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STREAMSIDE SALAMANDERS IN VALLEY FILL AND REFERENCE STREAMS IN SOUTHERN WEST VIRGINIA[1]

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Abstract. We sampled stream salamanders in southern West Virginia during 2001 in streams below head-of-hollow valley fills and in reference streams to determine if there were differing trends in relative abundance between these treatments. Head-of-hollow valley fill construction can cover headwaters, first-order, second-order, and higher order reaches with excess spoil materials; valley fills in southern West Virginia are often hundreds of hectares in size. Total salamander captures were higher in 3 reference streams (RS; N=389) than in 4 valley fill streams (VFS; N=289) and mean abundance was significantly greater in reference streams. Number of salamanders captured was positively related to number of rocks in the stream substrate. We suggest that alterations in water chemistry, substrate composition (greater silt cover), and fewer rocks below valley fills all may have contributed to reduced salamander densities in VFS.

Additional Key Words: streamside salamanders, mountaintop removal mining, head-of-hollow valley fills, water chemistry

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Introduction

Mountain headwaters are home to many plethodontid salamander species in the eastern United States (Bishop, 1967). In headwaters, salamanders are often the dominant vertebrate predators in abundance or biomass (Burton and Likens, 1975; Hall et al., 1978; Murphy and Hall, 1981; Hairston, 1987). Stream plethodontids typically exhibit high densities and stable population sizes and age structures (Hairston, 1987; Burton and Likens, 1975; Welsh, Jr. and Ollivier, 1998; Jung et al., 2000, Rocco and Brooks, 2000).

Salamanders are ideal for use as bioindicators (Kucken et al., 1994; Welsh, Jr. and Ollivier, 1998) because they have porous skin that quickly reacts to changes in terrestrial and aquatic environmental quality (Jones, 1986; Blaustein and Wake, 1990), and they are philopatric (Welsh, Jr. and Lind, 1992). Salamanders are limited in mobility due to physiological constraints (e.g., require moisture) and anatomical characteristics (Green and Pauley, 1987) which makes them more desirable for use as bioindicators than animals that exhibit seasonal movements such as fish and invertebrates (Welsh, Jr. and Ollivier, 1998). All of these traits, coupled with the small home ranges of salamanders, suggest that local abundances of stream salamanders should reflect impacts of disturbance (Corn and Bury, 1989). Amphibian monitoring programs use stream salamanders as potential indicators of headwater stream quality (Ohio Environmental Protection Agency, 2002) and densities of stream amphibians in general have been used as indicators of ecosystem stress (Welsh, Jr. and Ollivier, 1998; Lowe and Bolger, 2002).

Mountaintop Removal Mining Process

Mountaintop removal is a large-scale surface mining technique (Barnhisel et al., 2000) used in West Virginia, Virginia, Tennessee, Kentucky, and Pennsylvania (United States Environmental Protection Agency, 2000). The unconsolidated geological material resulting from overburden removal constitutes a much greater volume than the once-consolidated material (United States Environmental Protection Agency, 2000). Not all overburden can be returned to the mountaintop because steep slopes can result in long-term stability problems (Sciulli et al., 1986; Bell et al., 1989; United States Environmental Protection Agency, 2000). Therefore, excess spoil is deposited into valleys near the active mine site, creating a valley fill (United States Environmental Protection Agency, 2000) at the headwaters of watersheds (Daniels and

Stewart, 2000). Because mountaintop-mining disturbance encompasses a large area, reconstruction of landforms for complex head-of-the-hollow valley fills may require reclamation of first-, second-, third-, and higher-order drainage basins (Toy and Black, 2000). It is common for valley fills in southern West Virginia to be hundreds of hectares in size (Daniels and Stewart, 2000) and to contain thousands of cubic meters of fill material (Plass, 2000).

Water Quality

Two studies on water quality of streams impacted by mountaintop removal mining found elevated levels of specific conductance in valley fill streams (Bryant et al., 2002; Hartman et al., unpubl. data) and one discovered high levels of sulfate, hardness, and total dissolved solids in fill streams (Bryant et al., 2002). Additionally, both Hartman et al. (unpubl. data) and Bryant et al. (2002) reported high concentrations of calcium, magnesium, manganese, and potassium. Levels of sodium, copper, nickel, and iron (Hartman et al., unpubl. data), as well as selenium and nitrate / nitrite concentrations and acidity (Bryant et al., 2002) also were high in valley fill streams. Hartman et al. (unpubl. data) sampled storm water for their water chemistry analyses.

Many studies on the relation of water chemistry to amphibian diversity and abundance documented negative impacts of low pH on herpetofauna, such as direct mortality of embryos and larvae (see reviews by Freda, 1986 and Pierce, 1993). Low pH and acid mine drainage (AMD) are conditions not usually found in streams affected by mountaintop removal mining (J. Skousen, person. commun., Extension Specialist on Land Reclamation and Professor of Soil Science at West Virginia University) because the coalfields of southern West Virginia have $\leq$1% sulphur content (Gerena, 2001). In the southern coalfields, pyrite exists in small, isolated pockets; thus, with proper overburden handling and placement, pyrite can be isolated and kept from water and air so that it does not become oxidized and produce acidic soil and water conditions (J. Skousen, person. communiction, Extension Specialist on Land Reclamation and Professor of Soil Science at West Virginia University).

Disruption of aquatic habitats by mountaintop removal mining may affect entire watersheds (Starnes and Gasper, 1995), especially those with large or complex head-of-hollow valley fills. Aquatic impacts include direct loss or fragmentation of habitat, as well as alterations in habitat structure and water chemistry. The southern Appalachians exhibit extremely high diversity of salamander populations (Petranka, 1998); therefore, any impacts sustained by stream salamander populations from mountaintop mining may be of regional significance. For these reasons, the watersheds below valley fills and any impacts sustained by them and their biotic components deserve considerable attention.

Few studies have sampled stream salamanders in streams below valley fills. We initiated an exploratory study in 2001 to characterize relative abundance of stream salamanders in streams below valley fills compared to reference streams not impacted by mining activities. Due to the sensitivity of stream salamanders to disturbances in the environment, we predicted that relative abundance would be higher in reference streams.

Materials and Methods

Study Sites

Study areas were located on and near 3 mountaintop mines in southwestern West Virginia: Hobet 21, Cannelton, and Dal-Tex. These mines were located in Boone, Kanawha and Fayette, and Logan counties, and in Mud River and Little Coal River, Twentymile Creek, and Spruce Fork watersheds, respectively. The 3 mines were spatially separated by considerable distance (e.g. over 160 km between Dal-Tex and Cannelton Mines) to provide inference to a larger geographic area (Hall et al., 1978). Study sites were located within the Allegheny Plateau physiographic province, which is characterized by moderate to strong relief and contains central hardwood forests (Strausbaugh and Core, 1977). Habitat types on the mines included reclaimed shrub-pole habitats, reclaimed grasslands, and forest fragments. The 2 reclaimed habitats covered approximately 2431, 2180, and 1819 ha (Balcerzak and Wood, 2003), while fragmented forest covered 339, 214, and 155 ha on each of the 3 mines. General substrate characteristics of streams in the region include narrow headwaters dominated by boulders while further downstream, substrate becomes smaller.

We sampled in 2 treatments: valley fill streams (VFS) and reference streams (RS). Both treatments were contained within mixed mesophytic forests with 60-80 year-old, second-growth, mature hardwoods. Overstory species included tuliptree (*Liriodendron tulipifera*), red and sugar maples (*Acer rubrum* and *A. saccharum*), American sycamore (*Plantanus occidentalis*), northern red, white, and black oaks (*Quercus rubra*, *Q. alba*, and *Q. velutina*); pignut, bitternut, and shagbark hickories (*Carya glabra*, *C. cordiformis*, and *C. ovata*); American beech (*Fagus* *grandifolia*), white ash (*Fraxinus americana*), and black birch (*Betula lenta*). Understory species (seedlings, saplings, poles) included black gum (*Nyssa sylvatica*), flowering dogwood (*Cornus florida*), ironwood (*Carpinus caroliniana*), spicebush (*Lindera benzoin*), and other common hardwood species, including the above-mentioned overstory species.

Valley fill streams were located below head-of-hollow valley fills in forested valleys that were bordered on 3 sides by reclaimed mine habitat (i.e., fragmented forest). They included Big Horse Creek, Lavender Fork (both on Hobet 21 Mine), Rockhouse Creek (on Dal-Tex Mine), and Hughe's Fork (on Cannelton Mine). Reference streams were in large tracts of intact forest and were not directly impacted by mountaintop removal mining. We selected reference streams within close proximity to valley-fill streams so that spatial separation would not be a confounding factor in our study (Hall et al., 1978). The reference streams were Spring Branch (near Hobet 21 Mine), Pigeonroost Branch (close to Dal-Tex Mine), and Ash Fork (near Cannelton Mine).

Study Design

We quantified herpetofaunal diversity and abundance by sampling each of 3 VFS and 3 RS once per month in May, June, and August-October 2001. We added a fourth VFS (Rockhouse Creek) and sampled it in September and October. We sampled different 35-m segments in each stream each month. By moving down and sampling new, adjacent stream segments, the intention was to sample as much of the entire length of each stream as possible. We conducted stream surveys in the first-order reaches of 2 RS (5 35-m stream segments sampled in each stream) and in both intermittent reaches (3 35-m segments) and second-order reaches (2 35-m segments) of a third RS. Stream surveys in VFS included second-order reaches of 3 streams (5 35-m segments in 2 of the streams and 2 35-m segments in the third stream). In the fourth VFS, we surveyed third-order reaches (5 35-m segments) (Table 1).

We classified each segment sampled by stream order (intermittent, first-order, second-order, or third-order) and by predominant substrate (e.g., cobble; Table 1). Stream order was determined from the Federal Interagency Stream Restoration Working Group (1998; pages 16, 25-26). Intermittent streams have seasonal flow that lasts longer than 30 days per year. First-order streams are the uppermost channels in a drainage network down to their first confluence.

Second-order streams are formed below the confluence of 2 first-order channels. Third-order streams begin below the junction of 2 second-order channels.

Because creation of valley fills involves the burial of streambeds with large boulders, it is impossible to survey the first- and second-order stream sections that existed prior to mining. For example, coal removal and its associated filling, construction, and drainage installation affected over 30 km (~20 km of first order and ~10 km of second order) of Big Horse Creek, while in Rockhouse Creek, ~4 km of first-order and ~1.5 km of second-order streams were similarly impacted (J. McDaniel, Arch Coal, pers. comm.). Therefore, for VFS, we considered first-order stream sections to be the furthest upstream portion of the valley fills from which water was free flowing and not overlain with riprap.

We used sampling methods similar to those of Crump and Scott, Jr. (1994). We turned over all cobble-sized rocks (65-256 mm; Jung, 2002) and coarse woody debris (CWD) in the stream channel and up to 1-m from the edge of the stream and checked under them for herpetofauna. We toe- clipped individuals to identify recaptures. We did not identify G. porphyriticus to subspecies level (*G. p. porphyriticus*, Northern Spring Salamander vs. *G. p. duryi*, Kentucky Spring Salamander). We kept a count of all rocks and CWD inspected during the sample, with the exception of cover objects that clouded the water with bottom substrate upon lifting (Table 1).

In addition to stream searching, we placed 3 leaf litter bags in each stream and checked them monthly (June to October 2001) to target capture of larval and juvenile salamanders. Methods generally followed those of Pauley and Little (1998). We cut plastic netting with 3-4 cm mesh size into 45-50 cm x 30 cm sections and stacked leaf litter, moss, and small CWD onto it. We then folded over the netting, creating a bag-like compartment, and cinched off the ends using cable ties and the tops using binder clips. We positioned bags in pools within the stream and anchored them down using rocks. Once each month, we emptied contents of leaf litter bags into a basin and searched through them for salamanders.

Table 1. Habitat characteristics and number of stream salamanders captured at reference streams (N = 3) and valley fill streams (N = 4) by stream order in a reclaimed mountaintop removal mine landscape in southern West Virginia, 2001. Habitat characteristics based on Amphibian Monitoring Program protocol (Jung et al. 1999): BA = bank (river edge, soil, lacks rocks); RU = run (smooth current); BL = boulder (> 1.5 m in diameter); RA = rapid (fast current broken by obstructions); LR = large rocks (0.5-1.5 m in diameter); PO = pool (standing water); SR = small rocks (0.1- 0.5 m in diameter); CA = cascade (water flowing over slanting rocks); RG = rubble / gravel (< 0.1 m in diameter); RI = riffle (ripples and waves); WD = woody debris; DR = dry (no visible moisture or water).

Stream	**Segment**	**Substrate Type**	**Channel Type**	**No. of Coarse Woody Debris Sampled**	**No. of Rocks Sampled**	**No. of Salamanders Captured**
Valley Fill Streams – Second Order						
Big Horse	1	SR, RG	RI	21	689	5
	2	SR, RG	RI	7	480	3
	3	SR, RG	RI	12	137	7
	4	SR, RG, BA	RI	6	1554	7
	5	SR, RG, BA	RI	19	821	2
Lavender Fork	1	SR, RG, WD	PO, RU	24	67	4
	2	SR, RG, WD	RU	74	71	0
	3	SR, RG, WD	RU	39	98	1
	4	SR, RG, BA, WD	RI, PO, RU	95	75	3
	5	SR, RG, BA, WD	RI, PO, RU	104	127	0
Rockhouse Creek	1	SR, RG, BA, WD	RI, PO	19	3012	59
	2	SR, RG, BA	RI	0	1495	76
Valley Fill Streams – Third Order						
Hughe's Fork	1	SR, RG, LR	RA	5	758	10
	2	SR, RG, LR	RA	5	457	15
	3	SR, RG, LR, BL	RA, PO	0	343	5
	4	SR, RG, BA, LR	RI	6	1266	17
	5	SR, RG, BA	RI, PO	25	1935	48
Reference Streams - Intermittent						
Pigeonroost Branch	1	SR, LR	RI, PO, CA	25	638	33
	2	SR, LR	DR	37	527	13
	3	SR, LR, BA	DR	28	1144	8
Reference Streams – First Order						
Spring Branch	1	SR	RI	67	392	20
	2	SR	RI	38	579	19
	3	SR, RG, WD	RI	18	345	11
	4	SR, WD	RI, PO	61	1473	22
	5	SR, WD	RI, PO	3	1219	8
Ash Fork	1	SR, LR	RI, PO	13	157	11
	2	SR, WD	PO	46	140	45
	3	SR, WD	DR	70	34	14
	4	SR, BA, WD	DR, PO	16	223	24
	5	SR, BA, WD, LR	DR, PO	111	698	58
Reference Streams – Second Order						
Pigeonroost Branch	1	SR, R/G	RI, PO	9	342	20
	2	SR, R/G, BA	RI, PO	3	2928	66

Data Analysis

We present captures for each species and overall mean relative abundance. We compared salamander abundance between VFS and RS with analysis of variance. Mean salamander abundance per segment was the dependent variable, while independent variables were treatment (VFS vs. RS) and stream order. We also related salamander abundance in each segment to number of rocks and coarse woody debris objects with Pearson product-moment correlation. We used a conservative alpha level of 0.10 to determine when differences were significant.

Results

We captured 678 individual herpetofauna of 15 species, 13 species in VFS and 10 in RS (Table 2). Total number of individuals captured was higher in RS (n = 389) than in VFS (n = 289) even though we sampled 2 extra stream segments in VFS (Table 3).

Salamanders comprised 97% of total captures and were the only species captured that require flowing streams as habitat. We captured 270 individuals of 7 species in VFS and 386 individuals of 8 species in RS (Table 2).

Obligate stream salamanders were the only species included in abundance calculations per stream segment; we excluded 13 Red Efts (*Notophthalmus v. viridescens*), 8 Eastern Red-backed Salamanders (*Plethodon cinereus*), and 1 Cumberland Plateau Salamander (*Plethodon kentucki*) from these analyses because these species are not entirely dependent on stream habitat. Overall mean relative abundance of salamanders per 35-m stream segment was 15.9 ± 9.5 in VFS and 25.7 ± 14.4 in RS (Table 3). Second-order VFS had the highest (68.5 ± 7.5) and lowest (1.8 ± 0.97) means of salamanders per stream segment (Table 3). Salamander abundance was significantly greater in RS than in VFS (F=3.27, *P*=0.081). Salamander abundance was positively and strongly related to number of rocks (r=0.63, *P*=0.0001) but not to number of CWD (r=-0.06, *P*=0.76).

Using leaf litter bags, we captured 20 salamander larvae in RS and 3 in VFS. Of those captured in RS, 9 were Northern Dusky Salamanders (*Desmognathus fuscus*), 1 was a Southern Two-lined Salamander (*Eurycea cirrigera*), and the remaining 10 could not be identified to species. In the VFS, 1 larvae was a Southern Two-lined Salamander and the other 2 were unidentifiable.

Table 2. Number of individuals and species of herpetofaunal groups captured in stream surveys in 1 intermittent reference stream (3 35-m stream segments sampled), 2 first-order reference streams (10 35-m stream segments sampled), 1 second-order reference stream (2 35-m stream segments sampled), 3 second-order valley fill streams (12 35-m stream segments sampled) and 1 third-order VFS (5 35-m stream segments sampled), on and near reclaimed mountaintop removal mines in southern West Virginia, May-October, 2001.

	Valley Fill Streams		**Reference Streams**		
Species	**Second Order**	**Third Order**	**Intermittent**	**First Order**	**Second Order**
Salamanders					
Cumberland Plateau Salamander			1		
Plethodon kentucki					
Eastern Red-backed Salamander			8		
Plethodon cinererus					
Seal Salamander	7	8	34	57	17
Desmognathus monticola					
Northern Dusky Salamander	76	42		102	47
D. fuscus					
Desmognathus spp. (Seal or N. Dusky)	7	8	8	22	8
Southern Two-lined Salamander	57	15	8	21	7
Eurycea cirrigera					
Long-tailed Salamander	1	1			
E. longicauda					
Spring Salamander	2		1	2	1
Gyrinophilus porphyriticus					
Red Eft	6	2		1	4
Notophthalmus v. viridescens					
Northern Red Salamander		1	1		
Pseudotriton r. ruber					
Unidentified Salamander	17	20	2	28	6
Total	173	97	63	233	90
Toads and Frogs					
Fowler's Toad	1				
Bufo fowleri					
American Bullfrog	1			1	
Rana catesbeiana					
Northern Green Frog	5				
R. clamitans melanota					
Pickerel Frog	3			1	
R. palustris					
Rana spp.	3				
Unidentified Frog				1	
Total	13	0	0	3	0
Snakes					
Northern Ring-necked Snake	1				
Diadophis punctatus edwardsii					
Common Watersnake	1	1			
Nerodia s. sipedon					
Total	2	1	0	0	0
Grand Total	191	98	63	236	90

Table 3. Mean and standard error (SE) of coarse woody debris, rocks, and obligate stream salamanders per 35-m segment of valley fill and reference streams on and near reclaimed mountaintop removal mines in southwestern West Virginia, May–October 2001.

Treatment	Stream Name	No. Segments Sampled	Stream Classification	Coarse Woody Debris		Rocks		Salamanders	
				Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**
Reference	Pigeonroost Branch	3	Intermittent	30.00	3.61	769.67	189.89	18.00	7.64
	Spring Branch	5	First Order	37.40	12.23	801.60	229.22	16.00	2.74
	Ash Fork	5	First Order	51.20	18.24	250.40	115.94	30.40	9.11
	Pigeonroost Branch	2	Second Order	6.00	3.00	1635.00	1293.00	43.00	23.00
	Overall	15		36.33	20.83	722.60	441.45	24.80	13.78
Valley Fill	Big Horse Creek	5	Second Order	13.00	3.05	736.20	234.83	4.80	1.02
	Lavender Fork	5	Second Order	67.20	15.55	87.60	11.22	1.60	0.81
	Rockhouse Creek	2	Second Order	9.50	9.50	2253.50	758.50	67.50	8.50
	Hughe's Fork	5	Third Order	8.20	4.33	951.80	293.12	19.00	7.54
	Overall	17		27.12	19.80	787.35	411.97	15.41	9.36

Discussion

Greater numbers of salamanders were captured in RS using both sampling methods, suggesting that RS support higher levels of stream salamanders than VFS. Similarly, Hamilton (2002) found a lower relative abundance of salamanders in 2 of 3 VFS compared to RS and Williams (2003) reported significantly fewer total salamanders (adults and larvae combined) and larval salamanders in VFS overall (first- and second-order reaches combined) and in second-order reaches of VFS when compared to RS. Additionally, a lower relative abundance of adult salamanders and adult *Desmognathus* salamander spp. in first-order VFS than in first-order RS was observed by Williams (2003). While density is not always a reliable indicator of habitat quality for other taxa (e.g. birds; Van Horne, 1983), Krzysik (1979) defined an optimal locality for a streambank salamander to be one that supports the highest densities of a given species. Furthermore, Corn and Bury (1989) stated that density of stream amphibians is likely to be a good indicator of habitat quality. Therefore, our results suggest that RS generally provide more suitable habitats for stream salamanders than VFS.

Although salamander density in VFS generally was low (Table 3), one of the second-order VFS Rockhouse Creek supported the highest salamander density in our study. The 2 segments sampled in this stream had high abundance of rocks (Table 1). We found a positive, significant relationship between number of rocks and number of salamanders captured. Similarly, Davic and Orr (1987) observed a positive relationship between rock density and larval, juvenile, and adult salamander population densities in a mountain stream in North Carolina. Further, Hartman et al. (unpubl. data) sampled habitat in Rockhouse Creek and found that its Rapid Bioassessment Protocol (RBP) scores (USEPA 1989) based on 11 habitat components were much higher than 3 other VFS and 3 other RS sampled in their study. They determined Rockhouse Creek to be of intermediate stream quality and that it scored similar to a RS with which it was paired. Hartman et al. (unpubl. data) also suspected that reclamation procedures used at Rockhouse Creek may have been superior to those used at other VFS. It should be noted that Rockhouse Creek was the only creek sampled by Hartman et al. (unpubl. data) that we also sampled in our study. Therefore, one should not assume that the other VFS and RS in our study are low in quality like those in the Hartman et al. (unpubl. data) study.

Many studies have examined the effects of low pH and acidic conditions on amphibians (see reviews by Freda, 1986 and Pierce, 1993), but more work on impacts of alkaline mine drainage on stream salamanders is greatly needed. While valley fill streams can have high metal and cation concentrations, they often contain high pH and high alkalinity. Mean pH levels reported by Hartman et al. (unpubl. data) for valley fill streams (7.2) and reference streams (7.7) are not within the range found harmful to amphibians (see reviews by Freda, 1986 and Pierce, 1993).

Water quality has significant effects on amphibians (see reviews by Freda, 1986 and Pierce, 1993), although effects vary among and within species and in relation to the combination and concentration of chemical components, among other factors. Substrate cover also can influence site occupancy by salamanders. Fine sediment such as silt and sand can fill interstitial spaces between rocks, which reduces available habitat for salamanders and their invertebrate prey (Hall et al., 1978; Murphy and Hall, 1981; Hawkins et al., 1983; Corn and Bury, 1989; Lowe and Bolger, 2002) and may subsequently increase their exposure to predators (Lowe and Bolger, 2002). Williams (2003) found that percent cover of silt was greater in VFS than in RS both overall and in first-order reaches and that fine sediment cover was greater in first-order VFS when compared to first-order RS. Conversely, Hartman et al. (unpubl. data) found no difference in fine sediment levels in first-order headwaters between streams located below valley fills and reference streams and suspected that there was an initial spike in sediment during and immediately following valley fill construction from placement of overburden into streams, but that over time, the sediment dissipated. High levels of conductivity found in valley fill streams (Bryant et al., 2002; Hartman et al., unpubl. data) also may have contributed to lower salamander densities in VFS. High conductivity was one factor that limited distribution of Desmognathine larvae in a study conducted by Gore (1983). Thus, the combined alterations in water chemistry, substrate composition (greater silt cover), and fewer rocks below valley fills may have contributed to reduced salamander densities in VFS.

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Literature Cited

Balcerzak, M. J. and P. B. Wood. 2003. Red-shouldered hawk (*Buteo lineatus*) abundance and habitat in a reclaimed mine landscape. Journal of Raptor Research 37:188-197.

Barnhisel, R. I., R. G. Darmody and W. L. Daniels, Eds.. 2000. Reclamation of Drastically Disturbed Lands. American Society of Agronomy, Inc., Madison.

Bell, J. C., W. L. Daniels and C. E. Zipper. 1989. The practice of "approximate original contour" in the Central Appalachians. I. Slope stability and erosion potential. Landscape and Urban Planning 18:127-128. http://dx.doi.org/10.1016/0169-2046(89)90004-2.

Bishop, S. C. 1967. Handbook of Salamanders. Comstock Publishing, Ithaca.

Blaustein, A.R. and D.B. Wake. 1990. Declining amphibian populations: a global phenomenon? Trends in Ecology and Evolution 5:203-204. http://dx.doi.org/10.1016/0169-5347(90)90129-2.

Bryant, G., S. McPhilliamy and H. Childers. 2002. A survey of the water quality of streams in the primary region of mountaintop / valley fill coal mining: October 1999 to January 2001. United States Environmental Protection Agency, Region III and Signal Corporation, Wheeling.

Burton, T. M. and G. E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. Copeia 541-546. http://dx.doi.org/10.2307/1443655.

Corn, P. S. and R. B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. Forest Ecology and Management 29:39-57. http://dx.doi.org/10.1016/0378-1127(89)90055-8.

Crump, M. L. and N. J. Scott, Jr. 1994. Visual encounter surveys. p. 84-92. *In* W. K. Heyer, M. A. Donnelly, R. W. McDarmid, L. C. Hayek and M. S. Foster (eds.). Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institute Press, Washington D. C.

Daniels, W. L. and B. R. Stewart. 2000. Reclamation of Appalachian coal refuse disposal areas. p. 433-459. *In* R. I. Barnhisel, R. G. Darmody and W. L. Daniels (eds.), Reclamation of Drastically Disturbed Lands. American Society of Agronomy, Inc., Madison.

Davic, R. D. and L. P. Orr. 1987. The relationship between rock density and salamander density in a mountain stream. Herpetologica 43:357-361.

Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration: Principles, Processes, and Practices. GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653.

Freda, J. 1986. The influence of acidic pond water on amphibians: a review. Water, Air, and Soil Pollution 30:439-450. http://dx.doi.org/10.1007/BF00305213

Gerena, C. 2001. Smarter but smaller: competition and regulatory uncertainty pose challenges for West Virginia’s coal producers. Region Focus Winter:13-21.

Green, N. B. and T. K. Pauley. 1987. Amphibians and Reptiles in West Virginia. University of Pittsburgh Press, Pittsburgh.

Hairston, Sr. N. G. 1987. Community Ecology and Salamander Guilds. Cambridge University Press, New York.

Hall, J.D., M.L. Murphy and R.S. Aho. 1978. An improved design for assessing impacts of watershed practices on small streams. Verhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie 20:1359-1365.

Hamilton, M. S. 2002. Effects of developmental activities on streamside salamander communities in Boone County, West Virginia. M. S. Thesis, Marshall University, Huntington, West Virginia.

Hawkins, C. P., M. L. Murphy, N. H. Anderson and M. A. Wilzbach. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States. Canadian Journal of Fisheries and Aquatic Sciences 40:1173-1185. http://dx.doi.org/10.1139/f83-134.

Jones, K. B. 1986. Amphibians and reptiles. p. 267-290. *In* A. Y., Cooperrider, J. B. Raymond and H. R. Stardt (eds.), Inventory and Monitoring of Wildlife Habitat. U. S. Department of the Interior, Bureau of Land Management Service Center, Denver.

Jung, R. E. 2002. Streamside salamander inventorying and monitoring: Northeast refuges and parks – Summer 2002. United States Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland.

Jung, R. E., S. Droege, J. R. Sauer and R. B. Landy. 2000. Evaluation of terrestrial and streamside salamander monitoring techniques at Shenandoah National Park. Environmental Monitoring and Assessment 63:65-79. http://dx.doi.org/10.1023/A:1006413603057.

Krysik, A. J. 1979. Resource allocation, coexistence, and the niche structure of a streambank salamander community. Ecological Monographs 1979:173-194. http://dx.doi.org/10.2307/1942512.

Kucken, D. J., J. S. Davis, J. W. Petranka and C. K. Smith. 1994. Anakeesta stream acidification and metal contamination: effects on a salamander community. Journal of Environmental Quality 23:1311-1317. http://dx.doi.org/10.2134/jeq1994.2361311x.

Lowe, W. H. and D. T. Bolger. 2002. Local and landscape-scale predictors of salamander abundance in New Hampshire headwater streams. Conservation Biology 16:183-193. http://dx.doi.org/10.1046/j.1523-1739.2002.00360.x.

Murphy, M. L. and J. D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 38:137-145. http://dx.doi.org/10.1139/f81-018

Ohio Environmental Protection Agency. 2002. Ohio's primary headwater streams: fish and amphibian assemblages. Technical report, Division of Surface Water, Columbus.

Pauley, T. K. and M. Little. 1998. A new technique to monitor larval and juvenile salamanders in stream habitats. Banisteria 12:32-36.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institute Press, Washington.

Pierce, B. A. 1993. The effects of acid precipitation on amphibians. Ecotoxicology 2:65-77. http://dx.doi.org/10.1007/BF00058215 PMid:24203120.

Plass, W. T. 2000. History of surface mining reclamation and associated legislation. p. 433-459. *In* R. I. Barnhisel, R. G. Darmody, and W. L. Daniels (eds.). Reclamation of Drastically Disturbed Lands. American Society of Agronomy, Inc., Madison.

Rocco, G. L. and R. P. Brooks. 2000. Abundance and distribution of a stream plethodontid salamander assemblage in 14 ecologically dissimilar watersheds in the Pennsylvania Central Appalachians. Final Report No. 2000-4, prepared for U.S. Environmental Protection Agency Region III by Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State Univ., State College.

Sciulli, A. G., G. P. Ballock and K. K. Wu. 1986. Environmental approach to coal refuse disposal. Mining Engineering 38:181-186.

Starnes, L. and D. C. Gasper. 1995. Effects of surface mining on aquatic resources in North America. Fisheries 20:20-26.

Strausbaugh, P. D. and E. L., Core. 1977. Flora of West Virginia. 2nd ed. Seneca Books, Inc., Morgantown.

Toy, T. J. and J. P. Black. 2000. Topographic reconstruction: The theory and practice. p. 41-75. *In* R. I. Barnhisel, R. G. Darmody, and W. L. Daniels (eds.). Reclamation of Drastically Disturbed Lands American Society of Agronomy, Inc., Madison.

United States Environmental Protection Agency. 2000. Mountaintop mining / valley fill environmental impact statement. Preliminary draft January 2001, EPA/903/R-00/013, Environmental Protection Agency Region 3, Philadelphia, Pennsylvania.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901. http://dx.doi.org/10.2307/3808148.

Welsh, Jr. H.H. and A.J. Lind. 1992. Populations ecology of two relictual salamanders from the Klamath Mountains of Northwestern California. p. 419-437. *In* D. R. McCullough and R. H. Barrett (eds.). Wildlife 2001: Populations. Elsevier Applied Science, London.

Welsh, Jr. H. H. and L. M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's Redwoods. Ecological Applications 8:1118-1132. http://dx.doi.org/10.1890/1051-0761(1998)008[1118:SAAIOE]2.0.CO;2 http://dx.doi.org/10.2307/2640966.

Williams, J. M. 2003. Impacts on terrestrial and streamside herpetofauna by mountaintop removal mining in southern West Virginia. Ph. D. Dissertation, West Virginia University, Morgantown, West Virginia.