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Effects of Contaminated Sediments on a Backwater Restoration Project in the Mississippi River Delta

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Abstract: Success of any aquatic restoration project is based on the assumptions that physical features can be manipulated in such a way as to improve habitat, water quality or both. An additional assumption is that there is nothing inherent about the site that would prevent the target community from exploiting the newly restored habitat. Examples of inherent features that may cause restoration failure include barriers, contaminants, or site instability. Because persistent pesticides continue to be reported as low-level contaminants in aquatic ecosystems in the lower Mississippi River alluvial plain, any site selected for restoration in this region of the United States should be tested for contamination. Sediment samples were collected from three backwater sites; two controls and one restoration, as a part of a river backwater restoration project in the Mississippi Delta. Sediment was analysed for 7 metals, 15 persistent pesticides and 13 current-use pesticides and tested for toxicity using *Hyalella azteca*. Fish were also sampled at each site prior to restoration construction to establish baseline information on fish production and community structure. Preliminary analysis indicates that sediments from the control sites were more toxic than the restoration site and supported few numbers of fish.

Keywords: *pesticides, habitat, aquatic ecosystem, Hyalell aazteca, fish*

Introduction

Historically the Mississippi Delta has been one of the most productive areas in the country. This area has been primarily farmed in cotton, *Gossypium sp.* and rice, *Oryza sativa*. By the late 1960 production shifted toward soybeans and extensive tracts of "marginal" land were cleared and drained. In the early to mid-1970s thousands of acres of row crops were converted to ponds for catfish production (Knight and Welch, 2004). The past two years have seen a dramatic increase in acres of corn, *Zea mays*, planted in anticipation of the need for biofuels.

The delta is typically flat, and was originally drained by highly sinuous and often braided rivers and streams. The rivers were narrower and deeper than today and frequently flooded. The meandering of delta rivers and streams resulted in the formation of hundreds of oxbow lakes covering much of the landscape. Channelization and drainage projects have increased the number of oxbow lakes by cutting off river bend ways.

Agriculture has played a significant role in damaging physical habitat as well as degrading water quality. In oxbow lakes, we typically see three problems; one related to physical habitat and the other two to water quality. Flood control and channelization, while creating oxbow lake habitat, has also resulted in a permanent or semi-permanent separation of the lakes from the river that supplies water and fauna. Sediment laden runoff entering the oxbows exacerbates the lakes problems by creating shallow water conditions with soft sediment bottoms. With only intermittent recharge from the adjacent river and water often removed for irrigation many oxbow lakes dry completely by late summer.

Understanding how lakes function helps provide insight into how degraded water quality can affect oxbow lakes. Since these lakes are no longer heterotrophic systems as they were when still a part of the river system, they must now depend upon autotrophic organisms capturing sun light to maintain productivity. As turbidity increased from sediment-filled agricultural runoff, light is decreased resulting in a decline in primary productivity. Of course the sediments are not the only pollutants in agricultural runoff. Many of our persistent and current use insecticides have an affinity for clay particles in the sediment in agricultural runoff. Because of extensive pesticide use over many

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decades in the Mississippi Delta, these compounds can be found in almost all landscape features, but particularly in Delta lakes and wetlands (Knight et al. 2002).

A major assumption of restoration aquatic projects is that physical features can be manipulated in such a way as to improve habitat, water quality or both (Shields et al. 2002).An additional assumption is that there is nothing inherent about the site that would prevent the target community from exploiting the newly restored habitat. Examples of inherent features that may cause restoration failure include barriers, contaminants or site instability (Brookes et al., 1996). Because persistent pesticides continue to be reported as low-level contaminants in aquatic ecosystems in the lower Mississippi River alluvial plain any site selected for restoration in this region of the United States should be tested for contamination.

This study is a part of a river backwater restoration project examining the effects of controlling water level and sediment entering a cut off bend way of the Coldwater River. The main source of sediment was directed into a portion of the lake that was managed as a wetland, while water level was controlled and maintained at a higher depth in the upper portion of the lake. The research reported here was designed to test for sediment toxicity and to examine associated fish communities for indications of barriers that would prevent successful restoration.

Materials and Methods

This study was conducted in oxbow lakes of the Coldwater River located near the towns of Savage in Tunica County, and Byhalia in Marshall County, Mississippi, USA as well as the adjacent river channel (Fig. 1).Land-use surrounding the lake and river sites row-crop cultivation. Sediment samples were collected from the three backwater sites; two controls (Southern Oxbow and Byhalia) and one restoration (Northern Oxbow) and analysed for 7 metals, 15 persistent pesticides and 13 current-use pesticides. Theses sediments were also tested for toxicity using *Hyalella azteca*. Fish were collected from the oxbow sites as well as adjacent river bend ways.

Surface sediment samples from the top 5 cm from each of oxbow lake were collected using a sediment core sampler, placed in amber coloured glass jars, preserved on ice and transported to the USDA-ARS National Sedimentation Laboratory, Oxford, Mississippi, USA for sediment characterization and pesticide analysis. Uncontaminated sediments from the University of Mississippi Biological Field Station were also collected as control materials. Bulk sediment samples were dried at 60° C for 24 h and then extracted with ethyl acetate for pesticide analysis according to Cooper et al. (2003) and Bennett et al. (2000). Sediment samples were analyzed for 15 current and historic-use pesticides and selected associated metabolites. Historic-use pesticides included: Aldrin, Dieldrin, *p,p'*-DDT, *p,p'*-DDD, *p,p'*-DDE, αBHC, βBHC, δBHC, γBHC, Chlordane, Toxaphene, Endrin, Endrin aldehyde, Endosulphan I, Endosulphan II, Endosulphan sulfate, Heptachlor, Heptachlor epoxide, Mirex, Methoxyclor. Current use pesticided included:Trifluralin, Pendimethalin, Atrazine, Cyanazine, Alchlor, Metolachlor, Chlorpyrifos, Methyl Parathion, Chlorfenapyr, Bifenthrin, λ-cyhalothrin, Fipronil, and Fipronil Sulfone. Additionally, arsenic, copper, lead, mercury, chromium, cadmium and zinc concentrations were measured. Analytical chemistry was conducted at the National Sedimentation Laboratory, Oxford, MS, according to Bonnetet al. (2000) using a Hewlett-Packard 6890 gas chromatograph equipped with an HP 7683 ALS autoinjector and inductively coupled plasma emission spectrometry. Extraction efficiencies of all fortified samples (both water and sediment) analysed for quality assurance/quality control were ≥ 90%.

Twenty-eight day static non-renewal bulk sediment toxicity tests using4-5 d old *Hyalella azteca* were conducted according Nebeker et al. (1984) and USEPA (1994) protocols. Standard physical and chemical water characteristics for sediment tests (temperature, pH, dissolved oxygen, conductivity, hardness, alkalinity, ammonium-N, nitrate-N, and nitrite-N) were measured according to APHA (1998). Bioassay endpoints measured were survival and growth (as wet weight in mg).

Data were analyzed using SigmaStat® v.2.03 statistical software (SPSS 1997) and included descriptive statistics and one-way analysis of variance (ANOVA) on survival and growth (as wet weight) with Tukey's multiple-range test, when appropriate. When data failed parametric assumptions, a Kruskal-Wallace one-way ANOVA on ranks with Dunn's multiple-range test was utilized. When significant impairment was observed ($P \leq 0.05$), a linear regression was performed on the impaired endpoint versus pesticide concentration (Steel et al. 1997).

Fish were sampled using boat mounted electro fishing equipment using pulsed DC current from both lake and river sites to establish baseline information on fish production and community structure. Voltages were varied depending upon the specific conductance of the water at each site. Sites were sampled for 20 minutes and in such a manner as to cover the major habitats within each reach. Shocking times were recorded to the nearest second so that catch per unit of effort could be calculated. Fish were identified by species and measured for total length. Weights were estimated based on length weight relationships for freshwater fishes in Mississippi and Alabama (Swingle 1972). All fish that could be identified on site were released after measurements were taken. Those individuals that could not be readily identified in the field were labelled and preserved in 10 % formalin solution and identified and measured in the laboratory. Number of species, catch per unit of effort and numbers per unit of effort were calculated for each collection.

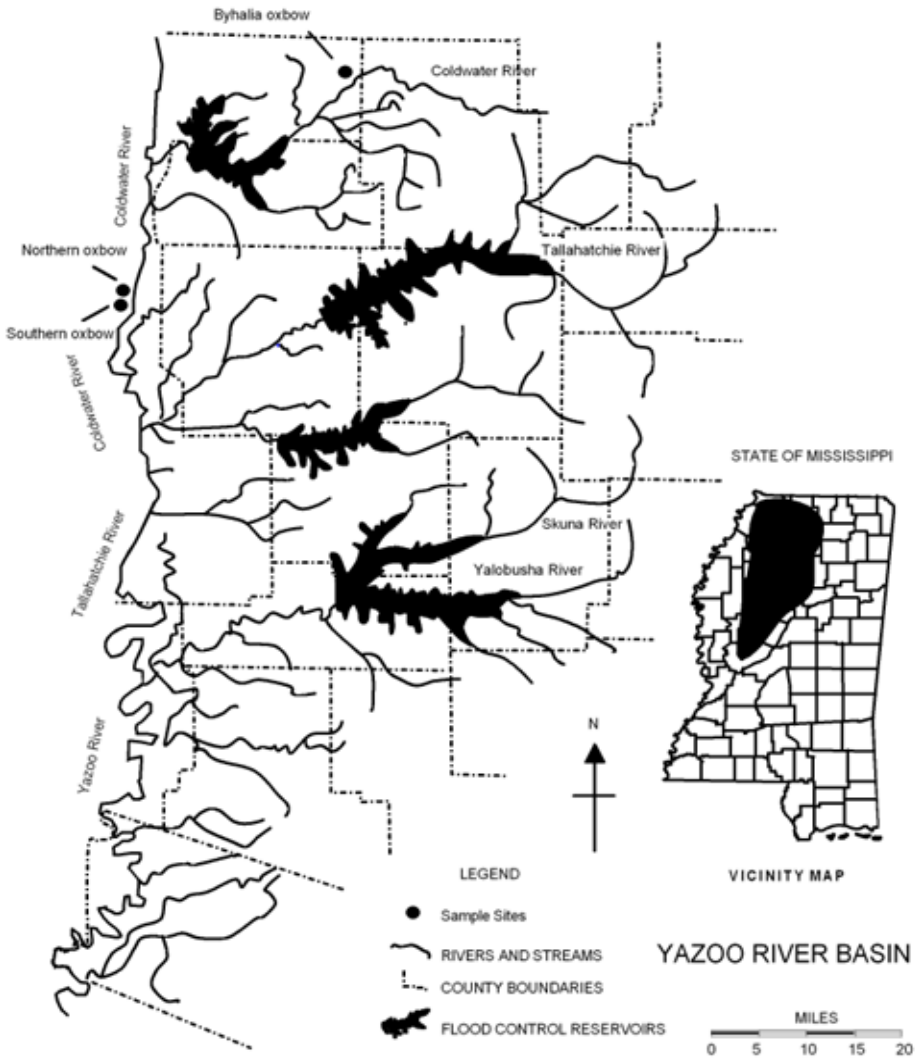

Figure 1. Map of Yazoo River Basin showing location of Coldwater and Byhalia oxbow sites

Results and Discussion

Pesticides

Current use pesticides which are typically short lived were not detected from the sediment samples collected during our study however the legacy pesticides Aldrin, α BHC and γ BHC (Lindane) and Heptachlor were found. Heptachlor was particularly high in the control sites (the southern oxbow and the upstream site at Byhalia, MS (Table 1).Metal concentrations were typically higher in sediments from the delta sites than those from Byhalia which was higher than the uncontaminated control sediment (Table 2).These concentrations are similar to those reported for other Mississippi sediments by Cooper and Gillespie (2001), Knight and Cooper (1996), and Winger and Lasier (1998).

Table 1. Legacy pesticide and metabolite concentrations (ng/g) in oxbow lake sediments

Pesticide or metabolite	Southern Oxbow	Northern Oxbow	Wetland	Byhalia	Control
Aldrin	22.5	8.75	2.91	0.90	1.84
Dieldrin	ND	ND	ND	ND	ND
p,p'-DDT, DDD, DDE	ND	ND	ND	ND	ND
αBHC	17.15	3.63	ND	1.26	ND
βBHC	ND	ND	ND	ND	ND
δBHC	ND	ND	ND	ND	ND
γBHC	393.29	104.15	1.02	48.21	ND
Chlordane	ND	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND
Endrin aldehyde	ND	ND	ND	ND	ND
Endosulphan I	0.90	ND	ND	0.90	ND
Endosulphan II	0.90	0.90	ND	0.90	ND
Endosulphan sulfate	ND	ND	ND	ND	ND
Heptachlor	8.97	1.71	0.90	56.15	0.90
Heptachlor epoxide	0.90	0.90	0.90	0.90	ND
Mirex	ND	ND	ND	ND	ND
Methoxyclor	ND	ND	ND	ND	ND

Table 2. Metal (mg/kg) concentrations in Mississippi oxbow lake sediments

Pesticide or metabolite	Southern Oxbow	Northern Oxbow	Northern Oxbow	Wetland	Byhalia
Arsenic	1.48	2.13	5.21	2.74	0.38
Copper	19.25	16.75	12.50	7.00	0.50
Lead	20.50	20.25	18.25	8.50	2.25
Mercury	0.105	0.121	0.076	0.083	0.030
Chromium	11.50	10.50	7.50	5.50	1.50
Cadmium	4.00	4.00	3.00	2.50	ND
Zinc	64.00	55.25	48.75	8.50	1.25

Hyalella

The simple presence or absence of these materials means little even if it is significantly higher than some uncontaminated control sediment without consideration of its impact on organisms in the system. The important question is what affect this will have on our biota and therefore our project. The survival, growth, and behaviour of *Hyalella azteca* exposed to sediments from our test sites showed that survival was affected by something from the southern oxbow and Byhalia site. Sediments from the area planned for wetland construction and the southern site affected suppressed growth (Table 3). The southern site also showed significant reduction in guarding behaviour. There were not enough survivors to test growth or behaviour at the Byhalia sites.

Table 3. Twenty-eight-day responses of *Hyalella Azteca* exposed to oxbow lake sediments

Site	**Survival (%)**	**Growth (mg wet)**	**Pre-copulatory Guarding**
Southern Oxbow	66.7±21.5	1.1±0.4 *	0±0 *
Northern Oxbow	90.5±13.1	2.5±0.4	1.3±1.3
Wetland	92.9±13.1	1.8±0.3 *	1.3±1.1
Byhalia	11.9±8.1 *	N/A	N/A
Control	92.9±13.1	3.0±0.8	1.9±0.9

**Statistically significantly different from controls*

Refining our analysis verified only heptachlor significantly affected survival, and while concentration of γ BHC was high, it did not have a survival effect. Both growth and precopulatory behaviour was suppressed by Aldin, BHC, Heptachlor, copper, lead, chromium and zinc (Table 4).

Table 4. Spearman Rank correlations of intermittent oxbow lake sediment contaminants versus 28-day *Hyalella azteca* responses

Contaminar	Survival (N=35	Growth (N=28	Precopulatory Guarding Behaviour (N=28
Aldrin	-0.28 (*P*=0.099	-0.62 (*P*<0.001)	-0.60 (*P*<0.001)*
αBHC	-0.32 (*P*=0.059	-0.50 (*P*=0.007)	-0.57 (*P*=0.002)*
γBHC	-0.31 (*P*=0.061	-0.62 (*P*<0.001)	-0.60 (*P*<0.001)*
Heptachlor	-0.76 (*P*<0.001)	-0.50 (*P*=0.007)	-0.57 (*P*=0.002)*
Copper	-0.02 (*P*=0.928	-0.62 (*P*<0.001)	-0.60 (*P*<0.001)*
Lead	-0.02 (*P*=0.928	-0.62 (*P*<0.001)	-0.60 (*P*<0.001)*
Chromium	-0.02 (*P*=0.928	-0.62 (*P*<0.001)	-0.60 (*P*<0.001)*
Zinc	-0.02 (*P*=0.928	-0.62 (*P*<0.001)	-0.60 (*P*<0.001)*

**Statistically significant correlation between contaminant and response.*

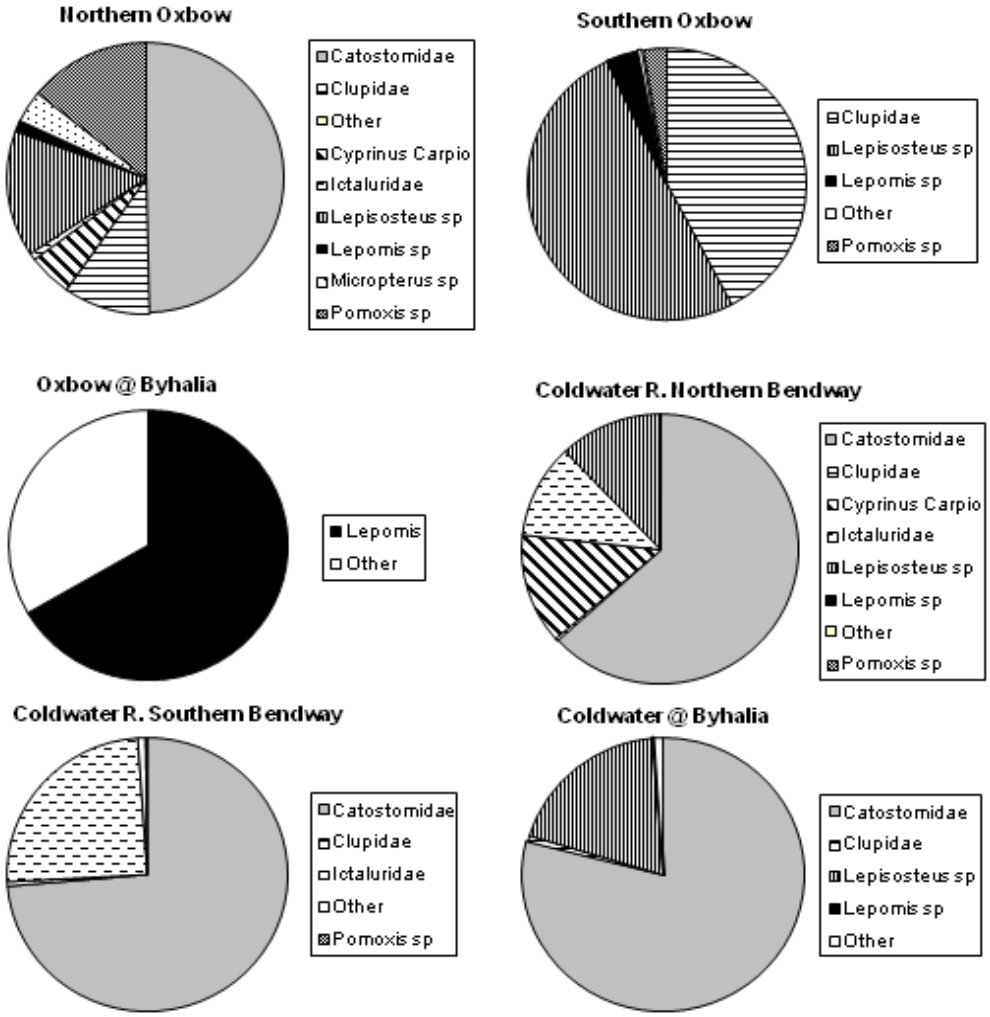

Figure 2. Percent catch by weight of fish from Coldwater River oxbows and adjacent river channel

Fish

Electrofishing from all sites produced 75.7 kg of fish from 474 individuals representing 27 species. Species richness was relatively low for all collection sites when considering that Mississippi is home to over 200 species of freshwater fishes (Ross 2001). Riverine sites produced 12 species, 135 specimens and 37.3 kg of fish while the oxbow sites produced 19 species, 239 individual specimens and 38.4 kg of biomass. Catch by number from our test sites show that while both the northern and the southern oxbow were dominated by clupeids, the northern oxbow (the least contaminated site)

supported more species and more centrarchids (Figure 2). All sites had higher catches and diversity than the Byhalia oxbow site which only produced two fish representing two species. Species composition was typical of oxbow fish communities in Mississippi and includedbigmouth and smallmouth buffalo, *Ictiobuscy prinellus* and *I. bubalus*, channel catfish, *Ictalurus punctatus*, common carp, *Cyprinuscarpio*, spotted gar, *Lepisosteus oculatus*, and a variety of centrarchids including black and white crappie Pomox is *nigromaculatus* and *P annularis*, largemouth bass, *Micropterus salmoides*, bluegill, *Lepomisma crochirus* and orange spotted sunfish, *Lepomishumilis* (Knight and Welch, 2004). Catch by weight showed that the less contaminated northern oxbow was dominated by buffalo, *Ictiobus sp*. crappie, *Pomoxis sp*. and catfish, *Ictalurus sp*., while the catch from the southern oxbow was dominated by gar *Lepisosteus sp*. and gizzard shad, *Dorosoma cepedianum*(Figure 3).

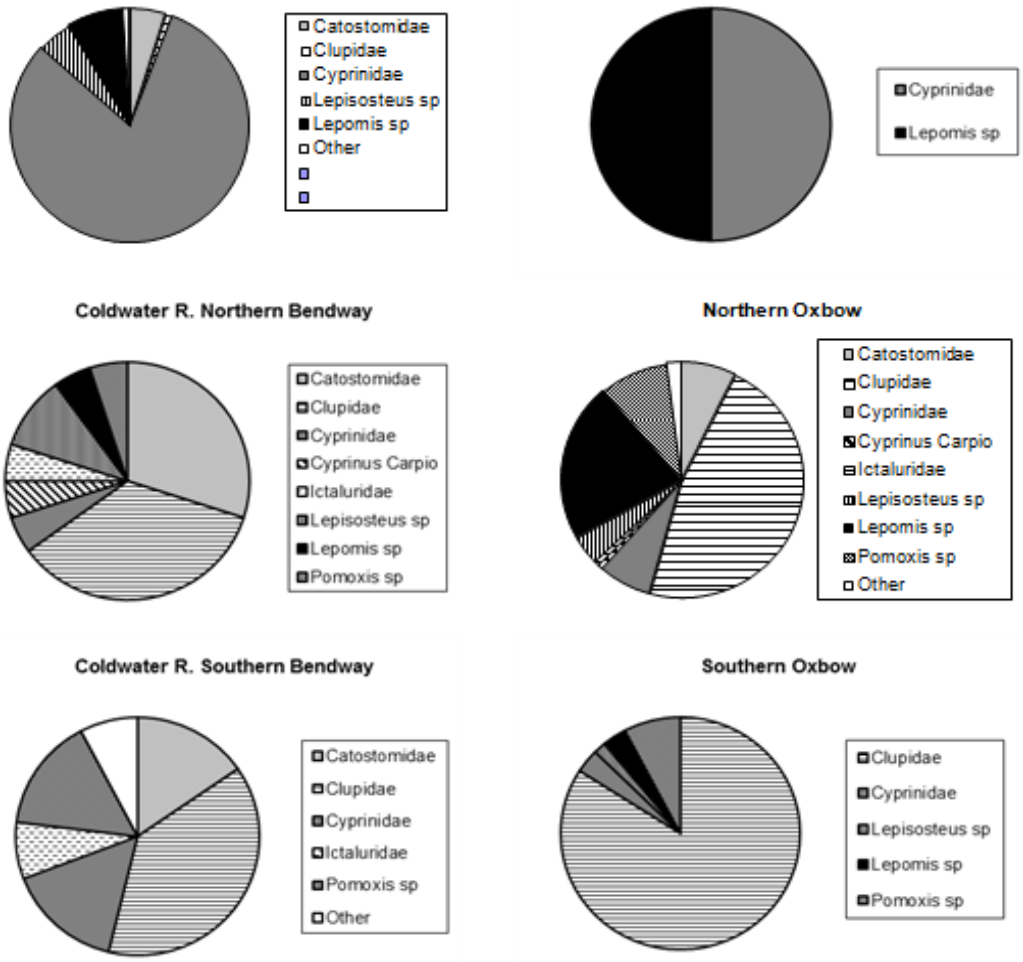

Figure 3. Percent catch by number of fish from Coldwater River oxbows and adjacent river channel

River catches produced similar total biomass to oxbow catch despite the fact that the Byhalia oxbow site produced only 9 grams of fish. Numbers of specimens were almost twice that of the oxbows compared to the river samples producing 135 and 239 individuals, respectively, and the oxbows supported more species; 19 for the oxbow as opposed to 12 for the river sites. Based on the fish catch information alone, the very low catches for the Byhalia site indicated this site would not be suitable site to use as an experimental control. Coupling this information with the high mortality of *Hyalella* exposed to sediments form the Byhalia oxbow site the fish community data indicates some type of ecological impairment is occurring at a fundamental level and perhaps warrants additional study.

Conclusion

This study, conducted as a part of a river backwater restoration project was designed to test for sediment toxicity and to examine associated fish communities for indications of barriers that would prevent successful restoration. While current use pesticides were not detected from the sediment

samples collected during our study, legacy pesticides were found. Metal concentrations were typically higher in sediments from the delta sites than those from control site. Despite the presence of low levels of pesticide and metals, little effect on *Hyalella azteca* was observed. Additionally the Delta sites supported a more diverse and healthier or, perhaps, a more desirable fish community than our control sites. Delta sites produced 7 more species, larger catches and more specimens of fish than the control site. The results from the Byhalia control site indicate that this site was not a good control to measure success of our restoration project. Although the sediments from the southern oxbow produced a toxic response in *Hyalella azteca* this oxbow still supported a fish community that was somewhat typical of Mississippi Delta oxbow lakes. The ecological data from the Byhalia sites pointed toward some type of impairment of its designated use of supporting fish and wildlife. While contaminates were found, further investigation is necessary to point to a specific stressor.

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