HERPETOFAUNAL ABUNDANCE IN FORESTED EDGE AND INTERIOR LOCATIONS OF WEST VIRGINIA

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Abstract.—The diversity of forest types in the Central Appalachians provides important habitat for amphibians and reptiles. As development continues, increased fragmentation is evident on the landscape. The objectives of our study were to determine the influence of location within a forest (edge or interior) and landscape position (riparian and upland) on West Virginia herpetofaunal species abundance and diversity. Using drift fence arrays, we captured individuals from 17 amphibian species and 6 reptilian species during 43,144 trap-nights. Eastern red-backed salamanders (*Plethodon cinereus* Green) (30 percent of captures), wood frogs (*Lithobates sylvaticus* LeConte) (17 percent), eastern American toads (*Anaxyrus a. americanus* Holbrook) (16 percent), and red-spotted newts (efts) (*Notophthalmus v. viridescens* Rafinesque) (12 percent) were most commonly captured. Eastern American toads were more abundant in upland than riparian areas, and eastern red-backed salamanders, wood frogs and red-spotted newts were captured equally in riparian and upland areas. Wood frogs and red-spotted newts were encountered more frequently in interior than edge locations; red-backed salamanders and eastern American toads were captured equally in interior and edge locations. Northern slimy salamanders (*P. glutinosus* Green) were more abundant in upland than riparian areas and also were more abundant in interior than edge locations. Species richness and diversity were not different between locations or landscape position. Our results suggest that edges adversely impact abundance of some, but not all, species of amphibians and these influences are not dependent on the landscape position.

INTRODUCTION

The distribution and habitat association of terrestrial and aquatic amphibians and reptiles are poorly known compared to those of other forest vertebrates (Drost and Fellers 1996, Dunson et al. 1992). Therefore, research that measures herpetofaunal population changes among habitats is needed to conserve local and global native species richness and composition (Busby and Parmelee 1996, DeGraaf and Rudis 1990, Millar et al. 1990, Phillips 1990, Probst and Crow 1991). Herpetofaunal species are integral components of ecosystems and often compose the greatest vertebrate biomass in an area (Burton and Likens 1975, Vitt et al. 1990). Herpetofauna also serve as both predator and prey to numerous organisms, including small mammals, birds, and even other herpetofauna. Therefore, evaluating herpetofaunal population status among various habitat types and conditions is critical for the proper management of these species (Blaustein and Wake 1990, Burton and Likens 1975).

During the last several decades, awareness of the importance of herpetofaunal species and their habitats has grown as documentation of amphibian and reptile declines has increased (Blaustein 1994, Blaustein and Wake 1990, Gibbons et al. 2000, Pechmann and Wilbur 1994, Pechmann et al. 1991, Wake 1991). Reasons for declines include deforestation, habitat fragmentation, and exploitation (Grialou et al. 2000, Kuusipalo and Kangas 1994, Ward et al. 2008). Although the process of forest

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fragmentation may create only temporary effects within a forested landscape, the effects of edge remain largely unstudied for amphibians and reptiles (DeGraaf and Yamasaki 1992, Windmiller et al. 2008). Populations of several herpetofaunal species depend on the quantity and quality of the microhabitat they occupy; as a result, many herpetofaunal species may be negatively impacted by the changes in structural habitat characteristic of management-induced forest edges (deMaynadier and Hunter 1998).

Throughout the Appalachian region, the impacts of logging, mining, and other land use practices are evident throughout the landscape, yet the influence of such operations remains unclear for existing native biota (Mitchell et al. 1999, Petranka et al. 1994). Since the late 19th and early 20th centuries, extensive logging and frequent fires have occurred throughout the upland forest region of the Appalachians, leaving present-day forests in a mosaic of second- and third-growth communities (Stephenson 1993). Therefore, it is imperative that research be conducted to evaluate and identify the significance of habitat disturbances and edge effects on native biota. The objectives of our study were to determine the influence of location (edge and interior) and habitat (riparian and upland) on herpetofaunal species abundance, richness, and diversity.

STUDY AREA

We conducted our study on three tracts (Cantonment [378 ha], Briery Mountain [423 ha], and Pringle [854 ha]) that form the 1,655-ha Camp Dawson Collective Training Area (CDCTA) in Preston County, West Virginia (Osbourne et al. 2002). The CDCTA, located in north-central West Virginia, has served as a military training site for the West Virginia Army National Guard since 1909.

Elevations on Camp Dawson range from 122-853 m. During the last two centuries logging, strip and deep mining for coal, and farming have affected the study area (Osbourne et al. 2002). In addition to military training, natural resource management is a top priority, with a special emphasis on protection of state rare plants and animals, management of game species and hunting, and management to achieve a diversity of landscape components (Anderson et al. 2004). Eighty-one percent of the area was covered by mixed mesophytic forests, successional forests of low-elevation plateaus, or mature or successional floodplain forests (Vanderhorst 2002). The base had 1,085 ha of upland forested area and 313 ha of forested riparian area (Osbourne et al. 2005). Forest interior (>100 m from the forest edge) made up 749 ha and forest edge, 649 ha; the remaining 267 ha was classified as open areas (Osbourne et al. 2005).

METHODS

Trapping

We collected herpetofauna from standard cross-shaped pitfall arrays with a 19-L bucket in the middle and at the end of each 7.5-m silt fence length (Bury and Corn 1987, Greenberg et al. 1994, Mengak and Guynn 1987, Osbourne et al. 2005). We buried silt fencing 3-4 cm deep and placed buckets flush with the ground. A small amount of water (0-5 cm) was kept in the bottom of each bucket to provide a dry substrate for some rodents, but reduce the possibility of escape and desiccation of captured herpetofauna (Spurgeon and Anderson 2002). Double-ended funnel traps, constructed from aluminum hardware cloth and plastic funnels, were installed at each array with one trap along each side of a fence section to target snakes (Bury and Corn 1987, Spurgeon and Anderson 2002). The body of the funnel trap was 46 cm long and each funnel had an outside diameter of 10 cm and an inner-opening diameter of 5 cm. Traps were held in place by clearing away all debris and making a shallow depression in the soil for them to rest on. Rocks, sticks, and soil were packed against the traps and between the traps and fence to stabilize the traps and prevent organisms from passing through the gaps.

We located all arrays in forested areas. We determined locations for arrays by classifying sites as riparian or upland areas and interior or edge array locations. We considered riparian areas to be characterized by riparian vegetation and located <100 m from a permanent water body; upland habitat was anything not fitting the description of riparian habitat (Laerm et al. 1997, Osbourne et al. 2005). We defined edge locations as arrays <100 m from the edge of a forest, and interior locations were areas ≥100 m from the edge of a forest.

From July 5 to October 27, 2000, we collected individuals from 13 arrays distributed as 6 riparian, 7 upland, 8 edge, and 5 interior (5 riparian-edge, 1 riparian-interior, 3 upland-edge, and 4 upland-interior). During the second year of sampling (April 6 to October 29, 2001), we added 7 new arrays for a total of 20. The distribution of our arrays among treatments was 10 riparian, 10 upland, 11 edge, and 9 interior sites (6 riparian-edge, 4 riparian-interior, 5 upland-edge, and 5 upland-interior sites). Pitfall arrays were continuously open and we checked them once every 24 to 72 hours for captures. We determined species for all captures and live individuals were released onsite (Osbourne et al. 2005, Spurgeon and Anderson 2002). Methods for marking individuals were modified from Martof (1953), Brown and Parker (1976), and Cagle (1939). Small fingernail clippers were used to clip amphibians' toes at an angle and the digit removed was recorded. Antibacterial cream was applied to the digit to prevent infection. Ventral scale clipping on snakes was performed with surgical scissors and the number of scales from the cloacal vent was recorded for identification (Brown and Parker 1976). Turtle shells were notched with pliers and the notch location was recorded.

Pitfall Array Characterization

Using the center of each pitfall array as a reference point, we randomly established five 1 m by 1 m plots, located within a 10-m radius around the pitfall array, in which habitat variables were measured (deMaynadier and Hunter 1998). In each of these plots, length, width, and height measurements were taken on all coarse woody debris and rocks that were present so volumes could be calculated. Within the 1 m by 1m grid, we visually estimated the percentage of herbaceous ground cover (absolute value) (Daubenmire 1968) and measured percentage of canopy closure with a spherical densiometer. From the reference point, we used a 10-factor wedge prism to obtain basal area (m^2/ha) of surrounding trees (Avery and Burkhart 1983).

Data Analyses

We calculated relative abundance of amphibians and reptiles for each trapping array by using a standardized catch-per-unit effort measurement (CPUE) of captures/100 trap nights (Bury and Corn 1987, McComb et al. 1993, Osbourne et al. 2005). Marked individuals were not included in abundance estimates because they had already been counted when initially captured. The experimental unit was the pitfall array, and we chose CPUE because it provides a relative measure of capture rate that can easily be compared between treatments. We compared relative abundance among treatments for all amphibians and reptiles combined and individually for each species representing ≥1 percent of captures (Osbourne et al. 2005). We also compared species richness (number of species/100 trap nights) and Shannon Diversity Index (diversity index/100 trap nights) among treatments to detect any variation in the composition of the herpetofaunal community (Krebs 1999, Krohne 1998).

We compared total relative abundance, relative abundance per species, richness, and diversity between riparian and upland habitats and between edge and interior by using a completely randomized block analysis of variance (ANOVA) model (Osbourne et al. 2005). Our independent variables were habitat (upland or riparian) and location (interior or edge), and our blocked variables were year and tract of land. We tested normality assumptions with a univariate procedure (PROC UNIVARIATE) (SAS Institute, Cary, NC) and homogeneity of variance (HOV) assumptions with Bartlett's test. We rank transformed species richness and Shannon diversity because we were unable to fit normality and HOV assumptions (Conover and Iman 1981). We used square-root and quarter-root transformations on total relative abundance and relative abundance of individual species that met normality assumptions when transformed (Dowdy and Wearden 1991, Zar 1999). We analyzed species with low capture rates and many zero values at individual trapping arrays by using a generalized linear Poisson regression model (PROC GENMOD) (SAS Institute). Abundance of northern red salamanders (*Pseudotriton r. ruber* Latreille) was not analyzed because they were not captured in any riparian arrays, and the Poisson model could not fit a curve for this species.

We used the same ANOVA model and similar procedures as in the herpetofauna relative abundance comparison to determine any significance in mean values of habitat variables measured at pitfall arrays. Least square means was used to determine where differences occurred when there were habitat and location interactions for pitfall array habitat variables (Krebs 1999). All tests were considered significant at alpha = 0.05.

RESULTS

Habitat and Edge Effects on Herpetofauna

Total captures from pitfalls in this study were 858 individuals from 23 species (17 amphibian and 6 reptilian species) in 43,144 trap-nights (Table 1). There were 11 species that each represented ≥1 percent of captures.

Mean CPUE for total amphibian and reptile captures, species richness, and Shannon diversity all were similar between habitat types (Table 2) and locations (Table 3). We found no interaction between habitat and location for total CPUE ($F_{1, 26} = 0.62$, $P = 0.439$), species richness ($F_{1, 26} < 0.01$, $P = 0.957$), or diversity ($F_{1, 26} = 0.56$, $P = 0.462$).

Of the species that fit normal curves, eastern American toads (*Anaxyrus a. americanus* Holbrook) were more abundant in upland than riparian habitats; eastern red-backed salamanders (*Plethodon cinereus* Green), wood frogs (*Lithobates sylvaticus* LeConte), and red-spotted newts (efts) (*Notophthalmus v. viridescens* Rafinesque) were encountered equally in riparian and upland habitats (Table 2). Wood frogs and red-spotted newts were captured more frequently in interior than edge locations, and red-backed salamanders and eastern American toads were encountered equally in

Table1.—Number of individuals for amphibian and reptilian species captured in pitfall traps on the Camp Dawson Collective Training Area in Preston County, West Virginia during 2000 and 2001

	Number of individuals captured			
Species	2000	2001	Total	Percentage of total captures
Eastern red-backed salamanders (*Plethodon cinereus* Green)	144	114	258	30
Wood frogs (*Lithobates sylvaticus* LeConte)	49	100	149	17
Eastern American toads (*Anaxyrus a. americanus* Holbrook)	45	93	138	16
Red-spotted newts (efts) (*Notophthalmus v. viridescens* Rafinesque)	26	80	106	12
Northern green frogs (*L. clamitans melanota* Rafinesque)	8	46	54	6
Northern slimy salamanders (*Plethodon glutinosus* Green)	22	15	37	4
Allegheny Mountain dusky salamanders (*Desmognathus ochrophaeus* Cope)	9	20	29	3
Northern red salamanders (*Pseudotriton r. ruber* Latreille)	2	20	22	3
Pickerel frogs (*Lithobates palustris* LeConte)	9	8	17	2
Four-toed salamanders (*Hemidactylium scutatum* Schlegel)	10	6	16	2
Eastern gartersnakes (*Thamnophis s. sirtalis* Linnaeus)	4	3	7	1
Northern spring salamanders (*Gyrinophilus p. porphyriticus* Green)	1	3	4	<1
Northern dusky salamanders (*Desmognathus f. fuscus* Rafinesque)	1	2	3	<1
Appalachian seal salamanders (*Desmognathus monticola* Dunn)	3	0	3	<1
Eastern snapping turtles (*Chelydra s. serpentina* Linnaeus)	2	1	3	<1
Fowler's toads (*Anaxyrus fowleri* Hinckley)	2	0	2	<1
Gray tree frogs (*Hyla versicolor* LeConte /*Hyla chrysoscelis Cope*)	2	0	2	<1
Northern ring-necked snakes (*Diadophis punctatus edwardsii* Merrem)	2	0	2	<1
Eastern milksnakes (*Lampropeltis t. triangulum* LaCépède)	0	2	2	<1
Northern two-lined salamanders (*Eurycea b. bislineata* Green)	0	1	1	<1
Spring peepers (*Pseudacris crucifer* Wied-Neuwied)	1	0	1	<1
Smooth greensnakes (*Opheodrys vernalis* Harlan)	1	0	1	<1
Eastern ratsnakes (*Pantherophis alleghaniensis* Holbrook)	1	0	1	<1

interior and edge locations (Table 3). No interactions were produced between habitat type and location for individual species capture rates ($F_{1, 26} \leq 0.76$, $P \geq 0.390$).

Northern slimy salamanders were more abundant in upland than riparian habitats ($\chi^2 = 5.65$, $P = 0.017$) and were more abundant in interior than edge locations ($\chi^2 = 4.74$, $P = 0.030$). All other species analyzed with the generalized Poisson regression showed similar relative abundance in upland and riparian habitats (Table 4) and in interior and edge trapping locations (Table 5). No interactions were observed between habitat and trapping location for individual species relative abundances ($\chi^2 \leq 0.91$, $P \geq 0.340$).

Table 2.—Average relative abundance in captures/100 trap nights (CPUE), species richness, and Shannon Diversity Index for amphibian species captured in pitfall traps in riparian (2000: n=6; 2001: n=10) and upland (2000: n=7; 2001: n=10) habitats on the Camp Dawson Collective Training Area in Preston County, West Virginia during 2000 and 2001

	Riparian		Upland			
Species or index	$\bar{x}$	SE	$\bar{x}$	SE	$F_{1,26}$	P
CPUE						
Eastern red-backed salamanders (*Plethodon cinereus* Green)	0.41	0.20	1.30	0.50	1.64	0.211
Wood frogs (*Lithobates sylvaticus* LeConte)	0.44	0.11	0.29	0.08	3.38	0.077
Eastern American toads (*Anaxyrus americanus* Holbrook)	0.22	0.05	0.45	0.12	4.91	0.036
Red-spotted newts (efts) (*Notophthalmus v. viridescens* Rafinesque)	0.20	0.08	0.29	0.08	0.01	0.918
All species combined	1.75	0.35	2.90	0.65	1.21	0.282
Species richness/100 trapnights	0.48	0.07	0.54	0.10	0.02	0.903
Shannon diversity/100 trapnights	0.11	0.02	0.11	0.01	0.26	0.615

Table 3.—Average relative abundance in captures/100 trap nights (CPUE), species richness, and Shannon Diversity Index for amphibian species captured in pitfall traps in edge (2000: n=8; 2001: n=11) and interior (2000: n=5; 2001: n=9) locations on the Camp Dawson Collective Training Area in Preston County, West Virginia during 2000 and 2001

	Edge		Interior			
Species or index	$\bar{x}$	SE	$\bar{x}$	SE	$F_{1,26}$	P
CPUE						
Eastern red-backed salamanders (*Plethodon cinereus* Green)	0.86	0.42	0.88	0.40	0.50	0.487
Wood frogs (*Lithobates sylvaticus* LeConte)	0.25	0.07	0.53	0.11	9.49	0.005
Eastern American toads (*Anaxyrus americanus* Holbrook)	0.32	0.07	0.37	0.13	1.78	0.194
Red-spotted newts (eft) (*Notophthalmus v. viridescens* Rafinesque)	0.11	0.04	0.43	0.11	5.50	0.027
All species combined	2.10	0.55	2.73	0.53	1.57	0.222
Species richness/100 trapnights	0.53	0.10	0.49	0.06	0.40	0.532
Shannon diversity/100 trapnights	0.11	0.02	0.12	0.01	0.77	0.387

Table 4.—Average relative abundance in captures/100 trap nights (CPUE) of amphibian and reptilian species captured in pitfall traps in riparian (2000: n=6; 2001: n=10) and upland (2000: n=7; 2001: n=10) habitats on the Camp Dawson Collective Training Area in Preston County, West Virginia during 2000 and 2001

	Riparian		Upland			
Species	$\bar{x}$	SE		SE	$\chi^2_{1,26}$	P
Northern green frogs (*Lithobates clamitans melanota* Rafinesque)	0.15	0.06	0.09	0.06	1.32	0.250
Northern slimy salamanders (*Plethodon glutinosus* Green)	0.03	0.02	0.20	0.07	5.65	0.017
Allegheny Mountain dusky salamanders (*Desmognathus ochrophaeus* Cope 1859)	0.09	0.04	0.05	0.05	0.07	0.785
Northern red salamanders (*Pseudotriton r. ruber* Latreille)	0.00	0.00	0.09	0.06	NA	NA
Pickerel frogs (*Lithobates palustris* LeConte)	0.07	0.04	0.03	0.01	1.68	0.195
Four-toed salamanders (*Hemidactylium scutatum* Schlegel)	0.03	0.01	0.07	0.04	0.11	0.737
Eastern gartersnake (*Thamnophis s. sirtalis* Linnaeus)	0.02	0.01	0.03	0.02	<0.01	0.999

Table 5.—Average relative abundance in captures/100 trap nights (CPUE) of amphibian and reptilian species captured in pitfall traps in edge (2000: n=8; 2001: n=11) and interior (2000: n=5; 2001: n=9) locations on the Camp Dawson Collective Training Area in Preston County, West Virginia during 2000 and 2001

	Edge		Interior			
Species	$\bar{x}$	SE	$\bar{x}$	SE	$\chi^2_{1,26}$	*P*
Northern green frogs (*Lithobates clamitans melanota* Rafinesque)	0.13	0.06	0.11	0.08	0.80	0.371
Northern slimy salamanders (*Plethodon glutinosus* Green)	0.06	0.04	0.20	0.06	4.74	0.030
Allegheny Mountain dusky salamanders (*Desmognathus ochrophaeus Cope 1859*)	0.11	0.05	0.01	0.01	2.99	0.084
Northern red salamanders (*Pseudotriton r. ruber* Latreille)	0.06	0.06	0.03	0.01	NA	NA
Pickerel frogs (*Lithobates palustris* LeConte)	0.07	0.03	0.02	0.01	0.58	0.446
Four-toed salamander (*Hemidactylium scutatum* Schlegel)	0.03	0.01	0.07	0.05	0.10	0.746
Eastern gartersnake (*Thamnophis s. sirtalis* Linnaeus)	0.02	0.01	0.03	0.02	<0.01	0.999

Table 6.—Means and standard errors for habitat characteristics measured in two habitat and two treatment groups in which pitfall arrays were established on the Camp Dawson Collective Training Area in Preston County, West Virginia during 2000 and 2001

	Habitat				Treatment			
	Upland		Riparian		Edge		Interior	
Habitat characteristic	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Volume coarse woody debris (cm^3/m^2)	324.84	143.22	159.7	88.36	264.73	165.07	275.73	101.75
Rock volume (cm^3/m^2)	372.26	175.57	1,705.27	1,141.98	279.99	165.07	1,445.72	843.88
Canopy closure (percent)	61.36	7.17	76.12	8.1	48.26	7.43	87.4	6.38
Herbaceous ground cover (percent)	54.17	4.77	69.48	6.38	67.85	5.15	49.21	5.48
Basal area (m^2/ha)	13.99	2.11	14.54	2.41	8.78	1.84	20.5	2.26

Habitat Characteristics of Pitfall Arrays

Mean volume of coarse woody debris was similar between upland and riparian habitats ($F_{1,26}$ = 0.06, P = 0.813), as were mean canopy closure ($F_{1,26}$ = 1.67, P = 0.202), mean herbaceous ground cover ($F_{1,26}$ = 0.45, P = 0.504), and mean basal area (m^2/ha) ($F_{1,26}$ = 0.24, P = 0.628); however, mean rock volume was greater in riparian than upland habitats ($F_{1,26}$ = 7.01, P = 0.011) (Table 6). Mean volume of coarse woody debris ($F_{1,26}$ = 1.36, P = 0.248) and herbaceous ground cover ($F_{1,26}$ = 1.78, P = 0.188) were similar between edge and interior treatments; however, mean rock volume was greater in interior than edge treatments ($F_{1,26}$ = 5.86, P = 0.019), as were canopy closure ($F_{1,26}$ = 11.92, P = 0.001) and mean basal area ($F_{1,26}$ = 13.70, $P < 0.001$) (Table 6). There was no habitat-treatment interaction for coarse woody debris ($F_{1,26}$ = 1.61, P = 0.211), canopy closure ($F_{1,26}$ = 0.21, P = 0.649), herbaceous ground cover ($F_{1,26}$ = 0.44, P = 0.508), or basal area ($F_{1,26}$ = 0.02, P = 0.895). There was a habitat-treatment interaction for mean rock volume ($F_{1, 26}$ = 5.23, P = 0.026).

DISCUSSION

Edge and Interior

Abundance of wood frogs and of red-spotted newts were lower in edges than in interior locations within our study area. Wood frogs generally breed in vernal pools surrounded by mature forests and are susceptible to habitat fragmentation (Windmiller et al. 2008). They are most commonly found in moist, deciduous forests with well-developed leaf litter (Green and Pauley 1987). Although others have found that red-spotted newts were less closely associated with forested, interior sites than other salamander species (de Maynadier and Hunter 1998), we found that capture rates were higher at interior arrays. This difference is likely due to differences in habitat variables between the two studies. Our interior arrays had more rock volume, greater canopy closure, and more basal area compared to edges. An abundance of trees, which leads to high canopy cover, is important for forest-dwelling amphibians because it helps to maintain a deep litter layer and moist microclimate. Moreover, the presence of these variables appears to be more important than the absence of a coarse woody debris effect.

In our study, edge did not appear to influence red-backed salamanders, eastern American toads, northern green frogs (*Lithobates clamitans melanota* Latreille), Allegheny Mountain dusky salamanders (*Desmognathus ochrophaeus* Cope), pickerel frogs (*L. palustris* LeConte), four-toed salamanders

(*Hemidactylium scutatum* Schlegel), eastern gartersnakes (*Thamnophis s. sirtalis* Linnaeus), and overall species richness and diversity. Others have found that red-backed salamanders are most abundant in mature forests with deep soils, abundant litter, and scattered logs and rocks (Burger 1935, Green and Pauley 1987, Heatwole 1962). However, capture rates of red-backed salamanders and many other salamander species must be interpreted with caution because subsurface habitat use is so prevalent (Nagel 1977, Petranka 1998, Test and Heatwole 1962). Nonetheless, pitfalls are adept at capturing these underground-dwelling species as they emerge at night to forage. On our study area, the volume of coarse woody debris and herbaceous ground cover was similar between edge and interior locations, which likely contributed to the similar relative abundance estimates; similar volumes of coarse woody debris between sites appeared particularly important for red-backed salamanders.

Eastern American toads are generalist species found in various forested and open cover types (Green and Pauley 1987, Knutson et al. 1999). Therefore, it is not surprising that edge had little influence on the species. However, some have found that logging can affect American toad metamorphs, which may avoid open-canopy cover (deMaynadier and Hunter 1998, Rothermel and Semlitsch 2002). On our study area, canopy cover was 37 percent higher in interior areas (85 percent) compared to edges (48 percent), but most wetlands on the study area are located in edges. Thus, metamorphs dispersing from wetlands on Camp Dawson have to travel through open areas.

An area not classified as edge by our definition still may have undergone disturbance. Forested areas on the study site have been logged and some were even mined or farmed in the past, like much of the Central Appalachians; consequently, abundance has been reduced even in the interior areas (Perkins and Hunter 2006). Mining in particular has potentially disrupted dispersal corridors and movements among habitat patches and restoration of these areas should serve to reduce edge effects (Anderson et al. 2004). However, we believe our criterion of a 100-m distance from edge was sufficient because road effects on salamanders may extend only 35 m, according to research involving both gravel and paved roads (Semlitsch et al. 2007). Moreover, more-interior areas (60-80 m) may actually harbor fewer salamanders than the 35- to 60-m distances (Marsh and Beckman 2004, Semlitsch et al. 2007), indicating that some limited nearby disturbance may not be completely detrimental to woodland salamander populations.

Overall, edges had little influence on relative abundance of amphibians in our study area. We believe this finding is due to relatively low capture rates for most species and similar disturbance regimes throughout the interior and edges. In other areas, edges may have a more significant impact if disturbance regimes are more pronounced in edges compared to interior areas. Thus, we hypothesize that landscape-level disturbance regimes override localized edge effects for amphibians.

Riparian and Upland Habitats

Herpetofaunal community structure differed little between the upland and riparian areas. Slimy salamanders and eastern American toads were the only species we found to differ in abundance between upland and riparian areas; they were more abundant in uplands than riparian zones. Abundant cover objects and moist microclimates within deciduous forests are preferred areas for slimy salamanders (Grover 1998). Coarse woody debris, canopy closure, herbaceous ground cover, and basal area were similar in riparian and upland areas and only rock volume, which was five times greater in riparian than upland areas, differed. It is likely that microsite differences–rock volume, an unmeasured variable, or possibly the synergistic effect of multiple differences (albeit nonsignificant)–influenced relative abundance overall.

Eastern American toads, although dependent on wetlands for reproduction, are not dependent on streams and associated riparian areas for reproduction. Wetlands were primarily located in open areas adjacent to riparian sites, which were not sampled as part of this study. Some wetlands in upland areas adjacent to logging roads and other disturbed areas provided areas conducive to breeding and reproducing. Thus, the upland forested areas were likely closer to the best breeding areas, potentially explaining why uplands had more toads. All other species analyzed, including green frogs, Allegheny Mountain dusky salamanders, pickerel frogs, four-toed salamanders, eastern gartersnakes, red-backed salamanders, and red-spotted newts, were nonsignificant, although in several cases abundance was two to three times higher in one habitat or the other. Overall capture rates were relatively low for most of these species.

Although we captured some stream salamanders (e.g., Allegheny Mountain dusky salamanders), we did not capture many and thus did not analyze these species, which contributed to our finding of few overall differences. We would have expected more stream and streamside salamanders in riparian areas, but these species often do not leave headwater streambeds and thus were likely not picked up with our sampling regime.

CONCLUSIONS

Overall, all forested areas—riparian and upland, edge and interior—are crucial for maintaining the herpetofaunal community in the Central Appalachians. Even though we found few differences between edges and forested interior or between wooded riparian and upland areas, we do not suggest that these various areas are interchangeable. For example, upland habitat cannot replace destroyed riparian habitat, and riparian habitat cannot replace upland habitat (Osbourne et al. 2005). Thus, both still need to be maintained. Similar interpretations apply to edges and interiors. It is important for future studies to evaluate habitat use from a landscape perspective in addition to localized effects. Although we found some differences in relative abundance and habitat characteristics between upland and riparian areas and edge and interior locations, the results are not always intuitive. Interactions among habitat types such as forests and wetlands appear to be important sources of unmeasured variation in this study. Evaluating these synergies and interactions will strengthen future research efforts aimed at understanding herpetofaunal habitat use and edge effect in forested environments.

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