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Natural Resource Stewardship and Science

Aquatic Invertebrate Monitoring at Buffalo National River

2005-2011 Status Report

Natural Resource Technical Report NPS/BUFF/NRTR—2013/757

ON THE COVER
Buffalo River at Buffalo National River
Photograph from: The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program files

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2005-2011 Status Report

Natural Resource Technical Report NPS/BUFF/NRTR—2013/757

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Contents

Figures

Page

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

Executive Summary

Since 2005 the National Park Service Heartland Inventory and Monitoring Network (HTLN) has monitored water quality in streams at Buffalo National River (BUFF) by assessing aquatic invertebrate community structure following a monitoring protocol developed specifically for the park. Two objectives are addressed by this protocol: 1) Determine the status and trends of invertebrate species diversity, abundance and community metrics, and 2) Relate the invertebrate community to overall water quality through quantification of metrics related to species richness, diversity and region specific multi-metric indices as indicators of water quality and habitat condition. This report summarizes the results of monitoring conducted from 2005 to 2011.

Six mainstem river sites and 23 tributary sites were sampled during a November-February index period. At each sampling site, three benthic invertebrate samples were collected from each of three successive riffles at each sampling site using a Slack-Surber sampler. Taxa were identified to the lowest practical taxonomic level (usually genus) and counted.

Aquatic invertebrate metrics calculated for the data included taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) richness, Shannon's Diversity Index, and Hilsenhoff Biotic Index. The invertebrate metrics calculated for sampling sites were generally consistent with those previously reported for unimpaired streams in the Ozark region. Stream Condition Index (SCI) scores showed that most mainstem river sites across years were not impaired (SCI $\geq$16). Some sites in some years were scored as mildly impaired, but the observed range of SCI scores within sites is attributed to the natural variability that occurs within benthic invertebrate communities rather than issues related to water quality. BUFFM03 and BUFFM04 generally had the lowest SCI scores among all sampling sites across all years sampled. This may be due to these sites being located near losing reaches during periods of low flow, in addition to anthropogenic disturbances in the tributaries flowing into these stream reaches. SCI scores calculated from invertebrate collections taken at Buffalo River water quality sampling sites in 2005 showed a similar magnitude to neighboring HTLN sites.

Ozark Rivers Stream Invertebrate Multimetric Index (ORSIMI) calculated for mainstem Buffalo River sampling sites generally equaled or exceeded the baseline values for the index. These scores show that the aquatic invertebrate communities of Buffalo River monitoring sites, as described by the individual metrics, have either improved or have not changed appreciably in comparison to the baseline data used to develop the index.

Most tributaries had SCI scores that showed they were not impaired, but some had SCI scores indicating they were impaired at the time of sampling. Presently, there are insufficient data to accurately assess tributary status in the Buffalo River Watershed using only aquatic invertebrate communities. Because stream invertebrate communities may be highly variable over time, additional sampling must be conducted to determine whether those scores truly indicate impairment, or whether they simply reflect the natural inherent variability of the system.

Aquatic invertebrate monitoring at BUFF provides a sound tool to recognize both deterioration and chronic decline of water quality at BUFF.

Acknowledgments

We thank Hope Dodd, Mike DeBacker, Faron Usrey, Shawn Hodges, Jared James, Angela Bandy, Ryan Green, Cary Nabors, Kyle Ellis, Jennifer Haack, and Jessica Luraas, for assisting with this project. We thank Dr. Kip Heth and Brandy Bergthold for reviewing an earlier draft of this report.

Introduction

Buffalo National River (BUFF), located in north central Arkansas, is one of the two largest units of the National Park Service in the Ozark Plateaus. The Buffalo River and its tributaries are located in an area of extensive karst topography, making the rivers vulnerable to contaminated groundwater recharge and interbasin transfer of groundwater from adjacent watersheds. BUFF was established to protect the corridor of the Buffalo River and its tributaries. However, the NPS jurisdictional boundary around the Buffalo River is generally a narrow corridor that encompasses only about 11% of the watershed, while over 50% of the watershed is in private ownership. This leaves much of the watershed unprotected from human activities such as timber management, landfills, grazing, livestock operations, urbanization, gravel mining, stream channelization, and removal of riparian vegetation. Since the establishment of Buffalo National River in 1972, more of the watershed has been deforested than is protected within the boundaries of the National River (Mott 2000). Over a 27-year study period, the annual increase in pasture land in the BUFF watershed was almost equal to the annual decrease in forested land (Scott and Hofer, 1995). Increases in bank erosion rates and changes in channel morphology through time have been correlated with increased land clearing of steep uplands within a tributary basin (Stephenson and Mott 1992) and historical riparian land clearing (Jacobson and Primm 1997). Presently, all new discharges to the catchments of the Buffalo River are prohibited as part of an anti-degradation strategy. Although wadeable streams of the Ozarkian region, including those at BUFF, generally are in good condition, the previously noted stressors threaten their integrity (United States Environmental Protection Agency 2006).

Aquatic invertebrates are an important tool for understanding and detecting changes in ecosystem integrity, and they can be used to reflect cumulative impacts that cannot otherwise be detected through traditional water quality monitoring. The broad diversity of invertebrate species occurring in aquatic systems similarly demonstrates a broad range of responses to different environmental stressors. Benthic invertebrates are relatively easy to collect, and they can be analyzed at many different levels of precision. They are sensitive to a wide variety of impacts that occur in the Ozark, such as changes in chemical constituents (including metals) hydrological alterations, sedimentation, bank erosion, land use, and other changes in the watershed. Furthermore, changes in the diversity and community structure of benthic invertebrates are relatively simple to communicate to resource managers, administrators, and park visitors because the loss of biological communities is of interest and concern to these groups.

There have been several previous studies conducted on stream invertebrate communities at BUFF (see Bowles *et al*. 2007 for review). Water quality and stream invertebrate community assessments conducted at BUFF (Bradley 2001, Bryant 1997, Mathis 2001, Mott 1997, Usrey 2001) have shown a strong negative correlation between agricultural nonpoint source chemical pollution (nitrates) and stream water quality and invertebrate community structure. However, these studies were either single season events that did not assess inter-annual variation in samples, or they did not assess trends in data to detect potential water quality degradation. Bowles et al. (2007) published a stream invertebrate monitoring protocol to assess aquatic invertebrate community structure at fixed sites on the Buffalo River and selected tributaries at BUFF. This protocol was designed to incorporate the spatial relationship of invertebrates with their habitat. Two broad objectives are addressed by this protocol: 1) determine the status and trends of invertebrate species diversity, abundance, and community metrics, and 2) relate the invertebrate community to overall water quality through quantification of metrics related to species richness, abundance, diversity, and region-specific multi-metric indices as indicators of water quality and habitat condition (DeBacker et al. 2005). This report summarizes the results for monitoring conducted from 2005-2011.

Methods

Site Selection

Methods and procedures used in this report follow Bowles *et al*. (2007). Sampling was conducted annually at six permanent mainstem river sites on the Buffalo River from 2005-2009 and during 2011 (Fig. 1). All samples were collected during a November through February index period. BUFFM01 was dry during the index period in 2005 and could not be sampled, and in 2006 BUFFM06 was flooded during most of the index period and also could not be sampled. In addition, 23 tributary sites were sampled from 2006-2010 during the same index period (Table 1). These tributaries comprised a 5-year rotating panel described in the original monitoring protocol (Bowles et al. 2007). All sites were selected by use of the Generalized Random Tessellation Stratified (GRTS) method, which generates a spatially balanced sample with a high degree of randomness (see Bowles et al. 2007). Seven tributaries at BUFF could not be sampled for invertebrates during the index period because they were dry or had insufficient flow (see Bowles et al. 2007 for a list of those tributaries).

Recommended revisions of the protocol (DeBacker et al. 2012) listed several tributaries at BUFF that were prioritized for future sampling by BUFF management, including some of those previously sampled. These included Mill Creek at Pruitt (BUFFT07), Davis Creek (BUFFT15), Calf Creek (BUFFT19), Bear Creek (BUFFT20), Clabber Creek (BUFFT27), Middle Creek (BUFFT30), and Leatherwood Creek (BUFFT31), all of which were resampled during 2011.

Invertebrate Sampling

Three benthic invertebrate samples were collected from each of three successive riffles at each sampling site using a Slack-Surber sampler (500 μm mesh, 0.25 m^2). The sample area was agitated for 2 minutes with a garden cultivation tool, and large pieces of substrate were scrubbed with a brush as necessary. Bulk samples were placed in plastic jars and preserved with either 99% isopropyl or 95% ethyl alcohol. Samples were sorted in the laboratory following a subsampling routine described in Bowles *et al*. (2007), and taxa were identified to the lowest practical taxonomic level (usually genus) and counted.

In addition to sampling conducted by HTLN, BUFF staff collected invertebrate samples from mainstem Buffalo River water quality sites and tributaries (Fig. 1). Collection methods used by BUFF staff were similar to those reported here. Data for the mainstem sites are analyzed in this report for the purpose of comparison to HTLN monitoring sites. Mixon-Hinsey (2008) reported on the tributary data collected by BUFF staff.

Water Quality and Habitat Assessment

For each benthic sample taken, current velocity (meters/second) and depth (cm) were recorded directly in front of the sampling net frame. Qualitative habitat variables (percent embeddedness, periphyton, filamentous algae, aquatic vegetation, deposition, and organic material) were estimated within the sampling net frame as percentage categories (0, <10, 10-40, 40-75, >75). Habitat data were analyzed as midpoints of each category. Twenty pieces of substrate were collected from inside the sampling net frame, scrubbed with a soft brush to remove attached invertebrates, rinsed in a wash bucket, and measured using the Wentworth scale (Wentworth 1922).

Static readings of water quality parameters (temperature, dissolved oxygen, specific conductance, pH) were recorded at each riffle sampled with hand-held calibrated instruments at mainstem and tributary sites (Appendix A). Stream discharge was measured at each site where flow conditions permitted using the methods of Carter and Davidian (1969). Hourly readings of water quality parameters (temperature, dissolved oxygen, specific conductance, pH, turbidity) were recorded continuously at least 1 week prior to sampling using data loggers at fixed sites on the Buffalo River located near BUFFM02, BUFFM04, and between BUFFM05 and BUFFM06. The length of logger deployment varied, but it typically was about 2 weeks in duration. Data loggers were not used on tributaries. The water quality and discharge data collected for this study are only intended to describe the prevailing conditions that may influence the structure of invertebrate communities. As such, they may help explain variability between sampling periods, but they should not be used as an analytical tool in the strictest sense (Bowles et al. 2007). Moreover, the water quality and discharge data represent only a small snapshot of the broader range of possible conditions over longer periods, and should be cautiously interpreted. Due to the limitations of using water quality data obtained with data loggers, the invertebrate community is used here as a surrogate of long-term water quality conditions. Summary data for habitat variables are presented in Appendix A.

A preliminary nonmetric multidimensional scaling (NMS) analysis applied to habitat and invertebrate data showed most habitat variables were weakly correlated with NMS ordination axes in both mainstem sites and tributaries (DeBacker et al. 2012). Because of this inconclusive finding, further analysis of habitat data are not conducted in this report. A broader analysis of habitat data in relation to benthic invertebrate community structure will be conducted when additional data become available.

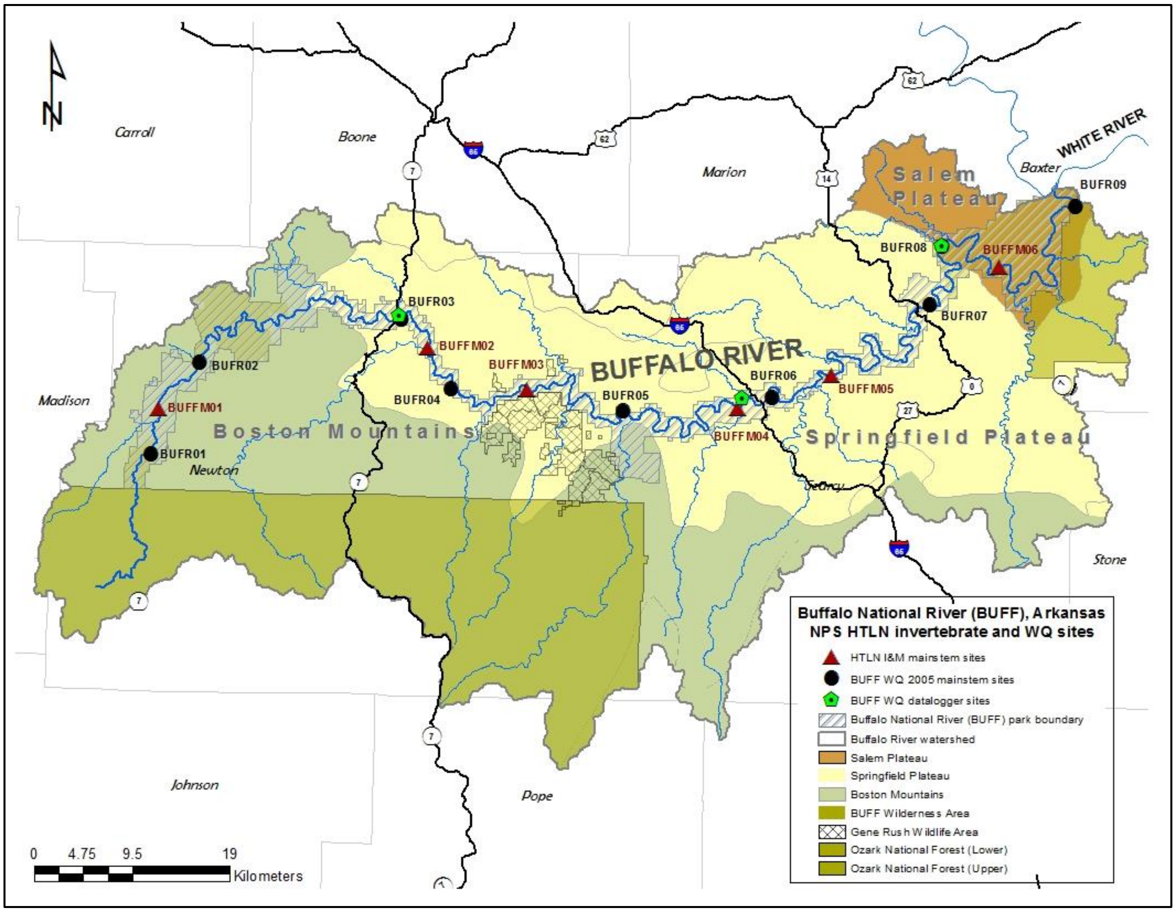

Figure 1. Location of water quality and benthic invertebrate sampling sites on the Buffalo River. BUFF water quality sampling locations are black circles, HTLN monitoring sites are red triangles, and data logger sites are green pentagons

Table 1. Tributaries sampled at Buffalo National River during 2006-2011.

Year	Reach ID	Site/Trib Number	Trib Name	County	Lower Stretch UTMX	Lower Stretch UTMY
2006	BUFFT03	03	Whiteley	Newton	463933.84	3982976.75
	BUFFT09	09	Little Buffalo	Newton	490340.91	3987600.00
	BUFFT22	22	Spring	Searcy	536995.44	3986311.00
	BUFFT24	24	Hickory	Marion	540092.81	3992069.50
	BUFFT30	30	Middle	Marion	551428.31	3993556.50
	BUFFT31	31	Leatherwood	Marion	551307.69	3996258.00
2007	BUFFT05	05	Cecil	Newton	479905.44	3992743.25
	BUFFT07	07	Mill	Newton	487979.09	3990501.25
	BUFFT25	25	Little Panther	Marion	540006.31	3993475.25
	BUFFT33	33	Stewart	Marion	552646.50	4000976.50
2008	BUFFT04	04	Sneeds	Newton	472172.12	3990497.25
	BUFFT13	13	Big	Newton	495709.59	3981030.75
	BUFFT15	15	Davis	Newton	504216.16	3984923.25
	BUFFT16	16	Mill Branch	Newton	504310.34	3984978.25
2009	BUFFT01	01	Smith	Newton	464098.72	3978179.75
	BUFFT06	06	Glade	Newton	481332.88	3992648.50
	BUFFT10	10	Wells	Newton	490814.66	3986624.00
	BUFFT11	11	Rock	Newton	492478.22	3984111.00
	BUFFT20	20	Bear	Searcy	526905.38	3983413.50
	BUFFT23	23	Water	Searcy	538186.50	3989492.75
2010	BUFFT08	08	Vanishing	Newton	489406.03	3989463.00
	BUFFT14	14	Lick	Newton	499899.69	3983426.50
	BUFFT17	17	Richland	Searcy	509734.38	3975988.00
	BUFFT27	27	Clabber	Marion	540925.44	3998147.75
2011	BUFFT07	07	Mill	Newton	487979.09	3990501.25
	BUFFT15	15	Davis	Newton	504216.16	3984923.25
	BUFFT19	19	Calf	Searcy	520463.22	3981045.50
	BUFFT20	20	Bear	Searcy	526905.38	3983413.50
	BUFFT27	27	Clabber	Marion	540925.44	3998147.75
	BUFFT30	30	Middle	Marion	551428.31	3993556.50
	BUFFT31	31	Leatherwood	Marion	551307.69	3996258.00

Invertebrate Metrics and Stream Condition Index (SCI)

For each benthic sample, taxa richness, Ephemeroptera, Plecoptera and Trichoptera (EPT) richness, Shannon's Index of Diversity, and Hilsenhoff's Biotic Index (HBI) were calculated. These and other community metrics are described in Barbour et al. (1999). They are generally considered sufficiently sensitive to detect a variety of potential pollution problems in Ozark streams throughout the region without respect to state jurisdictional boundaries. Mean metric values were established by averaging the values for each of three samples per riffle and then averaging the means for the three riffles to establish a site mean (n=3).

Using the mean values of these four metrics for each monitoring site, the Stream Condition Index (SCI) was calculated (Sarver et al. 2002). The SCI is a multimetric index founded on the reference site approach based on data collected from 26 streams in the Ozark region (Rabeni et al. 1997). The SCI is based on scores from the previously listed four metrics, which were chosen as sound measures of community structure and balance (Rabeni et al. 1997) (Table 2). All metric values are normalized so that they become unitless and can be compared, and have equal influence on the SCI results following the suggestion of Barbour et al. (1999). The lower or upper quartile of the distribution for each metric is used as the minimum value representative of reference conditions (Table 3).

The SCI scores produce three possible levels of stream condition: 1) fully biologically supporting (unimpaired), 2) partially biologically supporting (impaired), and 3) non-biologically supporting (very impaired). Unimpaired or reference sites typically score ≥16, so scores of 16-20 infer a stream that is fully biological supporting. These streams have the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region. Sites with scores of 10-14 indicate streams that are partially biologically supporting, and scores of 4-8 designate streams that are not biologically supporting. Both partially biologically supporting and non-biologically supporting categories indicate impaired streams that do not meet the beneficial use of protection of aquatic life. See Sarver et al. (2002) and Bowles et al. (2007) for further details on how these metrics and the SCI are calculated.

Some caution is required when evaluating SCI results. The SCI increases with lower HBI metric scores. HBI is strongly influenced by the abundance of the dipteran family Chironomidae, which have a tolerance value of 6, but representatives of many chironomid genera are intolerant to disturbance. Assigning a high tolerance value to all chironomids gives the indication that water quality may be degraded when in reality it is not. Chironomids represent a major portion of the benthic community in nearly all Ozark stream samples, and in undisturbed streams the majority is often intolerant Orthocladinae (Wallace and Rabeni 2008).

Table 2. Mean metric values from riffle habitat of reference streams (n=5) in the Ozark ecoregion during fall index period (from Rabeni et al. 1997).

Metric	Mean	Standard Error	Minimum	Maximum
Taxa richness	28.3	3.29	23.5	41
EPT richness	13.1	0.69	11.5	15
HBI	4.3	0.34	3.3	5
Shannon’s Diversity Index	2.43	0.13	2.08	2.72

Table 3. Descriptive statistics and scores for the metrics for the fall index period based on single habitat coarse substrate (riffle) data.

	Statistics					Scores		
Metric	1%	25%	50%	75%	99%	5	3	1
Taxa richness	16	21	26	29	35	>=21	20-11	<11
EPT richness	5	9	11	12	14	>=9	8-5	<5
HBI	3.0	3.6	4.9	5.3	5.8	<=5.3	5.4-7.7	>7.7
Shannon's Diversity Index	1.33	2.29	2.44	2.61	2.96	>=2.29	2.28-1.15	<1.15
SCI Scoring: >16 not impaired, 10-14 impaired, 4-8 very impaired.								

Ozark Rivers Stream Invertebrate Multimetric Index (ORSIMI)

Although the SCI performs well for Ozark streams (Rabeni et al. 1997, Sarver et al. 2002), its categorical nature does not allow for an assessment of the magnitude of change that might occur in streams. The Ozark Rivers Stream Invertebrate Multimetric Index (ORSIMI) (DeBacker et al. 2012) was developed to fill this gap. Although the SCI is usually for assessing overall impairment, the ORSIMI is a more relevant index for interpreting degree of change in the invertebrate communities.

The ORSIMI is similar to the SCI in that it is based on four metrics: taxa richness, EPT richness, Shannon's Index, and the HBI (Table 4). The ORSIMI index is arbitrarily scaled to 100 for the baseline period (in this case, 5 years). The average of each metric value over the baseline period is multiplied by a constant so that each metric contributes a total of 25 toward the 100 score total. The HBI score is subtracted from 10, because a lower HBI score indicates better water quality, and 10 is the maximum value for the HBI. All future data are compared to that baseline (i.e., the same constant is multiplied by each metric in all future years). Each site is calculated independently from the rest, because sites are not directly comparable. The index can be expanded if additional metrics are shown to be useful for interpreting change in community structure. The ORSIMI was calculated only for mainstem sampling sites with multi-year data.

Similar to the SCI, each of the four metrics of the ORSIMI contributes the same weight to the overall index (based on baseline conditions), but the new index has greater resolution and sensitivity. For the SCI, any changes within 75% of the hypothesized distribution of values for any of the metrics would have no change on the index. In comparison, any change of any magnitude in any metric will result in a change in the overall ORSIMI. That change potentially could be negative or positive (i.e., total scores may be >100 if conditions improve). Unlike the SCI, there are no subjective judgments on what values indicate "impairment", and any comparisons are simply made to the baseline condition.

Table 4. ORSIMI baseline values for BUFF mainstem river sites based on data collected 2005-2009.

Site	Mean Taxa Richness	Mean EPT Richness	Mean Shannon Index	Mean HBI	10-HBI	ORSIMI
BUFFM01	26.639	15.75	1.9431	4.95134	5.0487	100
BUFFM02	24.4	12.578	2.1571	4.68747	5.3125	100
BUFFM03	21.089	12.178	2.0814	4.24772	5.7523	100
BUFFM04	20.711	11.222	1.8063	4.82323	5.1768	100
BUFFM05	21.111	11.378	1.9871	4.30295	5.697	100
BUFFM06	22.639	11.833	2.0667	4.48162	5.5184	100

Results

Mainstem Sites

SCI results

Although there was a fair amount of variation among years for each site, mean SCI scoring for BUFF streams shows that mainstem river sites generally were unimpaired across years sampled (Figs. 2-7). The exceptions were for BUFFM01 in 2007, BUFFM03 in 2009, BUFFM04 in 2005, BUFFM05 in 2006, and BUFFM03 and BUFFM04 in 2011. Although some of these sites were rated as impaired with a mean SCI, some of the individual riffles at those sites and in those years had SCI scores greater than 16. None of the individual riffles scored an acceptable level for BUFFM03 in 2011 or BUFFM04 in 2005. The high SCI scores for BUFF streams are supported by the high metric scores for taxa and EPT richness and relatively low HBI (Appendix B). The observed range of SCI scores within sites is attributed to the natural variability that occurs within benthic invertebrate communities rather than issues related to water quality. BUFFM03 and BUFFM04 generally had the lowest SCI scores among all sampling sites across all years sampled. This may be due to these sites being located near losing reaches during periods of low flow, in addition to anthropogenic disturbances in the tributaries flowing into these stream reaches. The SCI scores calculated from invertebrate collections taken at Buffalo River water quality sampling sites (Fig. 8) were similar in magnitude to neighboring HTLN sites (Fig. 3).

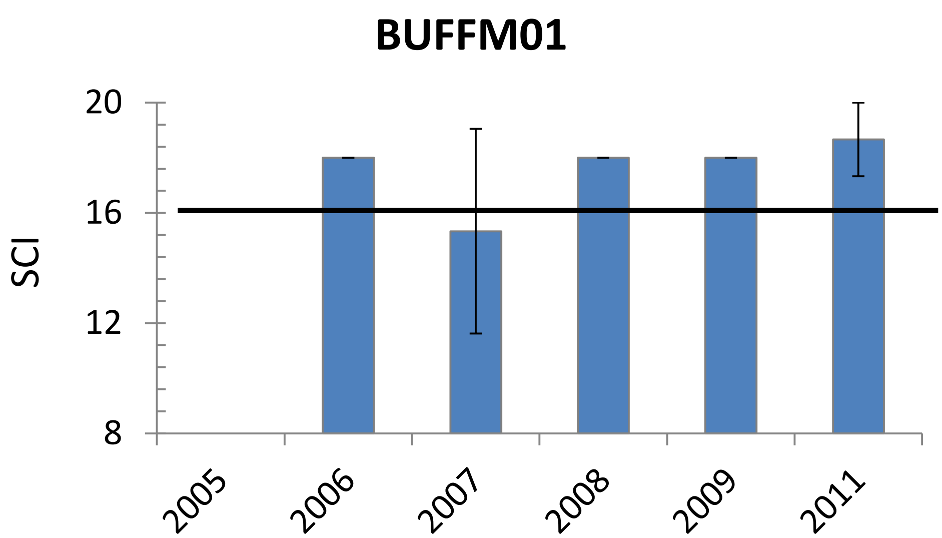

Figure 2. Mean SCI scores and standard errors (n=3) for BUFFM01, 2005-2011. The horizontal line represents an SCI of 16, the lower limit for rating a site unimpaired.

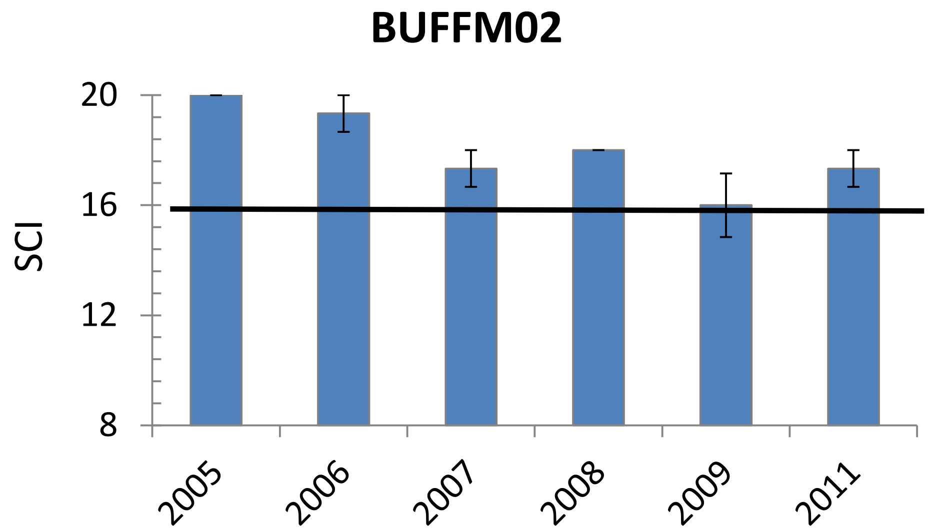

Figure 3. Mean SCI scores and standard errors (n=3) for BUFFM02, 2005-2011. The horizontal line represents an SCI of 16, the lower limit for rating a site unimpaired.

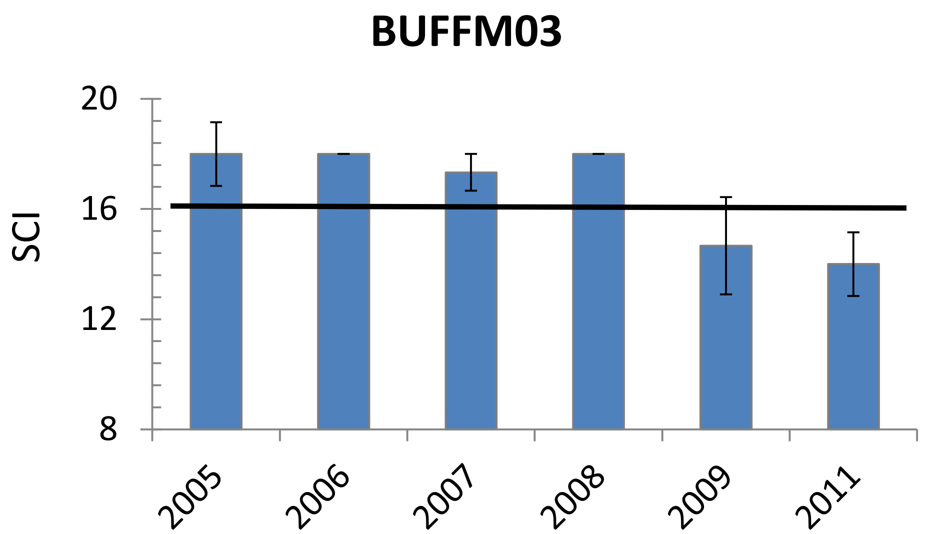

Figure 4. Mean SCI scores and standard errors (n=3) for BUFFM03, 2005-2011. The horizontal line represents an SCI of 16, the lower limit for rating a site unimpaired.

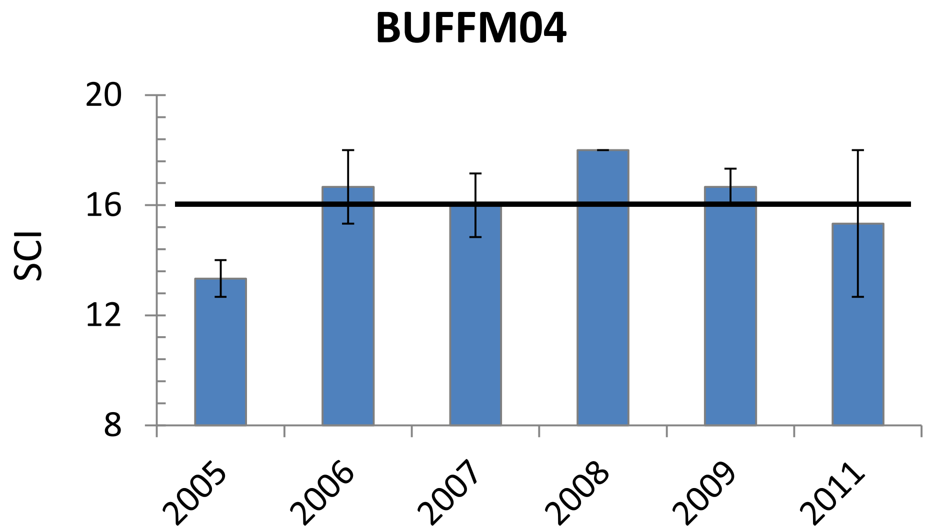

Figure 5. Mean SCI scores and standard errors (n=3) for BUFFM04, 2005-2011. The horizontal line represents an SCI of 16, the lower limit for rating a site unimpaired.

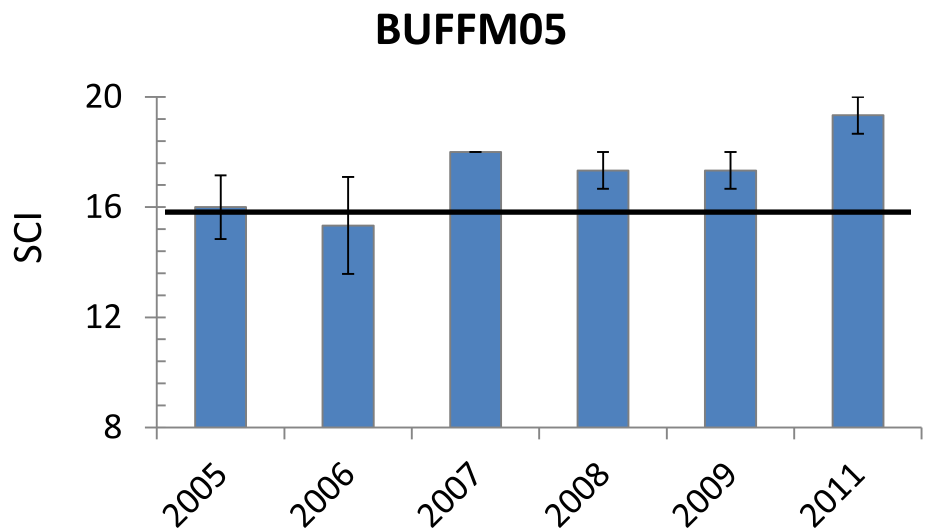

Figure 6. Mean SCI scores and standard errors (n=3)for BUFFM05, 2005-2011. The horizontal line represents an SCI of 16, the lower limit for rating a site unimpaired.

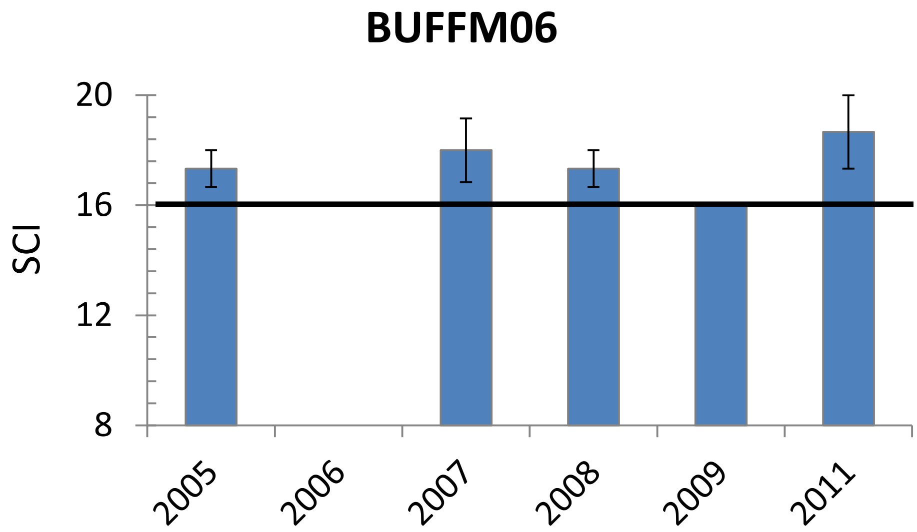

Figure 7. Mean SCI scores and standard errors (n=3) for BUFFM06, 2005-2011. The horizontal line represents an SCI of 16, the lower limit for rating a site unimpaired.

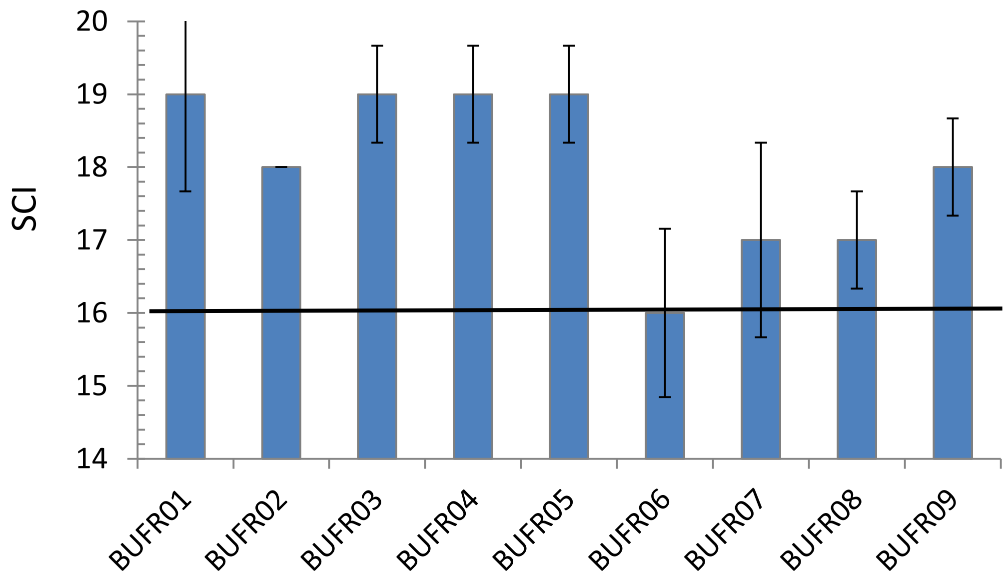

Figure 8. Mean SCI scores and standard errors (n=3) for Buffalo River water quality sampling sites, 2005. The horizontal line represents an SCI of 16, the lower limit rating a site unimpaired.

ORSIMI Results

All ORSIMI scores for mainstem Buffalo River sampling sites equaled or exceeded the baseline values for the index with the exception of BUFFM03, which had a value of 97 (Table 6). Most scores were within a few percentage points of the baseline, although BUFFMO5 increased by almost 20%. These scores show that the aquatic invertebrate communities of Buffalo River monitoring sites, as described by the individual metrics, have either improved (BUFFMO5) or have not changed appreciably in comparison to the baseline data used to develop the index.

Table 5. ORSIMI scores for Buffalo River mainstem sampling sites, 2011.

Site	Mean Taxa Richness	Mean EPT Richness	Mean Shannon Diversity Index	Mean HBI	10-HBI	ORSIMI
BUFFM01	26.22	14.22	2.26	5.03	4.97	101
BUFFM02	26.56	11.89	2.29	5.15	4.84	100
BUFFM03	25.44	12.44	1.88	5.79	4.21	97
BUFFM04	21.11	10.67	2.17	4.56	5.44	106
BUFFM05	28.56	15.67	2.36	5.21	4.79	119
BUFFM06	24.67	10.44	2.34	4.98	5.02	100

Tributary Sites

SCI Results

The range of SCI scores for the tributaries was broad (Table 7). Although most tributaries had SCI scores that showed they were not impaired, several were considered impaired. The largely high SCI scores for BUFF tributaries are supported by the high metric scores for taxa and EPT richness and relatively low HBI (Appendix B). Among the tributaries selected for prioritized sampling, BUFFT27, BUFFT30 and BUFFT31 had impaired SCI scores. BUFFT27 was scored as unimpaired in 2010, but it was rated as impaired in 2011. A flood event preceded the 2011 sampling event for this stream, and it is possible that the invertebrate community had not fully recovered prior to sampling. Similarly, BUFFT15 was judged unimpaired in 2008 but was found to be impaired in 2011. BUFFT30 and BUFFT31 had impaired SCI scores in both years they were sampled. All other priority tributaries at BUFF were unimpaired at the time of sampling. Presently, there are insufficient data to accurately assess tributary status in the Buffalo River Watershed using only aquatic invertebrate communities. Because stream invertebrate communities may be highly variable over time, additional sampling must be conducted to determine whether those scores truly indicate impairment, or whether they simply reflect the natural inherent variability of the system.

Table 6. Mean SCI score and standard errors (n=3) BUFF tributaries 2006-2011. Scores indicating impairment are in bold font.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	18.00 (1.15)	—	—	—	—	—
BUFFT09	16.67 (2.40)	—	—	—	—	—
BUFFT22	16.67 (1.76)	—	—	—	—	—
BUFFT24	**12.00 (1.15)**	—	—	—	—	—
BUFFT30	**12.00 (0)**	—	—	—	—	**13.33 (0.67)**
BUFFT31	**14.00 (2.00)**	—	—	—	—	**14.67 (1.76)**
BUFFT05	—	18.00 (2.00)	—	—	—	
BUFFT07	—	18.00 (1.15)	—	—	—	20.00 (0)
BUFFT25	—	**10.00 (1.15)**	—	—	—	—
BUFFT33	—	18.67 (0.67)	—	—	—	—
BUFFT04	—	—	18.67 (0.67)	—	—	—
BUFFT13	—	—	17.33 (0.67)	—	—	—
BUFFT15	—	—	16.67 (0.67)	—	—	**12.67 (1.76)**
BUFFT16	—	—	16.00 (1.15)	—	—	—
BUFFT01	—	—	—	18.67 (0.67)	—	—
BUFFT06	—	—	—	**14.00 (1.15)**	—	—
BUFFT10	—	—	—	18.00 (0)	—	—
BUFFT11	—	—	—	18.00(0)	—	—
BUFFT20	—	—	—	17.33 (0.67)	—	17.33 (1.76)
BUFFT23	—	—	—	**15.33 (0.67)**	—	—
BUFFT08	—	—	—	—	20.00 (0)	—
BUFFT14	—	—	—	—	19.33 (0.67)	—
BUFFT17	—	—	—	—	**10.00 (0)**	—
BUFFT27	—	—	—	—	16.67 (0.67)	**12.00 (0)**
BUFFT19	—	—	—	—	—	15.33 (2.40)

Discussion

No previous long-term, multiyear monitoring of aquatic invertebrates and stream habitat has been conducted at BUFF. Some short-term studies and special projects have been undertaken, however. These reports are summarized in Bowles *et al*. (2007). The range of variation among invertebrate metrics reported here is generally consistent with previous studies at BUFF and with other unimpaired streams in the region (Jones et al. 1981, Dick 1998, Bradley 2001, Mathis 2001, Sarver et al. 2002, Brown et al. 2003, Radwell 2005, Usrey and Hinsey 2006, Mixon-Hinsey 2008, Wallace and Rabeni 2008). SCI scores for mainstem sites and most tributaries indicate that these streams are not impaired and that there have not been biologically relevant changes in water quality over the 5-year baseline sampling period. Although some tributaries were scored as impaired, stream invertebrate communities are notoriously variable temporally and spatially, so the observed variation reported here does not necessarily reflect true impairment. Annual variation in benthic communities are influenced by a number of factors, including water chemistry, precipitation events, and changes in physical habitat. Other factors including water quality and habitat data, high taxa diversity, and a well-developed EPT fauna suggest these streams are not impaired. The invertebrate fauna of BUFF streams contains a high richness and diversity of EPT taxa, of which most species are intolerant of disturbance. In comparison, tolerance values for members of the family Chironomidae range from intolerant (0) to tolerant (10), but as a group they are assigned a tolerance value of 6. A study by Wallace and Rabeni (2008) on Ozark tributaries showed that the dominant Chironomidae in their samples were those with tolerance values generally less than 5 (6 taxa, mean tolerance value 4.5, range 1.4-7.7). Chironomids are generally well represented in benthic samples at BUFF, but we did not identify them to genus level in this study due to logistical and staffing limitations.

As noted by Sarver et al. (2002), the goal of assessing biological integrity in streams is to encompass all factors affecting those ecosystems. A stream with high biological integrity generally will have little or no influence from humans. While the streams at BUFF generally flow through a rural, undisturbed landscape, there are other anthropogenic stressors that could affect their water quality. The jurisdictional boundaries of BUFF are narrow, and the sources of water supplying park streams cover a large area outside that corridor. Surface water is a large component of river discharge during runoff events, and most surface water runoff in the Buffalo River drainage is outside BUFF boundaries. Occasional impacts to water quality are documented within park boundaries, including high levels of nutrients and fecal contamination. It is unknown what, if any, impacts such contamination events have on invertebrate communities in the streams.

Although there are likely some impacts to water quality in some segments of the Buffalo River, they currently are not of sufficient magnitude and duration to substantially degrade water quality, particularly with respect to aquatic invertebrate community structure. Mathis (2001) considered the water quality in the mid-reaches of the Buffalo River to be impacted, but only limited supporting evidence was offered. For example, Mathis (2001) showed that winter and spring nitrate-nitrogen concentrations in the Buffalo River at Woolum Access were greater than those of upstream sampling sites (~0.16 and 0.11 mg/l, respectively) and then decreasing again below Woolum. Mott (1997) similarly showed nitrate-nitrogen levels in the Buffalo River increased substantially beginning at the Woolum Access. Higher nutrient levels in the river likely explains the downstream increase in algae we recorded (Figure A-11). The observed increase in nutrients at this site is likely due to increased agricultural activity in the watershed in this region.

There is a karst losing reach on the Buffalo River near the Woolum Access below the confluence with Richland Creek. In this losing reach, much of the water (during most summers) runs underground for several kilometers before resurfacing at White's Spring (Bowles et al. 2007). This stretch of river was excluded from our sampling frame because it dries seasonally and the invertebrate communities located there may not be reflective of other areas of the river. This break also approximates a major geologic shift, as the upper section includes the Boston Mountain formation, and the lower primarily represents the Springfield and Salem Plateaus. The slightly lower SCI scores reported here from the mid-reaches of the Buffalo River may be due to the stressors caused by this natural geological condition coupled with increased nutrient loads in that region of the river. A variety of other unreported anthropogenic disturbances could also be contributing to the observed depression of SCI scores in the mid-river region. Many physical disturbances (unstable banks, bridge construction and repair, horse crossings) can cause localized impacts to streams. Any such effects are likely mitigated by the river by downstream distance of those crossings. The general assessment of this report is that the Buffalo River is generally of high quality, but there are some mild to moderate disturbances in the mid-river reaches that may be impacting the invertebrate communities that occur there. Overall, our sampling sites generally had high invertebrate diversity (including many species intolerant to disturbance), water quality within acceptable ranges for the region (Arkansas Pollution Control and Ecology Commission 2011), and a fairly well protected riparian corridor.

There are few available options to park management to mitigate any potential or on-going disturbances to streams in the park because impacts to their respective invertebrate communities and water quality largely originate outside of park boundaries. Within the park, continued conservation of buffer zones along streams in and upstream of the park boundaries will aid in protecting aquatic life as well as in-stream habitat from local chemical runoff and sedimentation. Maintaining buffer zones reduces bank erosion within the park by reducing hydraulic stressors related to storm events. A continued effort to stabilize banks in stream reaches where banks are eroding excessively will further help improve bank stability. Minimizing or eliminating stream crossings by horses and other traffic would also help maintain and stabilize the riparian zone and in-stream habitat. Aquatic invertebrate monitoring at BUFF provides a sound tool to recognize both deterioration and chronic decline of water quality.

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Appendix A. Habitat and water quality summary data for BUFF mainstem sampling sites. 2005-2011.

Table A-1. Water quality data for Buffalo River, 2006-2011 using water quality data loggers.

Site	Inclusive Dates	Statistic	Temperature (°C)	Dissolved Oxygen (mg/liter)	Specific Conductance (µS/cm)	pH	Turbidity (NTU)
Pruitt	December 28, 2006-February 2, 2007	Mean	6.89	13.33	117.13	9.16	8.92
		Standard Error	0.06	0.04	0.42	0.01	0.69
		Minimum	2.31	10.90	65.00	8.58	1.80
		Maximum	10.66	16.47	141.00	9.97	389.20
		N	862	862	862	862	862
	November 20, 2007-December 4, 2007	Mean	9.28	12.62	264.40	7.97	n/a
		Standard Error	0.10	0.08	0.21	0.00	n/a
		Minimum	7.50	9.26	244.00	7.86	n/a
		Maximum	14.71	14.56	268.00	8.05	n/a
		N	338	338	338	338	338
	December 1-11, 2008	Mean	5.68	12.23	217.54	8.08	4.36
		Standard Error	0.04	0.03	0.10	0.001	0.34
		Minimum	4.86	11.42	215	8.02	0.4
		Maximum	7.79	12.82	220	8.13	28.9
		N	231	231	231	231	229
	December 7-14, 2009	Mean	4.87	15.06	175.80	8.14	1.13
		Standard Error	0.08	0.0	0.44	0.006	0.03
		Minimum	2.87	13.35	166	7.98	0.6
		Maximum	6.38	16.73	183	8.29	2
		N	172	172	172	172	172

Table A-1. Water quality data for Buffalo River, 2006-2011 using water quality data loggers (continued).

Site	Inclusive Dates	Statistic	Temperature (°C)	Dissolved Oxygen (mg/liter)	Specific Conductance (µS/cm)	pH	Turbidity (NTU)
	December 1-22, 2011	Mean	7.76	12.23	125.82	7.92	4.45
		Standard Error	0.06	0.03	0.55	0.004	0.15
		Minimum	4.97	10.63	104	7.76	1.7
		Maximum	10.37	13.6	152	8.16	17.9
		N	506	506	506	506	506
Tyler Bend	November 20-December 5, 2007	Mean	10.66	12.06	260.98	8.02	0.28
		Standard Error	0.10	0.06	0.13	0.003	0.08
		Minimum	8.36	7.12	255	7.74	0
		Maximum	16.25	13.75	266	8.17	27
		N	358	358	358	358	358
	December 1-11, 2008	Mean	8.20	240.16	13.04	8.19	0.94
		Standard Error	0.06	0.13	0.05	0.005	0.10
		Minimum	6.63	234	11.35	8	0
		Maximum	10.95	245	14.83	8.41	9
		N	239	239	239	239	231
	December 7-16, 2009	Mean	7.01	13.52	210.66	7.99	2.12
		Standard Error	0.06	0.06	0.33	0.01	0.45
		Minimum	5.08	11.88	202	7.75	1
		Maximum	9.03	15.31	219	8.24	98.4
		N	218	218	218	218	218
	December 7-22, 2011	Mean	9.08	13.00	154.98	7.93	4.24
		Standard Error	0.06	0.04	0.62	0.003	0.31
		Minimum	6.9	11.12	134	7.82	0
		Maximum	11.41	14.65	191	8.13	53.3
		N	357	357	357	357	357

Table A-1. Water quality data for Buffalo River, 2006-2011 using water quality data loggers (continued).

Site	Inclusive Dates	Statistic	Temperature (°C)	Dissolved Oxygen (mg/liter)	Specific Conductance (µS/cm)	pH	Turbidity (NTU)
Rush	November 20-December 3, 2007	Mean	9.70	12.40	260.33	8.19	0.66
		Standard Error	0.123	0.06	0.16	0.003	0.07
		Minimum	7.21	9.7	253	8.08	0
		Maximum	15.95	14.12	265	8.3	14
		N	317	317	317	317	317
	December 1-10, 2008	Mean	6.20	262.62	14.22	8.32	0.12
		Standard Error	0.06	0.10	0.04	0.002	0.02
		Minimum	4.86	259	12.9	8.13	0
		Maximum	8.56	265	15.33	8.39	4.9
		N	219	219	219	219	219
	December 7-14, 2009	Mean	5.98	239.18	14.30	8.28	0.49
		Standard Error	0.08	0.29	0.07	0.01	0.006
		Minimum	3.96	232	12.4	8.09	0.3
		Maximum	7.93	245	16.11	8.45	0.6
		N	167	167	167	167	167
	December 7-22, 2011	Mean	8.99	12.27	165.33	7.92	5.83
		Standard Error	0.09	0.03	0.72	0.02	0.18
		Minimum	6.24	10.52	97	6.7	2.5
		Maximum	14.91	14	194	8.2	28.6
		N	358	358	358	358	358

Table A-2. Mean water temperature (^{o}C) (±standard error) at BUFF mainstem sampling sites using hand-held meters.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	8.13 (0.40)	10.97 (.30)	9.87 (0.09)	6.83 (0.37)	6.80 (0)
BUFFM02	8.50 (0.51)	7.77 (0.28)	8.73 (0.18)	6.53 (0.17)	3.30 (0.10)	6.97 (0.28)
BUFFM03	7.29 (0.20)	10.10 (0.10)	9.63 (0.12)	6.07 (0.76)	5.60 (0.06)	8.80 (0.21)
BUFFM04	7.90 (0.31)	7.03 (0.03)	9.2 (0.26)	7.20 (0.21)	3.23 (0.20)	6.80 (0.10)
BUFFM05	5.37 (0.07)	10.50 (0.15)	9.2 (0.32)	6.60 (0.21)	3.33 (0.09)	8.90 (0)
BUFFM06	6.33 (0.18)	—	2.93 (0.03)	6.30 (0.83)	11.2 (0.06)	7.77 (0.22)

Table A-3. Mean specific conductance (µS/cm) (±standard error) at BUFF mainstem sampling sites using hand-held meters.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	48.53 (0.30)	126.67 (0.03)	87.97 (0.66)	87.87 (1.13)	77.07 (0.23)
BUFFM02	188.73 (2.08)	112.73 (6.49)	180.60 (0.99)	143.50 (13.80)	193.40 (6.56)	170.34 (0.83)
BUFFM03	157.10 (14.10)	131.10 (0.90)	181.47 (7.34)	136.73 (16.30)	204.23 (0.79)	186.07 (1.42)
BUFFM04	174.30 (0.70)	217.53 (2.03)	164.10 (0.72)	112.43 (5.14)	193.17 (0.90)	172.53 (0.52)
BUFFM05	173.17 (0.75)	166.60 (19.08)	173.43 (2.14)	162.43 (2.22)	215.33 (0.43)	196.27 (1.90)
BUFFM06	185.60 (0.51)		—	124.13 (2.85)	235.43 (0.43)	198.43 (0.52)

Table A-4. Mean pH (±standard error) at BUFF mainstem sampling sites using hand-held meters.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	7.87 (0.10)	7.27 (0.06)	7.85 (0.33)	6.95 (0.08)	7.80 (0.05)
BUFFM02	7.57 (0.10)	7.58 (0.35)	7.43 (0.07)	7.98 (0.18)	7.70 (0.11)	8.45 (0.02)
BUFFM03	7.47 (0.10)	7.50 (0.10)	7.60 (0.07)	8.00 (0.20)	7.53 (0.06)	8.21 (0.06)
BUFFM04	7.55 (0.32)	7.75 (0.18)	7.67 (0.04)	8.19 (0.13)	7.77 (0.31)	7.96 (0.03)
BUFFM05	6.81 (0.85)	7.38 (0.08)	7.79 (0.09)	8.03 (0.19)	7.85 (0.03)	8.07 (0.04)
BUFFM06	8.08 (0.06)	—	—	7.99 (0.16)	7.91 (0.08)	8.32 (0.03)

Table A-5. Mean dissolved oxygen concentration (mg/l) (±standard error) at BUFF mainstem sampling sites using hand-held meters.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	11.043 (0.40)	8.43 (0.19)	11.48 (0.27)	9.54 (0.23)	11.97 (0.16)
BUFFM02	11.27 (0.29)	11.36 (0.43)	9.56 (0.13)	13.20 (0.26)	14.93 (0.17)	13.38 (0.01)
BUFFM03	11.30 (0.10)	10.31 (0.30)	9.20 (0.62)	13.88 (0.18)	13.14 (0.14)	12.14 (0.25)
BUFFM04	11.01 (0.14)	12.53 (0.47)	9.63 (0.36)	13.57 (0.55)	15.81 (0.18)	12.56 (0.21)
BUFFM05	13.78 (0.47)	10.51 (0.25)	9.59 (0.32)	12.44 (0.95)	15.29 (0.07)	12.18 (0.05)
BUFFM06	13.54 (0.09)	—	13.84 (0.02)	13.09 (0.20)	14.06 (0.14)	13.04 (0.30)

Table A-6. Mean depth (cm) (±standard error) for mainstem sampling sites on the Buffalo River.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	37.78 (5.32)	15.11 (4.78)	13 (0.84)	21.33 (3.79)	24.22 (7.00)
BUFFM02	16.89 (3.10)	35.44 (4.07)	17.44 (1.09)	13 (1.07)	30.44 (1.82)	33.56 (5.31)
BUFFM03	28 (5.98)	48 (4.03)	18.33 (1.53)	19.67 (4.58)	29.78 (5.14)	28.44 (1.61)
BUFFM04	21 (2.87)	38.89 (5.49)	20.33 (2.83)	26.89 (0.11)	44 (7.22)	66.89 (8.09)
BUFFM05	22.89 (4.68)	52.89 (4.85)	20.67 (0.67)	19.89 (2.75)	30.67 (0.88)	35.67 (9.49)
BUFFM06	13 (2.17)	—	12.44 (0.40)	33.44 (4.26)	38.78 (9.25)	36.22 (8.86)

Table A-7. Mean current velocity (m/sec) (±standard error) for mainstem sampling sites on the Buffalo River.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	0.80 (0.11)	0.28 (0.04)	0.43 (0.03)	0.56 (0.15)	0.42 (0.04)
BUFFM02	0.584 (0.14)	0.70 (0.12)	0.64 (0.04)	0.42 (0.10)	0.63 (0.11)	0.76 (0.03)
BUFFM03	0.66 (0.18)	1.12 (0.06)	0.66 (0.05)	0.69 (0.08)	0.59 (0.02)	0.74 (0.18)
BUFFM04	0.40 (0.09)	0.85 (0.09)	0.43 (0.04)	0.53 (0.01)	0.66 (0.06)	0.85 (0.19)
BUFFM05	0.56 (0.07)	1.32 (0.06)	0.57 (0.05)	0.86 (0.10)	0.88 (0.03)	0.76 (0.17)
BUFFM06	0.42 (0.10)	—	0.73 (0.17)	0.99 (0.06)	0.89 (0.01)	0.84 (0.13)

Table A-8. Mean discharge (m^3/sec) for mainstem sampling sites on the Buffalo River. Discharge for 2005-2009 was measured by hand while discharge for 2011 was taken from USGS gages (see DeBacker et al. 2012 for details).

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	4.2767	0.1695	0.2554	1.2784	1.16
BUFFM02	0.452	7.86753	0.33505	0.9824	3.376	1.869
BUFFM03	0.5752	22.3464	0.6299	1.8238	6.6652	1.44
BUFFM04	1.4338	13.0722	1.0328	2.726	11.7168	25.71
BUFFM05	2.04	32.28	1.4054	4.4758	15.272	51.82
BUFFM06	2.489	—	2.073	19.6978	26.6144	24.49

Table A-9. Mean substrate size (Wentworth scale) (±standard error) for BUFF mainstem sampling sites

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	14.87 (0.78)	15.31 (0.09)	15.07 (0.10)	15.25 (0.20)	16.11 (0.29)
BUFFM02	12.98 (0.22)	13.94 (0.25)	14.25 (0.18)	13.98 (0.29)	13.93 (0.38)	14.44 (0.48)
BUFFM03	13.64 (0.14)	14.2 (0.13)	14.58 (0.15)	13.84 (0.32)	13.55 (0.08)	13.78 (0.59)
BUFFM04	13.75 (0.12)	13.88 (0.13)	14.49 (0.07)	14.38 (0.06)	13.9 (0.34)	15.11 (0.22)
BUFFM05	13.18 (0.25)	13.72 (0.08)	14.2 (0.07)	14.44 (0.41)	13.9 (0.17)	14.67 (0.51)
BUFFM06	13.43 (0.22)	—	14.13 (0.27)	13.66 (0.61)	13.64 (0.49)	14.44 (0.87)

Table A-10. Mean percent embeddedness (±standard error) for BUFF mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	28.61 (3.61)	25 (0)	18.33 (3.85)	18.33 (3.85)	9.44 (4.44)
BUFFM02	26.39 (5.83)	25 (0)	25 (0)	32.22 (3.61)	35.83 (10.83)	28.61 (3.61)
BUFFM03	26.39 (5.83)	25 (0)	25 (0)	28.611 (3.61)	32.22 (7.22)	39.44 (9.55)
BUFFM04	33.61 (9.44)	25 (0)	32.22 (7.22)	25 (0)	28.61 (3.61)	28.61 (3.61)
BUFFM05	37.2 (5.10)	25 (0)	25 (0)	25 (0)	25 (0)	32.22 (7.22)
BUFFM06	25 (0)	—	35.83 (10.83)	50.28 (7.22)	46.67 (10.83)	35.83 (10.83)

Table A-11. Mean percent filamentous algae (±standard error) at BUFF mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	1.67 (1.67)	3.89 (3.09)	11.67 (3.85)	7.78 (5.47)	0 (0)
BUFFM02	0.56 (0.56)	3.89 (3.89)	5 (0)	13.33 (2.54)	9.44 (4.94)	14.44 (5.30)
BUFFM03	3.33 (3.33)	0.56 (0.56)	8.33 (3.33)	5.56 (5.56)	2.22 (0.56)	6.11 (5.30)
BUFFM04	2.22 (1.67)	0.56 (0.56)	3.89 (1.11)	2.22 (0.56)	11.67 (7.26)	0 (0)
BUFFM05	10 (1.11)	1.11 (0.56)	16.11 (5.88)	30 (8.55)	6.11 (3.09)	2.78 (2.78)
BUFFM06	22.78 (2.22)	—	12.78 (6.41)	3.33 (3.33)	10.83 (9.17)	6.11 (5.30)

Table A-12. Mean percent periphyton (±standard error) at BUFF mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	25 (0)	26.39 (5.10)	39.44 (7.22)	25 (0)	25 (0)
BUFFM02	25 (0)	25 (0)	25 (0)	32.22 (7.22)	35.83 (10.83)	25 (0)
BUFFM03	32.22 (7.22)	25 (0)	25 (0)	25 (0)	25 (0)	25 (0)
BUFFM04	22.22 (2.78)	25 (0)	35.83 (10.83)	46.67 (0)	39.44 (9.55)	25 (0)
BUFFM05	39.44 (3.61)	25 (0)	25	32.22 (3.61)	25 (0)	35.83 (10.83)
BUFFM06	32.22 (7.22)	—	22.78 (2.22)	25 (0)	25 (0)	25 (0)

Table A-13. Mean percent vegetation (±standard error) at BUFF mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	1.11 (1.11)	2.78 (2.78)	0 (0)	0 (0)	0 (0)
BUFFM02	0 (0)	6.67 (6.11)	0 (0)	2.78 (2.78)	0.56 (0.5)	0 (0)
BUFFM03	0.56 (0.56)	1.11 (0.56)	0 (0)	0 (0)	0.56 (0.56)	0 (0)
BUFFM04	0 (0)	16.67 (0.56)	0 (0)	0 (0)	1.11 (0.56)	0 (0)
BUFFM05	0 (0)	1.11 (0.56)	0 (0)	3.33 (3.33)	0 (0)	0 (0)
BUFFM06	0 (0)	—	0 (0)	0 (0)	0 (0)	0 (0)

Table A-14. Mean water temperature (^{o}C) (±standard error) at BUFF tributary sampling sites using hand-held meters.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	8.87 (0)	—	—	—	—	—
BUFFT09	8.03 (0)	—	—	—	—	—
BUFFT22	13.03 (0.1)	—	—	—	—	—
BUFFT24	12.77 (0)	—	—	—	—	—
BUFFT30	13.87 (0.2)	—	—	—	—	9.20 (0.15)
BUFFT31	13.40 (0)	—	—	—	—	9.10 (0.10)
BUFFT05	—	9.67 (0.46)	—	—	—	—
BUFFT07	—	8.73 (0.03)	—	—	—	7.90 (0.12)
BUFFT25	—	13.50 (0.06)	—	—	—	—
BUFFT33	—	2.93 (0.12)	—	—	—	—
BUFFT04	—	—	11.4 (0.26)	—	—	—
BUFFT13	—	—	7.03 (0.03)	—	—	—
BUFFT15	—	—	8.13 (0.20)	—	—	12.27 (0.07)
BUFFT16	—	—	13.87 (0.13)	—	—	—
BUFFT01	—	—	—	9.17 (0.07)	—	—
BUFFT06	—	—	—	4.97 (0.41)	—	—
BUFFT10	—	—	—	4.17 (0.07)	—	—
BUFFT11	—	—	—	4.97 (0.09)	—	—
BUFFT20	—	—	—	4.63 (0.19)	—	9.10 (0.06)
BUFFT23	—	—	—	5.10 (0.06)	—	—
BUFFT08	—	—	—	—	10.21 (0.04)	—
BUFFT14	—	—	—	—	4.36 (0.31)	—
BUFFT17	—	—	—	—	13.22 (0.12)	—
BUFFT27	—	—	—	—	8.96 (0.11)	7.70 (0)
BUFFT19	—	—	—	—	—	10.87 (0.13)

Table A-15. Mean specific conductance (µS/cm) (±standard error) at BUFF tributary sampling sites using hand-held meters**.**

Site	2006	2007	2008	2009	2010	2011
BUFFT03	92.50 (0.20)	—	—	—	—	—
BUFFT09	106.20 (0.20)	—	—	—	—	—
BUFFT22	218.63 (0.10)	—	—	—	—	—
BUFFT24	203.77 (1.00)	—	—	—	—	—
BUFFT30	315.23 (2.6)	—	—	—	—	336.77 (0.08)
BUFFT31	286.83 (7.00)	—	—	—	—	299.00 (0.06)
BUFFT05	—	181.30 (12.49)	—	—	—	—
BUFFT07	—	228.83 (0.99)	—	—	—	355.60 (0.78)
BUFFT25	—	199.00 (0.12)	—	—	—	—
BUFFT33	—	—	—	—	—	—
BUFFT04	—	—	124.53 (0.38)	—	—	—
BUFFT13	—	—	167.83 (2.10)	—	—	—
BUFFT15	—	—	294.50 (6.35)	—	—	410.73 (0.78)
BUFFT16	—	—	350.20 (5.09)	—	—	—
BUFFT01	—	—	—	138.10 (0.92)	—	—
BUFFT06	—	—	—	400.00 (0)	—	—
BUFFT10	—	—	—	332.17 (2.58)	—	—
BUFFT11	—	—	—	264.03 (0.09)	—	—
BUFFT20	—	—	—	228.83 (1.13)	—	203.67 (1.96)
BUFFT23	—	—	—	323.60 (0.50)	—	—
BUFFT08	—	—	—	—	411.33 (2.67)	—
BUFFT14	—	—	—	—	365.33 (0.33)	—
BUFFT17	—	—	—	—	143.00 (0.58)	—
BUFFT27	—	—	—	—	427.00 (2.08)	411.00 (0.40)
BUFFT19	—	—	—	—	—	237.17 (0.50)

Table A-16. Mean pH (±standard error) at BUFF tributary sampling sites using hand-held meters.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	7.58 (0)	—	—	—	—	—
BUFFT09	7.48 (0.10)	—	—	—	—	—
BUFFT22	7.34 (0.20)	—	—	—	—	—
BUFFT24	7.40 (0.10)	—	—	—	—	—
BUFFT30	7.97 (0.20)	—	—	—	—	8.34 (0.02)
BUFFT31	8.19 (0.10)	—	—	—	—	8.36 (0.01)
BUFFT05	—	7.50 (0.13)	—	—	—	—
BUFFT07	—	7.77 (0.10)	—	—	—	8.02 (0.01)
BUFFT25	—	7.30 (0.30)	—	—	—	—
BUFFT33	—	—	—	—	—	—
BUFFT04	—	—	8.40 (0.07)	—	—	—
BUFFT13	—	—	8.29 (0.03)	—	—	—
BUFFT15	—	—	8.07 (0.08)	—	—	7.86 (0.04)
BUFFT16	—	—	7.85 (0.03)	—	—	—
BUFFT01	—	—	—	6.64 (0.03)	—	—
BUFFT06	—	—	—	7.95 (0.09)	—	—
BUFFT10	—	—	—	7.81 (0.08)	—	—
BUFFT11	—	—	—	7.96 (0.02)	—	—
BUFFT20	—	—	—	8.26 (0.06)	—	8.57 (0.01)
BUFFT23	—	—	—	8.12 (0.06)	—	—
BUFFT08	—	—	—	—	8.09 (0.01)	—
BUFFT14	—	—	—	—	8.20 (0.04)	—
BUFFT17	—	—	—	—	7.83 (0.03)	—
BUFFT27	—	—	—	—	8.35 (0.02)	8.38 (0.02)
BUFFT19	—	—	—	—	—	8.62 (0.02)

Table A-17. Mean dissolved oxygen (mg/l) concentration (±standard error) at BUFF tributary sampling sites using hand-held meters.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	10.74 (0)	—	—	—	—	—
BUFFT09	12.06 (0.10)	—	—	—	—	—
BUFFT22	10.47 (0.30)	—	—	—	—	—
BUFFT24	9.59 (0.40)	—	—	—	—	—
BUFFT30	10.00 (0.10)	—	—	—	—	11.61 (0.03)
BUFFT31	9.76 (0.20)	—	—	—	—	11.43 (0.16)
BUFFT05	—	9.30 (0.58)	—	—	—	—
BUFFT07	—	9.99 (0.17)	—	—	—	11.82 (0.08)
BUFFT25	—	8.28(0.28)	—	—	—	—
BUFFT33	—	12.84 (0.27)	—	—	—	—
BUFFT04	—	—	11.85 (0.02)	—	—	—
BUFFT13	—	—	14.02 (0.11)	—	—	—
BUFFT15	—	—	12.64 (0.20)	—	—	10.24 (0.09)
BUFFT16	—	—	10.96 (0.10)	—	—	—
BUFFT01	—	—	—	7.48 (0.52)	—	—
BUFFT06	—	—	—	13.69 (0.12)	—	—
BUFFT10	—	—	—	14.19 (0.21)	—	—
BUFFT11	—	—	—	14.63 (0.01)	—	—
BUFFT20	—	—	—	16.60 (0.05)	—	13.56 (0.10)
BUFFT23	—	—	—	13.89 (0.04)	—	—
BUFFT08	—	—	—	—	9.89 (0.12)	—
BUFFT14	—	—	—	—	13.51 (0.06)	—
BUFFT17	—	—	—	—	10.46 (0.06)	—
BUFFT27	—	—	—	—	11.77 (0.05)	12.49 (0.04)
BUFFT19	—	—	—	—	—	13.65 (1.14)

Table A-18. Mean depth (cm) (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	17.22 (1.69)	—	—	—	—	—
BUFFT09	27.56 (3.25)	—	—	—	—	—
BUFFT22	17.78 (4.54)	—	—	—	—	—
BUFFT24	8.22 (2.49)	—	—	—	—	—
BUFFT30	17.89 (2.50)	—	—	—	—	25.89 (5.87)
BUFFT31	15.78 (2.63)	—	—	—	—	23.56 (1.35)
BUFFT05	—	9.11 (1.83)	—	—	—	—
BUFFT07	—	12.44 (1.25)	—	—	—	13.33 (2.34)
BUFFT25	—	9.67 (2.23)	—	—	—	—
BUFFT33	—	6.11 (0.86)	—	—	—	—
BUFFT04	—	—	22.33 (2.34)	—	—	—
BUFFT13	—	—	14.89 (3.86)	—	—	—
BUFFT15	—	—	6.78 (0.56)	—	—	14.22 (1.06)
BUFFT16	—	—	14.67 (1.07)	—	—	—
BUFFT01	—	—	—	10.56 (0.91)	—	—
BUFFT06	—	—	—	8.89 (1.35)	—	—
BUFFT10	—	—	—	11.78 (2.56)	—	—
BUFFT11	—	—	—	6.56 (0.29)	—	—
BUFFT20	—	—	—	19.11 (3.49)	—	26.00 (6.43)
BUFFT23	—	—	—	17.67 (0.47)	—	—
BUFFT08	—	—	—	—	8.67 (0.60)	—
BUFFT14	—	—	—	—	4.78 (0.62)	—
BUFFT17	—	—	—	—	25.89 (3.09)	—
BUFFT27	—	—	—	—	12.67 (0.77)	40.44 (1.56)
BUFFT19	—	—	—	—	—	22.78 (3.87)

Table A-19. Mean current velocity (m/sec) (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	0.55 (0.12)	—	—	—	—	—
BUFFT09	0.79 (0.10)	—	—	—	—	—
BUFFT22	0.59 (0.11)	—	—	—	—	—
BUFFT24	0.25 (0.08)	—	—	—	—	—
BUFFT30	0.70 (0.18)	—	—	—	—	0.77 (0.15)
BUFFT31	0.55 (0.10)	—	—	—	—	0.52 (0.08)
BUFFT05	—	0.28 (0.09)	—	—	—	—
BUFFT07	—	0.48 (0.14)	—	—	—	0.41 (0.04)
BUFFT25	—	0.22 (0.06)	—	—	—	—
BUFFT33	—	0.21 (0.05)	—	—	—	—
BUFFT04	—	—	0.67 (0.12)	—	—	—
BUFFT13	—	—	0.52 (0.22)	—	—	—
BUFFT15	—	—	0.29 (0.05)	—	—	0.43 (0.05)
BUFFT16	—	—	0.48 (0.05)	—	—	—
BUFFT01	—	—	—	0.38 (0.03)	—	—
BUFFT06	—	—	—	0.26 (0.03)	—	—
BUFFT10	—	—	—	0.43 (0.04)	—	—
BUFFT11	—	—	—	0.22 (0.05)	—	—
BUFFT20	—	—	—	0.60 (0.05)	—	0.63 (0.03)
BUFFT23	—	—	—	1.95 (0.09)	—	—
BUFFT08	—	—	—	—	0.16 (0.06)	—
BUFFT14	—	—	—	—	0.148 (0.02)	—
BUFFT17	—	—	—	—	0.71 (0.16)	—
BUFFT27	—	—	—	—	0.39 (0.05)	0.54 (0.05)
BUFFT19	—	—	—	—	—	0.64 (0.13)

Table A-20. Stream discharge (m^3/sec) measured for BUFF tributaries during invertebrate sampling.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	0.19	—	—	—	—	—
BUFFT09	5.19	—	—	—	—	—
BUFFT22	0.39	—	—	—	—	—
BUFFT24	0.10	—	—	—	—	—
BUFFT30	0.28	—	—	—	—	0.84085
BUFFT31	0.44	—	—	—	—	0.912
BUFFT05	—	0.02	—	—	—	
BUFFT07	—	0.06	—	—	—	0.4783
BUFFT25	—	0.01	—	—	—	—
BUFFT33	—	0.01	—	—	—	—
BUFFT04	—	—	0.31	—	—	—
BUFFT13	—	—	0.28	—	—	—
BUFFT15	—	—	0.02	—	—	0.4281
BUFFT16	—	—	0.19	—	—	—
BUFFT01	—	—	—	0.05	—	—
BUFFT06	—	—	—	0.01	—	—
BUFFT10	—	—	—	0.07	—	—
BUFFT11	—	—	—	0.03	—	—
BUFFT20	—	—	—	1.49	—	0.059
BUFFT23	—	—	—	0.39	—	—
BUFFT08	—	—	—	—	0.002	—
BUFFT14	—	—	—	—	0.053	—
BUFFT17	—	—	—	—	1.05	—
BUFFT27	—	—	—	—	0.08	1.9599
BUFFT19	—	—	—	—	—	1.0037

Table A-21. Mean substrate size (Wentworth scale) (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	14.76 (0.27)	—	—	—	—	—
BUFFT09	14.027 (0.19)	—	—	—	—	—
BUFFT22	13.73 (0.04)	—	—	—	—	—
BUFFT24	13.27 (0.19)	—	—	—	—	—
BUFFT30	15.02 (0.13)	—	—	—	—	15.67 (0.51)
BUFFT31	14.86 (0.11)		—	—	—	16.33 (0.38)
BUFFT05	—	15.32 (0.52)	—	—	—	
BUFFT07	—	14.28 (0.10)	—	—	—	13.78 (0.59)
BUFFT25	—	13.43 (0.35)	—	—	—	—
BUFFT33	—	15.38 (0.71)	—	—	—	—
BUFFT04	—	—	14.37 (0.44)	—	—	—
BUFFT13	—	—	14.59 (0.29)	—	—	—
BUFFT15	—	—	13.5 (0.19)	—	—	13.11 (0.29)
BUFFT16	—	—	14.26 (0.18)	—	—	—
BUFFT01	—	—	—	14.58 (0.29)	—	—
BUFFT06	—	—	—	14.66 (0.16)	—	—
BUFFT10	—	—	—	14.02 (0.11)	—	—
BUFFT11	—	—	—	14.06 (0.16)	—	—
BUFFT20	—	—	—	14.11 (0.39)	—	14.56 (0.72)
BUFFT23	—	—	—	13.05 (0.02)	—	—
BUFFT08	—	—	—	—	14.47 (0.26)	—
BUFFT14	—	—	—	—	13.68 (0.26)	—
BUFFT17	—	—	—	—	14.53 (0.09)	—
BUFFT27	—	—	—	—	13.96 (0.27)	13.78 (0.67)
BUFFT19	—	—	—	—	—	14.22 (0.40)

Table A-22. Mean percent embeddedness (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	25 (0)	—	—	—	—	—
BUFFT09	25 (0)	—	—	—	—	—
BUFFT22	22.8 (2.22)	—	—	—	—	—
BUFFT24	29.17 (7.22)	—	—	—	—	—
BUFFT30	25 (0)	—	—	—	—	25 (0)
BUFFT31	25 (0)	—	—	—	—	25 (0)
BUFFT05	—	25 (0)	—	—	—	—
BUFFT07	—	35.83 (10.83)	—	—	—	28.61 (3.61)
BUFFT25	—	25 (0)	—	—	—	—
BUFFT33	—	25 (0)	—	—	—	—
BUFFT04	—	—	25 (0)	—	—	—
BUFFT13	—	—	35.83 (6.25)	—	—	—
BUFFT15	—	—	25 (0)	—	—	32.22 (7.22)
BUFFT16	—	—	28.61 (3.61)	—	—	—
BUFFT01	—	—	—	25 (0)	—	—
BUFFT06	—	—	—	28.61 (3.61)	—	—
BUFFT10	—	—	—	28.61 (3.61)	—	—
BUFFT11	—	—	—	25 (0)	—	—
BUFFT20	—	—	—	32.22 (7.22)	—	39.44 (9.55)
BUFFT23	—	—	—	25 (0)	—	—
BUFFT08	—	—	—	—	25 (0)	—
BUFFT14	—	—	—	—	25 (0)	—
BUFFT17	—	—	—	—	16.11 (5.88)	—
BUFFT27	—	—	—	—	25 (0)	39.44 (7.22)
BUFFT19	—	—	—	—	—	25 (0)

Table A-23. Mean percent filamentous algae (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	2.78 (0.56)	—	—	—	—	—
BUFFT09	1.67 (1.11)	—	—	—	—	—
BUFFT22	0 (0)	—	—	—	—	—
BUFFT24	1.11 (0.56)	—	—	—	—	—
BUFFT30	0	—	—	—	—	0 (0)
BUFFT31	1.11 (0.56)	—	—	—	—	0 (0)
BUFFT05	—	9.44 (4.44)	—	—	—	—
BUFFT07	—	6.67 (1.67)	—	—	—	0 (0)
BUFFT25	—	0.83 (0.83)	—	—	—	—
BUFFT33	—	0 (0)	—	—	—	—
BUFFT04	—	—	7.22 (5.64)	—	—	—
BUFFT13	—	—	39.44 (7.22)	—	—	—
BUFFT15	—	—	2.78 (1.47)	—	—	0 (0)
BUFFT16	—	—	15.56 (2.00)	—	—	—
BUFFT01	—	—	—	0 (0)	—	—
BUFFT06	—	—	—	0 (0)	—	—
BUFFT10	—	—	—	11.11 (6.96)	—	—
BUFFT11	—	—	—	0 (0)	—	—
BUFFT20	—	—	—	7.22 (5.56)	—	0 (0)
BUFFT23	—	—	—	0 (0)	—	—
BUFFT08	—	—	—	—	0 (0)	—
BUFFT14	—	—	—	—	3.33 (0.96)	—
BUFFT17	—	—	—	—	0.56 (0.56)	—
BUFFT27	—	—	—	—	3.89 (0.56)	0 (0)
BUFFT19	—	—	—	—	—	0 (0)

Table A-24. Mean percent periphyton (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	25 (0)	—	—	—	—	—
BUFFT09	25 (0)	—	—	—	—	—
BUFFT22	18.33 (4.44)	—	—	—	—	—
BUFFT24	25 (0)	—	—	—	—	—
BUFFT30	25 (0)	—	—	—	—	25 (0)
BUFFT31	25 (0)	—	—	—	—	25 (0)
BUFFT05	—	39.44 (9.55)	—	—	—	—
BUFFT07	—	32.22 (3.61)	—	—	—	22.78 (2.22)
BUFFT25	—	11.67 (3.61)	—	—	—	—
BUFFT33	—	25 (6.67)	—	—	—	—
BUFFT04	—	—	25.00	—	—	—
BUFFT13	—	—	32.22 (3.61)	—	—	—
BUFFT15	—	—	25 (0)	—	—	22.78 (2.22)
BUFFT16	—	—	25 (0)	—	—	—
BUFFT01	—	—	—	28.61 (3.61)	—	—
BUFFT06	—	—	—	5 (0)	—	—
BUFFT10	—	—	—	46.67 (10.83)	—	—
BUFFT11	—	—	—	30 (3.15)	—	—
BUFFT20	—	—	—	53.61 (9.35)	—	25 (0)
BUFFT23	—	—	—	28.61 (3.61)	—	—
BUFFT08	—	—	—	—	25 (0)	
BUFFT14	—	—	—	—	25 (0)	
BUFFT17	—	—	—	—	25 (0)	
BUFFT27	—	—	—	—	25 (0)	25 (0)
BUFFT19	—	—	—	—	—	25 (0)

Table A-25. Mean percent aquatic vegetation (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	18.06 (6.94)	—	—	—	—	—
BUFFT09	2.22 (1.11)	—	—	—	—	—
BUFFT22	0 (0)	—	—	—	—	—
BUFFT24	7.78 (2.22)	—	—	—	—	—
BUFFT30	1.11 (1.11)	—	—	—	—	0.56 (0.56)
BUFFT31	3.33 (3.33)	—	—	—	—	0 (0)
BUFFT05	—	6.67 (3.47)	—	—	—	—
BUFFT07	—	0 (0)	—	—	—	0 (0)
BUFFT25	—	5.83 (4.17)	—	—	—	—
BUFFT33	—	0 (0)	—	—	—	—
BUFFT04	—	—	0 (0)	—	—	—
BUFFT13	—	—	0 (0)	—	—	—
BUFFT15	—	—	0.56 (0.56)	—	—	0 (0)
BUFFT16	—	—	0.56 (0.56)	—	—	—
BUFFT01	—	—	—	0 (0)	—	—
BUFFT06	—	—	—	0 (0)	—	—
BUFFT10	—	—	—	0 (0)	—	—
BUFFT11	—	—	—	0 (0)	—	—
BUFFT20	—	—	—	2.78 (2.78)	—	0 (0)
BUFFT23	—	—	—	0 (0)	—	—
BUFFT08	—	—	—	—	4.17 (4.17)	—
BUFFT14	—	—	—	—	0 (0)	—
BUFFT17	—	—	—	—	0 (0)	—
BUFFT27	—	—	—	—	0 (0)	0 (0)
BUFFT19	—	—	—	—	—	0 (0)

Appendix B. Individual metrics comprising the SCI index at BUFF mainstem and tributary monitoring sites, 2005-2011.

Table B-1. Mean taxa richness (±standard error) for Buffalo River mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	23 (1.17)	25.22 (6.53)	30.67 (2.34)	27.67 (1.39)	26.22 (0.56)
BUFFM02	24.33 (0.77)	25.11 (1.79)	23.78 (0.40)	26.89 (1.68)	21.89 (1.16)	26.56 (0.59)
BUFFM03	21.22 (0.44)	19.11 (0.97)	22.44 (0.91)	23.00 (0.38)	19.67 (1.45)	25.44 (6.73)
BUFFM04	18.67 (0.84)	21.44 (2.62)	20.22 (0.89)	23.00 (1.48)	20.22 (1.13)	21.11 (6.38)
BUFFM05	20.89 (1.60)	13.78 (2.04)	22.67 (0.77)	26.33 (2.83)	21.89 (3.28)	28.56 (3.23)
BUFFM06	24.33 (2.22)	—	29.11 (1.82)	19.89 (2.84)	17.22 (1.57)	24.67 (4.04)

Table B-2. Mean EPT richness (±standard error) for Buffalo River mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	16 (0.69)	12.44 (4.68)	16.89 (1.39)	17.67 (0.58)	14.22 (0.78)
BUFFM02	10 (0.51)	13.56 (1.64)	10.22 (0.87)	15.11 (1.13)	14 (1.00)	11.89 (0.48)
BUFFM03	10 (0.69)	12.89 (0.62)	11.33 (0.58)	14 (0.69)	12.67 (1.02)	12.44 (3.23)
BUFFM04	8.67 (0.51)	11.33 (1.68)	10.22 (0.56)	13.67 (0.69)	12.22 (1.68)	10.67 (3.18)
BUFFM05	8.89 (0.29)	7.67 (1.54)	10.67 (0.69)	15.67 (1.17)	14 (2.33)	15.67 (1.07)
BUFFM06	11.33 (1.07)	—	14.56 (1.24)	11.11 (1.13)	10.33 (0.84)	10.44 (1.57)

Table B-3. Mean Shannon's Diversity Index (±standard error) for Buffalo River mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	2.13 (0.16)	1.72 (0.42)	2.05 (0.13)	1.87 (0.19)	2.26 (0.04)
BUFFM02	2.61 (0.01)	2.31 (0.04)	2.15 (0.09)	2.12 (0.10)	1.60 (0.28)	2.29 (0.06)
BUFFM03	2.36 (0.10)	2.39(0.05)	1.91 (0.02)	2.18 (0.54)	1.58 (0.35)	1.88 (0.51)
BUFFM04	1.98 (0.04)	1.94 (0.03)	1.88 (0.03)	1.82 (0.08)	1.41 (0.18)	2.17 (0.21)
BUFFM05	1.99 (0.02)	2.29 (0.14)	2.034 (0.05)	1.90(0.12)	1.72 (0.17)	2.36 (0.11)
BUFFM06	2.38 (0.08)	—	2.26 (0.07)	2.04 (0.12)	1.58 (0.08)	2.34 (0.01)

Table B-4. Mean HBI (±standard error) for Buffalo River mainstem sampling sites.

Site	2005	2006	2007	2008	2009	2011
BUFFM01	—	4.06 (0.41)	5.78 (0.79)	5.04 (0.07)	4.92 (0.38)	5.03 (0.26)
BUFFM02	4.54 (0.20)	4.49 (0.18)	4.75 (0.15)	4.51 (0.28)	5.15 (0.26)	5.15 (0.44)
BUFFM03	4.84 (0.25)	3.68 (0.03)	4.36 (0.08)	3.75(0.14)	4.61 (0.53)	5.79 (0.06)
BUFFM04	5.40 (0.89)	4.64 (0.17)	5.06 (0.02)	4.93 (0.10)	4.07 (0.46)	4.56 (0.28)
BUFFM05	5.17 (0.03)	3.90 (0.08)	4.67 (0.13)	4.52 (0.26)	3.25 (0.08)	5.21 (0.03)
BUFFM06	4.78 (0.09)	—	5.41 (0.22)	4.04 (0.64)	3.70 (0.49)	4.98 (0.35)

Table B-5. Mean taxa richness (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	21.22 (2.41)	—	—	—	—	—
BUFFT09	19.89 (3.55)	—	—	—	—	—
BUFFT22	19.11 (3.19)	—	—	—	—	—
BUFFT24	16.33 (1.58)	—	—	—	—	—
BUFFT30	13.11 (0.78)	—	—	—	—	15.11 (0.91)
BUFFT31	13.44 (2.11)	—	—	—	—	16.22 (2.41)
BUFFT05	—	32.33 (2.64)	—	—	—	—
BUFFT07	—	23.67 (0.88)	—	—	—	26.44 (2.56)
BUFFT25	—	14.67 (2.52)	—	—	—	—
BUFFT33	—	30.11 (1.72)	—	—	—	—
BUFFT04	—	—	34 (1.58)	—	—	—
BUFFT13	—	—	26.56 (1.24)	—	—	—
BUFFT15	—	—	19.89 (2.02)	—	—	15.56 (1.66)
BUFFT16	—	—	22 (0.77)	—	—	—
BUFFT01	—	—	—	24.56(1.36)	—	—
BUFFT06	—	—	—	20.33 (1.71)	—	—
BUFFT10	—	—	—	32 (1.35)	—	—
BUFFT11	—	—	—	27.22 (1.75)	—	—
BUFFT20	—	—	—	22.11 (2.02	—	21 (0.88)
BUFFT23	—	—	—	17.56 (0.40)	—	—
BUFFT08	—	—	—	—	32.5 (2.17)	—
BUFFT14	—	—	—	—	29.78 (0.48)	—
BUFFT17	—	—	—	—	7.56 (0.44)	—
BUFFT27	—	—	—	—	25.33 (1.02)	14.89 (2.06)
BUFFT19	—	—	—	—	—	16.11 (4.55)

Table B-6. Mean EPT richness (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	11.78 (1.28)	—	—	—	—	—
BUFFT09	11.78 (2.21)	—	—	—	—	—
BUFFT22	7.22 (2.42)	—	—	—	—	—
BUFFT24	4.22 (0.68)	—	—	—	—	—
BUFFT30	4.22 (0.59)	—	—	—	—	5.67 (0.84)
BUFFT31	5.33 (1.20)	—	—	—	—	7.67 (1.20)
BUFFT05	—	12.56 (2.14)	—	—	—	—
BUFFT07	—	9.44 (0.40)	—	—	—	11.89 (0.87)
BUFFT25	—	2.22 (1.42)	—	—	—	—
BUFFT33	—	11.67 (0.88)	—	—	—	—
BUFFT04	—	—	18.44 (0.59)	—	—	—
BUFFT13	—	—	14 (1.20)	—	—	—
BUFFT15	—	—	11.11 (0.99)	—	—	6.56 (1.13)
BUFFT16	—	—	7.89 (0.56)	—	—	—
BUFFT01	—	—	—	14.11 (0.29)	—	—
BUFFT06	—	—	—	7.45 (0.13)	—	—
BUFFT10	—	—	—	16.78 (0.40)	—	—
BUFFT11	—	—	—	15.33 (1.71)	—	—
BUFFT20	—	—	—	14.67 (1.45)	—	12.78 (0.48)
BUFFT23	—	—	—	9.33 (0.69)	—	—
BUFFT08	—	—	—	—	16.17 (0.83)	—
BUFFT14	—	—	—	—	10.56 (0.40)	—
BUFFT17	—	—	—	—	1 (0.19)	—
BUFFT27	—	—	—	—	11.56 (0.40)	6.11 (0.59)
BUFFT19	—	—	—	—	—	10.78 (2.63)

Table B-7. Mean Shannon Diversity Index (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	2.21 (0.06)	—	—	—	—	—
BUFFT09	2.49 (0.16)	—	—	—	—	—
BUFFT22	2.44 (0.11)	—	—	—	—	—
BUFFT24	2.11 (0.07)	—	—	—	—	—
BUFFT30	1.72 (0.15)	—	—	—	—	1.50 (0.12)
BUFFT31	2.22 (0.09)	—	—	—	—	1.92 (0.11)
BUFFT05	—	2.48 (0.30)	—	—	—	
BUFFT07	—	2.20 (0.13)	—	—	—	2.70 (0.1)
BUFFT25	—	1.49 (0.21)	—	—	—	—
BUFFT33	—	2.06 (0.27)	—	—	—	—
BUFFT04	—	—	2.24 (0.08)	—	—	—
BUFFT13	—	—	1.77 (0.11)	—	—	—
BUFFT15	—	—	1.71 (0.09)	—	—	2.24 (0.15)
BUFFT16	—	—	2.11 (0.03)	—	—	—
BUFFT01	—	—	—	2.35 (0.20)	—	—
BUFFT06	—	—	—	1.78 (0.10)	—	—
BUFFT10	—	—	—	2.12(0.10)	—	—
BUFFT11	—	—	—	1.88 (0.16)	—	—
BUFFT20	—	—	—	1.93 (0.14)	—	2.25 (0.15)
BUFFT23	—	—	—	1.93 (0.04)	—	—
BUFFT08	—	—	—	—	3.10 (0.28)	—
BUFFT14	—	—	—	—	2.52 (0.07)	—
BUFFT17	—	—	—	—	1.42 (0.07)	—
BUFFT27	—	—	—	—	2.13 (0.04)	1.81 (0.16)
BUFFT19	—	—	—	—	—	2.01 (0.19)

Table B-8. Mean HBI (±standard error) for Buffalo River tributary sampling sites.

Site	2006	2007	2008	2009	2010	2011
BUFFT03	3.02 (0.26)	—	—	—	—	—
BUFFT09	4.61 (0.45)	—	—	—	—	—
BUFFT22	4.33 (0.20)	—	—	—	—	—
BUFFT24	5.34 (0.44)	—	—	—	—	—
BUFFT30	4.82 (0.36)	—	—	—	—	3.13 (0.40)
BUFFT31	4.62 (0.14)	—	—	—	—	5.29 (0.08)
BUFFT05	—	4.82 (0.41)	—	—	—	—
BUFFT07	—	4.36 (0.05)	—	—	—	4.42 (0.23)
BUFFT25	—	7.17 (0.43)	—	—	—	—
BUFFT33	—	3.99 (0.12)	—	—	—	—
BUFFT04	—	—	4.94 (0.09)	—	—	—
BUFFT13	—	—	5.19 (0.09)	—	—	—
BUFFT15	—	—	4.68 (0.22)	—	—	5.76 (0.22)
BUFFT16	—	—	5.09 (0.09)	—	—	—
BUFFT01	—	—	—	3.73 (0.06)	—	—
BUFFT06	—	—	—	5.83 (0.34)	—	—
BUFFT10	—	—	—	4.8 (0.08)	—	—
BUFFT11	—	—	—	4.87 (0.02)	—	—
BUFFT20	—	—	—	3.94 (0.28)	—	4.611 (0.40)
BUFFT23	—	—	—	5.21 (0.18)	—	—
BUFFT08	—	—	—	—	3.89 (0.38)	—
BUFFT14	—	—	—	—	5.23 (0.07)	—
BUFFT17	—	—	—	—	5.91 (0.18)	—
BUFFT27	—	—	—	—	5.38 (0.03)	5.57 (0.11)
BUFFT19	—	—	—	—	—	4.18 (0.21)

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