



Vulnerability of Stream Communities to Climate and Land Use Change at the Ozark National Scenic Riverways (OZAR)

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 nine mainstem sites were sampled annually for the aquatic invertebrate and fish communities from 2005 to 2010 and 2012 (Figure 1).
- Aquatic invertebrates were sampled using a slack surber sampler, identified to lowest taxonomic group (usually genus), and counted. A combination of boat, backpack, and barge electrofishing was used to capture fish, which were identified to species, measured for length and weight, and assessed for anomalies/diseases.
- 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.

- 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.

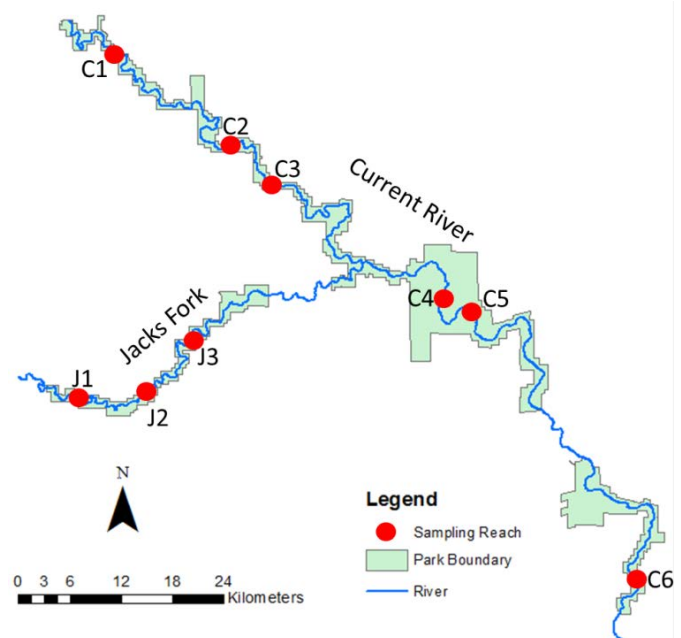


Figure 1. Map of the Ozark National Scenic Riverways and the nine mainstem river sites that have been historically sampled for fish and aquatic invertebrates.

- 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 63 fish species have been sampled at this park. The two lower Current River mainstem sites near Logyard and Grubb Hollow (Site C5 and C6) had the highest fish richness of 49 and 50 species, respectively. The Jacks Fork site downstream of Buck Hollow (J1) and the site near Bay Creek (J3) had the lowest fish richness of 33 species. 153 aquatic invertebrate taxa (Genus level) have been historically sampled at this park. The mainstem site near Grubb Hollow (Site C6) had the highest taxa richness (83) and the site downstream of Pulltite (C2) had the lowest taxa richness among mainstem sites (71).
- 43% of fish species were present each time the park was sampled while 82% of fish species were present in more than half of the years the

park was sampled. 46% of invertebrate taxa (family level) were present in the park each time it was sampled while 74% of taxa were present in more than half of the years it was sampled.

- The mainstem site near Robert's Field (Site C4) had the highest mean IBI score and ranged from 72 to 87 while site C1 near Cedar Grove had the lowest mean IBI and ranged from 56 to 81 (Figure 2). The site downstream of Pulltite (C2) had the highest variability in IBI scores. All mainstem sites rated as good or as reference condition based on fish community data.
- Site J1 had the highest mean HBI (lowest stream health based on invertebrate data) and ranged from 4.26 to 4.74 while site C3 near Round Spring had the lowest HBI (highest stream health) and ranged from 2.63 to 3.57 (Figure 3) Site C1 had the greatest variability in HBI scores.

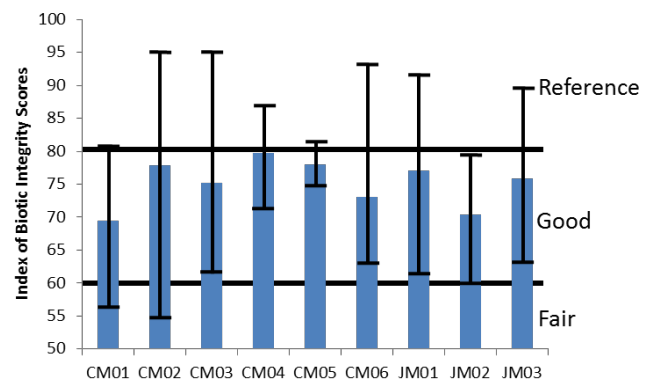


Figure 2. Mean Index of Biotic Integrity scores for fish communities at each of the mainstem river sites at the Ozark National Scenic Riverways. Bars represent ranges in scores during the seven sampling events in 2005 to 2010 and 2012. Horizontal lines indicate stream integrity categories based on IBI scores.

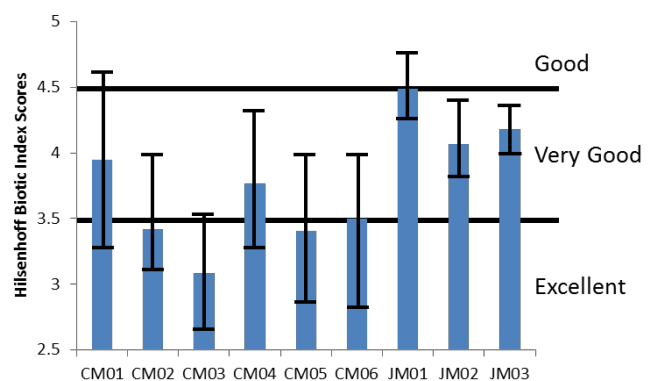


Figure 3. Mean Hilsenhoff Biotic Index scores for aquatic invertebrate communities at each of the mainstem river sites at the Ozark National Scenic Riverways. Bars represent ranges in scores during the seven sampling events in 2005 to 2010 and 2012. Horizontal lines indicate stream integrity ratings based on HBI scores.

- For fish species collected in the park, 56% were vulnerable to habitat degradation, 39% were vulnerable to warming temperature, 50% were vulnerable to a change in flow regime, and 19% were poor dispersers (Table 2). For EPT invertebrate taxa, 74% were vulnerable to habitat degradation, 19% were vulnerable to warming temperature, and 74% were vulnerable to a change in flow regime (Table 2).
- Site C1 and C5 had the highest fish community vulnerability. High vulnerability of site C1 was due to a high proportion of species vulnerable to habitat alteration and being poor dispersers while high vulnerability of site C5 was due to low species persistence over the years sampled. Site J3 had the lowest fish community vulnerability due to high species persistence and low vulnerability to warming temperatures (Table 3). Despite having the lowest taxa richness, site C2 had the highest EPT invertebrate community vulnerability due to the dominance by EPT taxa. Site C3 and J1 had the lowest EPT invertebrate community vulnerability (Table 3).
- Of the seven parks analyzed in the Heartland I&M network (six for aquatic invertebrates), the Ozark National Scenic Riverways had the fifth most vulnerable fish community and the second most vulnerable aquatic invertebrate EPT community (Table 2).

Table 3. Percent of fish species and EPT invertebrate taxa in the Ozark National Scenic Riverways 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)
C1	61	44	53	25	2.11	68	16	76	1.60
C2	55	45	48	23	2.08	81	23	84	1.87
C3	60	40	49	22	2.00	69	17	72	1.59
C4	59	43	46	22	2.00	76	21	72	1.69
C5	56	40	54	20	2.11	74	16	74	1.65
C6	55	37	55	20	1.96	76	17	72	1.66
J1	58	36	48	24	1.98	72	21	66	1.59
J2	59	44	47	26	2.03	75	21	68	1.64
J3	58	36	48	21	1.90	72	24	72	1.69

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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

Appendix 1. Fish species vulnerable (1) to habitat degradation, temperature increase, altered flow, and poor dispersal ability for species sampled in the Ozark National Scenic Riverways from 2005-2010 and in 2012. Reoccurrence is the inverse proportion of years a species was found in the park. Vulnerability (ranges 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>Pylodictis olivaris</i>	Flathead catfish			1		0.86	1.86
<i>Notemigonus crysoleucas</i>	Golden shiner			1		0.86	1.86
<i>Lepomis humilis</i>	Orangespotted sunfish	1				0.86	1.86
<i>Aphredoderus sayanus</i>	Pirate perch					0.86	0.86
<i>Maxostoma carinatum</i>	River redhorse	1		1		0.86	2.86
<i>Anguilla rostrata</i>	American eel			1		0.71	1.71
<i>Maxostoma macrolepidotum</i>	Shorthead redhorse		1	1		0.71	2.71
<i>Labidesthes sicculus</i>	Brook silverside					0.57	0.57
<i>Ichthyomyzon castaneus</i>	Chestnut lamprey	1	1	1		0.57	3.57
<i>Notropis atherinoides</i>	Emerald shiner		1			0.57	1.57
<i>Micropterus punctulatus</i>	Spotted bass			1		0.57	1.57
<i>Percina caprodes</i>	Logperch	1			1	0.43	2.43
<i>Minytrema melanops</i>	Spotted sucker	1		1		0.43	2.43
<i>Lampetra appendix</i>	American Brook lamprey		1			0.29	2.29
<i>Naturus flavater</i>	Checkered madtom	1		1		0.29	2.29
<i>Percina evides</i>	Gilt darter	1	1		1	0.29	3.29
<i>Notropis azarcanus</i>	Ozark shiner					0.29	1.29
<i>Oncorhynchus mykiss</i>	Rainbow trout	1	1	1		0.29	3.29
<i>Etheostoma zonale</i>	Banded darter	1			1	0.14	2.14
<i>Notropis amblops</i>	Bigeye chub	1	1			0.14	2.14
<i>Notropis boops</i>	Bigeye shiner	1	1			0.14	2.14
<i>Pimephales notatus</i>	Bluntnose minnow		1			0.14	1.14
<i>Notropis percobromus</i>	Carmine shiner					0.14	0.14
<i>Esox niger</i>	Chain pickerel			1		0.14	1.14
<i>Erimyzon oblongus</i>	Creek chubsucker	1		1		0.14	2.14
<i>Etheostoma eximium erizonum</i>	Current River saddled darter	1	1		1	0.14	3.14
<i>Maxostoma erythrurum</i>	Golden redhorse	1		1		0.14	2.14
<i>Lampetra aepyptera</i>	Least Brook lamprey	1	1			0.14	2.14
<i>Gambusia affinis</i>	Mosquitofish					0.14	0.14
<i>Erimyzon harrisi</i>	Ozark chub	1				0.14	1.14
<i>Lepomis microlophus</i>	Redear sunfish			1		0.14	1.14
<i>Lepomis miniatus</i>	Redspotted sunfish			1		0.14	1.14
<i>Lepomis gulosus</i>	Warmouth			1		0.14	1.14
<i>Notropis greeniei</i>	Wedgespot shiner	1				0.14	1.14
<i>Catostomus commersoni</i>	White sucker		1	1		0.14	2.14
<i>Cottus caroliniae</i>	Banded sculpin	1		1	1	0	3
<i>Maxostoma duquesnei</i>	Black redhorse	1		1		0	2
<i>Naturus maydeni</i>	Black River madtom			1		0	1
<i>Fundulus olivaceus</i>	Blackspotted topminnow	1	1		1	0	3
<i>Luxilus zonatus</i>	Bleeding shiner	1				0	1
<i>Lepomis macrochirus</i>	Bluegill			1		0	1
<i>Semotilus atromaculatus</i>	Creek chub	1	1			0	2
<i>Etheostoma uniporum</i>	Current River darter	1			1	0	2
<i>Etheostoma flabellare</i>	Fantail darter	1	1			0	3
<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>Micropterus salmoides</i>	Largemouth bass			1		0	1
<i>Lepomis megalotis</i>	Longear sunfish	1	1			0	2
<i>Hypentelium nigricans</i>	Northern hog sucker	1	1	1		0	3
<i>Fundulus catenatus</i>	Northern studfish				1	0	1
<i>Notropis nubilus</i>	Ozark minnow	1	1			0	2
<i>Cottus hypselurus</i>	Ozark sculpin	1	1	1	1	0	4
<i>Etheostoma caeruleum</i>	Rainbow darter	1	1		1	0	3
<i>Ambloplites ariommus</i>	Shadow bass			1		0	1
<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>Luxilus chrysocephalus</i>	Striped shiner	1				0	1
<i>Notropis telescopus</i>	Telescope shiner	1	1			0	2
<i>Cyprinella galbictura</i>	Whitetail shiner					0	0
<i>Ameiurus natalis</i>	Yellow bullhead			1		0	1

Appendix 2. Aquatic invertebrate taxa vulnerable (1) to habitat degradation, temperature increase, and altered flow in the Ozark National Scenic Riverways sampled from 2005-2010 and in 2012. Vulnerability (range from 0-3) is the sum of the habitat, temperature, and flow columns

Order	Family	Genus	Habitat	Temperature	Flow	Vulnerability
Ephemeroptera	Baetidae	Baetis		1	1	2
Ephemeroptera	Baetidae	Paracloeodes			1	1
Ephemeroptera	Baetidae	Pseudocloeon	1		1	1
Ephemeroptera	Baetiscidae	Baetisca	1		1	1
Ephemeroptera	Caenidae	Caenis			1	1
Ephemeroptera	Ephemeridae	Ephemera	1		1	1
Ephemeroptera	Ephemeridae	Hexagenia				0
Ephemeroptera	Heptageniidae	Rhithrogena	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	Siphonuridae	Siphonurus	1	1	1	1
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	Acroneuria	1			0
Plecoptera	Perlidae	Neoperla	1			2
Plecoptera	Perlidae	Paragnetina	1			0
Plecoptera	Perlidae	Perlesta	1			0
Plecoptera	Perlidae	Perlinella	1			0
Plecoptera	Perlidae	Helopicus				0
Plecoptera	Perlidae	Hydroperla	1		1	1
Plecoptera	Perlidae	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	Brachycentridae	Micrasema	1		1	1
Trichoptera	Glossosomatidae	Agapetus	1		1	1
Trichoptera	Glossosomatidae	Glossosoma	1		1	1
Trichoptera	Glossosomatidae	Protophila	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	Hydroptilidae	Hydroptila			1	1
Trichoptera	Hydroptilidae	Ochrotrichia			1	1
Trichoptera	Lepidostomatidae	Lepidostoma	1		1	1
Trichoptera	Leptoceridae	Ceraclea	1		1	1
Trichoptera	Leptoceridae	Nectopsyche	1		1	1

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