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Natural Resource Stewardship and Science

Aquatic Macroinvertebrate Monitoring in Shenandoah National Park

2009 Summary Report

Natural Resource Data Series NPS/SHEN/NRDS—2012/360

ON THE COVER
Portable Invertebrate Box Sampler used by David Demarest and D-frame net sampler used by Jeb Wofford on Twomile Run in Shenandoah National Park, 2010.
Photograph by: Wendy Hochstedler, Shenandoah National Park

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from Shenandoah National Park Natural and Cultural Resource Division and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

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Abstract

Shenandoah National Park (SHEN) monitors aquatic macroinvertebrate communities as part of the National Park Service (NPS) Vital Signs Program. Vital signs are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources (Fancy et al. 2009). Within Shenandoah National Park, macroinvertebrates are monitored to help characterize the status and trends of park aquatic ecosystems.

In 2009, 34 sites on 24 streams were sampled for aquatic macroinvertebrates. During each site visit, macroinvertebrates were collected, and discharge, water chemistry, and stream habitat parameters were measured. Macroinvertebrate samples included three quantitative (Portable Invertebrate Box Sampler or Surber sampler) and one qualitative sample (D-frame net) at each site. Specimen identification and enumeration was conducted by staff at the Virginia Polytechnic Institute. Of the 34 sites visited in 2009, 28 of these sites were "primary" sites that are visited every year. The additional six sites were "secondary" sites that included inventories of new streams or revisits to sites that had not been assessed in more than six years. Based on prior monitoring and research results (Moeykins and Voshell 2002), select macroinvertebrate metrics were assessed to characterize the status and trends of monitoring sites. Metrics in this report include taxa richness, percent EPT (Taxonomic orders of Ephemeroptera, Plecoptera, and Trichoptera) , percent intolerant organisms, Simpson's diversity index, and the Macroinvertebrate Aggregate Index Score (MAIS). Metrics were summarized by sites according to watershed underlying bedrock geology and associated acid neutralizing capacity (ANC) (Moeykins and Voshell 2002, Cosby et al. 2006).

In 2009, across all metrics, high ANC streams reflected more healthy ecological conditions when compared to low ANC streams. Following an assessment of data from 1987-2009, a significant increasing linear trend ($p<0.05$) was observed in taxa richness in both the high and low ANC groups. In contrast, significant decreasing linear trends were observed in low ANC streams for percent EPT and percent intolerant organisms. Summary metrics indicate that streams more capable of buffering acid rain events (i.e. streams with high ANC) support more functional macroinvertebrate assemblages than those more sensitive to acid deposition.

Acknowledgments

Data collectors for 2009 were D. Demarest, S. Hall, W. Hochstedler, L. Kramer, M. Kramer, S. Paul, J. Sylvia, and J. Wofford. Specimen identification and enumeration occurred via a cooperative agreement with Virginia Polytechnic Institute.

Introduction

The National Park Service (NPS) Vital Signs Program was initiated in order to assist the agency with meeting its long term mission of managing park resources “unimpaired for the enjoyment of future generations.” Vital signs are defined as a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources (Fancy et al. 2009). Assessing the status and trend of vital signs will inform management decisions and allow the Service to characterize how well the agency is meeting its core mission. Aquatic macroinvertebrates are vital to the function of stream ecosystems, are sensitive to environmental perturbations, and are frequently used as indicators of aquatic ecosystem function (Voshell et al. 1997, Barbour et al. 1999, Carter and Resh 2001). As such, monitoring the status and trends of macroinvertebrates helps SHEN meet the intention of the NPS vital signs program and ultimately, the mission of the NPS.

Shenandoah National Park (SHEN) comprises 80,539 ha (199,016 acres) and stretches 145 km (90 miles) along the spine of the Blue Ridge Mountains between Waynesboro and Front Royal, Virginia. SHEN is part of the NPS Mid-Atlantic Monitoring Network (MIDN), a collection of parks that were organized to support the development of integrated park natural resource inventory and monitoring programs (i.e. “vital signs”). Although the MIDN was formally established in 2008, monitoring in Shenandoah has a much longer history.

In 1986, aquatic macroinvertebrate sampling at SHEN was started as a research project to assess the impacts of gypsy moth (*Lymantria dispar*) and stream acidification on aquatic ecosystem function (Voshell 1992). A monitoring protocol was developed between 1986 and 1990 and in 1987-1988, SHEN included the macroinvertebrate field component into park operations. The protocol was officially incorporated into the park’s Inventory and Monitoring (I&M) Program in 1991 (via Voshell and Hiner 1990). Currently the SHEN macroinvertebrate monitoring protocol is being updated to meet NPS Inventory and Monitoring Program standards (Oakley et al. 2003; Wofford et al. 2011). Since 1986, 117 monitoring sites on 51 streams have been sampled for aquatic macroinvertebrates. As a result, 222 taxa of aquatic macroinvertebrates have been identified and the effects of acidification on aquatic ecosystems in SHEN continue to be well documented (Moeykins and Voshell 2002; Cosby et al. 2006).

This report presents a brief summary of information collected during 2009 aquatic macroinvertebrate vital signs monitoring in Shenandoah National Park and places it in context of data collected since 1987. Results are preliminary. More exhaustive analyses and interpretation occur during long term trend assessments. A long-term assessment of aquatic macroinvertebrates in SHEN is currently underway and a summary report is expected in 2013.

Objectives

The overarching goal of the aquatic macroinvertebrate monitoring program is to meet the objectives of the Vital Signs Program (as described above) and thereby provide a framework for monitoring long-term change in ecological integrity of aquatic ecosystems. The following objectives were established to help monitor ecosystem condition within flowing waters in SHEN.

1) Document status and trends of aquatic macroinvertebrate assemblages at sites within geologic and elevational groups by means of metrics that reflect abundance, richness, evenness, environmental requirements, ecological roles, and responses to various potential stressors.

2) Document status and trends of habitat condition (both instream and riparian) and water quality at selected sites by means of habitat assessments and point-in-time measurement of core water quality parameters.

3) Relate the condition of aquatic macroinvertebrate assemblages at selected sites to established regional biological criteria for ecological integrity.

Methods

A brief discussion of methods is noted below - full documentation of monitoring methods can be found in Wofford et al. (2011).

Macroinvertebrate sampling sites are spatially distributed across the park and are loosely stratified by elevation and the three dominant geologic types found in Shenandoah. With occasional exception, a core set of sites (i.e. primary sites; 28 sites on 18 streams) has been sampled each year since 1987. Along with that core group of sites, additional sites (i.e. secondary sites; 79 sites on 39 streams) are included in a rotational status and are sampled, at a minimum, on a decadal basis. Sample sites monitored in 2009 are shown in Figure 1.

Macroinvertebrate sampling sites are comprised of 100 meter stream reaches and sites are sampled during spring months (April-May). Upon reaching a monitoring site, a Hydrolab® multiprobe water quality meter (Hach Co., Loveland, CO) and a Marsh-McBirney® flow meter (Hach Co., Loveland, CO) are used to collect water quality and quantity information, respectively. Measures of temperature, dissolved oxygen, pH, conductivity, and stream discharge are collected. Various stream habitat characteristics are also measured or estimated, such as stream width, depth, and substrate.

During each site visit, three quantitative and one qualitative sample of the macroinvertebrate community are collected. Quantitative samples provide estimates of abundance and richness of taxa occurring in the most productive microhabitats in streams (i.e. riffles) and are collected with a Portable Invertebrate Box Sampler (PIBS) or a Surber sampler. These sampling devices provide a standardized area from which all macroinvertebrates are collected. Because quantitative samples only target riffle habitats, qualitative samples are also collected and provide additional information for estimates of the diversity of taxa within all habitats in a sample reach. A D-frame dip net is used to collect macroinvertebrates from all available habitat types during qualitative sampling. Ultimately, all collected insects are sorted from debris, identified to the lowest practical taxonomic level, and enumerated by a contracted laboratory. Since 1993, field data collection and macroinvertebrate identification has remained consistent with one field technician collecting the bulk of the quantitative samples each year and one contractor indentifying samples. Ultimately, all data is entered into a Microsoft Access database.

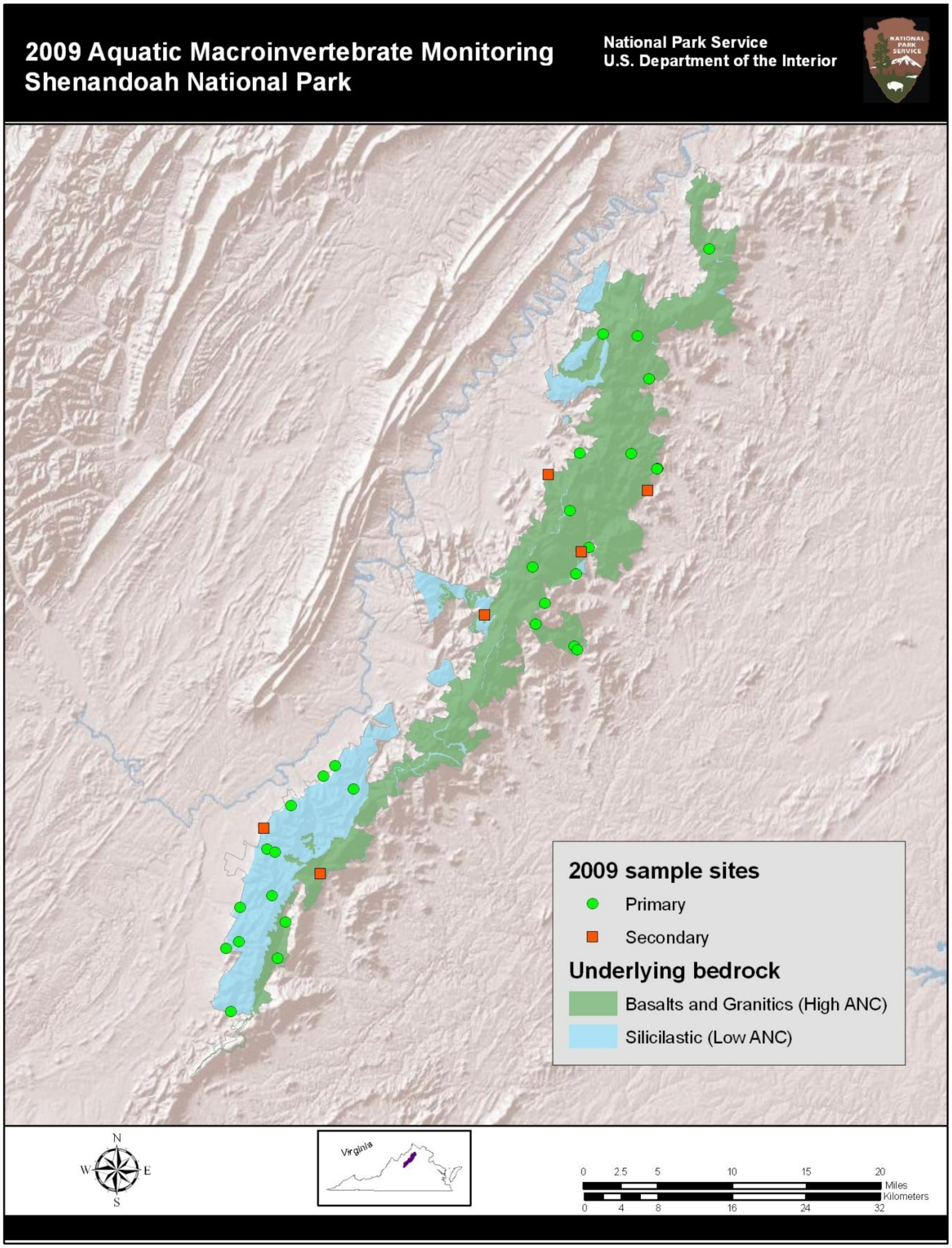

Figure 1. Map of Shenandoah National Park 2009 aquatic macroinvertebrate sample sites and underlying bedrock (ANC groups).

Annual data analysis involves assessment of select metrics that characterize macroinvertebrate community richness, composition, balance, and tolerance (Table 1). Specific metrics that were assessed include taxa richness, percent EPT (Taxonomic orders of Ephemeroptera, Plecoptera, and Tricoptera), percent intolerant organisms, Simpson's diversity index, and the Macroinvertebreate Aggreagate Index Score (MAIS). Quantitative and qualitative samples are pooled to calculate measures of taxa richness, otherwise only data from quantitative samples are used in analysis.

Briefly, taxa richness is the total number of taxa in the relevant sample. Percent EPT is the relative abundance of insects in those taxonomic orders – orders which are known to be sensitive to perturbations. Percent intolerant organisms is the percent abundance of macroinvertebrates with low pollution tolerance values (0, 1, 2 or 3; from Barbour et at 1999 and Merrit and Cummings 1996). Simpson's diversity index reflects the biotic diversity of a sample and is derived from species richness and abundance. The MAIS is an index utilizing 12 individual metrics and was designed for the Blue Ridge ecoregion to assess overall stream health (Moeykens and Voshell 2002). Taxa richness, percent EPT, percent intolerant taxa, Simpson's diversity index, and MAIS can all be expected to decline with perturbation.

Only data from primary sites (sites that are visited consistently from year to year; see Appendix A) were assessed in these analyses though water chemistry and summary macroinvertebrate metrics are reported for all sites (Appendix A and Appendix B, respectively). Data from secondary sites (which include new inventories or sites that have not been visited at least once over 10 years) are analyzed during longer term comprehensive analyses and associated reports.

Prior assessments have revealed macroinvertebrate communities in SHEN are strongly influenced by acid deposition and that bedrock geology and a watershed's ability to buffer acid events can dramatically influence macroinvertebrate assemblages (Moeykins and Voshell 2002; see Cosby et al 2006 for review). As conducted by Moeykins and Voshell (2002) , monitoring sites were assigned to two groups for analysis based upon the associated watersheds capability to buffer acid deposition. Resulting groups are high ANC (Acid Neutralizing Capacity) (high capacity to buffer acid rain events, ANC values > 50 μeq/L) and low ANC (low capacity to buffer acid rain events, ANC values ≤50 μeq/L) (Cosby et al. 2006). High ANC streams occur over basaltic or granitic geology, and low ANC streams occur over siliciclastic bedrock (Cosby et al 2006).

Metrics were analyzed for trends using linear regression with transformations as appropriate (Ramsey 1996). Regression lines are only displayed when a regression was significant ($p < 0.05$). It is important to note that some assumptions associated with the regression may be violated (functionally increasing the confidence in significance) and thus, significance of trends should be interpreted with caution (Ramsey 1996). The aggregated MAIS metric was also assessed using a control chart (Morrison 2008). Control charts provide a simple visual assessment of a metric and supply "threshold" values (termed "warning limits"). When a particular metric crosses these warning limits, the system is considered to soon be "out of control" and additional analyses or management actions may be required. Control charts provide an alternative to regression analyses for assessing biomonitoring information (Morrison 2008). For control chart analyses, the first 10 years of data (1987-1997) were used as a baseline. Site means and standard deviations were then averaged over these 10 years in each ANC group in order to calculate group means and measures of standard error. Using these estimates, 95% confidence limits were established as warning limits.

Results and Discussion

Thirty-four sites on 24 streams were monitoring during 2009 (Figure 1). Of these, 28 were primary sites that are monitored annually and 6 were secondary sites (Appendix A). Ultimately, 39,906 individual macroinvertebrates were identified and enumerated. No new taxa were collected.

For the primary sites in 2009, the high ANC streams had higher mean values of all calculated metrics (Table 1; Appendix B). Because all of the relevant metrics can be expected to decline with perturbation, it is clear that macroinvertebreate assemblages within the high ANC group represent less disturbed ecological conditions when compared to the low ANC group. This observation has been supported by numerous assessments of macroinvertebrates in SHEN and is consistent across years (Figures 2-6). Across all metrics, low ANC streams scored 27% lower than high ANC streams.   In addition, the low ANC group showed higher variability in metric estimates than those streams in the high ANC group (Table 1). This increased variability in the low ANC group may result from a general lack of community stability in these streams as a result of individual acid rain events.

Table 1. Mean taxa richness, percent EPT (Ephemeroptera, Plecoptera, Trichoptera), percent intolerant organisms, Simpson's diversity index, and the Macroinvertebrate Aggregated Index Score for each ANC group in 2009 for the 28 primary sites. Standard deviation and standard error are shown in parentheses, respectively.

Metric	High ANC (>50 ueq/L)	Low ANC (<50 ueq/L)	Metric Response to Perturbation
Taxa Richness	28.8 (6.5, 1.5)	24.3 (3.9, 1.3)	Decline
Percent EPT	55.5 (19.0, 4.5)	34.4 (20.4, 6.8)	Decline
Percent Intolerant Organisms	56.2 (16.9, 4.0)	32.2 (21.7, 7.2)	Decline
Simpson's Diversity Index	0.77 (0.15, 0.04)	0.63 (0.18, 0.06)	Decline
Macroinvertebrate Aggregated Index Score	15.8 (1.96, 0.46)	11.8 (3.07, 1.02)	Decline

It is important to note that although assemblages do differ across ANC groups every year, a review of year-to-year changes indicates that ANC groups generally trend in similar directions (i.e. from any one year to the next, metrics for both groups tend to either go up or go down). This implies that larger scale (i.e. parkwide) environmental phenomena (e.g. drought, floods, temperatures, etc.) are influencing both groups similarly. In addition, a further review of Figures 2-6 indicates that most metrics are highly variable over time, with some measures doubling or being reduced by half from one year to the next (e.g. percent EPT in the low ANC group, 1998-1999) (Figure 3). Because of large short term variability, it is important to note that long term changes are more reliable for assessing resource conditions, particularly when management actions are under consideration.

Including available data from 1987 to 2009, significant increasing linear trends were observed in taxa richness in both ANC groups (Figure 2). This increasing trend, in conjunction with the lack of a corresponding trend in Simpson's Diversity Index (Figure 5), implies that more rare species (species with very few individuals) may be colonizing park streams. An increase in the number of species present can be interpreted as an improvement in the ecological condition of park streams. In contrast, significant decreasing linear trends were observed in multiple metrics (i.e. percent EPT and percent intolerant organisms) in the low ANC group (Figures 3 and 4). These trends may represent the continued degradation of these ecosystems by acid deposition. The MAIS score, a multi-metric macroinvertebrate index, did not decline below warning limits, indicating no significant change from the baseline (1987-1997) period for either ANC group (Figure 6).

Macroinvertebrate data from 2009 indicate that many aquatic ecosystems in SHEN remain negatively affected by acid deposition and associated changes in water chemistry. Significant declining trends in specific macroinvertebrate metrics (i.e. percent EPT or percent intolerant taxa) imply that portions of the macroinvertebrate assemblage continue to decline in their relative abundance. Nevertheless, a lack of a declining trend in the aggregated MAIS provides some evidence that, although certain groups of the macroinvertebrate community have remained degraded (and continue to degrade), overall macroinvertebrate community health has not significantly declined further since the early days of the monitoring program.

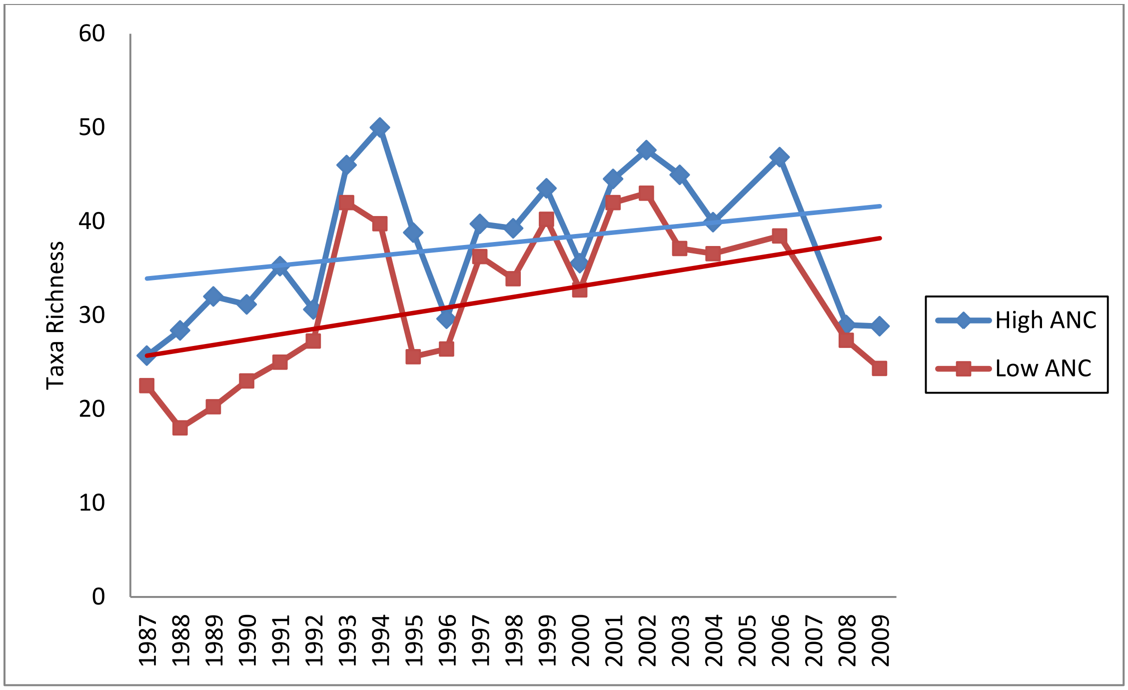

Figure 2. Mean taxa richness in primary sites by ANC group from 1987 - 2009. Significant increasing linear trends occur in both the high ANC (diagonal blue line) and low ANC (diagonal red line) groups ($p<0.05$).

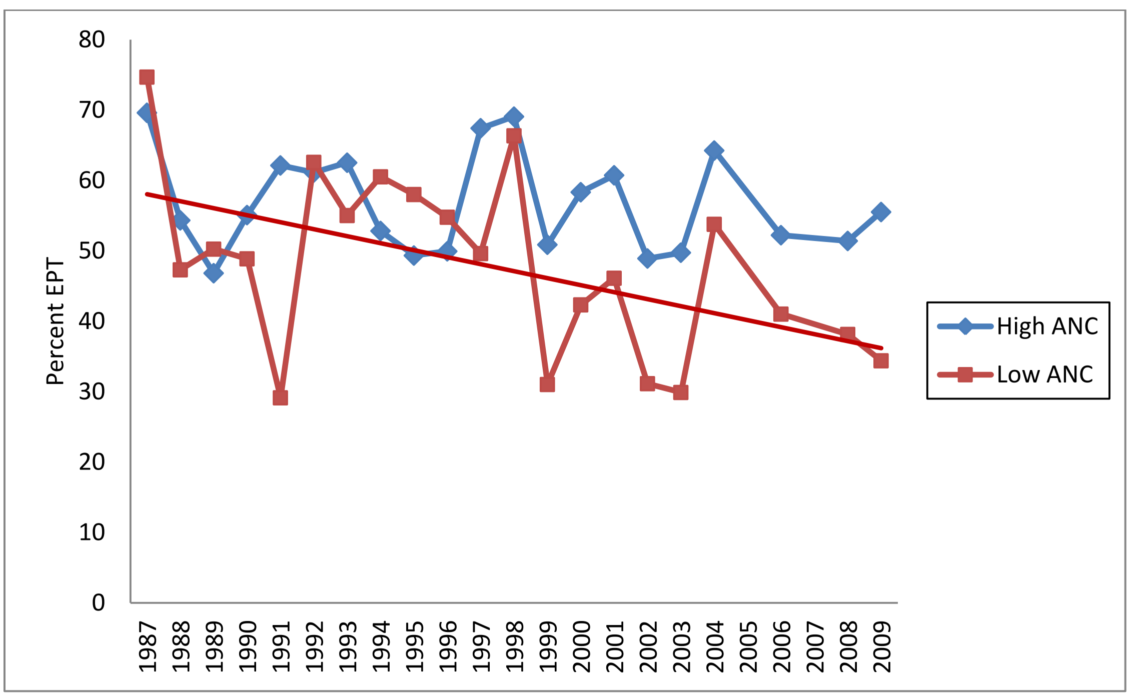

Figure 3. Mean percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in primary sites by ANC group from 1987 – 2009. A significant decreasing linear trend (diagonal red line) occurs in the low ANC group ($p<0.05$).

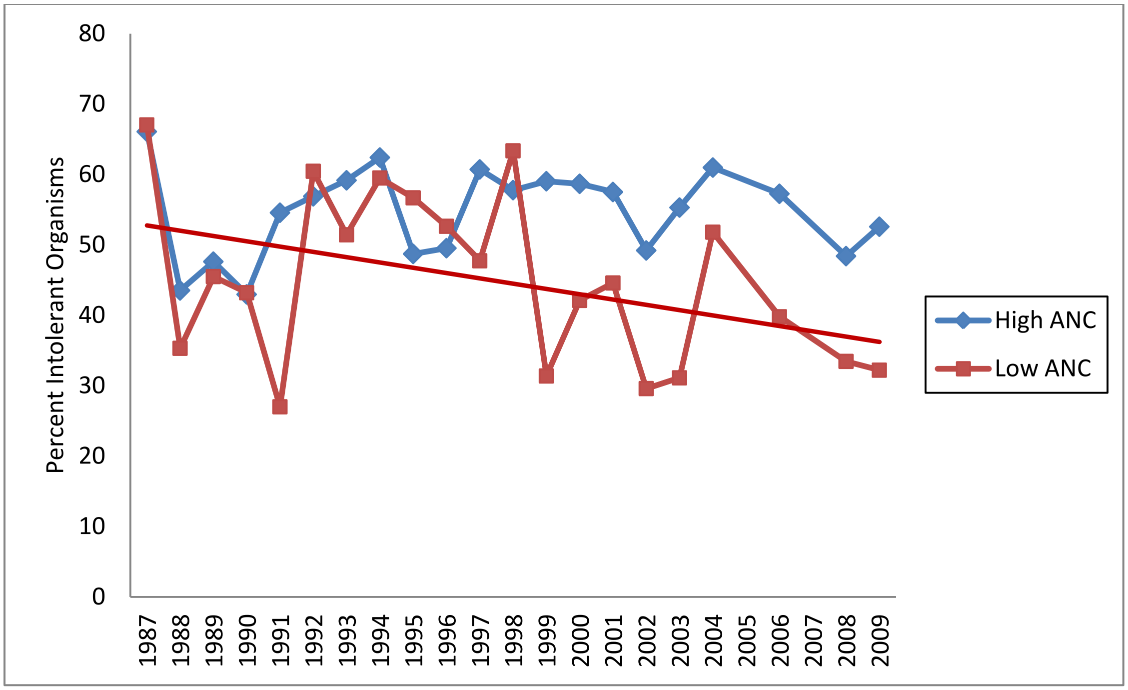

Figure 4. Mean percent of organisms intolerant to pollution in primary sites by ANC group from 1987 – 2009. A significant decreasing linear trend (diagonal red line) occurs in the low ANC group ($p<0.05$). An increasing trend in the high ANC group was almost significant at $p=0.08$.

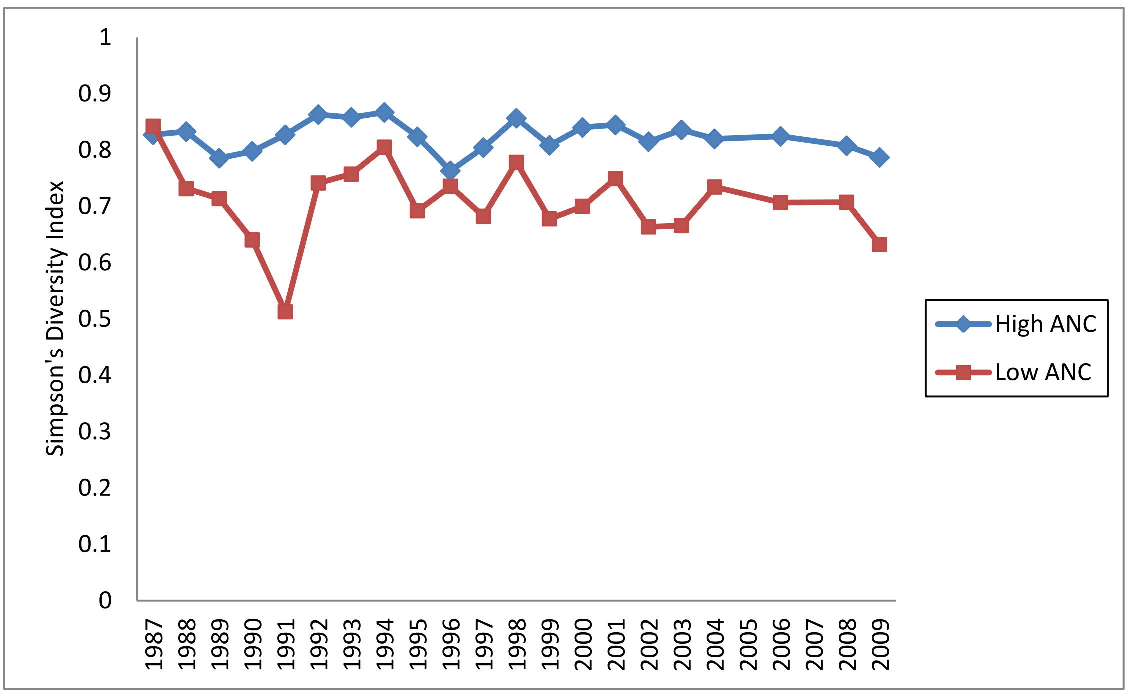

Figure 5. Mean Simpson's diversity index in primary sites by ANC group from 1987 – 2009. A decreasing trend in the low ANC group was almost significant at $p=0.06$.

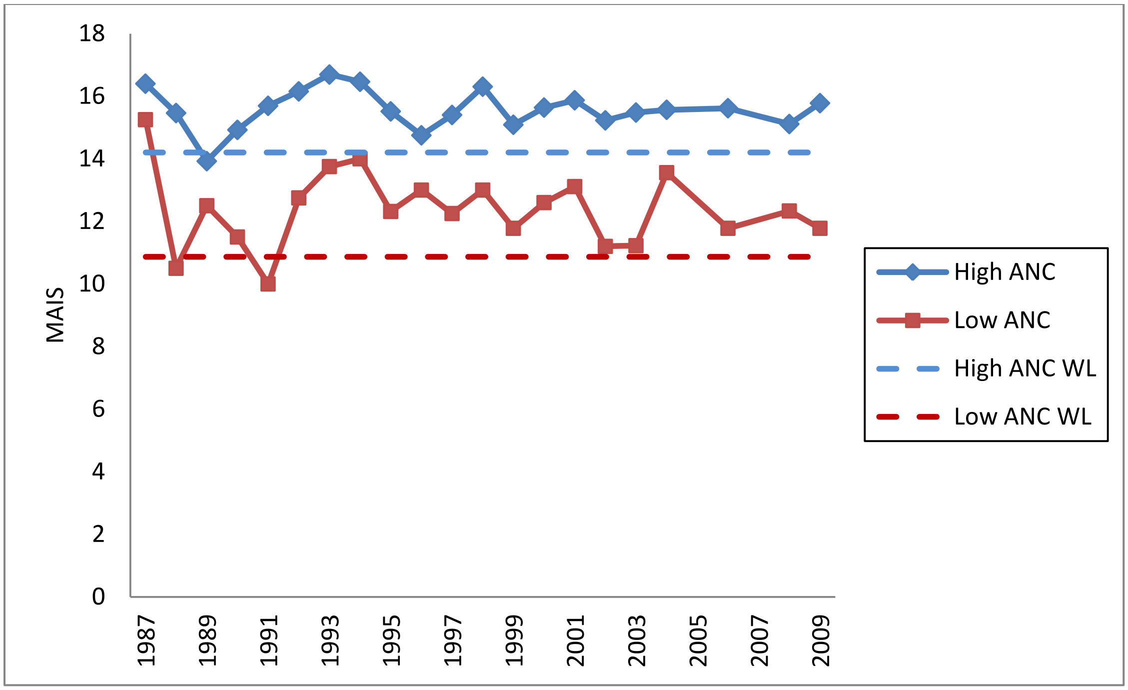

Figure 6. Control Chart of mean Macroinvertebrate Aggregate Index Score (MAIS) in primary sites by ANC group from 1987 – 2009. Warning limits (WL) are 95% confidence limits around the first 10 years of data (1987-1997). Only lower warning limits are displayed. When data values descend below a warning limit, the system is deemed to soon be "out of control" (Morrison 2008)

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Appendix A: Sample site information and water quality data for 2009

Stream	Site #	ANC Group	Sample Rotation[1]	Date	Temperature (C)	DO[2]	Conductivity (µS)	pH
Hazel River	2F090	High	Primary	06-May-09	9.61	10.50	17.00	7.04
Hazel River	2F303	High	Primary	05-May-09	10.55	10.99	18.00	7.53
Jeremy's Run	1F118	High	Primary	16-Apr-09	5.46	11.52	44.00	7.65
Land's Run	1F002	High	Primary	13-Apr-09	5.11	11.64	33.00	7.51
North Fork Dry Run	2F131	High	Primary	16-Apr-09	7.81	10.80	25.00	7.31
Madison Run	3F025	High	Primary	14-Apr-09	8.13	10.42	21.00	7.44
North Fork Moormans River	3F044	High	Primary	12-May-09	12.32	10.42	28.00	7.74
North Fork Moormans River	3F084	High	Primary	12-May-09	10.83	11.03	28.00	7.47
Piney River	1F308	High	Primary	05-May-09	9.04	10.49	21.00	7.27
Piney River	1F003	High	Primary	05-May-09	10.51	10.81	32.00	7.45
Rapidan River	2F093	High	Primary	23-Apr-09	11.53	11.34	18.00	--
Rapidan River	2FVA5	High	Primary	23-Apr-09	6.77	10.55	18.00	8.05
Rose River	2F055	High	Primary	30-Apr-09	9.18	10.22	25.00	8.11
Rose River	2F015	High	Primary	30-Apr-09	10.84	10.62	23.00	7.94
Staunton River	2F306	High	Primary	07-May-09	9.95	10.55	11.00	6.85
Staunton River	2F072	High	Primary	07-May-09	12.42	10.13	17.00	7.36
Whiteoak Canyon Run	2F009	High	Primary	06-May-09	10.68	11.03	25.00	7.11
Whiteoak Canyon Run	2F253	High	Primary	06-May-09	10.56	9.96	25.00	7.50
Whiteoak Run	3F271	Low	Primary	14-Apr-09	8.13	10.42	18.00	7.31
Lower Lewis Run	3F105	Low	Primary	13-May-09	11.39	10.82	20.00	6.31
Meadow Run	3F107	Low	Primary	21-Apr-09	10.84	10.88	15.00	5.63
Meadow Run	3F109	Low	Primary	21-Apr-09	8.30	11.78	15.00	5.65
Onemile Run	3F126	Low	Primary	18-May-09	11.52	10.65	15.00	5.79

Appendix A: Sample site information and water quality data for 2009 (continued)

Stream	Site #	ANC Group	Sample Rotation[1]	Date	Temperature (C)	DO[2]	Conductivity (µS)	pH
Paine Run	3F300	Low	Primary	14-May-09	10.43	10.40	21.00	5.95
Paine Run	3F123	Low	Primary	11-May-09	11.08	10.62	20.00	6.12
Sawmill Run	3F143	Low	Primary	14-Apr-09	7.63	10.58	17.00	6.58
Twomile Run	3F302	Low	Primary	13-May-09	9.45	10.50	21.00	6.21
Twomile Run	3F103	Low	Primary	11-May-09	11.20	10.12	19.00	6.03
Broad Hollow Run	2F067	High	Secondary	18-May-09	10.78	10.50	17.00	7.67
Cedar Run	2F062	High	Secondary	20-May-09	8.85	11.22	24.00	7.67
Doyles River	3F087	High	Secondary	19-May-09	8.93	11.32	29.00	7.60
East Branch Naked Creek	2F029	High	Secondary	20-May-09	11.02	10.62	29.00	7.54
Kettle Canyon	2F208	High	Secondary	27-Apr-09	11.27	9.92	39.00	7.81
Deep Run	3F265	Low	Secondary	14-May-09	12.64	10.15	19.00	5.78

[1] Primary sites are sampled annually, secondary sites are sampled at a minimum on a decadal basis

[2] Dissolved oxygen (mg/L)

Appendix B: Sample site macroinvertebrate summary metrics for 2009

Stream	Site #	ANC Group	Taxa Richness	Percent EPT	Percent Intolerant Organisms	Simpson's Diversity Index	MAIS
Hazel River	2F090	High	28	58.7	52.8	0.85	18
Hazel River	2F303	High	28	51.8	49.5	0.75	15
Jeremy's Run	1F118	High	34	32.7	36.8	0.75	15
Land's Run	1F002	High	24	77.4	71.1	0.77	16
North Fork Dry Run	2F131	High	26	70.7	63.0	0.84	17
Madison Run	3F025	High	17	50.7	44.8	0.79	14
North Fork Moormans River	3F044	High	38	38.8	49.9	0.88	16
North Fork Moormans River	3F084	High	19	54.5	59.8	0.80	15
Piney River	1F308	High	25	48.6	37.6	0.83	15
Piney River	1F003	High	28	54.9	45.8	0.87	17
Rapidan River	2F093	High	27	77.7	66.5	0.86	16
Rapidan River	2FVA5	High	27	61.4	61.2	0.85	17
Rose River	2F055	High	23	77.4	77.0	0.76	15
Rose River	2F015	High	22	77.0	69.9	0.85	18
Staunton River	2F306	High	34	44.3	40.0	0.81	16
Staunton River	2F072	High	43	71.3	64.8	0.88	18
Whiteoak Canyon Run	2F009	High	31	52.9	51.1	0.88	17
Whiteoak Canyon Run	2F253	High	24	44.3	45.1	0.68	13
Whiteoak Run	3F271	Low	22	68.9	67.8	0.80	14
Lower Lewis Run	3F105	Low	23	19.7	18.1	0.44	10
Meadow Run	3F107	Low	21	31.4	26.9	0.58	12
Meadow Run	3F109	Low	26	26.6	24.4	0.68	11
Onemile Run	3F126	Low	21	11.9	7.6	0.54	7
Paine Run	3F300	Low	21	60.6	59.9	0.79	15

Appendix B: Sample site macroinvertebrate summary metrics for 2009 (continued)

Stream	Site #	ANC Group	Taxa Richness	Percent EPT	Percent Intolerant Organisms	Simpson's Diversity Index	MAIS
Paine Run	3F123	Low	22	10.0	5.7	0.29	8
Sawmill Run	3F143	Low	20	4.6	4.5	0.24	10
Twomile Run	3F302	Low	25	39.9	36.3	0.76	13
Twomile Run	3F103	Low	31	40.2	43.1	0.81	16
Broad Hollow Run	2F067	High	24	32.7	29.0	0.81	13
Cedar Run	2F062	High	19	68.9	67.2	0.71	15
Doyles River	3F087	High	25	60.8	60.5	0.78	15
East Branch Naked Creek	2F029	High	26	46.5	48.5	0.86	18
Kettle Canyon	2F208	High	25	83.0	73.6	0.68	15
Deep Run	3F265	Low	24	20.3	18.6	0.73	11