National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Fish Monitoring in Shenandoah National Park

2010 Summary Report

Natural Resource Data Series NPS/SHEN/NRDS—2012/361

ON THE COVER
Brook trout from the Rapidan River in a bucket ready to be measured and weighed, 6/30/2010.
Photograph by: Steve Paull, Shenandoah National Park

Fish Monitoring in Shenadoah National Park

2010 Summary Report

Natural Resource Data Series NPS/SHEN/NRDS—2012/361

J.E.B. Wofford and E.D. Demarest.

National Park Service
Shenandoah National Park
3655 U.S. Highway 211 East
Luray, VA 22835

September 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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 Resources Division and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Please cite this publication as:

Wofford, J. E. B., and E. D. Demarest. 2012. Fish monitoring in Shenandoah National Park: 2010 summary report. Natural Resource Data Series NPS/SHEN/NRDS—2012/361. National Park Service, Fort Collins, Colorado.

NPS 134/116859, September 2012

Contents

Figures

Page

Tables

Page

Abstract

Shenandoah National Park (SHEN) monitors fish 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, fish are monitored to help characterize the status and trends of park aquatic ecosystems.

During 2010, a total of 66 sites along 38 park streams were sampled. Of the 66 sites that were monitored, 41 of these sites are “primary” sites that were visited every year until 2004 and then every other year thereafter. In contrast, the other 25 sites were “secondary” sites that included inventories of new streams or revisits to sites that had not been assessed in more than 8 years. A total of 32,360 individual fish representing 26 species were captured from all monitoring sites. No new species were detected during monitoring efforts. Data were ultimately summarized by sites according to watershed underlying bedrock geology and associated acid neutralizing capacity (ANC) groups as defined in Cosby et al. (2006).

Within primary sites across the park, recruitment of juvenile brook trout (*Salvelinus fontinalis*) in 2010 was essentially non-existent and age 0 (i.e. “juvenile” or “young-of-the-year”) trout densities were near record lows. Age 0 trout density averaged 3.2 trout per 100 m^2, approximately 6 times lower than long-term averages (19.1 per 100 m^2) and representing a year class failure for brook trout populations in SHEN. This year-class failure was likely the result of large winter flows during January and March of 2010 – developing brook trout eggs are very sensitive to disturbance during winter months. Age 1+ (i.e. “adult”) brook trout densities in 2009 were above long-term averages, but likely declined during late summer and early fall as a result of extremely low base flows in most park streams. An analysis of data from 1996-2010, indicates a significant decreasing trend in age 0 trout densities in high ANC streams. In contrast, a significant increase in age 1+ trout densities in low ANC streams was documented.

Acid deposition continues to influence fish species richness as well as brook trout production in SHEN. Streams with less capability to buffer acid rain events generally have fewer fish species, have poorer brook trout reproduction, and support smaller populations of adult brook trout. Nevertheless, as noted above, other large scale environmental phenomena such as droughts, floods, and other weather related events, continue to play a large role in determining trout abundance. It should also be noted that data are highly variable and longer-term monitoring is required to accurately assess trends.

Acknowledgments

The fisheries crew for 2010 consisted of Samantha Bizeau, David Demarest, Patricia Downey, Ellen George, Jason Hendershot, Bryan Jones, Mathew Lippy, Zak Slagle, Jennifer Rogers, and Jeb Wofford. Other National Park Service employees and SCA volunteers that assisted were: Dan Adamiak, Sean Allen, Katherine Blackwood, Aaron Bradner, Christina Harman, Coleman Minney, Steve Paull, Jim Schaberl, and Porter Stevens. Volunteers consisted of Tim Slagle, Vanessa Miller, Chase White, and Garrett Wilson. Virginia Department of Game and Inland Fisheries personnel and volunteers who participated in the program include (by last name): Harris, Isel, Lim, Odenkirk, Owens, Thacker, Willis, and Willson. Thanks to all 30 plus people who helped make the 2010 Shenandoah National Park fisheries monitoring season a success.

Introduction

The National Park Service (NPS) Vital Signs Program was initiated in order 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 biota have long been recognized as an important resource in Shenandoah National Park, with brook trout playing a major role in the initial establishment of the park in the 1930’s. The relatively pristine and high elevation streams in Shenandoah currently support coldwater aquatic communities that are increasingly rare in Virginia and the Southeast (EBTJV 2006). Within coldwater ecosystems, fish populations can serve as measures of aquatic ecosystem health and are frequently used to assess environmental disturbance (Simon 1999). And, because salmonids are sensitive to environmental change (Meehan 1991), brook trout (*Salvelinus fontinalis*) populations are often used as a measure of cold-water ecosystem function. As such, monitoring the status and trends of fish communities 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 2003, monitoring in Shenandoah has a much longer history.

Since 1982, Shenandoah National Park staff have worked to monitor brook trout populations and associated mountain stream habitats. Monitoring plans were initially instituted in order to develop and advance the understanding of brook trout population dynamics (Atkinson 2002). In order to better detect and track the influence of a variety of environmental stressors on park ecosystems, monitoring efforts within the park were expanded to include all fish species in 1995. Also during 1995, other major revisions to monitoring protocols were instituted. These revisions included a reduction in the number of monitoring sites, annual sampling of sites, and additional reliance on three-pass depletion electrofishing. Since 1982, 224 monitoring sites in 92 streams have been sampled for fish at various time intervals. As a result, 38 fish species have been documented in SHEN and local brook trout population dynamics have been well characterized. The SHEN fish monitoring protocol is currently being updated to meet NPS Inventory and Montoring Program standards (i.e. Oakley et al. 2003; Wofford and Demarest 2011).

This report presents a brief summary of information collected during 2010 fish vital signs monitoring in Shenandoah National Park and places it in context of data collected since 1996. Results are preliminary. More exhaustive analyses and interpretation occur during long term trend assessments. A long-term assessment of fish populations in SHEN is currently underway and a summary report is expected in 2013.

Objectives

The overarching goal of the SHEN fish monitoring program is to meet the objectives of the NPS Vital Signs Program (as described above) and thereby provide a framework for monitoring long-term change in aquatic ecosystem integrity according to watershed, geology, and elevation. Four specific monitoring objectives are identified for fish populations in Shenandoah National Park:

1) Determine long-term trends in fish species abundance and biomass and community composition within selected stream sites over time.

2) Determine long-term trends in condition factors and reproduction of salmonids and centrarchids (i.e. gamefish) within selected stream sites over time.

3) Determine relationships between physical and biological parameters and fish community and population dynamics (species abundance, community composition, biomass, condition, reproduction, etc.) within selected stream sites over time.

4) Establish baselines and thresholds of fish population metrics that trigger additional research or management actions.

Methods

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

Fish sampling sites are spatially distributed across the park and are loosely stratified by watershed, elevation, and by the three dominant geologic types found in Shenandoah. Park staff currently monitor 41 sites on 18 streams every two years (primary sites) with additional sites sampled rotationally at least once every eight years (secondary sites) (Figure 1). Twenty-five secondary sites on 20 streams were monitored in 2010. Sites are monitored during summer months (June-August).

Monitoring of fish populations entails electrofishing surveys of standardized stream sections, generally 100 m long. Streams are sampled quantitatively (via a three-pass depletion) with one to three backpack electrofishers. All salmonids and centrarchids (i.e. trout and sunfish) are individually measured and weighed. All other fish are identified, counted, and a cumulative weight is measured by species. A Hydrolab® multiprobe water quality meter (Hach Co., Loveland, CO) is used to measure water quality parameters including temperature, dissolved oxygen, pH, and conductivity. Stream discharge is measured with a Marsh McBirney flow meter (Hach Co., Loveland, CO). Various stream habitat characteristics (e.g. wetted width, substrate, gradient, etc) are measured or estimated.

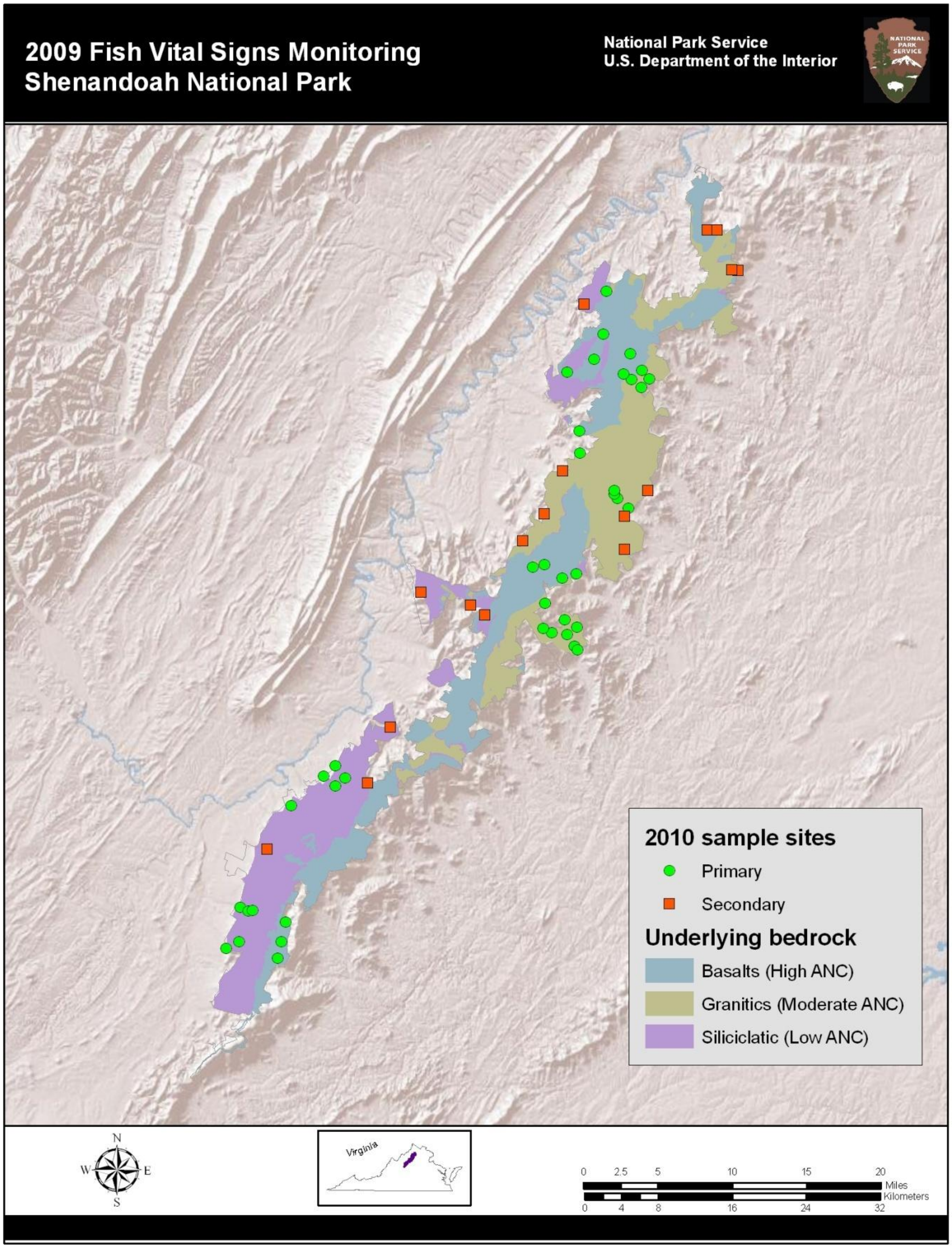

Figure 1. Map of Shenandoah National Park 2010 fish monitoring sites and underlying bedrock geology (ANC groups).

Annual data analysis involves assessment of select metrics that characterize brook trout abundance and condition, as well as species richness within sites (Table 1). Species richness is the count of fish species observed in a particular sample. Brook trout abundance is calculated as the "population" estimate at the sample site via a maximum likelihood calculator that uses depletion data (Van Deventer 1989). The calculator produces an estimate which represents the likely number of fish present within a sample site given that some individuals evaded capture. For simplicity, we continue to use the term "population" to represent the numbers of fish within a sample site, not to represent the true population (i.e. group of all interbreeding individuals) that exists at larger scales. For comparison purposes, abundance is standardized by the sample area and is therefore represented as trout density (#individuals per 100 m^2). Trout age classes (age 0 and age 1+) are determined via length-frequency analysis at each site. Mean relative weight (i.e. condition) for age 1+ brook trout (Wege and Andersen, 1978) was calculated using established length-specific weight predicted from a published weight-length regression for the species (Hyatt and Hubert, 2001).

Prior assessments have revealed fish populations in SHEN are strongly influenced by acid deposition events (largely in the form of rain) and that bedrock geology and a stream's ability to buffer acid events can dramatically influence fish condition, abundance, and species richness (Cosby et al. 2006). As such, sites were grouped for analysis based upon their capability to buffer acid deposition events. Resulting groups are high ANC (high capacity to buffer acid rain events, ANC values >150 μeq/L), moderate ANC (moderate capacity to buffer acid rain events, ANC values >50≤150 μeq/L) and low ANC (low capacity to buffer acid rain events, ANC values ≤ 50 μeq/L). High ANC streams occur over basaltic geology and moderate and low ANC streams occur over granitic and siliciclastic bedrock, respectively (Cosby et al. 2006).

Table 1. Mean species richness, brook trout density (# of individuals per 100 m^2), and age 1+ brook trout relative weight for each ANC group in 2010 for primary sites. Standard deviation and standard error are shown in parentheses.

Metric	High ANC (>150 μeq/L)	Moderate ANC (>50-≤150 μeq/L)	Low ANC (≤ 50 μeq/L)
Species Richness	6.0 (3.12, 0.76)	5.5 (4.32, 1.15)	2.5 (0.53, 0.17)
Age 0 brook trout density	3.05 (2.81, 0.68)	1.97 (1.69, 0.45)	3.62 (5.12, 1.69)
Age 1+ brook trout density	21.4 (18.6, 4.5)	15.7 (10.4, 2.8)	11.6 (7.5, 2.4)
Age 1+ brook trout relative weight	0.87 (0.07, 0.02)	0.91 (0.08, 0.2)	0.89 (0.06, 0.02)
# of sample sites	17	14	10

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).

Due to major protocol revisions in the mid-1990's, this report only includes data from 1996 to present. Only primary sites were assessed in these analyses (i.e. line graph figures) though summary metrics and water quality data from all sites are listed in Appendix B. One primary site (Lower Lewis Run) was not included in the regression analyses due to relatively little long term data for that site. In addition, data from the year 2000 did not include sample site length and width information, so data from that year were excluded from relevant analyses. Secondary sites are assessed during longer-term comprehensive analyses and associated reports. Water quality data and habitat parameters are also only assessed in longer-term trend analyses.

Results and Discussion

In 2010, 66 sites on 38 streams were assessed, including 41 primary sites and 25 secondary sites (Appendix A, Figure 1). Ultimately, 32,360 individual fish representing 26 species were captured and identified. No new species were collected.

In 2010, species richness in the 41 primary sites was greater in high and moderate ANC streams when compared to low ANC streams (Table 1). This result is consistent across years and has been noted in additional studies as well (Figure 2; see Cosby et al. 2006 for review). The discrepancy between high and moderate ANC streams and low ANC streams can likely be largely attributed to acidification (Bulger et al. 1999). Nevertheless, it is important to note that additional environmental attributes associated with low ANC streams might contribute to their low species counts. For instance, the majority of the low ANC streams in Shenandoah appear to be highly sensitive to drought and, as a result, can experience extremely low or zero flow during even minor droughts. These relatively common low flow events in these streams could negatively affect fish species richness. In addition, due to subsurface flows (dry stream sections) these streams are isolated from downstream reaches every summer and therefore, colonization rates by downstream fish species is reduced or eliminated during summer months.

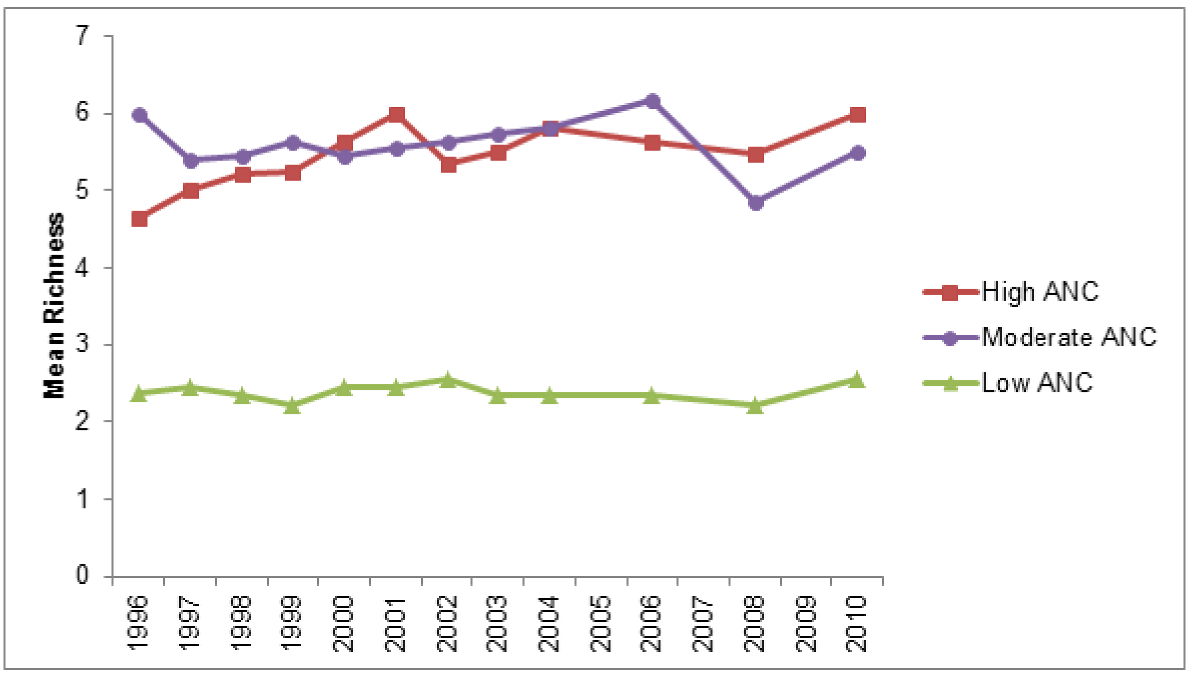

Figure 2. Mean species richness in primary sites by ANC group from 1996 - 2010.

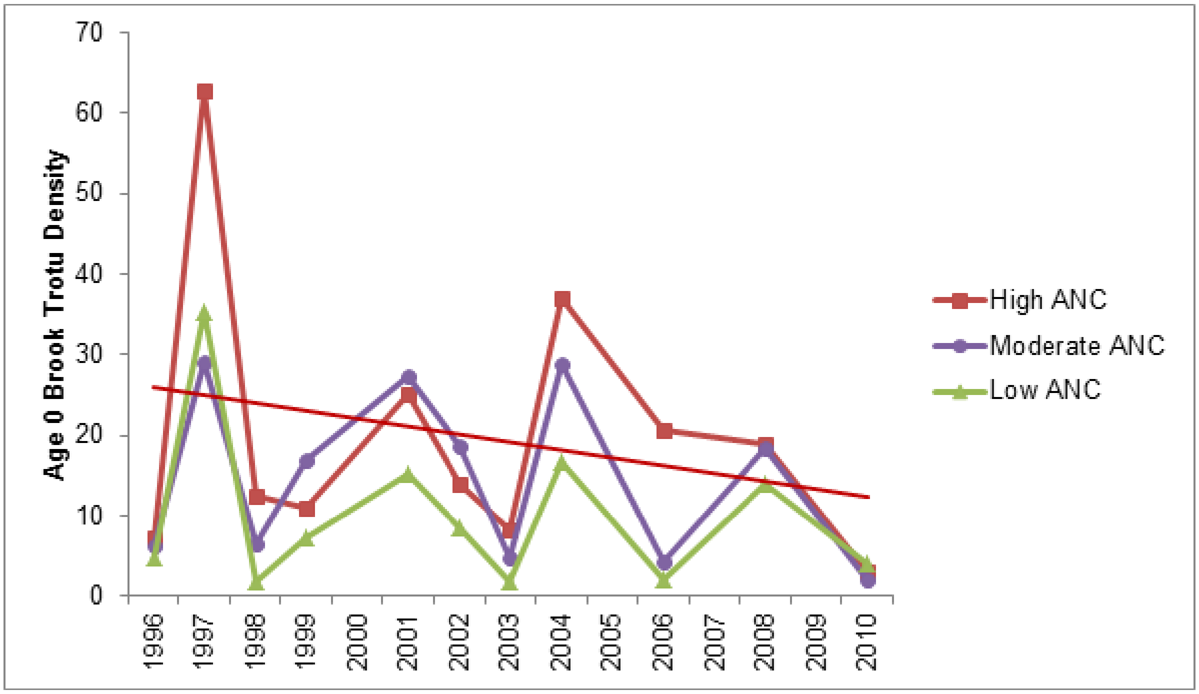

Figure 3. Mean age 0 (i.e. juvenile) brook trout density (# individuals per 100 m^2) at primary sites by ANC group from 1996 - 2010. A significant decreasing trend (diagonal red line) was observed in the high ANC group ($p<0.05$).

Across the 40 primary sites, brook trout reproduction in 2010 was lower than has been recorded in well over a decade and was the lowest on recent record for the moderate and high ANC groups (Figure 3). Since 1996, the mean density of age 0 brook trout was 23.5 per 100 m^2, 15.2 per 100 m^2, and 12.8 per 100 m^2 in the high, moderate, and low ANC groups, respectively. In 2010, these numbers were approximately an order of magnitude less (3.1, 2.0 and 3.6, respectively), essentially documenting a year-class failure across all ANC groups. Poor reproduction in 2010 was likely the result of large winter flows during January and March (Figure 4), a time when brook trout eggs and fry are highly susceptible to large flow events. The January high flow event represents the 2nd largest January flow in over 70 years of record keeping at the associated gauge on the South Fork of the Shenandoah River in Luray, VA.

A significant decreasing trend was observed in age 0 brook trout densities in the high ANC group ($p<0.05$) and decreasing trends were almost significant in the moderate and low ANC groups ($p = 0.07$) (Figure 3). It is important to note that linear regression is highly sensitive to the start and end data points (Ramsey 1996) particularly when the time scale of the data is limited. For example, the decreasing trend noted above was almost entirely a result of the poor reproduction in 2010 and therefore, may not represent a true long-term decline.

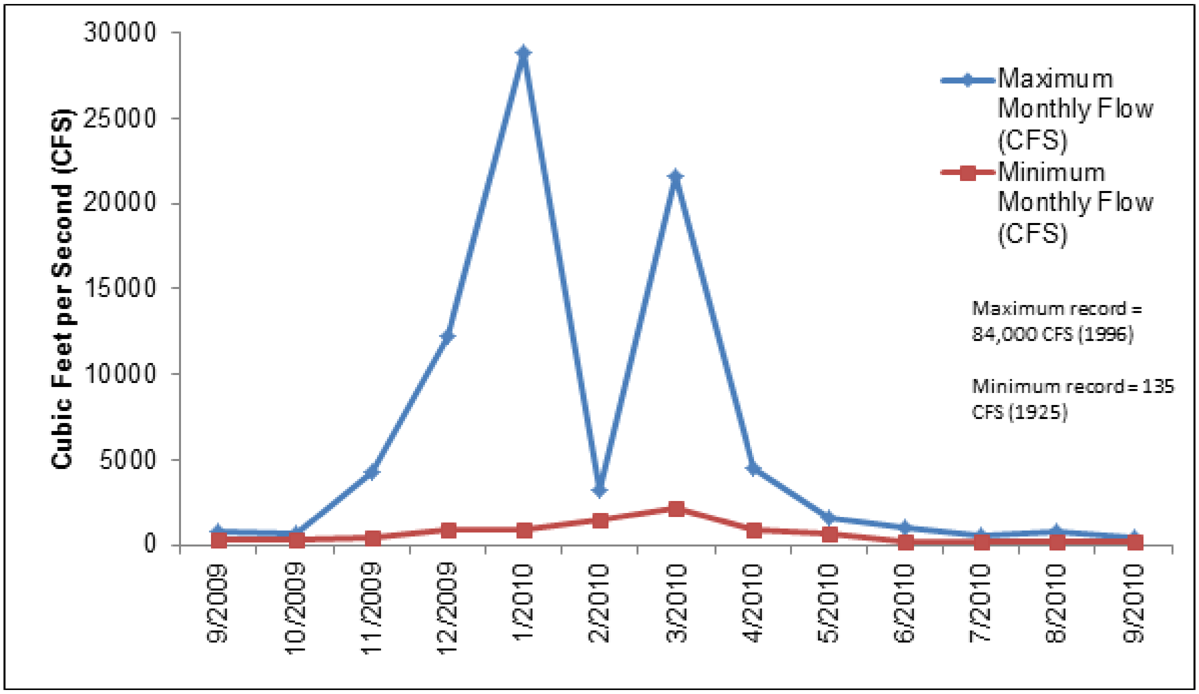

Figure 4. September 2009 – September 2010 discharge at the USGS South Fork Shenandoah gauge in Luray, VA. (USGS; http://waterdata.usgs.gov/va/nwis/uv?site_no=01629500).

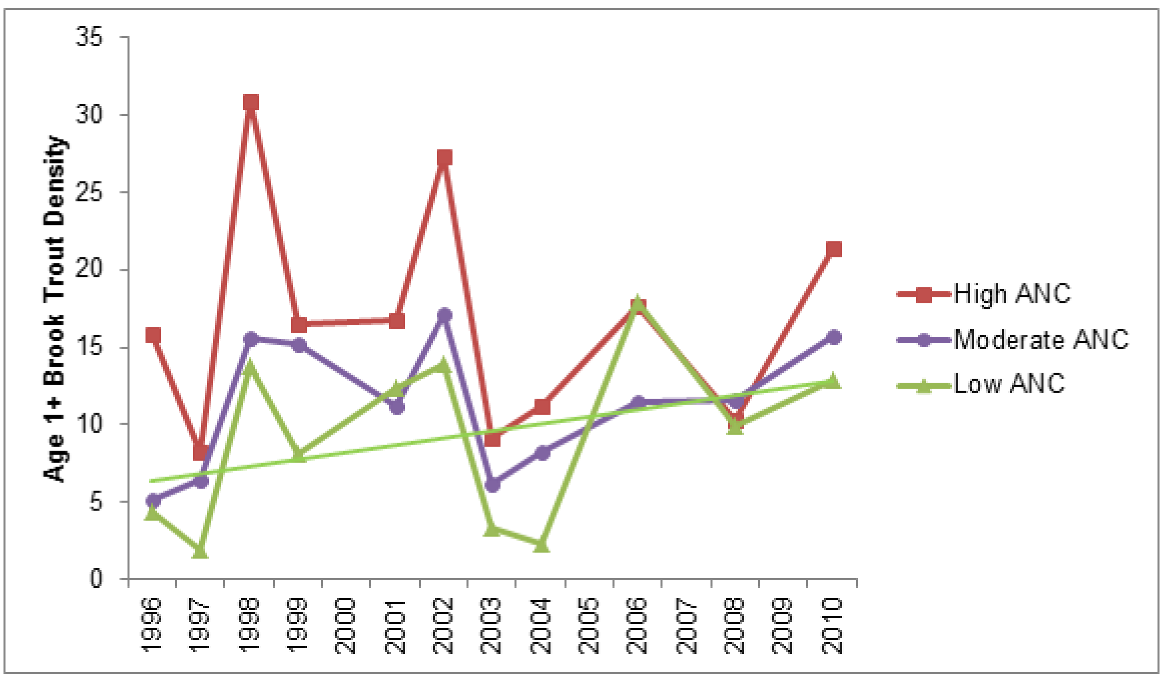

Figure 5. Mean age 1+ (i.e. adult) brook trout density (# individuals per 100 m^2) in primary sites by ANC group from 1996 - 2010. An increasing positive trend (diagonal green line) was observed in the low ANC group ($p<0.05$).

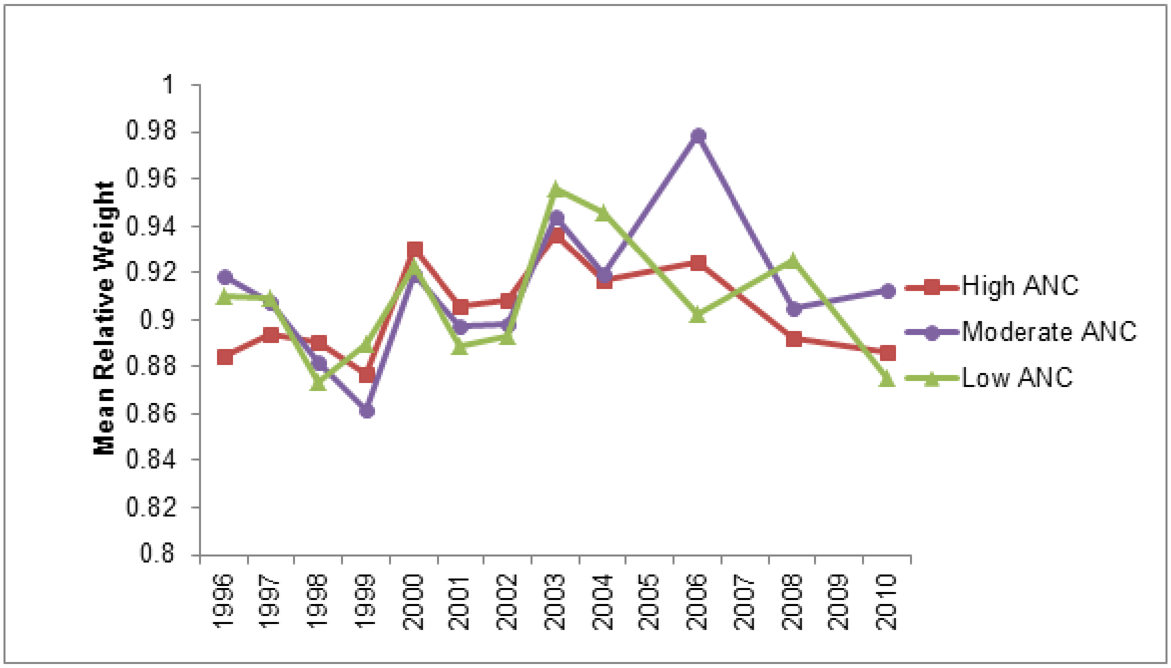

Figure 6. Mean age 1+ (i.e. adult) brook trout relative weight (i.e. condition) in primary sites by ANC group from 1996 - 2010.

In contrast to age 0 trout, age 1+ brook trout were observed in densities that were higher than historical averages across all ANC groups (Figure 5). Results of fish monitoring to date indicate that adult numbers are largely correlated with the reproductive success the year prior (Shenandoah National Park, unpublished data), and as such, data from 2010 suggest a relatively good year of reproduction in 2009 (fish monitoring did not occur in 2009). Nevertheless, 2010 summer stream flows in SHEN approached record lows, and these extremely low flows likely contributed to higher than average summer and early fall trout mortality (post-monitoring). An assessment of results from 1986-2010 indicates a significant increasing trend in age 1+ brook trout densities in the low ANC group ($p<0.05$; Figure 5). As noted above, with a limited time period of monitoring, this significance may represent the influence of the start and end data points and may not represent a true long-term increase (Ramsey 2006).

Relative weights of fish can be used to detect physiological stress, environmental perturbations, or beneficial environmental conditions (see Pope and Kruse 2007 for review). A visual assessment of historic data (Figure 6) indicates that relative weight is potentially less sensitive to ANC group than other metrics and in 2010, no patterns associated with ANC group were revealed (Table 1). Nevertheless, across all ANC groups from 1996-2010, some patterns can be observed. For instance, in many cases, when one ANC group experiences a good year for mean brook trout relative weight, other groups also appear to show relative weight increases (e.g. 1997-1998). Similarly, the reverse is also true – when a bad year for brook trout relative weight occurs, those effects are observed across all ANC groups (e.g. 2002-2003). Though this pattern is not universal (i.e. ANC groups do trend in different directions during certain years), its occasional emergence does support the conclusion that large-scale environmental factors other than ANC are influencing individual brook trout growth.

A review of historic data suggests that, with few exceptions, metrics associated with brook trout populations in SHEN trend in similar directions across ANC groups, suggesting that large-scale environmental factors (i.e. floods, droughts, weather associated phenomena) are influencing these fish parameters equally, if not more than acidification (Figures 3, 5, and 6). Nevertheless, acidification continues to influence brook trout parameters with reproduction being generally negatively influenced by acid deposition events in low ANC streams. Although 2010 reproduction in low ANC streams was relatively higher than in other ANC groups, this remains an exception over longer time periods.

Fish data from 2010 indicate that fish populations and communities in some primary streams in SHEN remain negatively affected by acid deposition and associated changes in water chemistry. Though results across ANC groups were variable, over the historical record, low ANC streams have lower fish diversity, poorer trout reproduction, and similarly, more sparse adult populations. Data also suggest that additional large scale environmental factors other than acidification also have a major influence on fish community and population dynamics.

Literature Cited

Bulger, A.J., B.J. Cosby, C.A. Dolloff, , K.N. Eshleman, J.R. Webb, and J.N. Galloway. 1999. Shenandoah National Park: Fish in Sensitive Habitats (SNP: FISH): An Integrated Assessment of Fish Community Responses to Stream Acidification. National Park Service Final Report. 570 pp. Available at http://www.nps.gov/nero/science/FINAL/Shen Fish/Shen Fish.htm.

Cosby, B. J., J. R. Webb, J. N. Galloway, and F. A. Deviney. 2006. Acidic Deposition Impacts on Natural Resources in Shenandoah National Park. Technical Report NPS/NER/NRTR—2006/066. National Park Service. Philadelphia, PA.

EBTJV (Eastern Brook Trout Joint Venture). 2006. Eastern brook trout: status and threats. Prepared by Trout Unlimited, Arlington, Virginia, for the Eastern Brook Trout Joint Venture. 36 p.

Fancy, S.G., J.E. Gross and S.L. Carter. 2009. Monitoring the condition of natural resources in U.S. National Parks. Environmental Monitoring and Assessment 151:161-174.

Hyatt, M.W. and W.A. Hubert. 2001. Proposed standard weight equations for brook trout. North American Journal of Fisheries Management 21:253-254.

Meehan, W.R. (ed). 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Pope, K.L. and C.G. Kruse, 2007. Condition. Pages 423- 471 *in* C.S. Guy and M.L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Simon, T.P. (ed). 1999. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press. Boca Raton, Florida.

U.S. Geological Survey. 2010. USGS Real-Time Water Data for Virginia. Available at http://waterdata.usgs.gov/va/nwis/uv?site_no=01629500 (accessed 1 March 2010).

Van Deventer, J. A., and W.S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data-user's guide for MicroFish 3.0. Gen.

Tech. Rep. INT-254. U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Wege, G.J., and R.O. Anderson. 1978. Relative weight (W_r): a new index of condition for largemouth bass. Pages 79-91 *in* G. Novinger and J. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, special Publication 5, Bethesda, MD.

Wofford, J.E.B. and E.D. Demarest. 2011. Shenandoah National Park Fish Monitoring Protocol: Version 2.2. Draft in Progress. Natural Resource Report NPS/XXXX/NRR—2011/XXX. National Park Service, Fort Collins, Colorado.

Appendix A: Sites sampled during 2010

Stream	Site #	ANC Group	Sampling Rotation[1]
Dry Run, North Fork	2F131	Moderate	Primary
Hannah Run	2F050	Moderate	Primary
Hogcamp Branch	2F055	High	Primary
Hughes River	2F038, 2F039, 2F040	Moderate	Primary
Jeremy's Run	1F007, 1FVA1, 1F118	High	Primary
Lower Lewis Run	3F105	Low	Primary[2]
Meadow Run	3F107, 3F109	Low	Primary
Moorman's River, North Fork	3F084, 3F045, 3F044	High	Primary
One Mile Run	3F126, 3F128	Low	Primary
Overall Run	1F132	High	Primary
Paine Run	3F123, 3F124, 3F125	Low	Primary
Pass Run	2F095	Moderate	Primary
Piney River	1F003, 1F145, 1F138	High	Primary
Rapidan River	2F093, 2F135, 2FVA4, 2FVA5	Moderate	Primary
Rose River	2F015, 2F016, 2F017	High	Primary
Staunton River	2F072, 2F074, 2F075, 2F076	Moderate	Primary
Thornton River, North Fork	1F030, 1FVA2, 1FVA3	High	Primary
Two Mile Run	3F103, 3F102	Low	Primary
Big Branch	3F079	High	Secondary
Big Run	3F257, 3F021	Low	Secondary
Bolton Branch	1F056, 1F058	Moderate	Secondary
Broad Hollow Run	2F067	Moderate	Secondary
Brokenback Run	2F252	Moderate	Secondary
Dry Run, South Fork	2F140	Moderate	Secondary
Fultz Run	2F122	Low	Secondary
Happy Creek	1F229	High	Secondary
Hawksbill Creek	3F262, 3F263	High	Secondary
Hawksbill Creek, East	2F119	Moderate	Secondary
Hawksbill Creek, Little	2F110	Moderate	Secondary
Heiskell Hollow (East Fork Compton Creek)	1F231	High	Secondary
Hickerson Hollow	1F230	High	Secondary
Madison Run	3F025	Low	Secondary
Naked Creek, East Branch	2F029	High	Secondary
Naked Creek, W.Branch (Post 1996)	2F113	High	Secondary

Appendix A: Sites sampled during 2010 (continued)

Stream	Site #	ANC Group	Sampling Rotation[1]
Ragged Run	2F060	Moderate	Secondary
Sawmill Run	3F143, 3F144	Low	Secondary
Swift Run	3F041, 3F043	High	Secondary
Thornton River, South Fork	2F036	Moderate	Secondary

[1] Primary sites are sampled every other year, secondary sites are sampled on a rotational basis at least once every 8 years.

[2] Lower Lewis Run (Site 3F105) became a primary site in 2006 when brook trout were confirmed to have been extirpated from that stream. Due to relatively little data available from Lower Lewis prior to the extirpation, it was not included in the analyses in this report.

Appendix B: Sample site water quality data and fish summary metrics

Site ID	Sample Date	Time	Temperature (°C)	DO[1]	Conductivity (µS)	pH	Taxa Richness	Brook trout Age 0 density[2]	Brook trout Age1+ density[2]	Mean brook trout condition
1F003	2010-06-22	-	18.17	8.68	38.0	7.01	6	2.96	6.77	0.90
1F007	2010-07-27	13:38	22.41	8.70	54.1	6.73	5	1.70	19.53	0.85
1F030	2010-07-21	-	22.78	8.14	49.9	6.59	12	1.13	6.60	0.83
1F056	2010-08-02	12:22	20.02	8.52	41.7	6.55	3	1.37	23.71	0.84
1F058	2010-08-02	9:22	18.62	8.64	36.7	6.34	3	4.14	27.80	0.86
1F118	2010-07-29	8:19	20.16	7.58	50.9	6.48	4	5.27	28.69	0.86
1F132	2010-07-12	14:02	20.56	9.58	71.5	7.59	2	6.19	3.10	0.88
1F138	2010-06-21	9:36	16.60	8.75	31.0	6.86	2	10.89	38.25	0.90
1F145	2010-06-22	8:40	16.51	8.68	37.0	6.75	6	6.24	19.76	0.89
1F229	2010-08-04	14:02	22.09	6.27	105.4	6.35	2	0.00	0.00	NA
1F230	2010-07-28	8:37	19.74	8.62	41.9	6.52	3	0.00	0.00	NA
1F231	2010-08-19	9:06	21.37	2.73	91.0	6.57	4	1.60	1.60	0.88
1FVA1	2010-07-27	9:16	20.97	5.11	48.8	6.04	4	4.28	75.11	0.85
1FVA2	2010-07-22	14:08	20.69	3.46	58.1	6.01	9	1.32	3.51	1.05
1FVA3	2010-07-22	10:00	20.74	8.25	55.5	6.77	7	1.65	6.99	0.82
2F015	2010-07-21	10:30	20.00	10.80	-	6.20	10	0.56	22.28	0.87
2F016	2010-07-21	14:50	21.00	10.00	-	6.20	7	1.11	19.05	0.93
2F017	2010-07-21	13:50	19.75	8.90	29.2	6.36	3	0.64	24.02	0.87
2F029	2010-08-03	9:08	19.10	8.43	33.6	6.34	2	2.31	25.46	0.85
2F036	2010-07-12	7:50	18.98	9.35	102.2	6.68	12	0.60	0.60	0.95
2F038	2010-07-07	12:58	21.57	9.09	20.3	6.47	15	0.43	4.11	0.92
2F039	2010-07-07	9:02	18.61	9.40	20.4	6.51	5	1.77	11.33	0.88
2F040	2010-07-06	-	-	-	-	-	4	3.01	13.64	0.91

Appendix B: Sample site water quality data and fish summary metrics (continued)

Site ID	Sample Date	Time	Temperature (°C)	DO[1]	Conductivity (µS)	pH	Taxa Richness	Brook trout Age 0 density[2]	Brook trout Age1+ density[2]	Mean brook trout condition
2F050	2010-07-06	-	-	-	-	-	3	1.17	12.61	0.92
2F055	2010-07-21	10:10	17.24	9.19	29.1	6.57	2	4.17	42.58	0.89
2F060	2010-07-19	8:52	20.39	7.51	20.5	5.62	2	3.08	10.78	0.90
2F067	2010-07-20	8:25	20.72	8.27	21.7	5.66	2	0.97	4.83	0.87
2F072	2010-06-30	14:06	17.63	-	18.0	-	5	6.91	17.16	0.94
2F074	2010-06-24	9:14	17.78	8.92	17.0	6.67	2	2.79	18.60	0.94
2F075	2010-06-23	9:52	15.88	9.31	16.0	6.68	2	1.72	35.15	0.91
2F076	2010-06-23	14:23	15.95	9.09	14.0	6.71	2	0.97	28.36	0.88
2F093	2010-06-30	8:40	18.63	-	21.0	-	14	0.73	0.85	0.88
2F095	2010-06-02	11:00	17.41	9.17	74.0	7.10	9	0.82	4.48	0.89
2F110	2010-08-05	12:44	19.53	8.63	40.2	6.50	2	1.12	18.30	0.91
2F113	2010-08-03	13:55	20.44	7.95	61.0	6.75	6	2.57	2.57	0.76
2F119	2010-08-05	8:15	19.24	8.75	28.7	6.00	2	6.68	30.18	0.93
2F122	2010-07-19	14:37	23.35	7.14	47.7	6.01	2	5.12	12.79	0.86
2F131	2010-06-01	13:41	15.61	8.77	23.0	6.40	2	0.99	5.31	0.97
2F135	2010-06-28	8:30	19.71	-	22.0	-	7	1.94	17.09	0.94
2F140	2010-07-20	12:42	19.86	8.31	41.1	6.36	2	12.16	16.21	0.89
2F252	2010-07-28	13:43	22.44	8.42	19.6	6.09	3	1.19	2.14	0.84
2FVA4	2010-06-28	12:54	20.55	-	21.0	-	4	3.37	21.63	0.91
2FVA5	2010-06-29	8:27	17.84	-	21.0	-	3	0.96	29.35	0.90
3F021	2010-08-09	9:10	21.21	9.00	25.6	6.22	10	0.00	0.00	NA
3F025	2010-07-14	12:45	19.97	8.98	23.3	5.82	4	0.00	0.00	NA

Appendix B: Sample site water quality data and fish summary metrics (continued)

Site ID	Sample Date	Time	Temperature (°C)	DO[1]	Conductivity (µS)	pH	Taxa Richness	Brook trout Age 0 density[2]	Brook trout Age1+ density[2]	Mean brook trout condition
3F041	2010-07-26	9:15	20.63	8.43	94.1	6.39	10	0.94	4.40	0.84
3F043	2010-07-26	13:45	19.85	8.70	100.7	6.51	4	1.45	2.90	0.97
3F044	2010-06-10	15:43	18.48	8.40	31.0	6.88	5	2.26	32.31	0.93
3F045	2010-06-10	10:13	16.86	8.89	31.0	6.81	7	0.99	13.85	0.91
3F079	2010-07-15	10:42	20.17	8.52	21.2	5.82	2	2.67	33.78	0.86
3F084	2010-06-08	9:45	17.37	8.65	31.0	6.79	11	0.52	1.57	0.85
3F102	2010-06-14	8:54	16.77	6.45	17.0	5.89	2	2.85	8.19	0.90
3F103	2010-06-14	-	18.88	7.61	16.0	5.89	2	0.93	5.57	0.94
3F105	2010-07-08	9:27	20.39	7.60	17.1	5.39	2	0.00	0.00	NA
3F107	2010-06-07	9:30	16.48	8.19	15.0	5.33	3	3.38	21.74	0.84
3F109	2010-06-07	13:35	16.33	8.86	14.0	5.43	2	1.29	16.25	0.84
3F123	2010-06-16	8:43	19.16	7.48	18.0	5.91	3	1.47	5.13	0.90
3F124	2010-06-15	11:50	19.48	7.64	19.0	5.58	3	6.89	12.92	0.85
3F125	2010-06-15	-	16.82	6.17	21.0	5.60	3	17.09	18.21	0.87
3F126	2010-06-17	13:00	19.04	6.38	14.0	5.36	3	1.09	3.83	1.02
3F128	2010-06-17	9:28	17.09	7.63	17.0	5.95	2	1.16	24.00	0.91
3F143	2010-07-13	-	16.22	6.37	16.7	4.48	4	6.71	13.41	0.87
3F144	2010-07-13	9:25	17.58	6.17	15.7	4.98	6	1.39	8.35	0.89
3F257	2010-08-09	14:17	23.01	8.21	24.2	5.99	11	0.53	1.93	0.84
3F262	2010-08-11	12:09	24.64	9.68	86.20	7.50	16	0.00	0.00	NA
3F263	2010-08-11	8:43	20.05	6.63	47.5	6.19	8	2.48	17.33	0.78

[1] Dissolved oxygen (mg/L)

[2] Number of individuals per 100m^2