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Streamside Salamanders in an Acidic Blue Ridge Mountain Stream: Historical Comparisons and Relative Abundance

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INTRODUCTION

Headwater streams in the mountainous region of western Virginia have a high potential for acidification as a result of anthropogenically-generated acidic deposition (Cosby et al., 1991). The primary source in the Shenandoah Valley of Virginia is rain that is about ten times higher in acid concentration than unpolluted rainfall (Webb et al., 1989a). Acidification of surface waters is a problem where sulfate adsorption capacities of catchment soils are exhausted by continued acid deposition and when soils and underlying bedrock provide little buffering capacity to neutralize the acidity (Galloway et al., 1983; Webb et al., 1989b). St. Marys River in Augusta County, Virginia, lies within the region of acidic deposition in the Appalachians and is underlain by bedrock of the Antietam Formation, a low solubility quartzite, with minimal buffering capacity. Water quality analyses in St. Marys watershed have demonstrated reductions in acid neutralizing capacity (ANC) and consequent increases in acidity (Webb et al., 1994, 1999).

Water chemistry and changes in the fauna of St. Marys River have been the subjects of a number of scientific investigations (e.g., Surber, 1951; Webb et al., 1989b; Kaufmann et al., 1993, 1999; Mohn et al., 1993; Bugas et al., 1999). During 1935-1937, E.W. Surber conducted studies on aquatic insects in this system (Surber, 1951). These data provide the baseline for continued investigations on benthic macroinvertebrates and the benchmark against which declines in species richness and abundance have been measured (Kauffman et al., 1999). Likewise, the fish fauna has been the subject of investigations for over 20 years, and similar declines in richness and abundance have been documented (Mohn et al., 1993; Bugas, 1999). Declines in invertebrates and fish are reportedly the result of increasing anthropogenic acidification (Camuto, 1991; Feldman & Conner, 1992).

In contrast to fish and invertebrates, the amphibian fauna has received little study. It is unknown whether these animals have responded in similar ways as the fish and invertebrates. The only historical information available is Surber's density estimates from the total number of unidentified salamanders captured in his standardized samples. To obtain insights into the streamside salamander fauna, we conducted inventory and monitoring surveys in St. Marys River mainstem and two tributaries in 1997 and 1998. These data serve as an initial baseline for relative abundance and densities of salamanders.

MATERIALS AND METHODS

We monitored streamside salamander assemblages with two methods: (1) quantitative substrate samples to obtain density estimates to compare with Surber's data and (2) time-constrained visual encounter surveys (Heyer et al., 1994) to obtain relative abundance data. We obtained three quantitative substrate samples using a

Carle® sampler at each of six sites along the St. Marys River on 24-25 June 1998 (Fig. 1). Each sample was collected in a riffle area. The substrate was agitated for several minutes to obtain salamanders from the substrate matrix. Carle® samplers are similar to Surber® samplers, except the sampling area is larger and salamanders cannot wash out around the net, thus increasing capture success. Surber's original data were presented as organisms/ft^2 but we transformed them into salamanders/m^2 for comparison to our data.

We conducted time-constrained visual encounter surveys during 1997 and 1998. These were performed at three sites along the St. Marys River mainstem (Lower, Middle, and Upper) and at two tributaries (Sugartree Branch and Bear Branch) (Fig. 1). Two to three sample plots were searched at each site and each plot was at least 10 m long and 100 m from other plots. During sampling, we turned over all surface objects and searched all microhabitats that might harbor amphibians. Sample time per plot was 0.5 h. We identified and captured where possible all individuals encountered, recording snout-vent length (SVL) and tail length to the nearest mm with a plastic ruler for each animal. Location and dates on which visual encounter surveys were conducted included: Lower St. Marys - 9 September 1997, 13 August 1998; Middle St. Mary's - 17 October 1997, 12 August 1998; Upper St. Mary's - 9 October 1997, 11 August 1998; Sugartree Branch - 15 October 1997, 13 August 1998; Bear Branch - 14 October 1997, 11 & 12 August 1998.

We did not collect quantitative habitat measurements at each visual encounter survey site but we did record qualitative site descriptions. One third of all sites had a canopy closure of >50%. Substrate type was dominated by cobbles and boulder (42% of all sites), with cobble and bedrock (33%) and cobble and gravel (25%) occurring in fewer sites. No one stream section was dominated by a single substrate type.

RESULTS

Comparison to Historical Data

Surber (1951) collected 19 benthic samples (20 replicates each) monthly between August 1935 and August 1937. Total benthic salamander density within that time frame averaged 2.8±1.5 salamanders/m^2 and varied by month and season (Fig. 2). Winter (November-January) salamander densities averaged 4.5 salamanders/m^2 (4.0 to 5.8) and summer (June-August) densities averaged 2.0 salamanders/m^2 (0.6 to 4.8). The difference between seasons is significant (t-test, $t = -3.22$, $P = 0.011$). Average salamander density in June 1936 was

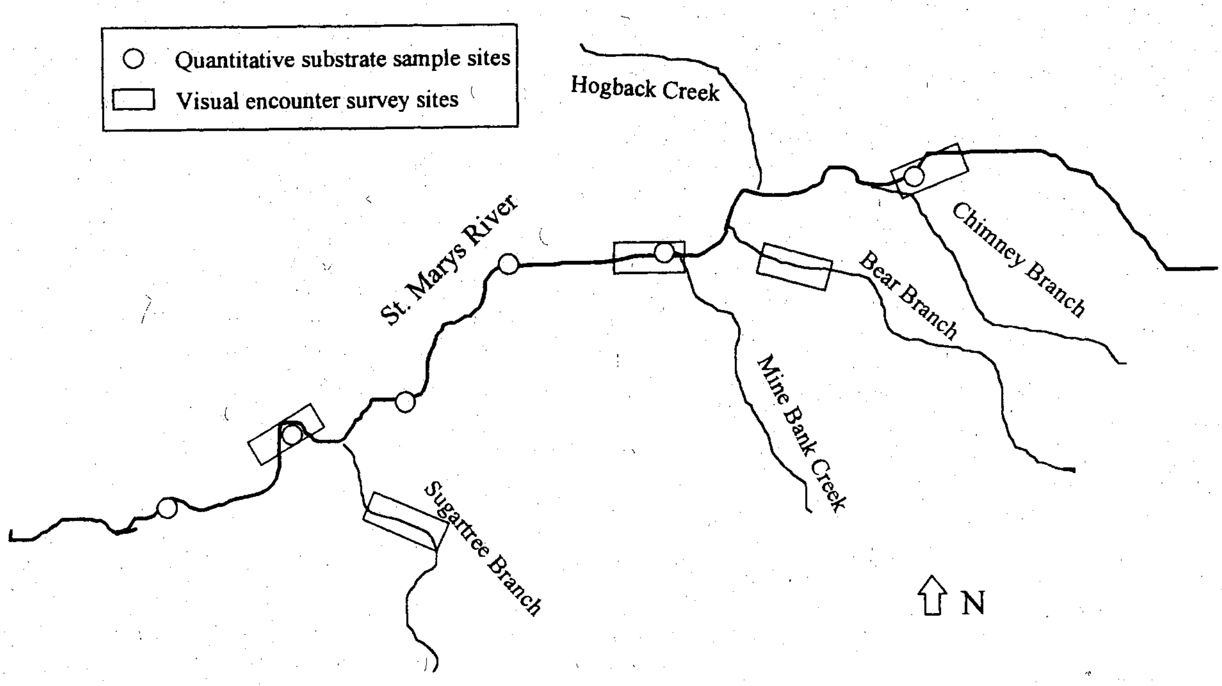

Fig. 1. Quantitative substrate sample sites and visual encounter survey sites along the St. Marys River and two tributaries, Augusta, County, Virginia.

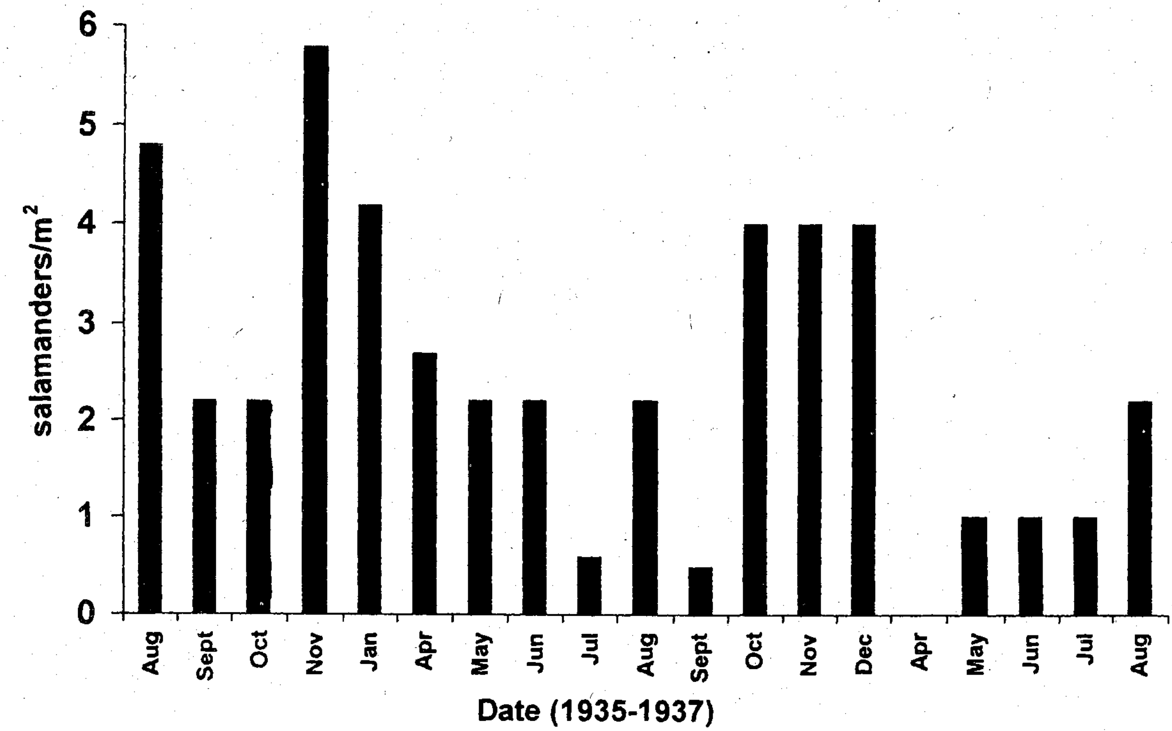

Fig. 2. Benthic salamander density in the St. Marys River, 1935-1937, based on data in Surber (1951). No data were provided for missing months.

$2.2/m^2$, whereas in June 1937 it was $1.0/m^2$. Our sample in June 1998 (mean = 0.6 salamanders/m^2) was not significantly different from either of the earlier June samples ($P > 0.5$).

Species Composition

We encountered all four species of streamside salamanders typical of streams in this section of the Blue Ridge Mountains of Virginia north of the James River (Mitchell, 1998): *Desmognathus fuscus*, *D. monticola*, *Eurycea cirrigera*, and *Gyrinophilus porphyriticus*. In addition, we encountered several terrestrial *Plethodon cinereus* near the water's edge. This species is not included in our comparisons. All four species were encountered during 1997 in different frequencies during visual-encounter surveys: *D. monticola* (39%), *G. porphyriticus* (22%), *D. fuscus* (21%), and *E. cirrigera* (17%). Only 3 species were found during the 1998 visual-encounter surveys. These samples were also dominated by *D. fuscus* (56%) and *D. monticola* (40%), with only a few *G. porphyriticus* (4%). No *Eurycea* were found in 1998.

Size Structure and Relative Abundance

Size structure of streamside salamander populations was determined using SVL measurements from captured individuals. Minimum body sizes at maturity (SVL, based on Petranka, 1998), used to define adults in this study, was 33 mm for *D. fuscus*, 48 mm for *D. monticola*, and 61 for *G. porphyriticus*. All *E. cirrigera* captured were adults. Many more adult *D. monticola* and *G. porphyriticus* were found in 1997 than 1998 (Fig. 3). Juvenile salamanders dominated samples in 1998.

Relative abundance of all salamander species (combined data) was higher at all sample sites in 1998 than in 1997 (Fig. 4). In 1997, abundance was highest in the tributaries (Bear Branch 11/h, Sugartree Branch 8/h), and lowest in Middle St. Marys (1/h). Relative abundance was also high in Bear Branch (23/h) and Sugartree Branch (21/h) in 1998. The Lower St. Marys river mainstem site had the lowest relative abundance in 1998 with 6/h.

DISCUSSION

Composition of the streamside salamander assemblage in the St. Marys watershed appears to be the same as that in other Blue Ridge Mountain streams in the area. Streams affected similarly by acid precipitation in Shenandoah National Park (SNP) supported populations of the same species of salamanders during 1995-1998 (Mitchell, 1998). The only species found in the SNP study that was not encountered in the St. Marys watershed is the northern red salamander (*Pseudotriton ruber*). Sampling effort is the likely explanation since *P. ruber* was rarely encountered in SNP. Thus, it appears that there has been no loss of salamander species in the St. Marys system, in contrast to losses of some invertebrates and fish (e.g., Kaufmann et al., 1999; Bugas et al., 1999).

Our June 1998 salamander density was not significantly lower than 1936 or 1937 densities, suggesting that salamanders have apparently not declined in abundance over the 60 year period. However, sample sizes were small and we currently do not have enough trend data to determine if any real changes have occurred. However, within this 60 year timeframe, water quality, specifically pH, has decreased substantially and there have been subsequent negative effects on the fish and invertebrate communities in the St. Marys watershed (Kauffman et al., 1999; Bugas et al., 1999). These changes parallel those documented elsewhere in the Appalachian region (Arnold et al., 1981; Herrmann et al., 1993; Guerold et al., 1995; Griffith et al., 1995).

The greater proportion of juvenile salamanders encountered in 1998 compared to 1997 may be the result of either greater reproductive success that year or a function of sample date. Samples in 1997 were taken in

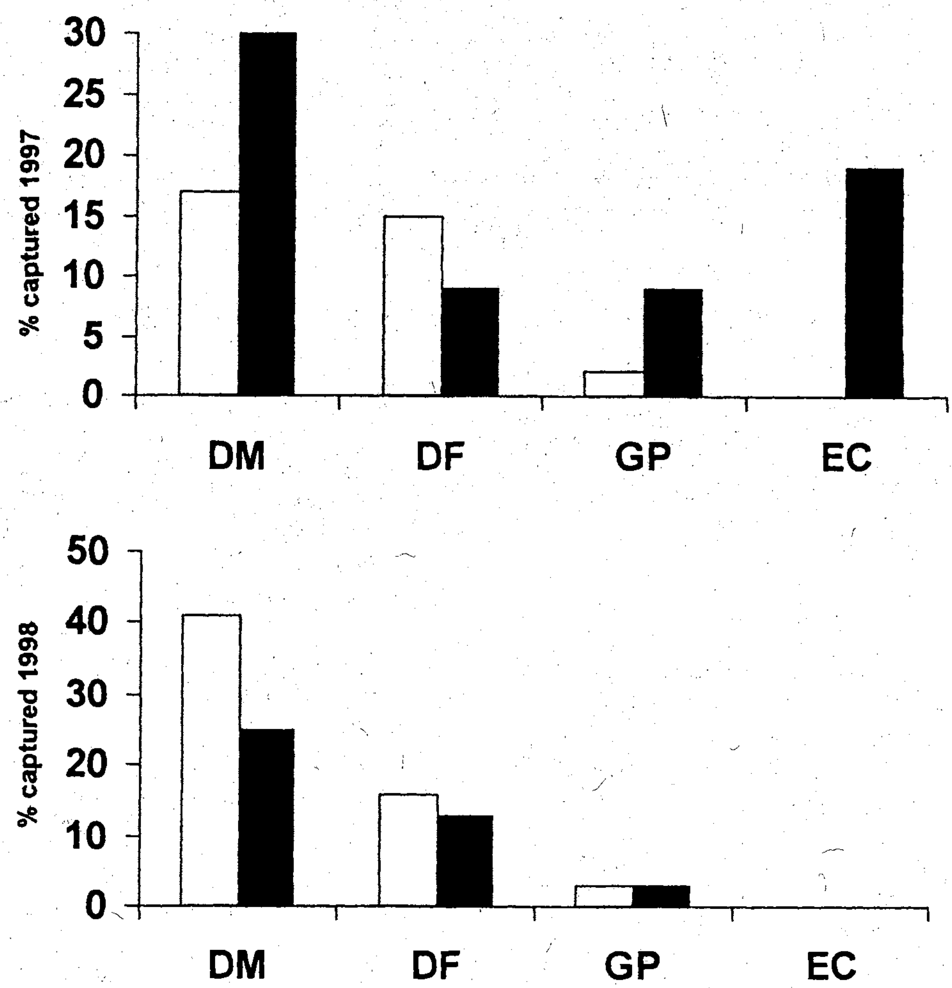

Fig. 3. Age structure of streamside salamander samples in St. Marys River and two tributaries, Augusta County, Virginia. Open bars represent juveniles and larvae and closed bars represent adults. Percent is % of all salamanders captured in each year. Abbreviations: *Desmognathus fuscus* (DF), *Desmognathus monticola* (DM), *Eurycea cirrigera* (EC), *Gyrinophilus porphyriticus* (GP).

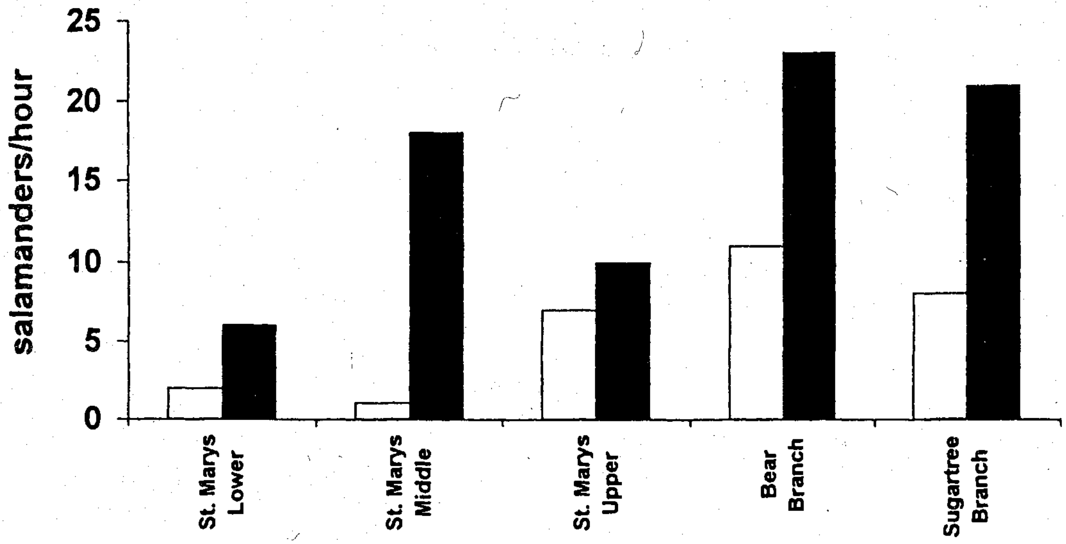

Fig. 4. Relative abundance of salamanders in St. Marys River and two tributaries by sample site for 1997 and 1998. Open bars represent 1997 samples and closed bars represent 1998 samples.

late September and early October, during which time fallen leaves in the stream made searching difficult. In 1998, sampling was conducted in August to avoid this problem. Occurrence of juveniles in both years demonstrates that streamside salamanders are experiencing reproductive success in St. Marys watershed. However, we do not know recruitment rates and how these numbers compare to historic trends.

Salamanders appear to be more tolerant of acidic conditions than some invertebrates and fish. They have been shown to reproduce in water with pH levels above *ca.* 4.5-5.0 and suffer a variety of effects at levels below pH 4.5 (Sadinski & Dunson, 1992; Horne & Dunson, 1994; Kutka, 1994). However, indirect effects on salamander survival and reproductive success could occur as the aquatic flora and fauna changes around them in response to increased acidity. These changes include a decreased nutritious food base as macroinvertebrate abundance and richness decreases (Arnold et al., 1981; Herrmann et al., 1993; Guerold et al., 1995), as microbial decomposition or detrital material is slowed (Tuchman, 1993), and as the planktonic and algal communities experience shifts toward more acid-tolerant species (Herrmann et al., 1993). An additional indirect effect is a reduction of predation by fish on salamander eggs and larvae as fish species abundance decreases or are extirpated (Resetarits, 1991, 1995).

Variation in stream habitats in various parts of watersheds (e.g., mainstem sections and tributaries), as well as presence or absence of predators are known to affect the composition of streamside salamander communities (Southerland, 1986; Resetarits, 1991). Relative abundance data from 1997 and 1998 suggest that streamside salamanders are more abundant in the tributaries and higher elevations in the watershed than in the lower reaches of the mainstem of St. Marys River. This is the reverse of the distribution of pH values and fish abundance (Webb et al., 1999; Kaufmann et al., 1999; Bugas et al., 1999). In our study, salamanders are more abundant where acidic conditions have negatively affected fish abundance and richness. This distributional relationship suggests that salamanders are responding positively to the reduction in predation. However, it is also possible that habitats differ enough among sites to affect abundance, with the better salamander habitat being in the tributaries and upper reaches of the mainstem. However, habitat variables we measured did not apparently vary enough among sites to limit salamander abundance at the downstream sites. These scenarios suggest hypotheses that could be tested with additional quantitative surveys and monitoring efforts. Long-term monitoring using our standardized methods should be used to develop inferences about population trends.

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LITERATURE CITED

Arnold, D.E., P.M. Bender, A.B. Hale, & R.W. Light. 1981. Studies on infertile acidic Pennsylvania streams and their benthic communities. Pp. 15-33 *In* R. Singer (ed.), Effects of Acid Precipitation on Benthos. Proceedings of a Regional Symposium on Benthic Biology. North American Benthological Society, Hamilton, NY.

Bugas, P.E., Jr., L.O. Mohn, & J.W. Kaufmann. 1999. Impacts of acid deposition on fish populations in St. Marys River, Augusta County, Virginia. Banisteria 13:191-200

Camuto, C. 1991. Dropping acid in the southern Appalachians: A wild trout resource at considerable risk. Trout 32:16-36.

Cosby, B.J., P.F. Ryan, J.R. Webb, G.M. Hornberger, & J.N. Galloway. 1991. Mountains of western Virginia. Pp. 297-318 *In* D.F. Charles (ed.), Acid Deposition and Aquatic Ecosystems: Regional Case Studies. Springer-Verlag, New York, NY.

Feldman, R.S., & E.F. Conner. 1992. The relationship between pH and community structure of invertebrates in streams of the Shenandoah National Park, Virginia, U.S.A. Freshwater Biology 27:261-276.

Galloway, J.N., S.A. Norton, & M.R. Church. 1983. Freshwater acidification from atmospheric deposition of sulfuric acid: a conceptual model. Environmental Science & Technology 17:541A-544A.

Griffiths, M.B., S.A. Perry, & W.B. Perry. 1995. Macroinvertebrate communities in headwater streams affected by acidic precipitation in the central Appalachians. Journal of Environmental Quality 24:233-238.

Guerold, F., D. Vein, G. Jacquemin, & J.C. Pihan. 1995. The macroinvertebrate communities of streams draining a small granitic catchment exposed to acidic precipitation. Hydrobiologia 301:141-148.

Herrmann, J., E. Degerman, A. Gerhardt, C. Johansen, P.E. Lingdell, & I.P. Miniz. 1993. Acid-stress effects on stream biology. Ambio 22:298-307.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, & M.S. Foster. 1994. Measuring and Monitoring Biological Diversity, Standard Methods for Amphibians. Smithsonian Institution Press, Washington, DC. 364 pp.

Horne, M.T., & W.A. Dunson. 1994. Behavioral and physiological responses of the terrestrial life stages of the Jefferson salamander, *Ambystoma jeffersonianum*, to low soil pH. Archives of Environmental Contamination and Toxicology 27:232-238.

Kauffman, J. W., L.O. Mohn, & P. E. Bugas, Jr. 1993. Effects of acidification on bottom fauna in St. Mary's River, Augusta County, Virginia. P. 12 *In* F.A. Deviney, Jr., & J.R. Webb (eds.), St. Mary's River Watershed Database Reference. Department of Environmental Sciences, University of Virginia, Charlottesville.

Kauffman, J. W., L. O. Mohn, & P. E. Bugas, Jr.. 1993. Effects of acidification on benthic fauna in St. Marys River, Augusta County, Virginia. Banisteria 13: 183-190

Kutka, F.J. 1994. Low pH effects on swimming activity of *Ambystoma* salamander larvae. Environmental Toxicology and Chemistry 13:1821-1824.

Mitchell, J.C. 1998. Amphibian decline in the mid-Atlantic region: Monitoring and management of a sensitive resource. Final Report. Legacy Resource Management Program, U.S. Department of Defense. 144 pp.

Mohn, L.O., J.W. Kauffmann, & P.E. Bugas, Jr.. 1993. Effects of acidification on bottom fauna and fish populations in St. Mary's River, Augusta County, Virginia. P. 13 *In* F.A. Deviney, Jr., & J.R. Webb (eds.), St. Mary's River Watershed Database Reference. Department of Environmental Sciences, University of Virginia, Charlottesville.

Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, DC. 587 pp.

Resetarits, W.J., Jr. 1991. Ecological interactions among predators in experimental stream communities. Ecology 72:1782-1793.

Resetarits, W.J., Jr. 1995. Competitive asymmetry and coexistence in size-structured populations of brook trout and spring salamanders. Oikos 73:188-198.

Sadinski, W.J., & W.A. Dunson. 1992. A multilevel study of effects of low pH on amphibians of temporary ponds. Journal of Herpetology 26:413-422.

Southerland, M.T. 1986. The effects of variation in streamside habitats on the composition of mountain salamander communities. Copeia 1986:731-741.

Surber, E. W. 1951. Bottom fauna and temperature conditions in relation to trout management in St. Mary's River, Augusta County, Virginia. Virginia Journal of Science 2:190-202.

Tuchman, N.C. 1993. Relative importance of microbes versus macroinvertebrate shredders in the process of leaf decay in lakes of differing pH. Canadian Journal of Fisheries & Aquatic Sciences 50:2707-2712.

Webb, J. R., B. J. Cosby, J. N. Galloway, & G. M. Hornberger. 1989a. Acidification of native brook trout streams in Virginia. Water Resources Research 25:1367-1377.

Webb, J. R., P. E. Bugas, Jr., B. J. Cosby, J. N. Galloway, G. M. Hornberger, J. W. Kauffman, L. O. Mohn, P. F. Ryan, & P .P. Smith. 1989b. Acidic deposition and the status of Virginia's wild trout resource. Pp. 228-233 *In* F. Richardson & R.H. Hamre (eds.), Wild Trout IV. Proceedings of the Symposium, American Fisheries Society, Yellowstone National Park, Wyoming.

Webb, J.R., & F. A. Deviney, Jr. 1999. The acid-base status of the St. Marys River: the Virginia trout stream sensitivity study results. Banisteria 13: 171-182

Webb, J. R., F.A. Deviney, J.N. Galloway, C.A. Rinehart, P.A. Thopson, & S. Wilson. 1994. The acid-base status of native brook trout streams in the mountains of Virginia. Report to the Virginia Department of Game and Inland Fisheries. Charlottesville, VA. 90 pp.