



Vulnerability of Stream Communities to Climate and Land Use Change at the Buffalo National River (BUFF)

Biotic communities are useful indicators of aquatic ecosystem health because a high quality, diverse, and functioning community reflects a high quality and functioning ecosystem. Stream habitats and communities are dynamic. Therefore, it is important to understand the natural variability of communities through time, such that changes from that natural variability may be used to make inferences of instability and the susceptibility to future climate and land use change. In addition, alterations in environmental conditions due to climate and land use change are major contributors to stream variability and degradation, but the extent that these impacts have on various regions and streams likely differ. Determining a stream's susceptibility to change from human caused impacts is necessary to determine stream communities that are most likely to experience a decrease in diversity, abundance, and function in the future. Data collected through monitoring equips park managers with the ability to understand the natural fluctuations in communities over time and among locations such that changes in future settings may be used to infer instability and, thus, vulnerability. Identifying locations where species are more vulnerable to degradation and determining the types of degradation that increases a community's vulnerability allows for an efficient science-based prioritization to manage and protect aquatic resources.

Methods:

For details on methods of site selection, aquatic invertebrate and fish sampling, habitat and water quality data collection, and data analysis see Bowles et al. (2007), Petersen et al. (2008) and Schwoerer (2016).

- The six mainstem sites were sampled annually for aquatic invertebrates from 2005-2011 and for fish community from 2006-2010, 2013 (Figure 1).
- Aquatic invertebrates were sampled using a slack surber sampler and identified to the lowest practical taxonomic level, usually genus. A combination of boat, backpack, and barge electrofishing was used to capture fish, which were identified to species, measured and inspected for diseases or abnormalities.
- The fish Index of Biotic Integrity (IBI; Dauwalter et al. 2003) was used to assess stream health based on fish community data and ranges from 0-100 with higher values indicating higher health. This index uses

seven metrics for scoring and includes: percent of individuals as algivorous, invertivorous, and piscivorous; percent of individuals with black spot anomaly; percent individuals as green sunfish, bluegill, yellow bullhead, and channel catfish; percent of individuals as invertivorous; percent of individuals as top carnivores; number of darter, sculpin, and madtom species; and number of lithophilic spawning species.

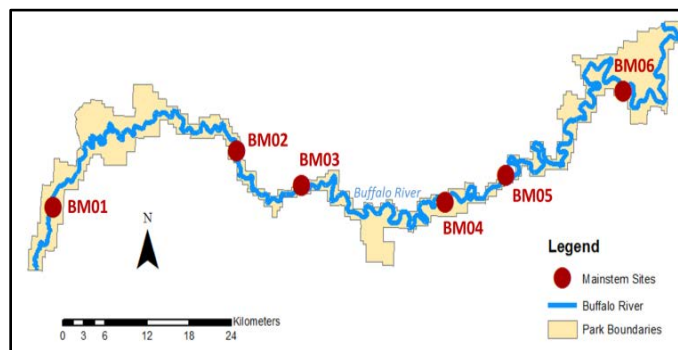


Figure 1. Map of the Buffalo National River and the six mainstem river sites that have been historically sampled for fish and aquatic invertebrates.

- The aquatic invertebrate Hilsenhoff Biotic Index (HBI; Hilsenhoff 1987) was used for stream health assessment based on all invertebrate taxa collected. The HBI uses taxa tolerance values to calculate a weighted community tolerance score based on abundances and ranges from 0-10 with *lower values indicating higher health*.
- Community variability was assessed by calculating the range in the biotic index scores (quantitative measure of stream health) at each site over each of the years it was sampled.
- Fish community vulnerability was calculated using methods found in Table 1. Fish vulnerable to habitat degradation (rock or gravel spawners or stream bed invertivores), warming temperatures (cool and cold-water species), altered flow regime (species requiring steady or variable yet predictable flow), or were a poor disperser (members in the topminnow, sculpin, and darter family) received a score of 1 in that category and all others received a 0. Scores range from 0 to 5. Fish species vulnerability scores can be found in Appendix 1.

- Aquatic invertebrate community vulnerability was calculated using methods found in Table 1 but did not take into account dispersal ability or persistence. Only mayfly, stonefly, and caddisfly (Ephemeroptera, Plecoptera, Trichoptera or EPT) taxa were used since they were best represented in available trait databases. Aquatic Invertebrates vulnerable to habitat degradation (taxa with < 4.5 HBI value), warming temperatures (stenotherm (< 5°C) or cold-cool eurytherm (0-15°C)), or an altered flow regime (species found in only one flow velocity classification of moderate or higher) received a 1 and all others received a 0. Scores range from 0 to 3. Invertebrate taxa vulnerability scores are in Appendix 2.

Table 1. Framework for developing species/taxa vulnerability scores (Siefert et al. 2016) that was used to calculate the community vulnerability score (mean of species/taxa vulnerability scores). Aquatic invertebrate vulnerability did not take into account dispersal ability or persistence. See above for vulnerability classifications.

Species Vulnerability Template		
Scoring	Habitat Degradation	0 or 1
	Warming Temperature	0 or 1
	Altered Flow Regime	0 or 1
	Dispersal Ability	0 or 1
	Species Persistence	1- (# Years Species Present/Total # Years Sampled)
Calculating	Environmental Tolerance	Habitat + Temperature + Flow
	Sensitivity	Dispersal Ability + Species Persistence
	Vulnerability	Environmental Tolerance + Sensitivity

Summary of Findings:

- A total of 54 fish species have been sampled across all years at this park. The mainstem site near Tyler Bend (Site BM04) had the highest fish richness (46 species) and the uppermost mainstem site (site BM01) had lowest fish richness (29 species). 171 aquatic invertebrate taxa (Genus level) have been sampled across all years at this park. The mainstem site near the Little Buffalo confluence (Site BM02) had the highest taxa richness (88) and the most downstream site (BM06) had the lowest taxa richness among mainstem sites (75).
- 75% of fish species were present each time the park was sampled while 87% of fish species were present in more than half of the years the park was sampled. 43% of invertebrate taxa (family level) were present in the park each time it was sampled while 69% of taxa were present in more than half of the years it was sampled.
- The mainstem site near Red Bluff (Site BM05) had the highest mean IBI score and ranged from 79 to 91 while site BM01 had the lowest mean IBI and ranged from 69 to 75 (Figure 2). Site BM01 had the highest mean HBI (lowest stream health based on invertebrate data) and ranged from 4.15 to 5.34 while site BM05 had the lowest HBI (highest stream health) and ranged from 3.47 to 5.20 (Figure 3).

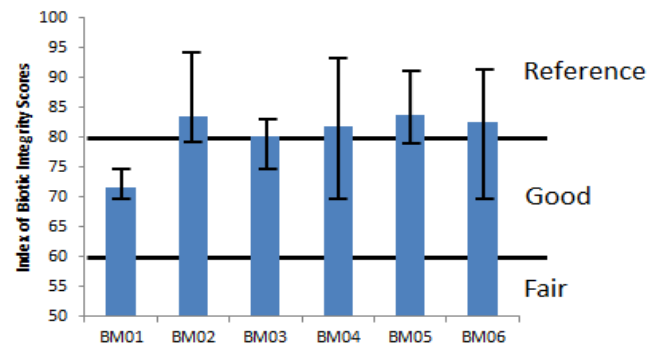


Figure 2. Mean Index of Biotic Integrity scores for fish communities at each of the mainstem river sites at the Buffalo National Rivers. Bars represent ranges in scores during the six sampling events in 2006-2010; 2013. Horizontal lines indicate stream integrity categories based on IBI scores.

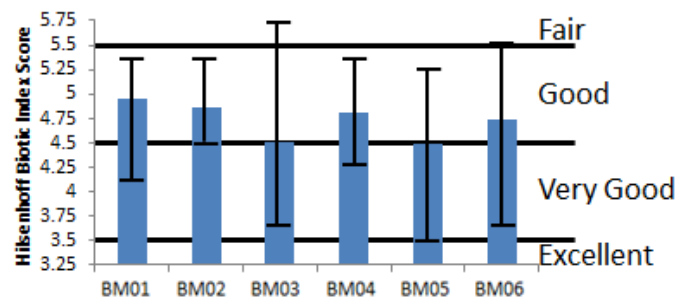


Figure 3. Mean Hilsenhoff Biotic Index scores for aquatic invertebrate communities at each of the mainstem river sites at the Buffalo National River. Bars represent ranges in scores during the seven sampling events in 2005 to 2011. Horizontal lines indicate stream integrity ratings based on HBI scores.

- For fish species collected in the park, 64% were vulnerable to habitat degradation, 47% were vulnerable to warming temperature, 45% were vulnerable to a change in flow regime, and 25% were poor dispersers (Table 2). For EPT invertebrate taxa, 72% were vulnerable to habitat degradation, 19% were vulnerable to warming temperature, and 74% were vulnerable to a change in flow regime (Table 2).

Table 2. Percent of fish species and EPT invertebrate taxa at seven National Park Service units within the central United States vulnerable to habitat degradation, warming temperatures altered flow regime or being a poor disperser (fish only) as well as overall park vulnerability score. Pipestone National Monument (PIPE), Tallgrass Prairie National Preserve (TAPR), Homestead National Monument of America (HOME), George Washington Carver National Monument (GWCA), Wilsons Creek National Battlefield (WICR), Ozark National Scenic Riverways (OZAR), and Buffalo National River (BUFF).

Park	Fish					Aquatic Invertebrate			
	Habitat	Temperature	Flow	Dispersal	Vulnerability (5)	Habitat	Temperature	Flow	Vulnerability (3)
HOME	27	27	53	0	1.45	48	14	90	1.52
TAPR	42	19	42	11	1.47	NOT SAMPLED			
OZAR	56	39	50	19	1.85	74	19	74	1.68
BUFF	64	47	45	25	1.95	72	19	74	1.65
PIPE	50	50	33	17	2.00	53	18	82	1.53
WICR	66	51	46	29	2.17	64	16	80	1.60
GWCA	69	63	44	38	2.31	67	25	83	1.75

- Site BM01 had the highest fish community vulnerability due to a high proportion of cool/cold water species and poor dispersers, while site BM03 (downstream of Carver) had the lowest fish community vulnerability (Table 3). Site BM02 had the highest invertebrate EPT vulnerability while site BM04 had the lowest invertebrate EPT vulnerability (Table 3).
- Of the seven parks analyzed in the Heartland I&M network (six for aquatic invertebrates), the Buffalo National River had the fourth most vulnerable fish community and the third most vulnerable aquatic invertebrate EPT taxa (Table 3).

Table 3. Percent of fish species and EPT invertebrate taxa in the Buffalo National River vulnerable to habitat degradation, temperature increase, flow modification, and dispersal ability (fish only) and the overall site vulnerability score.

Site	Fish					Aquatic Invertebrate			
	Habitat	Temp	Flow	Dispersal	Vulnerability (5)	Habitat	Temp	Flow	Vulnerability (3)
BM01	64	57	39	29	2.62	75	22	72	1.71
BM02	65	44	49	26	2.58	76	17	79	1.72
BM03	62	40	45	24	2.51	71	18	71	1.61
BM04	64	47	44	29	2.59	69	17	72	1.59
BM05	65	44	44	28	2.54	75	18	68	1.61
BM06	62	40	48	26	2.52	71	21	68	1.61

Appendix 1. Fish species vulnerable (1) to habitat degradation, temperature increase, altered flow, and poor dispersal ability in the Buffalo National River from 2006-2010, 2013. Reoccurrence is the inverse proportion of years a species was found within the park. Vulnerability (range from 0-5) is the sum of habitat, temperature, flow, dispersal, and reoccurrence columns.

Scientific Name	Common Name	Habitat	Temperature	Flow	Dispersal	Reoccurrence	Vulnerability
<i>Ichthyomyzon fossor</i>	Least Brook lamprey	1	1			0.83	2.83
<i>Lepomis humilis</i>	Orangespotted sunfish	1				0.83	1.83
<i>Oncorhynchus mykiss</i>	Rainbow trout	1	1	1		0.83	3.83
<i>Ictalurus punctatus</i>	Channel catfish			1		0.67	1.67
<i>Notemigonus crysoleucas</i>	Golden shiner			1		0.67	1.67
<i>Gambusia affinis</i>	Mosquitofish				1	0.67	0.67
<i>Moostoma macrolepidotum</i>	Shorthead redhorse		1	1		0.67	2.67
<i>Micropterus salmoides</i>	Largemouth bass			1		0.50	1.50
<i>Moostoma carinatum</i>	River redhorse	1		1		0.50	2.50
<i>Ichthyomyzon castaneus</i>	Chestnut lamprey	1	1	1		0.33	3.33
<i>Semotilus atromaculatus</i>	Creek chub	1	1			0.33	2.33
<i>Naturus flavater</i>	Checkered madtom			1		0.17	2.17
<i>Percina caprodes</i>	Logperch	1			1	0.17	2.17
<i>Etheostoma euzonum</i>	Arkansas saddled darter	1	1		1	0	3
<i>Etheostoma zonale</i>	Banded darter	1			1	0	2
<i>Cottus caroliniae</i>	Banded sculpin	1		1	1	0	3
<i>Notropis amblops</i>	Bigeye chub	1	1			0	2
<i>Notropis boops</i>	Bigeye shiner	1	1			0	2
<i>Moostoma duquesnei</i>	Black redhorse	1		1		0	2
<i>Fundulus olivaceus</i>	Blackspotted topminnow	1	1		1	0	3
<i>Lepomis macrochirus</i>	Bluegill			1		0	1
<i>Pimephales notatus</i>	Bluntnose minnow		1			0	1
<i>Labidesthes sicculus</i>	Brook silverside					0	0
<i>Notropis percobromus</i>	Carmine shiner					0	0
<i>Luxilus pilsbryi</i>	Duskystripe shiner	1	1			0	2
<i>Pylodictis olivaris</i>	Flathead catfish			1		0	1
<i>Percina evides</i>	Gilt darter	1	1		1	0	3
<i>Moostoma erythrurum</i>	Golden redhorse	1		1		0	2
<i>Lepomis cyanellus</i>	Green sunfish			1		0	1
<i>Etheostoma blennioides</i>	Greenside darter	1			1	0	2
<i>Nocomis biguttatus</i>	Hornyhead chub	1	1	1		0	3
<i>Lepomis megalotis</i>	Longear sunfish		1	1		0	2
<i>Lepisosteus osseus</i>	Longnose gar			1		0	1
<i>Hypentelium nigricans</i>	Northern hog sucker	1	1	1		0	3
<i>Fundulus catenatus</i>	Northern studdfish				1	0	1
<i>Etheostoma spectabile</i>	Orangethroat darter	1	1		1	0	3
<i>Ambloplites constellatus</i>	Ozark bass		1	1		0	2
<i>Erimystax harryi</i>	Ozark chub	1				0	1
<i>Naturus albat</i>	Ozark madtom	1		1		0	2
<i>Notropis nubilis</i>	Ozark minnow	1	1			0	2
<i>Cottus hypselurus</i>	Ozark sculpin	1	1	1	1	0	4
<i>Notropis ozarcanus</i>	Ozark shiner	1				0	1
<i>Etheostoma caeruleum</i>	Rainbow darter	1	1		1	0	3
<i>Naturus exilis</i>	Slender madtom	1	1	1		0	3
<i>Micropterus dolomieu</i>	Smallmouth bass			1		0	1
<i>Phoxinus erythrogaster</i>	Southern redbelly dace		1			0	1
<i>Etheostoma punctulatum</i>	Stippled darter	1	1		1	0	3
<i>Luxilus chrysocephalus</i>	Striped shiner	1				0	1
<i>Notropis telescopus</i>	Telescope shiner	1	1			0	2
<i>Notropis greeni</i>	Wedgespot shiner	1				0	1
<i>Cyprinella galactura</i>	Whitetail shiner					0	0
<i>Ameiurus natalis</i>	Yellow bullhead			1		0	1
<i>Etheostoma juliae</i>	Yoke darter	1	1		1	0	3

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Appendix 2. Mayfly, stonefly and caddisfly (EPT) taxa vulnerable (1) to habitat degradation, temperature increase, and altered flow in the Buffalo National River sampled from 2005-2011. Vulnerability (ranges from 0-3) is the sum of the habitat, temperature, and flow columns.

Order	Family	Genus	Habitat	Temperature	Flow	Vulnerability
Ephemeroptera	Ameletidae	Ameletus			1	1
Ephemeroptera	Baetidae	Procladius			1	1
Ephemeroptera	Baetidae	Pseudocloeon	1		1	1
Ephemeroptera	Baetiscidae	Baetisca	1		1	1
Ephemeroptera	Caenidae	Caenis			1	1
Ephemeroptera	Ephemeridae	Ephemerella	1		1	1
Ephemeroptera	Heptageniidae	Epeorus	1	1	1	2
Ephemeroptera	Heptageniidae	Rhythrogena	1	1	1	2
Ephemeroptera	Heptageniidae	Stenacron			1	1
Ephemeroptera	Heptageniidae	Stenonema	1		1	1
Ephemeroptera	Isonychiidae	Isonychia	1		1	1
Ephemeroptera	Leptophlebiidae	Leptophlebia				0
Ephemeroptera	Leptophlebiidae	Paraleptophlebia	1	1	1	2
Ephemeroptera	Tricorythidae	Tricorythodes				0
Plecoptera	Capniidae	Allocaenia	1	1	1	2
Plecoptera	Capniidae	Paracaenia	1		1	1
Plecoptera	Chloroperlidae	Alloperla	1	1	1	2
Plecoptera	Leuctridae	Leuctra	1		1	1
Plecoptera	Leuctridae	Zealeuctra	1		1	1
Plecoptera	Nemouridae	Amphinemura	1	1	1	2
Plecoptera	Nemouridae	Prostoia				0
Plecoptera	Perlidae	Acronuria	1			0
Plecoptera	Perlidae	Neoperla	1			2
Plecoptera	Perlidae	Paragnetina	1			0
Plecoptera	Perlidae	Perlesta	1			0
Plecoptera	Perlidae	Perlinella	1			0
Plecoptera	Perlodidae	Helopisus				0
Plecoptera	Perlodidae	Hydroperla	1		1	1
Plecoptera	Perlodidae	Isoperla	1	1	1	2
Plecoptera	Pteronarcyidae	Pteronarcys	1	1		1
Plecoptera	Taeniopterygidae	Strophopteryx	1			0
Plecoptera	Taeniopterygidae	Taeniopteryx	1		1	1
Trichoptera	Brachycentridae	Brachycentrus	1		1	1
Trichoptera	Glossosomatidae	Agapetus	1		1	1
Trichoptera	Helicopsychidae	Helicopsyche	1		1	1
Trichoptera	Hydropsychidae	Ceratopsyche	1		1	1
Trichoptera	Hydropsychidae	Cheumatopsyche			1	1
Trichoptera	Hydropsychidae	Hydropsyche	1		1	1
Trichoptera	Hydropsychidae	Potamyia			1	1
Trichoptera	Hydroptilidae	Hydroptila			1	1
Trichoptera	Hydroptilidae	Ochrotrichia			1	1
Trichoptera	Lepidostomatidae	Lepidostoma	1		1	1
Trichoptera	Leptoceridae	Nectopsyche	1		1	1

Citations:

- Bowles, D. E., J. A. Luraas, L. W. Morrison, H. R. Dodd, M. H. Williams, G. A. Rowell, M. D. DeBacker, J. A. Hinsey, F. D. Usrey, and J. L. Haack. 2007. Protocol for monitoring aquatic invertebrates at Ozark National Scenic Riverways, Missouri, and Buffalo National River, Arkansas. Natural Resource Report NPS/HTLN/NRR – 2007/009. National Park Service, Fort Collins, Colorado.
- Dauwalter, D. C., E. J. Pert, and W. E. Keith. 2003. An index of biotic integrity for fish assemblages in Ozark Highland Streams of Arkansas. Southeastern Naturalist 2: 447-468.
- Hilsenhoff, W. L., 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist 20: 31-39.
- Petersen, J. C., B. G. Justus, H. R. Dodd, D. E. Bowles, L. W. Morrison, M. H. Williams, and G. A. Rowell. 2008. Methods for monitoring fish communities of Buffalo National River and Ozark national Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1. U. S. Geological Survey Open-File Report 2007-1302, 94p.
- Schwoerer, J. M., 2016. Assessing the vulnerability of stream communities and the consistency and use of biotic indices in least-disturbed streams. MS thesis. University of Missouri, Columbia.
- Sievert, N., C. Paukert, Y. Tsang, and D. Infante. 2016. Development and assessment of indices to determine stream fish vulnerability to climate change and habitat alteration. Ecological Indicators.