Report as of FY2008 for 2007IN219B: "Fish Assemblages of Shallow Inner Bend Habitats of the Wabash River During 30 Years of Human Impacts"

Publications

- Articles in Refereed Scientific Journals:
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IWRRC Report

Title: FISH ASSEMBLAGES OF SHALLOW INNER BEND HABITATS OF THE WABASH RIVER DURING 30 YEARS OF HUMAN IMPACTS

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Problem: Although the fish assemblages of the Wabash River have been studied for some 30 years (Gammon 1998), relatively few detailed analyses of these data exist (Pyron and Lauer 2004, Pyron et al. 2006) and there are fewer ecosystem studies. The Wabash River includes the longest free-flowing stretch in the eastern U.S. and as such is a unique system for study.

Research Objectives: To resample fishes at 17 reaches where Gammon (1998) collected in 1977 and 1997. Test for changes over this 30-year period, in the fish assemblage of these inner bend habitats. Detailed habitat quantification will allow testing for variation in the 2007 fish assemblages of inner bend habitats with among site variation in substrate and flow. This project will demonstrate the effects of river hydrology on habitat quality to fishes, with a longterm goal for hydrologists and/or engineers to perform hydrological restoration that will enhance the quality of the river.

Methodology: We sampled 17 stations (Fig. 1) on the Wabash River from river mile 329 downstream to river mile 231 for fishes during summer 2009, during low discharge. These inner bend habitats were sampled with a 10-m long, 2-m high, 5-mm mesh seine for 30-m of shoreline (same distance sampled by Gammon [1994]). Fish were identified, measured, weighed, and released. Individuals that could not be identified readily in the field were preserved (in 10 % formalin) and brought to the lab for processing. Substrate composition and depths at each site were quantified using a pipe method (Mueller and Pyron in press.). This approach characterizes substrate categories and depths at 3-m increments from shore with a 3-m copper pole, for three transects spaced at 10-m along the shoreline (= nine points per site). Sediment was classified as boulder, cobble, gravel, sand, fines, or hardpan at each point. Current velocity was measured at approximately 0.6 max depth once per transect with a Marsh-McBirney flow meter. The resulting raw data are substrate categories as percentages, depth frequencies, and current velocity estimates. Percentage data were transformed by arcsin-root and frequency data were transformed by log base 10. Substrate data were reduced with principal components analysis (PCA) and significant axes determined by the broken-stick model (Jackson 1993). Resulting CPA axes used in predicting variation among fish assemblages in DCA (detrended correspondence analysis) as described below.

Fish abundance data were analyzed by examining metrics of mean abundance, mean Shannon-Wiener diversity, and mean evenness, and testing for differences among years with one-way ANOVA followed by Tukey multiple comparisons. We used rarefaction to standardize species richness to account for differences in abundances of compared samples (Gotelli &Graves 1996; Taylor et al. 2008). Species richness estimates were generated in EcoSim software (Gotelli &Entsberger 2001) for each year using 1000 random samples at specified abundance and mean species richness levels. We compared mean species richness among years by upper and lower 95 % confidence intervals. Samples were rarefied to the abundance levels of the smallest samples for comparisons of species richness for sites, by year with one-way ANOVA, followed by Tukey multiple comparisons using Minitab 15.1 software (www.minitab.com).

We used DCA in PC-ORD (McCune & Medford 1999) to examine multivariate assemblage variation in the 1977, 1997, and 2008 fish assemblages, after deleting rare species (fewer than three sites) and log (x + 1) transformation. We used the options to downweight rare species and rescale axes in PC-ORD. Our approach was to use two approaches to examine multivariate assemblage variation. The first approach examined temporal variation among the three collection periods by including all collection years in the analysis. Site scores on the resulting DCA axes were compared by collection year using one way ANOVA followed by Tukey multiple comparisons. In our second approach we used separate DCA analyses to examine within year spatial variation among sites for each year. We tested for significant correlations of DCA axes with river distance. In addition, we tested our 2008 DCA axes for correlations with substrate PC axes.

We used a Mantel test in PC-ORD (McCune & Medford 1999) to test for concordance in abundance of the 12 species with highest abundance in each collection year (Gido et al. 2000). The Mantel tests were performed on Euclidean distance matrices of correlations between species pairs, as a test of associations. A significant correlation between matrices indicates similar species associations (Gido et al. 2000).

Principal Findings We identified major shifts in assemblage composition among years. Variation that corresponded to an upstream-downstream pattern was present in 1977 and 2008. These changes in fish assemblages appear to be the results of changes in water quality, hydrology, and other disturbances.

Summary We sampled fishes at 17 sites by seine in 2008 to compare to collections from 1977 and 1997. We used the same collection methods as previous years and collected a total of 37 species. Mean site Shannon-Wiener diversity, species richness evenness, and abundance for all years were similar. We used a detrended correspondence analysis (DCA) to test for multivariate patterns in fish assemblage structure among all sites and all years. The DCA resulted in distinct assemblages in each collection-year, suggesting major shifts in assemblage composition among years. In addition, we used DCA to examine fish assemblage variation in individual years. Variation that corresponded to an upstream-downstream pattern was present in 1977 and 2008. We suggest that these changes in fish assemblages were the results of changes in water quality, hydrology, and other disturbances. This analysis demonstrates that the fish assemblages of inner bend habitats of a large river have high diversity and likely provide a refuge from predation for these smaller individuals.

Results and Significance Mean depth (± SD) of the sites in 2009 was 0.28 (± 0.13) m and mean CV depth was 0.78. Median substrate frequencies were 92 % for gravel, 8 % for sand and 0 for cobble, fines, and hardpan (these empty categories were not used in the PCA ordination). Mean depths for substrate categories were 0.13 (± 0.16) m for sand and 0.24 (± 0.19) m for gravel. Mean current velocity was 20 (± 8) cm / s.

The total abundance of fishes was 3672 in 1977, 3937 in 1997, and 2407 in 2008. Total species richness was 39 overall, 33 in 1977, 36 in 1997, and 33 in 2008. Rarefied species richness was significantly lower than 1977 collections at site 3 in 1997, site 6 in 2008, site 9 in 1997 and 2008, and site 10 in 2008 (Fig. 2). Mean rarified species richness by year was 8.0, 7.9, and 6.8, for years 1977, 1997, and 2008, respectively.

The DCA analysis of all collection years combined resulted in separation of the collections from 1977 on the first axis (Fig. 3). The 1977 collections had higher abundances of smallmouth buffalo, silver redhorse, and common carp than the 1997 and 2008 collections. The site scores for the first DCA axis were significantly different by collection year (one way ANOVA) and the 1977 collections were significantly different from the 1997 and 2008 collections (Tukey multiple comparisons). There was a significant difference in site scores on the second DCA axis (one way ANOVA) and the site scores for the 1997 collections were significantly different than scores for 2008, but the 1997 scores were not significantly different from the 1977 scores (Tukey multiple comparisons). The species with positive loadings on the second DCA axis were brook silverside and speckled chub (Fig. 3).

The DCA of the 1977 collections resulted in an ordination in which the first axis was significantly correlated with river location (Fig. 4, $r = - 0.76$, $P < 0.001$). The species that loaded highest and positively on this first DCA axis were silver redhorse, smallmouth buffalo, and river chub. Gizzard shad loaded negatively on the 1977 first DCA axis. The DCA analysis of the 1997 collections did not result in significant correlations of DCA axes with river location. The species that loaded strongest on this first DCA axis were mosquitofish and rainbow darter to the right, and suckermouth minnow and bigeye chub to the left. The DCA for the 2008 collections produced an ordination with the first axis significantly correlated with river location (Fig 4, $r = - 0.74$, $P < 0.001$). The species with the highest loadings on the first axis were bluegill and rosyface shiner.

The PCA analysis of 2008 substrate frequencies and depth variables resulted in a first axis that explained 46.3 % of variation. Eigenvalues for other PCA axes were not significantly different from random. The first substrate axis was significantly correlated with the first DCA axis for 2008 collections (Fig 5, $r = - 0.6$, $P = 0.009$).

Mantel tests did not result in concordance of species associations for comparisons of 1977, 1997, and 2008 collections (1977:2008 Mantel $r = 0.14$, $P = 0.14$; 1977:1997 Mantel $r = - 0.001$, $P = 0.52$; 1997:2008 Mantel $r = 0.17$, $P = 0.09$).

Significance

Fish assemblage changes in this 30-year period occurred simultaneous to changes in human impacts. Point source inputs were largely reduced as a result of federal legislation (Clean Water Act, Payment in Kind Program; Gammon 1998). However, sewage effluent from multiple facilities, nonpoint pollution, and runoff from urbanizations are continually discharged into the river. Hydrologic alterations of the flow regime remain an additional cause of further degradation of riverine habitat (Pyron et al. 2006, Pyron & Neumann

2008). Thus, changes in fish assemblages cannot be viewed as responses only to improvements or modifications of human alterations.

In 1977 and 2008, the fish assemblages had variation that was correlated with river distance. Our prediction is that these patterns in the fish assemblage were a response to a similar upstream-downstream gradient in habitat variables. In 1997, the river distance/fish assemblage relationship was altered. Without substrate data for 1997, we can only predict that the hydrology/substrate relationship was altered in 1997, in addition to other unknown variables that influenced recruitment of these fishes. Mueller and Pyron (in press) found strong relationships for fish assemblages with substrate variation at sites where fish were collected by boat electrofisher. Pyron & Lauer (2004) found fish assemblage variation with river distance based on annual boat electrofishing collections in 2001-2. Lohr & Fausch (1997) similarly found changes in fish assemblages in the Purgatoire River of Colorado during an 11-year period. They found increased variation in abundance of species at individual sites compared to variation among sites, similar to our results.

The substrate composition of these habitats is based on scouring and depositional patterns, controlled by the hydrologic regime of the river. We suggest that hydrologic alterations modify the scouring and depositional patterns and subsequent substrate composition and dynamics at individual sites. The result is substrate habitats that are dissimilar from habitats produced by a natural flow regime. The Wabash River mainstem has had significant hydrologic alterations during recent decades compared to historic flows (Pyron & Neumann 2008). Variation in substrate composition at individual sites is linked to extreme discharge events, and the local fish assemblages covary with substrate composition (Pritchett & Pyron unpubl. data). Koel & Sparks (2002) found significant effects of hydrologic alterations from dam operations on young-of-year fishes in the Illinois River, that were likely linked to substrate quality. Multiple mechanisms in the Illinois River ecosystem provide linkages for hydrologic alteration and substrate quality and recruitment of fishes (Koel & Sparks 2002).

Fish assemblages change temporally with human effects and frequently result in local or regional extinctions (Matthews 1998). Although we did not identify extinctions in the Wabash River, Gammon (1998) found three local extinctions: lake sturgeon (*Acipenser fulvescens*), muskellunge (*Esox masquinongy*), and stargazing darter (*Percina uranidea*). The Wabash River is not a pristine ecosystem and has multiple current anthropogenic impacts, including altered hydrologic regime, agricultural effects, and urbanization (Pyron et al. 2006). However, mean rarified species richness did not vary among the collection years for these Wabash River sites.

Flow regulation has resulted in alterations of the major rivers of the world (Dynesius & Nilsson 1994). Scientists and managers of rivers are promoting river restoration (Wohl et al. 2005), or river naturalization (Koel & Sparks 2002), to conserve these ecosystems. Richter et al. (2006) and Poff (2009) are promoting the hypothesis that restoring natural variability to river flows can achieve improvement in ecosystem health. Recent flow restoration projects have been successful (Richter & Thomas 2007) and we recommend similar approaches for restoring natural variability in flow of the Wabash River.

References

Dynesius, M. & Nilsson, C. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. Science 266:753-762.

Gammon, J.R. 1994. The Wabash River Ecosystem. A Report for Eli Lilly and Co., Indianapolis, IN and PSI Energy, Plainfield, IN.

Gammon, J.R. 1998. The Wabash River Ecosystem. Bloomington, IN: Indiana University Press.

Gido, K.B., Matthews, W.J. & Wolfinbarger, W.C. 2000. Long-term changes in a reservoir fish assemblage: stability in an unpredictable environment. Ecological Applications 10:1517-1529.

Gotelli, N.J. & Entsminger, 2001. EcoSim: Null models software for ecology. Version 7.0. Acquired Intelligence Inc. & Kelsey-Bear. http://homepages.together.net/~gentsmin/ecosim.htm.

Gotelli, N.J. & Graves, G.R. 1996. Null Models in Ecology. Smithsonian Institution Press, Washington, DC.

Jackson, D.A. 1993. Stopping rules in principal components analysis: a comparison of heuristical and statistical approaches. Ecology 74:2204-2214.

Junk, W.J., Bayley, P.B. & Sparks, R.E. 1989. The flood pulse concept in river-floodplain systems. In, Proceedings of the International Large River Symposium, Dodge, D.P. (ed.): 110-127.

Koel, T.M. & Sparks, R.E. 2002. Historical patterns of river stage and fish communities as criteria for operations of dams on the Illinois River. River Research and Applications 18:3-19.

Lohr, S.C. & Fausch, K.D. 1997. Multiscale analysis of natural variability in stream fish assemblages of a western Great Plains watershed. Copeia 1997:706-724.

Matthews, W.J. 1998. Patterns in Freshwater Fish Ecology. New York: Chapman & Hall.

Mueller, R. & Pyron, M. in press. Fish assemblages and substrates in the middle Wabash River, USA. Copeia.

McCune, B. & Medford, M.J. 1999. Multivariate Analysis of Ecological Data, Version 4.20, MjM Software, Gleneden Beach, Oregon.

Poff, N.L. 2009. Managing for variability to sustain freshwater ecosystems. Journal of Water Resources Planning and Management 135:1-4.

Pyron, M. & Lauer, T.E. 2004. Hydrological effects on patterns of fish assemblage structure in the middle Wabash River. Hydrobiologia 525: 203-213.

Pyron, M., Lauer, T.E. & Gammon, J.R. 2006. Stability of the Wabash River fish assemblages from 1974 to 1998. Freshwater Biology 51: 1789-1797.

Pyron, M. & Neumann, K. 2008. Hydrologic alterations in the Wabash River watershed. River Research and Applications 24:1-10.

Richter, B.D. & Thomas, G.A. 2007. Restoring environmental flows by modifying dam operations. Ecology and Society 12:12 online URL: http:www.ecologyandsociety.org/vol12/iss1/art12/

Richter, B.D., Warner, A.T., Meyer, J.L. & Lutz, K. 2006. A collaborative and adaptive process for developing environmental flow recommendations. River Research & Applications 22:297-318.

Taylor, C.M., Millican, D.S., Roberts, M.E. & Slack, W.T. 2008. Long-term changes to fish assemblages and the flow regime after extensive ecosystem fragmentation. Ecography 31:1-11.

Wohl, E., Angermeier, P.L., Bledso, B., Kondolf, G.M., MacDonnell, L., Merritt, D.M., Palmer, M.A., Poff, N.L. & Tarboton, D. 2005. River restoration. Water Resources Research 41:W10301.

Table 1. Results of Tukey comparisons of mean Shannon-Wiener diversity, and evenness for 1977, 1997, and 2008 collections at 17 inner bend sites on the Wabash River.

Statistic	Year	Mean	Tukey comparisons
S-W diversity	1977	1.41	A
	1997	1.39	A
	2007	1.74	A
Evenness	1977	0.13	A
	1997	0.12	A
	2007	0.12	A
Abundance	1977	216	A
	1997	232	A
	2007	392	A

Table 2. Abbreviations, relative abundance, and rank abundance for fishes captured at inner bend sites on the Wabash River. No abbreviations are supplied for species that were in low abundance and not included in DCA.

Species		Percent abundance			Rank abundance		
	Abbrev	1977	1997	2008	1977	1997	2008
Spotfin shiner	SPS	24.9	36.3	21.0	1	1	2
River shiner	RIS	21.4	2.9	9.3	2	6	5
Gizzard shad	GIZ	0.1	28.0	16.1	22	2	3
Sand shiner	SAS	5.8	8.9	15.3	5	3	4
Emerald shiner	EMS	16.8	4.6	26.4	3	5	1
Bluntnose minnow	BLM	15.8	2.0	0.3	4	8	14
Steelcolor shiner	STS	…	…	3.4	…	…	6
Bullhead minnow	BUM	…	2.0	0.5	…	7	10
River carpsucker	RIC	5.0	…	0.5	6	…	11
Shorthead redhorse	SHR	…	…		…	…	
Mississippi silvery minnow	MSM	…	8.5		…	4	
Golden redhorse	GOR	0.4	0.2	0.08	14	18	24
Smallmouth buffalo	SBU	2.2	…		7	…	
Central stoneroller	STO	1.4	0.5	0.2	8	11	20
Suckermouth minnow	SUM	1.3	0.4	0.08	9	13	27
Striped shiner	STB	…	1.8		…	9	
Spotted bass	SPB	…	0.03	0.5	…	28	12
Bigmouth buffalo		1.1	…		10	…	
Silver redhorse	SIR	0.2	…		17	…	
Silverjaw minnow	SJM	1.1	0.3	0.3	11	16	15
Black redhorse	BRH	0.1	0.5		24	12	
Bluegill	BLG	0.4	0.4	0.3	12	14	16
White bass	WHB	…	0.8		…	10	
Speckled chub	SPC	0.4	…	0.08	13	…	26
Mimic shiner	MMS	…	…	0.9	…	…	9
Common carp	CAR	0.3	…		15	…	
Northern hogsucker	HOG	0.2	0.03	0.04	18	31	30
Freshwater drum	FRD	…	0.3	0.12	…	15	22
Mosquitofish	MOF	…	0.1	1.1	…	23	8
Logperch	LOP	0.3	0.1	0.04	16	26	29
Bigeye chub	BEC	0.03	0.1	0.12	26	21	21
Channel shiner	CHS	…	…	2.0	…	…	7
Smallmouth bass	SBA	0.2	0.2	0.04	19	17	31
Bigeye shiner		…	…		…	…	
Creek chub	CRC	0.1	…		21	…	
Channel catfish		…	0.2	0.08	…	19	23
River chub		0.1	0.03		23	30	
Longnose gar	LOG	…	0.03	0.2	…	32	17
Brindled madtom		0.05	…		25	…	
Slenderhead darter	SLD	…	0.1		…	22	
Blackside darter		0.03	0.03		27	36	
Rosyface shiner	ROS	0.03	…	0.08	31	…	25
Rainbow darter	RAD	0.03	0.08		30	24	
Hornyhead chub	HOC	…	0.08		…	25	
Blue sucker		…	…		…	…	
Largemouth bass		0.03	0.03		29	33	
Fathead minnow		…	…		…	…	

Striped bass	STB	0.03	…		33	…	
Silver chub		0.03	0.3		32	20	
Rosefin shiner		…	…		…	…	
Dusky darter		…	0.05		…	27	
Shovelnose sturgeon		…	0.03		…	29	
Johnny darter	JOD	0.16	0.03	0.2	20	34	19
Greenside darter		…	0.03		…	35	
Stonecat		…	…		…	…	
White sucker		…	…		…	…	
Gravel chub		…	0.03		28	…	
Longear sunfish	LESF	…	…	0.4	…	…	13
Brook silverside	BRSI	…	…	0.2	…	…	18
Blackstripe topminnow		…	…	0.04	…	…	28
White crappie		…	…	0.04	…	…	32

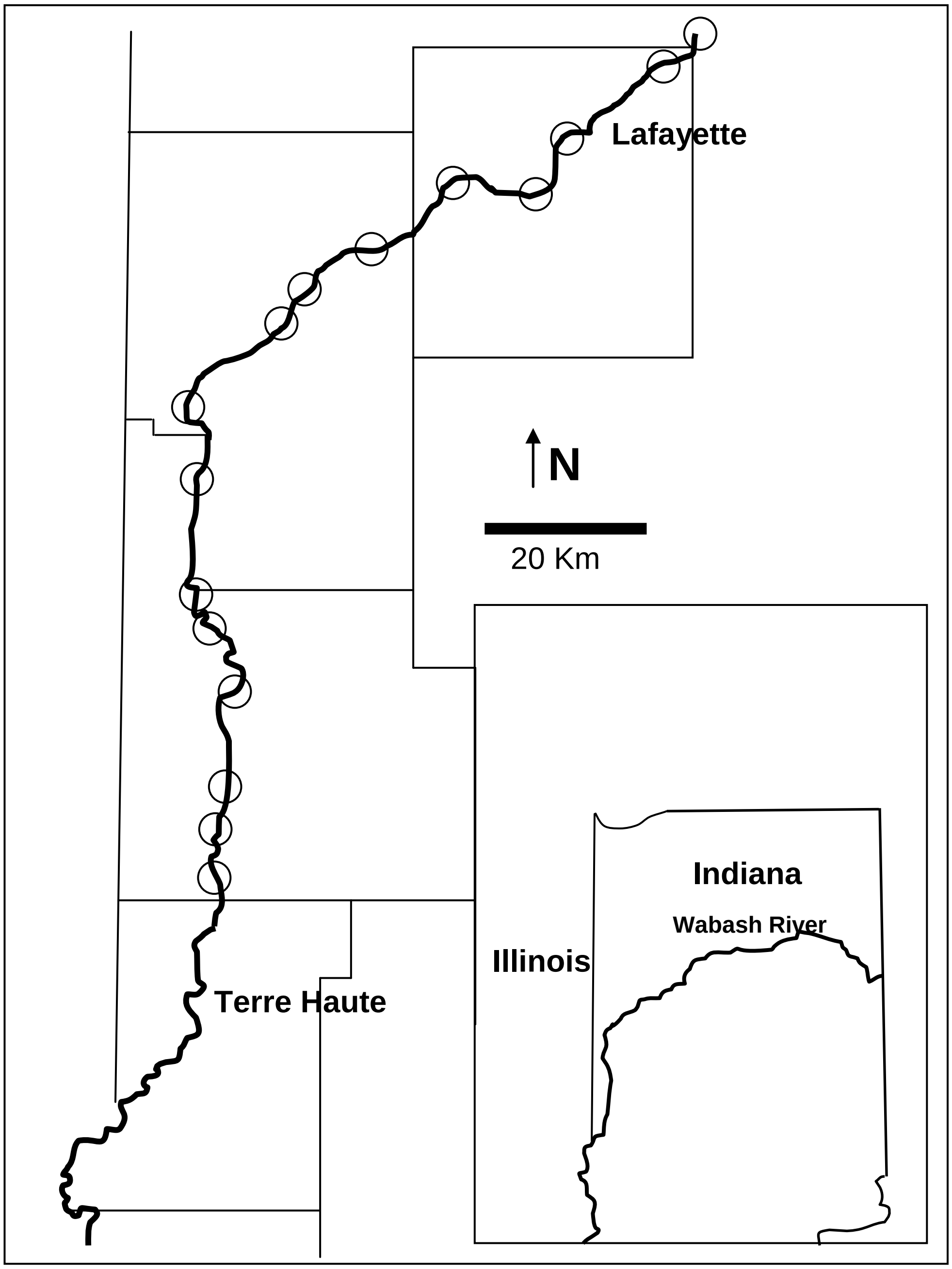
Fig. 1. Map of collection sites on the Wabash River.

Fig. 2. Species richness estimates from simulations in EcoSim for 1977, 1997, and 2008. The missing sites had low abundances in 2008 collections and were not included. Variation bars represent upper and lower 95 % confidence intervals.

Fig. 3. Results of a detrended correspondence analysis of the fish assemblages at 17 Wabash River sites during three sample periods. Species scores are on the top plot a odes for species are in Table 1). Sites are on the lower plot b.

Fig. 4. Results of three separate detrended correspondence analyses of the fish assemblages at 17 Wabash River sites for three sample periods. Codes for species are in Table 1.

Fig. 5. The first axis from a detrended correspondence analysis of the fish assemblages and the first axis from a principal component analysis of substrate variation at 17 sites on the Wabash River in 2008. Codes for species are in Table 1.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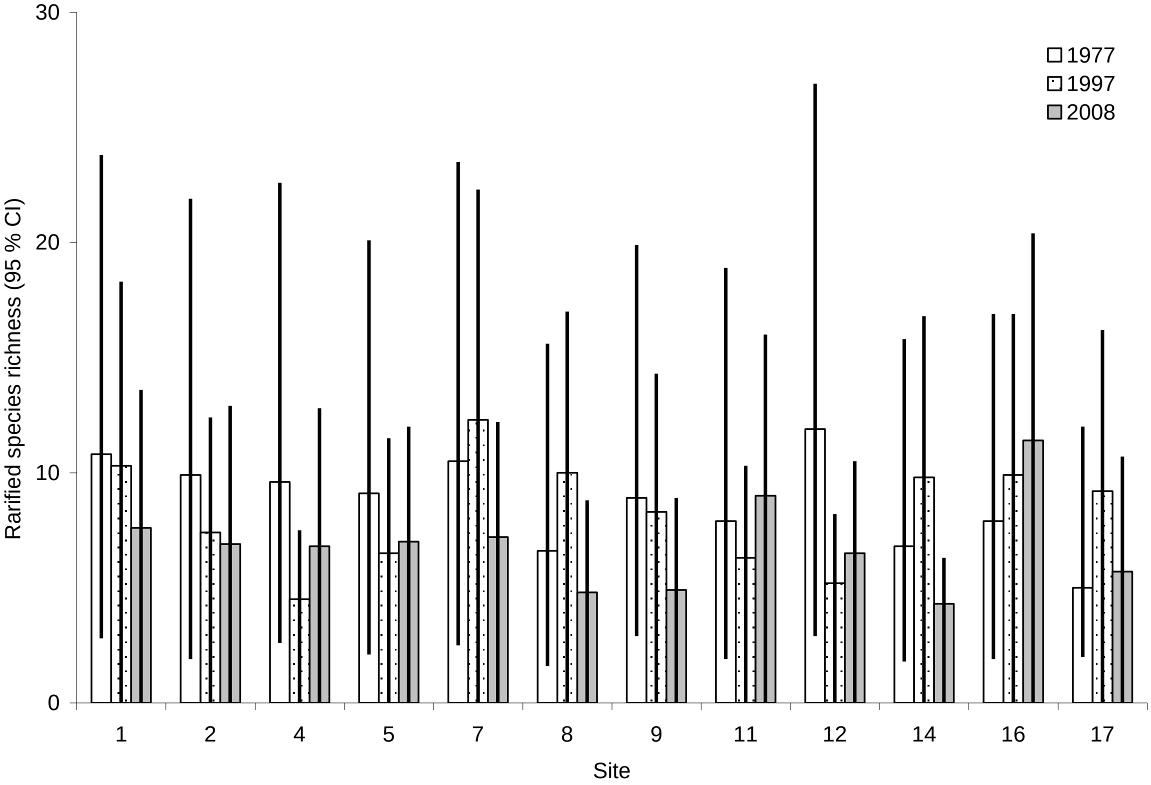
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Rarified species richness (95 % CI)
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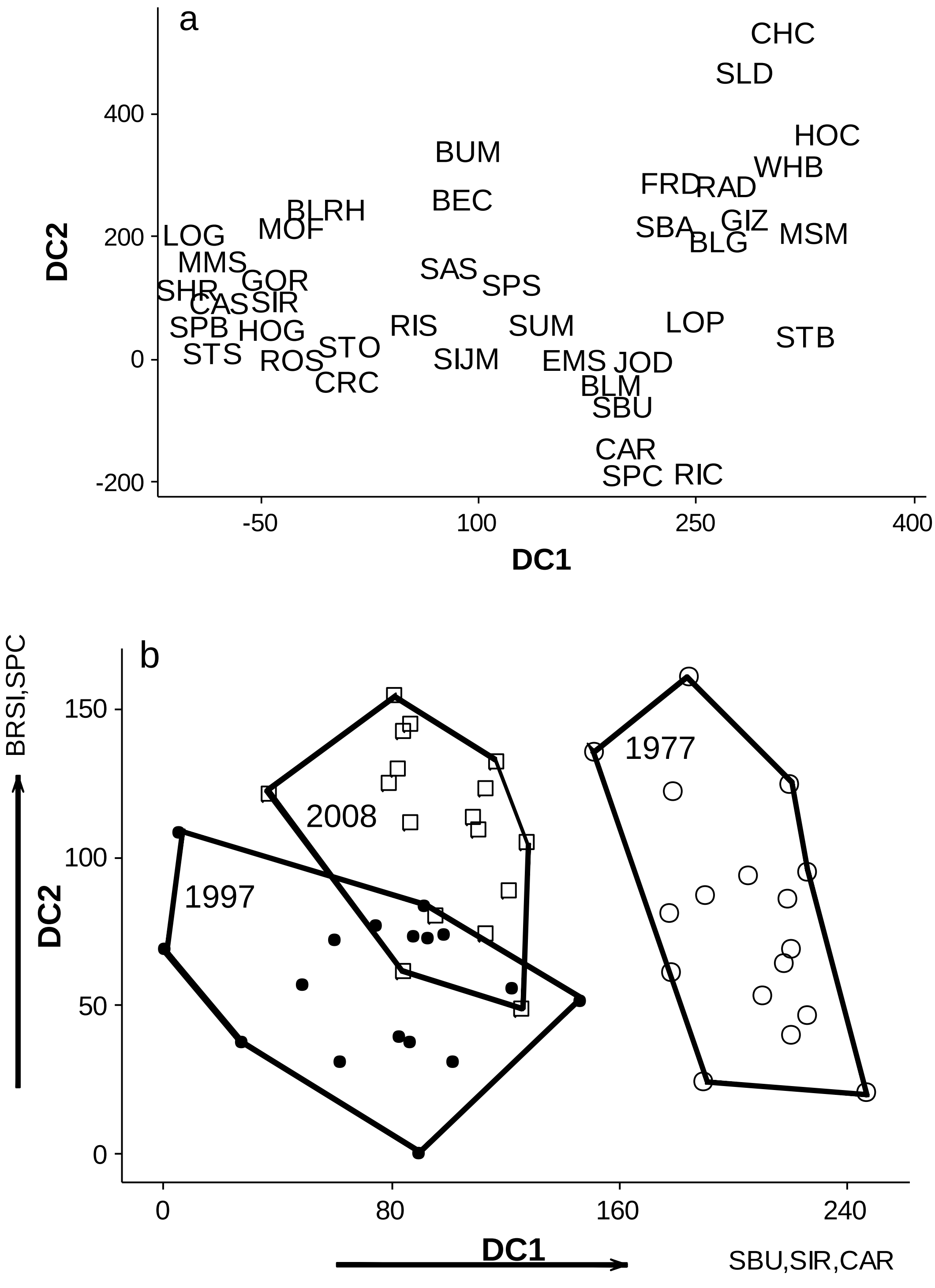
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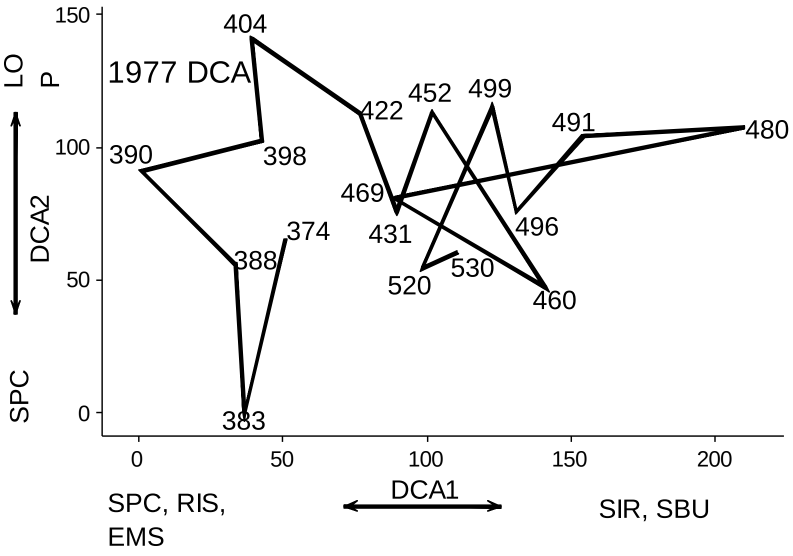
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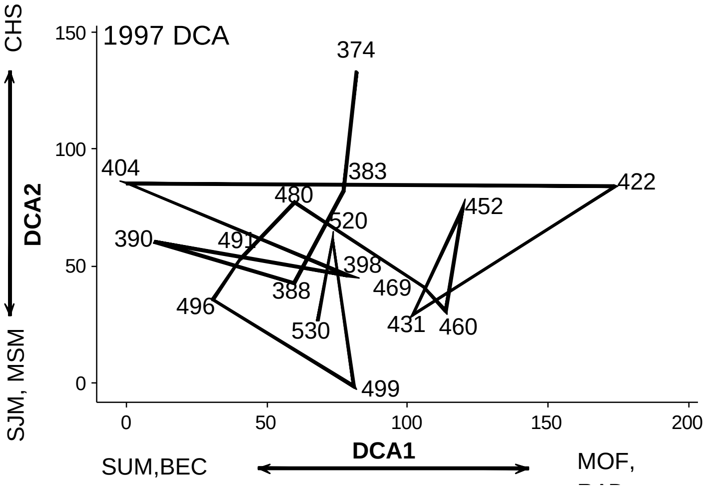
1997 DCA
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SUM,BEC
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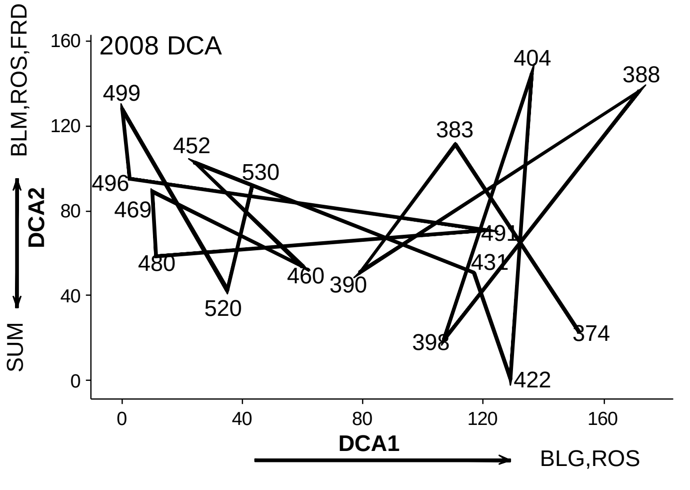
2008 DCA
BLM,ROS,FRD
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SUM
160
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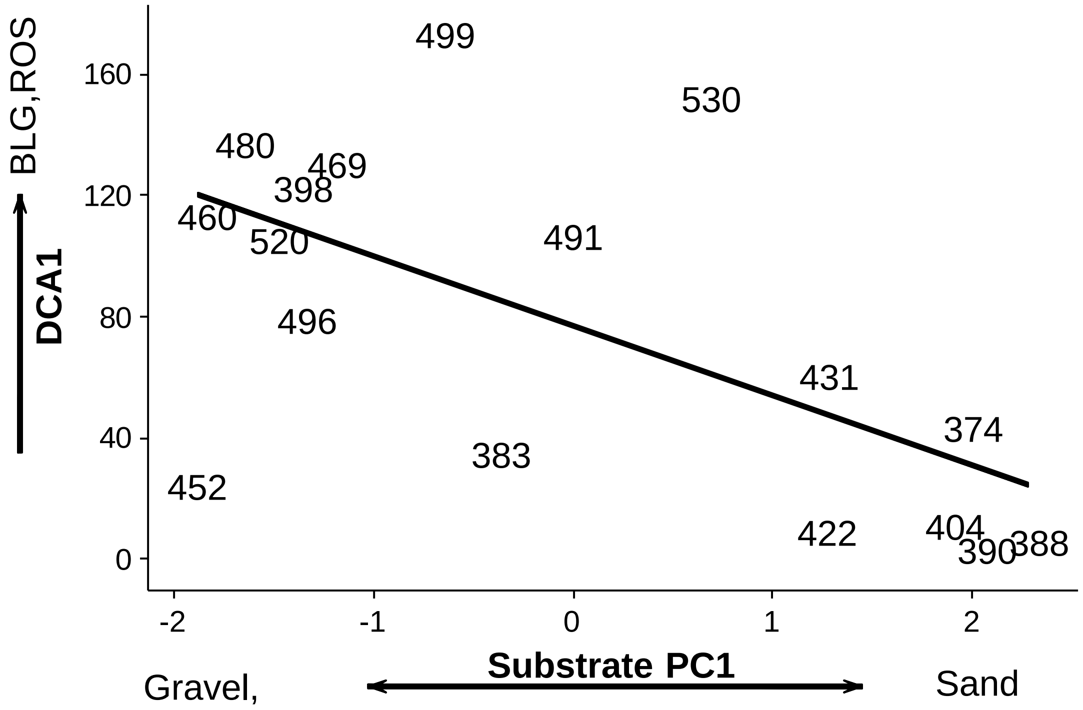
DCA1
BLG,ROS



Major Conclusions We identified major shifts in assemblage composition among years. These changes in fish assemblages appear to be the results of changes in water quality, hydrology, and other disturbances. This implies that even though there have been substantial improvements in water quality of the Wabash River during the past several decades, additional disturbances are present that produced temporal shifts in fish assemblages.

Publications Manuscript will be submitted to River Research and Applications in 2009. This project will be presented by a graduate student, Jayson Beugly, at the American Fisheries Society Conference in Nashville, TN September 2009.

Students The project provided partial support for one graduate student (Jayson Beugly) during the 2008-9 school year. Undergraduate students involved in the field component were supported on related grants (Jennifer Pritchett, Stephen Jacquemin).