



Five-Year Review and Recommendations for Revision of Aquatic Sampling Protocols at Buffalo National River and Ozark National Scenic Riverways

Natural Resource Report NPS/HTLN/NRR—2012/563



ON THE COVER

Current River at Ozark National Scenic Riverways

Photograph from: The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program files

Five-Year Review and Recommendations for Revision of Aquatic Sampling Protocols at Buffalo National River and Ozark National Scenic Riverways

Natural Resource Report NPS/HTLN/NRR—2012/563

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Contents

	Page
Figures.....	vi
Tables.....	vii
Executive Summary	ix
Acknowledgments.....	x
Introduction.....	1
Assessment of Current Workload	3
Monitoring Effort Based on the Current Protocols.....	3
Establishing Targets for Sustainable Field and Lab Workloads.....	6
Invertebrate Sampling	6
Fish Sampling	8
Alternatives for Achieving Sustainable Targets	10
Evaluation of Aquatic Invertebrate Field and Lab Methodologies	10
Evaluation of Number of Benthic Invertebrate Samples	10
Habitat Assessment.....	11
Ordination Analyses	11
Substrate	13
Stream Discharge	15
Evaluation of Aquatic Invertebrate Data Summary and Analysis.....	18
Buffalo River Index of Community Integrity (BRICI) —BUFF	18
Results for BUFF Invertebrate Community Metrics and BRICI, 2005-2010.....	19
Weaknesses of the BRICI and Its Use for Estimating Water Quality at BUFF	22
Missouri Stream Condition Index (SCI).....	24
SCI results for BUFF	25

Contents (continued)

	Page
SCI results for OZAR	27
Ozark Rivers Stream Invertebrate Multimetric Index (OSRIMI)	29
Evaluation of Fish Field and Lab Methodologies	31
Physical Habitat Data	31
Utility of Length/Weight Data	36
Evaluation of Fish Data Summary and Analysis	37
Evaluation of Ozark Highlands Index of Biotic Integrity	37
Summary of Proposed Changes	39
Changes to the Mainstem and Tributary Sampling	39
Proposed BUFF Revisit Plan	40
Recommended BUFF Revisit Design (4-year rotation)	40
Proposed OZAR Revisit Plan	41
Recommended OZAR Revisit Design for Mainstems and Tributaries (4-year rotation)	41
Changes to the Spring Communities Protocol	43
Ramifications of Changing the Revisit Design	43
Literature Cited	44

Figures

	Page
Figure 1. Map of BUFF showing locations of mainstem sites (annual panel) and tributaries (panels 1-5)	4
Figure 2. Map of OZAR showing locations of mainstem sites (annual panel) and tributaries (panels 1-5).	5
Figure 3. Current amount of fish monitoring related fieldwork for the HTLN Fisheries Biologist.	8
Figure 4. Current amount of vital signs monitoring field days for the HTLN Fisheries Biologist.	9
Figure 5. OZAR tributaries NMS ordination convex hull diagrams by year for invertebrates	14
Figure 6. BUFF tributaries NMS ordination convex hull diagrams by year for invertebrates	15
Figure 7. Mean BRICI scores and standard errors for Buffalo River mainstem sampling sites, 2005-2009.	20
Figure 8. BRICI scores for seven sites on the Buffalo River each based on five pooled samples and genus-level identifications.....	20
Figure 9. BUFF water quality sampling locations (black circles), and HTLN monitoring sites (red triangles).	21
Figure 10. Mean BRICI scores and standard errors for Buffalo National River tributary sampling sites, 2006-2010.....	21
Figure 11. Mean SCI scores and standard errors for Buffalo River mainstem sampling sites, 2005-2009.	26
Figure 12. Mean SCI scores and standard errors for Buffalo National River tributary sampling sites, 2006-2010.	27
Figure 13. Mean SCI scores and standard errors for Current River and Jacks Fork mainstem sampling sites, 2005-2009.....	28
Figure 14. Mean SCI scores and standard errors for Ozark National Scenic Riverways tributary sampling sites, 2006-2010.....	28
Figure 15. Convex hull diagrams for OZAR tributary fish. Each point represents a tributary	35

Tables

	Page
Table 1. Current laboratory workload for aquatic invertebrate monitoring at BUFF and OZAR.....	7
Table 2. Current field workload for aquatic invertebrate monitoring at BUFF and OZAR (crew size = 3).....	7
Table 3. Average number of field days for fish community monitoring in HTLN parks.....	8
Table 4. USGS staff gages at BUFF and OZAR used for making discharge estimates for monitoring sites.	17
Table 5. Quartile scores for the Buffalo River Index of Community Integrity (BRICI) based on lower level identifications at eight main channel sites of the Buffalo National River.....	19
Table 6. Mean metric values from riffle habitat of reference streams (n=5) in the Ozark ecoregion during fall index period.	25
Table 7. Descriptive statistics and scores for the metrics for the fall index period based on single habitat coarse substrate (riffle) data.	25
Table 8. ORSIMI values for OZAR mainstem river sites based on baseline data collected 2005-2009.....	30
Table 9. ORSIMI values for BUFF mainstem river sites based on baseline data collected 2005-2009.....	30
Table 10. Habitat variables (n = 27) measured at all sites during fish monitoring.....	33
Table 11. Summary of habitat variables correlated with nonmetric multidimensional scaling ordination axes.....	34
Table 12. Index of Biotic Integrity (IBI) scores, mean IBI and standard deviations for OZAR mainstem sites using the Ozark Highland IBI and Current River IBI.	38
Table 13. Index of Biotic Integrity (IBI) scores for OZAR tributaries using the Ozark Highland IBI and Current River IBI.	38
Table 14. Summary of changes between former protocols and the revised protocol.	42

Appendices

	Page
Appendix A. Proposal to modify fish community monitoring at Tallgrass Prairie National Preserve and Pipestone National Monument	47
Appendix B: List of tributaries sampled for invertebrates by year and location.	53
Appendix C: List of tributaries sampled for fish by year, location and watershed area.....	54
Appendix D. Proposed approach for conducting geomorphological assessments for BUFF and OZAR mainstem monitoring sites.	55
Appendix E. Habitat and water quality summary data for BUFF and OZAR mainstem sampling sites (invertebrate sampling at riffles).	56
Appendix F. Full methodological details and results of NMS ordinations of invertebrate communities.....	62
Appendix G. Individual metrics comprising the BRICI index at BUFF mainstem monitoring sites.....	78
Appendix H. Individual metrics comprising the SCI index at BUFF and OZAR mainstem monitoring sites.	84
Appendix I. Full methodological details and results of NMS ordinations of fish communities.....	88
Appendix J: List of fish species collected by park.	101

Executive Summary

The Heartland Inventory and Monitoring Network monitors the fish and aquatic invertebrates in the big river systems of the Buffalo National River and Ozark National Scenic Riverways. After five years of monitoring these river systems, it has become apparent that changes to the monitoring protocols are necessary, primarily because of workload limitations. Here we review the data from the first five years of monitoring, and we consider a number of changes to protocols for both fish and invertebrates. A relatively large number of habitat variables are collected by both the fish and invertebrate protocols, and relatively few were found to be highly correlated with ordination axes following a nonmetric multidimensional scaling procedure. Collection of habitat variables in the field takes relatively little time, however, and it is possible that such habitat data may be useful for future questions relating to specific taxa or sites. Ordination analyses showed that tributaries tended to group by year, indicating relatively strong inter-annual variability. This suggests that tributaries should be sampled more frequently than every five years. A revised revisit plan suggests sampling fewer tributaries more frequently. The plan also suggests decreasing the frequency of mainstem sampling from every year to every other year, a necessary reduction of sampling effort to meet workload goals. The indices used to evaluate fish and invertebrate communities were also re-evaluated to determine their ability to effectively describe the quality of aquatic communities and to detect temporal changes in stream integrity. For the springs at OZAR, recommended changes are to sample invertebrates every third year rather than every year, and include a new spring, Phillips Spring.

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Introduction

The Heartland Inventory and Monitoring Network (HTLN) monitors aquatic invertebrates, fish, and contaminant metals in the big river systems of the Buffalo National River (BUFF) and Ozark National Scenic Riverways (OZAR). HTLN also monitors the fish and aquatic invertebrates of small streams in a number of other network parks. During HTLN's 2008 annual meeting and start-up review, it was discussed and agreed by the review panel (consisting of Steve Fancy, Carmen Thomson, Bill Route and George Oviatt), park superintendents, and resource managers that the network was operating on a "razor-thin margin" (National Park Service 2008). While the review panel noted HTLN's impressive productivity accomplished with a relatively small staff and budget, they agreed that efforts should be made to trim costs and make field sampling more efficient. One concern was that the aquatics program staff was stretched too thin, and the review panel suggested that HTLN staff consider cutting back on field sampling until additional funding and staff could be obtained.

Fish and invertebrates have now been monitored at BUFF and OZAR for five consecutive years under protocols recently developed (Bowles et al. 2007, Petersen et al. 2008). Fish and invertebrate sampling in parks with small streams has been conducted for longer periods of time under older protocols. However, both the fish and invertebrate protocols for the parks with small streams have recently been revised (see Bowles et al. 2008a, Dodd et al. 2008, Appendix A) to reduce the frequency and intensity of sampling. The revised small stream protocols represent our first attempt to scale back to a sustainable workload.

In a memo to Superintendents Reed Detring and Kevin Cheri dated May 10, 2010, Mike DeBacker, HTLN Coordinator, called for the establishment of an ad-hoc committee of park natural resource managers and network staff to deliberate the merits of various approaches to scaling back the monitoring at big river parks (i.e., BUFF and OZAR) to a sustainable level. The individuals nominated to serve on the ad hoc committee include: Dr. David Bowles, Hope Dodd, Dr. Lloyd Morrison (HTLN), Barbara Wilson, Faron Usrey (BUFF), Victoria Grant, and Mike Gossett (OZAR).

To initiate this important review process, an initial meeting of the ad hoc committee was held at Wilson's Creek National Battlefield on February 17, 2011. Prior to the first meeting of the ad hoc committee, representatives from the parks were asked to review the protocols addressing invertebrates and fish, reply to a pre-meeting questionnaire, and craft some ideas for reducing the current workload of the aquatic program while maintaining the scientific integrity of the data.

This document reports on analyses and other efforts to evaluate various aspects of the monitoring protocols relevant to the big river parks, and serves as an administrative history and record of decisions made during the revision process. The primary purpose of this report is to document evaluation of potential changes to the monitoring of fish and aquatic invertebrates at BUFF and OZAR. Changes that have been considered include sampling fewer sites, sampling less frequently, collecting fewer invertebrate samples per site, collecting data on fewer habitat variables, and not collecting data on fish lengths and weights. In addition to the need to decrease

staff workload, some of the metrics used to report the results of the monitoring have been found to be less than satisfactory, and are in need of replacement. Based on this review, recommendations are made for revising the protocols associated with sampling and analysis of data from the big river systems of BUFF and OZAR.

The protocols that have been developed for aquatic monitoring activities include:

Invertebrate monitoring in small streams: [Bowles, D. E., M. H. Williams, H. R. Dodd, L. W. Morrison, J. A. Hinsey, C. E. Ciak, G. A. Rowell, M. D. DeBacker, J.L. Haack. 2008. Monitoring Protocol for Aquatic Invertebrates of Small Streams in the Heartland Inventory & Monitoring Network. Natural Resource Report NPS/HTLN/NRR—2008/042. National Park Service, Fort Collins, Colorado.](#)

Fish monitoring in small streams: [Dodd, H.R., D.G Peitz, G.A. Rowell, D.E. Bowles, and L.W. Morrison. 2008. Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR - 2008/052. National Park Service, Fort Collins, Colorado.](#)

Invertebrate monitoring in big river systems: [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, 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,](#)

Fish monitoring in big river systems: [Petersen, J.C., Justus, B.J., Dodd, H.R., Bowles, D.E., Morrison, L.W., Williams, M.H., and Rowell, G.A., 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, 94 p., and](#)

Springs monitoring at OZAR: [Bowles, D. E., H. R. Dodd, M. H. Williams, L. W. Morrison, K. James, M. D. DeBacker, C. E. Ciak, J. A. Hinsey, G. A. Rowell, and J. L. Haack. 2008. Protocol for Monitoring Spring Communities at Ozark National Scenic Riverways, Missouri. Natural Resource Report NPS/HTLN/NRR - 2008/029. National Park Service, Fort Collins, Colorado.](#)

Contaminants monitoring in big river systems: [Schmitt, C.J., Brumbaugh, W.G., Besser, J.M., Hinck, J.E., Bowles, D.E., Morrison, L.W., and Williams, M.H., 2008, Protocol for monitoring metals in Ozark National Scenic Riverways, Missouri: Version 1.0: U.S. Geological Survey Open-File Report 2008–1269, 42 p.](#)

[A proposal to modify fish monitoring in small streams that has not yet been incorporated into the most recent version of the protocol is presented in Appendix A.]

Assessment of Current Workload

Monitoring Effort Based on the Current Protocols

Following the current protocols, HTLN aquatic staff monitored invertebrates and fish at mainstem sampling sites at BUFF and OZAR from 2005 through 2009, tributaries from 2006 to 2010, and spring communities at OZAR from 2007-2011. Six mainstem sites and 30 tributaries were scheduled for sampling at BUFF (Figure 1), and nine mainstem sites and 15 tributaries were scheduled for sampling at OZAR (Figure 2). Mainstem sites were sampled annually and tributaries were monitored on a 5-year rotating basis, with 6 tributaries per panel at BUFF and 3 tributaries per panel at OZAR (Bowles et al. 2007, Petersen et al. 2008).

For invertebrate monitoring, BUFFM01 was not sampled in 2005 because the channel was dry, and BUFFM06 was not sampled in 2006 because of flooding that occurred throughout the index period. Several tributaries in both parks could not be sampled for invertebrates during the index period because they were dry or had insufficient flow. For a list of tributaries actually sampled, see Appendix B (invertebrates) and Appendix C (fish). In addition to the mainstems and tributaries, six large springs have been monitored at OZAR. Aquatic vegetation and invertebrates have been monitored annually, and fish were sampled every 3 years.

For the mainstems and tributaries, the sampling effort was approximately 72 field person-days per year for invertebrates and approximately 204 field person-days for fish. Field work for monitoring springs at OZAR requires 15 person days per year for invertebrates and 10 person days per year for fish.

At each site, 9 benthic invertebrate samples were collected, resulting in a maximum of 216 samples annually. An additional 28 invertebrate samples are collected annually from OZAR springs. Laboratory time for processing invertebrate samples is extensive. Each sample takes on average 8 hours to process (from point of collection to data entry). Lab work associated with fish monitoring at BUFF and OZAR ranges from 15 to 24 samples processed annually, and requires 4-8 hours per sample site.

Based on this analysis, we identified two work load bottlenecks that are the primary focus of our investigation. For invertebrate sampling, the lab time required to process the large number of samples is the primary obstacle to sustainable operations. For fish monitoring, the demanding field work that necessitates large crews is not sustainable, particularly for the project leader.

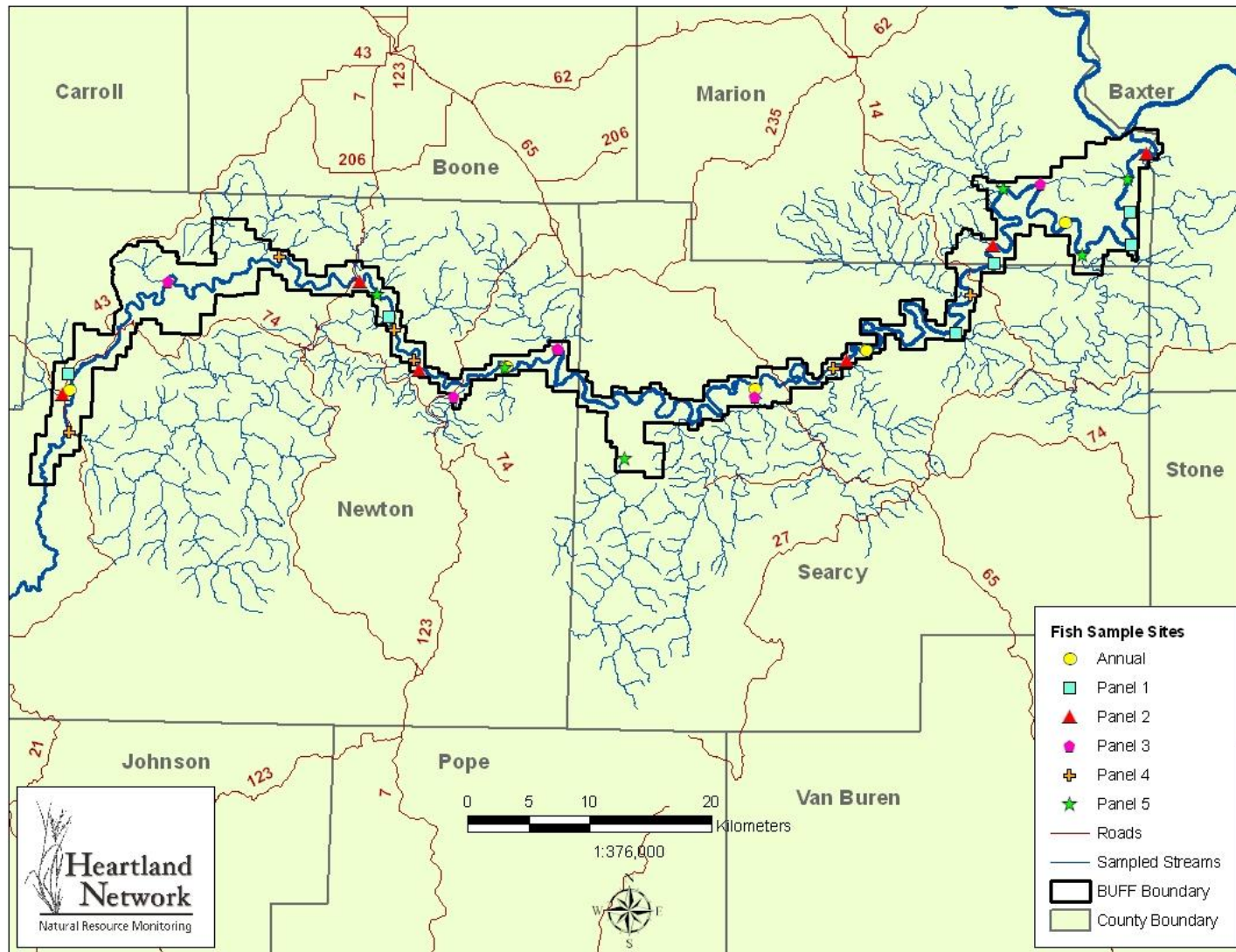


Figure 1. Map of BUFF showing locations of mainstem sites (annual panel) and tributaries (panels 1-5). Fish and invertebrates are sampled at the same sites.

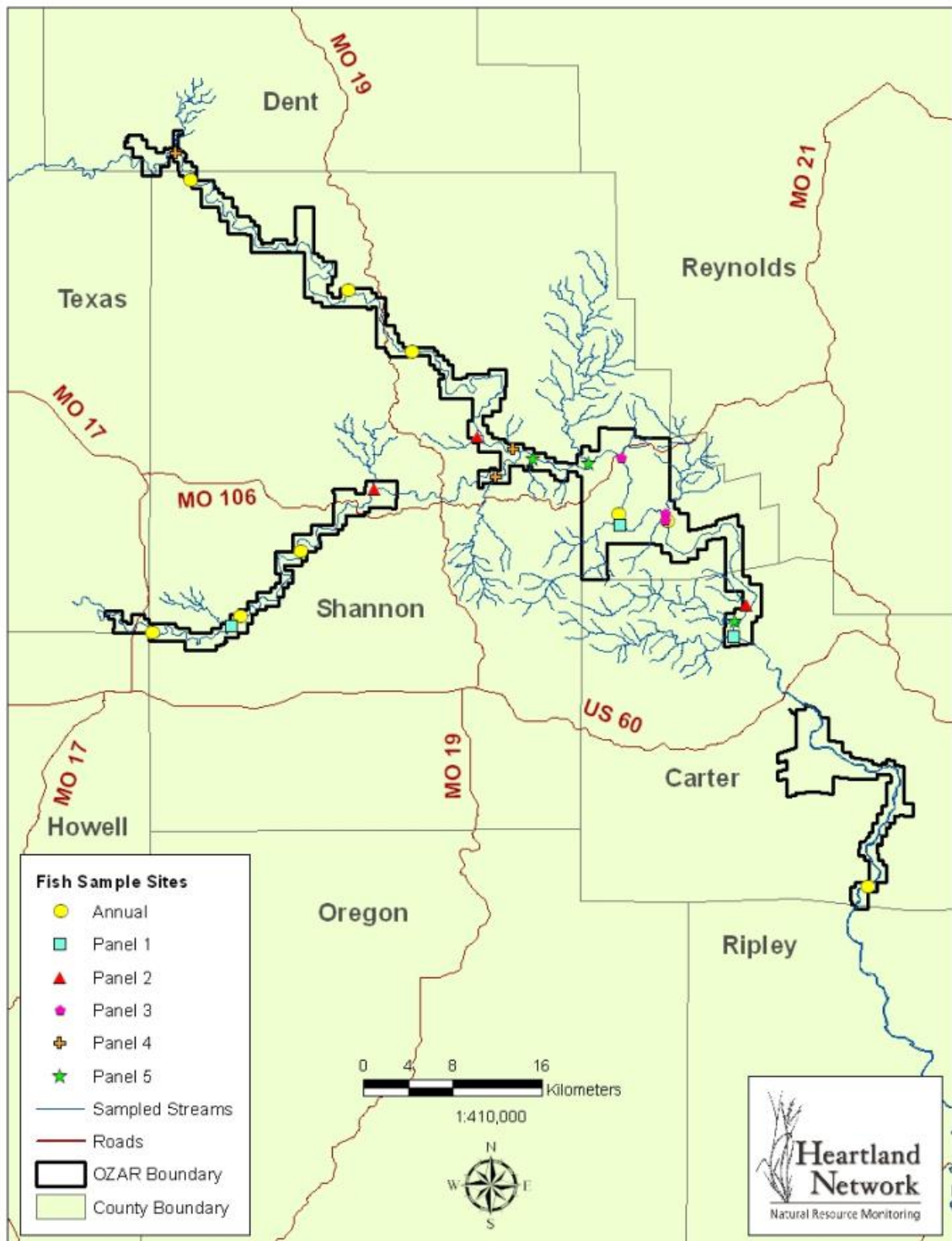


Figure 2. Map of OZAR showing locations of mainstem sites (annual panel) and tributaries (panels 1-5). Fish and invertebrates are sampled at the same sites.

Establishing Targets for Sustainable Field and Lab Workloads

Invertebrate Sampling

Network aquatic ecologists currently spend a collective average of 230 total person-days in the lab processing 307 benthic samples (Table 1), and an additional 34 days per person (on average) are spent in the field collecting those samples (Table 2). To this effort is added approximately 41 days those same staff members participate in fish monitoring.

The total field days per person and extensive lab time leaves essentially no residual time for working on other network projects or assisting parks on other projects that might arise. Additionally, despite the time expended in processing benthic samples, network staff consistently fell behind, resulting in failure to completely process samples in the year they were collected. In general, about one-half of the samples collected in a given year are not completely processed in that year. This has resulted in substantial delays in entering the data into the database, data analysis and report preparation.

Staff typically process samples collected during the spring from small streams from June-October (minus field days for fish and springs sampling, ~4 weeks). From November through April there are 78 days available for processing river/tributary samples collected from BUFF and OZAR (Table 3). Given an average river/tributary sample requires about 8 hours to collect and completely process, each aquatic ecologist can process only about 78 samples during this period, or 156 total samples. The invertebrate samples collected from the springs (n=28) are considerably more difficult to process compared to river samples—on average spring samples take roughly 3 times longer to process.

To ensure samples can be completely processed in the year they were collected, and to facilitate timely data entry, analysis, and reporting, we established a target of 156 annual samples for BUFF and OZAR combined. We also acknowledged that a portion of the reduction in sample size must come from springs at OZAR, given their additional processing time.

Table 1. Current laboratory workload for aquatic invertebrate monitoring in HTLN parks.

Sample Processing	#	% of Effort
Small streams (n=17)	63	21%
OZAR Springs (n=6)	28	9%
BUFF		
Tributaries (n=6 per year)	54	18%
River (n=6)	54	18%
OZAR		
Tributaries (n=3 per year)	27	9%
Rivers (n=9)	81	26%
TOTAL samples	307	
Total Estimated hours	1842	
Person-days	230.25	

Table 2. Current field workload for aquatic invertebrate monitoring in HTLN parks (crew size = 3).

Field Work	Days	% of Effort
Small streams (n=17)	5	15%
OZAR Springs (n=6)	5	15%
BUFF		
Tributaries (n=6 per year)	6	18%
River (n=6)	6	18%
OZAR		
Tributaries (n=3 per year)	3	9%
Rivers (n=9)	9	26%
TOTAL days (8 hour) days	34	
Total Estimated hours	816	
Person-days	102	

Fish Sampling

The HTLN aquatics crew (Fisheries Biologist, 2 Aquatic Ecologists, and 3 Seasonals) spend about 270 person-days in the field sampling fish annually (Table 3) with the Fisheries Biologist expending more than 50 days per year (Figure 3). Approximately 76% of their effort is sampling river fish communities at BUFF (38%) and OZAR (38%), and an additional 4% of their effort is sampling fish in OZAR springs (Table 3). Field work demand is particularly heavy for the Fisheries Biologist, who is also responsible for assisting with other vital signs monitoring field work such as river and stream invertebrates, vegetation and invertebrates at OZAR springs, and metal contaminants at river parks. With these additional vital signs responsibilities, the Fisheries Biologist spent over 60 days per year in the field over the past five years of monitoring (2006-2010) (Figure 4). Presently, the field workload placed on the Fisheries Biologist leaves little time to analyze and write reports in a timely manner or to assist parks in special projects. By comparison, other project leaders within HTLN typically average 40-45 field days per year, which is a sustainable fieldwork load to allow for reporting of monitoring results and to assist parks with additional needs. Our target was to reduce the required fieldwork of the Fisheries Biologist to 35 days per year to maintain current aquatic vital signs monitoring, and to add the geomorphology vital sign for BUFF and OZAR (which may add ~5 additional days, for a total of 40).

Table 3. Average number of field days for fish community monitoring in HTLN parks.

	Field Days for Past Years	Person- Days for Past Years	% of Person- Days for Past Years
Small Streams (crew of 4)	14	56	21
OZAR Springs (crew of 5)	2	10	4
BUFF (crew of 6)	17	102	38
OZAR (crew of 6)	17	102	38
Total days	50		
Person-days		270	

Figure 3. Current amount of fish monitoring related fieldwork for the HTLN Fisheries Biologist.

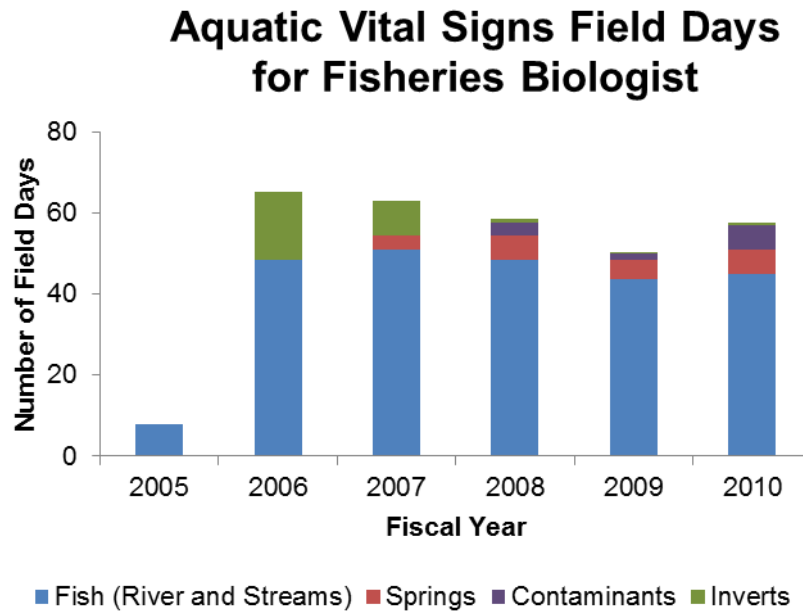


Figure 4. Current amount of vital signs monitoring field days for the HTLN Fisheries Biologist.

Alternatives for Achieving Sustainable Targets

Evaluation of Aquatic Invertebrate Field and Lab Methodologies

Evaluation of Number of Benthic Invertebrate Samples

The protocol for monitoring aquatic invertebrates at OZAR and BUFF (Bowles et al. 2007) requires the collection of nine total benthic samples from each site, three samples from each of three riffles. Reducing the number of samples per riffle, the number of riffles per site, or both, would decrease the amount of processing effort expended.

Invertebrate community structure among riffles in a given stream reach can be highly variable (Bowles 1989a, Carter et al. 1996, Karr and Chu 1999, Gebler 2004, Downes et al. 2006). For example, Gebler (2004) found that invertebrate community structure among stream riffles in a given stream reach can vary widely, suggesting that any particular set of sampling reaches could yield misleading estimates of population parameters and effects that can be detected. Gebler's study suggests that metric values from a single riffle or even a single stream reach may not be adequate to represent a stream segment. Downes et al. (2006) likewise showed that significant variation in faunal densities may occur over small spatial scales, which could provide misleading results in monitoring studies related to water quality. Bowles (1989a, b) and Carter et al. (1996) each found that single riffle sampling was generally inadequate to characterize a stream reach and may produce misleading results because of high variability among riffles. A multiple riffle sampling design was judged to be more appropriate for representing stream condition (Bowles 1989a, b). Carter et al. (1996) found that reach-scale (i.e., multiple riffles) variables discriminated better among invertebrate communities than did sample-scale (i.e., single riffle) variables.

A single sample from part of a riffle is not sufficiently precise for judging stream condition (Karr and Chu 1999). For example, Karr and Chu (1999) reported on the effects of replicate sampling using a bootstrap resampling algorithm based on five benthic samples taken per riffle. With only one replicate, a metric could either increase or decrease depending on which of the five replicates was chosen by the bootstrap algorithm. For three replicates, the relationship between metric scores and human influence is more consistent (Karr and Chu 1999). Karr and Chu (1999) therefore recommended a minimum of three benthic samples should be collected from a single riffle. Although collecting three benthic samples from a single riffle can adequately characterize that site, it generally fails to characterize a stream reach, thus justifying sampling from multiple riffles within a stream reach (Karr and Chu 1999).

Similarly, in his basin-wide study of the Buffalo River while developing an Index of Community Integrity (ICI), Mathis (2001) showed that three samples per riffle were adequate to assess the invertebrate community in the Buffalo River. This sample size was determined by first collecting five samples at a site. The samples were then compiled into all possible combinations of groups ranging from two sample pools to five sample pools in a group. The various metrics and ICI values were then calculated for each group and compared to the results of the group with five samples using several techniques. Mean ICI values were compared using Pearson's correlation analysis to the five pooled sample group, and the results showed Pearson's correlation

coefficients tended to be higher with increasing sample size. Mathis (2001) indicated the minimum acceptable number of samples should have a statistically significant correlation coefficient that was >0.90 ($p < 0.05$).

Usrey and Hinsey (2006), following procedures similar to Mathis (2001), compared three different riffles, one each from an upper, middle, and lower site on a major tributary of the Buffalo River using various sample sizes from three samples per riffle to nine samples per riffle. An ANOVA with Bonferroni's adjustment was used to test for significance between community metrics for each of the three sites at various sample sizes. This latter study showed that three samples per riffle are sufficient to characterize the benthic invertebrate community with respect to calculation of metrics. Canton and Chadwick (1988) also found three benthic samples yielded reliable estimates of invertebrate density. Bowles (1989a, b) found that estimates of benthic density and variability were not statistically different among sample sizes of 3, 6, and 12 samples within a riffle.

Collecting fewer samples from each riffle, would not allow for the adequate characterization of the riffles, and this would prevent comparisons to other studies in which the focus was on single riffles. By that same token, if the same sampling intensity per riffle was maintained, but fewer riffles in each stream stretch were sampled, the overall stretch would not be adequately characterized. This limitation is particularly problematic since making inferences to the stretch is fundamental to the overall design of the monitoring project. The minimum number of samples per site that take into account within and among riffle variability are already being collected. Reducing the number of samples per site would seriously reduce the overall degree of inference and the ability to make comparisons to other studies.

Recommendation: No changes to the current protocol. The current level of sampling effort is considered to be the minimum required to make inferences to both the riffles sampled and the overall stretch, and is supported by numerous studies published in the literature.

Habitat Assessment

Data on a diversity of habitat variables are recorded along with invertebrate collections at each site. Reducing the number of habitat variables would save time in the field collecting the data and time in the office entering and analyzing data.

Nine habitat variables are measured in association with the sampling net frame, including: depth, current velocity, dominant substrate, percent embeddedness, percent filamentous algae, percent aquatic periphyton, percent vegetation, percent deposition, and percent organic material. Exclusive of substrate, habitat data were highly variable among mainstem sites and years sampled (Appendix E).

Ordination Analyses

The aquatic invertebrate community data were evaluated for the relative importance of sampled habitat variables by an exploratory ordination approach: nonmetric multidimensional scaling (NMS; Kruskal 1964, Mather 1976). NMS is an ordination technique that orders sample units in

ordination space so that their interpoint distances reflect the redundant pattern of covariation in the original data (Peck 2010). In other words, it reduces the dimensionality of a complex data set, allowing visualization of patterns among sample sites (or species) along two or three derived axes. NMS also allows for the correlation of habitat variables with the derived axes in the final solution. This allows for the determination of strength of association of the habitat variables with the community assemblage overall. We applied the technique to evaluate broad patterns in community organization relevant to the goal of reducing workload, while realizing ordination results should not be viewed as confirmatory.

All aquatic invertebrate community data for both mainstems and tributaries, for both BUFF and OZAR were included. At BUFF, 10 metrics were evaluated, the same 10 as used to compute the BRICI index (see below). At OZAR, 4 metrics were evaluated, the same 4 as used to compute the SCI index (see below). A total of 14 habitat variables were included in the analyses, the nine associated with the sampling net frame described above, in addition to discharge, temperature, specific conductance, pH, and dissolved oxygen. Ordinations are usually applied to species abundance data, although there is no *a priori* reason such a technique could not be applied to metric data. This is particularly true for NMS, which is a nonparametric technique. It was not practical to use species abundance data for the aquatic invertebrates because not all taxa had been identified to the same level.

The full methodological details and results of the NMS analyses are presented in Appendix F. Here we summarize only the most relevant findings. Most habitat variables were weakly correlated with NMS ordination axes in both mainstem sites and tributaries. Overall, habitat variables for only two of the four datasets (BUFF mainstems and OZAR tributaries) had relatively strong correlations. Only one habitat variable—algae—exceeded the threshold for both datasets. This may be due in part to the use of metrics rather than species abundance data; metrics provided less resolution to detect patterns, which resulted in less separation among sites in ordination space. It is likely that many of the species included in these analyses have strong functional relationships with a number of habitat variables. Such relationships are obscured, however, when the overall community is evaluated.

One important finding from the ordination analyses is that tributaries at both OZAR (Figure 5) and BUFF (Figure 6) tend to group together by year sampled. Because the panel membership (i.e., year sampled) was determined by a process with a strong random component (the GRTS technique; see Bowles et al. 2007), this indicates that variability among years is relatively great, and the characterization of a tributary (i.e., metric or index values) will depend upon the year sampled. Thus comparison of tributaries sampled in different years could be obscured by differences among the years (e.g., variation in precipitation, water levels, etc.). Moreover, because of this inter-annual variability, sampling tributaries at relatively long (5-year) intervals means that several decades will be required before we are able to characterize the natural variability of a given tributary, in the absence of any directional change.

Recommendations: The actual collection of habitat data in the field, once at a site, takes relatively little time. Data entry in the office can be done by technicians, so that the collection and entry of this data does not impose a large time burden. Although habitat data revealed few important associations with overall community metrics, such habitat data may be used to answer

specific questions or hypotheses relating to certain taxa or sites. Thus it is proposed to retain the habitat variables in the revised protocol. The two exceptions to the proposed retention are percent deposition and percent organic material. Under field conditions the visual estimation method for these two methods is entirely subjective, less accurate, and more prone to observer bias compared to the other habitat variables. It is recommended that data for percent deposition and percent organic material no longer be collected. Finally, tributaries should be sampled at shorter intervals.

Substrate

Substrate for mainstem sampling sites at BUFF and OZAR from 2005-2009 were highly consistent and had relatively low variability (Appendix E). Substrate size for BUFF tributaries was similar to that of mainstem sites, but OZAR tributary substrate was smaller on average and more variable than that of the mainstem sites.

The substrate assessment procedures described in Bowles et al. (2007) have several identified weaknesses and limitations. Substrate is assessed only in riffle sampling areas and only within the sampling net frame (0.5 m²). Because invertebrate sampling is conducted only in riffles, measured substrates are highly consistent among sampling years and are not providing particularly useful information for interpreting invertebrate metrics. Measuring 20 pieces of substrate for every sample collected is a laborious process.

Recommendation: The current field procedure should be replaced by recording a dominant substrate size based on a visual estimate of three randomly selected pieces in the sampling net frame, as in Bowles et al. (2008). This approach provides a reasonable estimate of dominant substrate size while reducing overall field time and subsequent data entry and processing. More detailed substrate analysis with broader coverage would be included in geomorphological assessments (Appendix D).

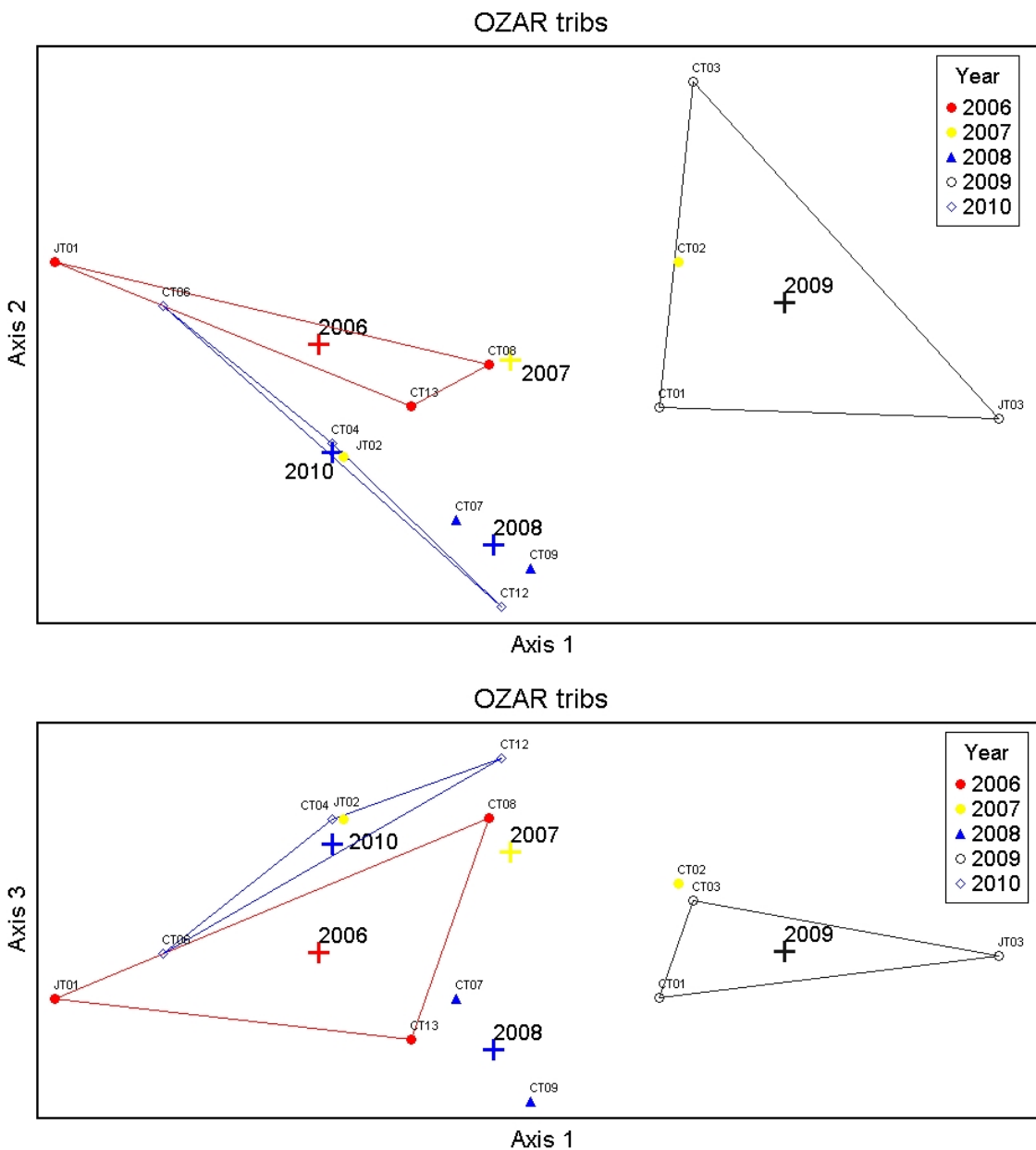


Figure 5. OZAR tributaries NMS ordination convex hull diagrams by year for invertebrates. Each point represents a tributary. Outlines (convex hulls) of the ordination space occupied by all tributaries sampled in each year are shown, along with the average position in space for the members of the group (centroids) marked as an "+".

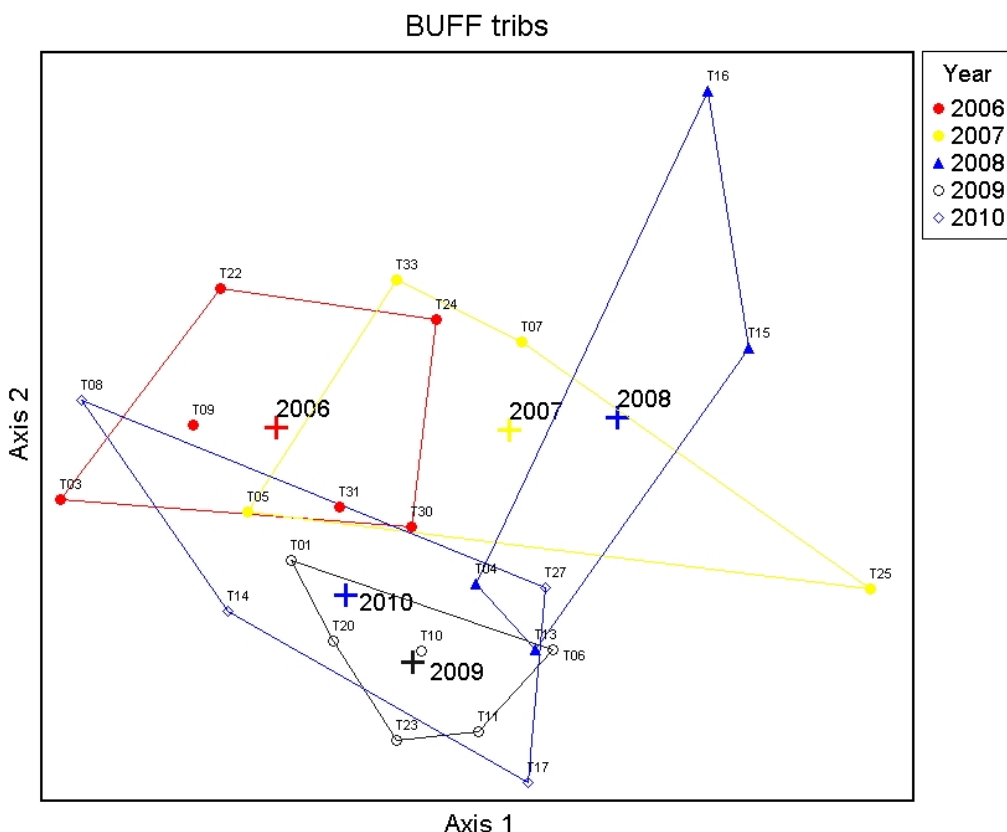


Figure 6. BUFF tributaries NMS ordination convex hull diagrams by year for invertebrates. Each point represents a tributary. Outlines (convex hulls) of the ordination space occupied by all tributaries sampled in each year are shown, along with the average position in space for the members of the group (centroids) marked as an “+”.

Stream Discharge

Discharge currently is used only to assess the relative amount of water in the stream at the time of sampling, to allow for more accurate comparisons of metric responses among sampling years (Appendix E). As used, it is not intended to be a precise measure of stream discharge.

Recommendations: Use streamflow data from the nearest USGS stream gage (Table 4) in place of manually measured discharge for mainstem river sampling sites. The URLs in Table 4 are for “real time” data and are only shown on these sites for 120 days. Final and approved historic data for these sites can be found at the following URLs:

http://waterdata.usgs.gov/ar/nwis/uv/?referred_module=sw (Arkansas),
http://waterdata.usgs.gov/mo/nwis/uv/?referred_module=sw (Missouri).

Manual discharge measurement (as described in Bowles et al. 2007) should be retained for tributaries where no USGS gages are located. Two components of discharge, depth and current velocity, are collected immediately in front of each benthic sample (Appendix E), and they were highly variable among sites and years sampled. This information was intended to help describe

the local conditions associated with invertebrate habitat. Although these variables were weakly correlated with invertebrate metrics (Appendix F), we recommend they be retained in the revised protocol because they may prove useful in evaluating the response of invertebrate communities to long-term change or disturbance.

Table 4. USGS stream gages at BUFF and OZAR used for making discharge estimates for monitoring sites.

Monitoring Site	Gage Name	Gage Number	URL
Buffalo National River			
BUFFM01	Boxley	07055646	http://waterdata.usgs.gov/ar/nwis/uv?site_no=07055646
BUFFM02	Pruitt	07055680	http://waterdata.usgs.gov/ar/nwis/uv?site_no=07055680
BUFFM03	Pruitt	07055680	http://waterdata.usgs.gov/ar/nwis/uv?site_no=07055680
BUFFM04	St. Joe	07056000	http://waterdata.usgs.gov/ar/nwis/uv?site_no=07056000
BUFFM05	St. Joe	07056000	http://waterdata.usgs.gov/ar/nwis/uv?site_no=07056000
BUFFM06	Harriett	07056700	http://waterdata.usgs.gov/ar/nwis/uv?site_no=07056700
Ozark National Scenic Riverways			
CURRM01	Montauk State Park	07064440	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07064440
CURRM02	Akers	07064533	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07064533
CURRM03	Akers	07064533	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07064533
CURRM04	Van Buren	07067000	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07067000
CURRM05	Van Buren	07067000	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07067000
CURRM06	Van Buren (plus Big Spring)	07067000, 07067500	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07067000 ; http://waterdata.usgs.gov/mo/nwis/uv?site_no=07067500
JACKM01	Mountain View	07065200	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07065200
JACKM02	Mountain View	07065200	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07065200
JACKM03	Mountain View	07065200	http://waterdata.usgs.gov/mo/nwis/uv?site_no=07065200

Evaluation of Aquatic Invertebrate Data Summary and Analysis

Buffalo River Index of Community Integrity (BRICI)—BUFF

Mathis (2001) developed the Index of Community Integrity (ICI), a multimetric index designed specifically for the Buffalo River based on the reference site approach. This multimetric index was later renamed the Buffalo River Index of Community Integrity (BRICI) to avoid confusion with other ICIs being used throughout the United States. The BRICI was designed using data collected by Mathis and his graduate students from eight sites distributed along the continuum of the main channel of the Buffalo River during the summer, fall, and winter of 1993 and spring of 1994. The BRICI is similar to indices developed by the Ohio EPA and other state agencies, although those indices were based on streams from state-wide areas.

Mathis (2001) evaluated and selected 10 metrics for the BRICI that he described as being sufficiently sensitive for detecting impairment. The metrics include: Margalef's Index of Taxa Richness, Shannon's Diversity Index, % Dominant Taxa, % Chironomidae, % Plecoptera, % Trichoptera, % Elmidae, % Corbicula, % Intolerant, and % Collector-Filterer. These and other community metrics are described in Barbour *et al.* (1999).

Scoring the metrics involves dividing the data from all sites for a given metric into specific quartiles (<25th percentile, 25th-50th percentile, 51th-75th percentile, >75th percentile) (Table 5). Values in the highest percentile range are assumed to represent high water quality. Those in the lowest range are assumed to indicate low water quality, and intermediate percentiles represent water quality somewhere between high and low. The quartile range in which each metric falls determines what score that metric receives. Data that fall into each of these ranges are scored 4, 6, 8, and 10, respectively for metrics that decrease with increasing disturbance, and 10, 8, 6, and 4 for percent Chironomidae, percent *Corbicula*, and percent dominant. Scores for each individual metric are summed to create the BRICI score.

Table 5. Quartile scores for the Buffalo River Index of Community Integrity (BRICI) based on lower level identifications at eight main channel sites of the Buffalo National River. Note: Margalef's and Shannon's Diversity Indices were scored based on 3 pooled samples. Percent Plecoptera was scored independently for summer and fall communities versus winter and spring.

Metric	BRICI SCORES			
	4	6	8	10
Margalef's Index	<3.83	3.83-4.39	4.40-4.94	>4.95
Shannon's Diversity Index	<2.13	2.13-2.34	2.35-2.53	>2.53
% Chironomidae	>34.72	26.24-34.72	15.28-26.23	<15.28
% Plecoptera (Summer & Fall)	<0.18	0.18-0.71	0.72-3.31	>3.31
% Plecoptera (Spring & Winter)	<13.76	13.76-23.76	23.77-32.80	>32.80
% Trichoptera	<1.37	1.37-4.06	4.07-9.55	>9.55
% Elmidae	<0.10	0.10-0.56	0.57-1.30	>1.30
% <i>Corbicula</i>	>1.46	0.05-1.46	0.01-0.04	0
% Collector-Filterer	<2.34	2.34-7.77	7.78-18.59	>18.59
% Intolerant	<2.29	2.29-9.24	9.25-18.28	>18.28
% Dominant	>66.58	58.59-66.58	50.89-58.58	<50.89

Results for BUFF Invertebrate Community Metrics and BRICI, 2005-2010

BRICI scores were variable among years sampled for each site although there was broad overlap among standard error bars suggesting there are few biological differences (Figure 7). Lowest BRICI scores were observed for BUFFM04, while scores for the remaining sites were generally similar. The BRICI scores reported here show a longitudinal pattern similar to those reported by Mathis (2001) (Figure 8) at the BUFF water quality sampling sites (Figure 9). BRICI scores for tributaries were also variable (Figure 10). The individual metrics comprising the BRICI were highly variable among sites and years (Appendix G).

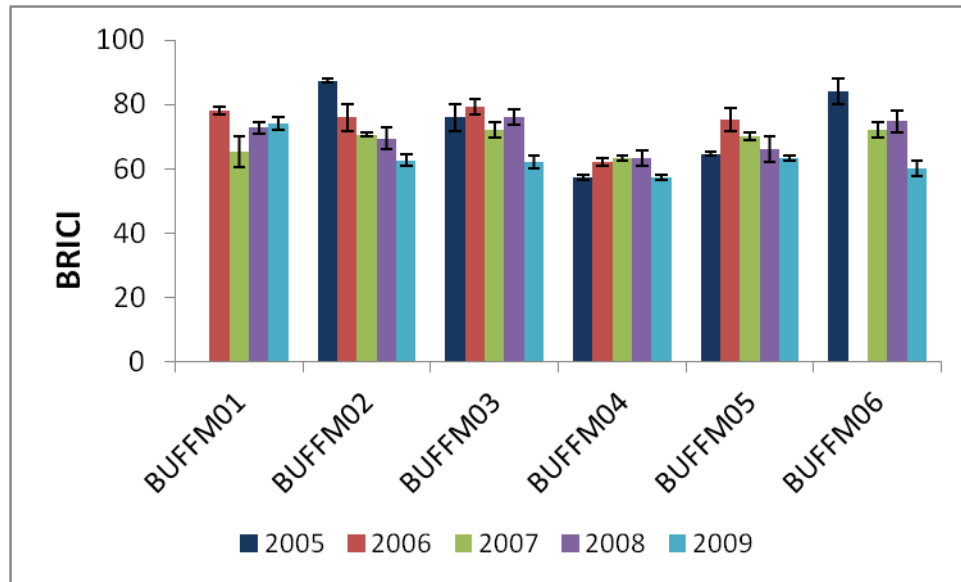


Figure 7. Mean BRICI scores and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

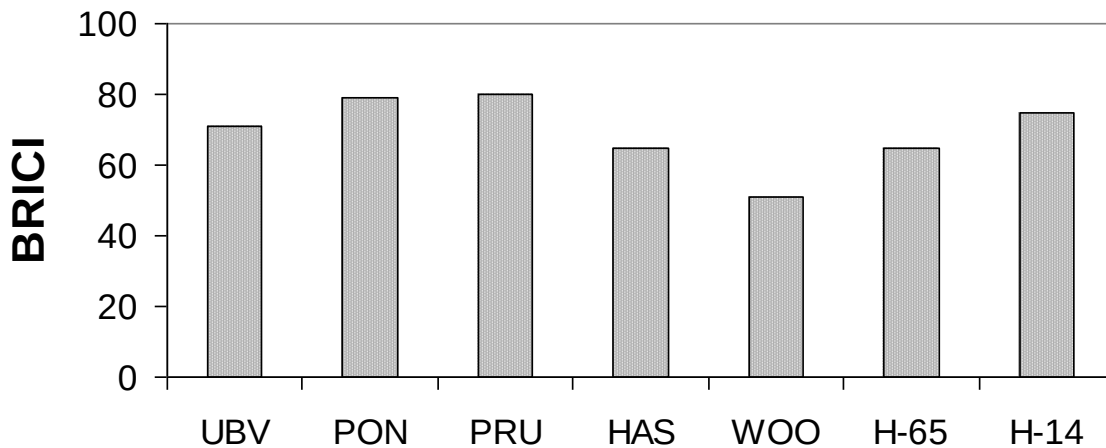


Figure 8. BRICI scores for seven sites on the Buffalo River each based on five pooled samples and genus-level identifications (from Mathis 2001). UBV, Upper Buffalo River just below the wilderness boundary; PON, Ponca bridge; PRU, Pruitt landing; HAS, Hasty low-water bridge; WOO, Woolum Access; H65, US Highway 65 bridge; H14, Arkansas Highway 14.

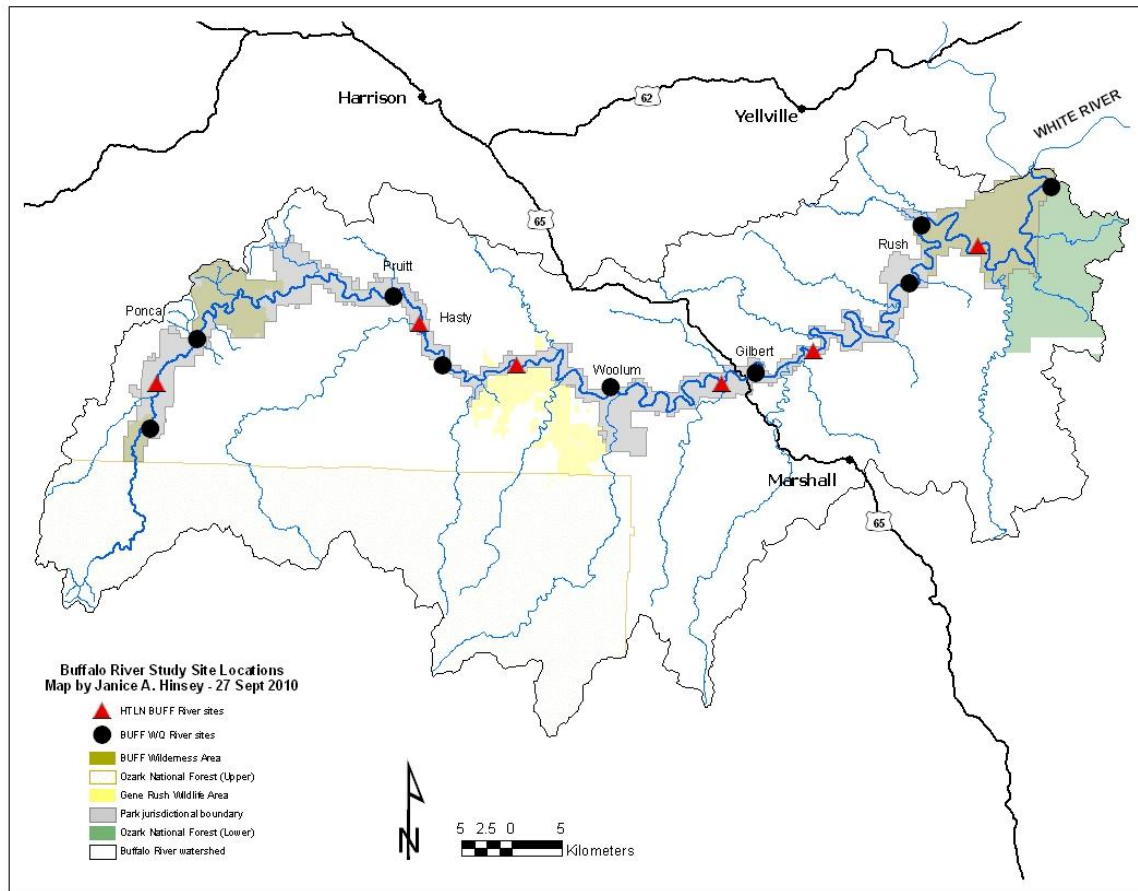


Figure 9. BUFF water quality sampling locations (black circles), and HTLN monitoring sites (red triangles).

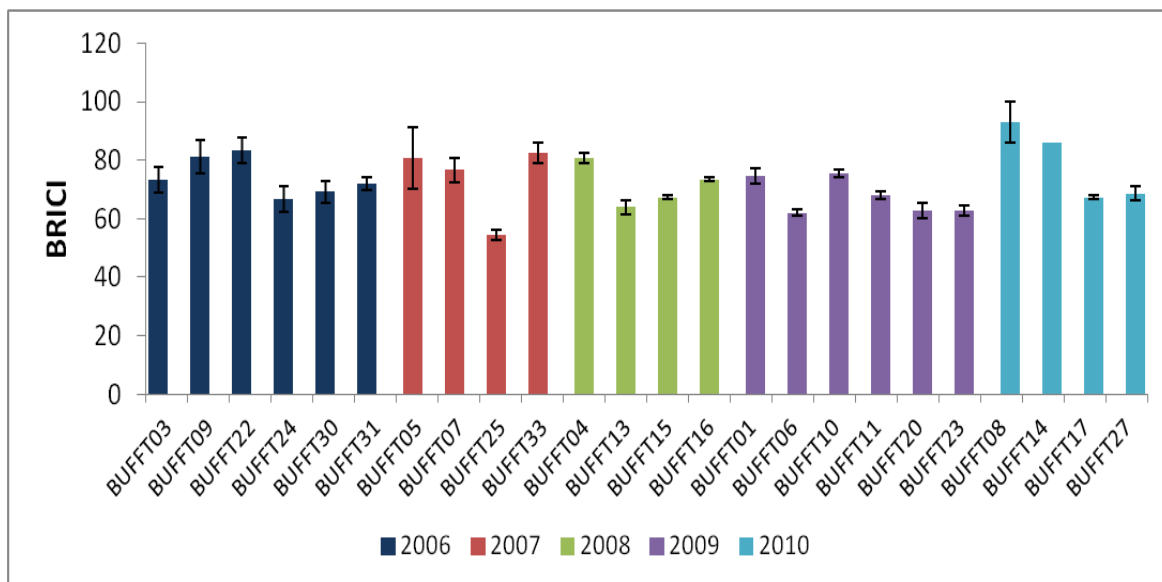


Figure 10. Mean BRICI scores and standard errors for Buffalo National River tributary sampling sites, 2006-2010.

Weaknesses of the BRICI and Its Use for Estimating Water Quality at BUFF

Subsequent to the report describing the BRICI (Mathis 2001), and upon a closer evaluation of the individual metrics and philosophy underlying this index, several problems have been noted. Mainstem sites on the Buffalo River follow the river continuum (Vannote et al. 1980) and sampling sites along that continuum cannot be directly or appropriately compared, thus obviating the attempt by Mathis (2001) to use a reference condition approach for mainstem river sites within a single river basin.

The index is based on only 6 mainstem sampling sites sampled across four seasons in a single year. As such, the index fails to adequately address interannual variation that occurs among invertebrate communities. That variation is clearly evident among years in the summary data presented herein. Relying on BRICI scores for any given year could easily result in an inaccurate assessment of stream condition.

Mathis (2001) tested the BRICI on only four tributaries in the Buffalo River Watershed. Given the large number of tributaries in that watershed, a sample size of four is entirely insufficient to fully evaluate the index. In this study, a known impaired tributary, Mill Creek (BUFFT07), had one of the highest BRICI scores among all sites. This paradox suggests the index is not accurate for tributaries. Also, some of the metrics are not well suited for the tributaries (e.g., *Corbicula* are generally absent from tributaries at BUFF).

A clear approach for interpreting the BRICI was not described by Mathis (2001). Mathis recommended using the reference condition approach in which the highest score in the watershed is used to compare all other scores. He suggested that individual sites with BRICI values < 30% of reference condition indicate that slight to moderate impact has occurred while values < 50% denote severe impact (Mathis 2001). The primary difficulty with the reference site approach was noted above. Other approaches such as assigning the BRICI scores to quartiles possibly could be used, but there are insufficient data to support such an approach, and it was not recommended by Mathis (2001).

Shannon's Diversity Index and Margalef's Index generally exhibit the same trend when used on a given data set and are often highly autocorrelated (Danilov and Eklund 2001), so using both indices is redundant. Also, it has been demonstrated that Margalef's Index is sensitive to community structure and small losses in species in the community and over time could lead to erratic responses in the performance of the index. Margalef's Index presumes a linear relation between the number of species and the logarithm of the area or the number of individuals, but this relationship typically is not linear (Washington 1984). Washington (1984) further found little justification for using this poorly defined index to describe biological communities. Mathis (2001) did not provide a strong justification for using Margalef's Index. Although Shannon's Diversity Index also has issues associated with it—particularly its biological relevance (Washington 1984)—it has the benefit of being widely used in stream ecology studies, making the interpretation of values for the BUFF easier to assess in the broader sense.

Shannon's diversity index values among samples in this study were rarely scored above a "3" and more typically a "1". For biological data, values of Shannon's Diversity Index range generally from 1.5 (low species richness and evenness) to 3.5 (high species evenness and

richness). However, taxa richness in the Buffalo River and its tributaries is generally high and similar relative to other unimpaired streams in the region.

The % Chironomidae metric was usually high in most samples and was rarely scored above 1. Not all Chironomidae are intolerant, thus this metric likely artificially lowers the BRICI scores (Rabeni and Wang 2001), potentially suggesting impairment where there may be none.

The use of the % Elmidae metric is not well founded in literature, or in the elmids taxa we collect (i.e., *Stenelmis*) in the Buffalo River Watershed. Most of the elmids collected in BUFF samples represent a mix of intolerant (*Microcyloepus*, *Optioservus*) and tolerant (*Stenelmis*) genera in approximately equal portions. This metric, although identified by Mathis as potentially useful, is not particularly strong in light of 5-years of baseline data collected by HTLN, and the common co-occurrence of tolerant and intolerant taxa in samples is contradictory.

Percent *Corbicula* was low at all mainstem BUFF sites, and these clams are largely absent from smaller tributaries. In the river, the riffle habitat that is sampled is not ideal habitat for Asian clam, which prefer sandy deposits with reduced flows located out of the thalweg (Belanger et al. 1985). *Corbicula* likely will never be abundant in BUFF riffles because conditions in that habitat are not optimum for this clam. As such, this is a poor metric for assessing water quality at BUFF.

Mathis (2001) grouped the % Plecoptera metric into Summer/Fall and Winter/Spring categories for the purpose of scoring with the former having higher benthic densities than the latter. It is not clear what Mathis meant by these periods or what months they encompass. Our interpretation of this metric has been official seasons based on the winter solstice (i.e., winter begins on December 21). Since sampling is usually completed by this date, we used the Summer/Fall period in our calculations, and the numbers of stoneflies we collect in our samples are similar to what Mathis reported.

While % Trichoptera generally is a sound metric for assessing water quality, it should be noted that this metric includes all genera, and not just intolerant taxa. One of the most common caddisfly genera in BUFF samples is *Cheumatopsyche*, which has a tolerance value of 6.6. However, not all species of *Cheumatopsyche* are tolerant, including some of those occurring at BUFF. The actual proportions of tolerant and intolerant *Cheumatopsyche* remain to be determined.

Mathis (2001) included % Collector-Filterer as a surrogate for determining if energy flow through the system has been modified (i.e., a decrease in the metric might be tied to nitrification). The potential response of this metric to changes in energy flow would be crude at best compared to water chemistry-based methods. As such, this metric does not merit retention.

Percent Intolerant Taxa generally is a sound metric for assessing stream integrity. Mathis proposed this metric to include only taxa having tolerance values of 1 or less. For BUFF samples, the inclusive tolerance value range was increased to 3. Otherwise, scores of 1 would have been applied to nearly all BUFF samples, resulting in lower BRICI scores.

With rare exception, % Dominant Taxa received the lowest score (1) in nearly all samples, largely due to the dominance of Chironomidae in the samples. Additionally, many chironomids are intolerant of disturbance and using the family level identification for this diverse group only

serves to mask this group's real potential for assessing disturbance. Rabeni et al. (1997) showed this metric to be a relatively poor performer for Ozark streams in Missouri where % dominant taxon in reference and organically enriched streams broadly overlapped.

Recommendation: The BRICI, as proposed by Mathis (2001), has too many weaknesses to make it a useful, accurate, or reliable index. The use of this multimetric index for assessing stream integrity at BUFF should be discontinued. Instead, a well-tested and applicable multimetric index (see Missouri SCI below) or other sound index must be adopted. Because Rabeni et al. (1997) included scoring for the Ozarks region in the SCI, this index is applicable to the streams at BUFF.

Missouri Stream Condition Index (SCI)

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 four metrics that were chosen as sound measures of community structure and balance (Rabeni et al. 1997). They include Taxa Richness, EPT (Ephemeroptera, Plecoptera, Trichoptera) Richness, Shannon's Diversity Index, and Hillsenhoff Biotic Index (HBI) (Table 6). These and other community metrics are described in Barbour *et al.* (1999). These four metrics are generally considered sufficiently sensitive to detect a variety of potential pollution problems in Ozark streams. Some of the potential disturbances that can be detected using these metrics include:

- Gross organic pollution.
- Agriculturally developed catchments- Ephemeroptera and Plecoptera have shown reductions in abundance or richness.
- Increases in acidity- Taxa richness, EPT taxa, and Shannon Diversity Index typically decrease in response to increasing acidity. Mayflies are especially sensitive to low pH.
- Effects of logging and clear cutting.
- Heavy metal pollution- Taxa richness and EPT richness have been shown to decrease in response to this type of pollution. However, further research indicates that mayflies may decrease in richness and abundance while caddisflies increase under these conditions, resulting in a static EPT. If no difference in the EPT is found, analysis of the richness and percent composition of mayfly taxa should be performed.
- Insecticides- both the EPT index and the NCBI easily detected disturbances to a stream treated with certain insecticides.
- Metric Scoring for the SCI

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). Reference data provided in Doisy and Rabeni (1999), including four sites in the Current River watershed and other Ozarkian streams, were used to determine a range for each metric with one of three possible scores assigned to each range. The lower or upper quartile of the distribution for each metric is used as the minimum value representative of reference conditions (Table 7).

Some caution is required when evaluating SCI results. The SCI increases with lower HBI metric scores. HBI is strongly influenced by the abundance of Chironomidae, which have a tolerance

value of 6, but many chironomids are intolerant. By 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 are intolerant Orthocladinae (Wallace and Rabeni 2008).

The caddisfly (Trichoptera) genus *Cheumatopsyche* is well represented in most benthic samples. Because many species in this genus are somewhat tolerant of organic pollution, it is assigned a tolerance value of 6.6. However, the dominant species of *Cheumatopsyche* at OZAR based on adult identifications are *Cheumatopsyche sordida*, *Cheumatopsyche rossi*, and *Cheumatopsyche aphanta*. These species only inhabit headwater streams and spring-dominated systems, and *C. rossi* is endemic to the Ozarks, which clearly suggests they are intolerant to disturbance. By using the currently accepted tolerance value for *Cheumatopsyche*, biotic index values may be incorrectly inflated. Assignment of a more liberal tolerance value (to be determined) would probably make for more realistic biotic index scores for undisturbed Ozark streams.

Table 6. 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
Hilsenhoff Biotic Index	4.3	0.34	3.3	5
Shannon's Diversity Index	2.43	0.13	2.08	2.72

Table 7. Descriptive statistics and scores for the metrics for the fall index period based on single habitat coarse substrate (riffle) data.

Metric	Statistics					Scores		
	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
Hilsenhoff Biotic Index	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
Scoring: >16 not impaired, 10-14 impaired, 4-8 very impaired.								

SCI results for BUFF

SCI scoring for BUFF streams shows that all of the mainstem river sites were not impaired across the 5-year monitoring period (Figure 11), although there was a fair amount of variation among years for each site. In comparison, the range of SCI scores for the tributaries was broad (Figure 12). Although most tributaries had SCI scores that showed they were not impaired,

several were considered impaired. The high SCI scores for BUFF streams are supported by the high metric scores for Taxa and EPT richness and relatively low HBI (Appendix H).

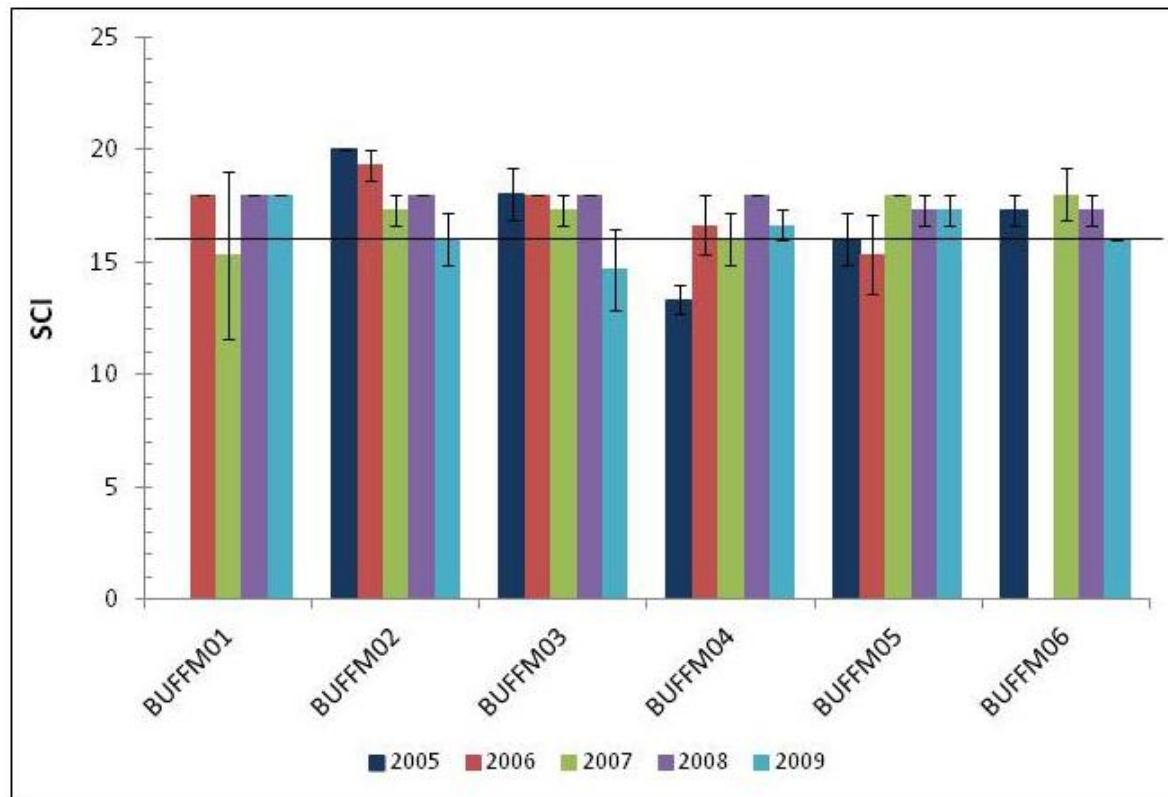


Figure 11. Mean SCI scores and standard errors for Buffalo River mainstem sampling sites, 2005-2009. The black vertical line represents the cut-off (SCI=16) for being considered not impaired.

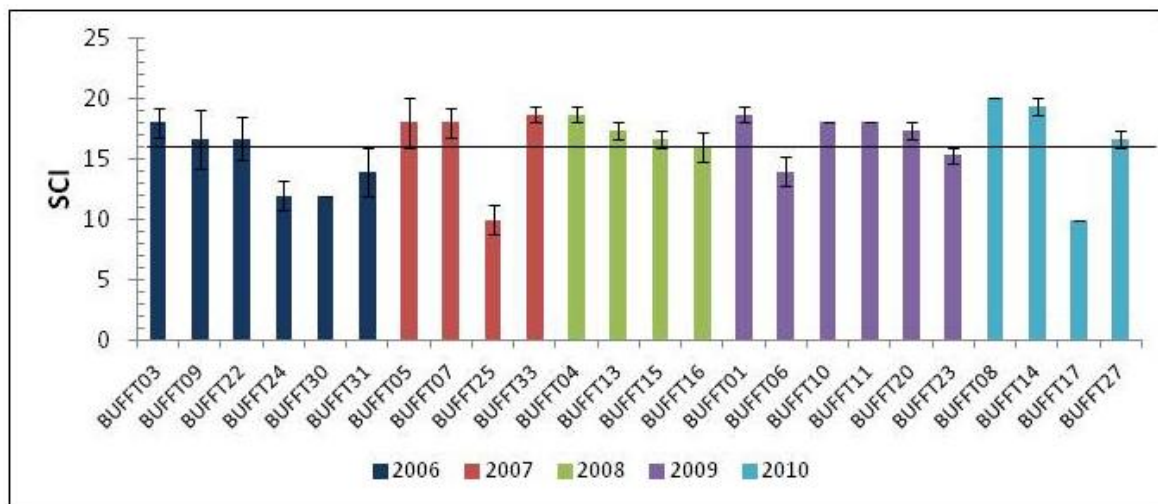


Figure 12. Mean SCI scores and standard errors for Buffalo National River tributary sampling sites, 2006-2010. The black vertical line represents the cut-off (SCI=16) for being considered not impaired.

SCI results for OZAR

SCI scores for all mainstem sites on the Current River and Jacks Fork consistently indicated they are not impaired (Figure 13). The tributaries also rated unimpaired except for JACKT03 (Figure 14). However, the tributaries scores were based on a single sampling event, so their SCI scores must be interpreted more cautiously. The high SCI scores for nearly all OZAR streams were supported by the high metric scores for Taxa and EPT richness and low HBI (Appendix H).

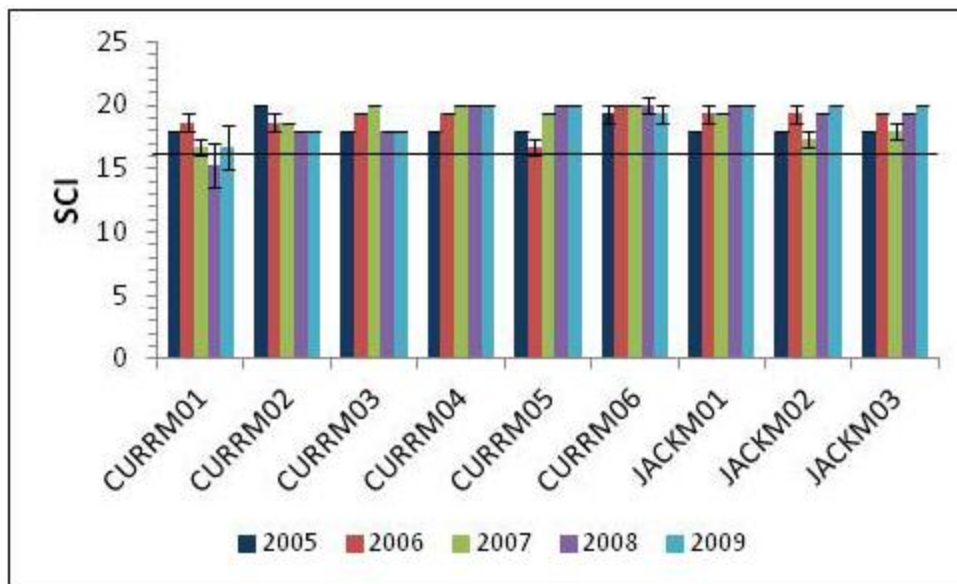


Figure 13. Mean SCI scores and standard errors for Current River and Jacks Fork mainstem sampling sites, 2005-2009. The black vertical line represents the cut-off (SCI=16) for being considered not impaired.

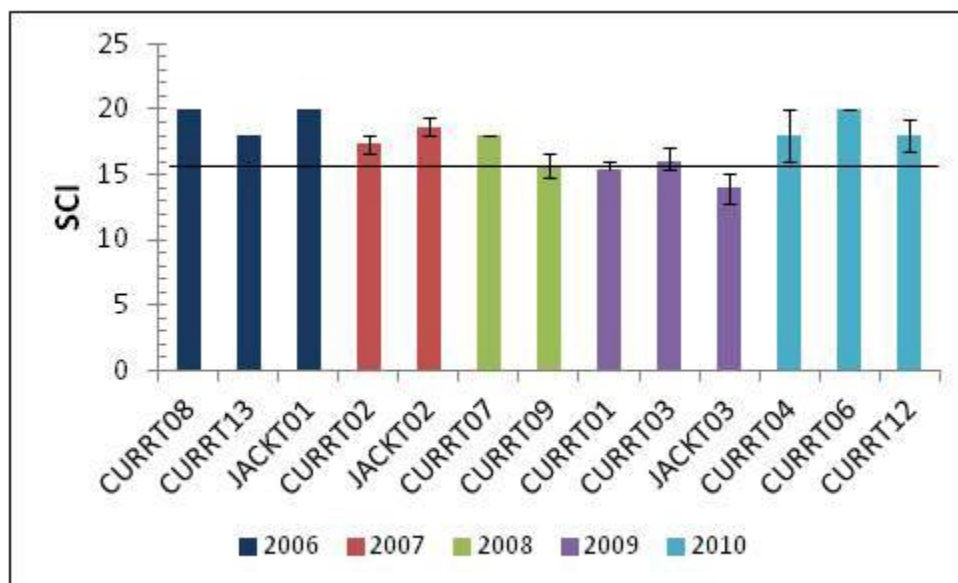


Figure 14. Mean SCI scores and standard errors for Ozark National Scenic Riverways tributary sampling sites, 2006-2010. The black vertical line represents the cut-off (SCI=16) for being considered not impaired.

Ozark Rivers Stream Invertebrate Multimetric Index (ORSIMI)

As described above, the BRICI was judged inadequate for the purpose of providing park managers meaningful information on change in the aquatic invertebrate communities at BUFF. The SCI was recommended as a replacement multimetric index for the BRICI. Although the SCI performed generally well for both parks, there are minor issues related to accurate scoring that must be resolved to maximize the benefit of that index. The Ozark Rivers Stream Invertebrate Multimetric Index (ORSIMI) was developed by our network 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 Diversity Index, and the HBI (Tables 8 and 9). 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 would be 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.

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 OSIMI. 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"; any comparisons will simply be to a baseline condition.

Recommendation: Apply the newly developed ORSIMI index along with the SCI at BUFF and OZAR.

Table 8. ORSIMI values for OZAR mainstem river sites based on baseline data collected 2005-2009.

Site	Mean Taxa Richness	Mean EPT Richness	Mean Shannon's Diversity Index	Mean HBI	10-HBI	ORSIMI
CURRM01	21.511	10.747	2.0284	4.0471	5.9529	100
CURRM02	23.846	13.622	2.0455	3.2185	6.7815	100
CURRM03	28.756	14.978	2.1372	3.0547	6.9453	100
CURRM04	29.178	14.756	2.4487	3.7018	6.2982	100
CURRM05	26.222	13.311	2.3616	3.2468	6.7532	100
CURRM06	27.456	13.811	2.4473	3.4151	6.5849	100
JACKM01	27.6	13.178	2.4732	4.4285	5.5715	100
JACKM02	24.722	12.556	2.322	4.0113	5.9887	100
JACKM03	24.867	11.156	2.404	4.0892	5.9108	100

Table 9. ORSIMI values for BUFF mainstem river sites based on baseline data collected 2005-2009.

Site	Mean Taxa Richness	Mean EPT Richness	Mean Shannon's Diversity 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

Evaluation of Fish Field and Lab Methodologies

Physical Habitat Data

Data for a relatively large number of habitat variables are recorded at each fish sampling site (Table 10). Although precision instruments are used for some variables, others are based on visual observations, and some are only evaluated within a few broad categories. Like the invertebrates, data recording, entry, and maintenance represent additional tasks associated with sampling the fish communities. To evaluate the potential utility of this habitat data, we applied an exploratory NMS ordination on the overall fish community, as described above for the invertebrates. Fish community data for both mainstems and tributaries, for both BUFF (2006-2010) and OZAR (2006-2010) were included in analyses. The ordination technique allowed for the evaluation of each habitat variable relative to each ordination axis in the final NMS solution.

At BUFF, six reaches on the Buffalo River were sampled in May/June from 2006 to 2010 (Figure 1). At OZAR, six reaches on the Current River and three on the Jacks Fork were sampled in October/November from 2005 to 2009 (Figure 2). From 2006 to 2010, a reach from each of 30 tributaries was sampled at BUFF (Figure 1, Appendix C) and a reach from each of 14 tributaries at OZAR (Figure 2, Appendix C). Fish were collected using pulsed DC electrofishing gear. Selection of sampling gear was based on the efficiency of each gear type to capture fish in various habitat conditions. Mainstem reaches were sampled using a combination of gear types: boat electrofishing in the deep pools and towed barge or backpack electrofishing in shallower riffle and run areas. Tributaries were generally narrow and shallow and were sampled with either backpack or towed barge electrofishing gear. Fish were identified to species, if possible, and counted. *Compostoma* sp. were not identified further than genus level due to the difficulty in species level identification of the two species (Central Stoneroller, *C. anomalum* and Largescale Stoneroller, *C. oligolepis*) in the field. A subsample of 30 individuals per species were measured and weighed, and any diseases or anomalies were recorded.

Physical habitat data were collected in conjunction with fish sampling with the exception of OZAR mainstem sites in 2005. An 11 transect method was used to collect data on in-stream habitat, fish cover, and bank conditions within the entire reach. Water quality data (temperature, dissolved oxygen, pH, and conductivity) were collected before and after fish sampling at each reach using hand-held meters. Detailed methods on fish sampling procedures and habitat and water quality collection can be found in Petersen et al. (2008). Data were collected for a total of 27 habitat variables (Table 10): 4 physio-chemical variables; 3 instream habitat variables; 9 fish cover; 8 bank variables; and 3 variables that described the size of the site.

Because interest was in overall fish communities, all taxa (except hybrids and those that could not be identified to species level) were included in the analyses. This is clearly appropriate when the goal is to examine patterns in species diversity or test hypothesis regarding whole-community structure (McCune and Grace 2002).

Fifteen of the 27 habitat variables were relatively strongly correlated with one of the ordination axes in at least one data set. Measurements of site size were found to be important for fish communities at BUFF and OZAR. Watershed area was the only habitat variable to exceed the correlation threshold for all four datasets (Table 11). Width and depth were important for both

BUFF and OZAR tributary datasets, and width was important for the OZAR mainstems. Of the nine habitat variables related to fish cover, seven were found to be important for fish communities with most of these variables important in only one dataset (primarily OZAR tributaries). Canopy cover was the only instream habitat variable found to be important and was important for three of the four data sets (Table 11). Among bank variables measured, bank angle was important in BUFF mainstem and OZAR tributaries. Bank cover types (trees, shrubs, grass, bare) were not important in any data sets. Only two physiochemical variables, temperature (at BUFF) and dissolved oxygen (at OZAR mainstem), were correlated to fish communities.

OZAR tributaries revealed a relatively large degree of separation based on year sampled (Figure 15), although this pattern was not observed for BUFF tributaries. Similar patterns were observed for tributaries in both parks for the invertebrates, and similar inferences apply (i.e., comparison of tributaries sampled in different years could be obscured by differences among the years, and several decades will be required before we are able to characterize the natural variability of a given tributary). Because all tributaries have been sampled only once, we have no direct information on this variability.

It is likely that robust functional responses exist among many of the fish species and variables evaluated. These may be obscured, however, when conducting broad analyses at the community level. We did not attempt to evaluate species-specific response functions, in the absence of specific hypotheses of relevance to resource managers. Moreover, the large number of species and habitat variables involved would have rendered this approach a non-informative exercise in simple data dredging. If species-specific questions or hypotheses of interest to resource managers can be formulated in the future, however, this habitat data may be extremely useful.

The findings at the community level suggest that habitat variables not found to be significant correlates to fish communities (12 variables) or those found to be important correlates in only one dataset (8 variables) could be removed during future sampling events. However, eliminating non-significant variables or variables only significant in one data set at the community level will save little time in the field, as many of these variables are observational and take very little time to record. This action would save some time during data entry and space in the database, but the time and space savings would be negligible.

Recommendation: Continue to collect all habitat variables listed in the protocol (see Petersen et al. 2008), but not analyze all variables for annual status reports. Future questions posed by park staff may warrant analysis of certain habitat parameters in issue-specific one-time reports.

The clustering of OZAR tributaries by year in the ordination plots suggest that the year in which a tributary is sampled is important, and tributary communities may be characterized by a relatively large degree of natural temporal variability. Thus, tributaries should be sampled more frequently to characterize the natural variability, or we will not be able to differentiate any potential directional change.

Table 10. Habitat variables (n = 27) measured at all sites during fish monitoring.

Variable	Units	How measured
Physio-chemical variables		
Water temperature	°C	Temperature/Dissolved Oxygen probe on stream bottom upstream of riffle
pH		pH probe on stream bottom upstream of riffle
Specific conductance	uS/cm	Conductivity probe on stream bottom upstream of riffle
Dissolved oxygen	mg/L	Temperature/Dissolve oxygen probe on stream bottom upstream of riffle
Instream habitat variables		
Substrate	Wentworth	Average size within 10cm diameter around point where depth taken
Embeddedness	% category	Observed within 10cm diameter around point where depth taken
Canopy cover	% category	Observed within ± 1 m upstream and downstream of transect
Fish cover variables		
Filamentous algae	Presence	Observed within 10cm diameter around point where depth taken
Hydrophytes/mosses	Presence	Observed within 10cm diameter around point where depth taken
Boulders	Presence	Observed within 10cm diameter around point where depth taken
Small woody debris	Presence	Observed within ± 1 m upstream/downstream of transect
Large woody debris	Presence	Observed within ± 1 m upstream/downstream of transect
Trees/roots	Presence	Observed within ± 1 m upstream/downstream of transect
Overhanging vegetation	Presence	Observed within ± 1 m upstream/downstream of transect
Undercut bank	Presence	Observed within ± 1 m upstream/downstream of transect
Bluff within 5m of water	Presence	Observed within ± 1 m upstream/downstream of transect
Bank variables		
Bank angle	Degree category	Observed within ± 1 m upstream/downstream of transect at bottom of bank
Vegetation cover	% category	Observed within ± 1 m upstream/downstream of transect and 10m on bank
Bank height	Meters category	Observed within ± 1 m upstream/downstream of transect and 10m on bank
Bank substrate	Type category	Observed within ± 1 m upstream/downstream of transect at bottom of bank
Bank cover –large trees	Presence	Observed within ± 1 m upstream/downstream of transect and 10m on bank
Bank cover –small trees, shrubs	Presence	Observed within ± 1 m upstream/downstream of transect and 10m on bank
Bank cover – grasses, forbs	Presence	Observed within ± 1 m upstream/downstream of transect and 10m on bank
Bank cover – bare rock/sediment	Presence	Observed within ± 1 m upstream/downstream of transect and 10m on bank
Size		
Watershed area	km ²	Area upstream of sample site; calculated from 10 m DEM using HUC12
Mean width	m	Measured at each transect with tape measure or range finder
Mean depth	cm	Measured at three points per transect with wading rod

Table 11. Summary of habitat variables correlated with nonmetric multidimensional scaling ordination axes. An “X” indicates the variable exceeded the 0.5 correlation coefficient that was set as the threshold for inclusion of habitat vectors on the joint plots (see Appendix I).

Variable	BUFF Mains	OZAR Mains	BUFF Tribes	OZAR Tribes
Physio-chemical variables				
Water temperature	X		X	
pH				
Specific conductance				
Dissolved oxygen		X		
Instream habitat variables				
Substrate				
Embeddedness				
Canopy cover	X		X	X
Fish cover variables				
Filamentous algae				X
Hydrophytes/mosses				X
Boulders				
Small woody debris				X
Large woody debris		X		
Trees/roots	X			X
Overhanging vegetation				X
Undercut bank				X
Bluff within 5m of water				
Bank variables				
Bank angle	X			X
Vegetation cover	X			
Bank height				
Bank substrate				
Bank cover –large trees				
Bank cover –small trees, shrubs				
Bank cover – grasses, forbs				
Bank cover – bare rock/sediment				
Size				
Watershed area	X	X	X	X
Mean width		X	X	X
Mean depth			X	X

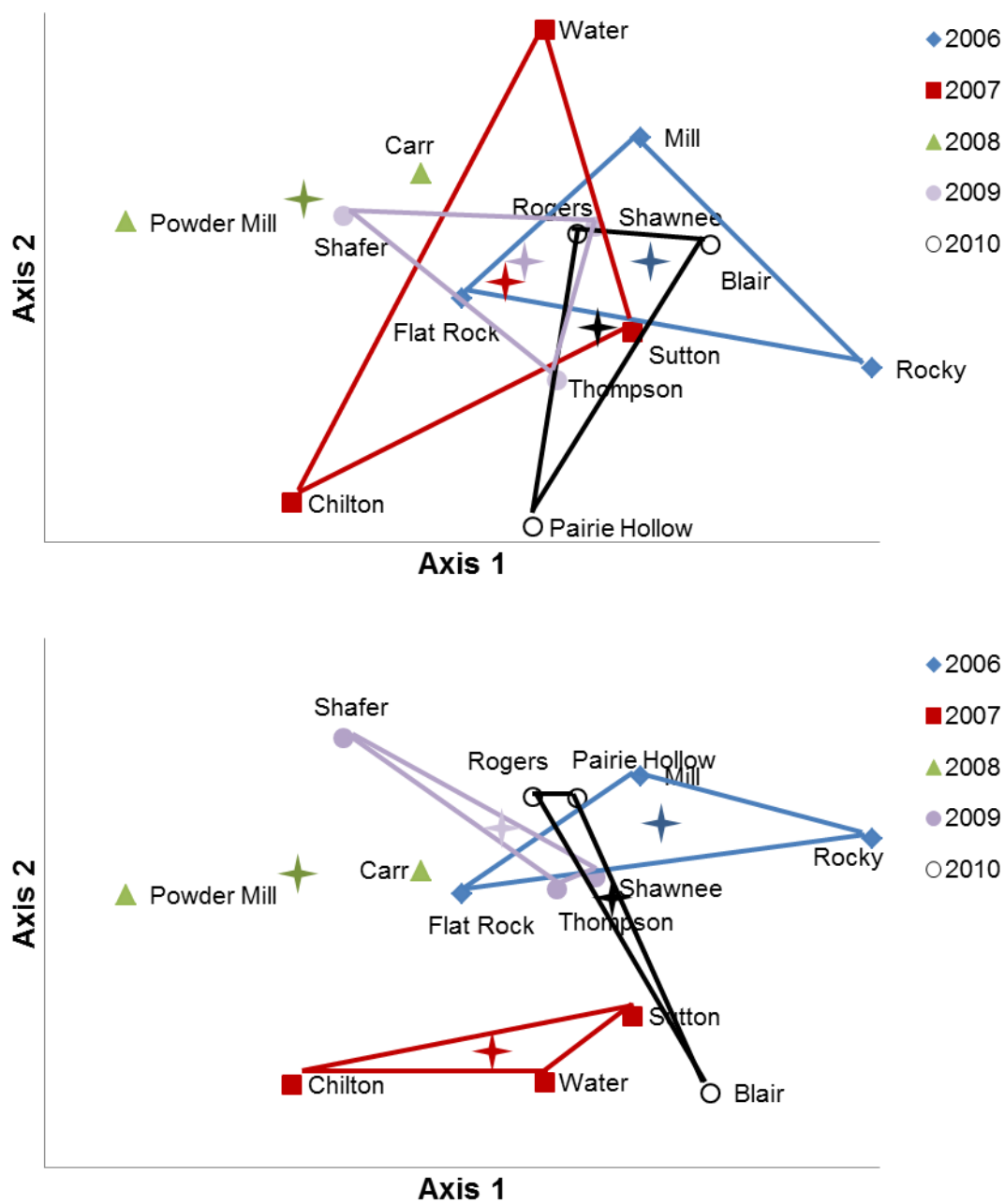


Figure 15. Convex hull diagrams for OZAR tributary fish. Each point represents a tributary. Points are coded by year the tributary was sampled.

Utility of Length/Weight Data

Length/weight data can be used to determine the size structure of the fish community. A healthy size structure is needed to sustain fish populations and the entire community. Too many small fish can indicate a stunted population and too many large fish could indicate low reproduction and recruitment. In addition, length/weight data can be used to separate juveniles from adult spawners to answer questions about population dynamics and the effects of management actions on specific life stages of species of interest (such as game fish or species of conservation concern). Without this data, HTLN could not determine which fish of a given species are of similar size or determine species size ranges and abundance of young of the year, juveniles, and adults. Collecting such data does require more field time than simply counting specimens. However, only a subsample of fish (30 per species) is measured. These measurements are recorded by one crew during the time when a separate crew collects habitat data. Therefore, there is realistically no extra field time required as the habitat crew must collect data after the fish sampling is completed. Collecting length/weight data does require more data entry time and database space. However, the information that is obtained and the questions that can be answered with length/weight data outweigh the cost of data entry time and database space.

Recommendation: Retain collecting individual length/weight data on a subsample of 30 specimens of each species.

Evaluation of Fish Data Summary and Analysis

Evaluation of Ozark Highlands Index of Biotic Integrity

The Index of Biotic Integrity (IBI) developed by Dauwalter et al. 2003 has been used to analyze the HTLN long-term fish monitoring data to assess stream integrity and fish community health (see BUFF 2006-2007 Fish report, Dodd 2009a; OZAR 2005-2007 Fish report, Dodd 2009b). This IBI was developed specifically for the Ozark Highlands region using data collected from 96 stream sites from northwest Arkansas. Similar to other IBIs developed and used in the Midwest (e.g., Fausch et al. 1984), the Ozark Highlands IBI uses a least-disturbed reference condition in which to score metrics that classify fish communities according to trophic status, spawning preferences, tolerance to human disturbance, and incidence of disease. However, unlike most IBIs, individual metric scores of the Ozark IBI are determined by linear equations and threshold limits, resulting in both metric scores and IBI scores that are on a continuous scale.

An IBI for the Current River was developed by Hoefs (1989) using sites from both mainstem and tributaries on the Current River. This IBI consists of metrics that classify fish communities according to trophic status, spawning preferences, and tolerance to human disturbance. The Current River IBI also consists of metrics that classify taxa richness parameters, while the Ozark Highlands IBI consists of metrics that classify incidence of disease. Similar to other Midwest region IBIs, each metric of the Current River IBI is given a score of 1, 3, or 5 based on the raw metric value with a minimum score of 10 and a maximum score of 50. This IBI score is not on a continuous scale (in other words, some scores between 10 and 50 cannot be mathematically obtained). To determine which IBI is appropriate for the Current River, HTLN fish community data from OZAR (2005-2010) were analyzed using both the Ozark Highlands IBI and the Current River IBI.

The Current River IBI varied little among mainstem sites or tributaries (Tables 12 and 13) or among years at mainstem sites, and did not differentiate stream integrity (i.e. IBI score) among the upper Current River, lower Current River, and Jacks Fork (Table 12). Scores ranged from 44 to 46 for the nine mainstem sites (six Current River, and three Jacks Fork) and 40 to 46 for tributaries. Based on fish community parameters such as species richness, diversity, and species abundance (see OZAR 2005-2007 Fish report, Dodd 2009b; see Appendix I, Figures 4 and 5 on NMS ordination for OZAR mainstems), fish communities in the upper Current, lower Current, and Jacks Fork group differently and tributaries tend to have lower richness and abundance.

Recommendations: The Current River IBI does not have the sensitivity to detect differences among sites or years and should not be used for assessment of trends in fish communities at OZAR. The Ozark Highland IBI, which was developed for the Ozark region (and not one specific watershed) and has been used by others to determine environmental/fish community relationships (see Petersen 2004), should be retained for future use in trend analysis. An IBI score, however, regardless of which index is used, should not be a stand-alone method of assessment. Information from individual metrics (both raw values and metric scores) are important to report and should be assessed to determine which factor may be driving temporal changes in stream integrity.

Table 12. Index of Biotic Integrity (IBI) scores, mean IBI and standard deviations for OZAR mainstem sites using the Ozark Highland IBI (Dauwalter et al. 2003) and Current River IBI (Hoefs 1989).

Mainstem site	2005	2006	2007	2008	2009	Mean	Standard Deviation
Ozark Highlands IBI							
C1	81	69	70	87	76	76.9	7.6
C2	64	62	63	63	56	61.6	3.4
C3	91	70	73	75	72	76.2	8.3
C4	74	79	68	67	69	71.4	5.1
C5	83	74	95	83	72	81.2	9.2
C6	78	68	91	87	74	79.6	9.2
J1	92	79	83	73	78	81.0	7.2
J2	95	86	81	93	92	89.2	5.8
J3	85	82	77	91	75	81.8	6.4
Current River IBI							
C1	46	46	46	46	46	46.0	0.0
C2	44	46	46	46	46	45.6	0.9
C3	46	46	46	46	46	46.0	0.0
C4	46	44	46	46	46	45.6	0.9
C5	44	46	46	46	46	45.6	0.9
C6	46	46	46	46	46	46.0	0.0
J1	44	44	44	46	44	44.4	0.9
J2	44	44	44	44	46	44.4	0.9
J3	44	44	44	46	44	44.4	0.9

Table 13. Index of Biotic Integrity (IBI) scores for OZAR tributaries using the Ozark Highland IBI and Current River IBI.

Tributary	Ozark Highlands IBI	Current River IBI
Shafer Spring	60	46
Sutton	73	44
Thompson	72	44
Prairie Hollow	57	44
Blair	79	42
Powder Mill	61	40
Rocky	84	44
Carr	76	46
Chilton	72	44
Rogers	65	46
Mill	83	44
Flat Rock Hollow	66	46
Water Branch	74	46
Shawnee	87	46

Summary of Proposed Changes

Changes to the Mainstem and Tributary Sampling

Even if all the reductions in data collection considered above were to be enacted, the overall sampling effort would still be much greater than the target goals specified in the beginning of this report. A primary reason for this is much of the overall time required to sample a site is spent traveling to or from the site. Thus, to reach these goals, more draconian measures are necessary, and include reducing the frequency of sampling, the spatial coverage, or both. Relatively few sites are sampled on the mainstems at BUFF and OZAR, and reducing the number of sites on the mainstems is not recommended.

Relatively few tributaries are sampled, and the ability to make overall inferences to an entire park is limited, because each watershed is unique. Thus, most inferences derived from tributary sampling will pertain to the particular tributaries sampled. Natural resources staff from BUFF and OZAR have requested that tributaries be sampled more frequently than the present 5 year sampling interval, and they further indicated that certain tributaries were of greater interest to them as management targets. Because tributaries monitored by HTLN were selected primarily at random, many of the tributaries currently sampled are not of great interest to park management. Furthermore, ordination analyses revealed that the assessment of the tributaries depended on the year that they were sampled, and suggest a long time will be required at the current return interval before the natural variability can be described in these tributaries, much less detection of directional change. Stronger inferences could be made to tributaries sooner if they were sampled more frequently. While sampling all tributaries currently in the sample frame would only result in an increasing workload, sampling fewer tributaries more frequently is an option.

Recommendations: To meet the objective of reducing the workload of HTLN staff to a sustainable level, but without reducing sample quality and data comparability, it is our recommendation to change sampling frequency of both mainstems and tributaries. Mainstem sites will be sampled every other year rather than every year. To meet the requests of park staff for more frequent sampling of tributaries of management interest while still retaining a random component to the spatial design, the proposed and recommended revisit plans presented below were devised in consultation with natural resources staff from each park. Park natural resources staff and HTLN staff mutually agreed that the recommended plan is suitable for the intended purpose in their respective parks.

Proposed BUFF Revisit Plan

Six mainstem sites (locations unchanged) will be sampled every other year. Targeted tributaries (4 of 6 tributaries identified by BUFF as their highest priorities) were selected in the order listed by the park. These targeted tributaries will be sampled every other year. Two tributaries listed as priorities by the park were excluded from further consideration. Cave Creek lies entirely (or largely so) outside the jurisdictional boundaries of BUFF; Tomahawk Creek has insufficient length inside the jurisdictional boundary to conduct all required sampling. The remaining targeted tributaries listed were part of the original GRTS panels.

The paneled tributaries will be sampled every four years. The six paneled tributaries have been sampled by HTLN under the GRTS design. These tributaries remained after eliminating the problematic tributaries (i.e., dry during first visit). All of the paneled tributaries were listed by BUFF as priority sampling sites.

Recommended BUFF Revisit Design (4-year rotation):

Year 1

All 6 mainstem sites

4 targeted tributaries (Mill Creek at Pruitt, Davis Creek, Calf Creek, Bear Creek)

Panel 1 tributaries (Clabber Creek, Middle Creek, Leatherwood Creek)

Year 2

No sampling

Year 3

All 6 mainstem sites

4 targeted tributaries (Mill Creek at Pruitt, Davis Creek, Calf Creek, Bear Creek)

Panel 2 tributaries (Cecil Creek, Little Buffalo River, Water Creek)

Year 4

No sampling

Proposed OZAR Revisit Plan

Nine mainstem sites (locations unchanged) are sampled every other year. Two targeted tributaries, identified by OZAR as their highest priorities, were selected. Both targeted tributaries were part of the original random GRTS panels. All targeted tributaries will be sampled every other year.

The four paneled tributaries for OZAR were in order of priority as provided by OZAR, after eliminating the problematic tributaries (i.e., flood plain issues, insufficient sampling area within park's jurisdictional boundary). Paneled tributaries will be sampled every four years.

Spring invertebrate sampling is changed to a three-year rotation with each spring being sampled once every three years. Phillips Spring was listed as a priority sampling site by OZAR (ranked #6). We evaluated this site and determined that it was better suited for inclusion in the springs monitoring panel. Initial sampling of Phillips Spring was conducted in July 2011. Springs monitoring will now include seven springs (Alley, Big, Blue, Pulltite, Round, Welch, and Phillips) with vegetation, habitat, and water quality monitored annually and invertebrates and fish monitored in the same year on a three-year rotation (see Bowles et al. 2008b for rotation schedule).

Recommended OZAR Revisit Design for Mainstems and Tributaries (4-year rotation):

Year 1

No river/tributary sampling

Year 2

9 mainstem sites (6 Current River, 3 Jacks Fork)
2 targeted tributaries (Sinking Creek, Shawnee Creek)
Panel 1 tributaries (Big West, Blair)

Year 3

No river/tributary sampling

Year 4

9 mainstem sites (6 Current River, 3 Jacks Fork)
2 targeted tributaries (Sinking Creek, Shawnee Creek)
Panel 2 tributaries (Rocky, Big East)

Table 14. Summary of changes between former protocols (Bowles et al. 2007; Petersen et al. 2008) and the revised protocol.

Change Made	Former Protocol	Revised Protocol
Invertebrate and Fish Protocols		
Number of mainstem river sampling sites per park	6 BUFF, 9 OZAR	6 BUFF, 9 OZAR
Sampling frequency of mainstem sites	Once Yearly	Once every 2 years
Number of tributary sampling sites (BUFF)	30 tributaries each sampled every 5 years	4 targeted tributaries sampled once every 2 years; 2 panels of four tributaries each-each panel sampled every 4 years
Number of tributary sampling sites (OZAR)	15 tributaries each sampled every 5 years	2 targeted tributaries sampled once every 2 years; 2 panels of 2 tributaries each-each panel sampled every 4 years
Invertebrate Protocol		
Number of invertebrate riffles/sites per stream	3	3
Number of invertebrate samples per riffle	3	3
Total number of invertebrate samples per site per date	9	9
Sampling device	Slack-Surber sampler	Slack-Surber sampler
Mesh size of sampling device	500 μ m	500 μ m
Subsampled portion of sample	25%	25%
Metrics	Described in Data Analysis section	Taxa richness, EPT richness, Hilsenhoff biotic index, Shannon's Diversity Index
Multimetric index	BRICI=BUFF, SCI=OZAR	SCI and ORSIMI (both parks)
Substrate Assessment	20 measured substrate pieces per sample (Wentworth Scale)	Dominant size (Wentworth Scale) in sample frame based on visual estimation
Stream discharge	Yes; hand measured	Yes, taken from USGS staff gages closest to mainstem sampling sites; discharge will be measured manually for tributaries
Water quality	Unattended hourly CORE 5 readings (datasonde) at fixed mainstem locations only; Static CORE 5 readings (hand-held meters) for each riffle at all sites	Unattended hourly CORE 5 readings (datasonde) at fixed mainstem locations only; Static CORE 5 readings (hand-held meters) for each riffle at all sites

Changes to the Spring Communities Protocol

Only a few minor changes are recommended for the Springs Community Protocol (Bowles et al. 2008b). Invertebrate sampling will no longer be conducted annually at each spring. Instead, invertebrate sampling will now follow the fish sampling schedule with each spring being sampled every 3 years. Aquatic vegetation and fish sampling schedules will not be changed. There are no proposed changes in habitat data collection. Phillips Spring has been added to the list of springs that are monitored.

Ramifications of Changing the Revisit Design

The ramifications of the proposed changes to the revisit design are fairly straightforward. Decreasing the frequency of sampling the mainstems and springs will mean that relatively fewer data points are available over time. Thus for any statistical analyses in which sample size is equivalent to number of sampling events, less statistical power will be available for any given time period. Also, a longer period of time will be required before we can be confident that we have observed the natural range of variability inherent in the system. Finally, for any drastic changes, it may be longer before such an event is observed by our monitoring. It is highly unlikely, however, that any such major events would not be noticed otherwise.

Decreasing the number of tributaries sampled will greatly decrease our ability to make park-wide inferences to tributaries in general. Due to the unique aspects of each watershed, however, it has become increasingly apparent that attempting to make such park-wide inferences, as proposed in the original protocol, would be very limited. Also, due to the inter-annual variability we now know exists in the tributaries, several decades would be required before we could observe the natural range of variability. By focusing on tributaries that are of direct interest to park resource managers, we will be able to provide more relevant information. Moreover, by sampling tributaries more frequently we will be able to determine the natural range of variability in the selected tributaries much sooner, and have better information with which to investigate potential directional trends. Greater statistical power will characterize any statistical analyses in which sample size is equivalent to the number of sampling events. Finally, any drastic changes in the tributaries sampled would potentially be noticed much sooner.

Literature Cited

- Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrate, and fish, 2nd ed. EPA 841-B-99-002, U.S. Environmental Protection Agency, Washington, DC.
- Belanger, S. E., Farris, J. L., Cherry, D. S., Cairns, J., Jr., 1985. Sediment preference of the freshwater Asiatic clam, *Corbicula fluminea*. *Nautilus* 99:66–73.
- Bowles, D. E. 1989a. Ecology of net-spinning Trichoptera in the Mulberry River, Arkansas. Ph.D. Dissertation, University of Arkansas, Fayetteville, AR.
- Bowles, D. E. 1989b. Life history and variability in secondary production estimates for *Corydalus cornutus* (Megaloptera: Corydalidae) in an Ozark stream. *Journal of Agricultural Entomology* 7:61-70.
- Bowles, D. E., H. R. Dodd, M. H. Williams, L. M. Morrison, K. James, M. D. DeBacker, C. E. Ciak, J. A. Hinsey, G. A. Rowell, and J. L. Haack. 2008b. Protocol for Monitoring Spring Communities at Ozark National Scenic Riverways, Missouri. Natural Resource Report NPS/HTLN/NRR—2008/029. National Park Service, Fort Collins, CO.
- 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, 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, CO.
- Bowles, D. E., M. H. Williams, H. R. Dodd, L. W. Morrison, J. A. Hinsey, C. E. Ciak, G. A. Rowell, M. D. DeBacker, and J. L. Haack. 2008a. Monitoring Protocol for Aquatic Invertebrates of Small Streams in the Heartland Inventory & Monitoring Network. Natural Resource Report NPS/HTLN/NRR—2008/042. National Park Service, Fort Collins, CO.
- Carter, J. L., S. V. Fend, and S. S. Kennelly. 1996. The relationships among three habitat scales and stream benthic invertebrate community structure. *Freshwater Biology* 35:109-124.
- Canton, S. P., and J. W. Chadwick. 1988. Variability in benthic invertebrate density estimates from stream samples. *Journal of Freshwater Ecology* 4:291-297.
- Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143.
- Danilov, R.A., and N. G. A. Ekelund. 2001. Comparative studies on the usefulness of seven ecological indices for the marine coastal monitoring close to the shore on the Swedish east coast. *Environmental Monitoring and Assessment* 66: 265-279

- Dauwalter, D.C., Pert, E.J., and Keith, W.E., 2003, An index of biotic integrity for fish assemblages in Ozark Highland Streams of Arkansas, *Southeastern Naturalist*, v. 2, p. 447-468.
- Dodd, H.R., D.G Peitz, G.A. Rowell, D.E. Bowles, and L.M. Morrison. 2008. Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR - 2008/052. National Park Service, Fort Collins, Colorado.
- Dodd, H.R. 2009a. Fish community monitoring at Buffalo National River: 2006-2007 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/185. National Park Service, Fort Collins, Colorado.
- Dodd, H. R. 2009b. Fish community monitoring at Ozark National Scenic Riverways: 2005-2007 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/224. National Park Service, Fort Collins, Colorado.
- Doisy, K. E., and C. F. Rabeni. 1999. Draft biological monitoring program for the Ozark National Scenic Riverways. Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri, Columbia, MO.
- Downes, B. J., P. S. Lake, and E.S. G. Schreiber. 2006. Spatial variation in the distribution of stream invertebrates: implications of patchiness for models of community organization. *Freshwater Biology* 30:119-132.
- Fausch, K.D., J.R. Karr, and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. *Transactions of the American Fisheries Society* 113:39-55.
- Gebler, J. B. 2004. Mesoscale spatial variability of selected aquatic invertebrate community metrics from a minimally impaired stream segment. *Journal of the North American Benthological Society* 23:616–633.
- Hoefs, N.J., 1989, Applying the index of biotic integrity to resource inventory in the Current River Basin, Missouri: Masters thesis, Colorado State University, Fort Collins, Colo., 111 p.
- Kruskal, J. B. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika* 29: 1-27.
- Karr, J. R., and E. W. Chu. 1999. Restoring life in running waters—better biological monitoring. Island Press, Washington, DC.
- Mather, P. M. 1976. Computational methods of multivariate analysis in physical geography. John Wiley & Sons, London.
- Mathis, M. L. 2001. Development of a Multi-metric System for Biological Water-Quality Monitoring for the Buffalo National River, University of Central Arkansas, Conway, AR.

- McCune, B. and J. B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, OR.
- National Park Service. 2008. 3-year Start-up Review of Heartland I&M Network Report and Recommendations from Review Panel, August 19-21, 2008.
- Peck, J. E. 2010. Multivariate Analysis for Community Ecologists: Step-by-Step Using PC-ORD. MjM Software Design, Gleneden Beach, OR.
- Petersen, J.C. 2004. Fish communities of the Buffalo River Basin and nearby basins of Arkansas and their relation to selected environmental factors, 2001-2004: U.S. Geological Survey Scientific Investigations Report 2004-5119, 93 p.
- 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, 94 p.
- Rabeni, C. F., and N. Wang. 2001. Bioassessment of streams using macroinvertebrates: are Chironomidae necessary? *Environmental Monitoring and Assessment* 71:177-185.
- Rabeni, C. F., R. J. Sarver, N. Wang, G. S. Wallace, M. Weiland, and J. T. Peterson. 1997. Development of regionally based biological criteria for streams of Missouri. A report to the Missouri Department of Natural Resources. Cooperative Fish and Wildlife Research Unit, 112 Stephens Hall, University of Missouri, Columbia, MO.
- Schmitt, C. J., W. G. Brumbaugh, J. M. Besser, J. E. Hinck, D. E. Bowles, L. W. Morrison, L.W., and M. H. Williams. 2008, Protocol for Monitoring Elemental Contaminants in the Ozark National Scenic Riverways, Missouri: Version 1.0: U.S. Geological Survey Open-File Report 2008-1269.
- Usrey, F. D., and J. A. Hinsey. 2006. Characterization of Macroinvertebrate Community and Drift in a Tributary of Buffalo National River, National Park Service Final Report, PMIS No. 82725. Buffalo National River, Harrison, AR.
- Washington 1984. Washington, H. G. 1984. Diversity, biotic and similarity indices. A review with special relevance to aquatic ecosystems. *Water Research* 18:653-694.
- Vannote, R. L., G. W. Minshal, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries Aquatic Science* 37:130-137.

Appendix A. Proposal to modify fish community monitoring at Tallgrass Prairie National Preserve and Pipestone National Monument

Proposal to modify fish community monitoring at Tallgrass Prairie National Preserve and Pipestone National Monument

By Hope R. Dodd

Introduction:

Since 2001, fish monitoring has been completed annually at Tallgrass Prairie National Preserve (TAPR) and Pipestone National Monument (PIPE) with initial focus on the status of the federally-endangered Topeka shiner (Peitz and Rowell, 2004). In 2007, a proposal was submitted to and approved by the Board of Directors to re-focus the fish monitoring protocol to the collection of community data, rather than monitoring one individual species. In 2008, a revised protocol was published (see Dodd *et al.*, 2008) outlining changes that included: 1) sampling all habitat types available within the stream reach to produce a reach-based approach similar to that used in other national-level protocols, 2) collection of length and weight data on all fish species to develop a better understanding of community size structure and composition, 3) enhance habitat collection to better characterize the streams and initiate water quality data-logging during fish sampling to evaluate diel patterns, and 4) retaining one representative downstream reach in each stream and adding a site on Fox Creek at TAPR. In addition, the revised protocol established a rotating panel for sampling seven additional small stream parks (EFMO, GWCA, HEHO, HOME, HOSP, PERI, WICR) where little or no information on the aquatic resources were known. The justification for the above listed revisions was that more data on fish community, habitat, and water quality would be collected at TAPR and PIPE allowing for a more accurate assessment of the aquatic community, and deficiencies in aquatic resource monitoring at seven other Heartland Network (HTLN) parks would be resolved without substantially increasing the work load of HTLN staff.

During HTLN's 2008 annual meeting and start-up review, it was discussed and agreed upon by the review panel, park superintendents, and resource managers that the network was operating on a "razor-thin margin" (National Park Service 2008). While the review panel noted HTLN's impressive productivity accomplished with a relatively small staff and budget, they agreed that efforts should be made to trim costs and make field sampling more efficient. One concern was that the aquatics program staff was stretched too thin, and the review panel suggested that HTLN staff consider cutting back on field sampling until additional funding and staff could be obtained. Another suggestion by park resource managers was to use park staff to assist in field sampling, where appropriate, to reduce HTLN travel costs and field work.

This proposal suggests a plan to reduce some of the work load on aquatic program staff by modifying the sampling regime at TAPR and PIPE. Because fish monitoring at the seven rotational parks is currently at a minimal level with regards to HTLN travel cost and time, sampling frequency and methodology will continue as outlined in Dodd *et al.* 2008. Proposed changes in sampling for TAPR and PIPE will allow for continued annual fish monitoring at these two parks while maintaining rotational sampling at the seven other small stream parks.

Implementation Plan and Methodology:

The work load of Network aquatic program staff is currently at maximum capacity, and adjustments are needed in the event of HTLN budget constraints, staff turnover or loss, or equipment failure (see National Park Service 2008). Annual fish monitoring at TAPR and PIPE will continue on an annual basis due to the parks' requirement to track the status of Topeka shiners but will continue at a reduced level during certain years. As proposed here, TAPR and PIPE will be placed on a three year rotational panel (similar to the other seven small stream parks) whereby once every third year each park will receive the entire sampling regime (fish, habitat, and water quality) described in Dodd *et al.* 2008 (Table A-1). This full sampling regime will coincide with the year in which aquatic invertebrate sampling is completed at the parks. On those years, all sampling will be conducted by HTLN staff. All stream reaches (listed in Dodd *et al.*, 2008) will be sampled for fish community composition (including Topeka shiners) and size structure, as well as measurements of physical habitat and water quality.

During the two off-cycle years (Table A-1), an abbreviated sampling regime is proposed. In this instance, sampling will focus on obtaining data on Topeka shiners by collecting data in only those sample reaches where Topeka shiners are known to occur in the parks (subset of reaches listed in Dodd *et al.*, 2008; see Table 2 and Figures A-1 and A-2). The abbreviated regime will include sampling only pool habitat types (preferred habitat of Topeka shiners) and identifying and counting only Topeka shiners collected in these reaches. Habitat and water quality measurements will not be collected during years of abbreviated sampling to decrease the number of staff members necessary to complete sampling. Staff at PIPE have assisted with fish monitoring in previous years; therefore, it is proposed that sampling be conducted by staff at PIPE during these off-cycle years. Although PIPE resource management staff are familiar with the sampling methods, an initial training session on sample techniques and fish identification will be given to park personnel prior to the first year of abbreviated sampling. This proposed design will decrease field sampling time (by 40% at TAPR and 67% at PIPE) and cost (by 52% at TAPR and 67% at PIPE) for HTLN while maintaining a high-level of annual fish monitoring, which will continue to provide parks comprehensive data on fish communities (full sampling regime) as well as necessary data on Topeka shiner status and their surrounding fish communities (abbreviated regime).

Table A-1. Rotational design for fish monitoring at TAPR and PIPE. F = full sample regime; A = abbreviated sample regime.

Study Park	Year									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
TAPR	F	A	A	F	A	A	F	A	A	F
PIPE	F	F	A	A	F	A	A	F	A	A

Table A-2. Reaches to be sampled during off-cycle years (abbreviated sampling regime) and total number of Topeka shiners found at these reaches in previously sampled years.

Reach	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
PIPE										
1 Lower	0	0	19	0	13	32	36	10	0	110
TAPR										
1 Lower	0	1	0	0	0	0	0	0	0	1
1 Middle	0	9	0	0	16	0	1	0	0	26
23 Middle	7	62	15	20	3	10	8	1	0	126

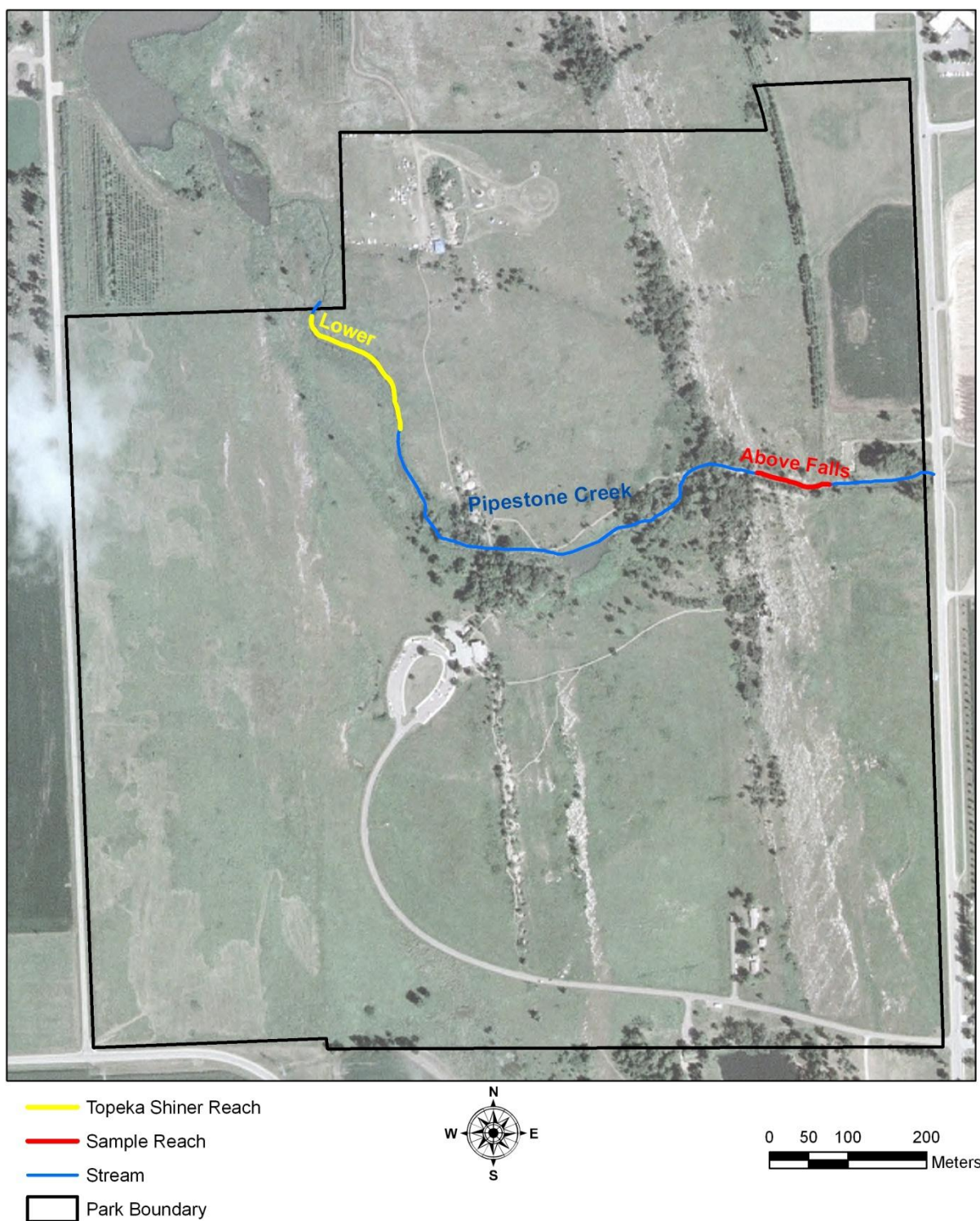


Figure A-1. Location reaches sampled at PIPE. Only the reach in yellow will be sampled in off-cycle years using the abbreviated sampling regime.

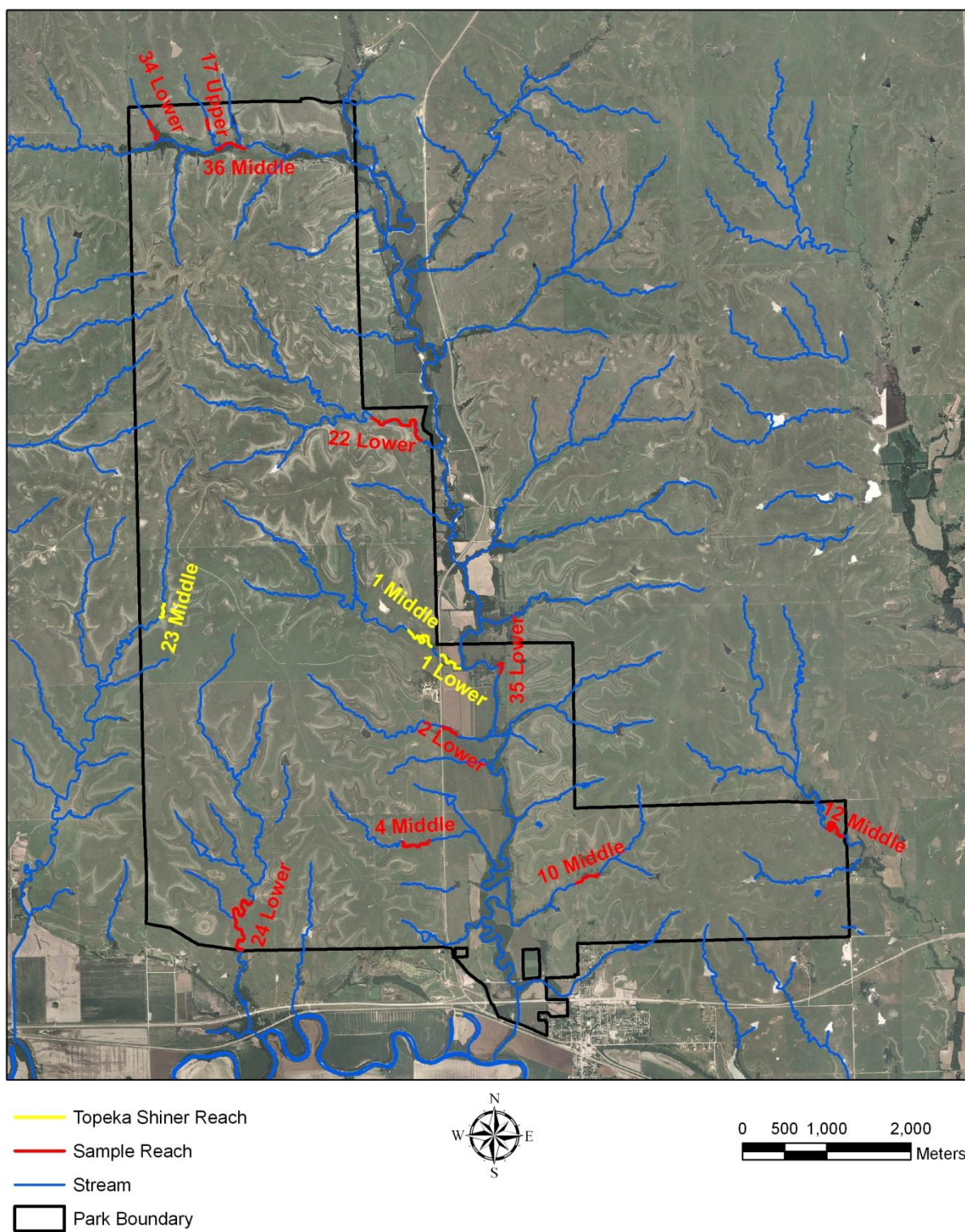


Figure A-2. Location of reaches sampled at TAPR. Only reaches in yellow will be sampled in off-cycle years using the abbreviated sampling regime.

References

- Peitz, D.G and Gareth A. Rowell. 2004. Fish Community Monitoring in Prairie Park Streams with Emphasis on Topeka shiner (*Notropis topeka*). Heartland I&M Network and Prairie Cluster Prototype Monitoring Program, National Park Service, Republic, MO.
- Dodd, H.R., D.G. Peitz, G.A. Rowell, D.E. Bowles, and L.M. Morrison. 2008. Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network. Natural Resources Report. NPS/HTLN/NRR – 2008/052. National Park Service, Fort Collins, Colorado.
- National Park Service. 2008. 3-year Start-up Review of Heartland I&M Network Report and Recommendations from Review Panel, August 19-21, 2008.

Appendix B: List of tributaries sampled for invertebrates by year and location.

Abbreviation	Tributary name	Year sampled	Location
OZAR tributaries			
CT01	Shafer Spring	2009	Upper Current
CT02	Sutton	2007	Upper Current
CT03	Thompson	2009	Upper Current
CT04	Prairie Hollow	2010	Lower Current
CT06	Blair	2010	Lower Current
CT07	Powder Mill	2008	Lower Current
CT08	Rocky	2006	Lower Current
CT09	Carr	2008	Lower Current
CT12	Rogers	2010	Lower Current
CT13	Mill	2006	Lower Current
JT01	Flat Rock Hollow	2006	Jacks Fork
JT02	Water Branch	2007	Jacks Fork
JT03	Shawnee	2009	Jacks Fork
BUFF tributaries			
T01	Smith	2009	Upper Buffalo
T03	Whiteley	2006	Upper Buffalo
T04	Sneeds	2008	Upper Buffalo
T05	Cecil	2007	Upper Buffalo
T06	Glade	2009	Upper Buffalo
T07	Mill	2007	Upper Buffalo
T08	Vanishing	2010	Upper Buffalo
T09	Little Buffalo	2006	Upper Buffalo
T10	Wells	2009	Upper Buffalo
T11	Rock	2009	Upper Buffalo
T13	Big	2008	Upper Buffalo
T14	Lick	2010	Upper Buffalo
T15	Davis	2008	Middle Buffalo
T16	Mill Branch	2008	Middle Buffalo
T17	Richland	2010	Middle Buffalo
T20	Bear	2009	Middle Buffalo
T22	Spring	2006	Lower Buffalo
T23	Water	2009	Lower Buffalo
T24	Hickory	2006	Lower Buffalo
T25	Panther	2007	Lower Buffalo
T27	Clabber	2010	Lower Buffalo
T30	Middle	2006	Lower Buffalo
T31	Leatherwood	2006	Lower Buffalo
T33	Stewart	2007	Lower Buffalo

Appendix C: List of tributaries sampled for fish by year, location and watershed area.

Tributary name	Year sampled	Location	Watershed area (sq. km)
BUFF tributaries			
Smith	2009	Upper Buffalo	21.79
Whiteley	2006	Upper Buffalo	13.92
Sneeds	2008	Upper Buffalo	11.76
Cecil	2007	Upper Buffalo	58.87
Glade	2009	Upper Buffalo	6.38
Mill	2007	Upper Buffalo	55.02
Vanishing	2010	Upper Buffalo	3.77
Little Buffalo	2006	Upper Buffalo	371.32
Wells	2009	Upper Buffalo	31.38
Rock	2009	Upper Buffalo	15.84
Sheldon Branch	2007	Upper Buffalo	7.53
Big	2008	Upper Buffalo	231.78
Lick	2010	Upper Buffalo	11.58
Davis	2008	Middle Buffalo	72.44
Mill Branch	2008	Middle Buffalo	10.19
Richland	2010	Middle Buffalo	312.26
Calf	2008	Middle Buffalo	127.54
Bear	2009	Middle Buffalo	238.49
Brush	2007	Middle Buffalo	52.06
Spring	2006	Lower Buffalo	34.07
Water	2009	Lower Buffalo	99.14
Hickory	2006	Lower Buffalo	10.22
Panther	2007	Lower Buffalo	17.33
Clabber	2010	Lower Buffalo	68.71
Boat	2008	Lower Buffalo	10.34
Big	2010	Lower Buffalo	347.32
Middle	2006	Lower Buffalo	29.05
Leatherwood	2006	Lower Buffalo	32.93
Cow	2010	Lower Buffalo	8.79
Stewart	2007	Lower Buffalo	6.89
OZAR tributaries			
Shafer Spring	2009	Upper Current	21.94
Sutton	2007	Upper Current	10.54
Thompson	2009	Upper Current	6.54
Prairie Hollow	2010	Lower Current	7.05
Blair	2010	Lower Current	112.26
Powder Mill	2008	Lower Current	13.44
Rocky	2006	Lower Current	57.52
Carr	2008	Lower Current	46.82
Thorny	2008	Lower Current	10.56
Chilton	2007	Lower Current	10.48
Rogers	2010	Lower Current	47.35
Mill	2006	Lower Current	61.84
Flat Rock Hollow	2006	Jacks Fork	12.89
Water Branch	2007	Jacks Fork	28.53
Shawnee	2009	Jacks Fork	51.87

Appendix D. Proposed approach for conducting geomorphological assessments for BUFF and OZAR mainstem monitoring sites.

Outline of proposed approach for collecting geomorphological data for BUFF and OZAR:

1. Mainstem GRTS sites only
 - a. Conducted at established reaches, or an extension of an established reach to allow collection of required data described below.
2. Data will supplement instream and bank data currently being collected during fish monitoring.
3. Side scan sonar will be used to map the stream longitudinal profile along the approximate thalweg.
 - a. Proportion of glides, riffles, runs, and pools (by type) in each sampled longitudinal profile will be determined.
 - b. Proportion of total bank length that is eroded.
4. Three cross-sections through glide habitats (3 riffle/glide sequences per Panfil and Jacobson approach). At each cross-section, the following will be recorded:
 - a. Establish channel bottom profile (depth soundings, channel profile) using a Garmin 535s GPS plotter/dual beam sonar.
 - b. A single 100-count pebble survey will be conducted using the Wentworth scale.
 - c. Bank angles and height at each cross-section (both banks will be measured) with a laser rangefinder/hypsometer.
 - d. For any point bars or islands in reach, relative size will be determined using three widths (upper, middle, lower) at GPS fixed locations, and length.
7. Considerations to be resolved:
 - a. Amount of field time at each site.
 - b. Amount of office time dedicated to GPS support.
 - c. Cost of a side-scan sonar unit.

Appendix E. Habitat and water quality summary data for BUFF and OZAR mainstem sampling sites (invertebrate sampling at riffles).

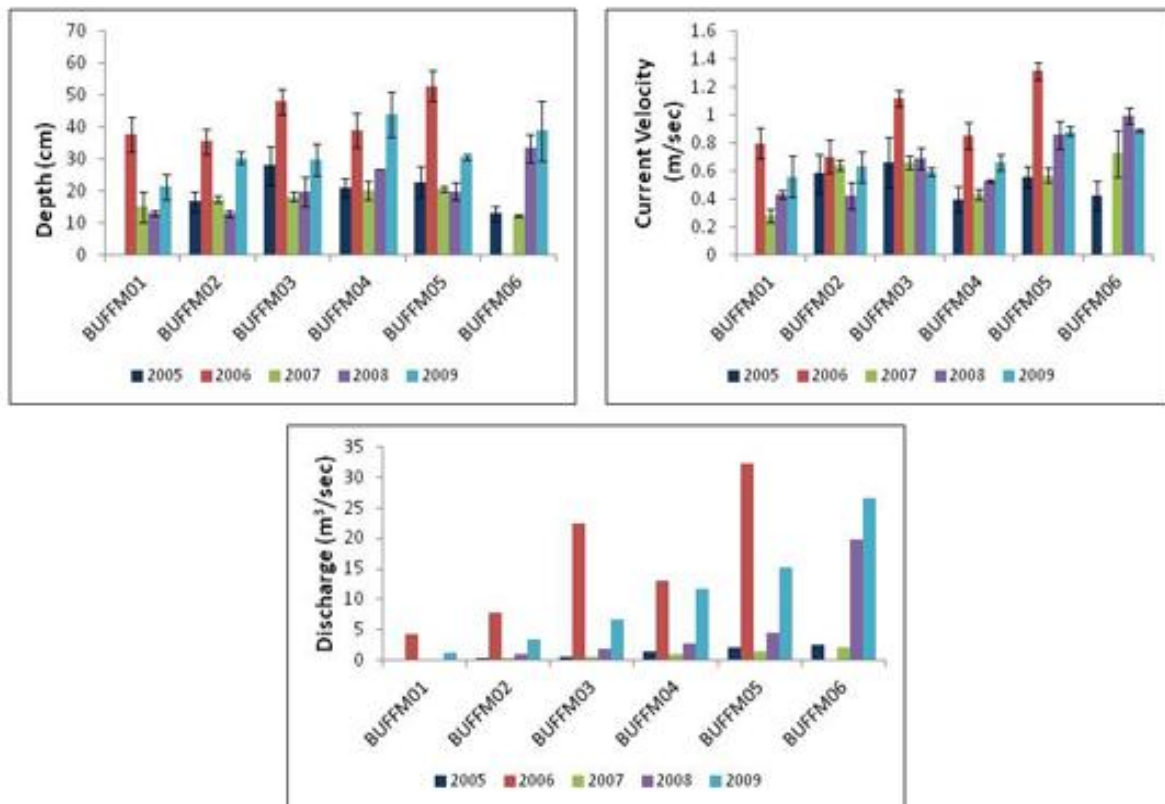


Figure E-1. Means and standard errors for depth and current velocity, and discharge for mainstem sampling sites on the Buffalo River, 2005-2006.

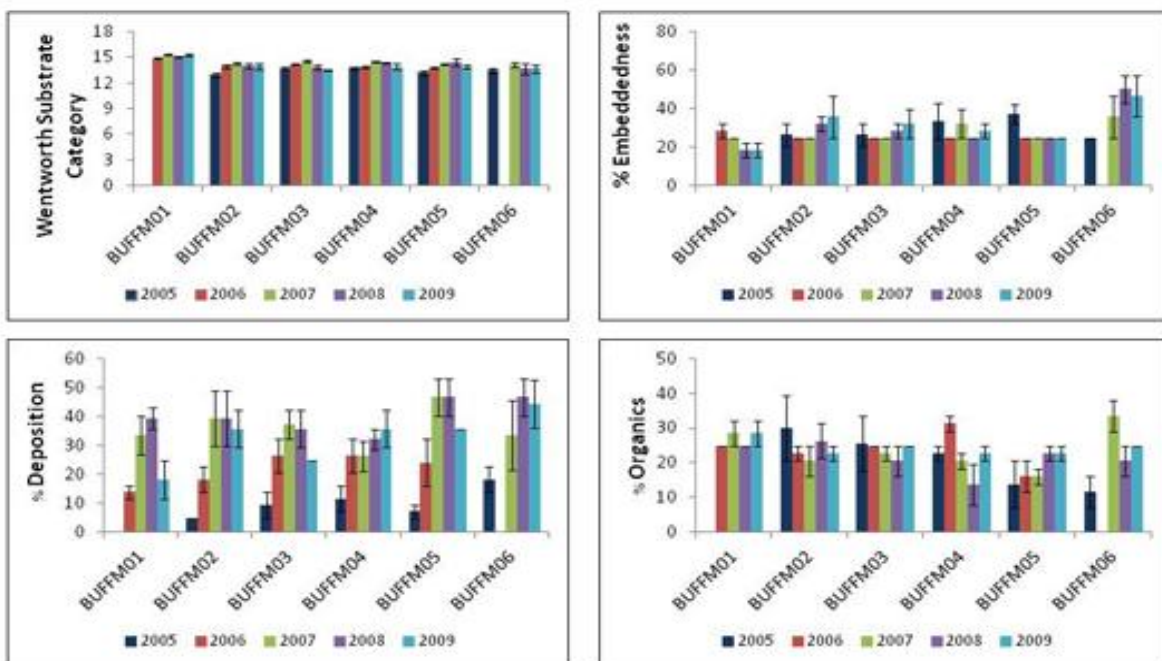


Figure E-2. Mean and standard errors of substrate size, percent embeddeness, percent deposition, and percent organics for BUFF mainstem sampling sites, 2005-2010.

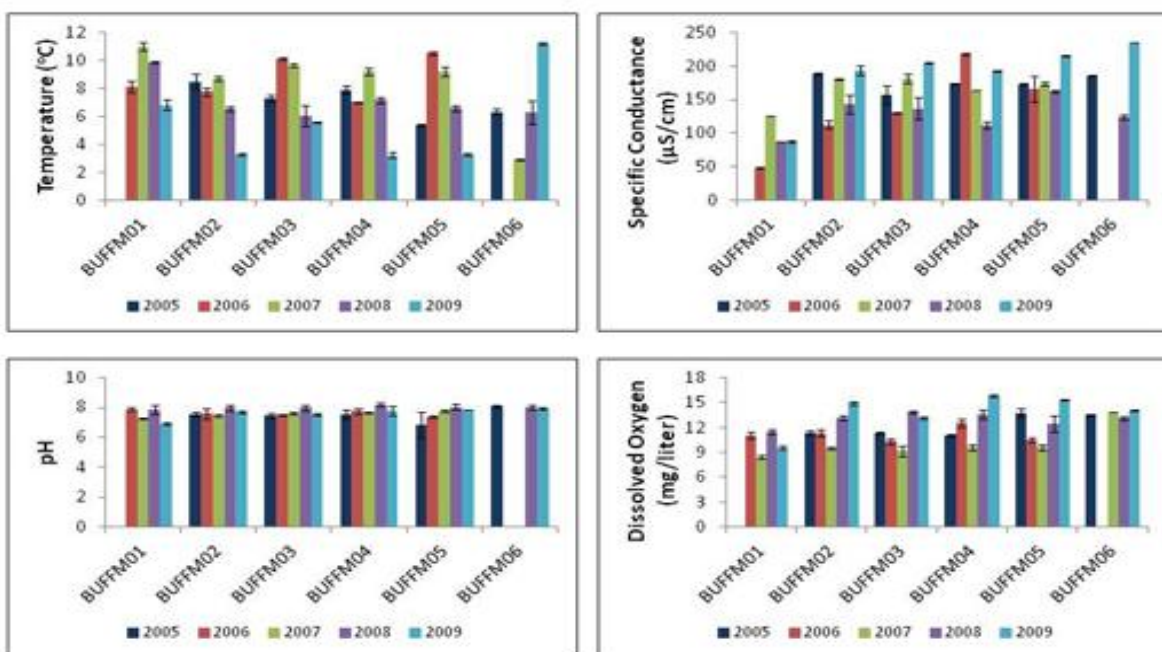


Figure E-3. Means and standard errors of temperature, specific conductance, pH and dissolved oxygen concentration with standard errors for BUFF mainstem sampling sites, 2005-2010.

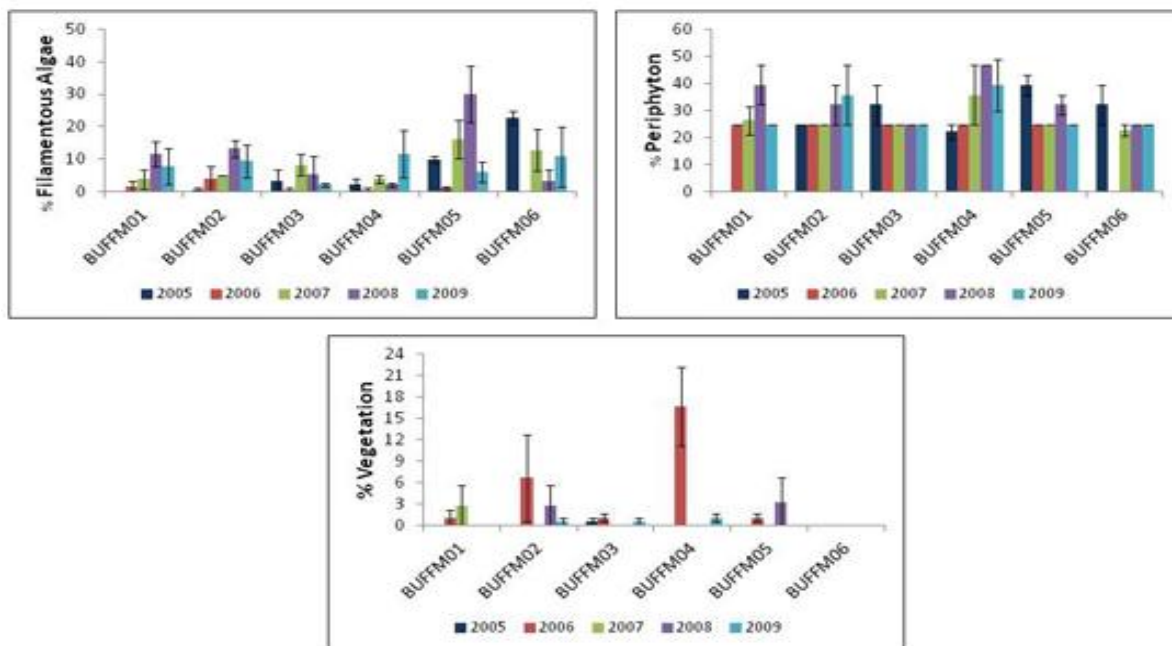


Figure E-4. Means and standard errors of percent filamentous algae, percent periphyton, and percent vegetation for BUFF mainstem sampling sites.

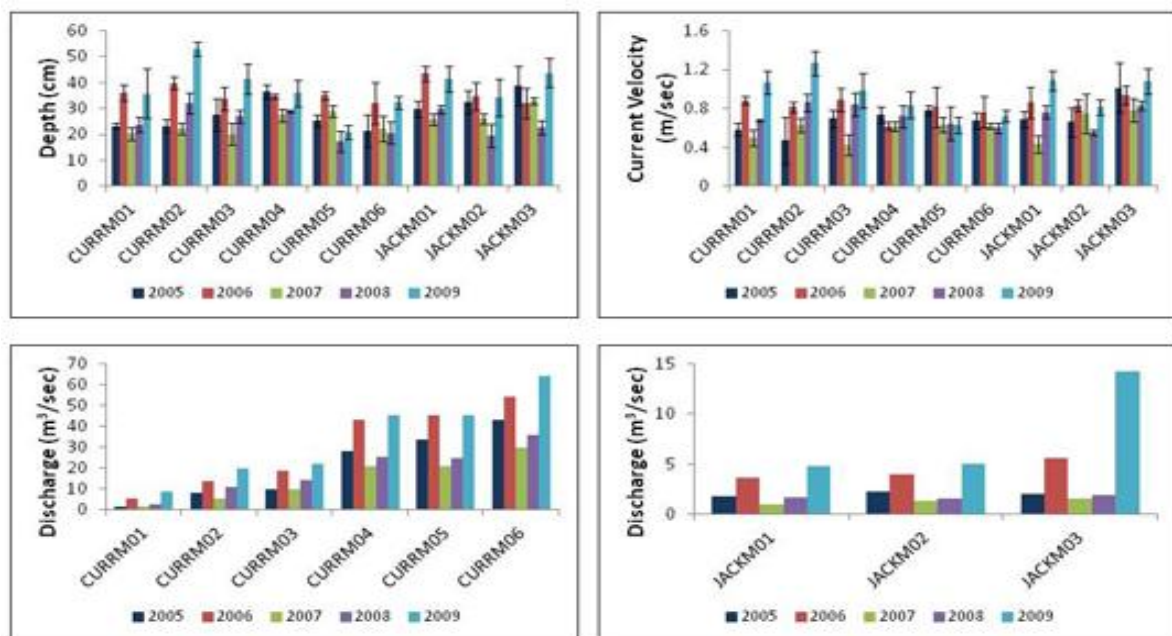


Figure E-5. Mean depth and current velocity and standard errors, and discharge for mainstem sampling sites on the Current River and Jacks Fork, 2005-2006.

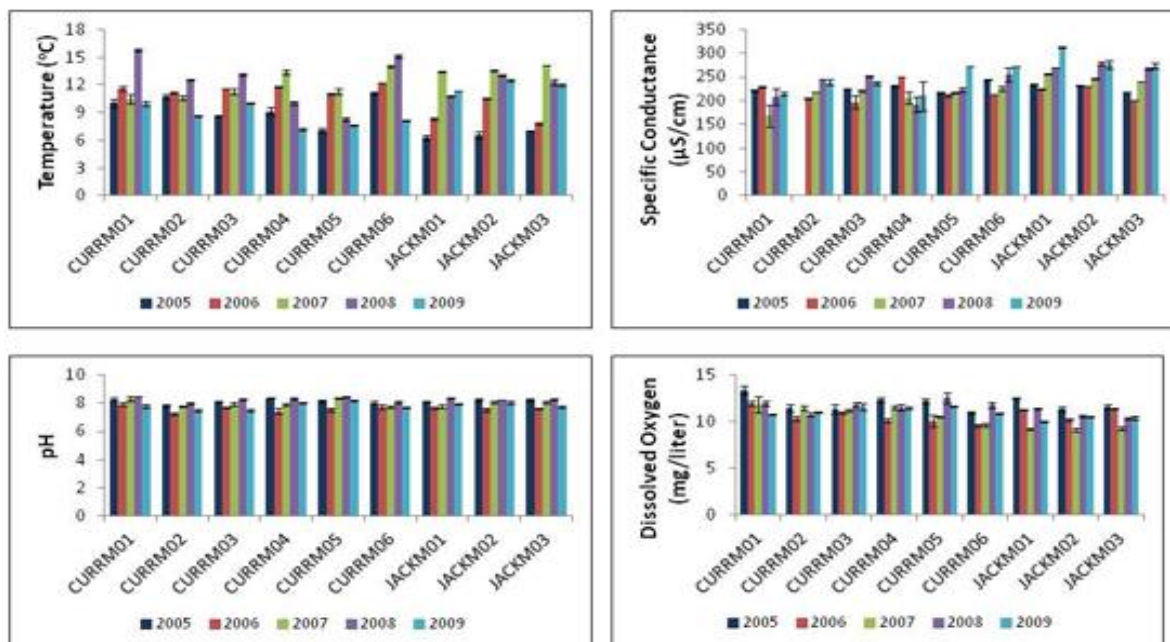


Figure E-6. Mean temperature, pH, specific conductance, pH, and dissolved oxygen concentration with standard errors for the Current River and Jacks Fork, 2005-2006.

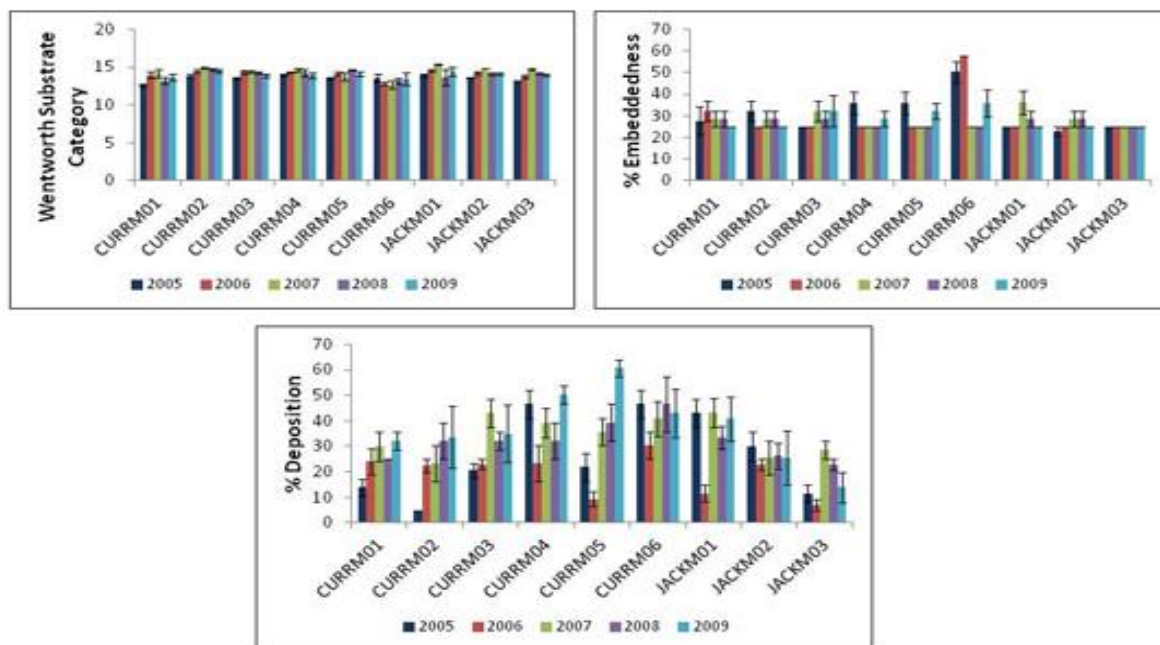


Figure E-7. Mean substrate size and percent embeddedness and percent deposition with standard errors for the Current River and Jacks Fork, 2005-2010.

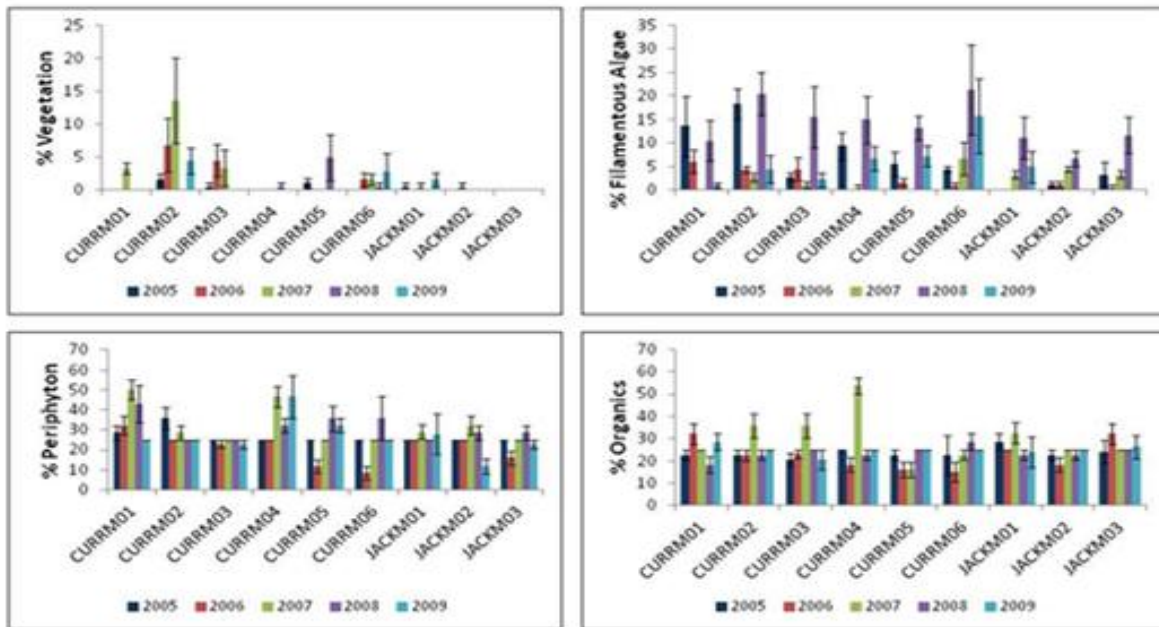


Figure E-8. Mean percent vegetation, filamentous algae, periphyton, and organics with error bars for mainstem sampling sites on the Current River and Jacks Fork, 2005-2010.

Table E-1. Stream discharge measured for BUFF tributaries, 2006-2010, during invertebrate sampling.

Tributary	Year	Discharge	Tributary	Year	Discharge
BUFFT03	2006	0.19	BUFFT15		0.02
BUFFT09		5.19	BUFFT16		0.19
BUFFT22		0.39	BUFFT01	2009	0.05
BUFFT24		0.10	BUFFT06		0.01
BUFFT30		0.28	BUFFT10		0.07
BUFFT31		0.44	BUFFT11		0.03
BUFFT05	2007	0.02	BUFFT20		1.49
BUFFT07		0.06	BUFFT23		0.39
BUFFT25		0.01	BUFFT08	2010	0.002
BUFFT33		0.01	BUFFT14		0.05
BUFFT04		0.31	BUFFT17		1.05
BUFFT13		0.28	BUFFT27		0.08

Table E-2. Stream discharge measured for tributaries at OZAR, 2006-2010, during invertebrate sampling.

Tributary	Year	Discharge	Tributary	Year	Discharge
CURRT08	2006	1.26	CURRT01	2009	0.43
CURRT13		0.94	CURRT03		0.03
JACKT01		0.08	JACKT03		0.56
CURRT02	2007	no data	CURRT04	2010	0.003
JACKT02		0.01	CURRT06		0.26
CURRT07	2008	0.02	CURRT12		0.025
CURRT09		0.03			

Appendix F. Full methodological details and results of NMS ordinations of invertebrate communities.

Methodology

PC-ORD (version 6.0; McCune and Grace 2002, Peck 2010) was employed to obtain the NMS solutions. Preliminary solutions were obtained using autopilot mode, on the “slow and thorough” setting. This procedure was run at least three times for each data set, to determine the appropriate dimensionality and evaluate the consistency of results, as recommended by Peck (2010). These runs always produced consistent results and the same dimensionality, for each data set. The final NMS run for each data set employed the Sorenson distance measure and 250 runs with real data, at the dimensionality determined by the autopilot setting. The option to automatically rotate the axes to orthogonal principal axes was selected; this eigenanalysis procedure is a rigid rotation designed to make the axis independent of each other (Peck 2010).

Both the metrics and habitat variables were calculated or measured in different units and on scales of different magnitudes, and thus a general relativization by columns was performed on both data sets prior to analyses. The value of p chosen for the relativization was 1, which is appropriate for the Sorensen distance measure (McCune and Grace 2002). For the BUFF tributaries dataset, if the metrics were relativized, no useful ordination was obtained; NMS was run on this dataset without relativization of the metrics.

Correlation coefficients of the 14 habitat variables with all ordination axes were calculated for each data set. The squared correlation coefficients (i.e., coefficients of determination) express the amount of variation in position along an axis that is explained by a given habitat variable. Such correlations should primarily be used for descriptive purposes, and the use of P -values is discouraged in such cases because of lack of independence of ordination scores, and the effect of sample size on P -values (McCune and Grace 2002). Nevertheless, a correlation coefficient of 0.5 corresponds to a P -value of between 0.07 and 0.001—depending on the sample size of the dataset—and represents a range of significance values that most ecologists would accept as indicating a biologically important effect, perhaps making some adjustment for the multiple comparisons inherent in such an analysis.

Results

The OZAR tributaries had a stress score of 2.18 (Table F-1), which ranks as an excellent ordination with no risk of drawing false inferences (Kruskal 1964, Clarke 1993; multiplying Clarke’s rule by 100 to make it comparable with Kruskal and PC-ORD). The BUFF mainstems had a stress score of 7.40, which ranks as a good to excellent ordination. Stress scores for the two other data sets (10.7 and 16.67) are in the good to fair range (Kruskal 1964, Clarke 1993). Most ecological data sets have stress between 10 and 20, and values below 15 are usually considered quite satisfactory (McCune and Grace 2002). Instabilities for all data sets were <0.00000 (Table F-1). Because NMS is not based on partitioning of variance, the coefficients of determination (R^2) in Table F-1 do not represent variance explained by the ordination, but rather a comparison of how well the distances between points in ordination space represent distances in the original n -dimensional space, and the relative contribution of each axis (McCune and Grace 2002).

Table F-1. Results of nonmetric multidimensional scaling analyses (NMS) for aquatic invertebrates showing number of samples (sites in all years), number of metrics included, number of dimensions in final result, stress score, instability, and cumulative coefficient of determination for all axes retained in the final solution.

Dataset	No. of Samples	No. of Metrics	Dimensions	Stress	Instability	Iterations	r^2 (cumulative)		
							Axis1	Axis 2	Axis 3
BUFF mains	28 ¹	10	3D	7.40	0.00000	79	0.554	0.799	0.949
OZAR mains	45 ²	4	2D	10.70	0.00000	126	0.715	0.949	N/A
BUFF tributaries	24	10	2D	16.67	0.00000	54	0.519	0.833	N/A
OZAR tributaries	13	4	3D	2.18	0.00000	54	0.791	0.917	0.980

¹ Includes six sites sampled on an annual basis for five years (two sites were not sampled in one of the years).

² Includes nine sites sampled on an annual basis for five years.

For OZAR mainstems, a 2-dimensional solution was selected (Table F-1), and no habitat variables had correlations with the ordination axes exceeding the threshold ($r = 0.5$) (Table F-2). The 9 sites revealed some separation in ordination space over the 5-year period, with the three Jacks Fork sites and the upper-most Current site located in the upper portion of the ordination space, and the more downstream Current sites located in the lower portion (Figure F-1). No clear separation was apparent when sites were grouped by year (Figure F-2). The relative change in each site over time in ordination space is depicted in Figure F-3.

For BUFF mainstems, a 3-dimensional solution was selected (Table F-1), and correlations of three habitat variables—velocity, depth, and algae—exceeded the threshold (Table F-2, Figure F-4). When grouped by site, no obvious geographical patterns emerged (Figure F-5). There were, however, distinct differences among several years, although in a manner that would indicate oscillations or variability rather than directional change through time (Figure F-6). The relative change in each site over time in ordination space is depicted in Figure F-7.

For OZAR tributaries, a 3-dimensional NMS solution was selected (Table F-1). Four habitat variables had correlation coefficients exceeding the threshold: water temperature, algae, embeddedness, and dissolved oxygen (Table F-3, Figure F-8). Lower Current sites overlapped broadly with the Jacks Fork sites, whereas Upper Current sites occurred in a more restricted ordination space (Figure F-9).

A 2-dimensional NMS solution was selected for BUFF tributaries (Table F-1), and no habitat variables had correlation coefficients exceeding the threshold (Table F-3, $r = 0.5$). The Upper, Middle, and Lower tributary sites broadly overlapped in ordination space (Figure F-10).

Table F-2. Pearson correlation coefficients for 14 habitat variables against NMS ordination axes for BUFF and OZAR mainstems. For BUFF (n = 28), *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.373 and 0.475, respectively. For OZAR (n = 45) *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.293 and 0.380, respectively.

Habitat variable	BUFF			OZAR	
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2
Substrate	0.164	0.272	-0.431	0.038	-0.034
Discharge	0.416	-0.370	0.134	-0.272	-0.408
Depth	0.601	-0.357	0.207	-0.028	-0.083
Velocity	0.244	-0.510	0.134	0.065	-0.041
Water temperature	-0.024	0.146	0.163	0.057	0.267
Specific conductance	0.023	0.210	0.406	-0.217	0.244
pH	-0.166	-0.196	-0.362	-0.044	0.364
Dissolved oxygen	0.231	-0.196	-0.172	-0.041	-0.038
Embeddedness	-0.035	0.036	0.013	-0.036	-0.115
Vegetation	0.176	-0.135	-0.052	0.254	-0.433
Algae	-0.279	0.163	-0.491	-0.262	0.037
Periphyton	0.111	0.343	-0.358	-0.060	0.244
Deposition	0.110	0.170	-0.450	-0.297	-0.064
Organics	0.164	-0.132	0.163	0.021	0.017

Table F-3. Pearson correlation coefficients for 14 habitat variables against NMS ordination axes for BUFF and OZAR tributaries. For BUFF (n = 24), *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.404 and 0.515, respectively. For OZAR (n = 13) *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.552 and 0.683, respectively.

Habitat variable	BUFF		OZAR		
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 3
Substrate	-0.287	0.062	-0.369	0.228	0.335
Discharge	-0.255	0.002	0.158	0.046	-0.058
Depth	-0.159	-0.164	0.085	0.077	-0.086
Velocity	-0.083	-0.278	0.239	0.031	-0.312
Water temperature	0.169	0.333	-0.121	-0.558	0.311
Specific conductance	0.156	-0.094	0.353	0.156	0.251
pH	0.054	-0.345	-0.186	0.241	0.113
Dissolved oxygen	0.033	-0.356	0.280	0.573	-0.164
Embeddedness	0.155	0.168	0.517	0.310	0.146
Vegetation	-0.365	0.121	-0.202	-0.159	0.365
Algae	0.204	-0.017	0.021	-0.587	-0.392
Periphyton	-0.245	-0.162	-0.382	0.112	0.079
Deposition	-0.316	-0.162	0.456	0.211	-0.062
Organics	-0.295	0.236	-0.067	-0.268	0.305

OZAR mains

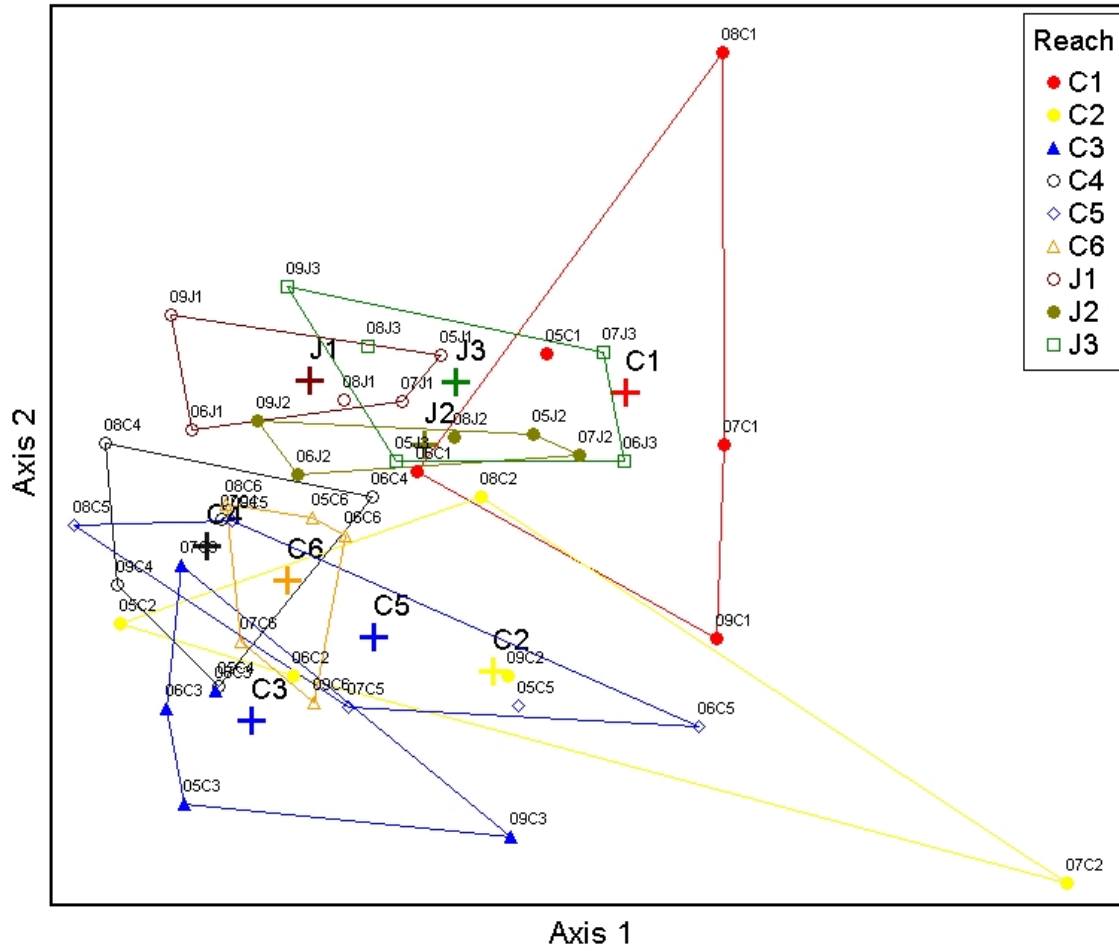
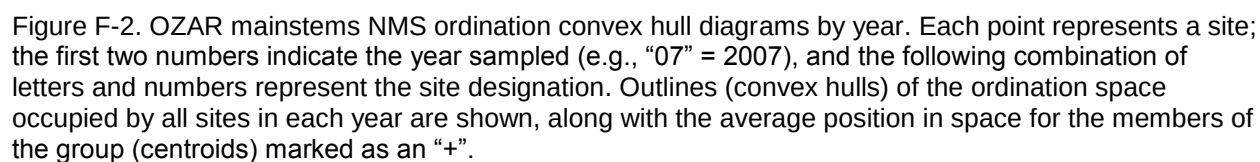


Figure F-1. OZAR mainstems NMS ordination convex hull diagrams by site. Each point represents a site; the first two numbers indicate the year sampled (e.g., “07” = 2007), and the following combination of letters and numbers represent the site designation. Outlines (convex hulls) of the ordination space occupied by each site in all years are shown, along with the average position in space for the members of the group (centroids) marked as an “+”.



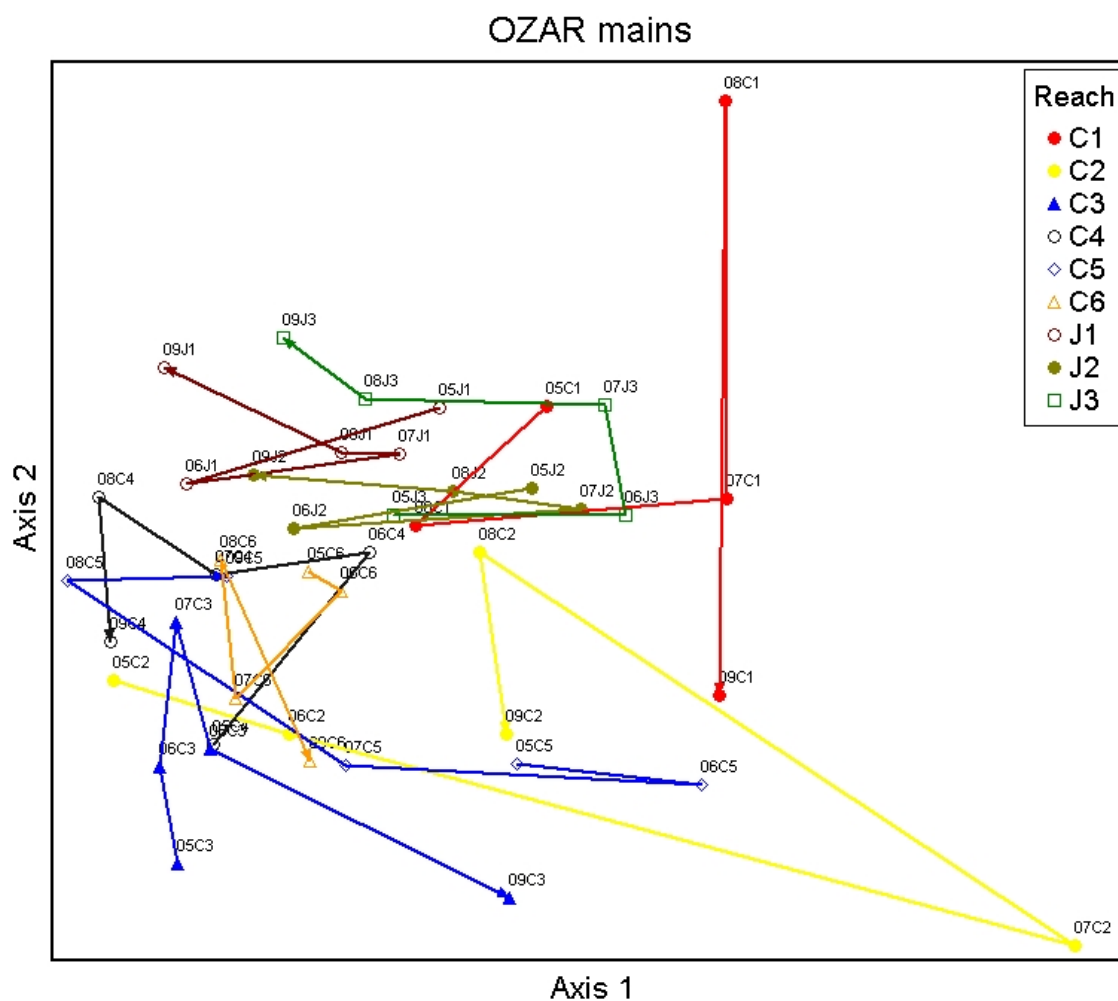


Figure F-3. Successional vectors for OZAR mainstems. Each point represents a site; the first two numbers indicate the year sampled (e.g., “07” = 2007), and the following combination of letters and numbers represent the site designation. Arrows indicate direction of change in relative position in ordination space over time for each site.

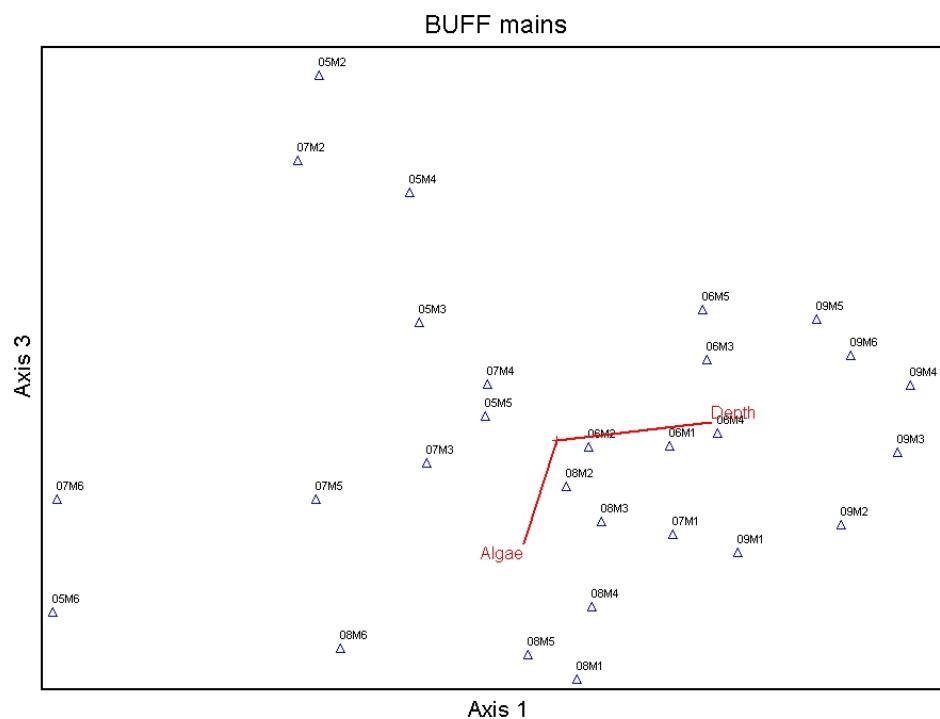
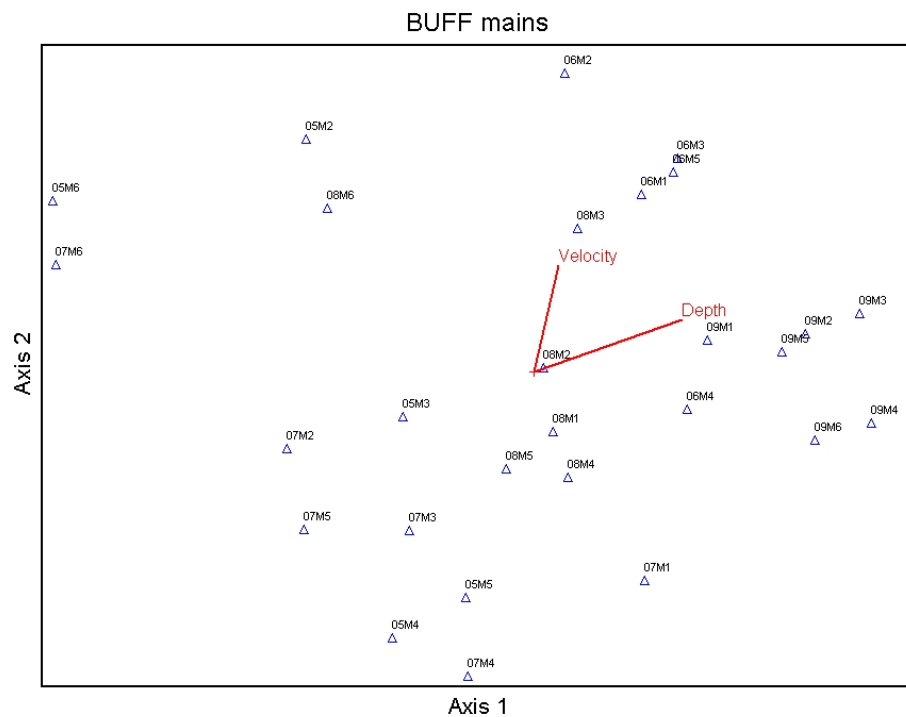


Figure F-4. BUFF mainstems NMS ordination joint plots, with correlation vectors overlaid onto ordination space. Each point represents a site; the first two numbers indicate the year sampled (e.g., “07” = 2007), and the following combination of letters and numbers represent the site designation. Each vector is directional and proportional in length to its correlation with each of the NMS axes.

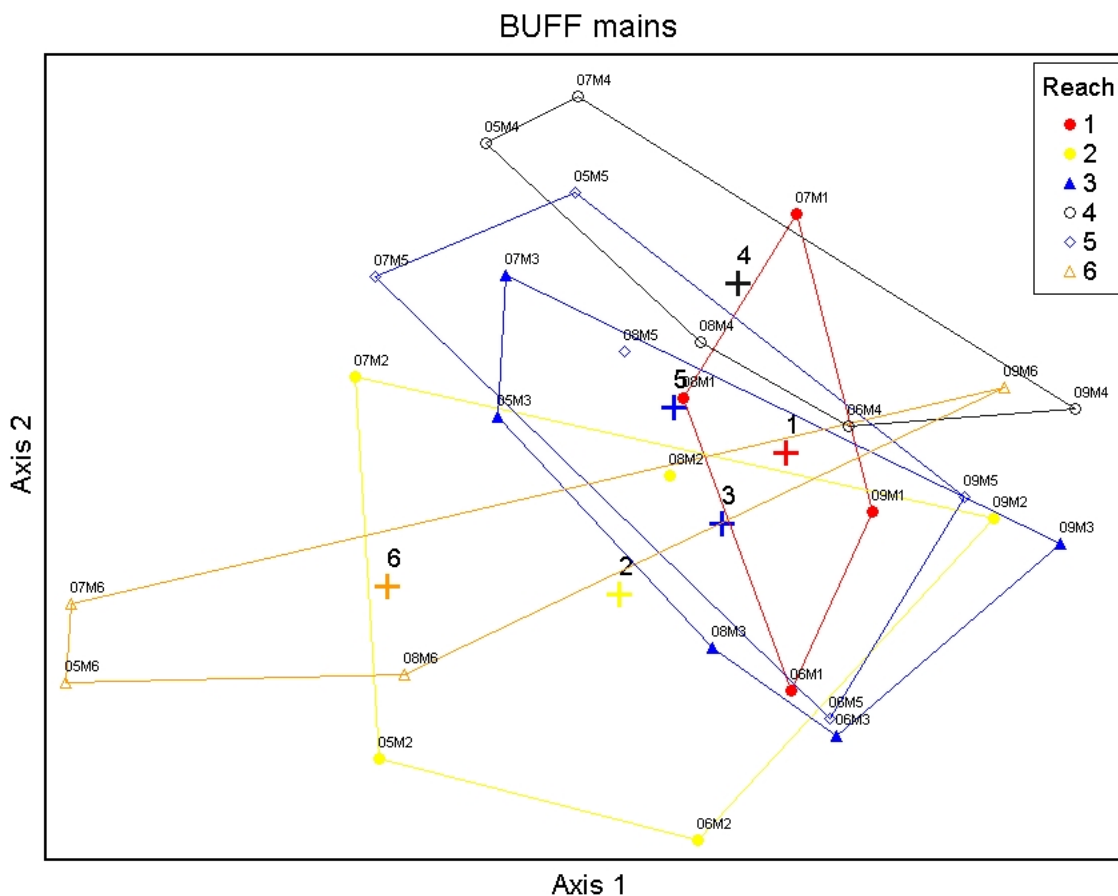


Figure F-5. BUFF mainstems NMS ordination convex hull diagrams by site. Each point represents a site; the first two numbers indicate the year sampled (e.g., “07” = 2007), and the following combination of letters and numbers represent the site designation. Outlines (convex hulls) of the ordination space occupied by each site in all years are shown, along with the average position in space for the members of the group (centroids) marked as an “+”.

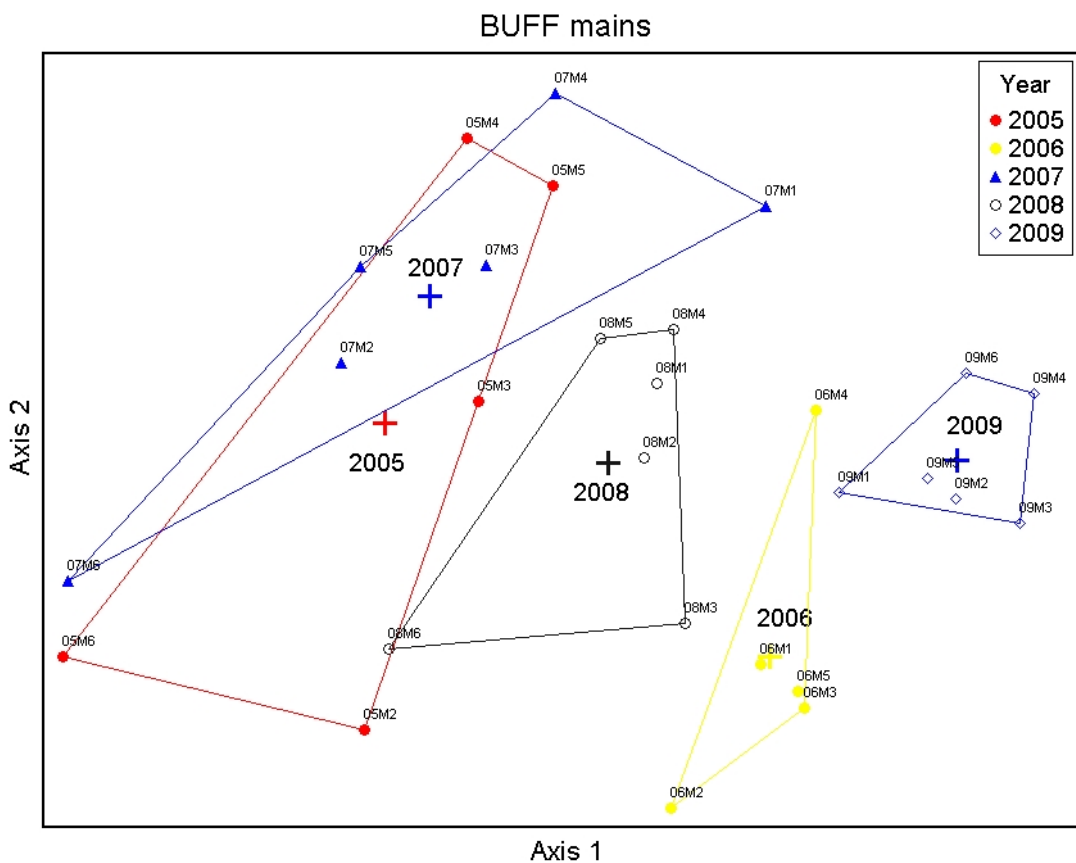


Figure F-6. BUFF mainstems NMS ordination convex hull diagrams by year. Each point represents a site; the first two numbers indicate the year sampled (e.g., “07” = 2007), and the following combination of letters and numbers represent the site designation. Outlines (convex hulls) of the ordination space occupied by all sites in each year are shown, along with the average position in space for the members of the group (centroids) marked as an “+”.

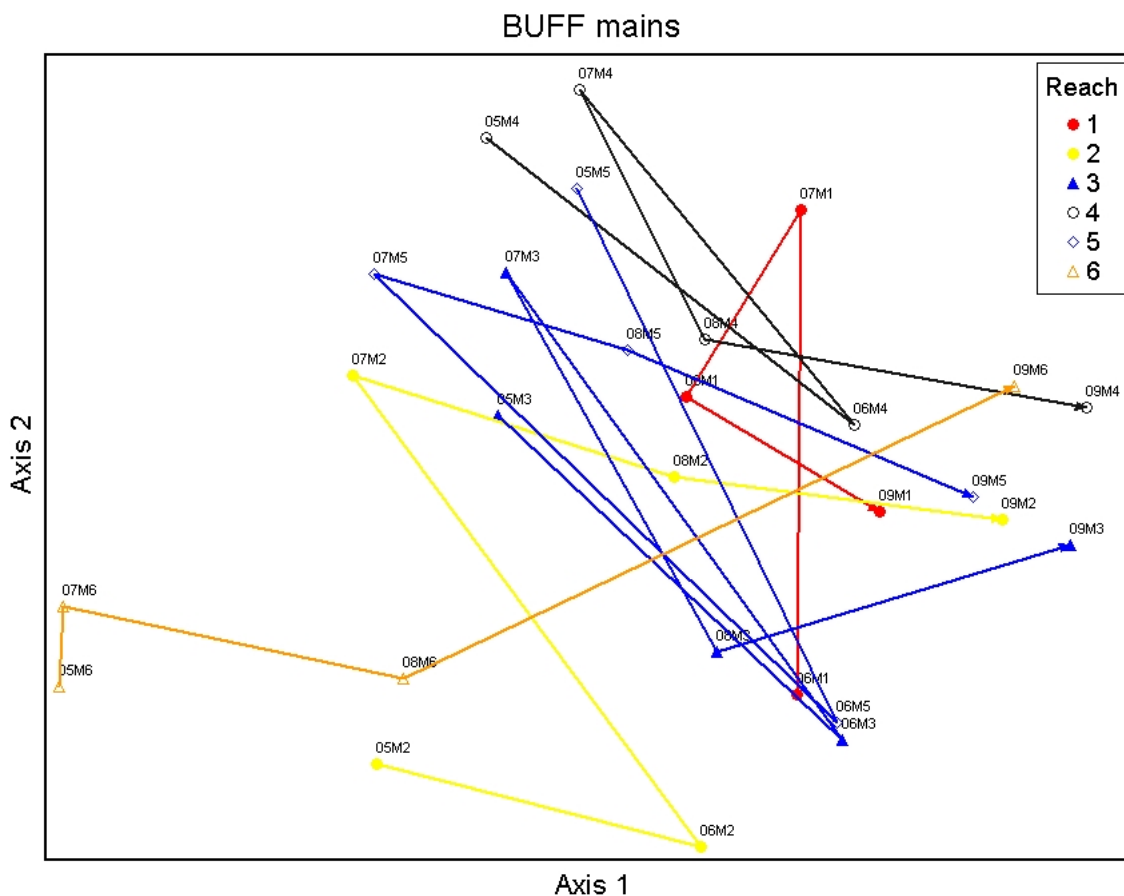


Figure F-7. Successional vectors for BUFF mainstems. Each point represents a site; the first two numbers indicate the year sampled (e.g., “07” = 2007), and the following combination of letters and numbers represent the site designation. Arrows indicate direction of change in relative position in ordination space over time for each site.

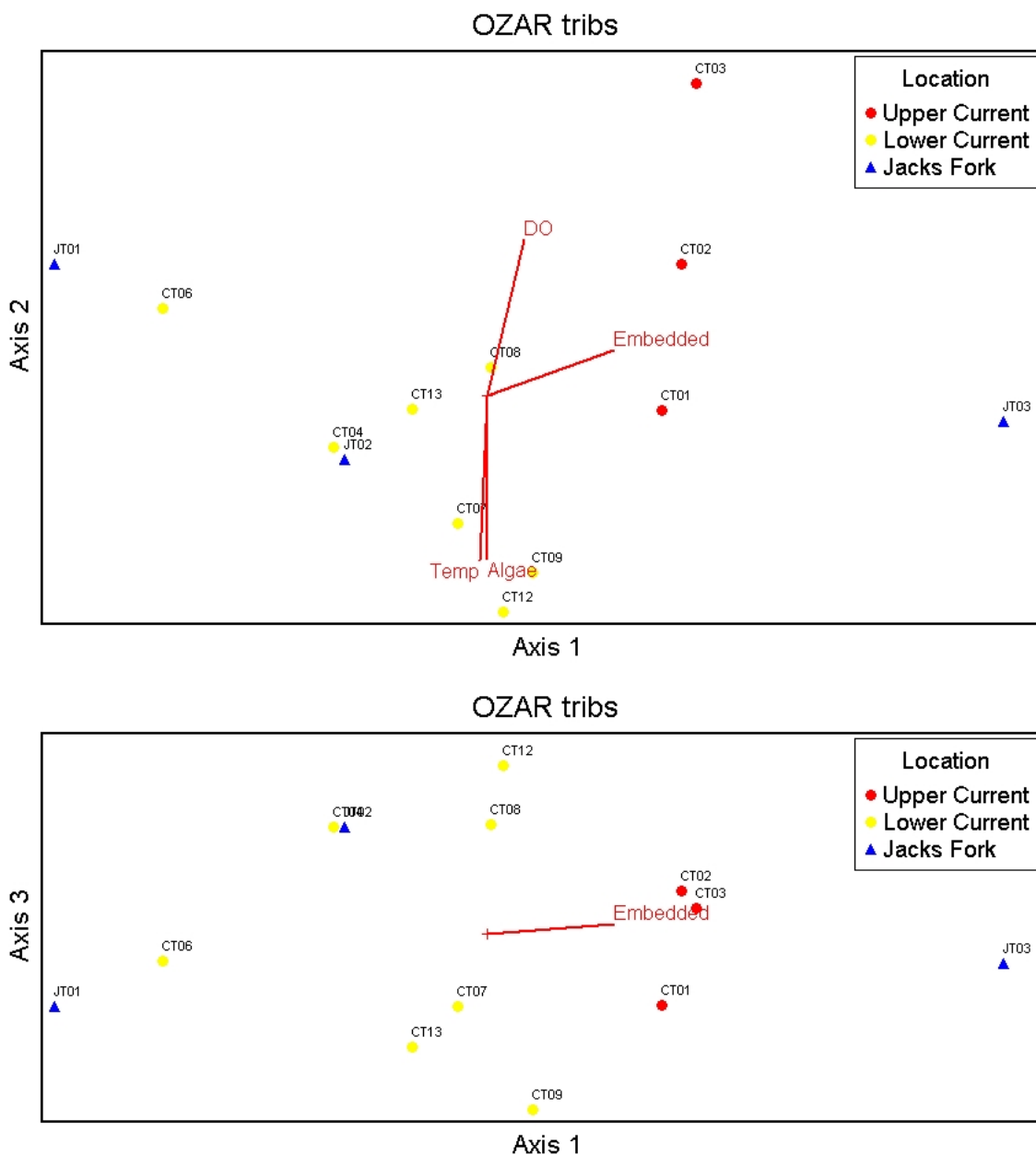


Figure F-8. OZAR tributaries NMS ordination joint plots, with correlation vectors overlaid onto ordination space. Each point represents a tributary. Each vector is directional and proportional in length to its correlation with each of the NMS axes.

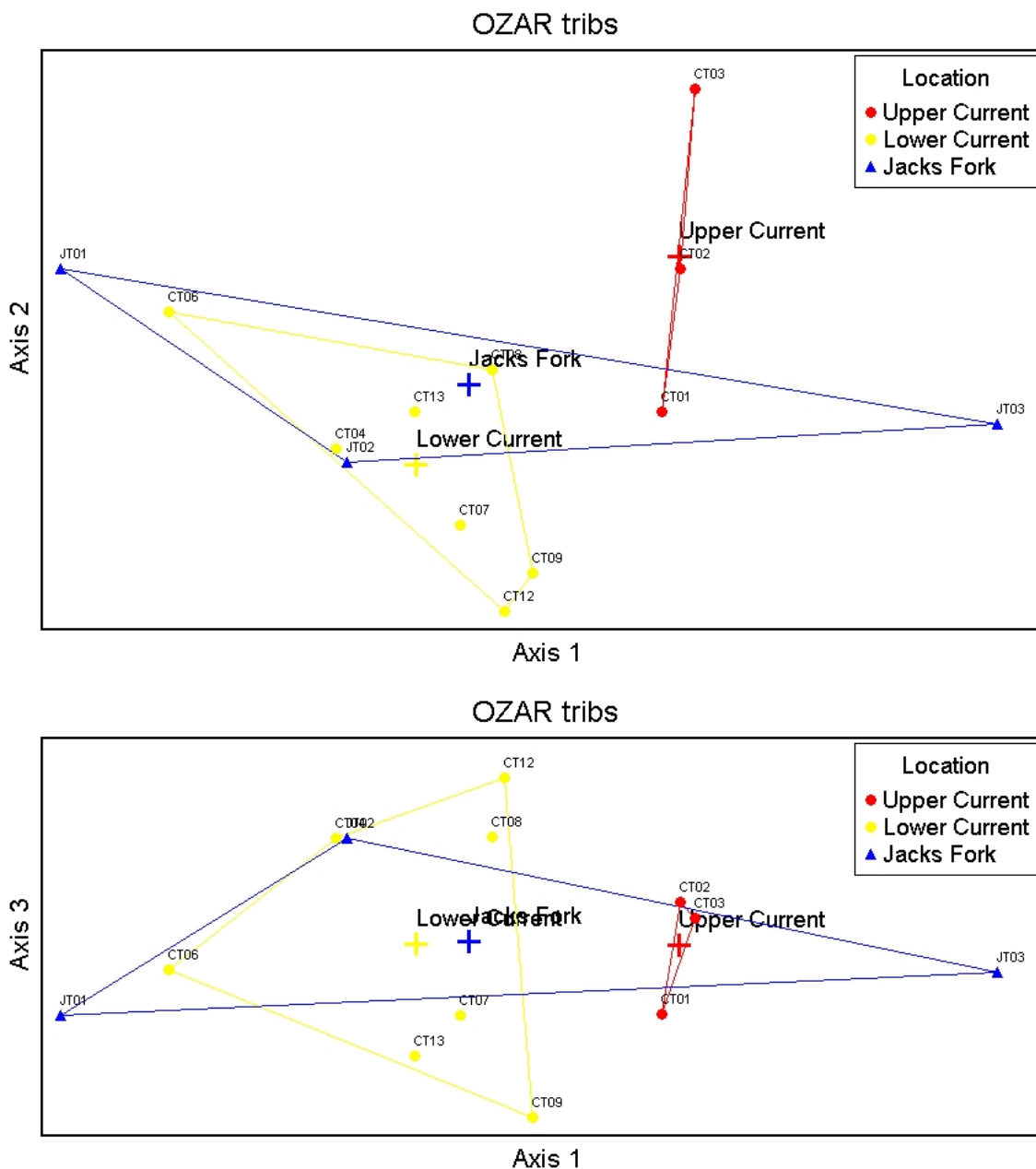


Figure F-9. OZAR tributaries NMS ordination convex hull diagrams by site. Each point represents a tributary. Outlines (convex hulls) of the ordination space occupied by each group of sites are shown, along with the average position in space for the members of the group (centroids) marked as a "+".

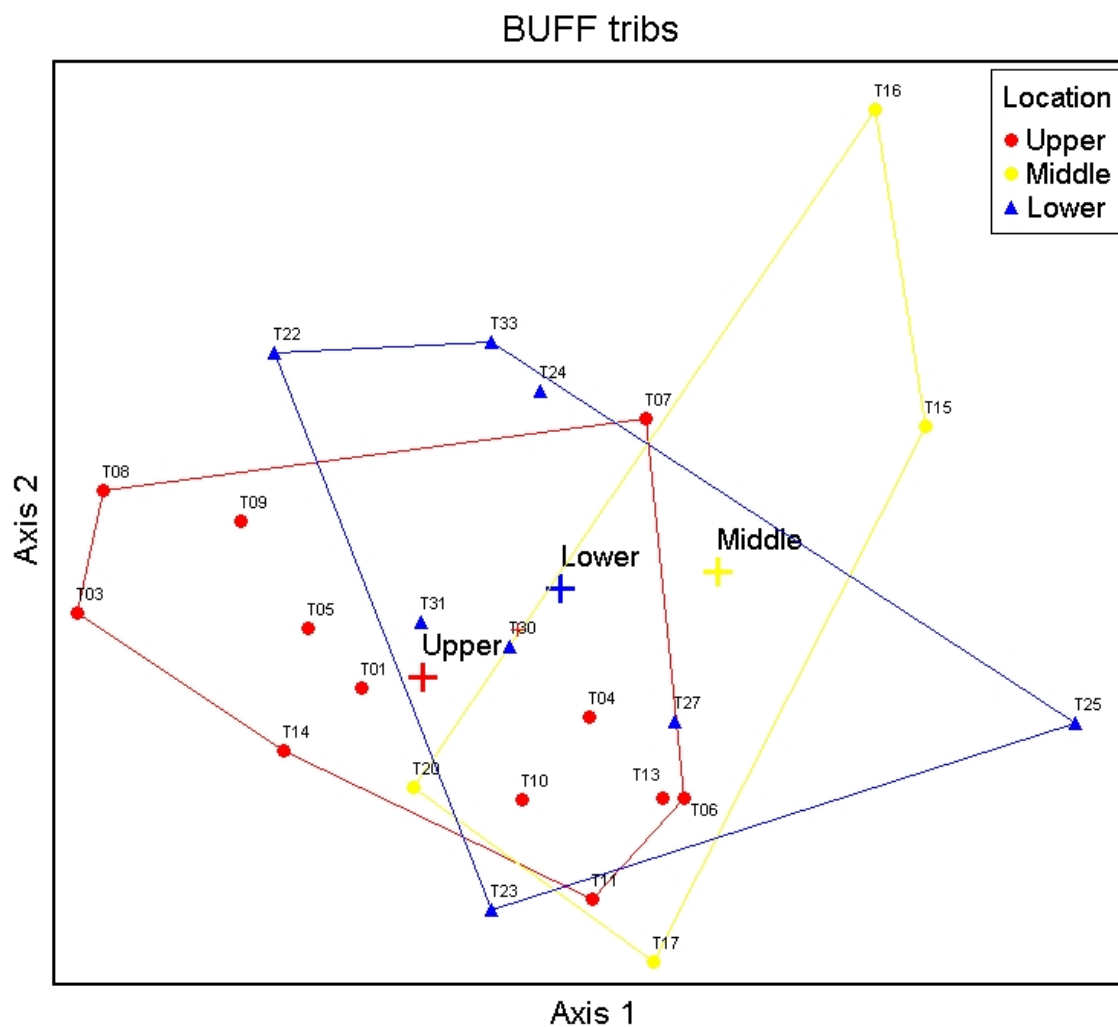


Figure F-10. BUFF tributaries NMS ordination convex hull diagrams by site. Each point represents a tributary. Outlines (convex hulls) of the ordination space occupied by each group of sites are shown, along with the average position in space for the members of the group (centroids) marked as an "+".

References:

- Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143.
- Kruskal, J. B. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika* 29: 1-27.
- McCune, B. and J. B. Grace. 2002. *Analysis of Ecological Communities*. MjM Software Design, Gleneden Beach, OR.
- Peck, J. E. 2010. *Multivariate Analysis for Community Ecologists: Step-by-Step Using PC-ORD*. MjM Software Design, Gleneden Beach, OR.

Appendix G. Individual metrics comprising the BRICI index at BUFF mainstem monitoring sites.

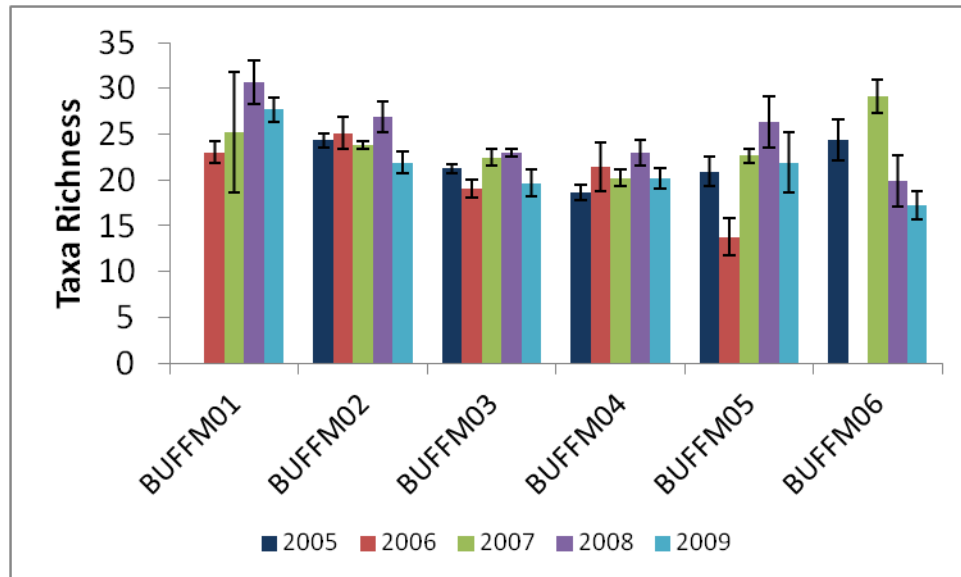


Figure G-1. Mean taxa richness and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

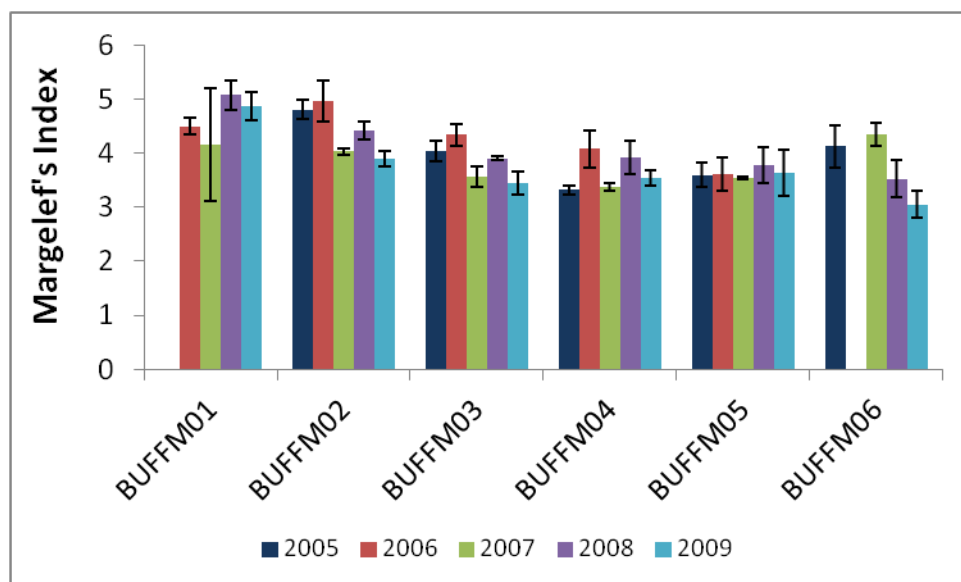


Figure G-2. Mean Margelefs Index and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

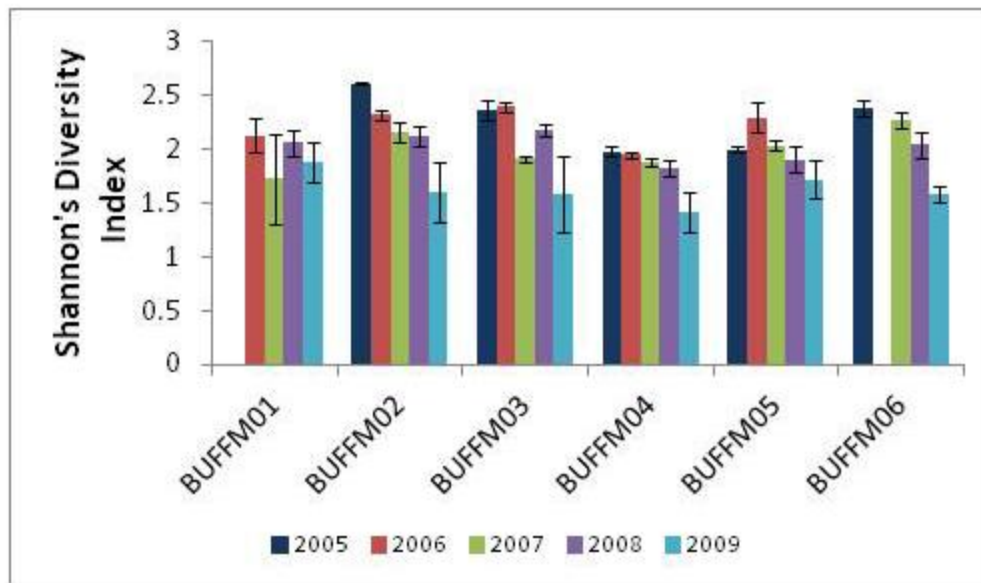


Figure G-3. Mean Shannon's Diversity Index and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

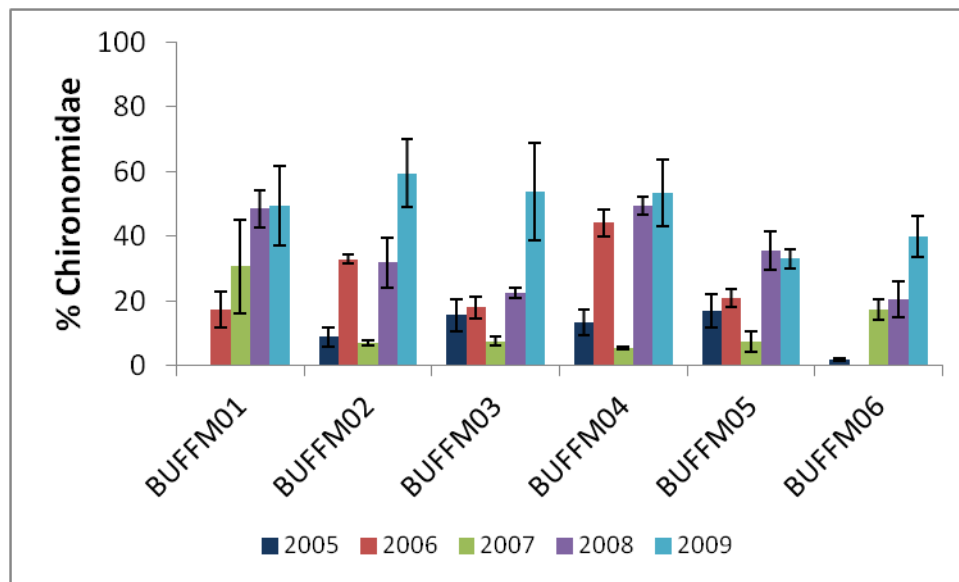


Figure G-4. Mean percent Chironomidae and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

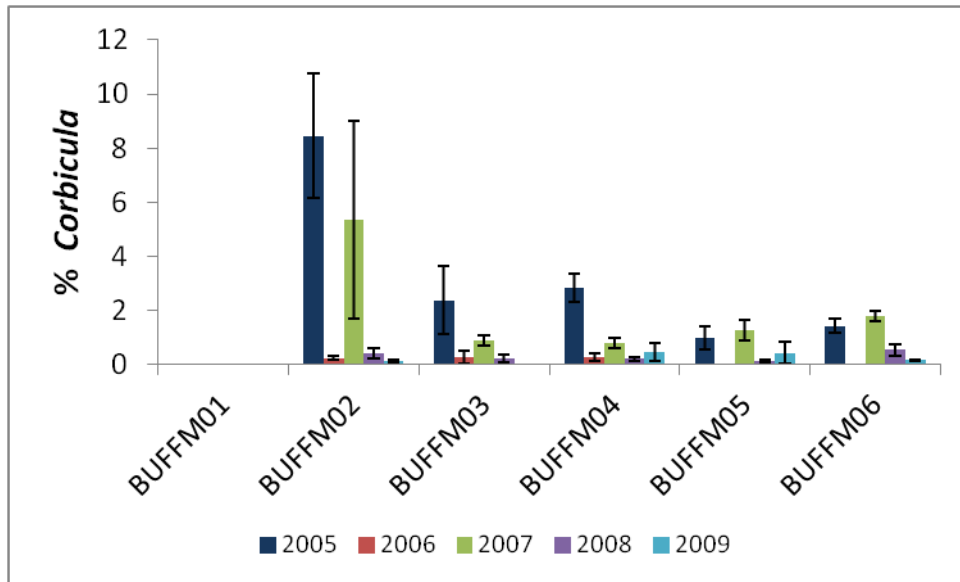


Figure G-5. Mean percent *Corbicula* and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

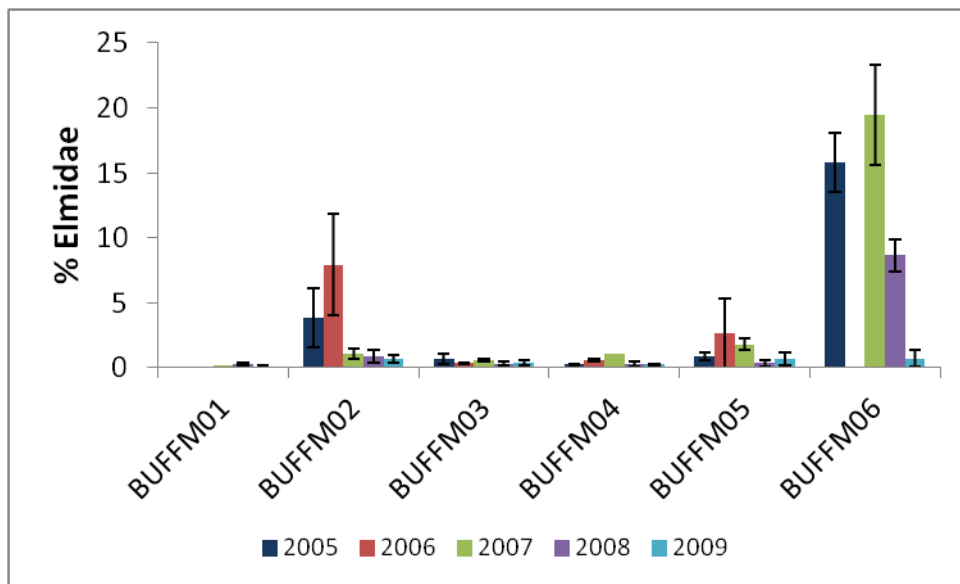


Figure G-6. Mean percent *Elmidæ* and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

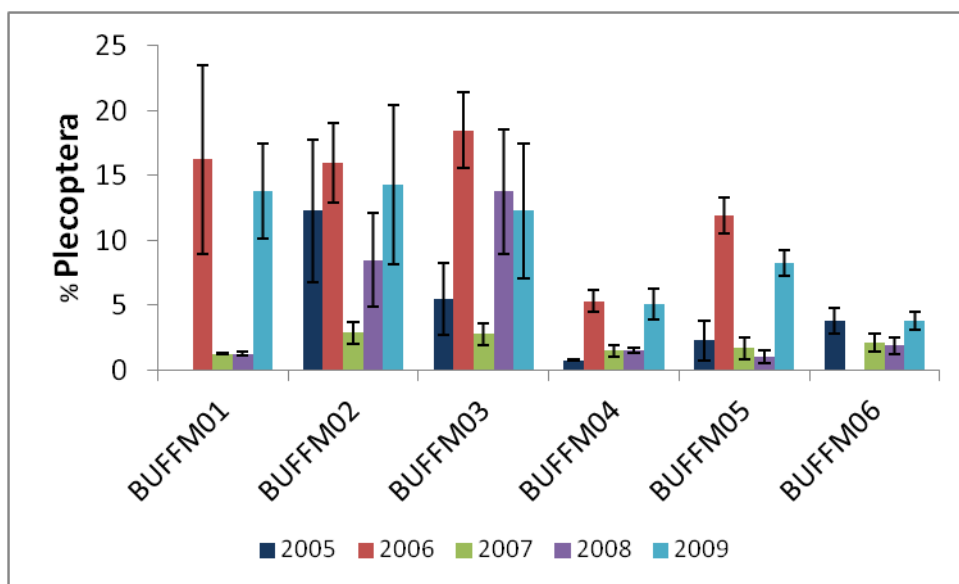


Figure G-7. Mean percent Plecoptera and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

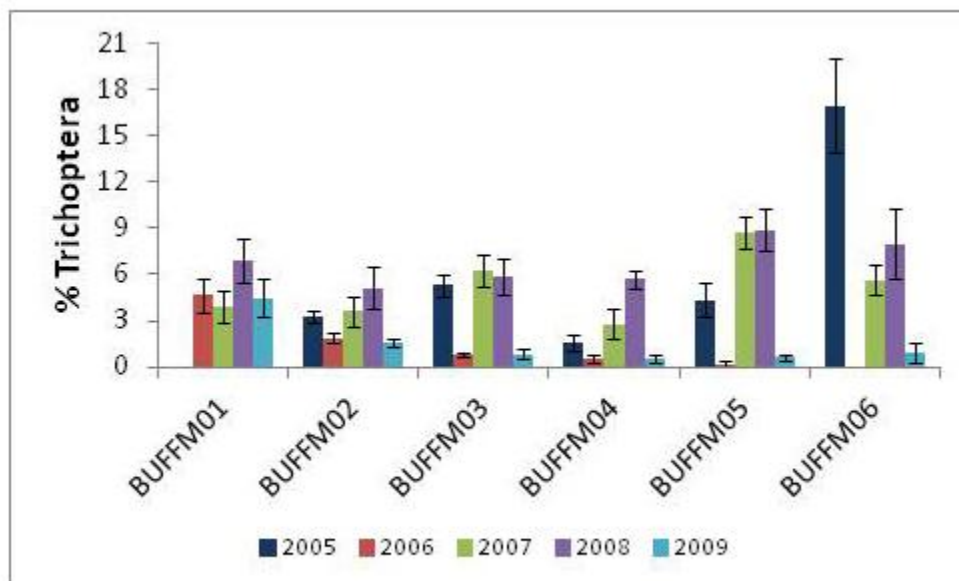


Figure G-8. Mean percent Trichoptera and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

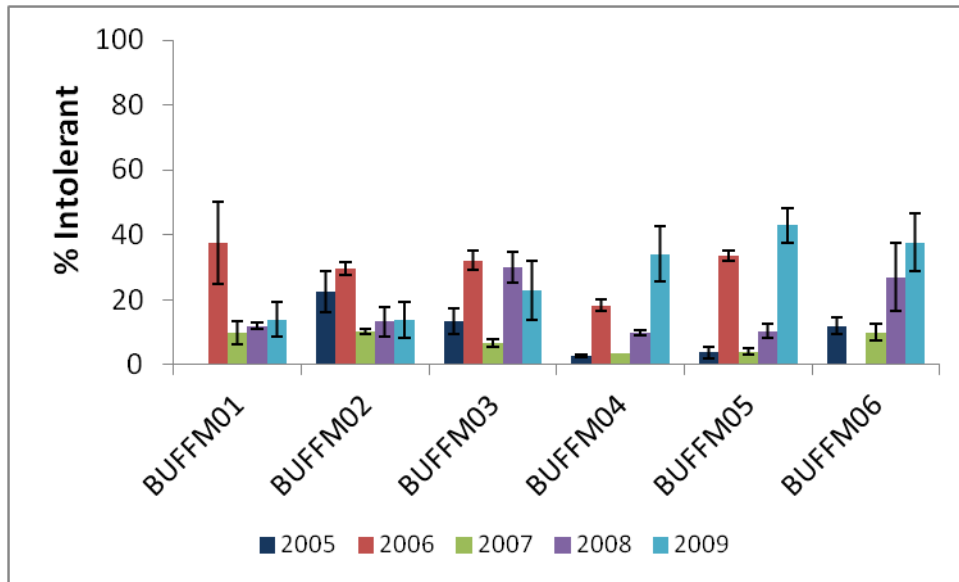


Figure G-9. Mean percent intolerant and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

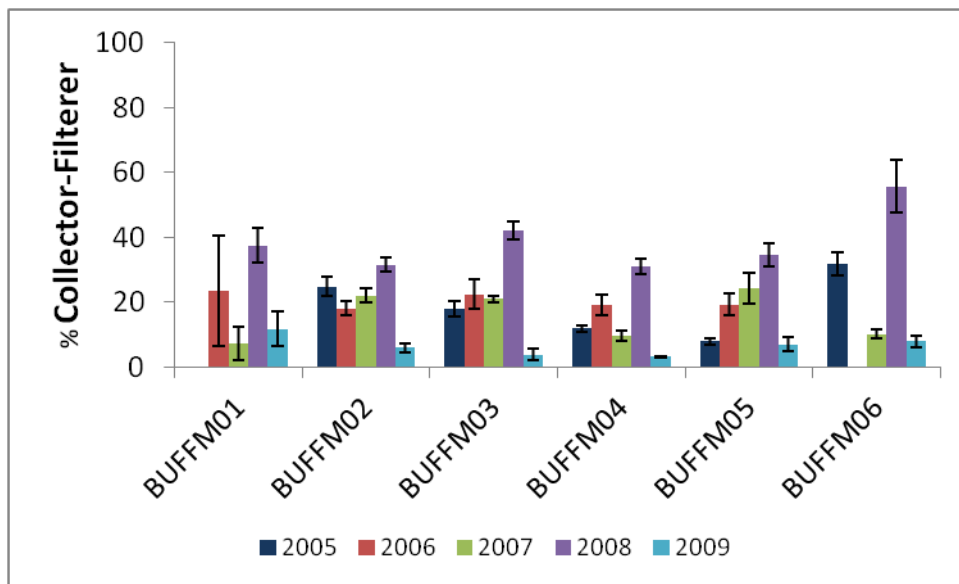


Figure G-10. Mean percent collector-filterer and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

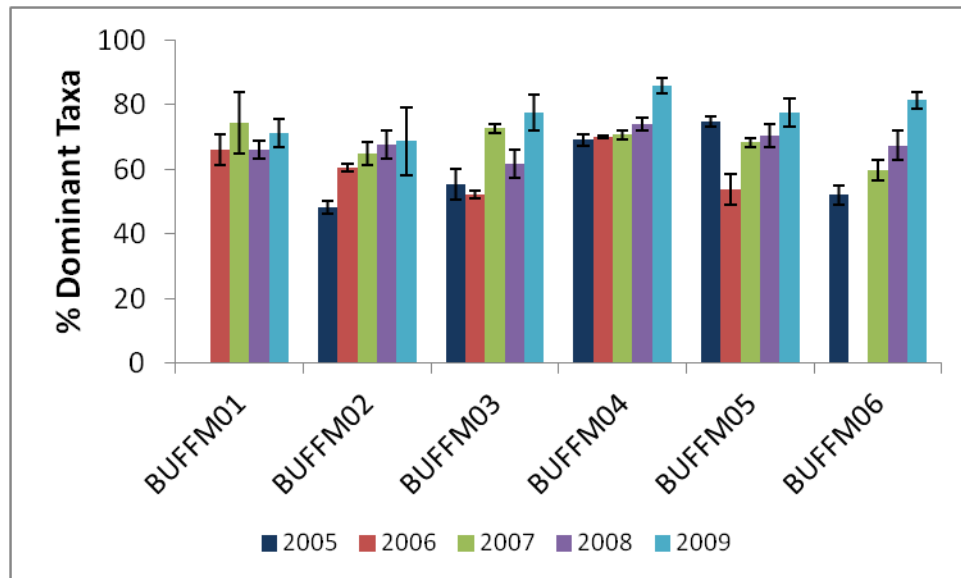


Figure G-11. Mean percent dominant taxa and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

Appendix H. Individual metrics comprising the SCI index at BUFF and OZAR mainstem monitoring sites.

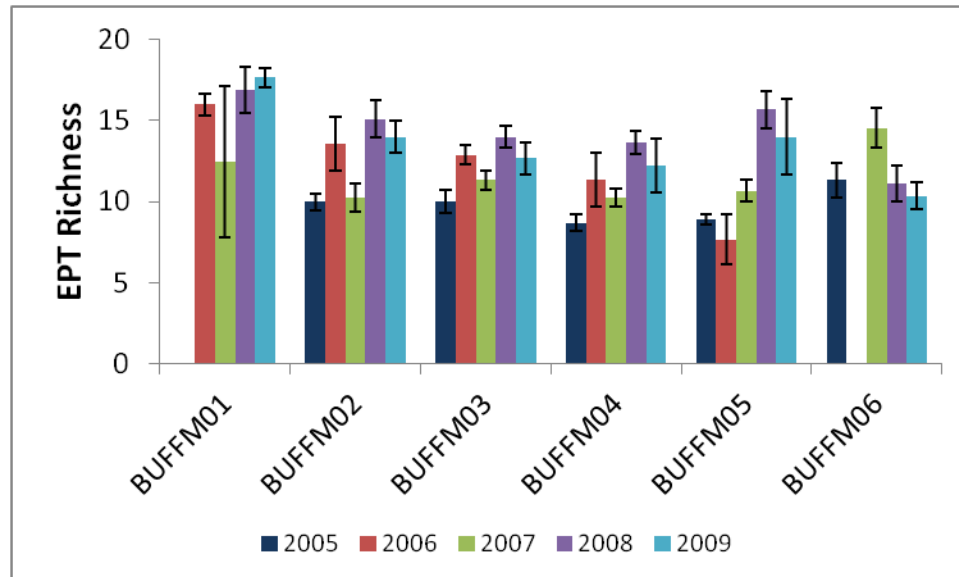


Figure H-1. Mean EPT richness and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

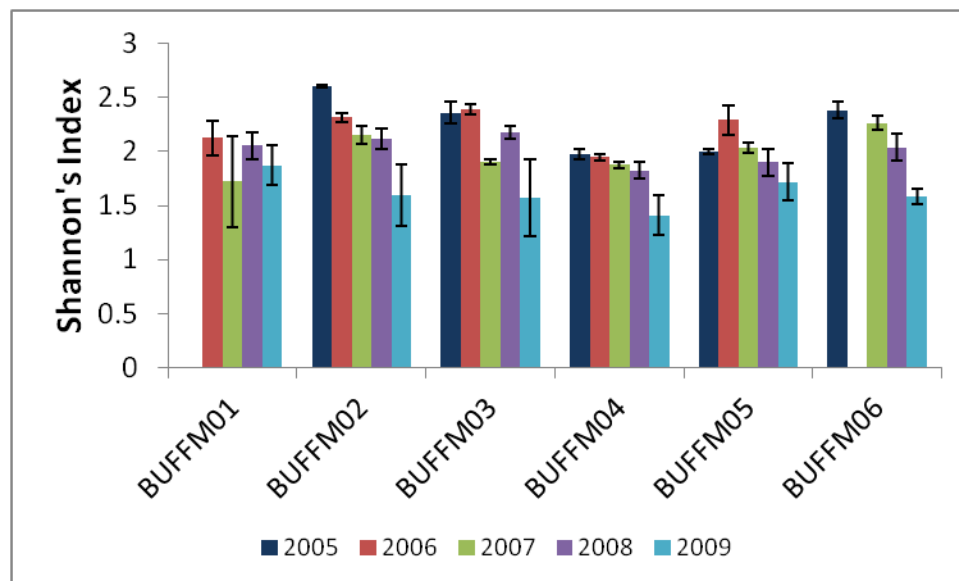


Figure H-2. Mean Shannon's Diversity Index and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

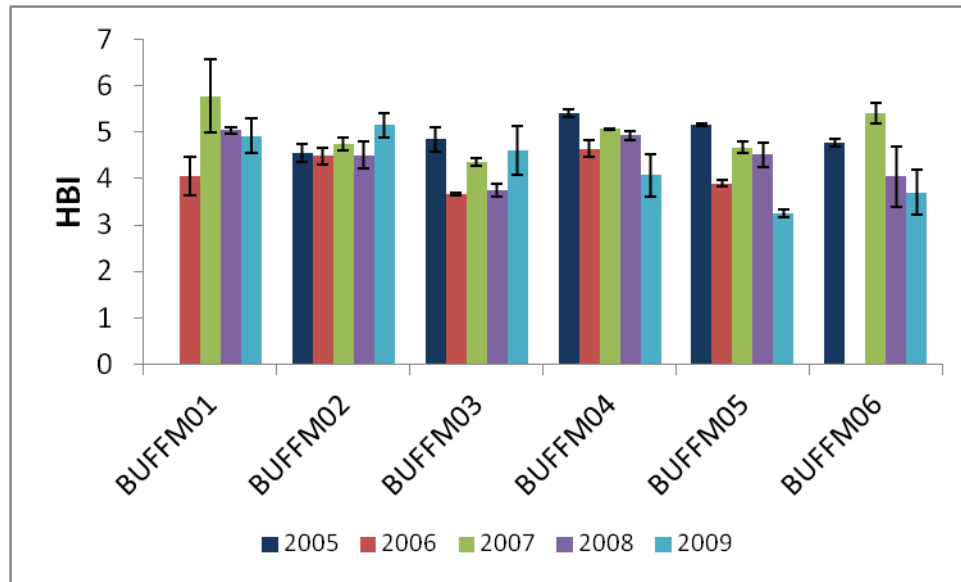


Figure H-3. Mean HBI and standard errors for Buffalo River mainstem sampling sites, 2005-2009.

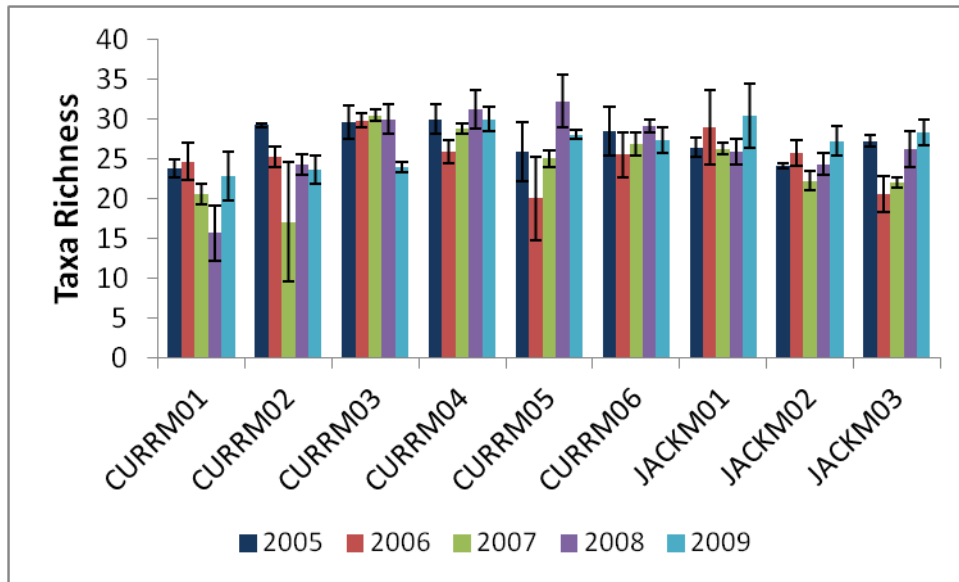


Figure H-4. Mean taxa richness and standard errors for Current River and Jacks Fork mainstem sampling sites, 2005-2009.

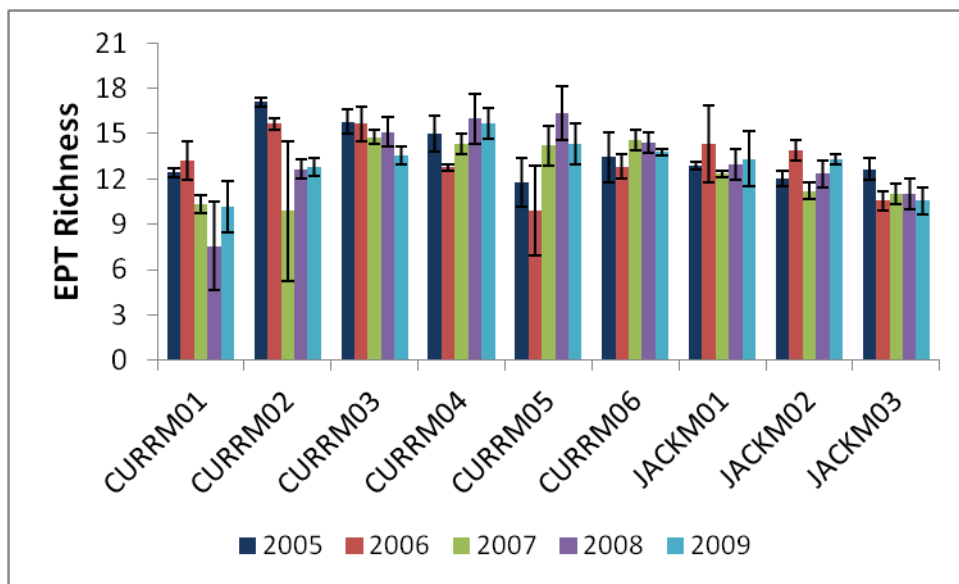


Figure H-5. Mean EPT richness and standard errors for Current River and Jacks Fork mainstem sampling sites, 2005-2009.

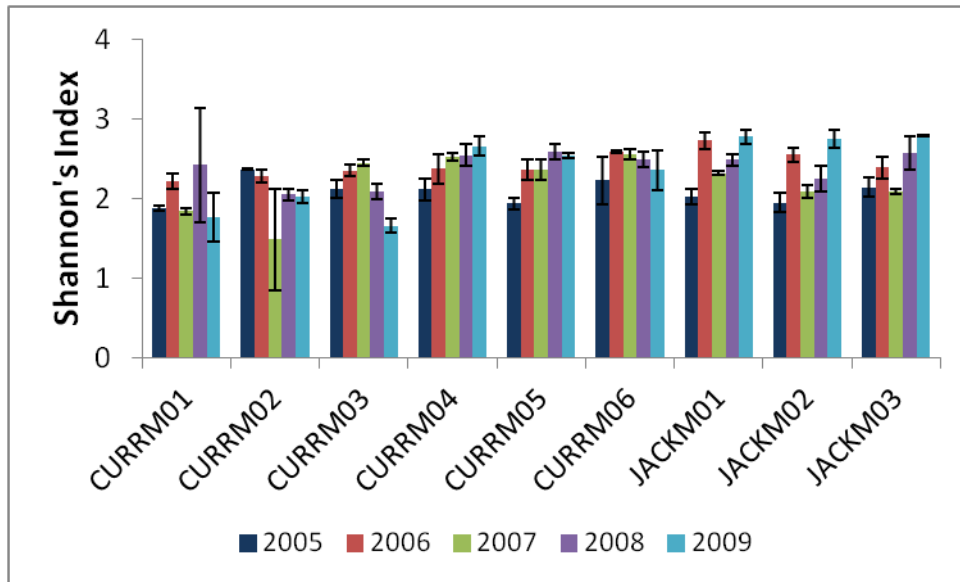


Figure H-6. Mean Shannon's Diversity Index and standard errors for Current River and Jacks Fork mainstem sampling sites, 2005-2009.

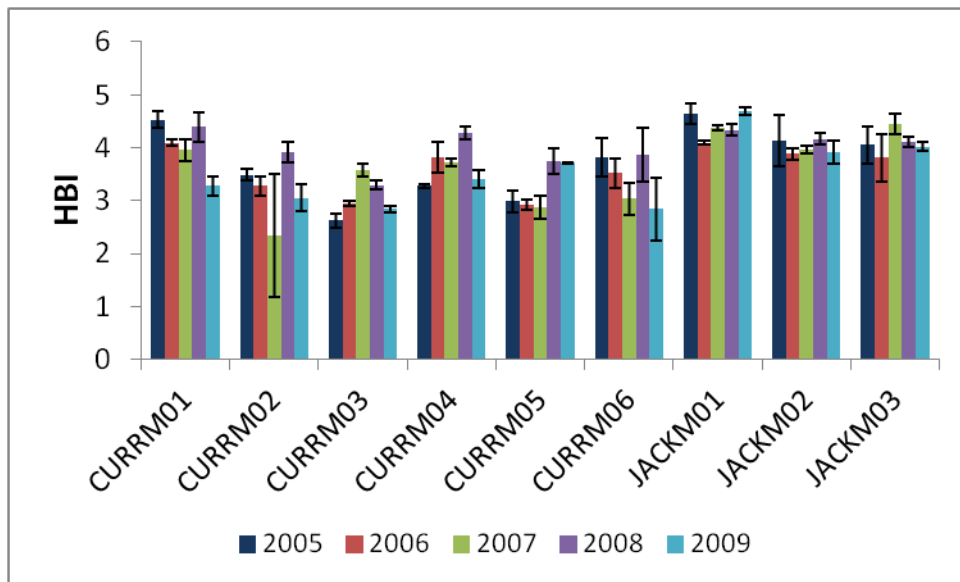


Figure H-7. Mean HBI and standard errors for Current River and Jacks Fork mainstem sampling sites, 2005-2009.

Appendix I. Full methodological details and results of NMS ordinations of fish communities.

Methodology

The methodology described in Appendix F for the invertebrates was also applied to the fish communities, with the following differences:

Prior to analyses, abundance data (numbers caught of each individual species) were log transformed, due to the high degree of variation in abundance among species. Because the data set contained zeros, a “1” was added to all abundances before applying the transformation (e.g., $\log[x+1]$). Habitat variables were measured in different units and on scales of different magnitudes, and thus a general relativization by columns was performed. The value of p chosen for the relativization was 1, which is appropriate for the Sorensen distance measure (McCune and Grace 2002). Because habitat parameters were not collected during fish sampling at OZAR mainstem reaches in 2005, only fish community data from 2006-2009 were used in the NMS analysis for OZAR mainstem sites.

Preliminary NMS runs for the BUFF mainstem sites in autopilot mode indicated that the most upstream site was very different from the five remaining sites. The most upstream site is located in the Boston Mountains physiographic province with differing physical habitat (gradient, substrate size) and water quality (specific conductance) features than the other five sites which are located in the Salem or Springfield Plateaus. This was a relatively trivial and expected result, and thus the most upstream site was deleted and subsequent analyses focused on the five remaining mainstem sites.

Correlation coefficients of the 27 habitat variables with all ordination axes were calculated for each data set, and habitat vectors were overlaid on the ordination graphs, producing joint plots.

Results

A cumulative total of 50 species were collected from the five BUFF mainstem sites and 62 species from the nine OZAR mainstem sites. Within tributaries, 45 species were collected from the 30 BUFF tributaries and 40 species from the 14 OZAR tributaries (See Appendix J for a list of all fish species).

The NMS analysis of all four data sets resulted in stress scores of <15 . The OZAR tributaries had the lowest stress score of 5.22 (Table I-1), which ranks as a good to excellent ordination with little risk of drawing false inferences (Kruskal 1964, Clarke 1993; multiplying Clarke's rule by 100 to make it comparable with Kruskal and PC-ORD). Stress scores for the three other data sets ranged from 11.17 to 14.81. These scores are in the good to fair range (Kruskal 1964, Clarke 1993). Instabilities for all data sets were <0.00000 (Table I-1). The cumulative r^2 for the NMS of each data set ranged from 0.772 to 0.954.

For BUFF mainstems, a 3-dimensional solution was selected (Table I-1). Although there was a large degree of overlap among sites, several sites did reveal separation (Figure I-1). When the ordination was plotted by year (all 5 mainstem sites sampled in 2006, 2007, etc.), again there was

overlap, but also some clear separation among some years (Figure I-2). Six habitat variables had correlations that exceeded the threshold of $r = 0.5$ (Table I-2, Figure I-3). These habitat variables described physio-chemical parameters, instream habitat, fish cover, bank characteristics, and site size at BUFF mainstems.

For OZAR mainstems, a 2-dimensional solution was selected (Table I-1). OZAR mainstem sites separated by location in the watershed. The three Jacks Fork sites and the three Upper Current sites were all well separated from other sites in ordination space and changed relatively little over the four years of sampling, resulting in clusters of points defined by the same site in different years (Figure I-4). The three Lower Current sites clustered closely together and over time revealed no clear separation among these three sites. Four habitat variables had correlations that exceeded the threshold (Table I-2, Figure I-5). These variables described physio-chemical and fish cover habitat and site size. For the two mainstem datasets, only watershed area was selected for both OZAR and BUFF

For both BUFF and OZAR tributaries, a 3-dimensional NMS solution was selected (Table I-1). BUFF tributaries did not cluster based on location in the watershed (tributaries in the Upper, Middle, or Lower Buffalo) or year sampled, but did separate by size (i.e. watershed area) (Figure I-6). At BUFF, five habitat variables that described physio-chemical and instream habitat and site size had correlations that exceeded the threshold (Table I-3, Figure I-7). At OZAR, eleven habitat variables had correlations exceeding the threshold (Table I-3, Figure I-8).

Table I-1. Results of nonmetric multidimensional scaling analyses (NMS) showing number of samples (sites in all years), total number of species collected (across all years sampled), number of dimensions in final NMS, stress score, instability, and cumulative coefficient of determination for all axes retained in the final NMS.

Dataset	No. of Samples	No. of Species	Dimensions	Stress	Instability	Iterations	r^2 (cumulative)		
							Axis1	Axis 2	Axis 3
BUFF mains	25 ²	50	3D	14.81	0.00000	88	0.477	0.612	0.772
OZAR mains	36 ¹	62	2D	13.96	0.00000	45	0.680	0.878	N/A
BUFF tributaries	30	45	3D	11.17	0.00000	108	0.576	0.795	0.904
OZAR tributaries	14	40	3D	5.22	0.00000	62	0.629	0.868	0.954

¹ Includes nine sites sampled on an annual basis for four years.

² Includes five sites sampled on an annual basis for five years.

Table I-2. Pearson correlation coefficients for 27 habitat variables against NMS ordination axes for BUFF and OZAR mainstems. For BUFF (n = 25), *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.396 and 0.505, respectively. For OZAR (n = 36) *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.329 and 0.424, respectively.

Habitat variable	BUFF			OZAR	
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2
Physio-chemical					
Water temperature	0.335	0.649	0.135	0.374	0.069
pH	-0.101	-0.150	0.088	0.169	0.029
Specific conductance	-0.091	-0.399	-0.056	0.446	0.097
Dissolved oxygen	0.069	-0.352	-0.278	-0.546	0.083
Instream Habitat					
Substrate	-0.143	0.056	-0.247	0.461	0.007
Embeddedness	0.288	0.132	0.384	-0.409	0.023
Canopy cover	-0.017	-0.731	0.051	-0.261	-0.154
Fish Cover					
Filamentous algae	0.354	0.180	0.065	-0.096	0.220
Hydrophytes/mosses	0.036	-0.316	-0.092	-0.321	0.411
Boulders	-0.413	-0.224	0.265	0.408	-0.116
Small woody debris	0.462	0.251	0.100	-0.363	-0.014
Large woody debris	0.031	-0.487	0.409	-0.544	0.370
Trees/roots	-0.181	-0.646	0.042	0.155	0.178
Overhanging vegetation	-0.166	0.165	-0.162	0.064	-0.274
Undercut bank	-0.252	-0.373	-0.080	-0.035	-0.182
Bluff within 5m of water	0.010	-0.009	0.119	0.159	-0.309
Bank					
Bank angle	0.570	-0.066	0.189	-0.188	0.062
Bank vegetation cover	-0.070	-0.267	0.558	0.016	0.155
Bank height	0.298	-0.313	-0.007	0.175	0.206
Bank substrate	-0.427	0.058	-0.318	-0.196	0.133
Bank cover –large trees	0.112	0.099	-0.205	-0.323	0.236
Bank cover –small trees, shrubs	-0.195	-0.105	-0.206	0.200	-0.072
Bank cover – grasses, forbs	-0.018	-0.211	-0.155	-0.224	0.059
Bank cover – bare rock/sediment	-0.286	-0.415	0.019	-0.118	-0.103
Size					
Watershed area	-0.040	0.573	-0.209	-0.353	0.765
Width	0.039	0.362	-0.248	-0.365	0.588
Depth	-0.099	-0.450	-0.049	-0.236	0.196

Table I-3. Pearson correlation coefficients for 27 habitat variables against NMS ordination axes for BUFF and OZAR tributaries. For BUFF (n = 30), *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.361 and 0.462, respectively. For OZAR (n = 14) *P*-values (2-tailed) of 0.05 and 0.01 are associated with absolute correlations of 0.532 and 0.661, respectively.

Habitat variable	BUFF			OZAR		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Physio-chemical						
Water temperature	-0.645	-0.103	-0.274	0.032	0.319	-0.426
pH	-0.346	0.164	0.291	0.074	0.063	-0.147
Specific conductance	0.045	0.128	-0.150	0.257	-0.047	-0.311
Dissolved oxygen	0.238	0.141	-0.039	0.148	-0.029	0.209
Instream Habitat						
Substrate	0.152	-0.218	0.081	0.102	-0.454	-0.142
Embeddedness	-0.159	0.081	-0.067	0.322	0.060	0.067
Canopy cover	0.685	0.072	0.081	-0.012	-0.545	-0.036
Fish Cover						
Filamentous algae	-0.240	-0.157	-0.143	-0.033	0.553	-0.327
Hydrophytes/mosses	0.129	0.196	-0.207	0.097	-0.570	0.215
Boulders	0.150	0.070	-0.104	0.100	-0.489	0.089
Small woody debris	-0.121	0.114	-0.399	0.073	-0.582	0.194
Large woody debris	-0.215	0.325	0.070	-0.089	0.350	0.048
Trees/roots	-0.016	0.100	0.151	-0.582	-0.304	0.094
Overhanging vegetation	-0.255	0.086	0.155	-0.108	-0.213	0.609
Undercut bank	-0.054	0.409	-0.213	-0.058	-0.120	0.666
Bluff within 5m of water	-0.151	-0.051	-0.012	-0.133	0.371	-0.008
Bank						
Bank angle	0.093	0.275	-0.339	0.360	0.399	-0.558
Bank vegetation cover	0.006	0.381	0.145	0.189	-0.038	-0.224
Bank height	0.031	0.336	-0.357	0.472	0.329	-0.317
Bank substrate	-0.332	0.088	0.127	-0.428	0.221	0.075
Bank cover –large trees	-0.061	-0.365	0.205	-0.139	-0.080	-0.158
Bank cover –small trees, shrubs	0.067	-0.109	-0.249	-0.142	0.063	0.127
Bank cover – grasses, forbs	0.205	0.271	-0.021	0.437	-0.075	0.087
Bank cover – bare rock/sediment	-0.021	0.186	0.244	0.197	-0.010	-0.147
Size						
Watershed area	-0.646	-0.038	-0.082	0.551	0.387	-0.112
Width	-0.659	0.117	-0.056	0.646	0.141	0.108
Depth	-0.598	-0.033	0.025	0.609	0.027	0.459

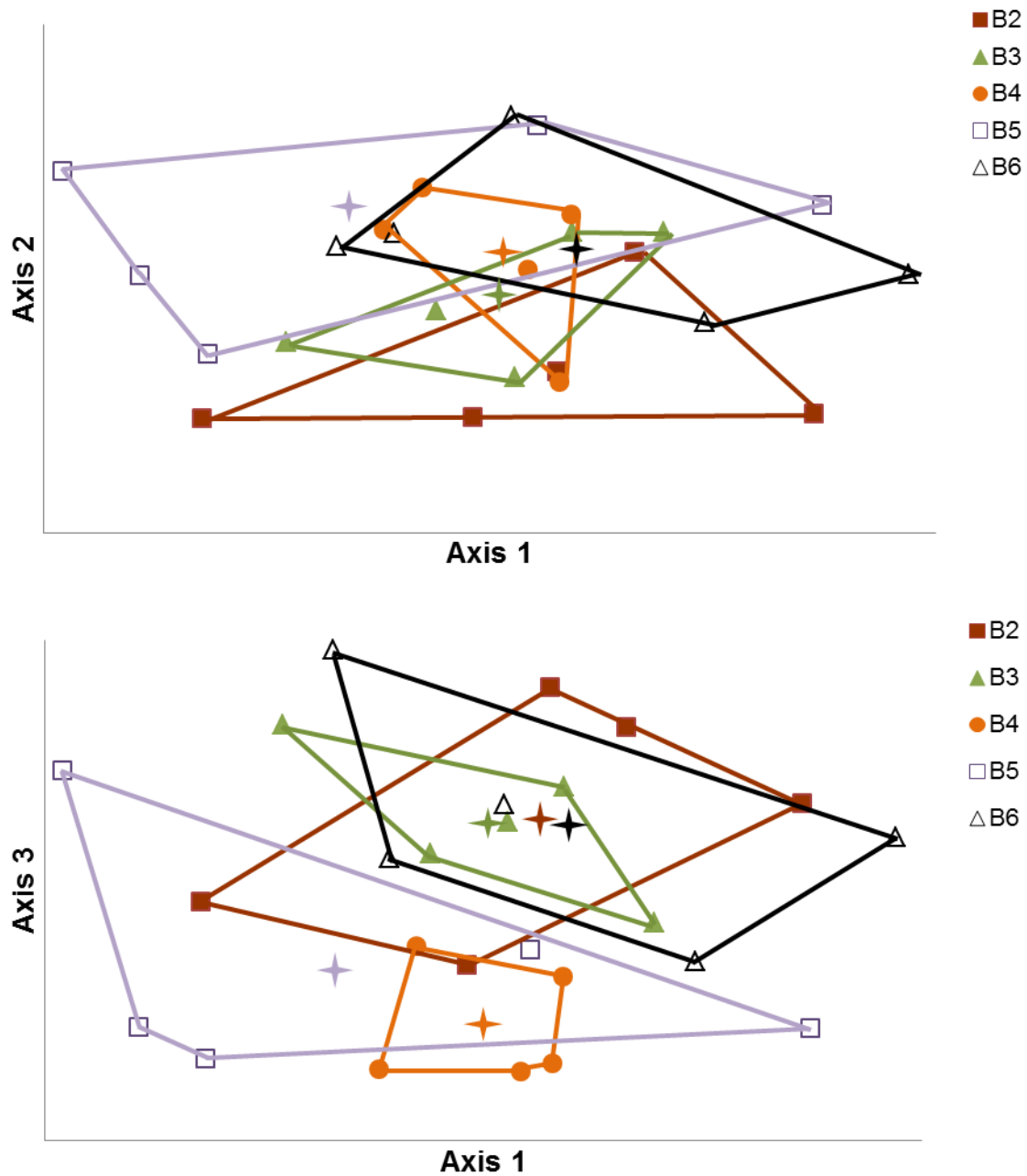


Figure I-1. Convex hull diagrams for BUFF mainstems. Points are color coded by site. Each point represents a year in which that site was sampled (5 years or points for each site). Each star represents the centroid for all years sampled at that site.

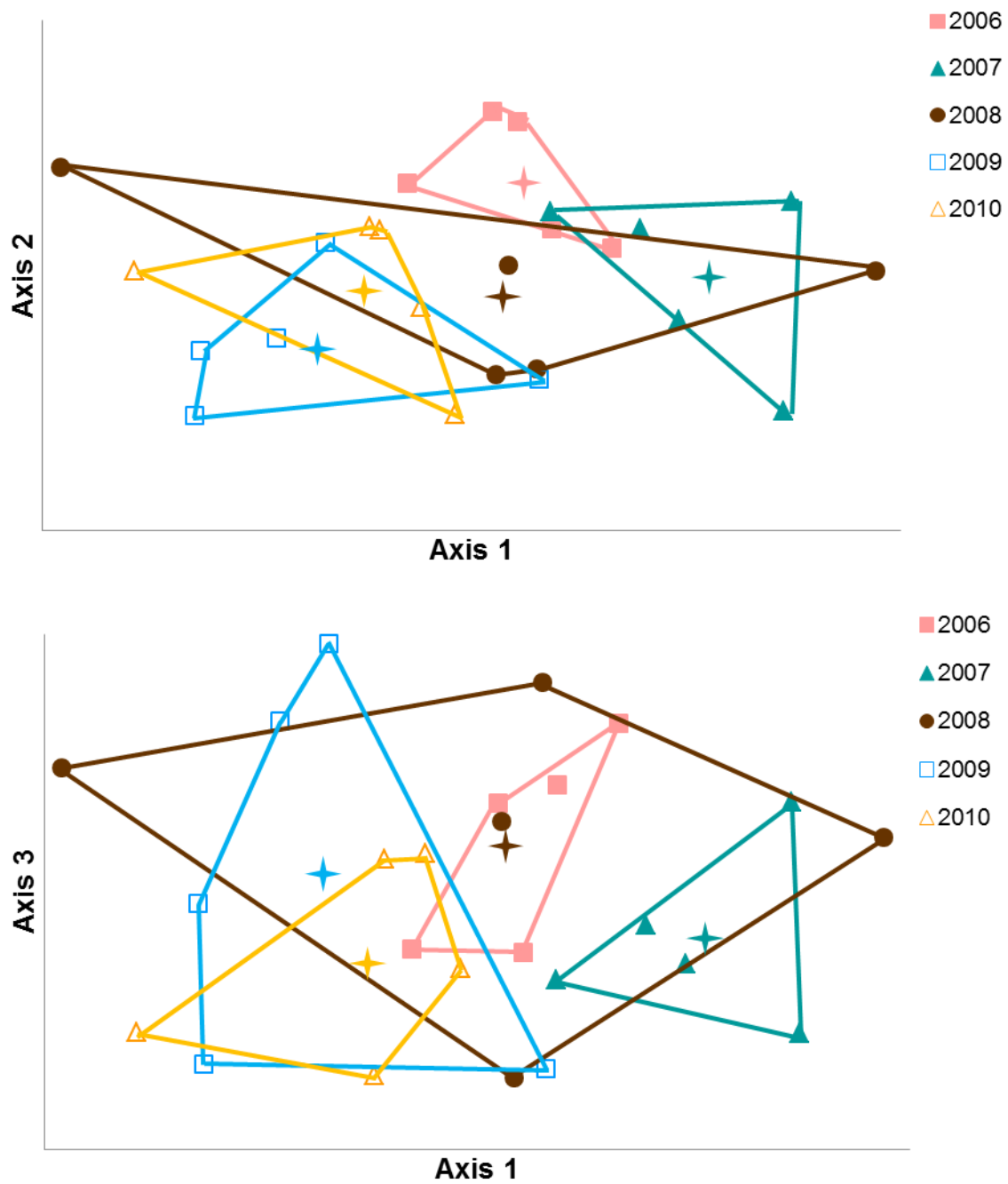


Figure I-2. Convex hull diagrams for BUFF mainstems. Points are color coded by year. Each point represents a site (5 sites sampled each year) for each year of monitoring. Each star represents the centroid for all sites sample in that year.

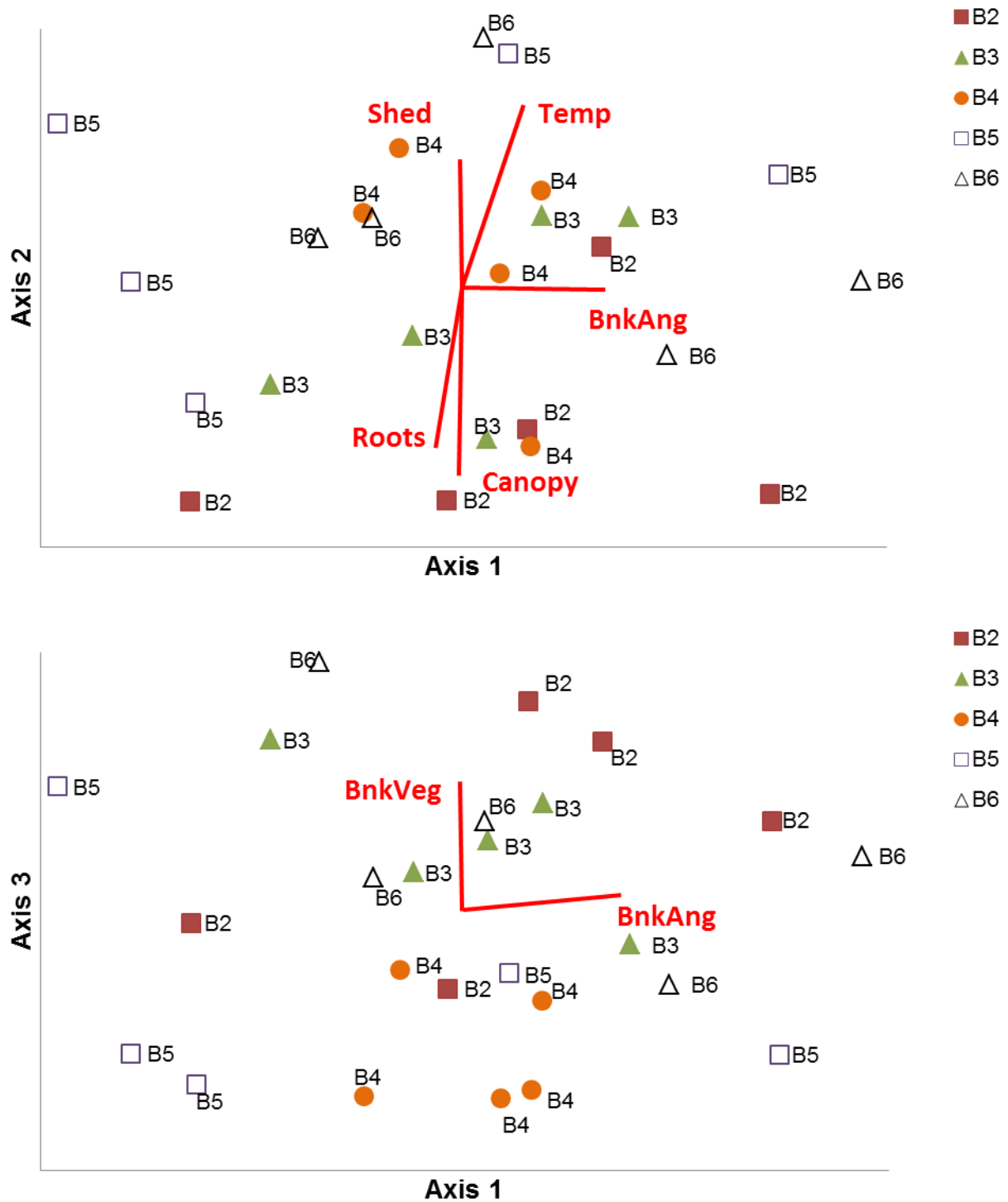


Figure I-3. BUFF mainstems NMS ordination joint plot with correlation vectors overlaid onto ordination space. Points are color coded by site. Each point represents a year in which that site was sampled. Each vector is directional and proportional in length to its correlation with each of the NMS axes. (a) Shed = watershed area, Temp = water temperature, Canopy = canopy cover, BnkAng = bank angle, Roots = trees/roots. (b) BnkAn = bank angle, BnkVeg = bank vegetation.

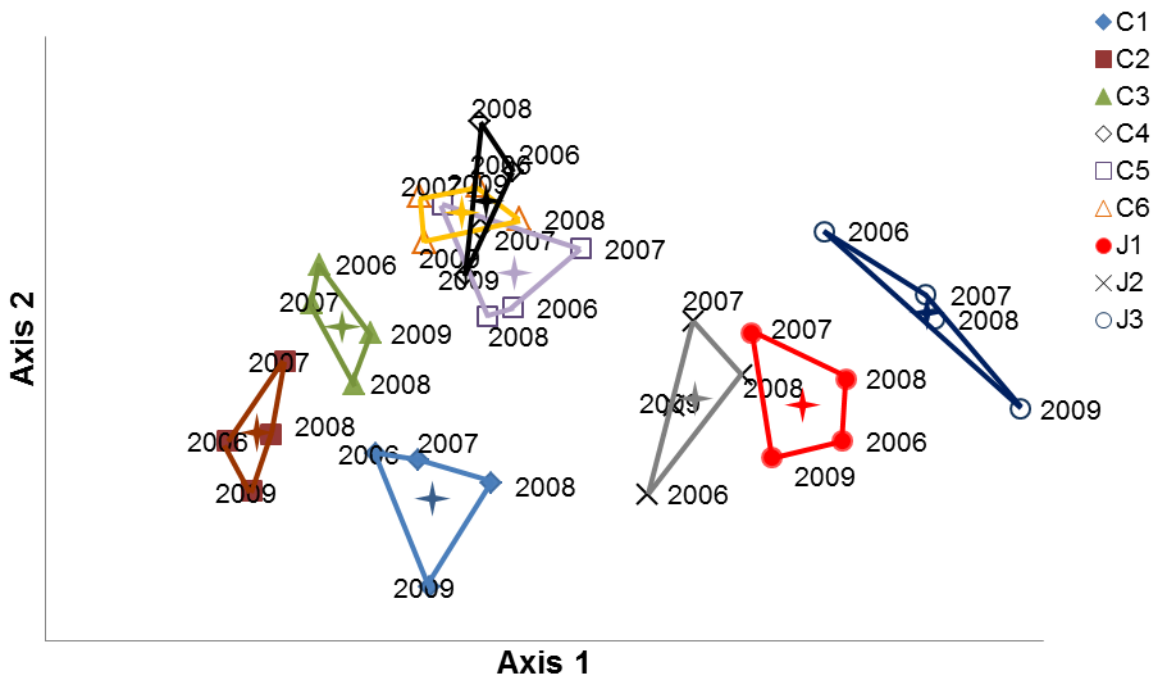
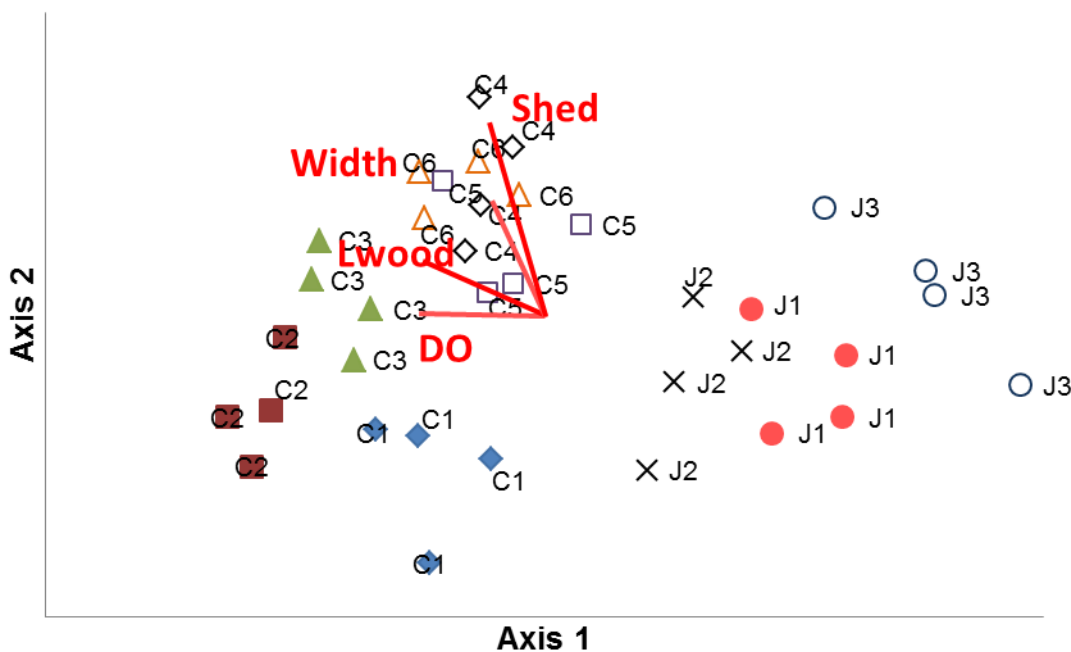


Figure I-4. Convex hull diagram for OZAR mainstems. Points are color coded by site (C1-C6 are located on the Current River; J1-J3 are located on the Jacks Fork). Each point represents a year in which that site was sampled (4 years or points for each site). Each star represents the centroid for all years sampled at a site.



Figures I-5. OZAR mainstems NMS ordination joint plot, with correlation vectors overlaid onto ordination space. Points are color coded by site. Each point represents a year in which that site was sampled. Each vector is directional and proportional in length to its correlation with each of the NMS axes. DO = dissolved oxygen, Shed = watershed area, LWood = large woody debris, Width = average width.

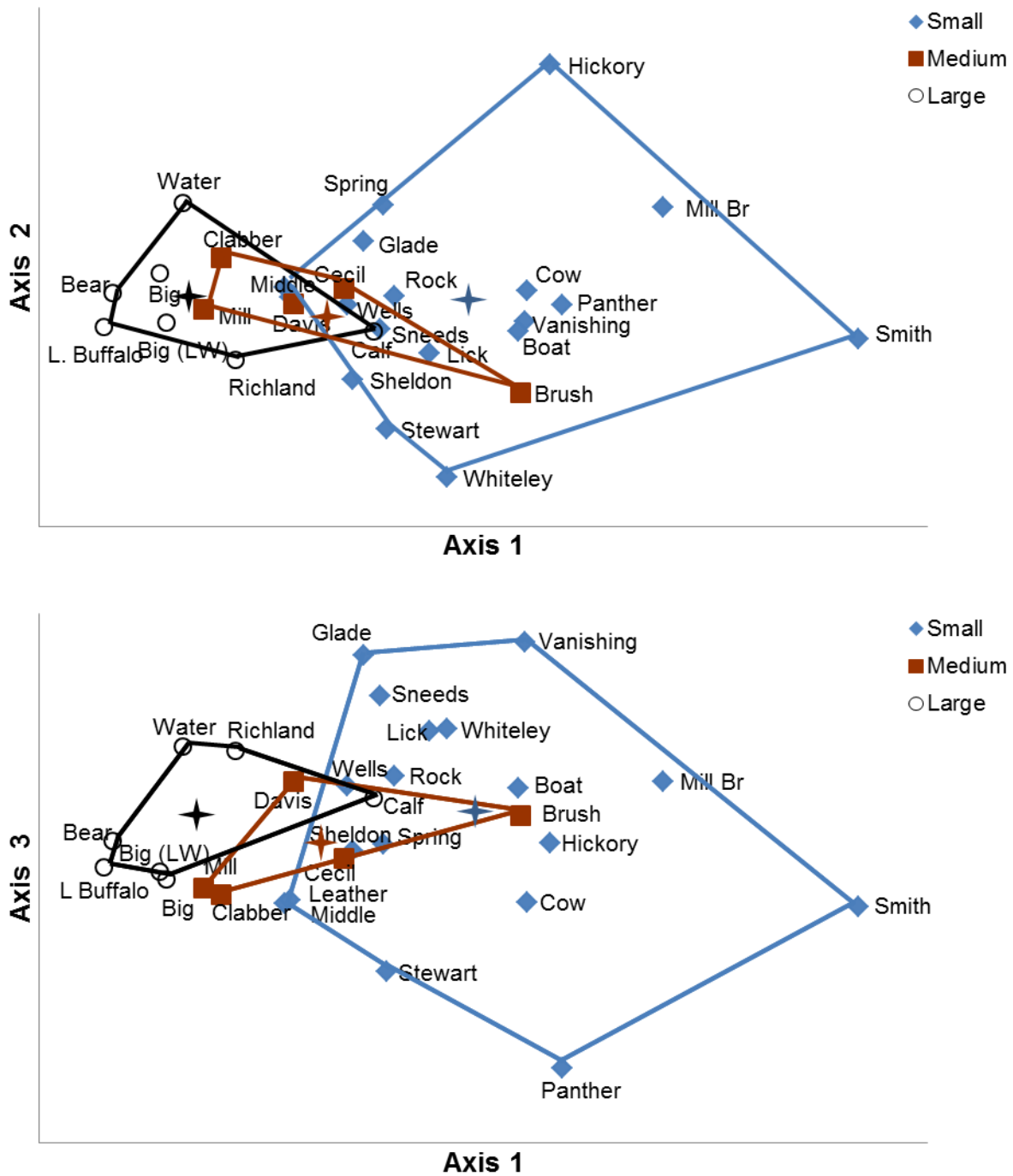


Figure I-6. Convex hull diagrams for BUFF tributaries. Each point represents a tributary. Points are coded by tributary size. Small watershed area is < 35 km², Medium 50-75 km², and Large >75 km².

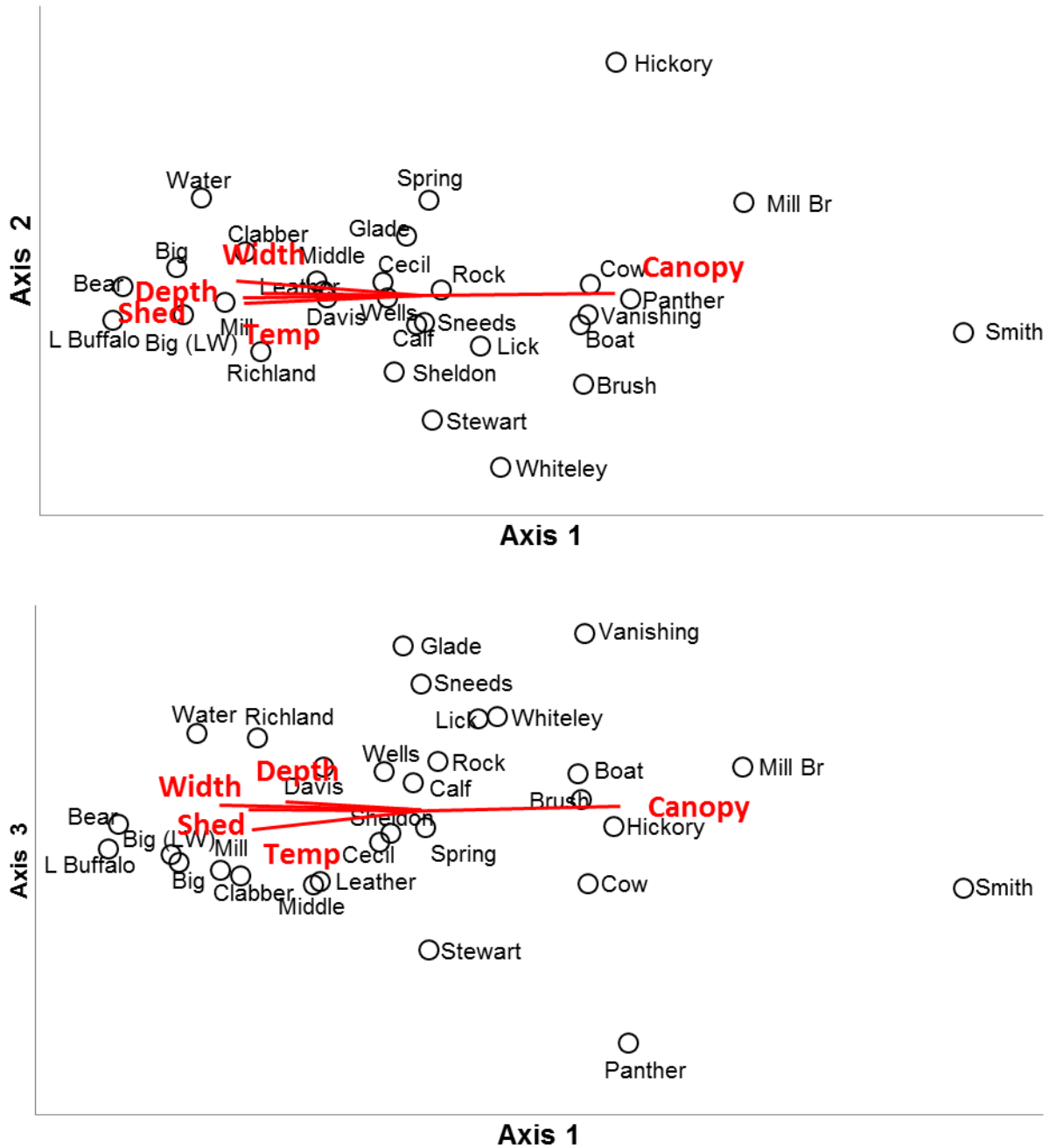


Figure I-7. BUFF tributaries NMS ordination joint plot, with correlation vectors overlaid onto ordination space. Each point represents a tributary. Each vector is directional and proportional in length to its correlation with each of the NMS axes. Canopy = canopy cover, Shed = watershed area, Temp = water temperature, Depth = average depth, Width = average width. Five variables listed are the same for both a) Axis 1vs. Axis 2 and b) Axis 1 vs. Axis 3.

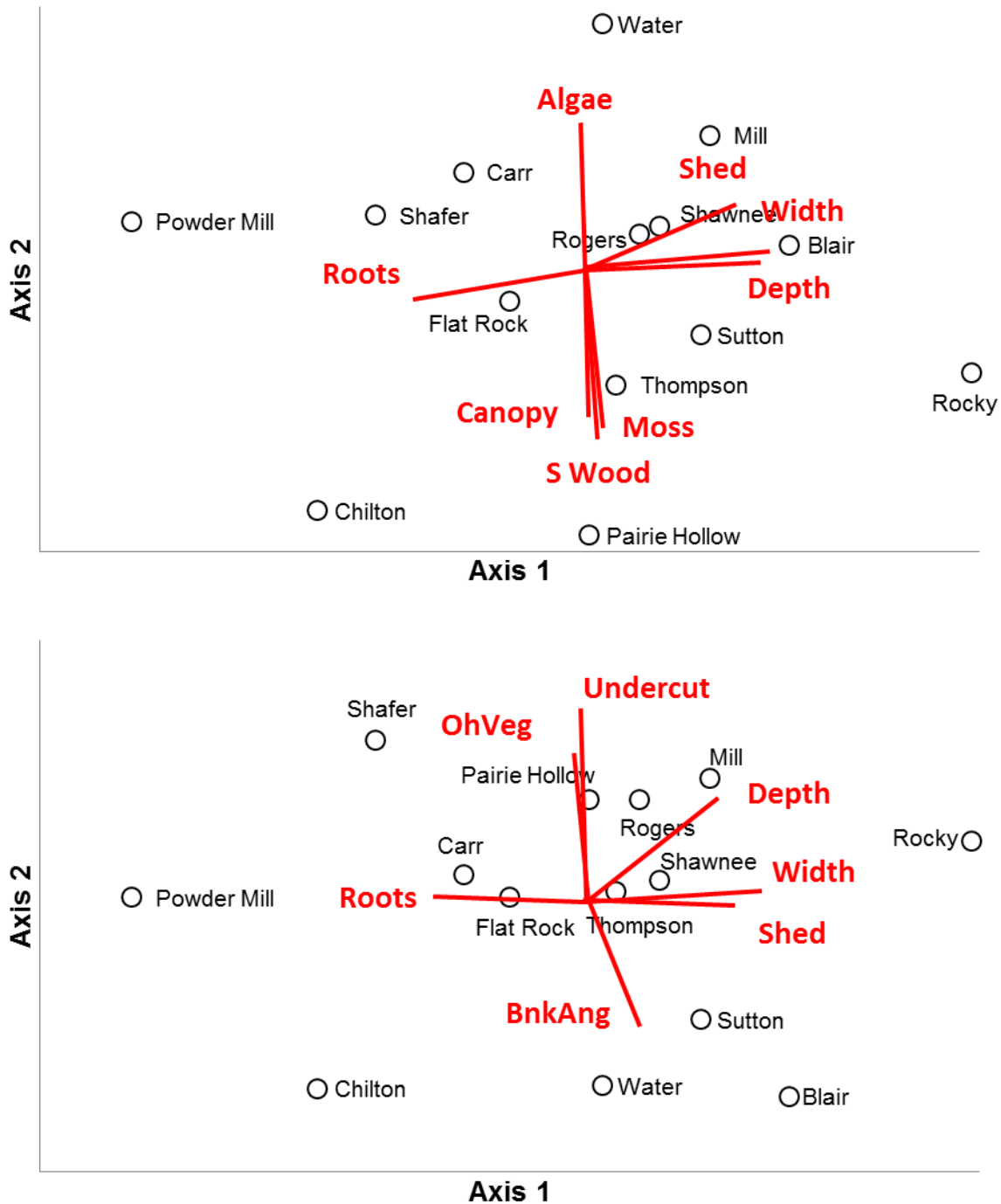


Figure I-8. OZAR tributaries NMS ordination joint plot, with correlation vectors overlaid onto ordination space. Each point represents a tributary. Each vector is directional and proportional in length to its correlation with each of the NMS axes. Panel a) Canopy = canopy cover, Shed = watershed area, Depth = average depth, Width = average width, Roots = trees/roots, Algae = filamentous algae, Moss = hydrophytes/mosses, S Wood = small woody debris. Panel b) BnkAng = bank angle, Shed = watershed area, Depth = average depth, Width = average width, Roots = trees/roots, Undercut = undercut banks, OhVeg = overhanging vegetation.

References

- Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143.
- Kruskal, J. B. 1964. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika* 29: 1-27.
- McCune, B. and J. B. Grace. 2002. *Analysis of Ecological Communities*. MjM Software Design, Gleneden Beach, OR.

Appendix J: List of fish species collected by park.

BUFF watershed

Ambloplites constellatus
Ameiurus natalis
Campostoma sp.
Cottus carolinae
Cottus hypselurus
Cyprinella galactura
Cyprinidae sp. *
Erimystax harryi
Etheostoma asprigene
Etheostoma blennioides
Etheostoma caeruleum
Etheostoma euzonum
Etheostoma juliae
Etheostoma punctulatum
Etheostoma spectabile
Etheostoma zonale
Fundulus catenatus
Fundulus olivaceus
Gambusia affinis
Hypentelium nigricans
Ichthyomyzon castaneus
Ichthyomyzon sp. *
Ictalurus punctatus
Labidesthes sicculus
Lepisosteus osseus
Lepomis cyanellus
Lepomis humilis
Lepomis macrochirus
Lepomis macrochirus x *L. cyanellus* *
Lepomis megalotis
Lepomis megalotis x *L. cyanellus* *
Luxilus chrysocephalus
Luxilus pilsbryi
Luxilus sp. *
Micropterus dolomieu
Micropterus salmoides
Moxostoma carinatum
Moxostoma duquesnei
Moxostoma erythrurum
Moxostoma macrolepidotum
Moxostoma sp. *
Nocomis biguttatus
Notemigonus crysoleucas
Notropis amblops
Notropis boops
Notropis greeniei
Notropis nubilus
Notropis ozarcanus
Notropis percobromus
Notropis sp. *
Notropis telescopus
Noturus albater
Noturus exilis
Noturus flavater
Oncorhynchus mykiss
Percina caprodes

Percina evides
Phoxinus erythrogaster
Pimephales notatus
Pylodictis olivaris
Semotilus atromaculatus

OZAR watershed

Ambloplites ariommus
Ameiurus natalis
Aphredoderus sayanus
Anguilla rostrata
Campostoma sp.
Catostomus commersoni
Cottus carolinae
Cottus hypselurus (currently renamed *Cottus immaculatus* in Current River watershed)
Cyprinella galactura
Cyprinidae sp. *
Erimystax harryi
Erimyzon oblongus
Esox niger
Etheostoma blennioides
Etheostoma caeruleum
Etheostoma euzonum erizonum
Etheostoma flabellare
Etheostoma uniporum
Etheostoma zonale
Fundulus catenatus
Fundulus olivaceus
Gambusia affinis
Hypentelium nigricans
Ichthyomyzon castaneus
Ichthyomyzon fossor
Ichthyomyzon gagei
Ichthyomyzon sp. *
Labidesthes sicculus
Lampetra aepyptera
Lampetra appendix
Lepomis cyanellus
Lepomis gulosus
Lepomis humilis
Lepomis macrochirus
Lepomis macrochirus x *L. cyanellus* *
Lepomis macrochirus x *L. miniatus* *
Lepomis megalotis
Lepomis megalotis x *L. cyanellus* *
Lepomis megalotis x *L. macrochirus* *
Lepomis microlophus
Lepomis miniatus
Lepomis miniatus x *L. megalotis* *
Luxilus chrysocephalus
Luxilus sp. *
Luxilus zonatus
Micropterus dolomieu
Micropterus punctulatus
Micropterus salmoides
Minytrema melanops
Moxostoma carinatum
Moxostoma duquesnei
Moxostoma erythrurum
Moxostoma macrolepidotum
Moxostoma sp. *

Nocomis biguttatus
Notemigonus crysoleucas
Notropis amblops
Notropis atherinoides
Notropis boops
Notropis greenei
Notropis nubilus
Notropis ozarcus
Notropis percobromus
*Notropis sp. **
Notropis telescopus
Notropis texanus
Noturus exilis
Noturus flavater
Noturus maydeni
Oncorhynchus mykiss
Percina caprodes
Percina evides
Phoxinus erythrogaster
Pimephales notatus
Pylodictis olivaris
Semotilus atromaculatus

* Not included in Nonmetric multidimensional scaling analyses.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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