatment	1	*Desmognathus quadramaculatus*	4-Jun-08				L
Blackwell	Treatment	2	*Gyrinophilus porphyriticus*	4-Jun-08	18	35	0.17	L
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	4-Jun-08				L
Blackwell	Treatment	5	*Eurycea cirrigera*	4-Jun-08				YOY
Blackwell	Treatment	5	*Eurycea cirrigera*	4-Jun-08				YOY
Blackwell	Treatment	5	*Gyrinophilus porphyriticus*	4-Jun-08				L
Blackwell	Treatment	6	*Eurycea cirrigera*	4-Jun-08	20	38	0.24	L
Blackwell	Treatment	9	*Desmognathus ocoee*	4-Jun-08				recMet
Blackwell	Treatment	9	*Eurycea cirrigera*	4-Jun-08				L
Blackwell	Treatment	9	*Eurycea cirrigera*	4-Jun-08				YOY
Yellow	Reference	1	*Eurycea cirrigera*	6-Jun-08	10	16	0.01	YOY
Yellow	Reference	3	*Desmognathus ocoee*	6-Jun-08	21	39	0.18	recMet
Yellow	Reference	4	*Eurycea cirrigera*	6-Jun-08				YOY
Yellow	Reference	5	*Eurycea aquatica*	6-Jun-08	32	57	0.67	L
Yellow	Reference	5	*Eurycea aquatica*	6-Jun-08	37	85	1.34	L
Yellow	Reference	5	*Eurycea cirrigera*	6-Jun-08	12	18	0.03	L
Yellow	Reference	6	*Eurycea aquatica*	6-Jun-08				L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Reference	7	*Desmognathus conanti*	6-Jun-08	20	33	0.11	J
Yellow	Reference	8	*Eurycea cirrigera*	6-Jun-08				L
Yellow	Reference	9	*Eurycea aquatica*	6-Jun-08	40	75	1.24	L
Yellow	Reference	9	*Eurycea aquatica*	6-Jun-08	33	67	1.31	L
Yellow	Reference	9	*Eurycea aquatica*	6-Jun-08	28	49	0.52	L
Yellow	Reference	10	*Pseudotriton ruber*	6-Jun-08				L
Yellow	Reference	10	*Eurycea guttolineata*	6-Jun-08				recMet
Yellow	Treatment	1	*Eurycea cirrigera*	6-Jun-08	32	63		L
Yellow	Treatment	1	*Eurycea cirrigera*	6-Jun-08	12	20	0.02	YOY
Yellow	Treatment	1	*Eurycea cirrigera*	6-Jun-08	11	18	0.02	YOY
Yellow	Treatment	3	*Eurycea cirrigera*	6-Jun-08	13	19	0.02	YOY
Yellow	Treatment	3	*Eurycea cirrigera*	6-Jun-08	12	17	0.02	YOY
Yellow	Treatment	3	*Desmognathus quadramaculatus*	6-Jun-08	34	65	0.02	L
Yellow	Treatment	5	*Gyrinophilus porphyriticus*	6-Jun-08	21	35	0.2	L
Yellow	Treatment	5	*Eurycea cirrigera*	6-Jun-08	10	17	0.02	YOY
Yellow	Treatment	5	*Eurycea cirrigera*	6-Jun-08	11	18	0.02	YOY
Yellow	Treatment	7	*Eurycea cirrigera*	6-Jun-08	11	16	0.02	YOY
Yellow	Treatment	7	*Eurycea cirrigera*	6-Jun-08	12	20	0.02	YOY
Yellow	Treatment	7	*Desmognathus ocoee*	6-Jun-08	18	35	0.18	J
Yellow	Treatment	7	*Desmognathus ocoee*	6-Jun-08	21	41	0.18	recMet
Yellow	Treatment	7	*Desmognathus ocoee*	6-Jun-08	20	37	0.26	recMet
Yellow	Treatment	8	*Eurycea cirrigera*	6-Jun-08	26	50	0.17	L
Yellow	Treatment	8	*Eurycea cirrigera*	6-Jun-08				YOY
Yellow	Treatment	8	*Eurycea cirrigera*	6-Jun-08				YOY
Yellow	Treatment	8	*Desmognathus ocoee*	6-Jun-08				recMet
Yellow	Treatment	9	*Gyrinophilus porphyriticus*	6-Jun-08	20	37	0.24	L
Yellow	Treatment	10	*Desmognathus monticola*	6-Jun-08				J
Yellow	Reference	1	*Eurycea cirrigera*	7-Jun-08	10	15	0.01	YOY
Yellow	Reference	3	*Eurycea cirrigera*	7-Jun-08	11	18	0.02	YOY
Yellow	Reference	4	*Eurycea cirrigera*	7-Jun-08				YOY
Yellow	Reference	5	*Eurycea cirrigera*	7-Jun-08	11	16	0.01	YOY
Yellow	Reference	5	*Eurycea aquatica*	7-Jun-08	32	62	0.95	L
Yellow	Reference	6	*Eurycea cirrigera*	7-Jun-08				L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Reference	6	*Eurycea cirrigera*	7-Jun-08				L
Yellow	Reference	6	*Eurycea cirrigera*	7-Jun-08				L
Yellow	Treatment	1	*Eurycea cirrigera*	7-Jun-08				L
Yellow	Treatment	1	*Eurycea cirrigera*	7-Jun-08				YOY
Yellow	Treatment	1	*Eurycea cirrigera*	7-Jun-08				YOY
Yellow	Treatment	2	*Eurycea cirrigera*	7-Jun-08	11	16	0.02	YOY
Yellow	Treatment	2	*Desmognathus monticola*	7-Jun-08	35	67	1	J
Yellow	Treatment	2	*Eurycea cirrigera*	7-Jun-08				L
Yellow	Treatment	5	*Eurycea cirrigera*	7-Jun-08	33	61	0.84	L
Yellow	Treatment	6	*Desmognathus ocoee*	7-Jun-08				recMet
Yellow	Treatment	7	*Desmognathus ocoee*	7-Jun-08	22	43	0.22	J
Yellow	Treatment	7	*Desmognathus ocoee*	7-Jun-08	18	31	0.16	J
Yellow	Treatment	7	*Desmognathus ocoee*	7-Jun-08	18	32	0.14	J
Yellow	Treatment	9	*Eurycea cirrigera*	7-Jun-08	37	54	1.43	L
Yellow	Treatment	9	*Gyrinophilus porphyriticus*	7-Jun-08	19	37	0.28	L
Yellow	Treatment	10	*Gyrinophilus porphyriticus*	7-Jun-08				L
Yellow	Treatment	10	*Eurycea cirrigera*	7-Jun-08				YOY
Yellow	Reference	5	*Eurycea cirrigera*	8-Jun-08	10	15	0.01	YOY
Yellow	Reference	5	*Eurycea cirrigera*	8-Jun-08	12	19	0.02	YOY
Yellow	Reference	6	*Desmognathus ocoee*	8-Jun-08				recMet
Yellow	Reference	6	*Eurycea cirrigera*	8-Jun-08				L
Yellow	Reference	6	*Eurycea cirrigera*	8-Jun-08				YOY
Yellow	Reference	8	*Eurycea cirrigera*	8-Jun-08				L
Yellow	Reference	9	*Eurycea aquatica*	8-Jun-08	35	68	1.38	L
Yellow	Reference	9	*Gyrinophilus porphyriticus*	8-Jun-08	40	58	1.24	L
Yellow	Reference	10	*Gyrinophilus porphyriticus*	8-Jun-08				L
Yellow	Treatment	1	*Eurycea cirrigera*	8-Jun-08	32	57	0.18	L
Yellow	Treatment	1	*Eurycea cirrigera*	8-Jun-08	12	18	0.02	YOY
Yellow	Treatment	2	*Desmognathus ocoee*	8-Jun-08				recMet
Yellow	Treatment	3	*Eurycea cirrigera*	8-Jun-08	33	58	0.84	L
Yellow	Treatment	3	*Eurycea cirrigera*	8-Jun-08	11	16	0.02	YOY
Yellow	Treatment	5	*Eurycea cirrigera*	8-Jun-08				YOY
Yellow	Treatment	5	*Desmognathus ocoee*	8-Jun-08				recMet

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Treatment	7	*Desmognathus ocoee*	8-Jun-08	20	24	0.18	recMet
Yellow	Treatment	7	*Desmognathus ocoee*	8-Jun-08	22	36	0.17	recMet
Yellow	Treatment	8	*Eurycea cirrigera*	8-Jun-08				YOY
Yellow	Treatment	8	*Eurycea cirrigera*	8-Jun-08				YOY
Yellow	Treatment	9	*Desmognathus quadramaculatus*	8-Jun-08	48	82	2.54	J
Yellow	Treatment	9	*Desmognathus monticola*	8-Jun-08	34	64	1.22	J
Yellow	Treatment	9	*Gyrinophilus porphyriticus*	8-Jun-08	19	38	0.14	L
Yellow	Treatment	10	*Eurycea cirrigera*	8-Jun-08				YOY
Yellow	Treatment	10	*Desmognathus ocoee*	8-Jun-08				J
Yellow	Treatment	10	*Eurycea cirrigera*	8-Jun-08				YOY
Blackwell	Reference	1	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	1	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	2	*Eurycea cirrigera*	30-Jun-08				Juv.
Blackwell	Reference	3	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	4	*Desmognathus ocoee*	30-Jun-08	35	65	0.7	
Blackwell	Reference	4	*Desmognathus monticola*	30-Jun-08	19	36	0.21	
Blackwell	Reference	4	*Eurycea cirrigera*	30-Jun-08	14	23		
Blackwell	Reference	4	*Desmognathus monticola*	30-Jun-08	18	23		
Blackwell	Reference	6	*Eurycea cirrigera*	30-Jun-08	10	20	0.01	YOY
Blackwell	Reference	6	*Desmognathus ocoee*	30-Jun-08	14	31	0.14	Juv.
Blackwell	Reference	6	*Eurycea cirrigera*	30-Jun-08	10	20	0.01	YOY
Blackwell	Reference	7	*Desmognathus quadramaculatus*	30-Jun-08				L
Blackwell	Reference	7	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	8	*Eurycea cirrigera*	30-Jun-08	11	20	0.02	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	30-Jun-08	12	21	0.01	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	30-Jun-08	20	36	0.2	Juv.
Blackwell	Reference	9	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	9	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	9	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	9	*Eurycea cirrigera*	30-Jun-08				Juv.
Blackwell	Reference	9	*Desmognathus ocoee*	30-Jun-08				Juv.
Blackwell	Reference	9	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Reference	9	*Eurycea cirrigera*	30-Jun-08				YOY

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	10	*Desmognathus ocoee*	30-Jun-08	19	36	0.19	Juv.
Blackwell	Reference	10	*Desmognathus ocoee*	30-Jun-08	18	34	0.15	Juv.
Blackwell	Reference	10	*Eurycea cirrigera*	30-Jun-08	12	22	0.01	YOY
Blackwell	Reference	10	*Eurycea cirrigera*	30-Jun-08	11	20	0.01	YOY
Blackwell	Reference	10	*Eurycea cirrigera*	30-Jun-08	13	21	0.02	YOY
Blackwell	Reference	10	*Eurycea cirrigera*	30-Jun-08	12	21	0.01	YOY
Blackwell	Reference	10	*Eurycea cirrigera*	30-Jun-08	10	18	0.01	YOY
Blackwell	Treatment	1	*Desmognathus monticola*	30-Jun-08				J
Blackwell	Treatment	2	*Desmognathus quadramaculatus*	30-Jun-08	50	103	4.11	
Blackwell	Treatment	2	*Desmognathus quadramaculatus*	30-Jun-08	25	44	0.44	L
Blackwell	Treatment	2	*Desmognathus quadramaculatus*	30-Jun-08	24	44	0.43	L
Blackwell	Treatment	2	*Eurycea cirrigera*	30-Jun-08	11	15	0.02	YOY
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	30-Jun-08				L
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	30-Jun-08				L
Blackwell	Treatment	4	*Eurycea cirrigera*	30-Jun-08	21	35		J
Blackwell	Treatment	5	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Treatment	5	*Eurycea cirrigera*	30-Jun-08				L
Blackwell	Treatment	6	*Eurycea cirrigera*	30-Jun-08	10	20	0.01	YOY
Blackwell	Treatment	6	*Eurycea cirrigera*	30-Jun-08	11	20	0.01	YOY
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	30-Jun-08				L
Blackwell	Treatment	7	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	30-Jun-08				L
Blackwell	Treatment	9	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Treatment	9	*Eurycea cirrigera*	30-Jun-08				YOY
Blackwell	Treatment	10	*Eurycea cirrigera*	30-Jun-08	11	20	0.01	YOY
Yellow	Treatment	1	*Eurycea cirrigera*	30-Jun-08				L
Yellow	Treatment	1	*Eurycea cirrigera*	30-Jun-08				L
Yellow	Treatment	1	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	2	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	2	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	2	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				YOY

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				L
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	4	*Eurycea cirrigera*	30-Jun-08				YOY
Yellow	Treatment	5	*Desmognathus ocoee*	30-Jun-08				J
Yellow	Treatment	6	*Eurycea cirrigera*	30-Jun-08	11	18	0.02	YOY
Yellow	Treatment	7	*Desmognathus ocoee*	30-Jun-08				J
Yellow	Treatment	7	*Eurycea cirrigera*	30-Jun-08				L
Yellow	Treatment	8	*Eurycea cirrigera*	30-Jun-08				L
Yellow	Treatment	9	*Eurycea cirrigera*	30-Jun-08				L
Yellow	Treatment	9	*Eurycea cirrigera*	30-Jun-08				L
Yellow	Treatment	10	*Eurycea cirrigera*	30-Jun-08	22	33	0.19	L
Yellow	Treatment	10	*Eurycea cirrigera*	30-Jun-08	21	31	0.15	L
Yellow	Treatment	10	*Eurycea cirrigera*	30-Jun-08	12	22	0.04	YOY
Yellow	Treatment	10	*Desmognathus ocoee*	30-Jun-08	21	36	0.18	J
Blackwell	Reference	1	*Eurycea cirrigera*	1-Jul-08	10	20	0.01	YOY
Blackwell	Reference	1	*Eurycea cirrigera*	2-Jun-08	11	20	0.01	YOY
Blackwell	Reference	2	*Desmognathus quadramaculatus*	2-Jun-08				L
Blackwell	Reference	5	*Desmognathus ocoee*	2-Jun-08	45	90	1.95	Juv.
Blackwell	Reference	7	*Desmognathus quadramaculatus*	2-Jun-08	40	75	2.43	Juv.
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Reference	8	*Eurycea cirrigera*	2-Jun-08				L
Blackwell	Reference	9	*Eurycea cirrigera*	2-Jun-08	13	30	0.23	L
Blackwell	Reference	9	*Eurycea cirrigera*	2-Jun-08	12	21	0.05	YOY
Blackwell	Reference	9	*Eurycea cirrigera*	2-Jun-08	10	18	0.01	YOY
Blackwell	Reference	10	*Eurycea cirrigera*	2-Jun-08				YOY
Blackwell	Reference	10	*Desmognathus quadramaculatus*	2-Jun-08				L
Blackwell	Treatment	1	*Desmognathus ocoee*	1-Jul-08	30	46	0.92	recMet
Blackwell	Treatment	1	*Eurycea cirrigera*	1-Jul-08	11	20	0.02	YOY
Blackwell	Treatment	2	*Eurycea cirrigera*	1-Jul-08				YOY
Blackwell	Treatment	2	*Eurycea cirrigera*	1-Jul-08				J

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	1-Jul-08	25	52	0.75	L
Blackwell	Treatment	4	*Eurycea cirrigera*	1-Jul-08				L
Blackwell	Treatment	6	*Eurycea cirrigera*	1-Jul-08				YOY
Blackwell	Treatment	6	*Eurycea cirrigera*	1-Jul-08				YOY
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	1-Jul-08	20	45	0.47	L
Blackwell	Treatment	7	*Eurycea cirrigera*	1-Jul-08	10	18	0.01	YOY
Blackwell	Treatment	7	*Eurycea cirrigera*	1-Jul-08	10	18	0.01	YOY
Yellow	Treatment	2	*Eurycea cirrigera*	1-Jul-08				L
Yellow	Treatment	2	*Eurycea cirrigera*	1-Jul-08				YOY
Yellow	Treatment	2	*Eurycea cirrigera*	1-Jul-08				YOY
Yellow	Treatment	3	*Eurycea cirrigera*	1-Jul-08	10	18	0.02	YOY
Yellow	Treatment	4	*Eurycea cirrigera*	1-Jul-08				YOY
Yellow	Treatment	4	*Eurycea cirrigera*	1-Jul-08				YOY
Yellow	Treatment	5	*Desmognathus ocoee*	1-Jul-08	15	32	0.2	recMet
Yellow	Treatment	6	*Pseudotriton spp.*	1-Jul-08				L
Yellow	Treatment	8	*Gyrinophilus porphyriticus*	1-Jul-08				L
Yellow	Treatment	8	*Eurycea cirrigera*	1-Jul-08				YOY
Yellow	Treatment	9	*Eurycea cirrigera*	1-Jul-08	31	60	1.28	L
Yellow	Treatment	10	*Pseudotriton spp.*	1-Jul-08				L
Yellow	Treatment	10	*Eurycea cirrigera*	1-Jul-08				YOY
Blackwell	Reference	1	*Desmognathus quadramaculatus*	3-Jul-08				L
Blackwell	Reference	1	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Reference	1	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Reference	3	*Desmognathus ocoee*	3-Jul-08				Juv.
Blackwell	Reference	4	*Desmognathus ocoee*	3-Jul-08	15	34	1.06	recMet
Blackwell	Reference	5	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Reference	5	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Reference	5	*Desmognathus quadramaculatus*	3-Jul-08				L
Blackwell	Reference	5	*Desmognathus ocoee*	3-Jul-08				recMet
Blackwell	Reference	5	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Reference	6	*Eurycea cirrigera*	3-Jul-08	10	18	0.01	YOY
Blackwell	Reference	7	*Desmognathus monticola*	3-Jul-08				Juv.
Blackwell	Reference	8	*Eurycea cirrigera*	3-Jul-08	10	18	0.01	YOY

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	9	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Reference	9	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Reference	9	*Desmognathus ocoee*	3-Jul-08				L
Blackwell	Treatment	2	*Desmognathus ocoee*	3-Jul-08	23	42	0.45	L
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	3-Jul-08				L
Blackwell	Treatment	4	*Desmognathus ocoee*	3-Jul-08				recMet
Blackwell	Treatment	4	*Eurycea cirrigera*	3-Jul-08	16	35	0.18	L
Blackwell	Treatment	6	*Desmognathus ocoee*	3-Jul-08	16	32		L
Blackwell	Treatment	10	*Eurycea cirrigera*	3-Jul-08				YOY
Blackwell	Treatment	10	*Eurycea cirrigera*	3-Jul-08				YOY
Yellow	Treatment	1	*Eurycea cirrigera*	3-Jul-08				recMet
Yellow	Treatment	1	*Eurycea cirrigera*	3-Jul-08				recMet
Yellow	Treatment	1	*Eurycea cirrigera*	3-Jul-08				YOY
Yellow	Treatment	1	*Eurycea cirrigera*	3-Jul-08				recMet
Yellow	Treatment	1	*Eurycea cirrigera*	3-Jul-08				YOY
Yellow	Treatment	2	*Eurycea cirrigera*	3-Jul-08	36	77		L
Yellow	Treatment	5	*Eurycea cirrigera*	3-Jul-08	31	70		L
Yellow	Treatment	7	*Desmognathus ocoee*	3-Jul-08	20	37		recMet
Yellow	Treatment	7	*Eurycea cirrigera*	3-Jul-08	12	22		L
Yellow	Treatment	7	*Eurycea cirrigera*	3-Jul-08	10	18		YOY
Yellow	Treatment	8	*Gyrinophilus porphyriticus*	3-Jul-08	24	35		L
Yellow	Treatment	10	*Gyrinophilus porphyriticus*	3-Jul-08	18	31		L
Blackwell	Reference	1	*Eurycea cirrigera*	2-Oct-08	13	23	0.07	L
Blackwell	Reference	1	*Desmognathus quadramaculatus*	2-Oct-08	15	31	0.16	L
Blackwell	Reference	4	*Eurycea cirrigera*	2-Oct-08	13	24	0.11	L
Blackwell	Reference	4	*Eurycea cirrigera*	2-Oct-08	13	19	0.06	L
Blackwell	Reference	4	*Desmognathus monticola*	2-Oct-08	22	65	0.65	recMet
Blackwell	Reference	6	*Eurycea cirrigera*	2-Oct-08	15	26	0.22	L
Blackwell	Treatment	4	*Eurycea cirrigera*	2-Oct-08	14	28	0.24	L
Yellow	Treatment	1	*Eurycea cirrigera*	2-Oct-08	16	29	0.14	L
Yellow	Treatment	3	*Eurycea cirrigera*	2-Oct-08	14	26	0.15	L
Yellow	Treatment	3	*Eurycea cirrigera*	2-Oct-08	15	30	0.19	L
Yellow	Treatment	3	*Desmognathus quadramaculatus*	2-Oct-08	16	32	0.22	L

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Yellow	Treatment	7	*Eurycea aquatica*	2-Oct-08	25	48	0.58	L
Yellow	Treatment	7	*Eurycea cirrigera*	2-Oct-08	12	21	0.06	YOY
Yellow	Treatment	9	*Desmognathus quadramaculatus*	2-Oct-08	33	69	0.96	L
Yellow	Treatment	10	*Gyrinophilus porphyriticus*	2-Oct-08	30	60	0.91	L
Yellow	Treatment	10	*Eurycea cirrigera*	2-Oct-08	24	38	0.38	recMet
Blackwell	Reference	4	*Eurycea cirrigera*	3-Oct-08	10	19	0.02	YOY
Blackwell	Reference	6	*Eurycea cirrigera*	3-Oct-08	16	27	0.28	L
Blackwell	Reference	7	*Desmognathus monticola*	3-Oct-08	36	67	1.22	Juv.
Blackwell	Reference	7	*Desmognathus monticola*	3-Oct-08	20	40	0.22	recMet
Blackwell	Reference	7	*Desmognathus ocoee*	3-Oct-08	21	39	0.22	recMet
Blackwell	Reference	9	*Eurycea cirrigera*	3-Oct-08	10	20	0.02	YOY
Blackwell	Reference	10	*Desmognathus quadramaculatus*	3-Oct-08	32	57	0.88	L
Blackwell	Treatment	4	*Eurycea cirrigera*	3-Oct-08	11	30	0.02	L
Blackwell	Treatment	9	*Eurycea cirrigera*	3-Oct-08	14	22	0.07	L
Blackwell	Treatment	10	*Eurycea cirrigera*	3-Oct-08	10	25	0.04	L
Yellow	Treatment	1	*Eurycea cirrigera*	3-Oct-08	10	25	0.04	L
Yellow	Treatment	8	*Eurycea cirrigera*	3-Oct-08	15	30	0.16	L
Yellow	Treatment	9	*Eurycea cirrigera*	3-Oct-08	10	19	0.02	L
Yellow	Treatment	10	*Eurycea cirrigera*	3-Oct-08	10	20	0.02	L
Blackwell	Reference	4	*Eurycea cirrigera*	4-Oct-08	13	25	0.08	YOY
Blackwell	Reference	4	*Eurycea cirrigera*	4-Oct-08	12	22	0.06	YOY
Blackwell	Reference	6	*Eurycea cirrigera*	4-Oct-08	14	26	0.09	L
Blackwell	Reference	6	*Eurycea cirrigera*	4-Oct-08	15	30	0.11	L
Blackwell	Reference	6	*Pseudotriton spp.*	4-Oct-08	36	66	1.21	L
Blackwell	Reference	7	*Desmognathus monticola*	4-Oct-08	33	62	0.74	Juv.
Blackwell	Reference	8	*Desmognathus monticola*	4-Oct-08	23	48	0.31	recMet
Blackwell	Reference	10	*Desmognathus quadramaculatus*	4-Oct-08	16	35	0.13	L
Blackwell	Treatment	9	*Desmognathus quadramaculatus*	4-Oct-08	41	90	2.79	J/A
Blackwell	Treatment	10	*Eurycea cirrigera*	4-Oct-08	12	22	0.03	L
Yellow	Treatment	1	*Eurycea aquatica*	4-Oct-08	33	61	1	L
Yellow	Treatment	1	*Eurycea aquatica*	4-Oct-08	16	29	0.16	L
Yellow	Treatment	7	*Pseudotriton spp.*	4-Oct-08	20	42	0.37	L
Yellow	Treatment	10	*Desmognathus ocoee*	4-Oct-08	22	47	0.34	J/A

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	2	*Eurycea cirrigera*	14-Nov-08	16	26	0.14	YOY
Blackwell	Reference	3	*Desmognathus quadramaculatus*	14-Nov-08	16	34	0.16	YOY
Blackwell	Reference	5	*Desmognathus quadramaculatus*	14-Nov-08	28	53	0.87	L
Blackwell	Reference	6	*Eurycea cirrigera*	14-Nov-08	15	21	0.07	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	14-Nov-08	10	21	0.06	YOY
Blackwell	Reference	8	*Desmognathus quadramaculatus*	14-Nov-08	10	20	0.06	YOY
Blackwell	Reference	8	*Eurycea cirrigera*	14-Nov-08	16	27	0.1	YOY
Blackwell	Reference	9	*Desmognathus quadramaculatus*	14-Nov-08	13	25	0.13	YOY
Blackwell	Reference	9	*Eurycea cirrigera*	14-Nov-08	12	26	0.08	YOY
Blackwell	Treatment	1	*Eurycea cirrigera*	14-Nov-08	16	28	0.1	L
Blackwell	Treatment	2	*Eurycea cirrigera*	14-Nov-08	10	23	0.06	YOY
Blackwell	Treatment	4	*Eurycea cirrigera*	14-Nov-08	17	36	0.2	L
Blackwell	Treatment	5	*Eurycea cirrigera*	14-Nov-08	10	21	0.04	YOY
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	14-Nov-08	16	28	0.16	L
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	14-Nov-08	12	24	0.13	YOY
Blackwell	Treatment	7	*Eurycea cirrigera*	14-Nov-08	12	22	0.07	YOY
Blackwell	Treatment	7	*Eurycea cirrigera*	14-Nov-08	11	22	0.07	YOY
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	14-Nov-08	13	25	0.11	YOY
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	14-Nov-08	15	30	0.13	L
Blackwell	Treatment	7	*Desmognathus quadramaculatus*	14-Nov-08	13	27	0.16	L
Blackwell	Treatment	8	*Eurycea cirrigera*	14-Nov-08	14	26	0.08	L
Blackwell	Treatment	8	*Eurycea cirrigera*	14-Nov-08	13	21	0.05	L
Blackwell	Treatment	9	*Eurycea cirrigera*	14-Nov-08	15	26	0.08	L
Blackwell	Treatment	10	*Eurycea cirrigera*	14-Nov-08	11	25	0.11	L
Yellow	Treatment	1	*Eurycea cirrigera*	14-Nov-08	16	32	0.21	L
Yellow	Treatment	6	*Eurycea cirrigera*	14-Nov-08	15	34	0.15	L
Yellow	Treatment	9	*Gyrinophilus porphyriticus*	14-Nov-08	31	61	0.88	L
Yellow	Treatment	10	*Eurycea cirrigera*	14-Nov-08	10	20	0.07	YOY
Blackwell	Reference	3	*Gyrinophilus porphyriticus*	15-Nov-08	77	120	6.65	L
Blackwell	Reference	3	*Desmognathus quadramaculatus*	15-Nov-08	22	35	0.7	L
Blackwell	Reference	5	*Desmognathus quadramaculatus*	15-Nov-08	32	55	0.87	L
Blackwell	Reference	6	*Eurycea cirrigera*	15-Nov-08	15	35	0.13	
Blackwell	Reference	6	*Eurycea cirrigera*	15-Nov-08	22	38	0.25	

Site		Trap	Species	Date	SVL (mm)	Total Length (mm)	Mass (g)	Age
Blackwell	Reference	6	*Eurycea cirrigera*	15-Nov-08	22	37	0.25	
Blackwell	Reference	8	*Desmognathus quadramaculatus*	15-Nov-08	22	37	0.28	L
Blackwell	Reference	9	*Eurycea cirrigera*	15-Nov-08	15	35	0.15	L
Blackwell	Treatment	1	*Eurycea cirrigera*	15-Nov-08	15	32	0.16	L
Blackwell	Treatment	2	*Eurycea cirrigera*	15-Nov-08	15	35	0.15	L
Blackwell	Treatment	4	*Desmognathus quadramaculatus*	15-Nov-08				J
Blackwell	Treatment	5	*Eurycea cirrigera*	15-Nov-08	14	30	0.14	L
Blackwell	Treatment	5	*Eurycea cirrigera*	15-Nov-08	15	35	0.15	L
Blackwell	Treatment	7	*Eurycea cirrigera*	15-Nov-08	10	30	0.14	L
Blackwell	Treatment	7	*Eurycea cirrigera*	15-Nov-08	15	30	0.15	L
Blackwell	Treatment	7	*Eurycea cirrigera*	15-Nov-08	15	31	0.15	L
Yellow	Treatment	2	*Eurycea aquatica*	15-Nov-08	30	58	0.76	L
Yellow	Treatment	4	*Eurycea cirrigera*	15-Nov-08	14	30	0.15	L
Yellow	Treatment	9	*Gyrinophilus porphyriticus*	15-Nov-08	32	53	0.85	L
Blackwell	Treatment	3	*Desmognathus quadramaculatus*	16-Nov-08	18	36	0.14	L
Blackwell	Treatment	3	*Eurycea cirrigera*	16-Nov-08	14	26	0.09	L
Blackwell	Treatment	6	*Eurycea cirrigera*	16-Nov-08	16	28	0.1	L
Blackwell	Treatment	8	*Desmognathus quadramaculatus*	16-Nov-08	17	35	0.25	L
Yellow	Treatment	1	*Eurycea cirrigera*	16-Nov-08	10	21	0.08	L
Yellow	Treatment	5	*Eurycea aquatica*	16-Nov-08	23	45	0.5	L
Yellow	Treatment	7	*Eurycea cirrigera*	16-Nov-08	10	21	0.07	YOY
Yellow	Treatment	7	*Desmognathus monticola*	16-Nov-08	25	46	0.62	recMet
Yellow	Treatment	7	*Eurycea cirrigera*	16-Nov-08	9	20	0.08	YOY
Yellow	Treatment	9	*Eurycea cirrigera*	16-Nov-08	18	36	0.16	L

CHAPTER 3

SEASONAL, SPECIES-SPECIFIC AND SIZE-RELATED VARIATION IN LARVAL SALAMANDER ISOTOPIC SIGNATURES AND DIET[1]

[1] Trice, A.E., A.D. Rosemond and J.C. Maerz. To be submitted to *Ecology Letters.*

ABSTRACT

Salamanders facilitate energy flow from aquatic to terrestrial ecosystems, serving as important predators in aquatic systems and prey sources for terrestrial animals. Relatively little is known about the trophic ecology of larval salamanders, such as seasonal patterns in acquisition and incorporation of carbon or variation in trophic position (as indicated by $\delta^{13}C$ and $\delta^{15}N$ signatures), beyond basic diet snapshots. Seasonal (fall, spring, summer) $\delta^{13}C$ and $\delta^{15}N$ of individual larvae were determined for three common species of salamander in four southeastern headwater streams (GA, USA). There were no seasonal or specific-specific differences in $\delta^{13}C$, indicating temporal consistency in resource utilization among species. Trophic position did not differ seasonally but differed by species. Large intraspecific variation, however, existed in both $\delta^{15}N$ and $\delta^{13}C$. Relationships between $\delta^{15}N$ and individual snout-vent length (SVL) indicated that *D. quadramaculatus* larvae became depleted in $\delta^{15}N$ as SVL increased, while E. *cirrigera* showed the opposite trend. A similar relationship between $\delta^{15}N$ and SVL from *D. quadramaculatus* collected from a different geographic area corroborated this pattern. Size-related changes in diet composition of *D. quadramaculatus* and *E. cirrigera* were not consistent with changes in $\delta^{15}N$ (e.g., increased % predatory prey with increased $\delta^{15}N$), but did show unique prey items to increase as body size increased in *D. quadramaculatus*. Isotopic signatures of salamander eggs and newly hatched larvae are consistent with variation in $\delta^{15}N$ due to maternal sources. Our results indicate that interpretations of seasonal and species specific variation in larval isotopic signatures can be robust to some individual variation, but for some taxa, loss of maternally-derived signatures should be considered in isotopic signature interpretations.

KEYWORDS: Body size, Carbon isotope, $\delta^{13}C$, $\delta^{15}N$, *Desmognathus ocoee, Desmognathus quadramaculatus, Eurycea cirrigera,* Nitrogen isotope, Snout-vent length

INTRODUCTION

Larval aquatic salamanders are top predators in the fishless headwater streams they occupy. Eastern deciduous forests, in particular, are known for their high diversity of salamanders (Petranka 1998). Moreover, these deciduous headwater streams experience seasonal patterns including heavy summer shading, autumn inputs of allochthonous detritus, spring autochthonous production and associated macroinvertebrate production (Webster et al. 2006). Although seasonal energy inputs dominate these stream ecosystems, prey utilization by salamanders likely shifts more with ontogeny. Studies that have utilized diet analysis indicate salamanders incorporate more terrestrially-derived prey items following metamorphosis, when they begin foraging more in the riparian zone (Hairston 1987, Davic 1991) whereas larval salamanders have been shown to ingest almost exclusively aquatic prey (Davic 1991). Shifts in diet, therefore, likely depend more on size and ontogeny.

Many types of organisms vary in their feeding ecology due to ontogenetic shifts, but may also be influenced in their diet and resource utilization by individual variation in physiology or resource selectivity. Ontogenetic shifts and associated stable isotopic values that indicate trophic position ($\delta^{15}N$) can be influenced by body size. For example, ontogenetic dietary changes of carnivorous fish species near Caribbean reefs resulted in increased $\delta^{15}N$ signatures as size increased (de la Moriniere et al. 2003). Post et al. (2003) noted a similar phenomenon in largemouth bass where diet shifts caused individual variation in $\delta^{15}N$ isotopic signatures. With regards to organisms in similar feeding guilds, Lancaster and Waldron (2001) noted invertebrate species from the same functional feeding group (*Baetis rhodani* and *Ecdyonurus torrentis*) with similar diets to have different $\delta^{15}N$ and $\delta^{13}C$ isotopic values, likely due to variation in the assimilation of resources. Physiological differences among individuals also likely cause some variance in isotopic signatures, which could confound data interpretation (Adams et al. 2004).

Isotopic composition shifts of individuals within a food web are generally interpreted as changes in resource utilization. Ontogenetic changes in diet are prevalent with consumers shifting in both diet and isotopic values as they age. However, these studies (Vander Zanden and Rasmussen 2001, Grey et al. 2004, Goedkoop et al. 2006) focused on changes from juveniles to adults. Newly hatched salamanders may be different from that of juveniles or adults in terms of isotopic composition. Moreover, their neonate tissues are derived from maternal resources rather than newly acquired food resources (Pilgrim 2007). Interpretation of trophic position could be altered if signatures of newly hatched individuals maintain maternal resource signatures for prolonged periods. Even if newly hatched larvae begin consuming the same resources as older larvae, isotopic composition will reflect a mixture of assimilated resources and maternal resources acquired at birth (Pilgrim 2007). This phenomenon will persist until adequate tissue turnover has occurred.

Salamanders are gape-limited predators due to their feeding mechanism of engulfing prey; this gape limitation may in turn contribute to the alteration of a salamander's isotopic composition. One potential limitation to gape size in predators is the natural selection for prey to grow rapidly into a body size refuge (Paine 1976; Urban 2008). Theory also predicts gape-limited predators impose strong selection for larger prey body size (Urban 2008). As a result, one might expect foraging success and rate of energy intake to increase with increasing body size relative to gape size (Forsman 1996). In turn, this likely affects isotopic signatures of predators, as there is a possibility for both selective feeding and individual signatures structured along a size class gradient. Since body size determines the range of prey sizes a predator can consume (Cohen et al. 1993), larger individuals are expected to occupy higher trophic positions (Jennings et al. 2001). With this idea in mind, we evaluated individual salamander isotopic composition ($\delta^{13}C$ and $\delta^{15}N$) in relation to body size (snout-vent length). We collected dominant salamander taxa from four similar streams in separate watersheds and analyzed them for isotopic signatures over three seasons. Diet analyses were conducted on two dominant taxa over two seasons. We addressed the following questions: 1) What patterns were observed for these taxa in $\delta^{13}C$ and $\delta^{15}N$ signatures across seasons? (2) Were there relationships between body size and isotopic signatures? and 3) Was diet composition consistent with trends observed between body size and isotopic signatures? We then used the observed patterns to discuss implications for interpretation of isotopic values for larval salamanders.

METHODS

The four study streams are second-order headwater tributaries to the Etowah River, which is a tributary of the Coosa River System (see Chapter 2 for a complete description). Three dominant salamander taxa were collected from all streams over three sampling periods, targeting different seasons. Isotopic analyses were conducted on all specimens (three taxa) and during all seasons and diet analyses were conducted on two taxa for two seasons. We determined $\delta^{13}C$ and $\delta^{15}N$ signatures and relationships to body size for *Desmognathus quadramaculatus* and *Eurycea cirrigera*. Both *D. quadramaculatus* and *E. cirrigera* are biphasic species in the family Plethodontidae. *D. quadramaculatus* larvae inhabit streams for ca. 3-4 years before metamorphosis (Bruce et al. 2002) and are larger conspecifics than *E. cirrigera* (Beachy 1997), of which larvae reside in streams approximately 18 months (Barrett et al. 2010).

STABLE ISOTOPE DETERMINATION – Salamanders were obtained during seasonal sampling (fall – November 23, 2008, spring – March 18, 2009 and summer – July 12, 2009) in four headwater streams. Salamander specimens were collected at night, when larvae are most active, using an aquarium dip net (1 mm mesh) and headlamp by turning over rocks and leaf litter within the stream (Johnson and Wallace 2005). Salamanders were immediately euthanized with Tricaine methanesulfonate (MS-222) buffered with sodium bicarbonate and rinsed with deionized water. Tails were then clipped, placed in vials and placed immediately on ice for stable isotope analyses, with the remaining body preserved in Kahle's solution in the field to preserve gut contents. Tails were frozen and stored at -80°C in the laboratory. Samples were then lyophilized, ground and weighed into tin capsules. Replication was attained at the individual level for salamander isotope values excluding the fall (2008) sampling period, as individuals were pooled due to lack of material. Samples were then combusted in a Carlo Erba (Milan, Italy) NA 1500 CHN analyzer coupled to a Finnigan Delta C mass spectrometer (Thermo Electron Corp., Waltham, MA, U.S.A.) as a continuous flow system at the Odum School of Ecology Analytical Lab, University of Georgia. A laboratory working standard (bovine liver and poplar leaves) was placed every 12 samples. Isotope ratios are expressed as $\delta^{13}C$ or $\delta^{15}N$ (with units of permil). Delta values are not absolute isotope abundances but differences between sample readings and one or another of the widely used natural abundance standards which are considered delta = zero (atmospheric air for N, At $\%^{15}N = 0.3663033$; Pee Dee Belemnite for C, At $\%^{13}C = 1.1112328$).

GUT CONTENT ANALYSIS – In addition to stable isotope analysis, gut contents of *D. quadramaculatus* and *E. cirrigera* were analyzed. Diet analysis was performed on approximately 7-13 individuals (n=45) per size class for *D. quadramaculatus* (size class = 13-17, 17-21, 21-26, 26-29, 29-38 mm SVL) and 7-11 individuals (n=43) per size class for *E. cirrigera* (size class = 10-15, 15-18, 18-20, 20-25, 25-31 mm SVL) comprised of salamanders from both spring and summer of 2009. We measured each animal's snout-vent length (SVL) from the tip of the snout to the posterior portion of the vent to the nearest mm. In the laboratory, guts were removed under a stereo microscope and contents teased out. Insect taxa were identified to genus when possible except for Chironomidae, which were identified as either non-Tanypodinae or Tanypodinae. Non-insect taxa were identified to order. All prey items were measured to the nearest millimeter using an ocular micrometer (Johnson and Wallace 2005). Prey biomass (AFDM) was estimated using established length-mass or head width-mass regressions (Sample et al.1993; Benke et al. 1999; Sabo et al. 2002).

DATA ANALYSES – Differences in species-specific and seasonal variation of $\delta^{15}N$ and $\delta^{13}C$ were investigated using a 2-way Analysis of Variance (ANOVA). The ANOVA was analyzed separately for both $\delta^{15}N$ and $\delta^{13}C$ testing for main effects of species and season, species*season interactions and blocked by streams. Data were tested for assumptions of normality prior to analyses and were log transformed if necessary to meet normality assumptions. Regression analysis was also used to test for the effect of larval SVL on individual variation in $\delta^{15}N$ and $\delta^{13}C$. Assumption of equal slopes among species could not be met; therefore, SVL could not be used as a covariate. Individuals were plotted as SVL vs. $\delta^{15}N$ for both *D. quadramaculatus* and *E. cirrigera.* Regression results were then compared to salamanders collected (August 2007) at the USDA Forest Service Coweeta Hydrologic Laboratory (Otto, NC) to investigate patterns across larger spatial scales.

Piecewise regression was used to characterize the response of $\delta^{15}N$ to SVL for *D. quadramaculatus* incorporating newly hatched individuals. A threshold point was obtained by statistically fitting a linear model to the data (Toms and Lesperance 2003). The threshold point represents the intersection of two lines, each with a different slope providing a point, in our case, where SVLs greater than the threshold point are appropriate to use for prediction of within stream $\delta^{15}N$ resources rather than maternal effects.

Gut contents data were analyzed using ANOVA and regression analysis. Total prey items/gut and total biomass/gut were analyzed for each individual (*D. quadramaculatus* and *E. cirrigera*) within a size class using ANOVA. Regression analysis was also used to test for an effect of size class on species richness of prey items within the five size classes. To investigate relationships with increased $\delta^{15}N$ and consumption of predators, regressions were analyzed for % predator within a given size class for both *D. quadramaculatus* and *E. cirrigera*. All ANOVA and regression statistics were performed using SAS® Version 9.2 (SAS Institute Inc., Cary, NC, USA).

RESULTS

There were no consistent differences in $\delta^{13}C$ signatures among salamander species or seasons (Table 3.1, Fig. 3.1). Species differed in $\delta^{15}N$ values (Table 3.1, Fig. 3.1), with mean *E. cirrigera* $\delta^{15}N$ values lower than that of *D. quadramaculatus*.

Body size was related to $\delta^{15}N$ signatures, but relationships are species dependent. *D. quadramaculatus* was depleted in $\delta^{15}N$ as SVL increased ($r^2 = 0.64$, Figure 3.2). *E. cirrigera* showed the opposite pattern with an enrichment of $\delta^{15}N$ with increasing SVL ($r^2 = 0.29$, Figure 3.2). A range of body sizes were found in both spring and summer, both of which were included in the analysis. Fall data was excluded due to lack of individual variation because of sample pooling. The pattern was also observed in *D. quadramaculatus* collected in summer 2007 (August 28) at the Coweeta Hydrologic Laboratory ($r^2 = 0.44$ Figure 3.3).

Salamander diets were variable within the five size classes. No relationship was found to exist with % predator consumed vs. size class for *D. quadramaculatus* and *E. cirrigera*. Species richness per size class increased as body size increased in *D. quadramaculatus* ($r^2 = 0.77$) indicating larger individuals incorporated a greater variety of prey types into their diet. *D. quadramaculatus* and *E. cirrigera* were analyzed for total number of prey items/gut and total biomass/gut (Table 3.2), neither variable was found to be significant.

The piecewise model indicated a significant threshold of 12 mm – 22.1 mm SVL ($r^2 = 0.62$, $p < 0.001$, Figure 3.4) and 22.1 – 37 mm SVL ($r^2 = 0.06$, $p = 0.12$, Figure 3.4). The slope of $\delta^{15}N$ decreased as SVL increased, with a change in slope after 22.11 mm (95% confidence intervals 19.71 and 24.51). After 22.1 mm, SVL is no longer a predictor of $\delta^{15}N$. SVL, therefore, can change a great deal without $\delta^{15}N$ being altered, which results in the low observed r^2 value (0.06) found with the second slope. The utility of the threshold point is defining a SVL with which $\delta^{15}N$ values represent within stream resources rather than maternal resources.

DISCUSSION

Our findings revealed salamanders within these headwater streams to exhibit individual variability in isotopic composition. Relationships with $\delta^{15}N$ and SVL, specifically, are species dependent. *E. cirrigera* increased in presumed or ‘apparent’ trophic position as size increased.

However, *D. quadramaculatus* showed an opposing trend. Moreover, $\delta^{15}N$ was significantly different for salamander species, while $\delta^{13}C$ did not exhibit these trends. Diet composition was similar among size classes; therefore, diet is unlikely driving the apparent decrease in trophic position of *D. quadramaculatus*. These confounding patterns in $\delta^{15}N$ and SVL raise questions both of salamander isotopic and diet composition as well as current interpretation of isotopic signatures when correlating with body size.

The observed depletion in $\delta^{15}N$ with increasing size of *D. quadramaculatus* was not predicted by our current assumptions about increases in body size, ontogenetic changes (de la Moriniere et al. 2003, Post et al. 2003) and trophic position (Peterson and Fry 1987). Depletion in $\delta^{15}N$, however, is theoretically proposed by Rio and Wolf (2005). Animals, generally, are expected to feed at higher trophic positions as body size increases, as larger individuals can incorporate larger prey. Increased $\delta^{15}N$ with body size is reported in studies including a community of fishes in the Celtic and North Sea (Jennings et al. 2001) as well as a study investigating Dover sole (Rau et al. 1981; Spies et al. 1989). Arim et al. (2010) also found trophic position to increase with increasing body size of killifish as well as an increase in the richness of prey items. Our research suggests opposing trends with a decrease in trophic position but an increase in prey items per gut as SVL increased. Larger energy demands of the predator could translate to increases in the number of prey consumed, although diet was likely not driving the decrease in trophic position observed.

Ontogenetic shifts were not likely driving the trends we observed. Diet results among studies, nonetheless, do suggest shifts in diet as animals grow. Lynch (1985) results suggest larger salamanders tend to shift their prey utilization to fewer prey items relative to their smaller conspecifics. However, Maglia (1996) found the mean number of prey items were similar among age classes. Davic (1983) documented ontogenetic shifts by *D. quadramaculatus* from aquatic to terrestrial prey selection. *D. quadramaculatus* larvae were found to feed on aerial prey beginning at a size class of 24-25 mm; however, terrestrial prey was found in guts beginning at the 28-29 mm size class (Davic 1991). We observed incorporation of terrestrial prey at 24 mm with aerial prey around 26 mm SVL. A *D. ocoee* was also observed in one individual within 26 mm SVL, although these occurrences are considered rare overall (Camp 1997; Trice, unpublished data). These results indicate the most intense pressure on benthic macroinvertebrates from the larval and juvenile size classes. Shifts ontogenetically might be adaptive by allowing a greater variety of prey for juvenile growth into reproductive adults while decreasing competition between juveniles and larvae for resources (Davic 1983). It should be noted that both *D. quadramaculatus* and *E. cirrigera* were also analyzed for % predator consumed per size class. With the idea in mind that *E. cirrigera* could be consuming a greater number of predators as it grew larger resulting in an increase in $\delta^{15}N$ whereas *D. quadramaculatus* could be exhibiting the reversal of this behavior. Neither of these trends was, however, observed.

Analysis of trophic structure is ingrained within the observation that values of $\delta^{15}N$ increase with trophic level increase (Adam and Sterner 2000). We have shown a contradictory pattern that was consistent in two watersheds, separated by over 100 miles. It is likely that it exists in other species and locations, the results of which could confound interpretation of food webs and trophic ecology. Investigating these common versus rare events are potentially important to ecosystems and are occurring biologically, although most analyses are often not incorporating these potential trends. Not incorporating this rarity or variability likely causes misinterpretation of what is occurring due to shifts in diets or other biological factors.

Simply averaging the $\delta^{15}N$ values of *D. quadramaculatus* and *E. cirrigera* alters our interpretation of trophic position. As averaging values 3.03 ‰ and 3.48 ‰ of *D. quadramaculatus* and *E. cirrigera* respectively do not incorporate individual variation where D. quadramaculatus individuals comprise a range (2.18 – 6.43 %) of $\delta^{15}N$ values. The trend of reduced $\delta^{15}N$ with increasing body size would never be realized using standard food web methods of only averaging values to obtain a mean. Individual variation is important to our interpretation of potential feeding mechanisms and may alter our results if not included. *D. quadramaculatus* of newly hatched larvae possess $\delta^{15}N$ values of approximately 6 ‰. Moreover, this is solely based on maternal resources as newly hatched individuals were caught immediately after egg emergence. Around 20 mm SVL larvae begin to express signatures that reflect within stream resources. Larvae smaller than this possess a mixture of both maternal and stream food resources. Our results illustrate the need to incorporate individual variation. Those wishing to express values specific to stream food web function, furthermore, should only select individuals above 20 mm SVL. Individuals above this size range could then be averaged to obtain a more representative trophic value.

While stable isotopes provide important information on trophic interactions, failure to consider individual variation likely affects interpretation of relationships. We observed a large degree of individual variation with *D. quadramaculatus* due to loss of maternal resources. Trophic interactions are often size-dependent therefore understanding size structure within a population is of fundamental importance. Investigating the relationships both with body size and loss of maternal resources may enhance our interpretation of headwater stream food webs. If conservation or management decisions are based on potential food web interactions, understanding sources of isotopic composition at various body sizes (age) could be of vital importance.

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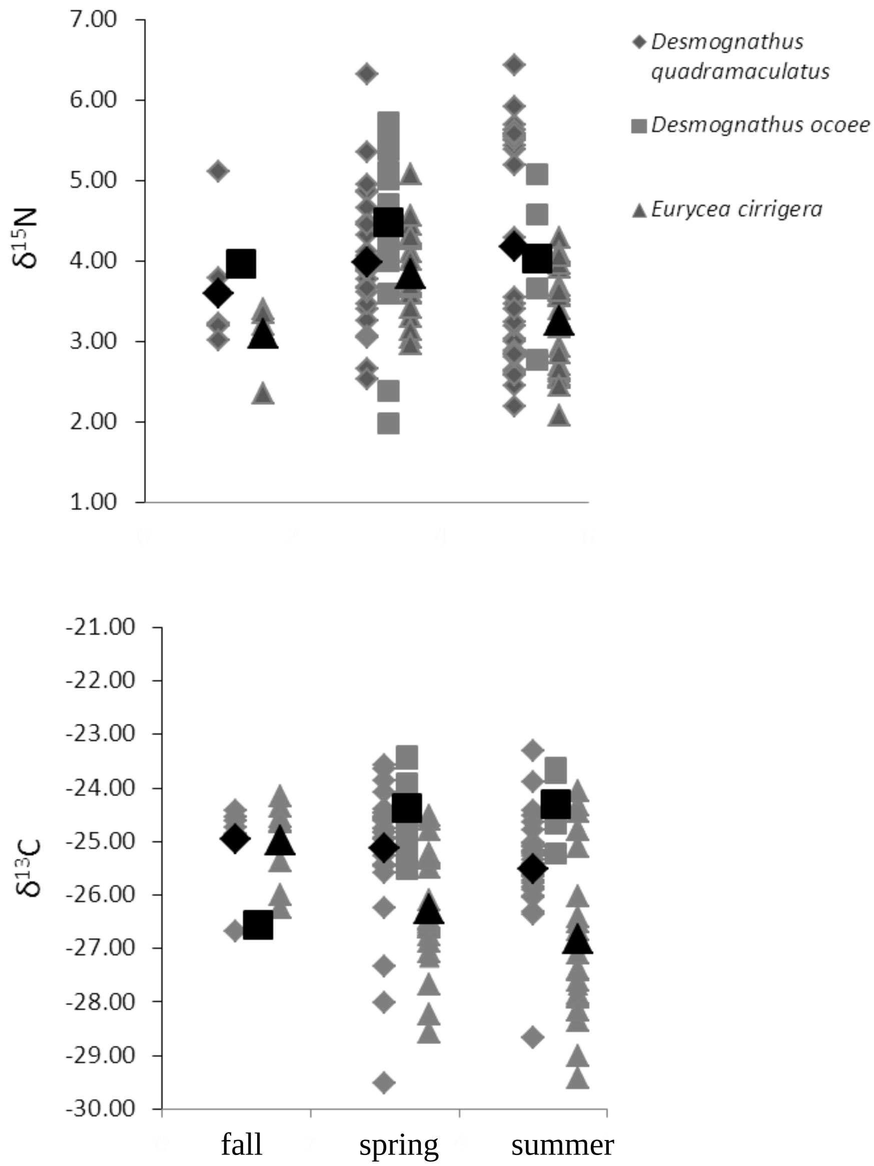

7.00
6.00
5.00
4.00
3.00
2.00
1.00
δ15N
Desmognathus quadramaculatus
Desmognathus ocoee
Eurycea cirrigera
-21.00
-22.00
-23.00
-24.00
-25.00
-26.00
-27.00
-28.00
-29.00
-30.00
δ13C
fall
spring
summer

Figure 3.1. Individual $\delta^{15}N$ and $\delta^{13}C$ values for three species of headwater stream salamanders (*Desmognathus quadramaculatus*, *Desmognathus ocoee* and *Eurycea cirrigera*) for each season (spring, summer or fall). Large black symbol denotes mean $\delta^{15}N$ and $\delta^{13}C$ value for each species per season. Mean and ranges for $\delta^{15}N$: fall – *D. quadramaculatus* (3.59, 3.01 – 5.11), *D. ocoee* (3.96), *E. cirrigera* (3.09, 3.05 – 3.40); spring – *D. quadramaculatus* (3.98) (2.53 – 6.32), *D. ocoee* (4.48) (1.98 – 5.72), *E. cirrigera* (3.83) (2.97 – 5.08); summer – *D. quadramaculatus* (4.17) (2.18 – 6.43), *D. ocoee* (4.02) (2.77 – 5.07), *E. cirrigera* (3.26) (2.08 – 4.28). Mean and ranges for $\delta^{13}C$: fall – *D. quadramaculatus* (-24.96) (-26.67 – -24.43), *D. ocoee* (-26.55), *E. cirrigera* (-24.99) (-26.26 – -24.15); spring – *D. quadramaculatus* (-25.13) (-29.52 – -23.57), *D. ocoee* (-24.37) (-25.51 – -23.46), *E. cirrigera* (-26.27) (-28.57 – -24.59); summer – *D. quadramaculatus* (-25.51) (-28.68 – -23.31), *D. ocoee* (-24.31) (-25.22 – -23.61), *E. cirrigera* (-26.83) (-29.42 – -24.05).

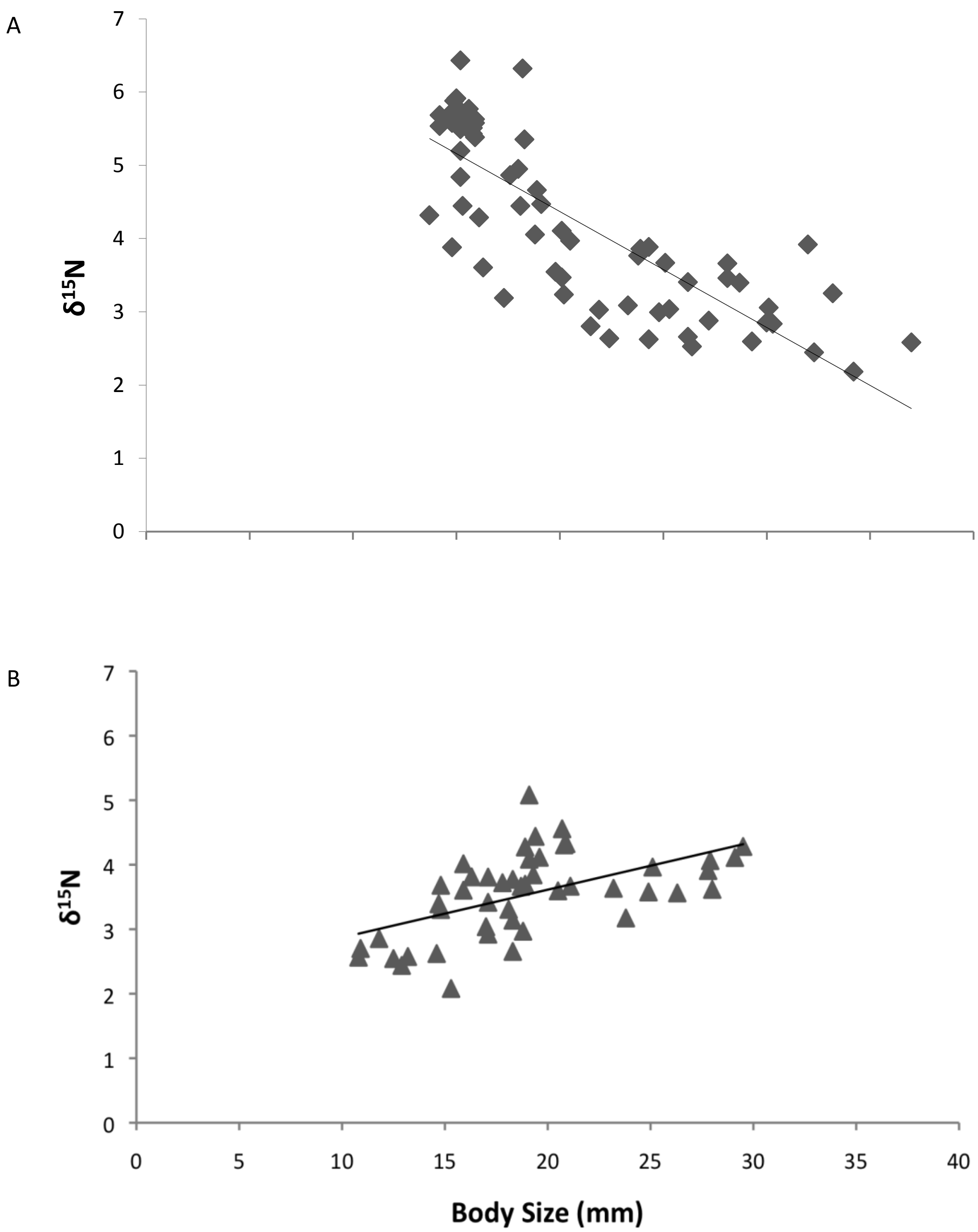

Figure 3.2. Individual $\delta^{15}N$ signatures vs. body size mm (SVL) for salamanders at Big Canoe, G.A. A denotes *Desmognathus quadramaculatus* ($r^2 = 0.64$, $p < 0.0001$, $y = -0.1581x + 7.5288$). B denotes *Eurycea cirrigera* ($r^2 = 0.29$, $p < 0.0001$, $y = 0.0742x + 2.1286$).

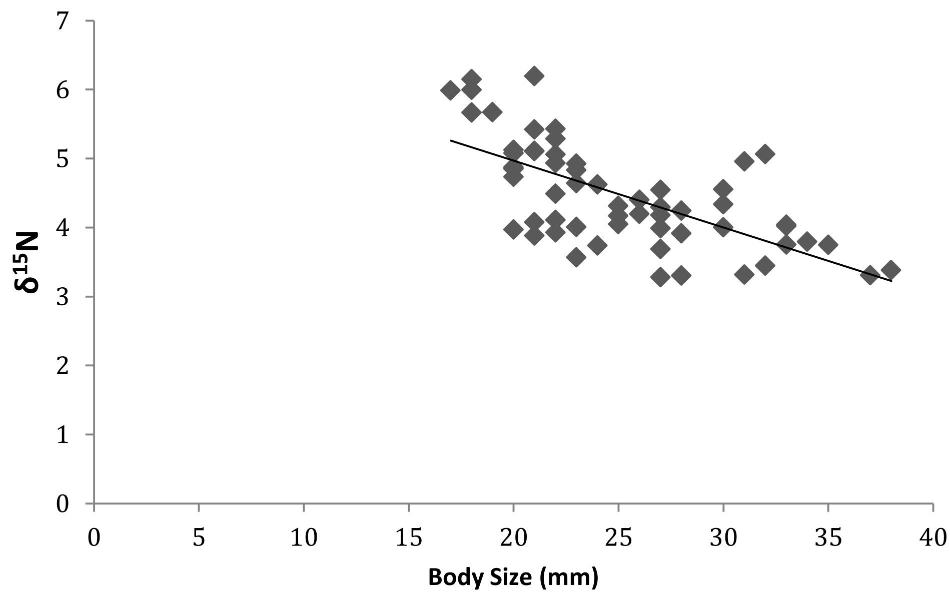

Figure 3.3. Individual $\delta^{15}N$ signatures vs. body size mm (SVL) for *Desmognathus quadramaculatus* at the Coweeta LTER, N.C. ($r^2 = 0.43$, $p = 0.0010$, $y = -0.0969x + 6.9095$).

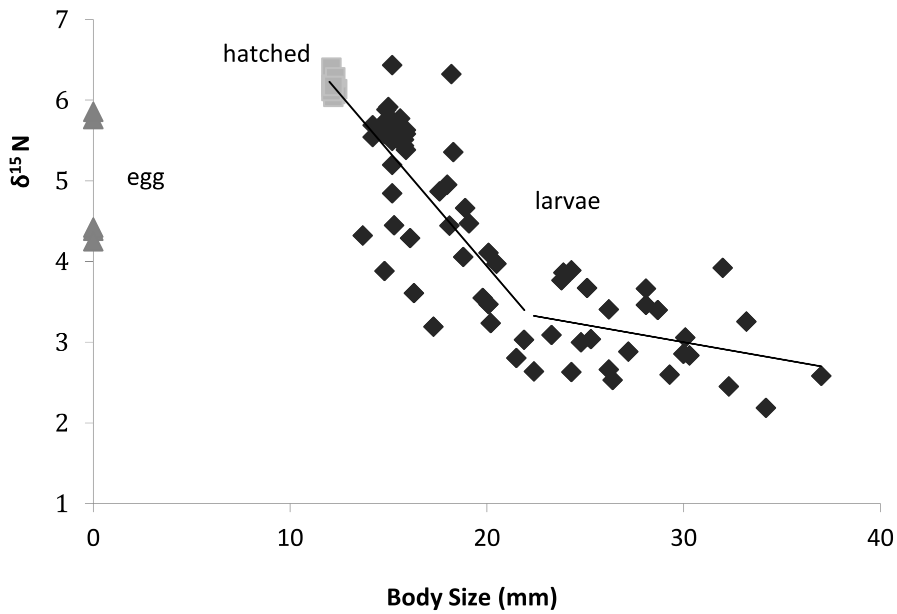

Figure 3.4. Relationship between individual δ^{15}N and body size (mm) for *Desmognathus quadramaculatus* values include egg, newly hatched and larvae with a breakpoint found at 22.11 mm. Value for first trend line (12-22.1 mm) is $r^2 = 0.62$, $p < 0.001$, $y = -0.2857x + 9.6549$. The second trend line (22.1-37 mm) is $r^2 = 0.06$, $p = 0.12$, $y = -0.0429x + 4.2851$ indicating body size is no longer a predictor of δ^{15}N.

Table 3.1. ANOVA results for $\delta^{13}C$ and $\delta^{15}N$ testing differences in salamander species (*Desmognathus quadramaculatus*, *Desmognathus ocoee* and *Eurycea cirrigera*) and season (spring, summer and fall) blocking for stream. An interaction effect was tested for species and season for both $\delta^{13}C$ and $\delta^{15}N$. Post-ANOVA test included for significant species main effect for $\delta^{15}N$. Categories with the same letter are not statistically different (Tukey-Kramer, $p < 0.05$).

Category	F	df	P
$\delta^{13}C$			
species	2.60	2,146	NS
season	0.96	2,146	NS
stream	16.63	3,146	< 0.001
species*season	2.08	4,146	NS
$\delta^{15}N$			
species	4.59	2,146	0.01
season	2.20	2,146	NS
stream	2.42	3,146	0.06
species*season	1.14	4,146	NS
Post-ANOVA $\delta^{15}N$			
Desmognathus quadramaculatus	a		
Desmognathus ocoee	a,b		
Eurycea cirrigera	b		

Table 3.2. Results of gut content statistical analyses for both *Desmognathus quadramaculatus* and *Eurycea cirrigera*. Total prey/gut and total biomass/gut were analyzed with ANOVA. % Predator/size class and unique prey items/size class analyzed with regression analysis. Categories are listed as analysis run as well as significance and regression equation where appropriate.

Category	significance	regression equation
D. quadramaculatus		
% predator/size class	NS	
unique prey items/size class	$r^2 = 0.77$	$y = 2.2x + 11.4$
E. cirrigera		
% predator/size class	NS	
unique prey items/size class	NS	

Appendix 3.1. Isotope values of $\delta^{15}N$ and $\delta^{13}C$ for larval species, eggs and newly hatched individuals including date, site and SVL.

Species	Type	Date sampled	Site	SVL (mm)	$\delta^{15}N$	$\delta^{13}C$
DO	larvae	Mar-09	BR	15	5.38	-24.35
DO	larvae	Mar-09	BR	14	5.72	-24.63
DO	larvae	Mar-09	BR	14.3	4.62	-25.50
DO	larvae	Mar-09	BR	13.1	5.39	-25.21
DO	larvae	Mar-09	BR	13.9	5.11	-23.45
DO	larvae	Mar-09	BR	13.2	4.70	-24.85
DO	larvae	Mar-09	BR	14.4	4.54	-23.90
DO	larvae	Mar-09	BR	14.1	5.00	-24.04
DO	larvae	Mar-09	BR	15	4.24	-25.18
DO	larvae	Mar-09	BT	11.1	5.41	-23.97
DO	larvae	Mar-09	BT	14.2	5.60	-23.40
DO	larvae	Mar-09	BT	10.8	4.57	-23.44
DO	larvae	Mar-09	YR	13.1	1.97	-25.04
DO	larvae	Mar-09	YR	14.9	2.38	-24.27
DO	larvae	Mar-09	YR	12.9	3.98	-23.93
DO	larvae	Mar-09	YR	13.8	4.22	-24.19
DO	larvae	Mar-09	YR	13.1	4.21	-24.10
DO	larvae	Mar-09	YT	14.2	3.59	-25.07
DO	larvae	Jul-09	BR	18.3	5.07	-23.61
DO	larvae	Jul-09	BR	16.1	4.58	-23.73
DO	larvae	Jul-09	BR	16.2	3.65	-25.21
DO	larvae	Jul-09	BR	26.1	2.76	-24.67
DQ	larvae	Mar-09	BR	26.2	3.40	-25.45
DQ	larvae	Mar-09	BR	18.1	4.44	-25.43
DQ	larvae	Mar-09	BR	19.1	4.47	-24.75
DQ	larvae	Mar-09	BR	18.8	4.05	-24.84
DQ	larvae	Mar-09	BR	23.3	3.08	-24.95
DQ	larvae	Mar-09	BR	20.1	4.10	-25.58
DQ	larvae	Mar-09	BR	26.2	2.65	-25.26
DQ	larvae	Mar-09	BR	13.7	4.31	-24.48
DQ	larvae	Mar-09	BR	20.5	3.96	-24.93
DQ	larvae	Mar-09	BR	15.2	4.84	-24.47
DQ	larvae	Mar-09	BT	26.4	2.52	-23.56
DQ	larvae	Mar-09	BT	25.3	3.03	-24.54
DQ	larvae	Mar-09	BT	33.2	3.25	-25.17
DQ	larvae	Mar-09	BT	18.3	5.35	-24.54

Species	Type	Date sampled	Site	SVL (mm)	$\delta^{15}N$	$\delta^{13}C$
DQ	larvae	Mar-09	BT	30.1	3.05	-25.47
DQ	larvae	Mar-09	BT	28.1	3.46	-24.95
DQ	larvae	Mar-09	BT	24.3	3.88	-24.60
DQ	larvae	Mar-09	BT	17.6	4.86	-24.76
DQ	larvae	Mar-09	BT	18.2	6.32	-23.65
DQ	larvae	Mar-09	BT	18.9	4.66	-24.40
DQ	larvae	Mar-09	BT	23.8	3.76	-24.57
DQ	larvae	Mar-09	BT	18	4.94	-24.84
DQ	larvae	Mar-09	BT	25.1	3.66	-26.23
DQ	larvae	Mar-09	YT	23.9	3.86	-28.01
DQ	larvae	Mar-09	YT	32	3.91	-29.51
DQ	larvae	Mar-09	YT	16.3	3.60	-24.59
DQ	larvae	Mar-09	YT	28.1	3.66	-27.32
DQ	larvae	Mar-09	YT	14.8	3.87	-23.85
DQ	larvae	Mar-09	YT	15.3	4.44	-24.08
DQ	larvae	Jul-09	BR	15.8	5.50	-25.64
DQ	larvae	Jul-09	BR	15.2	6.43	-25.54
DQ	larvae	Jul-09	BR	15.9	5.62	-25.46
DQ	larvae	Jul-09	BR	21.9	3.02	-25.57
DQ	larvae	Jul-09	BR	15.9	5.38	-24.79
DQ	larvae	Jul-09	BR	15.2	5.19	-25.10
DQ	larvae	Jul-09	BR	15.8	5.43	-25.02
DQ	larvae	Jul-09	BR	24.8	2.99	-25.67
DQ	larvae	Jul-09	BR	22.4	2.63	-26.36
DQ	larvae	Jul-09	BR	15.2	5.49	-26.03
DQ	larvae	Jul-09	BR	15	5.57	-25.91
DQ	larvae	Jul-09	BT	17.3	3.19	-25.34
DQ	larvae	Jul-09	BT	20.1	3.46	-24.43
DQ	larvae	Jul-09	BT	19.8	3.54	-24.52
DQ	larvae	Jul-09	BT	32.3	2.44	-25.64
DQ	larvae	Jul-09	BT	29.3	2.59	-25.27
DQ	larvae	Jul-09	BT	27.2	2.88	-25.44
DQ	larvae	Jul-09	BT	24.3	2.62	-26.04
DQ	larvae	Jul-09	BT	30	2.85	-25.72
DQ	larvae	Jul-09	BT	20.2	3.23	-25.02
DQ	larvae	Jul-09	BT	37	2.58	-25.85
DQ	larvae	Jul-09	BT	21.5	2.80	-25.20
DQ	larvae	Jul-09	YR	15.1	5.77	-25.82
DQ	larvae	Jul-09	YR	14.9	5.88	-26.06
DQ	larvae	Jul-09	YR	14.9	5.75	-25.97
DQ	larvae	Jul-09	YR	14.8	5.73	-25.71
DQ	larvae	Jul-09	YR	15.6	5.77	-25.66
DQ	larvae	Jul-09	YR	15.1	5.63	-25.61
DQ	larvae	Jul-09	YR	15.2	5.70	-25.70
DQ	larvae	Jul-09	YR	14.8	5.57	-25.21

Species	Type	Date sampled	Site	SVL (mm)	$\delta^{15}N$	$\delta^{13}C$
DQ	larvae	Jul-09	YR	14.2	5.68	-23.30
DQ	larvae	Jul-09	YR	14.2	5.53	-25.78
DQ	larvae	Jul-09	YR	14.7	5.62	-25.16
DQ	larvae	Jul-09	YT	28.7	3.39	-28.67
DQ	larvae	Jul-09	YT	15	5.91	-24.64
DQ	larvae	Jul-09	YT	16.1	4.28	-23.89
DQ	larvae	Jul-09	YT	15.1	5.54	-25.07
DQ	larvae	Jul-09	YT	15.9	5.57	-25.43
DQ	larvae	Jul-09	YT	34.2	2.18	-26.30
DQ	larvae	Jul-09	YT	30.3	2.83	-28.66
E	larvae	Mar-09	BR	17	3.03	-25.26
E	larvae	Mar-09	BR	18.1	3.30	-27.68
E	larvae	Mar-09	BR	19.6	4.11	-25.24
E	larvae	Mar-09	BR	18.3	3.13	-25.21
E	larvae	Mar-09	BT	17.8	3.72	-25.48
E	larvae	Mar-09	BT	16.3	3.81	-24.58
E	larvae	Mar-09	BT	19.1	5.08	-24.52
E	larvae	Mar-09	BT	15.9	3.60	-24.77
E	larvae	Mar-09	BT	15.9	4.01	-25.31
E	larvae	Mar-09	YT	20.5	3.59	-28.23
E	larvae	Mar-09	YT	20.9	4.32	-27.16
E	larvae	Mar-09	YT	17.1	3.41	-26.60
E	larvae	Mar-09	YT	19.4	4.43	-26.57
E	larvae	Mar-09	YT	21.1	3.66	-28.56
E	larvae	Mar-09	YT	20.7	4.55	-27.07
E	larvae	Mar-09	YT	19.3	3.84	-26.76
E	larvae	Mar-09	YT	18.3	3.77	-26.45
E	larvae	Mar-09	YT	18.7	3.66	-26.60
E	larvae	Mar-09	YT	18.8	2.96	-26.29
E	larvae	Mar-09	YT	18.9	3.69	-26.09
E	larvae	Mar-09	YT	17.1	3.80	-26.43
E	larvae	Mar-09	YT	18.9	4.27	-26.86
E	larvae	Mar-09	YT	20.8	4.30	-26.50
E	larvae	Jul-09	BR	13.2	2.57	-24.32
E	larvae	Jul-09	BR	10.8	2.56	-24.78
E	larvae	Jul-09	BR	19.1	4.08	-24.79
E	larvae	Jul-09	BR	14.6	2.62	-24.45
E	larvae	Jul-09	BR	23.8	3.17	-27.69
E	larvae	Jul-09	BT	10.9	2.70	-24.05
E	larvae	Jul-09	YR	17.1	2.92	-27.38
E	larvae	Jul-09	YR	12.5	2.54	-27.40
E	larvae	Jul-09	YR	15.3	2.08	-27.92
E	larvae	Jul-09	YR	18.3	2.65	-25.11
E	larvae	Jul-09	YT	14.8	3.30	-26.64
E	larvae	Jul-09	YT	29.5	4.28	-29.42

Species	Type	Date sampled	Site	SVL (mm)	$\delta^{15}N$	$\delta^{13}C$
E	larvae	Jul-09	YT	27.8	3.90	-27.90
E	larvae	Jul-09	YT	24.9	3.57	-27.84
E	larvae	Jul-09	YT	23.2	3.63	-26.50
E	larvae	Jul-09	YT	25.1	3.96	-28.15
E	larvae	Jul-09	YT	14.7	3.39	-27.09
E	larvae	Jul-09	YT	14.8	3.68	-26.84
E	larvae	Jul-09	YT	11.8	2.85	-26.01
E	larvae	Jul-09	YT	12.9	2.43	-28.36
E	larvae	Jul-09	YT	29.1	4.11	-28.16
E	larvae	Jul-09	YT	27.9	4.06	-27.61
E	larvae	Jul-09	YT	26.3	3.56	-29.01
E	larvae	Jul-09	YT	28	3.61	-26.40
DQ	egg capsule	Jul-10			4.37	-23.38
DQ	egg capsule	Jul-10			4.41	-23.65
DQ	egg capsule	Jul-10			4.24	-23.14
DQ	egg capsule	Jul-10			5.76	-23.30
DQ	egg capsule	Jul-10			5.76	-23.44
DQ	egg capsule	Jul-10			5.85	-23.45
DQ	newly hatched larvae	Jul-10			6.39	-25.16
DQ	newly hatched larvae	Jul-10			6.12	-25.09
DQ	newly hatched larvae	Jul-10			6.07	-25.12
DQ	newly hatched larvae	Jul-10			6.19	-25.02
DQ	newly hatched larvae	Jul-10			6.06	-24.85
DQ	newly hatched larvae	Jul-10			6.10	-25.11
DQ	newly hatched larvae	Jul-10			6.13	-25.65
DQ	newly hatched larvae	Jul-10			6.16	-25.37
DQ	newly hatched larvae	Jul-10			6.04	-25.12
DQ	newly hatched larvae	Jul-10			6.28	-24.99
DQ	newly hatched larvae	Jul-10			6.11	-24.88
DQ	newly hatched larvae	Jul-10			6.17	-24.61

SUMMARY AND CONCLUSIONS

In the preceding chapters, I have provided an evaluation of trophic ecology of larval headwater stream salamanders within the Blue Ridge Mountains of Georgia. This research provides insights into these important headwater predators, with hopes for their continued preservation. Data sets of this nature are critical to further understand both general isotope and feeding ecology as well as the ecology of salamanders.

Chapter 1 provides an overview of the importance of salamanders, as both within stream predators and prey for the surrounding forested riparian zone. Threats to conservation of salamanders were discussed as well as interesting facts emphasizing headwater streams and Plethodontid salamanders. The study region in particular is known to harbor an extraordinary diversity of salamanders, the majority of which are most abundant in these headwater stream and riparian ecosystems (Petranka 1998).

Headwater deciduous streams are strongly affected by seasonal dynamics. We investigated the effects of seasonality on isotopic composition and biomass contributions of food web structure (Chapter 2). We hypothesized macroinvertebrate and salamander biomass would exhibit seasonal trends. Macroinvertebrate biomass followed trends seasonally, however, salamander biomass varied only slightly. Food webs were predicted to shift in $\delta^{13}C$ seasonally; however, food webs did not exhibit seasonal shifts in $\delta^{13}C$ or $\delta^{15}N$. Larval salamanders were confirmed as top predators in these systems with gut content consistent with isotopic signatures. Using isotopes, biomass estimates, gut content analyses and Bayesian mixing models our results highlight the importance of using these methods to fully understand important food web relationships regarding these unique predators.

Isotopic composition of larval salamanders was explored in more detail in Chapter 3. Individual variation of isotopic signatures was investigated with respect to snout-vent length (SVL). Moreover, the focus centered on $\delta^{15}N$ of *Desmognathus quadramaculatus* and *Eurycea cirrigera*. *D. quadramaculatus* signatures exhibited trends unusual to traditional ideas of trophic position, as values decreased with increasing SVL. The opposing trend was observed for *E. cirrigera*. Loss of highly enriched $\delta^{15}N$ from maternal resources was likely driving the observed trend with *D. quadramaculatus*. Maternal effects should be considered, as investigating the relationships both with body size and loss of maternal resources may enhance our interpretation of headwater stream food webs.

This research represents one of a limited number of works advancing our knowledge of headwater stream larval salamanders with regards to isotopic composition and diet. These important predators provide key ecological functions (Davic and Welsh 2004, Milanovich 2010). What is more, declines are occurring at a disturbing rate in many areas globally before the full extent of amphibians ecological significance is understood (Whiles et al. 2006). Even more so, as watershed development severs connections with the terrestrial environment, through removal of vegetation and paving of lands, greater loss of salamander habitat occurs. The overarching goals of this thesis were to underline the importance of researching variability whether on an individual, spatial or temporal basis with regards to key ecosystem consumers. The importance of food webs and understanding energy flow dynamics of larval salamanders were also emphasized. Anthropogenic effects will be difficult to isolate without first understanding natural causes of variation on food web structure and function. With this idea in mind, this and other data sets will be integral for conservation management decisions regarding watershed land use change for headwater stream ecosystems.

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