Exhibit 34

Exhibit 34

Ecological condition of a stretch of the Sangamon River receiving effluent from the Sanitary District of Decatur: Focusing on water chemistry, qualitative habitat assessment, and the mussel, macroinvertebrate, and fish assemblages

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EXECUTIVE SUMMARY

We sampled two treatment reaches of the Sangamon River for water quality and macroinvertebrate and fish assemblages. The two treatment reaches were 1) upstream of the Decatur Sanitary District main discharge (downstream of the Lake Decatur Dam), and 2) downstream of the main discharge. We sampled six sites monthly for water quality; one site located in the upstream reach, and five sites located downstream of the SDD. Six sites were sampled during fall 2015 for macroinvertebrate assemblages; three sites located in the upstream reach and three located in the downstream reach. Four sites were sampled during spring 2015 for fish assemblages; two sites located in the upstream reach and two sites located in the downstream reach.

Water quality in the upstream and downstream reaches differed during periods when discharge, measured at the Route 48 Bridge, was below 200 cfs. Most macroinvertebrate indices showed no difference between the two reaches, except significantly higher percent EPT downstream of the SDD main effluent outfall. A single season indicted that there are differences in macroinvertebrate assemblages between microhabitat types, and when comparing a single maicrohabitat between reaches. Ongoing studies are evaluating specific microhabitats to try to discern critical habitat between the reaches. A total of twenty-one fish species was sampled using pulsed DC electrofishing from the two treatment reaches of the Sangamon River. Catch per unit effort was highest in the upstream reach (Site 1) and lowest in the downstream reach (Site 12). Catostomidae species comprised over 45% of the total sample.

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INTRODUCTION

Rivers and streams are impounded for a variety of reasons, including residential, commercial, and agricultural water supply; flood and debris control; and hydropower production (Kondolf 1997). However, impoundments may impact downstream aquatic systems and their surrounding terrestrial habitats. They can affect riverine systems by altering the flow regime, changing the sediment and nutrient loads, and modifying energy flow (Lignon *et al.* 1995). In addition, impoundments may lead to diminished water quality and availability, closures of fisheries, extirpation of species, and groundwater depletion for surrounding areas (Abramovitz 1996, Collier *et al.* 1996, Naiman *et al.* 1995). As a result, downstream reaches may no longer be able to support native species, which will be reflected by reduced integrity of biotic communities (Naiman *et al.* 1995, NRC 1992).

A natural flow regime is critical for sustaining ecosystem integrity and native biodiversity in rivers (Poff *et al.* 1997). Depending on the use of the dam, it may have varying effects on downstream aquatic habitats. Impoundments used for urban water supplies lead to a reduction in flow rates downstream of the dam throughout the entire year (Finlayson *et al.* 1994), as well as increase daily and seasonal variability in flow regime (Finlayson *et al*. 1994, McMahon & Finlayson 2003). In addition, abiotic variables including temperature, dissolved oxygen, turbidity, pH, conductivity, and solids concentrations are altered in the downstream river system (Finlayson *et al.* 1994).

Along with stream and river impoundments, point source and non-point source pollution can have profound and lasting effects on the ecological integrity of the system. Non-point sources of pollution include agriculture, livestock grazing, and urbanization, and point source pollutions include sanitary discharge and industrial waste. In order to reduce point source pollution, the Water Quality Act of 1972 encouraged wastewater treatment plants to upgrade their systems. As a result, many communities were forced to build advanced tertiary water treatment facilities (Karr *et al.* 1985). Updated facilities still release high concentrations of nutrients into surrounding rivers. Carpenter and Waite (2000) documented that concentrations of phosphorus were highest in streams draining agricultural basins and at sites influenced by wastewater discharges, and Twichell et al. (2002) reported that sewage effluent inputs had elevated nitrate levels. The enhanced nutrient discharge can be expected to increase productivity within a river because primary productivity and detrital processing usually are limited by low ambient stream nutrient concentrations (Stockner and Shortreed 1978, Elwood et al. 1981, Winterbourn 1990).

Unlike impoundments and pollution, droughts are a natural phenomenon, but they can also severely affect aquatic ecosystems. Droughts can alter the lotic systems in ways harmful to biota, including loss of habitat, food resources, and stream connectivity (Lake 2003). The overall effect drought has on aquatic communities varies, and often depends on the availability of refugia and life history of the organisms (Humpheries and Baldwin 2003, Lake 2003). Macroinvertebrates, especially sensitive taxa such as stoneflies and caddisflies, can be temporarily decimated by drought conditions (Boulton 2003). The effects of a drought depend on many factors, including its severity, length, and the previous condition of the lotic system: specifically anthropogenic perturbations. Human disturbances such as impoundments can be exacerbated by drought conditions, decreasing the amount of dilution for pollution sources in lotic systems. This can lower the resilience of the aquatic ecosystem (Bond *et al.* 2008), potentially worsening their effects.

The Sangamon River

The Sangamon River, the largest tributary to the Illinois River, flows for approximately 200 km in central Illinois, and its 14,000 km^2 watershed extends to 18 counties. Streams converging with the Sangamon River run through glacial and alluvial deposits, creating a low gradient stream with sand and gravel substrates. The Sangamon basin has experienced multiple point and non-point source impacts throughout the years. The Sangamon River watershed is dominated by agriculture and has the highest percentage of its land in crops of all major watersheds in the state (IDNR 2001). Major cities along the river include Bloomington, Decatur, and Springfield, and are home to more than 500,000 people. The Sanitary District of Decatur (SDD) serves more than 100,000 people and 24 major industrial users. The Sangamon River immediately below Lake Decatur is influenced by impoundment, altered flow regime, and point source discharges.

Due to multiple anthropogenic influences, the biotic integrity of the Sangamon River is in constant flux. An intensive sampling program began in 1998-99 and continued through 2015 to document temporal and spatial heterogeneity of an 8.5 km urban reach of the Sangamon River. Two new sampling sites were added starting in June 2015 to include a larger reach of the river. Sampling began directly below the Lake Decatur Dam and continued downstream to incorporate discharges from the Sanitary District of Decatur. These studies (Fischer & Pederson 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014) were intended to characterize stream habitat quality and assess impacts from ongoing reservoir and urban management by evaluating biotic integrity at various trophic levels in the context of the physical and chemical nature of the Sangamon River.

Original sampling locations were associated with operation of the Sanitary District of Decatur that were easily identified by landmarks within the city of Decatur, Illinois, USA. Sites were established in 1998 in conjunction with combined sewage overflow (CSO) facilities and the main treatment plant. Sites were located in the mainstem of the Sangamon River extending from directly below the Lake Decatur dam to the Mechanicsburg Road Bridge, located approximately 30 miles west of Decatur. Sites 1, 3, 4, 5, 6, 7, and 8 extend from the dam to directly above the discharge of the main treatment plant in the upstream reach, and sites 9, 11, 12, and 14 extend from the main treatment discharge to a point approximately 8 river miles downstream near Lincoln Trail Homestead State Park. Sites 15 and 16 extend from Mt. Auburn to Mechanicsburg in order to include a more expansive reach of the river.

We sought to assess the water quality, as well as the macroinvertebrate, and fish communities of the Sangamon River near Decatur, Illinois. We sampled the communities in two treatment reaches; one above and one below the Decatur Sanitary District main effluent. Although all of these metrics individually provide some measure of habitat, the combination of all data will provide a broader analysis of the quality of system. Both biotic and abiotic assessments of a given resource are used to determine how closely habitats compare to potential. The goal is to identify any factors affecting this ratio as targets for remediation. The analysis may include not only historic ecological indices of multiple trophic levels of biota, but economic and recreational value of an aquatic system as well. For example, although sportfish make up a small portion of the fish assemblage they almost always have the greatest economic and recreational value. As top predators, they may reflect changes in lower trophic levels, but many are not especially sensitive to water quality. In contrast, Unionid mussels have shown sensitivity to various assaults on lotic systems. Mussels can be affected by substrate type and flow (Harman

1972; Strayer 1983; Vaughn 1997; Watters 1999), and can be harmed by excessive concentrations of heavy metals, phosphorus, and nitrogen (Beckvar *et al.* 2000; Jacobson et al 1997; Mummert et al 2003; Wang et al 2007). As such, the U.S. Environmental Protection Agency proposed using mussel communities in setting ammonia standards (Great Lakes Environmental Center 2005). Based on this information it is important to include these specific communities in assessment of aquatic systems. Macroinvertebrates represent a diverse assemblage occupying multiple habitats in aquatic systems. They have shorter life spans and are less mobile than fishes. Thus they can offer more detailed insight into short term impacts or microhabitat specific concerns.

METHODS

Water Data Collection and Chemistry Determination

We collected water quality data monthly from June 2015 to April 2016. Sampling began downstream of the Lake Decatur Dam and the Oakland CSO and proceeded downstream. In the field, we used a YSI ProDSS handheld meter to measure dissolved oxygen, temperature, and specific conductivity, pH, and chloride. In June 2015 we began collecting water samples that were delivered to the SDD for nickel quantification. Water samples were collected just below the surface, returned to the lab on ice, and analyzed within accepted time limits. All analyses followed the Standard Methods for Examination of Water and Wastewater (APHA, 1995).

Total oxidized nitrogen (NO_2-N + NO_3-N) was determined using the cadmium reduction method, and ammonia nitrogen was determined with the phenate method. We used the ascorbic acid method to determine total phosphorus (following persulfate digestion) and soluble reactive phosphate (following filtration). A Thermo Scientific Evolution 300 UV-VIS spectrophotometer was used for all colorimetric nutrient analyses. Hardness and alkalinity were measured using titration to colorimetric endpoint methods. We considered quality control procedures during all analyses, including but not limited to parallel analyses of laboratory standards.

We calculated and report the averages of each variable for the upstream and downstream reaches, as well as for summer and winter seasons. Winter is defined as November 1 - April 30 when sanitary effluent does not undergo disinfection prior to release into the river. Summer is defined as May 1 – October 31 when sanitary effluent undergoes disinfection prior to release in the river. In order to determine overall differences between reaches and seasons, principal components analysis (PCA) was conducted for 11 variables after individually log transforming and normalizing the data.

Assessment of Macroinvertebrate and Freshwater Mussel Communities

Macroinvertebrate assemblages were sampled during summer of 2015 from microhabitats present at six sites in the Sangamon. Three sites (3, 5, 7) were upstream of the effluent discharge of Decatur’s sanitary district but below the dam of Lake Decatur and three (12, 14, 16) were below the discharge up to 25 miles downstream. Each site was approximately 100 meters in length. Five microhabitat types were sampled, if present, at all sites with three replicates per sample. These microhabitats included riffles, leaf packs, root wads, snags and fine sediments. Three sub samples were taken in each microhabitat type per site. Sampling procedures varied by microhabitat type and were done following the methods described by the EPA macroinvertebrate multihabitat sampling protocol (EPA 2012). Sampling fine sediments or riffle microhabitats included three “jabs” with an 18 inch square frame dipnet. A two foot section was sampled from rootwad and snag microhabitats. Leaf pack samples were taken from areas less than half the size of the dipnet. Contents from each jab were concentrated using a bucket sieve, individually placed in a sampling jar, and preserved by addition of 95% ethanol. These were labeled with the site number, microhabitat type, and any unique details about the sampled habitat, and taken back to EIU for processing and identification.

Processing and Identification

In the lab, we subsampled macroinvertebrates from each site using a 9 grid tray. Grids were selected at random until a target of at least 100 macroinvertebrates per microhabitat sample were picked with a minimum of three grids (33% of the sample) selected, plus any large or rare taxa. All individuals were identified to taxonomic levels required by Illinois RiverWatch (typically family-level). Voucher specimens were catalogued into the EIU invertebrate collection.

We assessed the relative abundance, taxonomic richness, Simpson's diversity (D), percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, and macroinvertebrate index of biotic integrity (MIBI) based on taxon-specific environmental sensitivity values using the Illinois RiverWatch protocol. The Simpson's diversity (D) was calculated using the formula:

$$D = \frac{1}{\Sigma p_i^2}$$

where p_i = is the proportion of the total number of individuals comprised by species *i*. We performed an one way ANOVA to assess differences between upstream and downstream sites. We also performed a two way ANOVA to assess differences in microhabitat type and the potential difference in equivalent microhabitats upstream as opposed to downstream sites. Analyses were performed using R (version 3.2.2; R Foundation for Statistical Computing 2015). Microsoft Excel was used to display pie charts for each microhabitat's community structure for each site.

Mussel assemblages will be sampled in summer 2016 in the second year of the grant.

Assessment of Fish Community

We sampled fish communities at two sites upstream of the SDD (Sites 1 and 6) and two sites downstream of SDD the (Sites 9 and 12) on 12 May 2015 using pulsed DC electrofishing (60 Hz, 25% duty cycle). Each site was sampled for a total effort of 30 minutes. An estimate of relative density was calculated as catch per unit effort (CPUE) as number of fish captured per hour. Fish were identified, weighed (g), measured (mm), and released. All fish that could not be identified in the field were immediately euthanized in formalin and taken back to the laboratory for identification.

RESULTS

Water Data Collection and Chemistry Determination

A total of 11 water quality variables were determined for six sites along the Sangamon River (Table 1). Principal Components Analysis extracted four factors that explained 81.3% of the total variation in water quality of the Sangamon River during the sampling period. Discrete sampling events (site, date) cluster on the basis of stream reach and season (Figure 1). Variables included in the analysis were temperature, dissolved oxygen, pH, conductivity, chloride, hardness, total alkalinity, total oxidized nitrogen, ammonia, total phosphorus, and nickel. Chloride was later removed due to lack of data. Variation in component 1 is largely due to total phosphorous ($r = 0.666$), conductivity ($r = 0.533$), temperature ($r = 0.378$), and total alkalinity ($r = 0.315$), whereas component 2 is heavily influenced by temperature ($r = 0.878$). Samples collected from the downstream and upstream during two periods of the year were significantly different (ANOSIM, Global $R = 0.301$, $p < 0.001$). Overall differences between upstream and downstream reaches continue to be influenced largely by total phosphate from the SDD treatment facility.

Pearson correlation analyses were used to assess the relationship between nickel concentrations and river discharge at sites 9, 12, 14, 15, and 16. Site 5, the only upstream site, was not included in the analyses because nickel was undetectable throughout the sampling period. Analyses revealed strong negative correlations for each site (Figure 2). However, these correlations were not statistically significant. Lowest nickel concentrations were seen at peak river flow, but nickel concentration varied extensively at low flow.

Assessment of Macroinvertebrate Community

A total of 26 different Riverwatch-level taxa was identified from the six sites sampled (Table 3). When comparing the combined assemblages at each site there was no significant difference between the 2 reaches for estimated relative abundance (p = 0.594) , total taxa richness (p = 0.504), EPT richness (p = 0.873) or MBI (p = 0.063) (Figure 2). Simpson's Diversity and percent EPT, however, was significantly higher downstream of SDD main outfall (p = 0.008, p = <0.001) (Figure 3). Macroinvertebrate assemblages varied by microhabitat type and by site within a microhabitat (Fig 4).

Differences in assemblages between microhabitat type were significant with the exception of MBI and EPT richness (p = 0.074, p = 0.263) (Figure 7). Differences in assemblage structure were also significant when comparing the same microhabitats upstream and downstream sites with the exception of overall richness and EPT richness (p = 0.115, p = 0.691) (Figure 7).

When comparing equivalent Microhabitats that were found at all sites (root wads, sediments, snags), estimated mean abundance and richness in snags and sediment habitats were significantly different between upstream and downstream sites (estimated abundance for sediments p = 0.006, snags p = 0.01; richness for sediments p = 0.042, snags p = 0.033) (Figure 6 and 5). However, snag values for these two parameters were higher downstream as opposed to sediments values which were higher upstream. Only snags had significantly higher values for both percent EPT and Simpson's Diversity downstream than upstream (*p* = <0.001, *p* = 0.017) (Figure 5). Root wads had significantly higher diversity downstream than upstream (*p* = 0.017) (Figure 4).

MIBI scores ranged between 5.3 ("poor") to 7.5 ("very poor"). Midges were much more abundant in the upstream reach while Hydropsychid caddisflies were much more abundant in the downstream reach. Taxa unique to the upstream reach included operculate snails and planorpid snails. Taxa unique to the downstream reach include dobsonflies and whirligig beetles.

Assessment of Fish Community

Pulsed DC electrofishing was conducted at four sites for 30 minutes each: 2 upstream and 2 downstream of the Sanitary District of Decatur. We sampled a total of 258 individuals from 21 species (Table 4). The most dominant family sampled was Catostomidae and comprised over 45% of the total sample. The sportfish community in the Sangamon River was comprised of sunfishes (*Lepomis* sp.), Largemouth Bass (*Micropterus salmoides*), and Spotted Bass *(Micropterus punctulatus)* (Table 4). The non-sportfish community was dominated by Gizzard Shad *(Dorosoma cepedianum),* Smallmouth Bufallo (*Ictiobus bubalus),* and River Carpsucker *(Carpoides carpio)* (Table 4).

Relative density, as estimated by catch per unit effort (CPUE) in fish per hour, was highest in the upstream reach at Site 1 and lowest in the downstream reach at Site 12 (Table 5).

DISCUSSION

The primary differences between the upstream and downstream reaches are likely attributable to metrics related to reservoir discharge and inputs from the SDD main discharge. Outflow from Lake Decatur is the primary input to the upstream reach, which is compromised as a result of management to maintain reservoir levels by eliminating outflow. The discharge from the main treatment plant of the SDD alters instream water chemistry, especially during periods of low reservoir discharge. Consistent flow downstream of the SDD's main outfall during low discharge periods may help maintain physical habitat quality while the upstream reach becomes disconnected pools. Although negative correlations of water flow and nickel concentrations were not statistically significant, the trend was for lower nickel concentrations during periods of high flow. These relationships may be of biological importance and agree with other water chemistry patterns. Due to the small amount of data on nickel concentrations in the Sangamon River, further examination of this relationship to river discharge is necessary. Future analyses should take into consideration the volume of reservoir outflow and discharge from the SDD's main outfall, as well as nickel concentration in the effluent stream, during the time of water sample collection.

The macroinvertebrate community above the effluent was heavily dominated by aquatic midges. Midges are common in organic rich habitats and are often the most abundant taxa in these habitats (Rabeni and Wang 2001). Most metrics commonly used to describe water quality (e.g., taxa richness, MBI) in terms of combined assemblages were not significantly different between reaches sampled, with the exception of percent EPT and Simpson's diversity which was significantly higher in the downstream reach. However, macroinvertebrate assemblages vary between microhabitats, and it appears that they communities from the same microhabitats also differ between upstream and downstream reaches (Figure 7). In light of these results we will continue to sample available microhabitats (riffles, root wads, leaf packs, snags, sediments) to better assess small scale influences on macroinvertebrate communities in the Sangamon River. Any potential habitat restoration should attempt to maximize the most productive microhabitats to support the largest diversity of macroinvertebrate assemblages.

Future, more extensive sampling using multiple gears will allow a more accurate representation of the fish species composition. Fish assemblages will be sampled during 2016 using pulsed DC electrofishing, as well as seines. Future sampling will assess the age structure, growth, and condition of several fish species in the Sangamon River. These data will be used to determine the economic value and best management strategy for the fishery in the Sangamon River.

Sampling of Unionid mussel populations will continue during Summer 2016 when the river returns to baseflow.

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TABLES AND FIGURES

Table 1. Measured water quality variables for six Sangamon River sites associated with the Sanitary District of Decatur. Variables below the detection limit are indicated as 0.00. Missing data are indicated by blank cells.

Date	Gage Height (ft)	Site	Discharge (cfs)	DO (mg/L)	Temp (C)	pH	Spec. Cond	Chloride	Hardnes (mg/L)	Total Alk (mg/L)	NO2/NO3 (mg/L)	NH4 (mg/L)	PO4 Total (mg/L)	Nickel (mg/L)
6/22/2015	10.81	5	2840	10.22	23.8	8.03	581		474.5	390.88	9.987420659	0.130701848	0.241086594	
7/20/2015	4.01	5	180	7.2	25.9	8.21	485.5		401.5	139.6	7.073427637	0.078468109	0.215351818	0
8/19/2015	2.28	5	3.6	5.12	25.1	8.28	650		401.5	237.32	1.530013339	0.618040447	0.427613103	0
9/21/2015	5.74	5	495	8.44	22.1	8.26	432.7	10	766.5	209.4	0	0.013098691	0.239227187	0
10/21/2015	1.98	5	0.87	5.82	12.7	7.778	678		521.95	181.48	2.300338004	0.051841312	0.047085865	0.00246
11/16/2015	2.1	5	2.4	4.8	8.4	7.64	666	16.26	470.85	195.44	0.101056748	0.255437017	0.064382873	0
12/16/2015	7.29	5	936	11.97	8.2	8.87	585	9.74	1153.4	195.44	9.80558262	0.052382273	0.08874265	0
1/19/2016	5.79	5	521	15.02	0.3	8.01	568	2.26	339.45	265.24	8.449519031	0.035252877	0.087534284	0
2/18/2016	3.72	5	165	14.77	1.4	8.39	589	5.47	518.3	153.56	6.458833496	0	0.157121302	0
3/22/2016	4.7	5	311	11.39	10.4	8.33	578	14.62	401.5	111.68	6.641280498	0.036075259	0.032973534	0.00412
4/21/2016	5.22	5	514	9.67	16.1	8.33	556	24.81	394.2	167.52	6.116768561	0	0.135638224	
6/22/2015	10.81	9	2840	9.92	24	8.03	726		383.25	223.36	12.39055072	0.15987026	0.689173295	
7/20/2015	4.01	9	180	8.03	25.9	8.32	903		474.5	181.48	4.548672903	0.161473745	0.977854077	0.00416
8/19/2015	2.28	9	3.6	7.94	27.3	7.71	2778		503.7	237.32	6.128723877	0.162522501	2.449945048	0.0163
9/21/2015	5.74	9	495	7.99	22.5	8.19	751	29.67	693.5	293.16	0	0.041085854	1.696143316	0.00426
10/21/2015	1.98	9	0.87	7.55	24.5	8.07	3961		467.2	390.88	8.819973958	0.232107958	17.90304277	0.0298
11/16/2015	2.1	9	2.4	7.64	22.8	8.14	4261	172.45	394.2	558.4	6.279613639	0.588140639	13.89687331	0.0425
12/16/2015	7.29	9	936	11.62	9.3	8.8	824	24.27	496.4	139.6	8.308487801	0.01003163	0.976792031	0.00298
1/19/2016	5.79	9	521	14.61	1.7	7.91	823	8.22	302.95	97.72	6.806809123	0.051888826	1.651028524	0.00254
2/18/2016	3.72	9	165	15.84	3.1	8.27	879	14.25	386.9	153.56	5.855467032	0	2.046609156	0.00305
3/22/2016	4.7	9	311	10.59	12	8.13	1122	35.42	332.15	181.48	6.447210653	0.061795932	2.396121712	0.0122
4/21/2016	5.22	9	514	8.96	17.3	8.2	864	87.72	346.75	195.44	6.266462878	0.01090158	1.594181879	
6/22/2015	10.81	12	2840	9.15	23.7	7.98	654		452.6	209.4	8.418854232	0.129843954	0.388859868	
7/20/2015	4.01	12	180	7.41	25.4	8.3	593		470.85	209.4	3.740821545	0.045858752	0.548501169	0.00246

8/19/2015	2.28	12	3.6	7.34	25.5	8.1	2112		459.9	209.4	5.254946643	0.374599709	1.889273912	0.0114
9/21/2015	5.74	12	495	7.6	22	8.19	666	27.52	722.7	237.32	0	0.019318061	1.356401374	0.00409
10/21/2015	1.98	12	0.87	4.96	20.3	8.06	3877		427.05	349	7.040390155	0.14712511	16.74307799	0.0291
11/16/2015	2.1	12	2.4	5.27	18.3	8.15	4115	211.32	423.4	572.36	2.780647349	0.691220671	14.79279128	0.0404
12/16/2015	7.29	12	936	11.72	8.4	8.84	652	14.07	405.15	153.56	8.103004198	0.0141634	0.480813495	0
1/19/2016	5.79	12	521	17.88	0.3	7.88	645	3.74	317.55	139.6	6.14972516	0.048769585	1.001577071	0
2/18/2016	3.72	12	165	13.37	3.1	8.22	915	11.96	321.2	153.56	3.301215668	0	2.064188325	0.00283
3/22/2016	4.7	12	311	10.62	10.5	8.27	797	25.02	686.2	55.84	7.999769415	0.064032512	1.110940648	0.00355
4/21/2016	5.22	12	514	8.5	16.8	8.18	702	52.7	412.45	223.36	7.688558883	0	0.992720578	
6/22/2015	10.81	14	2840	9.39	23.7	7.96	645		405.15	223.36	7.188680513	0.125554482	0.436528666	
7/20/2015	4.01	14	180	7.33	25.2	8.29	582		379.6	251.28	4.5298074	0.079950353	0.482583918	0
8/19/2015	2.28	14	3.6	6.45	25.6	7.92	3512		514.65	293.16	8.786099378	0.271548108	2.321791645	0.0188
9/21/2015	5.74	14	495	5.6	20.4	8.05	2808	187.46	693.5	139.6	7.883947569	0.083584879	9.792591408	0.0181
10/21/2015	1.98	14	0.87	7	14.4	8.13	3600		401.5	335.04	6.877399257	0.042827979	14.96901421	0.0268
11/16/2015	2.1	14	2.4	7.67	10.8	8.22	3197	151.5	438	474.64	4.137515556	0.156535762	15.42325207	0.0343
12/16/2015	7.29	14	936	11.52	8.5	8.79	665	14.34	401.5	181.48	7.193005387	0.01003163	0.628699866	0
1/19/2016	5.79	14	521	14.6	0.2	7.96	701	4.75	361.35	125.64	6.528812062	0.08308123	0.703310477	0
2/18/2016	3.72	14	165	13.56	2.7	8.24	808	8.99	383.25	111.68	9.596339109	0.095085676	1.616192322	0.00379
3/22/2016	4.7	14	311	10.5	10.5	8.2	817	20.45	313.9	13.96	7.19114506	0	1.215043391	0.00406
4/21/2016	5.22	14	514	8.1	17.2	8.1	920	101.89	346.75	181.48	9.457816305	0.13393442	1.618240331	
6/22/2015	10.81	15	2840	9.36	23.2	8	670		456.25	195.44	7.331723968	0.100675542	0.508031863	
7/20/2015	4.01	15	180	7.05	24.3	8.17	614		416.1	181.48	4.3457107	0.12145317	0.530685696	0.00505
8/19/2015	2.28	15	3.6	10.2	24.7	8.02	2114		470.85	251.28	4.597987995	0.075899417	1.777139685	0.0104
9/21/2015	5.74	15	495	7.57	19.3	8.17	3032	210.27	770.15	446.72	4.269968356	0.001696514		0.017
10/21/2015	1.98	15	0.87	8.3	13	8.14	3117		459.9	349	6.823068957	0	14.18433215	0.0201
11/16/2015	2.1	15	2.4	9.02	8.9	8.22	3500	208.31	543.85	474.64	4.137515556	0	14.62688054	0.0437
12/16/2015	7.29	15	936	11.22	8.6	8.76	673	10.18	357.7	167.52	7.721391793	0.077172893	0.614942994	0
1/19/2016	5.79	15	521	13.85	0	7.97	698	3.71	339.45	153.56	7.463893086	0.030054143	0.703310477	0
2/18/2016	3.72	15	165	13.48	2.7	8.29	773	7.21	441.65	181.48	8.671177198	0	1.099364756	0.00554

3/22/2016	4.7	15	311	10.6	10.3	8.25	748	13.01	324.85	167.52	6.770660395	0.04166671	0.704604135	0.00309
4/21/2016	5.22	15	514	8.73	16.1	8.16	724	44.25	321.2	181.48	5.218602663	0	0.839347946	
6/22/2015	10.81	16	2840	8.53	23.1	8.19	690		503.7	209.4	7.274506586	0.128986059	0.508031863	
7/20/2015	4.01	16	180	6.8	24.2	8.12	600		456.25	83.76	5.029498441	0.076985866	0.391725004	0.00321
8/19/2015	2.28	16	3.6	8.29	24.7	8.16	1859		511	167.52	1.696420631	0.107262947	1.841216386	0.00752
9/21/2015	5.74	16	495	7.63	19	8.3	1836	100.36	748.25	335.04	1.194241366	0.039012731	5.453313132	0.0102
10/21/2015	1.98	16	0.87	8.66	13.3	8.26	2619		481.8	307.12	5.953784163	0.001624175	8.763880025	0.0158
11/16/2015	2.1	16	2.4	10.19	8.7	8.31	2770	33.39	470.85	376.92	2.196150275	0.074633161	10.67820505	0.0394
12/16/2015	7.29	16	936	10.77	8.8	8.65	718	1.87	375.95	181.48	7.868165795	0.0141634	1.062772479	0.00257
1/19/2016	5.79	16	521	14.01	0	7.85	649	3.54	306.6	167.52	5.846455639	0.062286294	0.67925672	0
2/18/2016	3.72	16	165	13.2	3.4	8.26	790	4.75	383.25	167.52	6.760516728	0.093586464	1.20483977	0
3/22/2016	4.7	16	311	10.82	10.1	8.29	727	9.93	361.35	69.8	6.12376091	0	0.624008463	0.00312
4/21/2016	5.22	16	514	8.76	16.4	8.11	712	45.59	302.95	181.48	8.073143879	0	0.725070299	

Table 2. Monthly nickel values for 6 Sangamon River sites associated with the Sanitary District of Decatur. Values below the detection limit are indicated as 0.00. River discharge at Route 48 bridge at time of sampling is also recorded.

Nickel Concentration (mg/L)	**5**	**9**	**12**	**14**	**15**	**16**	**River discharge (cfs)**
July	0	0.00416	0.00246	0	0.00505	0.00321	180
August	0	0.0163	0.0114	0.0188	0.0104	0.00752	3.6
September	0	0.00426	0.00409	0.0181	0.017	0.0102	495
October	0.00246	0.0298	0.0291	0.0268	0.0201	0.0158	0.87
November	0	0.0425	0.0404	0.0343	0.0437	0.0394	2.4
December	0	0.00298	0	0	0	0.00257	936
January	0	0.00254	0	0	0	0	521
February	0	0.00305	0.00283	0.00379	0.00554	0	165
March	0.00412	0.0122	0.00355	0.00406	0.00309	0.00312	311

Table 3. Summary of Illinois RiverWatch-level identifications of macroinvertebrates sampled in six sites and habitats found at the site in the Sangamon River in summer 2015. Upstream of effluent outflow being A. and downstream being B. Tolerance values can range from 0 (intolerant) to 11 (tolerant).

A.		Upstream of effluent outfall												
		Riffles	Root Wad			Sediments			Leaf Packs		Snags			
		7	3	5	7	3	5	7	5	7	3	5	7
Aquatic Worm	10	3	-	-	-	1	1	22	19	-	-	-	-
Sowbug	6	-	-	18	-	-	-	-	2	-	-	-	-
Scud	4	-	1	62	2	-	-	-	-	-	-	-	-
Dragonfly	4.5	-	1	6	2	-	-	-	-	1	-	-	2
Broadwinged Damselfly	3.5	-	-	4	-	-	-	-	-	-	-	-	-
Narrowwinged Damselfly	5.5	-	1	9	5	-	-	5	7	7	-	2	3
Dobsonfly	5.5	-	-	-	-	-	-	-	-	-	-	-	-
Torpedo Mayfly	3	-	-	-	-	-	-	-	-	-	-	-	-
Swimming Mayfly	4	-	5	2	1	-	-	-	3	3	1	2	-
Clinging Mayfly	3.5	-	-	-	1	-	-	-	1	1	1	-	2
Crawling Mayfly	5.5	-	6	2	1	17	4	2	2	-	10	5	1
Burrowing Mayfly	5	-	-	-	-	-	-	2	-	-	-	-	-
Other Mayfly	3	-	-	-	-	-	-	2	-	-	-	-	-
Hydropsychid Caddisfly	5.5	684	-	-	8	-	-	4	-	83	-	-	37
Other Caddisfly	3.5	-	-	-	2	-	-	1	-	1	3	-	4
Riffle Beetle	5	2	3	4	-	-	-	-	5	6	-	-	2
Whirligig Beetle	4	-	-	-	-	-	-	-	-	-	-	-	-
Water Penny Beetle	4	-	-	-	-	-	-	-	-	-	-	-	-
Biting Midge	5	-	-	-	-	-	-	-	3	-	-	-	-
Bloodworm Midge	11	-	-	-	-	12	64	-	-	-	-	-	-
Midge	6	814	134	231	294	408	554	245	256	1182	468	647	507
Black Fly	6	-	-	-	-	-	-	-	-	1	-	-	-
Other Fly	10	1	-	-	4	-	-	-	-	-	-	1	2
Left-Handed Snail	9	-	1	3	-	1	-	-	-	-	-	4	-
Right-Handed Snail	7	-	-	1	-	-	1	-	-	-	-	-	-
Planorbid Snail	6.5	-	1	1	-	1	-	-	-	-	-	-	-
Operculate Snail	6	-	-	-	-	4	-	-	-	-	11	-	-

B.	Downstream of effluent outfall												
	12	14	12	14	16	12	14	16	12	14	12	14	**16**
Aquatic Worm	-	6	1	3	18	-	-	12	-	1	-	-	-
Sowbug	-	-	4	4	-	-	-	-	-	-	-	-	-
Scud	-	-	-	6	1	-	-	-	-	-	-	-	-
Dragonfly	-	-	5	17	4	-	1	3	-	1	-	-	-
Broadwinged Damselfly	-	-	1	-	-	-	-	-	-	-	-	-	-
Narrowwinged Damselfly	-	-	20	103	42	-	1	-	4	3	-	-	1
Dobsonfly	-	1	-	-	-	-	-	-	-	1	-	-	-
Torpedo Mayfly	-	17	-	-	-	-	-	-	-	9	-	-	-
Swimming Mayfly	-	-	-	-	-	-	1	-	-	-	-	-	-
Clinging Mayfly	1	34	-	-	1	-	-	-	-	6	-	-	1
Crawling Mayfly	3	315	-	3	-	1	1	-	-	-	-	-	-
Burrowing Mayfly	-	-	-	1	-	-	-	1	-	-	-	-	-
Other Mayfly	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydropsychid Caddisfly	640	673	1	4	8	24	-	1	808	119	157	13	33
Other Caddisfly	-	1	10	7	197	1	-	-	1	-	-	-	2
Riffle Beetle	9	12	6	51	4	-	-	-	1	3	-	-	-
Whirligig Beetle	-	-	-	-	1	-	-	-	-	-	-	-	1
Water Penny Beetle	-	-	-	-	-	-	-	-	-	-	-	-	-
Biting Midge	-	1	-	-	-	-	-	1	-	-	-	-	-
Bloodworm Midge	-	-	-	-	8	-	-	-	-	-	-	-	2
Midge	404	184	267	71	270	9	36	22	824	787	43	32	308
Black Fly	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Fly	-	-	-	-	3	-	-	-	-	-	-	-	-
Left-Handed Snail	-	-	12	1	5	-	-	-	2	-	-	-	-
Right-Handed Snail	-	-	-	-	-	1	-	-	-	-	-	-	-
Planorbid Snail	-	-	-	-	-	-	-	-	-	-	-	-	-
Operculate Snail	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4. Summary of fish species sampled using pulsed DC electrofishing upstream and downstream of the Sanitary District of Decatur in the Sangamon River on 12 May 2015.

		Site				
		Upstream		**Downstream**		
Species		**1**	**6**	**9**	**12**	**Total**
Aplodinotus grunniens	(Freshwater Drum)	0	1	0	1	2
Carpoides carpio	(River Carpsucker)	7	13	13	10	43
Carpoides velifer	(Highfin Carpsucker)	1	0	0	0	1
Cyprinus carpio	(Common Carp)	1	0	0	1	2
Dorosoma cepedianum	(Gizzard Shad)	45	3	6	0	54
Hypophthalmichthys molitrix	(Silver Carp)	2	11	10	4	27
Ictiobus bubalus	(Smallmouth Buffalo)	9	14	19	9	51
Ictiobus cyprinellus	(Bigmouth Buffalo)	5	3	1	0	9
Ictiobus niger	(Black Buffalo)	2	6	2	1	11
Lepisosteus osseus	(Longnose Gar)	1	1	1	1	4
Lepisosteus platostomus	(Shortnose Gar)	4	2	6	3	15
Lepomis cyanellus	(Green Sunfish)	2	3	1	1	7
Lepomis humilis	(Orangespotted Sunfish)	1	0	0	1	2
Lepomis macrochirus	(Bluegill)	3	5	3	2	13
Lepomis megalotis	(Longear Sunfish)	0	0	0	1	1
Micropterus punctulatus	(Spotted Bass)	2	1	0	0	3
Micropterus salmoides	(Largemouth Bass)	0	1	4	1	6
Morone saxatilis	(Striped Bass)	1	0	0	0	1
Moxostoma anisurum	(Shorthead Redhorse)	0	0	2	1	3
Notropis hudsonius	(Spottail Shiner)	2	0	0	0	2
Notropis ludibundus	(Sand Shiner)	1	0	0	0	1
Total		89	64	68	37	258

Table 5. Catch per unit effort (CPUE) for fish species sampled using pulsed DC electrofishing upstream and downstream of the Sanitary District of Decatur in the Sangamon River on 12 May 2015.

Reach	Site	CPUE (fish per hour)
Upstream	1	178
	6	128
		Upstream mean = 153
Downstream	9	136
	12	74
		Downstream mean = 105

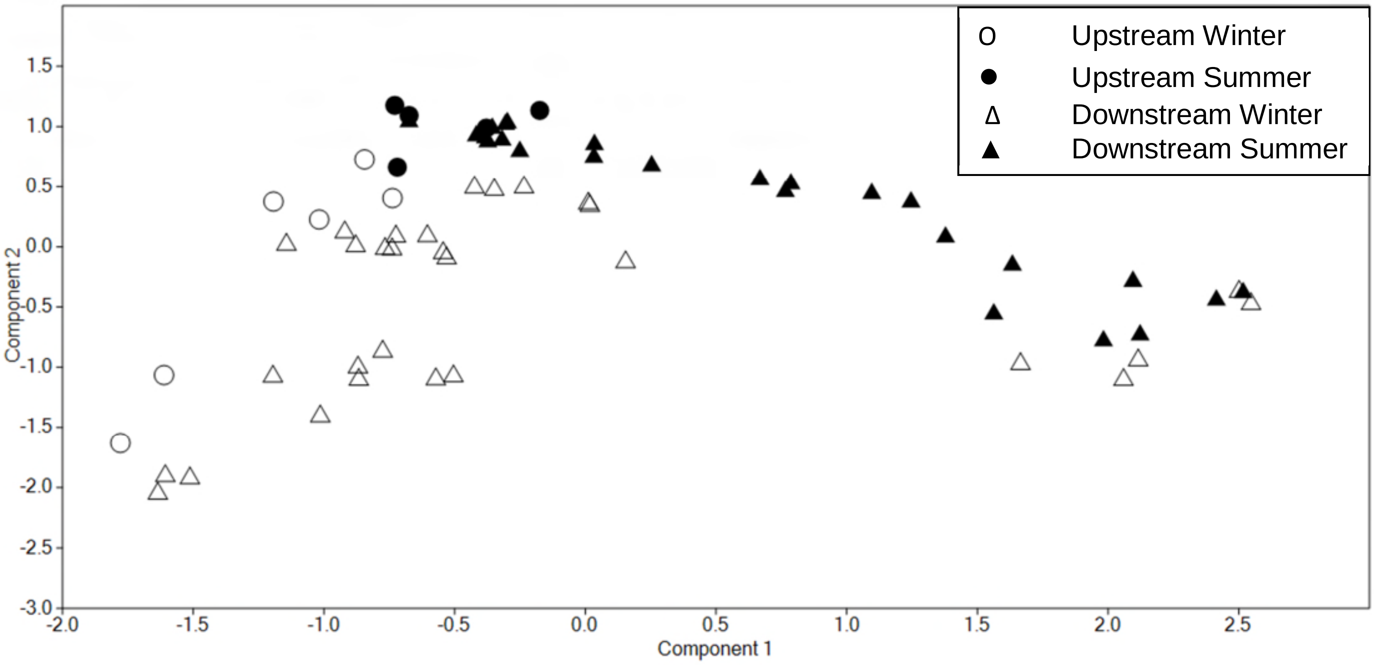


Figure 1. Principle components analysis of water quality data sampled during 2015-2016 from all mainstem water quality sites of the Sangamon River. PCA extracted four factors which account for a total of 81.3% of the variation in the data. Variation in component 1 is largely due to total phosphorous ($r = 0.666$), conductivity ($r = 0.533$), temperature ($r = 0.378$), and total alkalinity ($r = 0.315$), whereas factor 2 is heavily influenced by temperature ($r = 0.878$). Samples collected from the downstream and upstream during two periods of the years were significantly different (ANOSIM, Global $R = 0.301$, $p < 0.001$). Winter is defined as November 1 - April 30 when sanitary effluent does not undergo disinfection prior to release into the river. Summer is defined as May 1 – October 31 when sanitary effluent undergoes disinfection prior to release in the river.

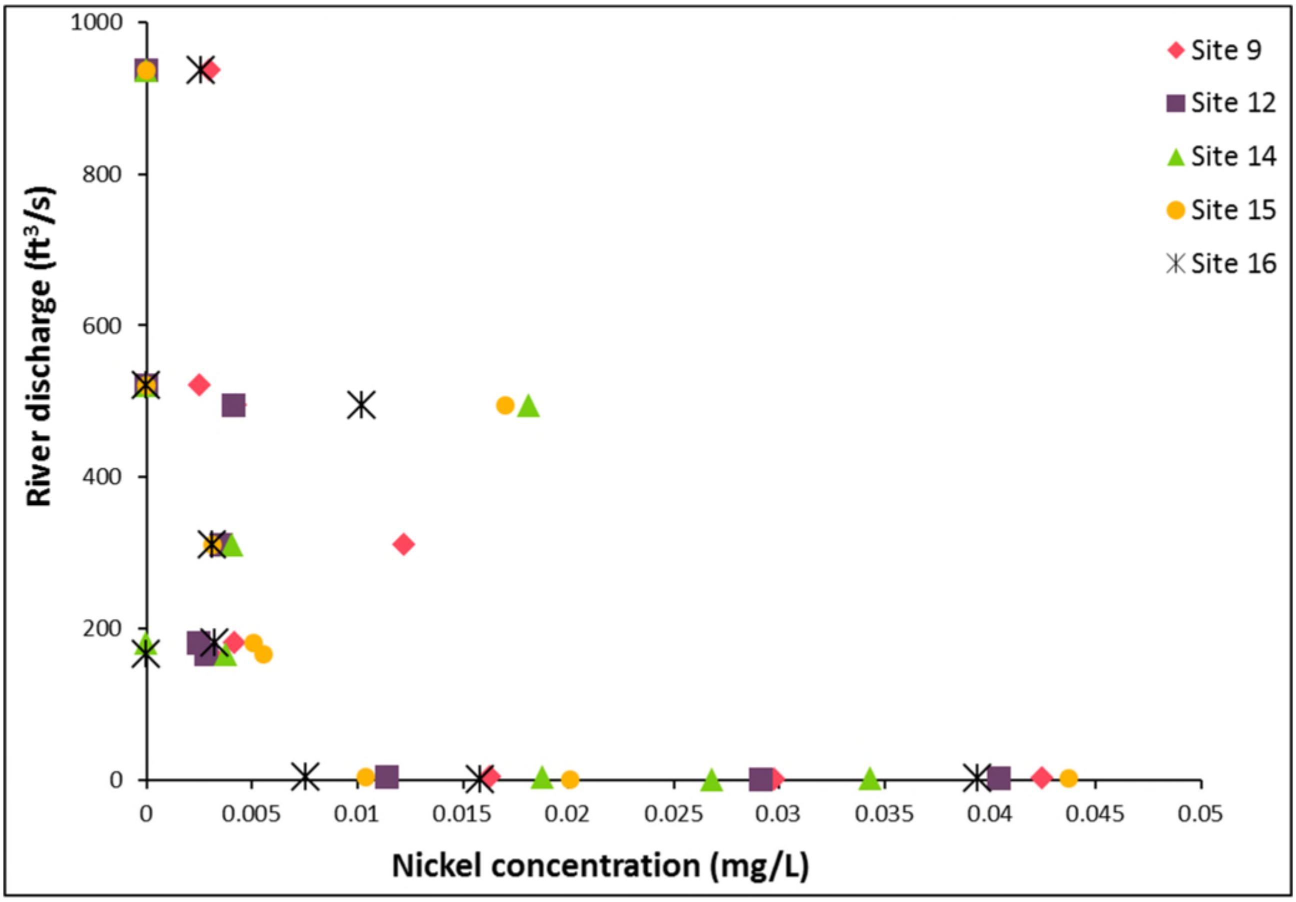


Figure 2. Scatter plot showing the relationship between nickel concentration and river discharge. Points represent each sampling event at each water quality site since July 2015. River discharge data are from the Route 48 Bridge. Nickel was only detected at Site 5 twice during the sampling period and was not included in this graph. Negative correlations were found for all sites in the downstream reach. However, these correlations were not statistically significant

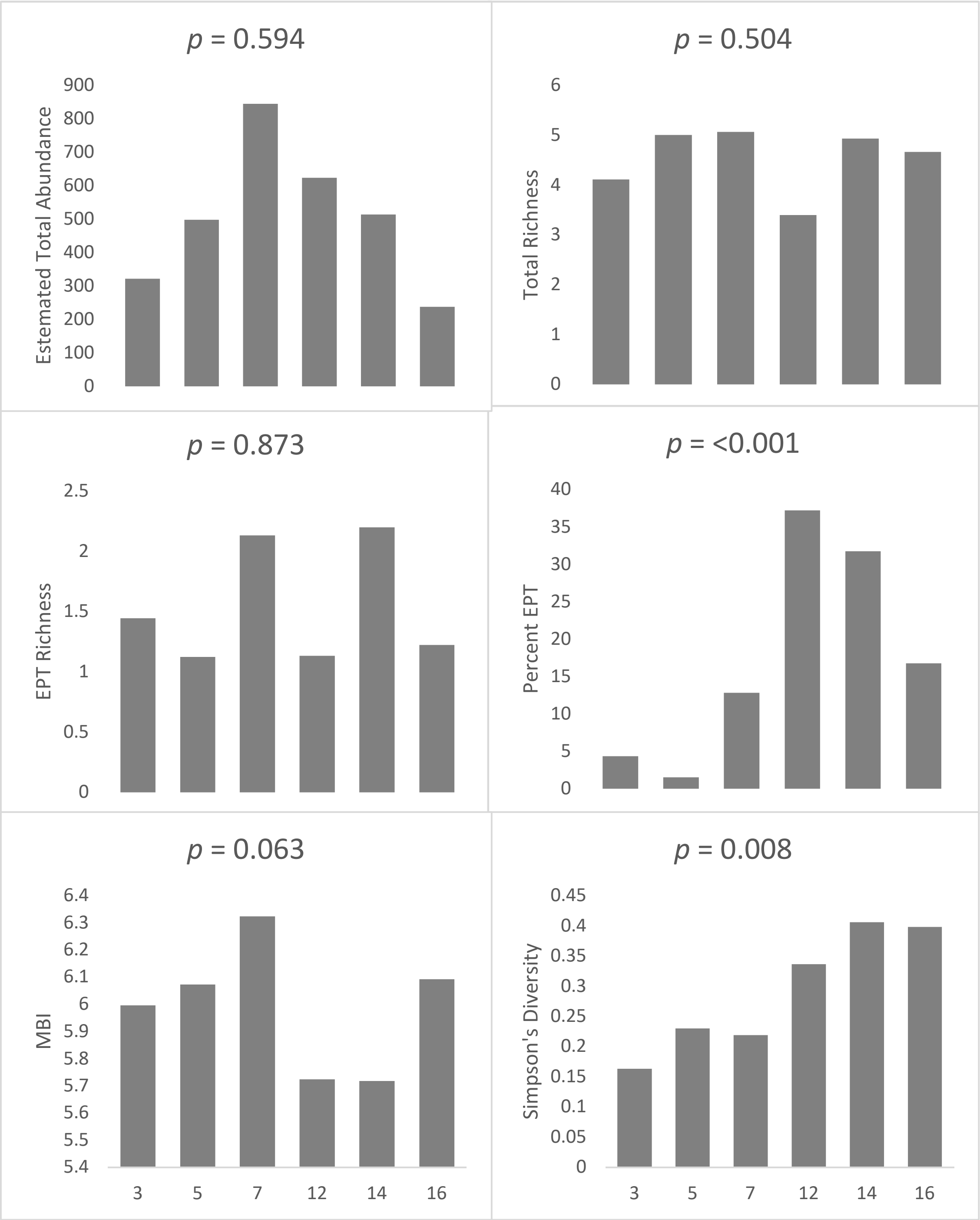


Figure 3. Comparison of the overall macroinvertebrate metrics in six sites of the Sangamon River in summer 2015. Sites 3, 5, and 7 are upstream of the main effluent outfall, and sites 12, 14, and 16 are downstream of the main effluent outfall. P-values compare the upstream reach to downstream reach. The percent EPT and Simpson's Diversity was significantly higher in the downstream reach (percent EPT p = <0.001, Simpson's Diversity p = 0.008)

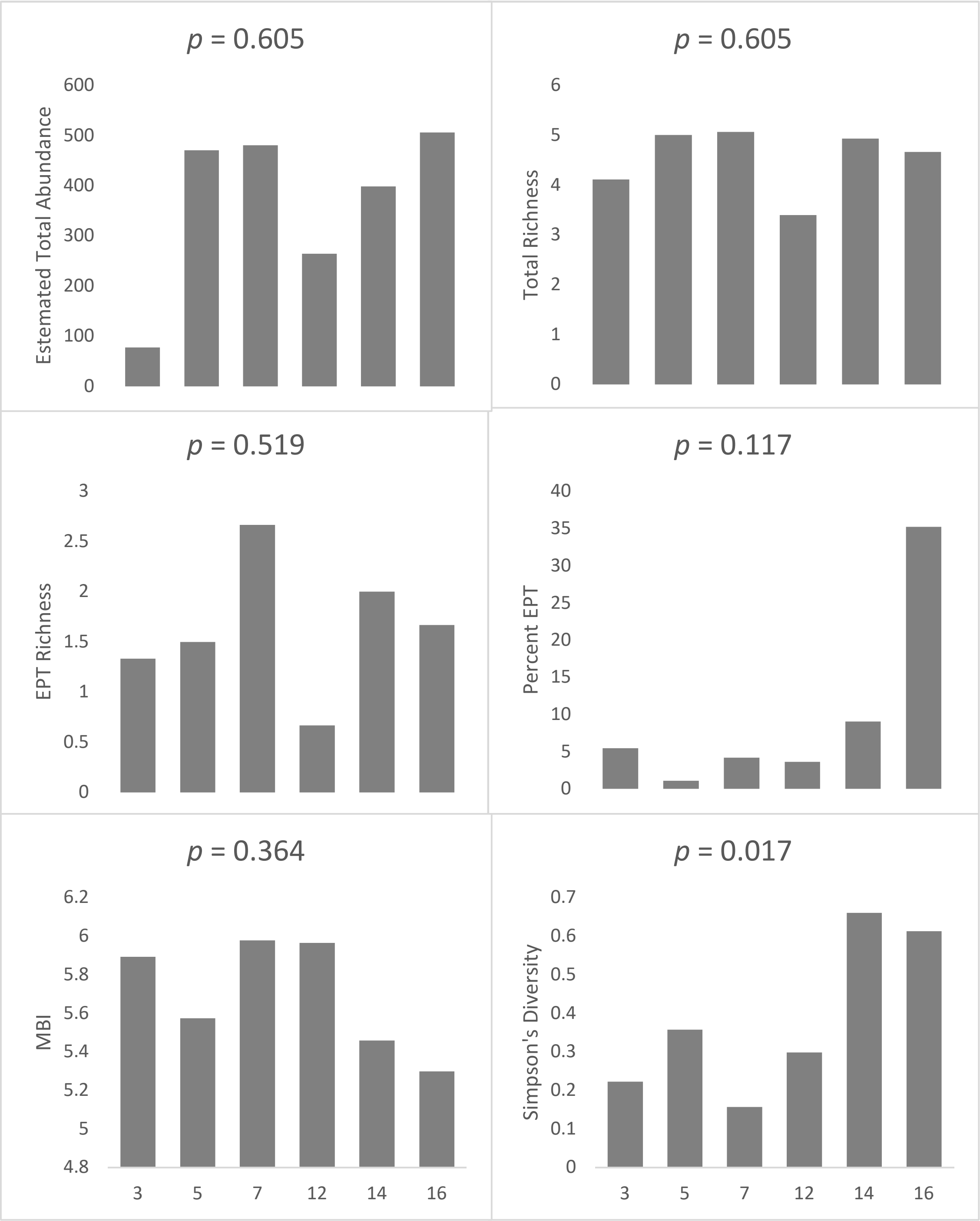


Figure 4. Comparison of macroinvertebrate metrics with root wads in six sites of the Sangamon River in summer 2015. Sites 3, 5, and 7 are upstream of the main effluent outfall, and sites 12, 14, and 16 are downstream of the main effluent outfall. P-values compare the upstream reach to downstream reach. Simpson's Diversity was significantly higher in the downstream reach (p = 0.017).

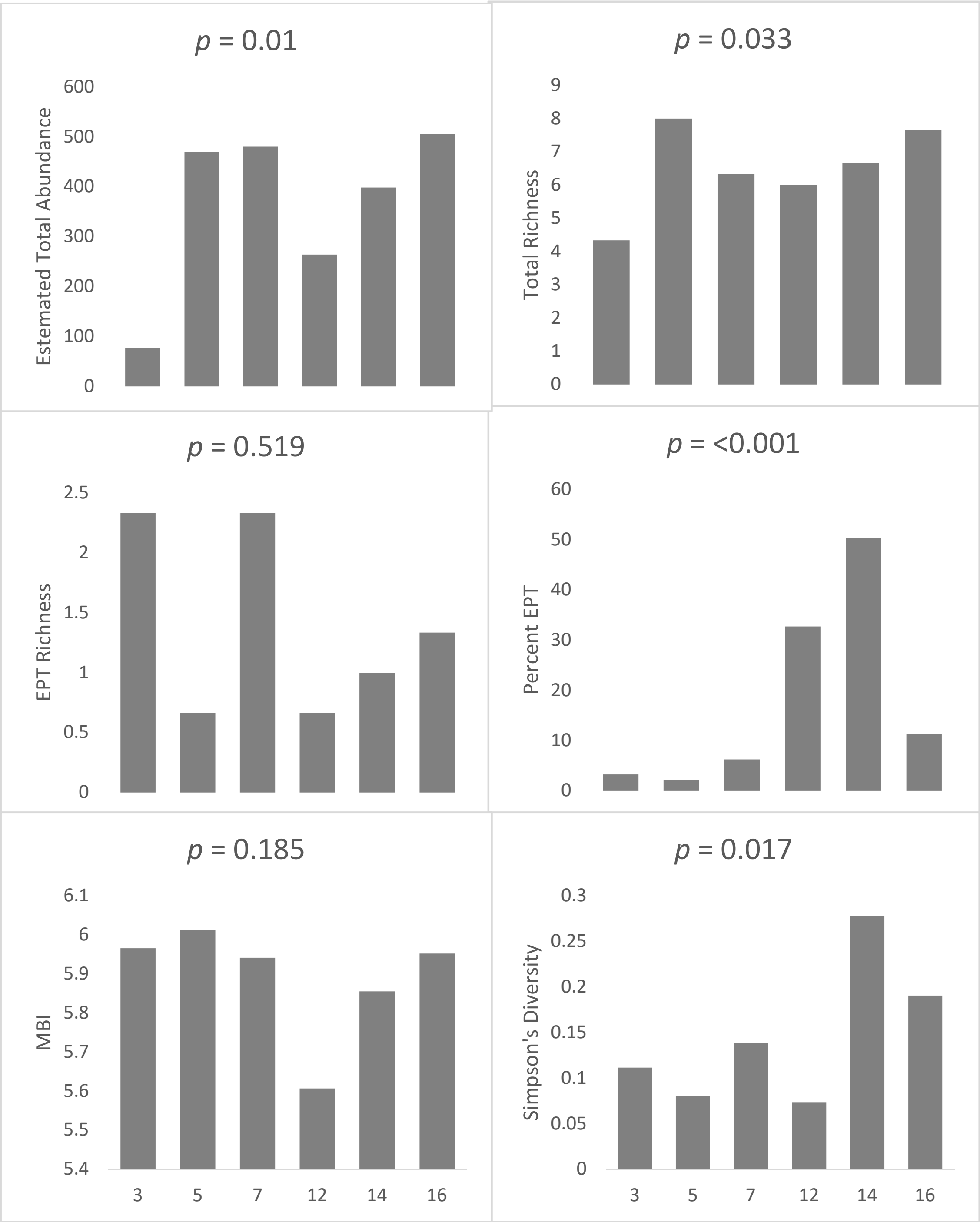


Figure 5. Comparison of macroinvertebrate metrics with snags in six sites of the Sangamon River in summer 2015. Sites 3, 5, and 7 are upstream of the main effluent outfall, and sites 12, 14, and 16 are downstream of the main effluent outfall. P-values compare the upstream reach to downstream reach. Simpson's diversity, percent EPT, total richness and estimated total abundance was significantly higher in the downstream reach (Simpson's diversity $p = 0.017$, percent EPT $p = <0.001$, total richness $p = 0.033$, estimated total abundance $p = 0.01$).

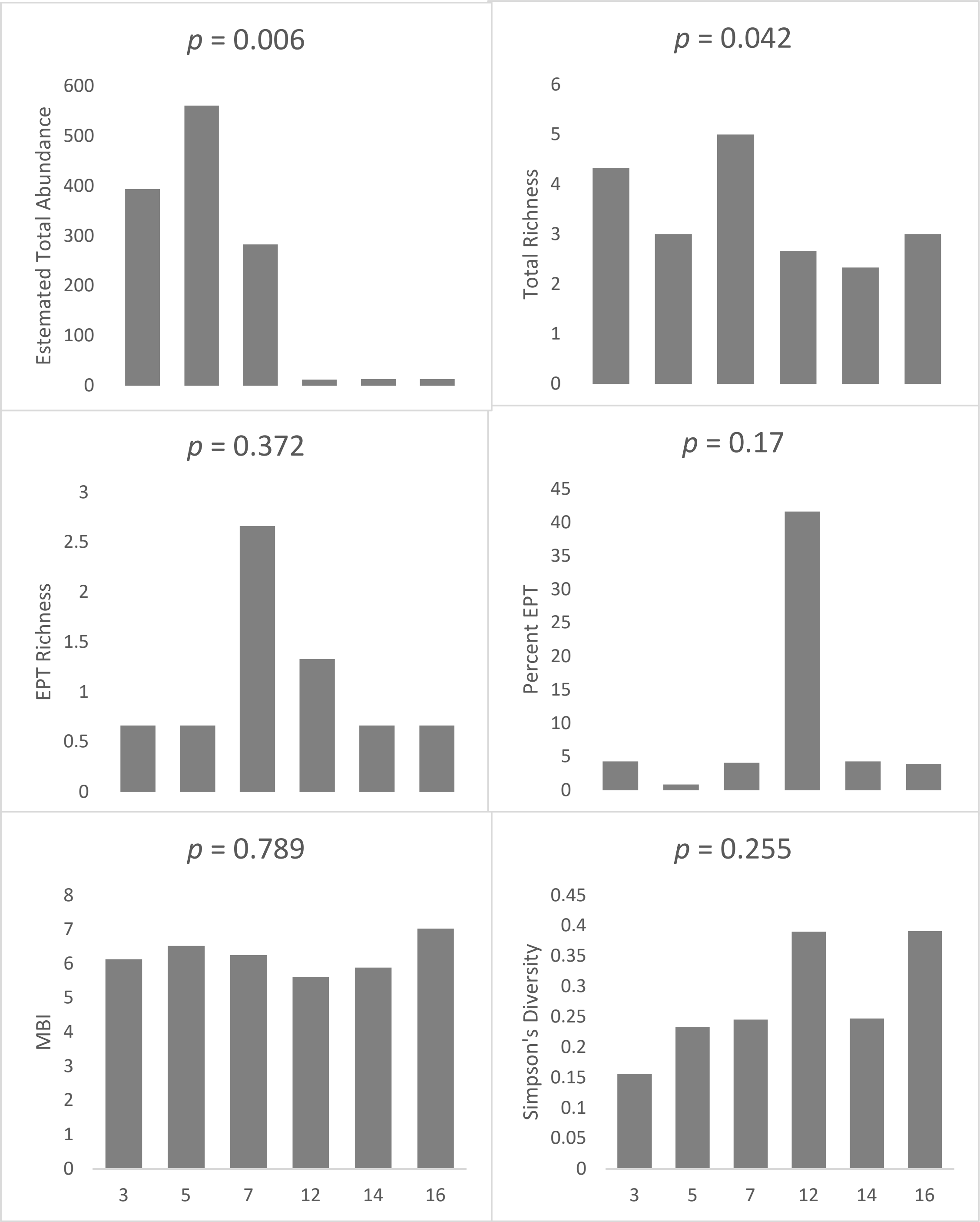
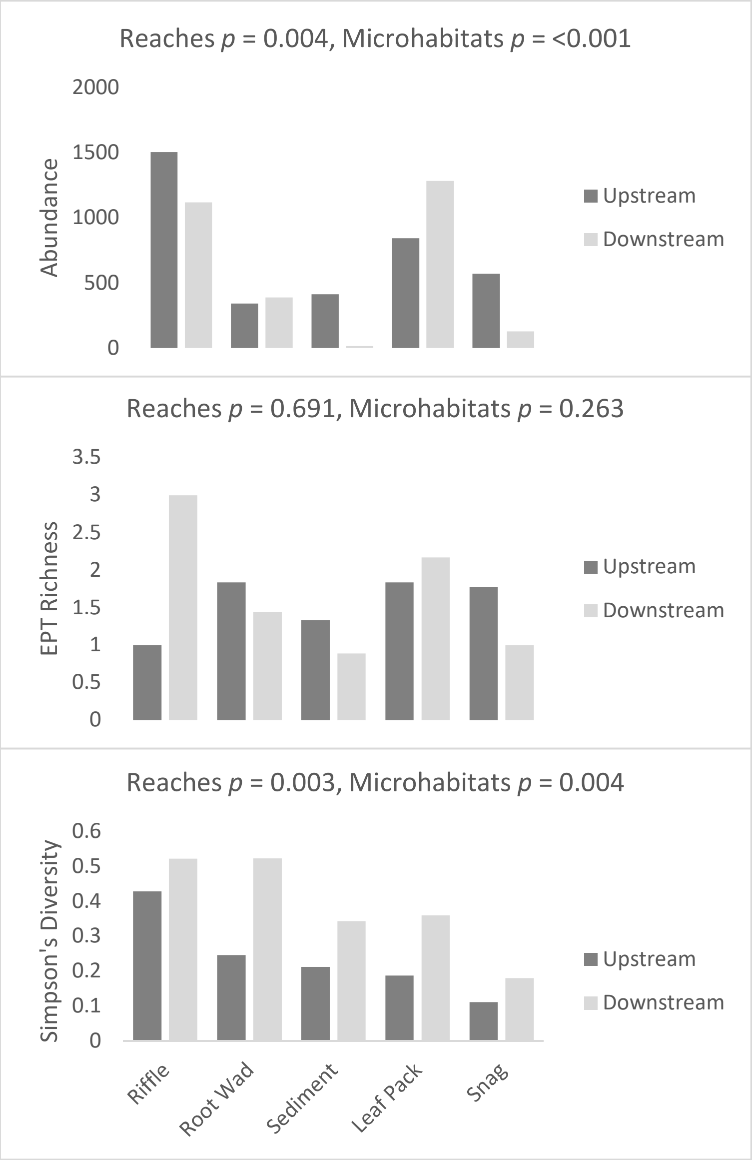


Figure 6. Comparison of macroinvertebrate metrics with snags in six sites of the Sangamon River in summer 2015. Sites 3, 5, and 7 are upstream of the main effluent outfall, and sites 12, 14, and 16 are downstream of the main effluent outfall. P-values compare the upstream reach to downstream reach. The total richness and estimated total abundance was significantly higher in the upstream reach (total richness $p = 0.042$, estimated total abundance $p = 0.006$).

A.


Reaches p = 0.004, Microhabitats p = <0.001
Abundance
2000
1500
1000
500
0
Upstream
Downstream
Reaches p = 0.691, Microhabitats p = 0.263
EPT Richness
3.5
3
2.5
2
1.5
1
0.5
0
Upstream
Downstream
Reaches p = 0.003, Microhabitats p = 0.004
Simpson's Diversity
0.6
0.5
0.4
0.3
0.2
0.1
0
Upstream
Downstream
Riffle
Root Wad
Sediment
Leaf Pack
Snag

B.

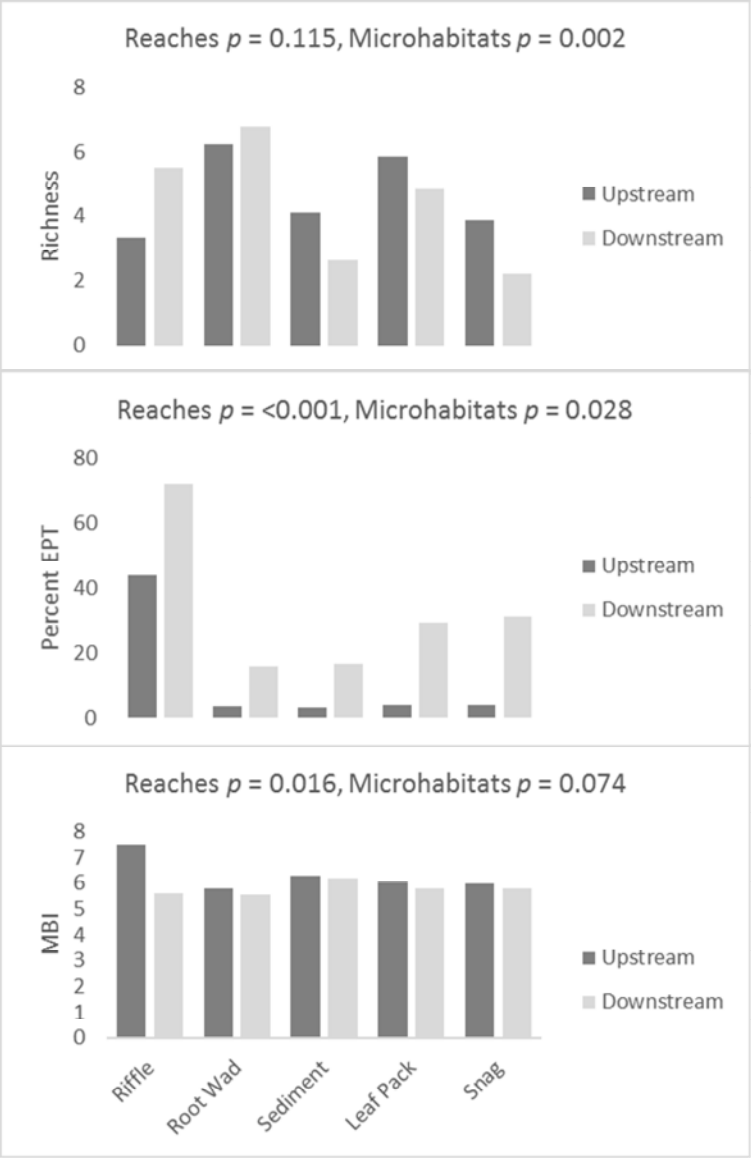
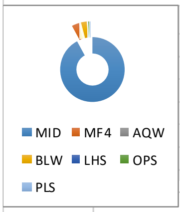


Figure 7. Comparison of macroinvertebrate metrics with the microhabitats sampled in both upstream and downstream of the main effluent outfall. P-values labeled "Reaches" represent the comparison of equivalent microhabitats between the upstream and downstream reaches. P-values labeled "Microhabitats" represent the comparison of different microhabitats within the upstream and downstream reaches. Microhabitats differ significantly (p = <0.05) between type in all parameters with the exception of EPT richness and MBI (p = >0.05). Microhabitats also differ significantly (p = <0.05) between reaches in all parameters with the exception of EPT richness and overall richness (p = >0.05). Simpson's diversity, EPT richness, and richness are in part A. MBI, percent EPT, and richness are in part B.

Site 3

Figure 8.

sediments



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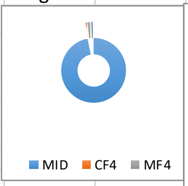
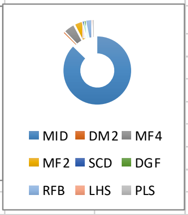
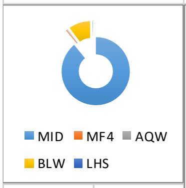


root wads



Site 5

sediments



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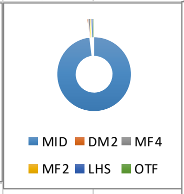
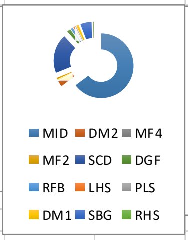
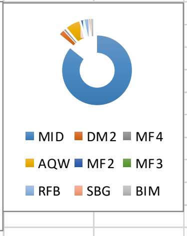


root wads

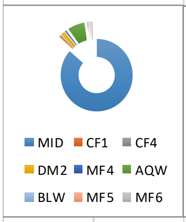


leaf packs



Site 7

sediments



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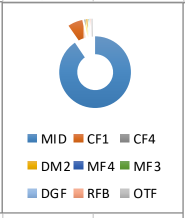

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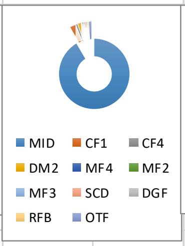

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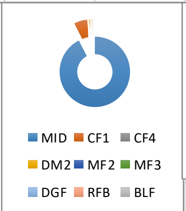
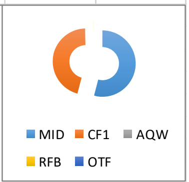
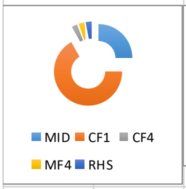


riffles



Site 12

sediments



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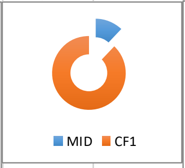
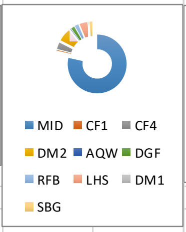
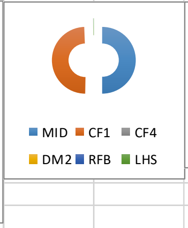


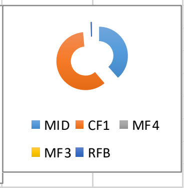
root wads



leaf packs

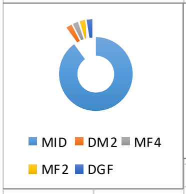


riffles



Site 14

sediments



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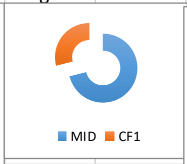
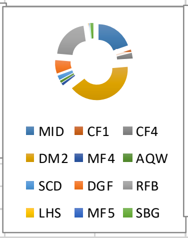
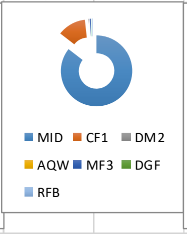


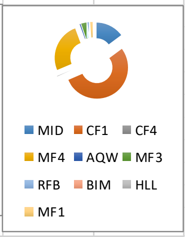
root wads



leaf packs

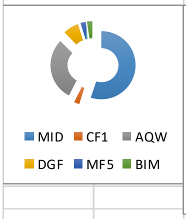


riffles



Site 16

sediments



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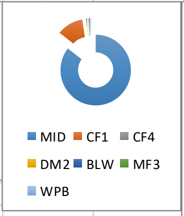
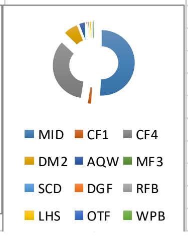


root wads



AQW	Aquatic Worm
SBG	Sowbug
SCD	Scud
DGF	Dragonfly
DM1	Broadwinged Damselfly
DM2	Narrowwinged Damselfly
HLL	Dobsonfly
MF1	Torpedo Mayfly
MF2	Swimming Mayfly
MF3	Clinging Mayfly
MF4	Crawling Mayfly
MF5	Burrowing Mayfly
MF6	Other Mayfly
CF1	Hydropsychid Caddisfly
CF4	Other Caddisfly
RFB	Riffle Beetle
WHB	Whirligig Beetle
WPB	Water Penny Beetle
BIM	Biting Midge
BLW	Bloodworm Midge
MID	Midge
BLF	Black Fly
OTF	Other Fly
LHS	Left-Handed Snail
RHS	Right-Handed Snail
PLS	Planorbid Snail
OPS	Operculate Snail

Figure 8. Macroinvertebrate assemblages in different microhabitats in upstream and downstream reaches of the Sangamon River. Sites 3, 5, and 7 above effluent outfall. Sites 12, 14, and 16 below outfall. Chironomids (shown In blue on each graph) dominate most assemblages. Assemblages vary between microhabitats at a single site (horizontal comparisons) and between sites within a single microhabitat (vertical comparisons). Rootwads habitats contain greatest diversity. Taxa codes are listed to the side.

APPENDIX

Sangamon River sites (Site # based on previous studies)

Site 1 – Lincoln Park CSO – above outfall
Site 3 – Lincoln Park CSO – below outfall
Site 5 – Oakland CSO (Lincoln Park) – below outfall
Site 6 – 7th Ward CSO (End Sunset Dr.) – above outfall
Site 9 – Main Treatment Plant (Off Main street) –down stream of main outfall
Site 12 – Bridge on Wyckles Road
Site 14 – Lincoln Trail Homestead State Park
Site 15 Mt. Auburn 2 miles north of Mt. Auburn
Site 16 Mechanicsburg Mechanicsburg Road Bridge

Routine collections for water quality assessment were conducted at Sites 5, 9, 12, 14, 15, and 16. Sites 15 and 16 are new sites for water quality assessment starting June 2015.

Macroinvertebrates were collected form Sites 3, 5, 7, 12, 14 and 16.

Fish were collected from Sites 1, 6, 9, 12.

Exhibit 35

Exhibit 35

Biotic assessment of water quality in a stretch of the Sangamon River receiving effluent from the Sanitary District of Decatur: Focusing on chemical assessment, macroinvertebrate assemblage, mussel assemblage, tiered-aquatic life use, and the sport fishery

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Submitted to:
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Decatur, IL 62522

May, 2014

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EXECUTIVE SUMMARY

We sampled three treatment reaches of the Sangamon River for water quality, habitat quality, macroinvertebrate assemblages, and bluegill parasite loads. The three treatment reaches were 1) reference - upstream of the Lake Decatur dam, 2) upstream - downstream of the dam but upstream of the Decatur Sanitary District main discharge, and 3) downstream - directly downstream of the main discharge. We sampled eleven sites monthly for water quality; seven sites located in the upstream reach, and four sites located downstream of the SDD. Seven sites were designated to sample annually for macroinvertebrates; four sites located in the upstream reach and three located in the downstream reach. Two reaches were sampled for mussels, fish, and Asian carp.

Water quality in the upstream and downstream reaches differed during periods when discharge, measured at the Route 48 Bridge, was below 200 cfs. Physical habitat quality was not significantly different between the three reaches. Macroinvertebrate indices showed no difference between the three reaches, except significantly higher density above the dam. Further studies with a different sampling protocol focusing on high quality habitats may discern finer differences among the reaches.

Mussel communities had greater relative density and species richness in the below dam reach. Mussels were not surveyed below SDD effluent due to minimal mussel counts in the previous year. Mussel communities were able to survive drought conditions and may be able to recolonize if conditions are favorable.

Bluegills in the Sangamon River both above and below SDD effluent have shown to accumulate parasites over time. Bluegills sampled below the effluent have lower infection levels.

High infection rates, however, do not seem to adversely affect bluegill the gonadosomatic index or relative weight. In 2014, we will reevaluate bluegill weight after parasites have been removed as it may be a better method of assessing condition.

A total of thirty-one fish species, were sampled using AC boat electrofishing during high water and seining methods during low water from the two treatment reaches of the Sangamon River. Because of high conductivity during low water, seines were implemented to sample fishes among all treatment reaches. AC electrofishing allowed us to sample different fish species that we were unable to capture using seines. Catch per unit effort was highest in the upstream reach (Site 4) and lowest in the downstream reach (Site 9).

The Sangamon River below Lake Decatur Dam supports a healthy population of adult (4-5 year old) Asian carp. Larval and juvenile (0-2 year old) Asian carp were unrepresented and were either nonexistent or were unable to be sampled. In 2014, sampling for Asian carp will begin earlier in the year (April) and will be conducted more frequently (monthly pulsed-DC electroshocking and bi-monthly larval sampling).

These findings and the sampling we will conduct summer 2014 can be used to assess the Sangamon River in regards to the Tiered Aquatic Life use (TALU).

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INTRODUCTION

Rivers and streams are impounded for a variety of reasons, including residential, commercial, and agricultural water supply; flood and debris control; and hydropower production (Kondolf 1997). However, impoundments may impact downstream aquatic systems and their surrounding terrestrial habitats. They can affect riverine systems by altering the flow regime, changing the sediment and nutrient loads, and modifying energy flow (Lignon *et al.* 1995). In addition, impoundments may lead to diminished water quality and availability, closures of fisheries, extirpation of species, and groundwater depletion for surrounding areas (Abramovitz 1996, Collier *et al.* 1996, Naiman *et al.* 1995). As a result of impoundments, downstream reaches may no longer be able to support native species, which will be reflected by reduced integrity of biotic communities (Naiman *et al.* 1995, NRC 1992).

A natural flow regime is critical for sustaining ecosystem integrity and native biodiversity in rivers (Poff *et al.* 1997). Depending on the use of the dam, it may have varying effects on downstream aquatic habitats. Impoundments used for urban water supplies lead to a reduction in flow rates downstream of the dam throughout the entire year (Finlayson *et al.* 1994), as well as increase daily and seasonal variability in flow regime (Finlayson *et al.* 1994, McMahon & Finlayson 2003). In addition, abiotic variables including temperature, dissolved oxygen, turbidity, pH, conductivity, and solids concentrations are altered in the downstream river system (Finlayson *et al.* 1994).

Along with stream and river impoundments, point source and non-point source pollution can have profound and lasting effects on the ecological integrity of the system. Non-point sources of pollution include agriculture, livestock grazing, and urbanization, and point source pollutions include sanitary discharge and industrial waste. In order to reduce point source pollution, the Water Quality Act of 1972 encouraged wastewater treatment plants to upgrade their systems. As a result, many communities were forced to build advanced tertiary water treatment facilities (Karr *et al.* 1985). Updated facilities still release high concentrations of nutrients into surrounding rivers. Carpenter and Waite (2000) documented that concentrations of phosphorus were highest in streams draining agricultural basins and at sites influenced by wastewater discharges, and Twichell et al. (2002) reported that sewage effluent inputs had elevated nitrate levels. The enhanced nutrient discharge can be expected to increase productivity within a river because primary productivity and detrital processing usually are limited by low ambient stream nutrient concentrations (Stockner and Shortreed 1978, Elwood et al. 1981, Winterbourn 1990).

Unlike impoundments and pollution, droughts are a natural phenomenon, but they can also severely affect aquatic ecosystems. Droughts can alter the lotic systems in ways harmful to biota, including loss of habitat, food resources, and stream connectivity (Lake 2003). The overall effect drought has on aquatic communities varies, and often depends on the availability of refugia and life history of the organisms (Humpheries and Baldwin 2003, Lake 2003). Macroinvertebrates, especially sensitive taxa such as stoneflies and caddisflies, can be temporarily decimated by drought conditions (Boulton 2003). The effects of a drought depend on many factors, including its severity, length, and the previous condition of the lotic system: specifically anthropogenic perturbations. Human disturbances such as impoundments can be exacerbated by drought conditions decreasing decrease the amount of dilution for pollution sources in lotic systems. This can lower the resilience of the aquatic ecosystem (Bond *et al.* 2008), potentially worsening their effects.

The Sangamon River

The Sangamon River flows for approximately 200 km in central Illinois, and its 14,000 km^2 watershed extends to 18 counties. Streams converging with the Sangamon River run through glacial and alluvial deposits, creating a low gradient stream with sand and gravel substrates. The Sangamon basin has experienced multiple point and non-point source impacts throughout the years. Land use around the river system is currently 80% agricultural, of which 85% is corn or soybeans. Major cities along the river include Bloomington, Decatur, and Springfield, and are home to more than 500,000 people. The Sangamon River immediately below Lake Decatur is influenced by impoundment, altered flow regime, and point source discharges.

Due to multiple anthropogenic influences, the biotic integrity of the Sangamon River is in constant flux. An intensive sampling program, beginning in 1998-99 and continuing from 2001-2010, was conducted to document temporal and spatial heterogeneity of an 8.5 km urban reach of the Sangamon River. Sampling began directly below the Lake Decatur Dam and continued downstream to incorporate discharges from the Sanitary District of Decatur (SDD). These studies (Fischer & Pederson 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010) were intended to characterize stream habitat quality and assess impacts from ongoing reservoir and urban management by evaluating biotic integrity at various trophic levels in the context of the physical and chemical nature of the Sangamon River.

Original sampling locations were associated with operation of the Sanitary District of Decatur that were easily identified by landmarks within the city of Decatur, Illinois, USA. Sites were established in 1998 in conjunction with combined sewage overflow (CSO) facilities and the main treatment plant. Sites were located in the mainstem of the Sangamon River extending from directly below the Lake Decatur dam to the Lincoln Memorial Highway Bridge, located five miles southwest of Decatur. Sites 1, 3, 4, 5, 6, 7, and 8 extend from the dam to directly above the discharge of the main treatment plant in the upstream reach, and sites 9, 11, 12, and 14 extend from the main treatment discharge to a point approximately 8 river miles downstream near Lincoln Trail Homestead State Park. One site (Allerton Park) was added in 2012 as an upstream reference reach to help quantify the effects the reservoir has on the Sangamon River.

Habitat Assessment

The Stream Habitat Assessment Procedure (SHAP), which assesses lotic habitat quality using features considered important to biotic integrity, was performed in 1998, 2001, and 2002. At each site, two individuals assessed metrics relating to substrate and instream cover, channel morphology and hydrology, and riparian and bank features to one of four habitat quality types, following guidelines established by the Illinois Environmental Protection Agency (1994). The average total score of the 15 metrics form the basis of an overall habitat quality rating for the stream reach under consideration. The SHAP was replaced with the Qualitative Habitat Evaluation Index (QHEI) (Rankin 1989) starting in 2010 as a more rigorous measure of physical habitat that also incorporates an objective invertebrate sampling.

This overall physical structure provides a base for the ability of the study reach to support diverse life. Routine assessment of characteristic water quality variables combined with substrate characteristics, channel morphology, and bank features help aid in our understanding of stream systems. Analyzing specific physical and chemical variables is essential to understanding the potential for anthropogenic impacts to affect biotic integrity as organisms often exist in narrow ranges of tolerance for these variables. We have compared various physical and chemical features of the Sangamon River sites from 2002-2013.

Parasite Load in Bluegill

Starting in fall 2012, we started to examine parasite loads in bluegill. Bluegill have been shown time and again to exist with high parasite burdens, however, it is under debate what effects this may cause the fish intermediate host. It is possible that under significantly large parasite burdens bluegill will have a higher relative weight than its uninfected counterpart due to the input of parasite mass. Therefore, it is imperative to determine if the fish species are susceptible to massive parasite burdens before equating a condition score based on length and weight.

Population Demographics of Invasive Asian Carps

Since the invasion of silver (*Hypophthalmichthys molitrix*) and bighead (*H. nobilis*) carps in North America, collectively referred to as Asian carp, they have established themselves in high abundances within the Mississippi River system. The Illinois River, a principle tributary of the Mississippi River, connects the Great Lakes to the Mississippi River system. Asian carp establishment in the Great Lakes has the potential to cause a massive negative financial impact to the fishing and recreational industries of the Great Lakes. During 2013 we began collecting data on silver carp in the Sangamon River to analyze population demographics and document potential spawning activity.

Tiered Aquatic Life Use

We sought to assess the water quality, as well as the macroinvertebrate, non-game fish, sportfish, and Unionid mussel communities of the Sangamon River near Decatur, Illinois. We sampled the communities in two treatment reaches; one above and one below the Decatur Sanitary District main effluent. Although all of these metrics individually provide some measure of habitat, the combination of all data will provide a more broad analysis of multiple uses as it pertains to the Tiered Aquatic Life Use (TALU).

The Tiered Aquatic Life Use is a broad measure of the value of habitat and includes both biotic and abiotic values of a given resource. The TALU includes not only historic ecological indices of multiple trophic levels of biota, but economic and recreational value of an aquatic system as well. For example, although sportfish make up a small portion of the fish assemblage they almost always have the greatest economic and recreational value. Additionally, Unionid mussels have shown sensitivity to various assaults on lotic systems. Mussels can be affected by substrate type and flow (Harman 1972; Strayer 1983; Vaughn 1997; Watters 1999), and can be harmed by excessive concentrations of heavy metals, phosphorus, and nitrogen (Beckvar *et al.* 2000; Jacobson et al 1997; Mummert et al 2003; Wang et al 2007). As such, the U.S. Environmental Protection Agency proposed using mussel communities in setting ammonia standards (Great Lakes Environmental Center 2005). Based on this information it is important to include these specific communities in assessment of aquatic systems.

METHODS

Water Data Collection and Chemistry Determination

We collected water quality data monthly from April 2013 to March 2014. Sampling began at the Lake Decatur Dam and proceeded downstream. In the field, we used a YSI Professional Plus handheld meter to measure dissolved oxygen, temperature, and specific conductivity, and pH. In May of 2013 we added a chloride probe to the meter and began taking measurements of chloride concentrations every month afterward. Water samples were collected just below the surface, returned to the lab on ice, and analyzed within accepted time limits. All analyses followed the Standard Methods for Examination of Water and Wastewater (APHA, 1995).

Suspended and total solids were determined by drying residue collected on standard glass fiber filters and unfiltered samples at 103-105 ^{o}C. We analyzed volatile and suspended solids by weight loss upon ignition at 550 ^{o}C. Total oxidized nitrogen (NO_2-N + NO_3-N) was determined using the cadmium reduction method, and ammonia nitrogen was determined with the phenate method. We used the ascorbic acid method to determine total phosphorus (following persulfate digestion) and soluble reactive phosphate (following filtration). A Thermo Scientific Evolution 300 UV-VIS spectrophotometer was used for all colorimetric nutrient analyses. Hardness and alkalinity were measured using titration to colorimetric endpoint methods. We considered quality control procedures during all analyses, including but not limited to parallel analyses of laboratory standards.

We calculated and report the averages of each variable for the upstream and downstream reaches. In order to determine overall differences between reaches, principle components analysis (PCA) was conducted for 15 variables after individually log transforming and normalizing the data. Variables that were highly correlated to another and thus redundant were eliminated from the analysis. All analyses were performed using Primer 6.1.14 (Clarke and Warwick 2001). Correlation analysis was performed to determine the relationship among measured and derived variables.

Assessment of Physical Habitat

We assessed physical habitat at low flow in summer 2013 using a modified Ohio's Qualitative Habitat Evaluation Index: QHEI (Rankin 1996) at four sites below the dam and above the effluent and three sites within 15 miles downstream of the effluent (Appendix 1). Each 100 m site was divided into six evenly-spaced transects. We measured substrate type and depth every five meters along the width of each transect. Between each transect, we estimated the percent of each instream cover type, the channel morphology, the amount of riparian zone and bank erosion, the pool and riffle quality, and gradient. Each section was scored individually making a total possible maximum score of 100.

Assessment of Macroinvertebrate Community

Macroinvertebrates were sampled during summer 2013 using a modification of USEPA's Rapid Bioassessment Protocol (Barbour et al. 1999) multihabitat 20-jab method. We sampled four sites below the dam and above the effluent and three sites within 15 miles downstream of the effluent (Appendix 1). The proportion of jabs in a specific substrate type was based on relative proportions in the Qualitative Habitat Evaluation Index (QHEI) calculated that year. We preserved the macroinvertabrates in 70% ethanol and transported them to the EIU Fisheries and Aquatic Research Lab for identification and enumeration. In the lab, we subsampled macroinvertebrates form each site using a thirty grid tray. Grids were selected at random until a target of at least 300 macroinvertebrates were picked with a minimum of three grids (10% of the sample) selected. All individuals were identified to taxonomic levels required by Illinois RiverWatch. Voucher specimens were catalogued into the EIU invertebrate collection.

We assessed the taxonomic richness, Simpson's diversity (D), Shannon-Weiner diversity (H'), percent Ephemeroptera, Pleucoptera, and Trichoptera (EPT) taxa, and macroinvertebrate index of biotic integrity (MIBI) based on taxon-specific environmental sensitivity values using the Illinois RiverWatch protocol. The Simpson's diversity (D) was calculated using the formula:

$$D = \frac{1}{\Sigma p_i^2}$$

- where p_i = is the proportion of the total number of individuals comprised by species *i*.

We calculated Shannon-Weiner diversity (H') using the formula:

$$H' = -\sum(p_i \times ln(p_i))$$

- where p_i = is the proportion of the total number individuals comprised by species *i*.

We estimated abundance as number of macroinvertebrates per jab .

We performed an ANOVA to assess differences between upstream and downstream sites. Sites were plotted using multidimensional scaling (MDS) based on Bray-Curtis similarity matrices (BC). Data were square root transformed and standardized by abundance. Similarity of assemblages among sample sites was portrayed in scatter plots of the first two ordination axes. Analyses were performed using Primer +.

Assessment of Unionid Mussel Community

Mussel assemblages were sampled during summer 2013 using timed hand searches. We sampled one site (Allerton Park) above the Lake Decatur dam and one site (Site 7) below the dam and above the effluent (Appendix 1). No sites were sampled below the effluent due to the high number of zero samples in this reach in the previous year. Four people spread out and searched within the 100 m site at random for one hour, creating four total man hours of effort. Searches were conducted visually and tactilely. All mussels were collected in mesh bags and identified to species according to Cummings and Mayer (1992). We took length measurements in field and returned all live mussels to the river. Dead shells collected were taken back to the lab for vouchers and identification conformation and were cataloged.

We calculated species richness (S), Simpson's diversity (D), Shannon-Weiner diversity (H'), and catch per unit effort (CPUE) for the mussel assemblages. Simpson's diversity and Shannon-Weiner diversity were calculated using the same formulas as outlined above. Catch per unit effort was determined as individual mussels caught per hour for the timed hand searches.

Assessment of Parasite Abundance in Bluegill

Bluegill collection

We sampled three treatment reaches during spring and fall 2013 using four gear types including three phase alternating current (AC) electrofishing using an unbalanced three dropper electrode array, direct current (DC) electrofishing backpack shocker, hook and line, and minnow fyke nets. Bluegills were removed from three reaches of the Sangamon River in Decatur Illinois: 1) Unimpacted, free-flowing river upstream of Lake Decatur Reservoir, 2) Impounded flow reach below Lake Decatur Dam, and 3) Impacted free-flowing river below the main sewage outfall. Since this study was not based on population dynamics, bluegills were captured in any way possible to ensure an adequate sample size with a standard length range. During collection, 60 bluegills of varying lengths were removed from each site per season. Specimens were placed in individual Ziploc® bags and frozen for dissection.

Snail Surveys

Snails were collected during fish sampling within the three sites in Spring and Fall 2013 in backwaters and slow-moving waters. The density of the snail population was estimated by collecting snails for 30 minutes along a 10 meter stretch of the bank. They were dissected immediately to ensure the parasite larvae (cercariae) were still viable for identification. The number and larval form of each parasite was recorded for each individual, along with the genus and life stage (adult/sub-adult) of each snail examined.

Fish dissection/Parasite abundance analysis

Bluegills were thawed and the total length (g) and weight (mm) were recorded prior to dissection for each individual. The kidney, liver, and gonads were removed and the wet weight of each individual organ was obtained. The sex of all mature individuals collected in the spring seasons were recorded. Some individuals that were expected to be mature based on total length did not have any noticeable gonads. In these cases, sex was determined based on secondary sex characteristics of all bluegills. Since the muscle of the heart made it difficult to remove the cysts reliably, the parasite abundance was based on an observational 0-5 scale. The scoring was based on an observation percentage of the surface of the heart infected. A score of 0 indicated no noticeable infection on the surface of the heart and each subsequent score increased by a 20% interval (i.e. 1= 0 to 20% of heart was infected, 2= 20 to 40%, 3= 40 to 60%, 4= 60 to 80%, 5=

80 to 100%). The tissues of the liver and kidney were mechanically sheared separately while in Ringer's Solution in order to facilitate the extraction of as many of the *P. minimum* metacercaria as possible. Total estimation of the parasite abundance in each organ was calculated by taking three 1 mL aliquots from a suspension of 10 to 15 mL depending on severity of infection. The average of the three aliquots was multiplied by the suspension in order to receive a total parasite abudance for the organ. At the end of dissection, the otoliths were removed and utilized to estimate age using two readers.

Statistical Analyses

In order to measure condition we used the relative weight (Wr) equation expressed by Murphy et al. (1991) for bluegill 80 mm or lager and Fulton's condition expressed by Blackwell et al. (2000) for bluegill less than 80 mm. The gonadosomatic index was calculated as the percent of gonad weight to body weight. The combined liver and kidney abundances were compared to the gonadosomatic index, age and Fulton's/Relative Weight condition using Spearman's correlation in SAS. Parasite abundance, gonadosomatic index, and condition were compared to site and season using an ANOVA in SAS. Prevalence (including heart, liver, and kidney), mean abundance and mean intensity (liver and kidney only) were calculated for each site and season. Prevalence refers to the percent of individuals infected. Mean abundance indentifies the average number of parasites per infected and uninfected fish, whereas mean intensity identifies the average number of parasites per infected fish only. A size structure and age structure was created for each site and season using Microsoft Excel 2007. We compared gonadosomatic index to gender and age in order to determine if gonad proportion varied based on demographics. Since gonadosomatic index did not differ significantly based on demographics, all analyses were conducted without separating males from females or the different age classes.

Assessment of Sportfish Community

We sampled two treatment reaches (upstream and downstream) in relation to the Sanitary District of Decatur effluent during spring and fall 2013 using three phase alternating current (AC) electrofishing using an unbalanced three dropper electrode array. During April we sampled the fish community assemblage using AC electrofishing. We sampled for thirty minutes at two upstream and three downstream sites. In previous years, conductivity was much higher in the downstream reach which caused the electrofishing gear to be ineffective; however, due to a large spring flood in 2013 the conductivity in the downstream reach dropped enough for the gear type to be efficient. As an estimate of relative density for electrofishing (AC), we calculated catch per unit effort (CPUE) as number of fish captured per electrofishing hour. AC electrofishing was also used to target Bluegill and began in mid-April, sampling randomly in a downstream manner until the most downstream sight was reached. During early-May AC boat electrofishing was used to target Asian Carp species (Silver Carp and Bighead Carp) below the Sanitary District of Decatur. Data from the Bluegill and Asian Carp studies are detailed further in following sections.

Fishes sampled using AC electrofishing were weighed to the nearest gram and measured to the nearest millimeter total length (TL). Targeted Bluegill were immediately frozen and taken back to the lab for further analysis; total length and weight were obtained in the lab. Asian carps were immediately killed using cerebral percussion and the length and weight were obtained. The otolith and cleithrum were also extracted and taken back to the lab for further analysis.

We also sampled fish communities at four sites upstream of SDD (Sites 3, 5, 7, and 8), and three sites downstream of SDD (Sites 11, 12 and 14) in August and September 2013 using the pull seine method. We completed two seine pulls which required one person to hold one end of the seine near shore, staying in place, while a second person pulled the seine out into the middle of the river and continued upstream, wrapping around to meet the person near shore. An estimate of relative density was calculated as catch per unit effort (CPUE) as number of fish captured per seine pull. Fish were immediately euthanized in formalin and were taken back to the laboratory for identification.

Population Dynamics of Invasive Asian Carps

Sampling for this study in 2013 occurred monthly from June to October. Sampling took place at two sites in the river: one below the dam in Decatur, and one downstream near Chandlerville by the IL route 78 bridge. The downstream site was sampled monthly and the Decatur site was sampled every other month. Bi-monthly upstream sampling at Decatur consisted of fifteen minutes of pulsed-DC electrofishing. Monthly sampling at the downstream site consisted of larval fish sampling and fifteen minutes of pulsed-DC electrofishing to collect adult fish. Larval collection was conducted using a 0.5 by 3 meter conical cylindrical ichthyoplankton net with an in-net mounted flow meter to determine volume of water sampled. Larval individuals were preserved in 95% ethanol until laboratory identification. The collection of adult fish was conducted by 60Hz pulsed-DC electrofishing for fifteen minutes per site. Once collected, field processing of fish included recording individual data (length, weight, sex, date, location, and individual ID #), removal of a postcleithrum, and a subset of head removal for later otolith extraction. No Asian carp were returned to the water alive.

All larval samples, postcleithra, and heads were brought back to the lab for further processing. Larval fish were identified to family for exclusion, and then to genus if in the family Cyprinidae. Postcleithra were dried, cleaned, and sectioned into ~1mm sections using an Isomet low speed saw. Sections were mounted to slides for digital photographing and subsequent aging. Otoliths were extracted from the collected heads in the lab to be compared against the postcleithra age. Length and age frequency histograms were calculated for adult fish in the Sangamon River. Additionally, relative abundance and sex ratios within the sites sampled were also calculated.

RESULTS

Water Data Collection and Chemistry Determination

A total of twenty water quality variables were determined for eleven sites along the Sangamon River (Table 1). Principle Components Analysis extracted five factors that explained 87.5% of the total variation in water quality of the Sangamon River during the sampling period. Discrete sampling events (site, date) cluster on the basis of discharge and stream reach (Figure 1). ANOSIM revealed significant differences between reaches (R = 0.43, $p < 0.001$) and between high and low flow regimes (R = 0.48, $p < 0.001$). The entire reach appears to be homogeneous when flow, measured at the Route 48 Bridge, was greater than 200 cfs. In contrast, upstream and downstream reaches were physically and chemically distinct when discharge dropped below this threshold. The main discontinuity between upstream and downstream sites is along PCA axis 1, which correlates strongly with several individual variables. During periods of relatively low stream discharge, downstream sites tend to have higher values for conductivity, hardness, total alkalinity, total phosphorus, soluble reactive phosphorus, fixed dissolved solids, and volatile dissolved solids while having lower observed concentrations of fixed and volatile suspended solids.

Assessment of Physical Habitat

Fine sediment dominated the substrate at each site assessed. Qualitative habitat scores ranged from 50.5 ("fair") to 67 ("good") out of 100 (Figure 2). Scores did not significantly differ by reach ($F_{2,5} = 2.11$, p = 0.2161).

Assessment of Macroinvertebrate Community

A total of 20 different taxa was identified from the eight sites sampled (Table 2). There was no significant difference between the 3 reaches for taxonomic richness ($F_{2,5} = 4.15$, $p = 0.09$), percent EPT taxa ($F_{2,5} = 0.39$, $p = 0.70$), or MIBI scores ($F_{2,5} = 0.25$, $p = 0.79$)(Table 3, Table 4). The estimated density, however, was significantly higher at Allerton Park than the other two reaches ($F_{2,5} = 14.10$, $P = 0.01$). MIBI scores ranged between 5.85 ("poor") to 6.67 ("very poor"). The reach upstream of the dam had scores indicating a higher quality assemblage for all parameters except the MIBI score (Table 3). Several sensitive taxa were found only at the above dam site, but the presence of bloodworm midges (an extremely tolerant taxa) countered this in the MIBI score. Multidimensional scaling revealed relative differences in taxonomic composition among the reaches (Figure 3). Clustering occurred (2D stress: 0.08) within treatment reaches.

Assessment of Unionid Mussel Community

A total of ten native species was recovered (Table 5); five species were recovered from Allerton Park and nine species were recovered from Site 7. Four species (*Amblema plicata*, *Quadrula pustulosa*, *Tritogonia verrucosa*, and *Quadrula quadrula*) were recovered from both sites. One unique species (*Pleurobema (sintoxia) coocineum*) was recovered from Allerton Park, and five unique species were recovered from Site 7 (*Lasmigona complanata*, *Obliquaria reflexa*, *Leptodea fragilis*, *Potamilus ohiensis*, and *Toxolasma parvis*). The most common species found was *Amblema plicata*, and this species, along with *Quadrula pustulosa,* and *Tritogonia verrucosa* made up 80.6% of the total individuals found. Relative density (CPUE), Species richness (S), Simpson's diversity (D), and Shannon-Wiener diversity (H') were all higher above the effluent than above the dam (Table 6).

Assessment of Parasite Abundance in Bluegill

Bluegill within the Sangamon River ranged from 20 to 180 mm in total length, with the average fish measuring 66 mm (Figure 4). In terms of age, bluegill ranged from 2 to 6 years old, with the average fish being 3.5 years old (Figure 5). Overall, the prevalence within this system was 95%, meaning 95% of the individuals sampled were infected with *P. minimum* metacercaria, and on average each infected individual had 193 cysts. Metacercaria were found with approximately the same abundances in the liver and kidney tissues, even though uninfected organs are not similar in mass (Figure 6, R^2= 0.7005, p=0.003). As bluegill grew, there was a significant increase in the parasite burden (Figure 7, R^2= 0.947, $p<0.0001$). However, bluegill gonadosomatic index (Figure 8, Spearman's Correlation= -0.081, p= 0.452) and relative weight used as a condition score (Figure 9, Spearman's Correlation= 0.2519, p= 0.056) did not significantly differ based on parasite infection levels.

Bluegills sampled below the effluent of the Sanitary District of Decatur were significantly smaller (average 45 mm total length) (F= 22.96, $p<0.0001$) and younger (average 3 years old) (F= 14.83, $p<0.0001$) than bluegill sampled below Lake Decatur Dam (average 88 mm total length and 4 years old). Parasite burdens were significantly higher below Lake Decatur Dam (Figure 10. F= 8.55, p= 0.0003). Since parasite burdens below the effluent of the Sanitary District of Decatur were consistently low, it is plausible that the effluent is modifying the parasite infection parameters in a significant way.

Assessment of Fish Community

We sampled a total of 5 sites, 3 upstream sites, and 2 downstream sites using AC boat electrofishing. Seine pulls were conducted at a total of 7 sites: 4 upstream of SDD and 3 downstream of SDD. Using both electrofishing and seining, we sampled a total of 1513 individuals from 35 species (Table 7). The five most dominant species sampled: Gizzard Shad (*Dorosoma cepedinum*), Bluegill (*Lepomis macrochirus*), Brook Silverside (*Labidesthes sicculus*), Green Sunfish (*Lepomis cyanellus*) and Red Shiner (*Cyprinella lutrensis*). The sportfish community in the Sangamon River was comprised of: Black Crappie (*Pomoxis annularis*), Bluegill (*Lepomis macrochirus*), White Crappie (*Pomoxis annularis*), Hybrid Striped Bass (*Morone saxatilis* X *Moronen chrysops*), Yellow Bass (*Morone mississippienis*), and Channel Catfish (*Ictalurus punctatus*) (Table 7). The non-sportfish community was dominated by Gizzard Shad (*Dorosoma cepedinum*), Green Sunfish (*Lepomis cyanellus*), Brook Silverside (*Labidesthes sicculus*), Freshwater Drum (*Aplodinotus grunniens*), Smallmouth Buffalo (*Ictiobus bubalus*) and Red Shiner (*Cyprinella lutrensis*) (Table 7).

Relative density (CPUE) of all fishes using AC electrofishing was highest in the upstream reach at site 4 and lowest in the downstream reach at Site 9 (Table 8). Fish captured using seine methods were dominated by Mosquitofish (*Gambusia affinis*), Red Shiners (*Cyprinella lutrensis*), and unidentified juveniles (less than 20 mm total length) (Table 7). Seine catch per unit effort (fish per seine pull) was highest at site 7 and site 14 (Table 9). The sportfish average total length was 41.37 ± 4.75 mm and weight was 41.59 ± 10.51 g (Table 11).

Population Dynamics of Invasive Asian Carps

In 2013, a total of 150 adult Asian carp was collected in the Sangamon River. We conducted a total of 120 minutes of electrofishing and 25 minutes of larval effort during 2013

(Table 11). We detected no larval Asian carp in the Sangamon River. Due to the low catch rate of Bighead carp, they were combined for analyses with Silver carp. Asian carp ranged in size from 480-790 mm (mean 563.34 ± SD 50.38 mm), weight from 1046-5002 g (mean 1959.75 ± SD 595.80), and age from 3-6 yr (mean 4.66 ± SD 0.79 yr) (Figs. 11-12). Asian carp lengths had an upstream mean of 587.012 ± SD 72.71 mm and downstream mean of 550.13 ± SD 25.38 mm (Figs. 13-14).

Relative abundance was calculated as individuals per hour of effort. The Sangamon River had an average relative abundance of 78.50 individuals per hour. Upstream and downstream sites displayed relative abundances of 82.67 and 76.00 individuals per hour, respectively. The Sangamon River displayed a nearly equal sex ratio, with 67 females and 83 males.

DISCUSSION

The primary differences between the upstream and downstream reaches are likely attributable to metrics related to reservoir discharge and inputs from the SDD main discharge. Outflow from Lake Decatur is the primary input to the upstream reach, which is compromised as a result of management to maintain reservoir levels by eliminating outflow. The discharge from the main treatment plant of the SDD alters instream water chemistry, especially during periods of low reservoir discharge. Consistent flow downstream of the SDD's main outfall during low discharge periods may help maintain physical habitat quality while the upstream reach becomes disconnected pools.

The macroinvertebrate communities were heavily dominated by aquatic midges. Midges are common in organic rich habitats and are often the most abundant taxa (Rabeni and Wang 2001). Metrics commonly used to describe water quality (e.g., MBI, %EPT) were not significantly different among reaches sampled. The estimated abundance of macroinvertebrates was significantly higher above the reservoir than the two reaches below Lake Decatur Dam and was able to support a much higher density. Several macroinvertebrates were only found at this site (e.g., Brachicentridae (TRICHOPERA) and Potamanthidae (EPHEMEROPTERA)) and had significantly higher taxa richness. Using the Illinois RiverWatch metrics for taxa richness and EPT taxa richness ratings, the above dam site was rated as "excellent". A large number of midges, however, resulted in a higher MBI and a rating of "very poor". This discrepancy may be due sampling protocol (RBP multihabitat approach) which requires proportional sampling from each of the habitat types present. The high diversity and sensitive taxa likely came from a limited high quality habitat, while the majority of the habitat supported primarily midges.

For this reason, we propose using a modified Illinois RiverWatch sampling protocol in 2014 which samples the best habitat types within a reach to maximize the potential of sampling the highest diversity of macroinvertebrates. This change will allow us to determine whether the best habitats are able to serve as refugia for sensitive taxa and may be more useful for describing differences between river reaches.

Mussel community structure above the dam was different than below the dam. Mussels were able to survive drought in refugia pools above the dam at Allerton Park. Higher density and diversity below the dam at Site 7 suggest that recolonization of downstream sites may be possible if water conditions are favorable.

Bluegills within the Sangamon River accumulate *Posthodiplostomum minimum* over time but have not shown an adverse effect to high parasitism rates. The Sanitary District of Decatur's effluent appears to modify parasite infection levels, allowing bluegills to age without gross levels of infection, nonetheless, over 90% of the population sampled were infected with parasite cysts. Even though some individuals above and below Lake Decatur Dam contain over 2,000 *Posthodiplostomum minimum* metacercaria encysted in the liver and kidneys, the bluegill population appears to thrive without any detrimental effects with regards to gonadosomatic index and relative weight as a means of condition. It is possible, however, that once the mass of the metacercaria is removed from the total body weight, the bluegills with high parasitism rates may exhibit a decrease in condition and appear less healthy than their uninfected counterparts. Using length and weight as a measure of fish condition may need to be reevaluated when the population is known to experience high parasitism burdens due to an overestimation of the total body weight.

The diversity of fish species was comparable to other Midwestern streams (Colombo unpublished data), with Gizzard Shad, Green Sunfish, Brook Silverside, Freshwater Drum, Smallmouth Buffalo and Red Shiner being the most numerically abundant non-game species and Black Crappie, Bluegill, White Crappie, Hybrid Striped Bass, Yellow Bass, and Channel Catfish being the most abundant sportfish species. Future sampling using multiple gears will allow a more accurate representation of the species composition; these data will be used to determine the economic value and best management strategy for the fishery in the Sangamon River.

Our data show that Asian carp in the Sangamon River in 2013 consist of an adult population 4-5 years of age. Larval and juvenile fish age 0-2 are unrepresented in the data, showing that these individuals are either difficult to sample or are not existing in the Sangamon River. Length frequency histograms show a wider distribution of size in the upstream site compared to the downstream site. It appears that Asian carp exist in the Sangamon River in an abundant, healthy adult population. This study will continue in 2014 beginning in April and continuing to October. Sampling will continue as in 2013 with the exception of sampling the upstream site every month rather than bi-monthly. Larval effort will also increase to bi-weekly rather than monthly.

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TABLES AND FIGURES

Table 1. Measured water quality variables for eleven Sangamon River sites associated with the Sanitary District of Decatur. Concentrations reported as 0.0 (0) are below detection limits.

Date	Site	DO	Temp	pH	Spec. Cond.	Hard.	Phen. Alk.	Total Alk.	NO2/NO3	NH4	PO4 total	PO4 SRP	TSS	FSS	VSS	TDS	FDS	VDS	TS	TFS	TVS
		mg/L	(○C)		mS cm-1	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12 04 2013	**1**	24.2	12.9	9.0	455.0	248.2	41.9	209.4	7.71	0.16	0.06	0.00	32.8	8.4	24.4	264.5	242.3	22.3	297.3	250.7	46.7
16 05 2013	**1**	18.0	20.5	8.6	504.0	620.5	41.9	209.4	9.16	0.03	0.11	0.00	20.4	9.6	10.8	547.6	189.1	358.5	568.0	198.7	369.3
11 06 2013	**1**	7.5	21.8	8.2	483.1	237.3	0.0	167.5	15.47	0.36	0.00	0.00	24.4	8.0	16.4	290.3	64.0	226.3	314.7	72.0	242.7
17 07 2013	**1**	5.9	28.7	8.5	522.0	281.1	14.0	153.6	6.26	0.16	0.08	0.00	18.4	6.8	11.6	268.3	130.5	137.7	286.7	137.3	149.3
16 08 2013	**1**	4.0	22.7	8.2	717.0	315.7	14.0	251.3	1.00	0.28	0.11	0.00	19.2	12.0	7.2	436.8	149.3	287.5	456.0	161.3	294.7
27 09 2013	**1**	4.3	19.6	7.9	916.0	372.3	0.0	321.1	0.69	8.94	0.87	0.11	257.0	51.0	206.0	617.7	277.0	340.7	874.7	328.0	546.7
24 10 2013	**1**	18.5	9.3	8.5	585.0	313.9	0.0	265.2	2.66	3.06	0.20	0.00	16.4	13.2	3.2	382.3	0.0	383.5	398.7	12.0	386.7
14 11 2013	**1**	11.0	5.3	7.2	340.8	266.5	0.0	209.4	1.46	0.11	0.14	0.01	10.8	7.2	3.6	331.9	135.5	196.4	342.7	142.7	200.0
20 01 2014	**1**	8.9	2.9	7.3	605.0	321.2	0.0	586.3	0.32	0.60	0.09	0.01	13.2	5.2	8.0	530.8	114.8	416.0	544.0	120.0	424.0
24 02 2014	**1**	16.6	0.5	7.2	125.5	94.9	0.0	69.8	0.62	0.87	0.64	0.19	88.0	13.0	75.0	132.0	67.0	65.0	220.0	80.0	140.0
19 03 2014	**1**	17.2	3.9	8.1	235.9	182.5	0.0	111.7	3.25	0.86	0.72	0.60	54.0	24.0	30.0	248.7	82.7	166.0	302.7	106.7	196.0
12 04 2013	**3**	25.8	12.8	8.8	460.0	237.3	14.0	181.5	8.47	0.26	0.05	0.00	33.3	6.7	26.7	268.0	136.0	132.0	301.3	142.7	158.7
16 05 2013	**3**	17.2	20.5	8.6	505.0	240.9	27.9	209.4	6.90	0.12	0.11	0.00	21.2	8.8	12.4	548.1	181.9	366.3	569.3	190.7	378.7
11 06 2013	**3**	7.9	21.8	8.2	485.9	251.9	0.0	181.5	7.90	0.21	0.17	0.07	28.0	8.8	19.2	294.7	64.5	230.1	322.7	73.3	249.3
17 07 2013	**3**	6.2	28.7	8.5	527.0	288.4	0.0	167.5	5.81	0.22	0.11	0.00	19.6	7.6	12.0	261.7	123.1	138.7	281.3	130.7	150.7
16 08 2013	**3**	4.0	21.2	8.3	720.0	361.4	14.0	265.2	1.19	0.03	0.09	0.05	17.6	9.6	8.0	501.1	147.7	353.3	518.7	157.3	361.3
27 09 2013	**3**	7.8	20.5	8.0	853.0	405.2	0.0	349.0	0.43	1.14	0.16	0.09	16.4	8.4	8.0	584.9	232.9	352.0	601.3	241.3	360.0
24 10 2013	**3**	12.5	9.1	8.4	534.0	335.8	0.0	265.2	3.62	1.98	0.12	0.04	10.8	6.8	4.0	373.2	2.5	370.7	384.0	9.3	374.7
14 11 2013	**3**	8.3	5.3	7.2	381.0	262.8	0.0	223.4	1.14	0.00	0.19	0.01	7.6	5.6	2.0	383.1	139.7	243.3	390.7	145.3	245.3
20 01 2014	**3**	15.7	4.6	7.4	714.0	350.4	41.9	279.2	0.22	0.22	0.05	0.00	3.2	2.4	0.8	648.8	118.9	529.9	652.0	121.3	530.7
24 02 2014	**3**	15.5	0.5	7.2	126.2	91.3	0.0	83.8	0.57	0.83	0.67	0.19	87.0	15.0	72.0	130.3	71.7	58.7	217.3	86.7	130.7
19 03 2014	**3**	14.9	3.9	7.8	225.6	149.7	0.0	125.6	3.39	0.86	0.70	0.61	84.0	50.0	34.0	216.0	50.0	166.0	300.0	100.0	200.0

Table 1cont.

Date	Site	DO	Temp	pH	Spec. Cond.	Hard.	Phen. Alk.	Total Alk.	NO2/NO3	NH4	PO4 total	PO4 SRP	TSS	FSS	VSS	TDS	FDS	VDS	TS	TFS	TVS
		mg/L	(○C)		mS cm-1	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12 04 2013	**4**	25.4	12.7	8.8	462.0	273.8	0.0	181.5	9.06	0.06	0.03	0.00	31.0	6.5	24.5	261.0	120.2	140.8	292.0	126.7	165.3
16 05 2013	**4**	17.6	20.5	8.6	504.0	244.6	0.0	181.5	8.79	0.13	0.10	0.00	22.4	11.6	10.8	538.9	175.1	363.9	561.3	186.7	374.7
11 06 2013	**4**	8.2	21.9	8.2	494.7	277.4	0.0	181.5	14.17	0.22	0.09	0.04	29.6	8.8	20.8	305.1	84.5	220.5	334.7	93.3	241.3
17 07 2013	**4**	6.9	28.9	8.5	523.0	270.1	27.9	195.4	6.57	0.09	0.10	0.00	23.2	7.6	15.6	271.5	139.1	132.4	294.7	146.7	148.0
16 08 2013	**4**	4.6	21.1	8.3	706.0	346.8	27.9	265.2	0.94	0.00	0.12	0.04	18.8	8.8	10.0	493.2	168.5	324.7	512.0	177.3	334.7
27 09 2013	**4**	4.1	19.3	8.0	721.0	352.2	0.0	188.5	0.62	0.23	0.12	0.12	12.4	4.8	7.6	494.3	168.5	325.7	506.7	173.3	333.3
24 10 2013	**4**	18.2	8.0	8.5	518.0	324.9	0.0	279.2	1.97	0.44	0.09	0.00	12.4	10.0	2.4	396.9	43.3	353.6	409.3	53.3	356.0
14 11 2013	**4**	3.2	4.5	7.3	411.0	295.7	0.0	251.3	0.82	0.02	0.33	0.09	10.0	6.0	4.0	410.0	150.0	260.0	420.0	156.0	264.0
20 01 2014	**4**	14.0	2.0	7.6	539.0	324.9	0.0	293.2	0.62	0.41	0.05	0.02	4.4	2.0	2.4	503.6	123.3	380.3	508.0	125.3	382.7
24 02 2014	**4**	14.2	0.5	7.2	128.5	76.7	0.0	69.8	0.63	0.88	0.58	0.21	78.0	12.0	66.0	143.3	58.7	84.7	221.3	70.7	150.7
19 03 2014	**4**	14.5	3.9	7.7	230.8	143.8	0.0	125.6	2.97	0.88	0.74	0.59	54.0	21.0	33.0	232.7	68.3	164.3	286.7	89.3	197.3
12 04 2013	**5**	26.8	12.7	8.8	464.0	255.5	27.9	195.4	8.72	1.48	0.07	0.00	37.0	8.0	29.0	247.0	89.3	157.7	284.0	97.3	186.7
16 05 2013	**5**	17.7	20.4	8.6	506.0	262.8	0.0	125.6	7.02	0.21	0.11	0.00	24.0	10.0	14.0	488.0	174.0	314.0	512.0	184.0	328.0
11 06 2013	**5**	8.3	21.9	8.2	488.9	248.2	0.0	181.5	16.98	0.19	0.12	0.00	30.0	9.6	20.4	348.7	139.7	208.9	378.7	149.3	229.3
17 07 2013	**5**	7.1	28.8	8.5	526.0	277.4	0.0	167.5	6.26	0.13	0.10	0.00	20.0	7.2	12.8	274.7	138.1	136.5	294.7	145.3	149.3
16 08 2013	**5**	4.9	21.4	8.3	686.0	352.2	27.9	279.2	1.61	0.00	0.06	0.06	14.4	9.2	5.2	477.6	132.1	345.5	492.0	141.3	350.7
27 09 2013	**5**	4.2	19.0	8.0	712.0	334.0	0.0	258.3	1.13	0.31	0.14	0.06	13.6	4.0	9.6	505.1	153.3	351.7	518.7	157.3	361.3
24 10 2013	**5**	14.7	10.3	8.3	594.0	335.8	0.0	237.3	0.53	0.27	0.10	0.00	9.6	6.8	2.8	462.4	51.9	410.5	472.0	58.7	413.3
14 11 2013	**5**	3.5	3.8	7.3	411.9	266.5	0.0	251.3	1.01	0.03	0.36	0.08	8.0	6.4	1.6	406.7	121.6	285.1	414.7	128.0	286.7
20 01 2014	**5**	13.1	1.5	7.6	529.0	324.9	0.0	279.2	0.39	0.39	0.04	0.02	2.4	0.8	1.6	516.3	137.9	378.4	518.7	138.7	380.0
24 02 2014	**5**	14.1	0.5	7.2	129.5	80.3	0.0	69.8	0.55	0.90	0.51	0.19	87.0	13.0	74.0	145.0	61.7	83.3	232.0	74.7	157.3
19 03 2014	**5**	18.0	4.0	7.7	243.6	149.7	0.0	139.6	2.60	0.80	0.63	0.52	62.0	27.0	35.0	238.0	53.0	185.0	300.0	80.0	220.0

Table 1 cont.

Date	Site	DO	Temp	pH	Spec. Cond.	Hard.	Phen. Alk.	Total Alk.	NO2/NO3	NH4	PO4 total	PO4 SRP	TSS	FSS	VSS	TDS	FDS	VDS	TS	TFS	TVS
		mg/L	(○C)		mS cm-1	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12 04 2013	**6**	10.0	12.7	8.8	464.0	251.9	0.0	195.4	8.22	1.62	0.07	0.00	157.5	11.0	146.5	159.8	126.3	33.5	317.3	137.3	180.0
16 05 2013	**6**	17.7	20.4	8.6	487.0	233.6	14.0	167.5	9.34	0.07	0.11	0.00	26.0	9.6	16.4	487.3	154.4	332.9	513.3	164.0	349.3
11 06 2013	**6**	8.1	21.9	8.2	490.3	251.9	0.0	195.4	14.17	0.07	0.08	0.08	30.8	9.2	21.6	354.5	133.5	221.1	385.3	142.7	242.7
17 07 2013	**6**	7.1	28.7	8.5	528.0	295.7	0.0	167.5	5.68	0.08	0.14	0.00	16.4	6.0	10.4	278.3	116.7	161.6	294.7	122.7	172.0
16 08 2013	**6**	5.4	21.9	8.2	803.0	416.1	14.0	293.2	0.26	0.33	0.07	0.02	8.8	2.0	6.8	583.2	202.0	381.2	592.0	204.0	388.0
27 09 2013	**6**	8.7	20.7	8.1	856.0	350.4	0.0	300.1	0.50	0.17	0.12	0.01	11.6	6.8	4.8	599.1	202.5	396.5	610.7	209.3	401.3
24 10 2013	**6**	14.2	11.0	8.3	598.0	328.5	0.0	251.3	1.12	0.40	0.05	0.00	8.8	5.2	3.6	463.2	65.5	397.7	472.0	70.7	401.3
14 11 2013	**6**	6.0	6.0	7.4	437.1	262.8	0.0	265.2	0.94	0.12	0.26	0.06	8.4	4.8	3.6	448.9	132.5	316.4	457.3	137.3	320.0
20 01 2014	**6**	12.5	1.6	7.7	239.0	328.5	0.0	293.2	0.92	0.30	0.06	0.01	5.6	4.4	1.2	503.7	114.3	389.5	509.3	118.7	390.7
24 02 2014	**6**	14.0	0.6	7.2	129.9	73.0	0.0	69.8	0.54	0.85	0.52	0.28	90.0	16.0	74.0	131.3	58.7	72.7	221.3	74.7	146.7
19 03 2014	**6**	15.0	3.8	7.8	231.1	146.0	0.0	125.6	2.83	0.81	0.58	0.53	59.0	26.0	33.0	249.0	80.7	168.3	308.0	106.7	201.3
12 04 2013	**7**	10.4	12.6	8.9	464.0	248.2	27.9	195.4	7.29	0.03	0.10	0.00	36.5	6.5	30.0	251.5	101.5	150.0	288.0	108.0	180.0
16 05 2013	**7**	20.6	20.3	8.6	504.0	233.6	0.0	195.4	8.91	0.10	0.16	0.00	14.8	7.2	7.6	513.2	175.5	337.7	528.0	182.7	345.3
11 06 2013	**7**	8.6	21.9	8.2	485.6	240.9	14.0	167.5	14.17	0.21	0.26	0.00	32.0	10.0	22.0	348.0	123.3	224.7	380.0	133.3	246.7
17 07 2013	**7**	9.4	28.5	8.6	477.0	262.8	14.0	153.6	6.54	0.20	0.06	0.00	18.8	9.6	9.2	247.9	119.7	128.1	266.7	129.3	137.3
16 08 2013	**7**	5.4	22.7	8.3	606.0	313.9	0.0	237.3	0.48	0.00	0.09	0.03	13.6	7.2	6.4	411.7	132.8	278.9	425.3	140.0	285.3
27 09 2013	**7**	7.0	21.3	8.2	607.0	281.1	0.0	223.4	1.32	0.23	0.15	0.00	93.2	15.2	78.0	374.8	127.5	247.3	468.0	142.7	325.3
24 10 2013	**7**	13.4	8.7	8.4	397.9	248.2	0.0	223.4	1.86	0.55	0.18	0.00	55.2	11.6	43.6	319.5	52.4	267.1	374.7	64.0	310.7
14 11 2013	**7**	8.0	5.4	7.6	358.1	211.7	0.0	223.4	2.36	0.00	0.14	0.01	6.4	4.4	2.0	360.3	96.9	263.3	366.7	101.3	265.3
20 01 2014	**7**	12.8	3.1	7.7	452.1	262.8	0.0	321.1	0.69	0.21	0.10	0.03	6.4	4.0	2.4	396.3	92.0	304.3	402.7	96.0	306.7
24 02 2014	**7**	13.8	0.5	7.3	131.4	84.0	0.0	69.8	0.52	1.65	0.67	0.21	89.0	20.0	69.0	141.7	56.0	85.7	230.7	76.0	154.7
19 03 2014	**7**	11.7	3.8	7.7	239.4	149.7	0.0	125.6	1.34	0.79	0.51	0.37	35.0	20.0	15.0	251.7	73.3	178.3	286.7	93.3	193.3

Table 1 cont.

Date	Site	DO	Temp	pH	Spec. Cond.	Hard.	Phen. Alk.	Total Alk.	NO2/NO3	NH4	PO4 total	PO4 SRP	TSS	FSS	VSS	TDS	FDS	VDS	TS	TFS	TVS
		mg/L	(○C)		mS cm-1	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12 04 2013	**8**	10.3	12.6	8.9	464.0	266.5	0.0	181.5	9.40	0.16	0.03	0.00	31.0	4.0	27.0	307.7	140.0	167.7	338.7	144.0	194.7
16 05 2013	**8**	18.3	20.3	8.6	504.0	262.8	27.9	181.5	9.34	0.21	0.11	0.00	23.6	9.2	14.4	528.4	166.8	361.6	552.0	176.0	376.0
11 06 2013	**8**	8.7	21.9	8.2	485.8	273.8	0.0	349.0	7.46	0.20	0.29	0.07	29.6	9.6	20.0	349.1	139.7	209.3	378.7	149.3	229.3
17 07 2013	**8**	8.9	28.6	8.5	494.0	317.6	0.0	167.5	5.71	0.15	0.10	0.00	19.2	6.0	13.2	260.8	114.0	146.8	280.0	120.0	160.0
16 08 2013	**8**	5.6	21.3	8.0	649.0	332.2	0.0	265.2	2.10	0.00	0.11	0.06	11.2	0.8	10.4	454.1	124.5	329.6	465.3	125.3	340.0
27 09 2013	**8**	7.8	19.9	8.2	662.0	299.3	0.0	237.3	1.07	0.41	0.12	0.04	26.8	8.8	18.0	458.5	143.2	315.3	485.3	152.0	333.3
24 10 2013	**8**	12.2	8.8	8.3	404.4	270.1	0.0	139.6	0.77	0.50	0.08	0.05	8.8	4.0	4.8	331.2	69.3	261.9	340.0	73.3	266.7
14 11 2013	**8**	6.3	4.6	7.7	360.3	182.5	0.0	223.4	1.01	0.00	0.21	0.02	3.6	2.4	1.2	344.4	86.9	257.5	348.0	89.3	258.7
20 01 2014	**8**	12.5	2.3	7.8	429.1	277.4	41.9	139.6	0.55	0.16	0.07	0.02	2.4	2.4	0.0	389.6	109.6	280.0	392.0	112.0	280.0
24 02 2014	**8**	13.6	0.6	7.3	133.9	76.7	0.0	69.8	0.50	1.56	0.52	0.19	89.0	18.0	71.0	144.3	67.3	77.0	233.3	85.3	148.0
19 03 2014	**8**	11.8	3.8	7.7	239.2	142.4	0.0	125.6	1.95	0.79	0.56	0.41	31.0	20.0	11.0	219.7	40.0	179.7	250.7	60.0	190.7
12 04 2013	**9**	10.3	13.8	8.8	490.0	248.2	0.0	223.4	6.50	0.16	1.97	1.50	36.0	8.0	28.0	510.7	117.3	393.3	546.7	125.3	421.3
16 05 2013	**9**	18.0	20.5	8.5	703.0	248.2	27.9	223.4	7.57	0.28	1.29	1.02	18.8	6.4	12.4	710.5	188.3	522.3	729.3	194.7	534.7
11 06 2013	**9**	8.6	22.0	8.1	827.0	303.0	0.0	223.4	17.31	0.31	2.02	0.64	33.2	12.0	21.2	580.1	162.7	417.5	613.3	174.7	438.7
17 07 2013	**9**	9.0	28.8	8.4	806.0	284.7	14.0	195.4	6.79	0.19	1.25	1.12	21.2	6.8	14.4	429.5	127.9	301.6	450.7	134.7	316.0
16 08 2013	**9**	4.4	28.8	8.2	4549.0	397.9	27.9	628.2	9.62	0.11	6.21	5.75	8.4	3.6	4.8	2726.3	280.4	2445.9	2734.7	284.0	2450.7
27 09 2013	**9**	7.1	29.0	8.2	4332.0	383.3	0.0	600.3	12.77	0.68	20.93	9.43	8.4	3.6	4.8	2515.6	296.4	2219.2	2524.0	300.0	2224.0
24 10 2013	**9**	7.8	23.3	8.1	3892.0	343.1	0.0	600.3	14.36	1.92	19.13	11.07	10.8	5.2	5.6	2601.2	221.5	2379.7	2612.0	226.7	2385.3
14 11 2013	**9**	6.9	20.8	7.6	3348.0	193.5	0.0	572.4	10.21	0.00	21.84	16.81	6.0	4.0	2.0	2290.0	232.0	2058.0	2296.0	236.0	2060.0
20 01 2014	**9**	9.3	16.1	7.6	2790.0	350.4	0.0	628.2	12.04	0.62	11.11	11.11	8.8	4.4	4.4	2171.2	210.3	1960.9	2180.0	214.7	1965.3
24 02 2014	**9**	13.6	0.6	7.3	135.9	87.6	0.0	69.8	0.66	1.68	1.47	1.40	87.0	17.0	70.0	150.3	52.3	98.0	237.3	69.3	168.0
19 03 2014	**9**	11.7	4.2	7.6	298.3	160.6	0.0	181.5	4.00	0.81	1.26	1.21	34.0	22.0	12.0	362.0	38.0	324.0	396.0	60.0	336.0

Table 1 cont.

Date	Site	DO	Temp	pH	Spec. Cond.	Hard.	Phen. Alk.	Total Alk.	NO2/NO3	NH4	PO4 total	PO4 SRP	TSS	FSS	VSS	TDS	FDS	VDS	TS	TFS	TVS
		mg/L	(○C)		mS cm-1	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12 04 2013	**11**	10.5	12.9	8.8	546.0	262.8	0.0	195.4	8.72	0.24	0.75	0.51	72.0	6.0	66.0	372.0	110.0	262.0	444.0	116.0	328.0
16 05 2013	**11**	17.9	20.5	8.5	637.0	292.0	14.0	209.4	9.04	0.12	0.70	0.52	21.6	6.8	14.8	583.7	149.2	434.5	605.3	156.0	449.3
11 06 2013	**11**	8.5	22.1	8.2	624.0	281.1	0.0	181.5	14.49	0.22	0.61	0.54	33.2	10.8	22.4	476.1	170.5	305.6	509.3	181.3	328.0
17 07 2013	**11**	8.1	28.9	8.4	978.0	292.0	14.0	209.4	6.77	0.14	1.72	1.72	22.0	8.8	13.2	530.0	120.5	409.5	552.0	129.3	422.7
16 08 2013	**11**	5.6	28.6	8.2	4398.0	321.2	27.9	614.2	10.40	0.22	6.42	4.36	8.4	4.4	4.0	2651.6	300.9	2350.7	2660.0	305.3	2354.7
27 09 2013	**11**	6.7	28.6	8.3	4308.0	354.1	14.0	572.4	12.22	0.64	19.77	8.98	12.4	5.2	7.2	2555.6	260.1	2295.5	2568.0	265.3	2302.7
24 10 2013	**11**	8.2	22.5	8.3	3838.0	350.4	0.0	628.2	10.95	1.58	21.87	11.24	12.0	6.4	5.6	2578.7	216.3	2362.4	2590.7	222.7	2368.0
14 11 2013	**11**	6.4	20.4	8.0	3302.0	226.3	0.0	572.4	11.50	0.00	23.73	16.48	9.2	3.2	6.0	2362.8	278.1	2084.7	2372.0	281.3	2090.7
20 01 2014	**11**	9.5	16.2	7.9	2915.0	357.7	0.0	572.4	11.90	0.60	13.71	13.71	5.6	4.4	1.2	2179.7	224.9	1954.8	2185.3	229.3	1956.0
24 02 2014	**11**	13.4	0.9	7.2	163.6	83.9	0.0	69.8	0.58	1.71	2.87	1.11	81.0	16.0	65.0	176.3	60.0	116.3	257.3	76.0	181.3
19 03 2014	**11**	11.5	5.1	7.6	415.0	164.3	0.0	153.6	3.86	0.78	2.46	1.36									
12 04 2013	**12**	10.4	12.2	8.8	489.0	281.1	14.0	181.5	9.73	0.11	0.53	0.26	10.5	9.0	1.5	428.2	107.0	321.2	438.7	116.0	322.7
16 05 2013	**12**	19.3	20.3	8.5	640.0	288.4	27.9	223.4	8.12	0.11	0.58	0.43	30.0	10.4	19.6	571.3	146.9	424.4	601.3	157.3	444.0
11 06 2013	**12**	7.8	22.1	8.1	560.0	292.0	0.0	125.6	18.28	0.40	0.98	0.74	31.2	8.4	22.8	491.5	171.6	319.9	522.7	180.0	342.7
17 07 2013	**12**	8.1	29.0	8.4	828.0	295.7	14.0	209.4	6.82	0.09	1.33	1.17	26.8	8.4	18.4	454.5	115.6	338.9	481.3	124.0	357.3
16 08 2013	**12**	4.8	27.1	8.2	4027.0	365.0	14.0	614.2	11.30	0.19	7.81	5.05	10.0	1.6	8.4	2468.7	287.7	2180.9	2478.7	289.3	2189.3
27 09 2013	**12**	5.9	25.3	8.3	4033.0	383.3	0.0	565.4	12.11	0.49	15.88	8.71	13.2	6.0	7.2	2626.8	254.0	2372.8	2640.0	260.0	2380.0
24 10 2013	**12**	9.3	17.6	8.5	3367.0	324.9	0.0	572.4	13.35	2.11	14.55	10.43	10.0	4.0	6.0	2576.7	200.0	2376.7	2586.7	204.0	2382.7
14 11 2013	**12**	9.7	14.9	8.1	2755.0	211.7	0.0	530.5	8.86	0.00	18.21	16.70	8.0	3.6	4.4	2222.7	243.1	1979.6	2230.7	246.7	1984.0
20 01 2014	**12**	12.6	11.7	8.1	2293.0	372.3	0.0	460.7	10.27	0.66	10.40	10.40	9.2	4.8	4.4	1932.1	219.2	1712.9	1941.3	224.0	1717.3
24 02 2014	**12**	13.6	0.5	7.4	199.1	120.5	0.0	97.7	0.79	1.26	1.16	1.16	38.5	6.0	32.5	226.8	70.0	156.8	265.3	76.0	189.3
19 03 2014	**12**	17.7	4.9	7.8	385.0	164.3	0.0	167.5	4.00	0.77	1.12	1.12	43.0	22.0	21.0	335.7	43.3	292.3	378.7	65.3	313.3

Table 1 cont.

Date	Site	DO	Temp	pH	Spec. Cond.	Hard.	Phen. Alk.	Total Alk.	NO2/NO3	NH4	PO4 total	PO4 SRP	TSS	FSS	VSS	TDS	FDS	VDS	TS	TFS	TVS
		mg/L	(○C)		mS cm-1	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12 04 2013	**14**	10.4	12.2	8.7	485.0	262.8	0.0	195.4	8.81	0.36	0.68	0.19	202.0	14.1	187.9	302.0	105.9	196.1	504.0	120.0	384.0
16 05 2013	**14**	18.6	19.9	8.5	633.0	259.2	27.9	223.4	8.61	0.01	0.70	0.37	30.0	7.6	22.4	579.3	149.7	429.6	609.3	157.3	452.0
11 06 2013	**14**	7.4	21.7	8.1	637.0	299.3	0.0	209.4	14.49	0.19	0.61	0.61	42.4	9.6	32.8	454.9	162.4	292.5	497.3	172.0	325.3
17 07 2013	**14**	6.9	29.2	8.4	704.0	295.7	27.9	209.4	6.72	0.18	1.11	0.90	30.4	8.0	22.4	464.3	116.0	348.3	494.7	124.0	370.7
16 08 2013	**14**	4.8	23.5	8.4	3330.0	394.2	34.9	558.4	11.36	0.00	5.73	5.38	10.4	2.8	7.6	2229.6	251.9	1977.7	2240.0	254.7	1985.3
27 09 2013	**14**	8.7	22.0	8.5	3505.0	379.6	7.0	565.4	11.20	0.26	16.18	8.83	16.8	6.4	10.4	2403.2	204.3	2198.9	2420.0	210.7	2209.3
24 10 2013	**14**	14.1	10.8	8.6	2592.0	339.5	0.0	488.6	15.10	1.63	19.67	10.47	9.2	4.0	5.2	2328.1	124.0	2204.1	2337.3	128.0	2209.3
14 11 2013	**14**	8.5	7.1	8.2	2275.0	197.1	0.0	530.5	10.21	0.00	20.68	16.23	4.8	2.8	2.0	2239.2	205.2	2034.0	2244.0	208.0	2036.0
20 01 2014	**14**	16.7	4.9	8.2	1703.0	335.8	41.9	474.6	6.59	0.01	12.21	9.15	7.2	5.2	2.0	1683.5	162.8	1520.7	1690.7	168.0	1522.7
24 02 2014	**14**	15.0	0.7	7.4	176.3	116.8	0.0	97.7	0.57	1.52	1.76	1.24	101.0	16.0	85.0	168.3	65.3	103.0	269.3	81.3	188.0
19 03 2014	**14**	15.3	4.8	7.8	348.4	182.5	0.0	167.5	5.17	0.80	1.31	1.04	60.0	27.0	33.0	372.0	73.0	299.0	432.0	100.0	332.0
Mean upstream		11.6	13.3	8.1	472.2	262.6	6.2	205.5	4.05	0.55	0.22	0.08	33.6	10.3	23.3	364.7	117.0	247.7	398.3	127.3	271.0
Mean downstream		10.4	17.2	8.1	1824.1	276.1	7.9	354.4	9.20	0.55	7.64	5.28	30.1	8.2	21.9	1327.3	169.7	1157.6	1357.4	177.9	1179.5

Table 2. Summary of Illinois RiverWatch classification of macroinvertebrates sampled in seven sites of the Sangamon River in summer 2013.

Classification	**Allerton**	**Site 3**	**Site 5**	**Site 7**	**Site 8**	**Site 11**	**Site 12**	**Site 14**
Flatworm	2	0	2	0	0	0	0	0
Aquatic Worm	7	2	1	0	11	22	4	5
Leech	0	0	0	0	0	0	0	0
Sowbug	0	0	0	0	0	0	0	0
Scud	0	10	1	0	0	0	0	0
Dragonfly	0	0	0	0	4	1	0	0
Broadwinged Damselfly	0	0	0	0	0	0	0	0
Narrowwinged Damselfly	1	0	4	15	3	2	1	10
Dobsonfly	0	0	0	0	0	0	0	0
Alderfly	0	0	0	0	0	0	0	0
Torpedo Mayfly	0	0	0	0	0	0	0	0
Swimming Mayfly	11	16	1	1	23	0	0	0
Clinging Mayfly	16	0	0	0	0	0	1	4
Crawling Mayfly	54	9	9	5	48	3	4	5
Burrowing Mayfly	1	0	0	0	0	0	0	0
Armored Mayfly	0	0	0	0	0	0	0	0
Other Mayfly	1	0	0	0	0	0	1	0
Stonefly	0	0	0	0	0	0	0	0
Hydropsychid Caddisfly	24	0	39	10	0	1	32	102
Snail Case Caddisfly	0	0	0	0	0	0	0	0
Saddle Case Caddisfly	0	0	0	0	0	0	0	0
Other Caddisfly	6	0	0	1	2	1	1	3
Riffle Beetle	29	3	3	0	0	0	8	7
Whirligig Beetle	0	0	0	0	0	0	0	0
Water Penny Beetle	0	0	0	0	0	0	0	0
Crane Fly	0	0	0	0	0	0	0	0
Biting Midge	9	0	0	0	2	5	0	1
Bloodworm Midge	76	18	1	16	13	1	0	0
Midge	618	238	213	243	108	129	195	226
Black Fly	0	0	0	1	0	0	0	0
Snipe Fly	0	0	0	0	0	0	0	0
Other Fly	0	0	0	2	2	0	0	1
Left-Handed Snail	0	0	0	0	9	13	0	2
Right-Handed Snail	0	0	0	0	0	0	0	0
Planorbid Snail	3	0	0	0	1	0	0	0
Limpet	0	0	0	0	0	0	0	0
Operculate Snail	0	0	0	0	0	0	0	0

Table 3. Comparison of macroinvertebrate indices sampled in eight sites of the Sangamon River in summer 2013.

	Allerton	**Site 3**	**Site 5**	**Site 7**	**Site 8**	**Site 11**	**Site 12**	**Site 14**
Organisms Sampled	858	296	274	294	226	178	247	366
Taxa Richness	15	7	10	9	12	10	9	11
RiverWatch MBI	6.29 Very Poor	6.13 Poor	5.91 Poor	6.23 Poor	6.27 Very Poor	6.67 Very Poor	5.93 Poor	5.85 Poor
Simpson's Diversity (D)	1.88	1.53	1.60	1.45	3.43	1.83	1.55	2.17
Shannon-Weiner Diversity (H')	1.15	0.80	0.81	0.74	1.63	1.02	0.78	1.09
%EPT	13.17%	8.45%	17.9%	5.8%	32.3%	2.8%	15.8%	31.1%
Estimated Abundance Per Jab	429	74	82	147	68	22	74	183

Table 4. ANOVA comparison of macroinvertebrate indices in three reaches of the Sangamon River in summer 2013.

	Df	MS	F	P
Taxa Richness	2,5	12.4375	4.15	0.0868
RiverWatch MBI	2,5	0.0625	0.25	0.7872
%EPT	2,5	56.3343	0.39	0.6983
Estimated Abundance Per Jab	2,5	49434.0625	14.10	0.0088

Table 5. Summary of mussels sampled using timed hand searches in sites of the Sangamon River during summer 2013. A total of 129 mussels were recovered from the two sites.

Species	**Allerton Park**	**Site 7**	**Total**
Amblema plicata	1	50	51
Lasmigona complanata	0	8	8
Leptodea fragilis	0	3	3
Obliquaria reflexa	0	2	2
Pleurobema (sintoxia) coocineum	1	0	1
Potamilus ohiensis	0	1	1
Quadrula pustulosa	38	1	39
Quadrula quadrula	2	6	8
Toxolasma parvis	0	1	1
Tritogonia verrucosa	13	1	14
Unknown species	0	1	0
Total	55	74	129

Table 6. Comparison of Unionid mussel community indices of two sites in the Sangamon River: Allerton Park (above Lake Decatur dam) and Site 7 (below Lake Decatur dam above SDD’s sanitary effluent). Catch per Unit Effort (CPUE) is calculated as individuals per hour during hand searches. Mussels collected using a calm rake were not included in CPUE but were included in other indices.

Index	**Allerton Park**	**Site 7**
Species Richness (S)	5	10
Catch per Unit Effort (CPUE)	13.75	17.25
Simpson’s diversity (D)	1.87	2.04
Shannon-Wiener diversity (H’)	0.86	1.17

Table 7. Summary of the species of fish sampled using AC electrofishing upstream and downstream of the Sanitary District of Decatur in the Sangamon River during spring 2013.

Species	Upstream	Downstream	Total
Bigmouth Buffalo *(Ictiobus cyprinellus)*	1	-	1
Black Crappie *(Pomoxis nigromaculatus)*	5	1	6
Blackstripe Topminnow *(Fundulus notatus)*	7	1	8
Bluegill *(Lepomis macrochirus)*	33	23	56
Bluntnose Minnow *(Pimephales notatus)*	19	14	33
Brook Silverside *(Labidesthes sicculus)*	35	55	90
Bullhead Minnow *(Pimephales vigilax)*	3	-	3
Channel Catfish *(Ictalurus punctatus)*	-	3	3
Common Carp *(Cyprinus carpio)*	-	1	1
Freshwater Drum *(Aplodinotus grunniens)*	4	13	17
Gizzard Shad *(Dorosoma cepedianum)*	555	184	739
Green Sunfish *(Lepomis cyanellus)*	15	5	20
Highfin Carpsucker (*Carpiodes velifer)*	-	1	1
Longear Sunfish *(Lepomis megalotis)*	-	6	6
Longear Sunfish X Bluegill *(Lepomis megalotis X Lepomis macrochirus)*	-	6	6
Longnose Gar *(Lepisosteus osseus)*	1	-	1
Mosquitofish *(Gambusia affinis)*	117	151	268
Orangespotted Sunfish *(Lepomis humilis)*	1	-	1
Quillback *(Carpiodes cyprinus)*	-	13	13
Red Shiner *(Cyprinella lutrensis)*	51	29	80
River Carpsucker *(Carpiodes carpio)*	1	7	8
Sand Shiner *(Notropis ludibendus)*	8	3	11
Shortnose Gar *(Lepisosteus platostomus)*	1	4	5
Smallmouth Bass *(Micropterus dolomieu)*	-	1	1
Smallmouth Buffalo *(Ictiobus bubalus)*	5	9	14

Table 7 cont.

Species	**Upstream**	**Downstream**	**Total**
Spotfin Shiner *(Cyprinella spiloptera)*	2	-	2
Spotted Bass *(Micropterus punctulatus)*	2	-	2
Steelcolor Shiner *(Cyprinella whipplei)*	5	-	5
Suckermouth Minnow *(Phenacobius mirabilis)*	1	-	1
Unidentified Juveniles (< 20 mm TL)	15	70	85
Walleye *(Sander vitreus)*	1	1	2
White Bass *(Morone chrysops)*	2	-	2
White Crappie *(Pomoxis annularis)*	11	5	16
White/Striped Bass *(Morone saxatilis X Morone chrysops)*	2	1	3
Yellow Bass *(Morone mississippienis)*	2	1	3
Total	905	606	1513

Table 8. The average density (fish per half hour) and sample size (N) of all fishes sampled using AC boat electrofishing at 3 sites upstream and 2 sites downstream the Sanitary District of Decatur during 2013.

Reach	**Site**	**CPUE**	**N**
Upstream			
	3	141	282
	4	112.5	225
	6	60.5	121
	All	115.28	628
Downstream			
	9	40.5	81
	11	58.5	117
	All	51.14	198

Table 9. The average density (catch per unit effort (fish per seine pull)) and sample size (N) of all fishes sampled using seining at 4 sites upstream and 3 sites downstream of the Sanitary District of Decatur during 2013.

Reach	**Site**	**CPUE**	**N**
Upstream			
	3	29.5	59
	5	15	30
	7	70.5	141
	8	23	46
	All	138	276
Downstream			
	11	58	116
	12	34	68
	14	76.5	153
	All	168.5	337

Table 10. Descriptive statistics (Minimum, maximum, average (± standard error), and sample size (N)) for all sportfishes captured upstream and downstream of the Sanitary District of Decatur during 2013.

	Total Length				**Weight**			
Site	Min.	Max.	Average	N	Min	Max	Average	N
Upstream	3	556	36.46 (5.46)	195	0.38	1732	38.35 (11.13)	188
Downstream	1.1	520	45.01 (9.10)	102	0.35	1591	47.56 (21.80)	102
Total	1.1	556	41.37 (4.75)	297	0.35	1732	41.59 (10.51)	290

Table 11. Asian carp catches by month and site, 2013. Upstream sites were not sampled in July and September.

	June	**July**	**August**	**September**	**October**	**Totals**
Upstream	4	N/A	30	N/A	21	**55**
Downstream	3	14	35	31	12	**95**
Totals	**7**	**14**	**65**	**31**	**33**	**150**

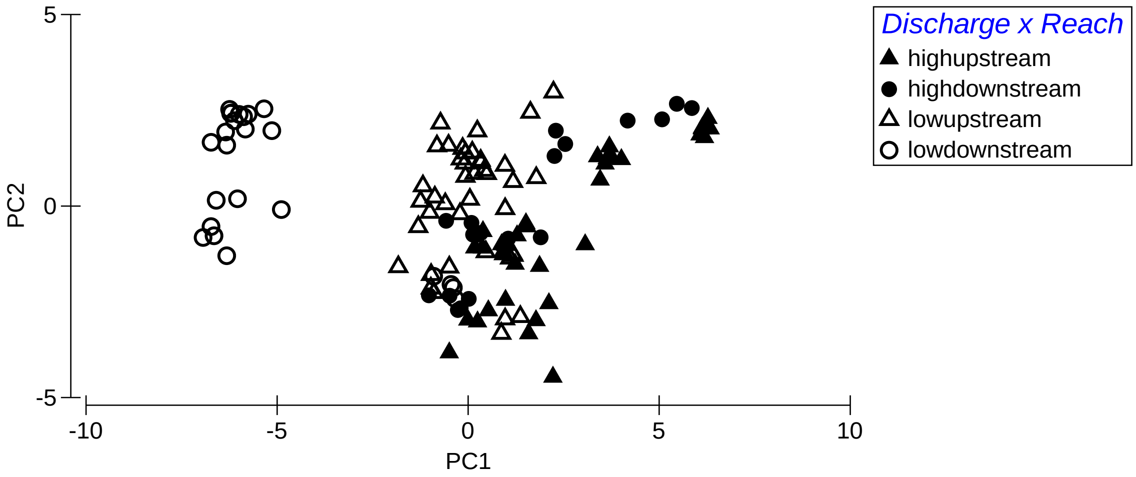

Figure 1. Principle components analysis of water quality data sampled during 2013- 2014 from all mainstem sites of the Sangamon River.

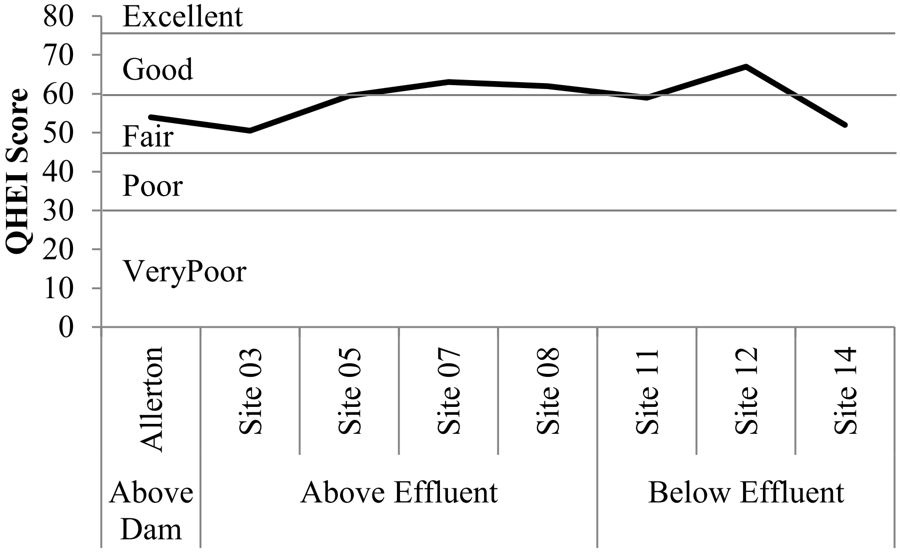

Figure 2. Qualitative Habitat Evaluation Index (QHEI) scores for three reaches upstream and downstream of the Lake Decatur dam and SDD's sanitary effluent in the Sangamon River. Habitat is scored out of 100. Reaches were not significantly different ($F_{2,5} = 2.11$, $p = 0.22$)

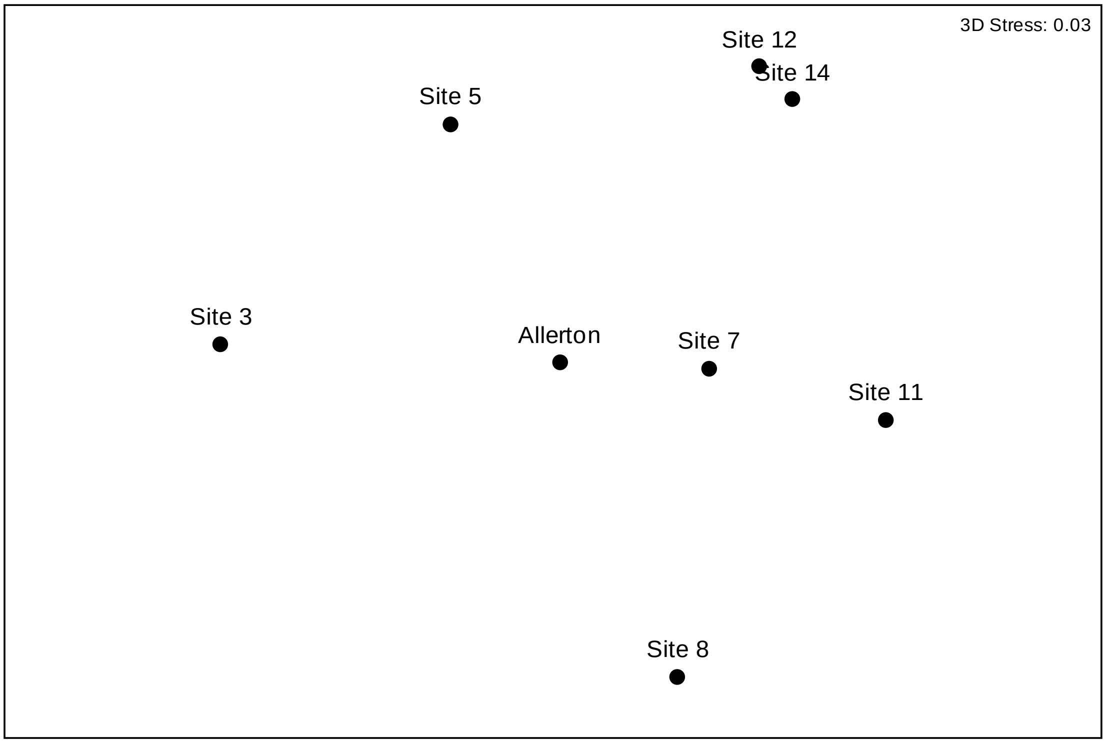

Figure 3. Multidimensional scaling plot of macroinvertebrate communities based on Bray-Curtis similarity (2D stress = 0.03).

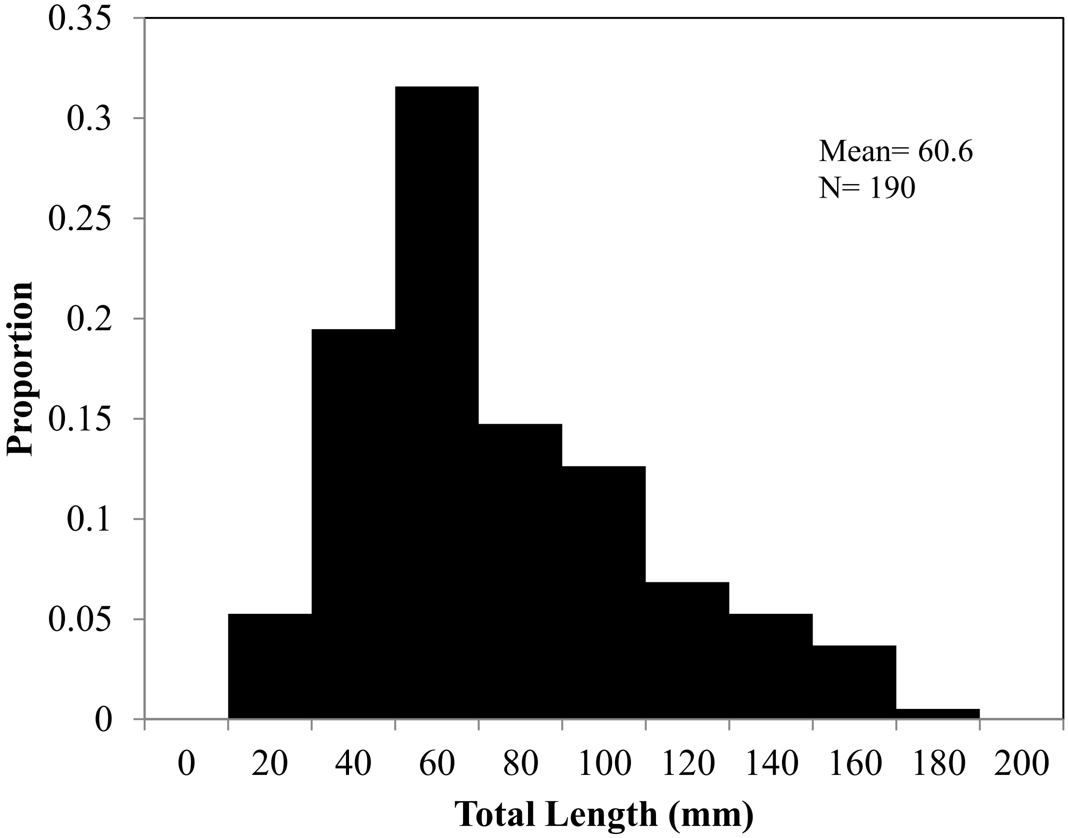

Figure 4. Length frequency histogram for all bluegill sampled using various gears on the Sangamon River during spring and fall of 2013.

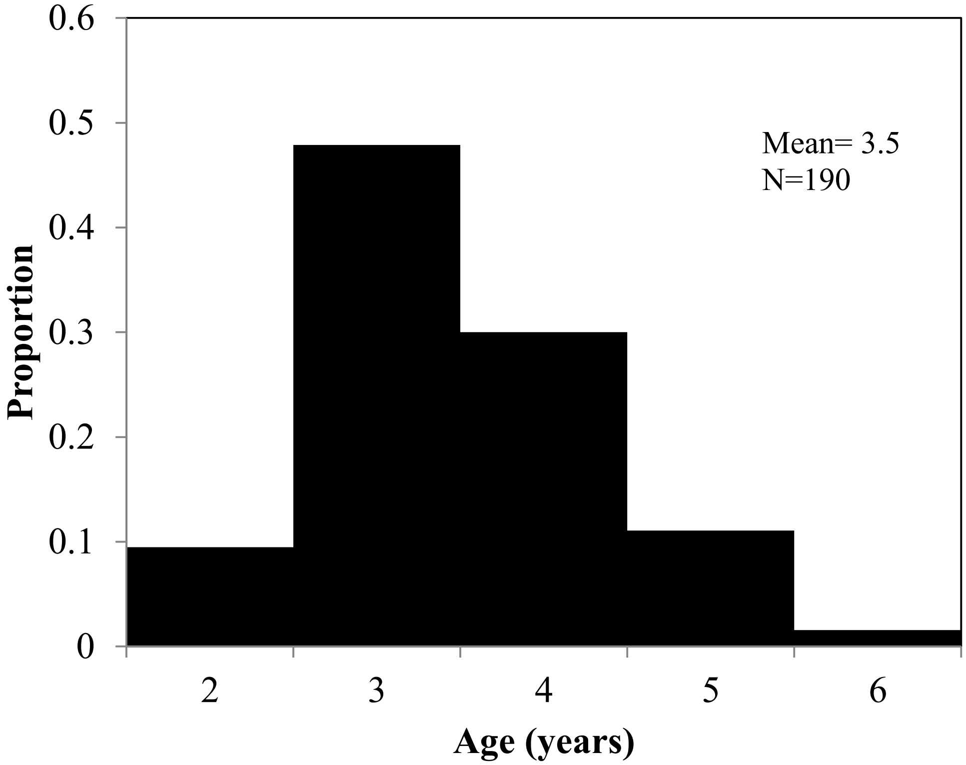

Figure 5. Age frequency histogram for all bluegill sampled using various gears on the Sangamon River during spring and fall of 2013.

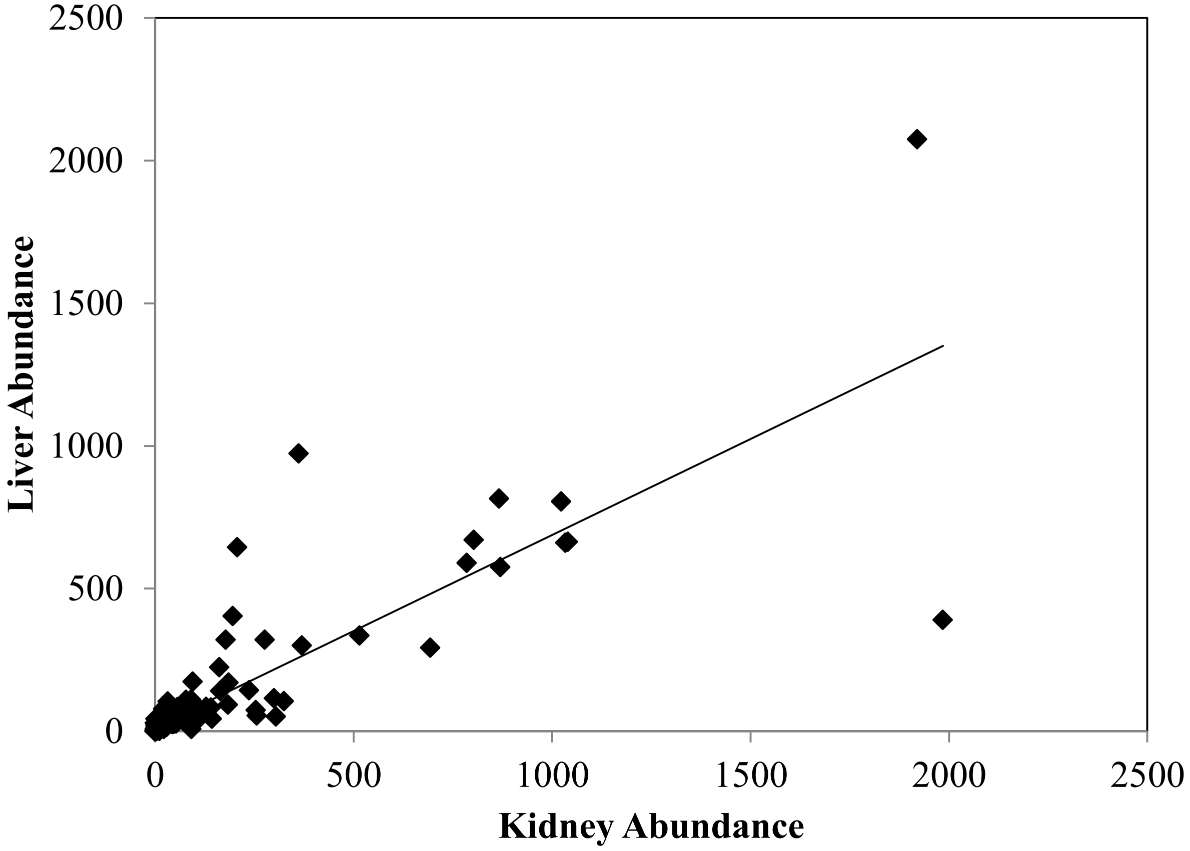

Figure 6. The kidney abundance of each bluegill sampled in the Sangamon River (N=190) in relation to the respective liver abundance.

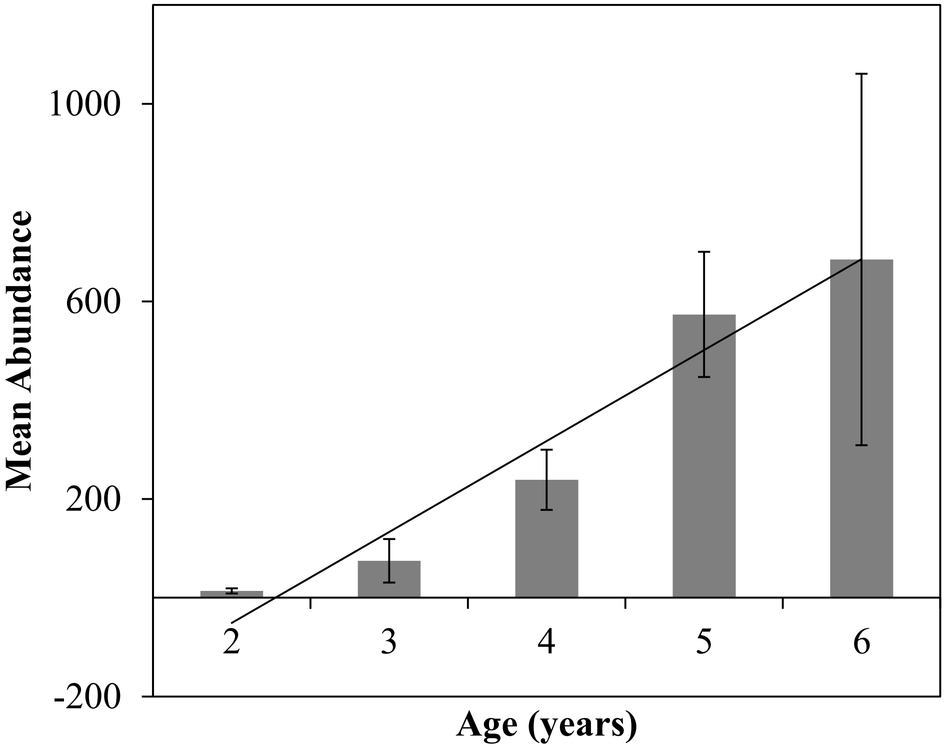

Figure 7. The mean abundance of *P. minimum* metacercaria in each bluegill age class sampled in the Sangamon River (N= 190).

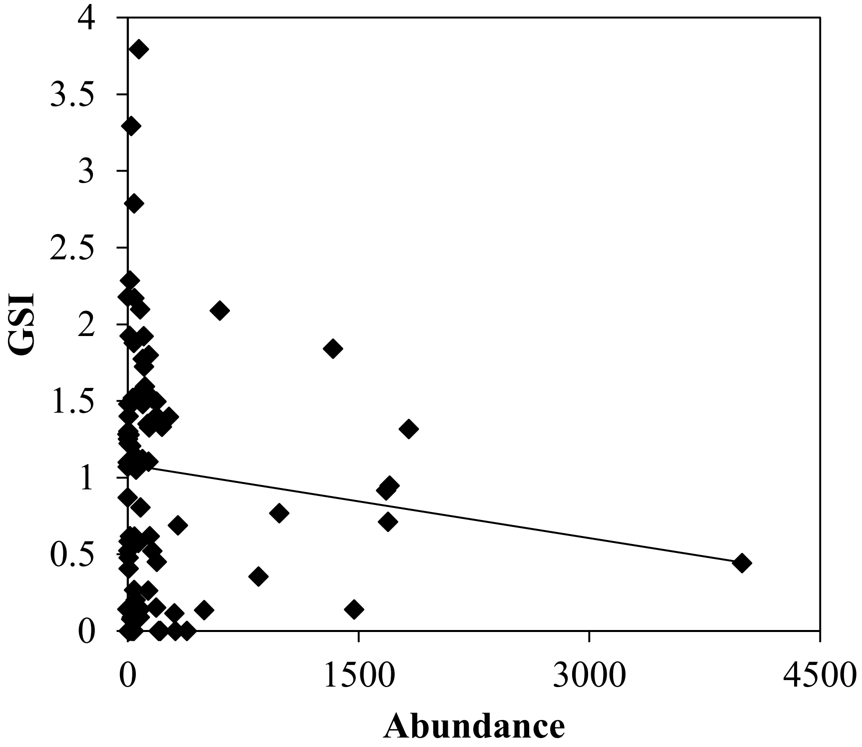

Figure 8. The correlation between gonadosomatic index of all mature bluegills (N= 88) sampled in the Sangamon River and the respective *P. minimum* metacercaria abundance.

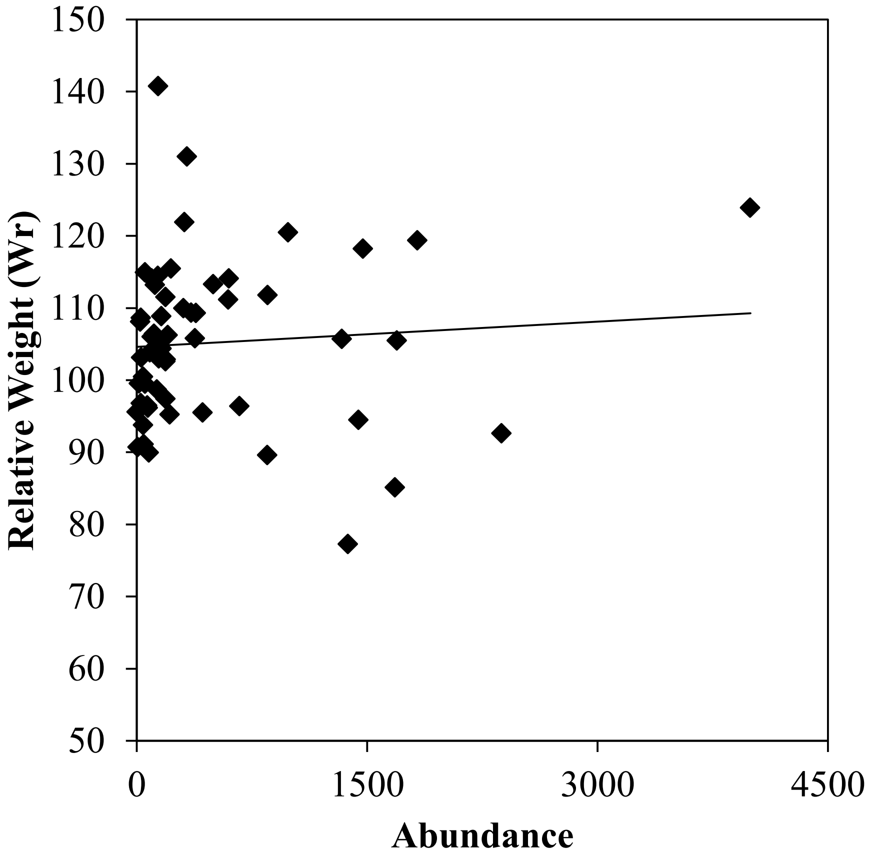

Figure 9. The correlation between the relative weight as a condition score for bluegills (N= 63) sampled in the Sangamon River and the respective *P. minimum* metacercaria abundance.

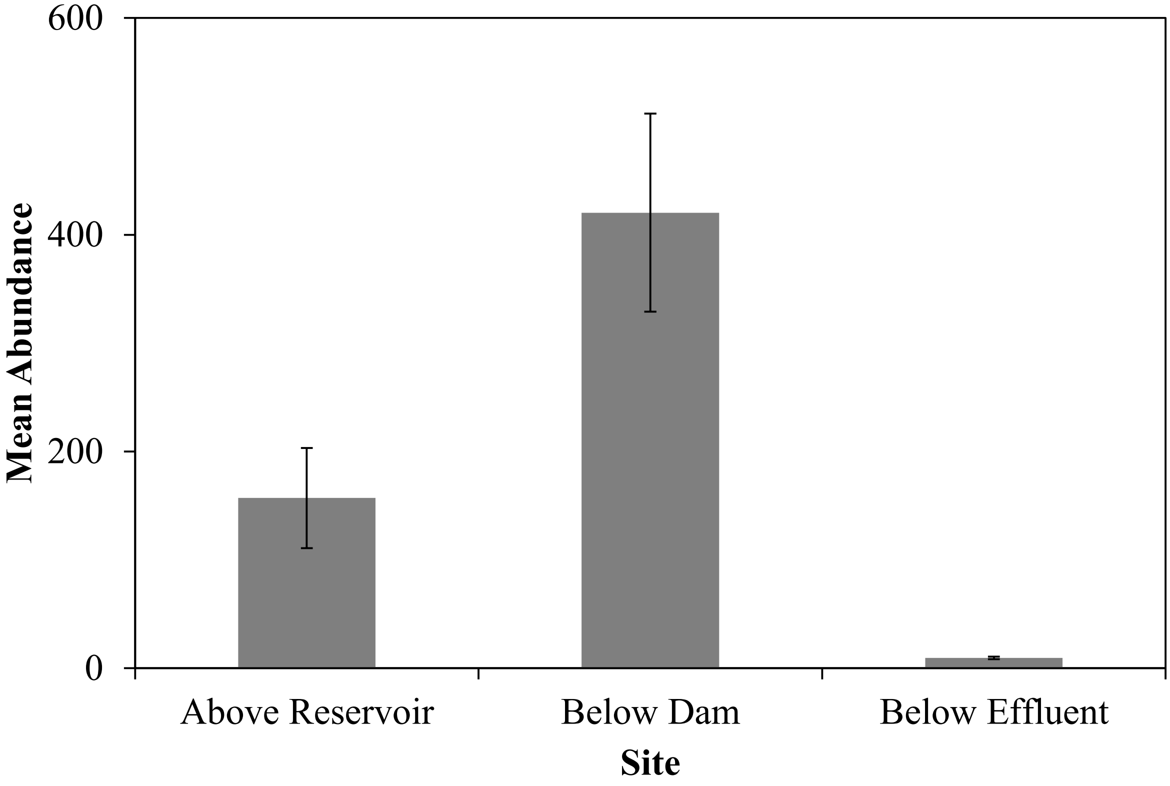

Figure 10. The mean abundance of *P. minimum* metacercaria for bluegills sampled above the reservoir (N= 62), below Lake Decatur Dam (N= 58), and below the effluent of the Sanitary District of Decatur (N= 70).

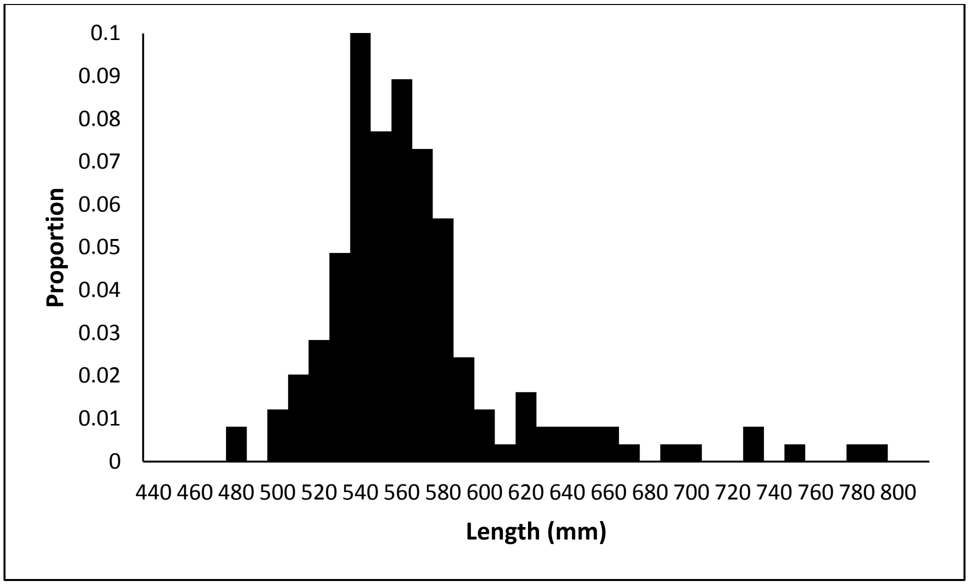

Figure 11. Length frequency of Asian carp in the Sangamon River, 2013.

Figure 12. Age frequency of Asian carp in the Sangamon River, 2013.

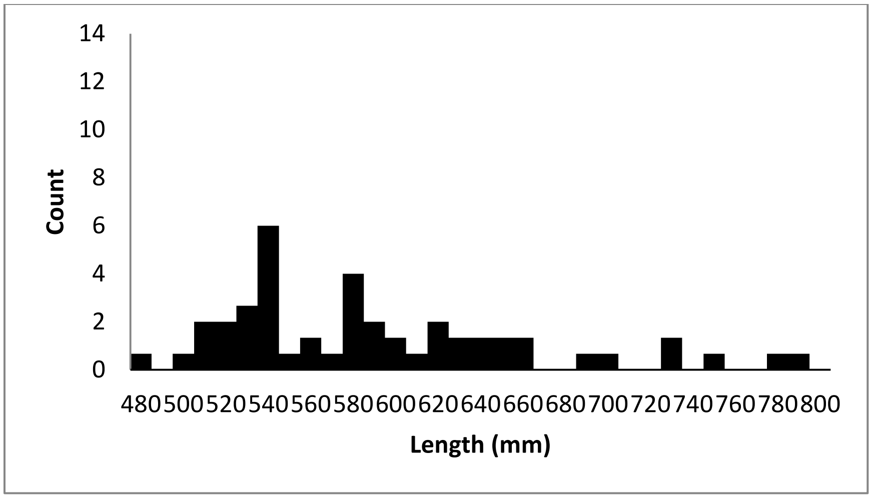

Figure 13. Length frequency of Asian carp in the upstream site, below Lake Decatur Dam, 2013.

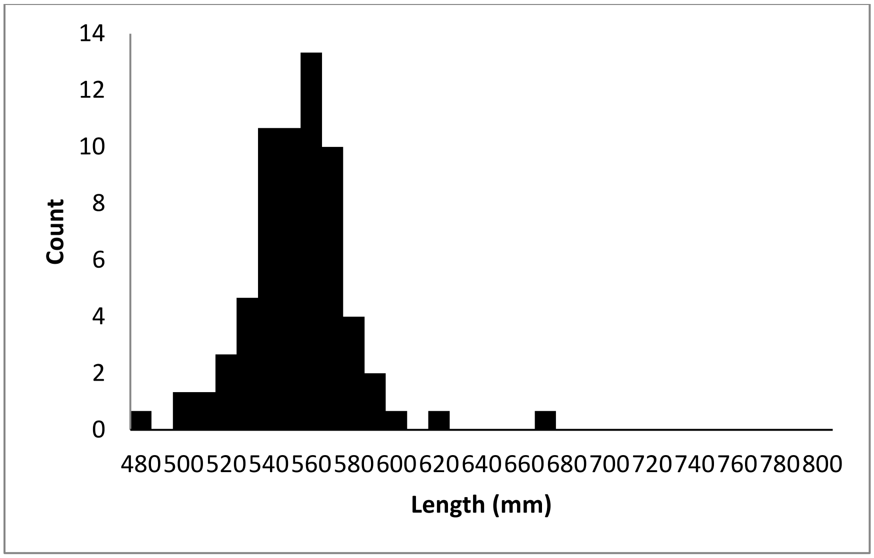

Figure 14. Length frequency of Asian carp in the downstream site, near Chandlerville, 2013.

APPENDIX 1
SANGAMON RIVER SITES

Sangamon River Sampling sites (Site # based on previously completed studies)

Allerton Park – above Lake Decatur Dam
Site 1 – Lincoln Park CSO – above outfall
Site 3 – Lincoln Park CSO – below outfall
Site 4 – Oakland CSO (Lincoln Park) - above outfall
Site 5 – Oakland CSO (Lincoln Park) – below outfall
Site 6 – 7th Ward CSO (End Sunset Dr.) – above outfall
Site 7 – 7th Ward CSO (End Sunset Dr.) - below outfall
Site 8 – Main Treatment Plant (Off Main street) – upstream of main outfall
Site 9 – Main Treatment Plant (Off Main street) –down stream of main outfall
Site 11 – Sangamon River directly downstream of Stevens Creek
Site 12 – Bridge on Wyckles Road
Site 14 – Lincoln Trail Homestead State Park

Routine collections for water quality assessment were conducted at all sites.

Macroinvertebrates were collected form Allerton Park and Sites 3, 5, 7, 8, 11, 12, and 14.

Mussels were collected from Allerton Park and Site 7.

Bluegill and snails were sampled above Lake Decatur Dam, below the dam and above SDD effluent, and below SDD effluent to Lincoln Trail Homestead State Park.

Sport fish were sampled at two sites above SDD effluent and three sites below SDD effluent.

Asian carp were sampled at one site below Lake Decatur Dam and one site downstream near Chandlerville.

Exhibit 36

Exhibit 36

Biotic assessment of water quality in a stretch of the Sangamon River receiving effluent from the Sanitary District of Decatur: Focusing on chemical assessment, macroinvertebrate assemblage, mussel assemblage, tiered-aquatic life use, and the sport fishery

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EXECUTIVE SUMMARY

We sampled four treatment reaches of the Sangamon River . The four treatment reaches were 1) reference - upstream of the Lake Decatur dam, 2) upstream - downstream of the dam but upstream of the Decatur Sanitary District main discharge, 3) downstream - directly downstream of the main discharge, and 4) recovery - 25 or more miles downstream of the main discharge. We sampled eleven sites monthly for water quality; seven sites located in the upstream reach, and four sites located downstream of the SDD. Seven sites were designated to sample annually for macroinvertebrate, mussel, sportfish, and non-game fish diversity; four sites located in the upstream reach and three located in the downstream reach. Three sites upstream of the Lake Decatur dam and five sites further downstream of the SDD's main discharge were added to the study this year.

Water quality in the upstream and downstream reaches differed during periods when discharge, measured at the Route 48 Bridge, was below 10 cfs, which occurred the majority of the sampling period due to a national drought. Physical habitat was of significantly higher quality in the reaches above the reservoir and below the effluent. Macroinvertebrate diversity, as estimated by Simpson's D and Shannon-Weiner H', showed no difference between the four reaches ($p > 0.05$). Likewise, River watch MIBI scores and percent EPT taxa showed no difference ($p > 0.05$) between reaches. Due to the drought, it is unlikely that any sites reached their full potential, but the reaches above the dam and below the effluent had greatly improved scores, indicating potentially better communities when under non-drought conditions. Further studies concentrating on high quality taxa and habitat during normal flow may discern finer differences among the reaches.

Mussel communities had the greatest relative density and species richness in the above dam reach. The above effluent and 25+ miles below effluent reaches had statistically similar relative densities and richness scores ($p > 0.05$). Mussel diversity, as estimated by Simpson's D and Shannon-Weiner H', showed no significant differences between the reaches ($p > 0.05$). Mussel communities are significantly affected by the Lake Decatur dam and SDD's main discharge, but show signs of recovery when further downstream.

A total of forty fish species, seventeen of which were sportfish species, were sampled using AC boat electrofishing during high water and seining methods during low water from the four treatment reaches of the Sangamon River,. Because of high conductivity during low water, seines were implemented to sample fishes among all treatment reaches. AC electrofishing was recently conducted and allowed us to sample different fish species, such as Walleye and Buffalo, that we were unable to capture using seines. During this recent high water event, fish were distributed throughout the three reaches downstream of the dam. There was no difference in relative density of all fishes among treatment reaches, implying that these sections of the river are suitable for various sportfish and non-sport fish species. To provide an assessment of habitat use during periods of low to moderate flows, a tracking study could be initiated. These findings and the sampling we will conduct summer 2013 can be used to assess the Sangamon River in regards to the Tiered Aquatic Life use (TALU).

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INTRODUCTION

Rivers and streams are impounded for a variety of reasons, including residential, commercial, and agricultural water supply; flood and debris control; and hydropower production (Kondolf 1997). However, impoundments may impact downstream aquatic systems and their surrounding terrestrial habitats. They can affect riverine systems by altering the flow regime, changing the sediment and nutrient loads, and modifying energy flow (Lignon *et al.* 1995). In addition, impoundments may lead to diminished water quality and availability, closures of fisheries, extirpation of species, and groundwater depletion for surrounding areas (Abramovitz 1996, Collier *et al.* 1996, Naiman *et al.* 1995). As a result of impoundments, downstream reaches may no longer be able to support native species, which will be reflected by reduced integrity of biotic communities (Naiman *et al.* 1995, NRC 1992).

A a natural flow regime is critical for sustaining ecosystem integrity and native biodiversity in rivers (Poff *et al.* 1997). Depending on the use of the dam, it may have varying effects on downstream aquatic habitats. Impoundments used for urban water supplies lead to a reduction in flow rates downstream of the dam throughout the entire year (Finlayson *et al*. 1994), as well as increase daily and seasonal variability in flow regime (Finlayson *et al*. 1994, McMahon & Finlayson 2003). In addition, abiotic variables including temperature, dissolved oxygen, turbidity, pH, conductivity, and solids concentrations are altered in the downstream river system (Finlayson *et al.* 1994).

Along with stream and river impoundments, point source and non-point source pollution can have profound and lasting effects on the ecological integrity of the system. Non-point sources of pollution include agriculture, livestock grazing, and urbanization, and point source pollutions include sanitary discharge and industrial waste. In order to reduce point source pollution, the

Water Quality Act of 1972 encouraged wastewater treatment plants to upgrade their systems. As a result, many communities were forced to build advanced tertiary water treatment facilities (Karr *et al.* 1985). Updated facilities still release high concentrations of nutrients into surrounding rivers. Carpenter and Waite (2000) documented that concentrations of phosphorus were highest in streams draining agricultural basins and at sites influenced by wastewater discharges, and Twichell et al (2002) reported that sewage effluent inputs had elevated nitrate levels. The enhanced nutrient discharge can be expected to increase productivity within a river because primary productivity and detrital processing usually are limited by low ambient stream nutrient concentrations (Stockner and Shortreed 1978, Elwood et al 1981, Winterbourn 1990).

Unlike impoundments and pollution, droughts are a natural phenomenon, but they can also severely affect aquatic ecosystems. Droughts can alter the lotic systems in ways harmful to biota, including loss of habitat, food resources, and stream connectivity (Lake 2003). The overall effect drought has on aquatic communities varies, and often depends on the availability of refugia and life history of the organisms (Humpheries and Baldwin 2003, Lake 2003). Macroinvertebrates, especially sensitive taxa such as stoneflies and caddisflies, can be temporarily decimated by drought conditions (Boulton 2003). The effects of a drought depend on many factors, including its severity, length, and the previous condition of the lotic system: specifically anthropogenic perturbations. Human disturbances such as impoundments can be exacerbated by drought conditions decreasing the amount of dilution for pollution sources in lotic systems. This can lower the resilience of the aquatic ecosystem (Bond *et al.* 2008), potentially worsening their effects.

The river runs for approximately 200 km in central Illinois, and its 14,000 km^2 watershed extends to 18 counties. Streams converging with the Sangamon River run through glacial and alluvial deposits, creating a low gradient stream with sand and gravel substrates. The Sangamon basin has experienced multiple point and non-point source impacts throughout the years. Land use around the river system is currently 80% agricultural, of which 85% is corn or soybeans. Bloomington, Decatur, and Springfield, are the main cities along the river and are home to more than 500,000 people. The Sangamon River immediately below Lake Decatur is influenced by impoundment, altered flow regime, and point source discharges.

Due to multiple anthropogenic influences, the biotic integrity of the Sangamon River is in constant flux. An intensive sampling program, beginning in 1998-99 and continuing from 2001-2011, was conducted to document temporal and spatial heterogeneity of an 8.5 km urban reach of the Sangamon River. Sampling began directly below the Lake Decatur Dam and continued downstream to incorporate discharges from the Sanitary District of Decatur (SDD). These studies (Fischer & Pederson 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011) were intended to characterize stream habitat quality and assess impacts from ongoing reservoir and urban management by evaluating biotic integrity at various trophic levels in the context of the physical and chemical nature of the Sangamon River.

Original sampling locations were associated with operation of the Sanitary District of Decatur that were easily identified by landmarks within the city of Decatur, Illinois, USA. Sites were established in 1998 in conjunction with combined sewage overflow (CSO) facilities and the main treatment plant. Sites are located in the mainstem of the Sangamon River extending from directly below the Lake Decatur dam to the Lincoln Memorial Highway Bridge, located five miles southwest of Decatur. Sites 1, 3, 4, 5, 6, 7, and 8 extend from the dam to directly above the discharge of the main treatment plant in the upstream reach, and sites 9, 11, 12, and 14 extend from the main treatment discharge to a point approximately 8 river miles downstream near Lincoln Trail Homestead State Park. Eight new sites were added to our sampling regime this year. Five sites, beginning approximately 25 miles downstream of the SDD effluent, were added to determine when mussel populations recovered dowstream. Three sites (Highway 32 bridge, Allerton Park, and Saint Lodge Park) were added in an upstream reference reach to help quantify the effects the reservoir has on the Sangamon River. The addition of these sites will give us a total of four reaches (refence above the dam, upstream above the effluent, downstream below the effluent, and recovery 25+ miles below the effluent) to compare and contrast Unionid mussel, macroinvertebrate, and fish assemblages.

The Stream Habitat Assessment Procedure (SHAP), which assesses lotic habitat quality using features considered important to biotic integrity, was performed in 1998, 2001, and 2002. At each site, two individuals assessed metrics relating to substrate and instream cover, channel morphology and hydrology, and riparian and bank features to one of four habitat quality types, following guidelines established by the Illinois Environmental Protection Agency (1994). The average total score of the 15 metrics form the basis of an overall habitat quality rating for the stream reach under consideration. The SHAP was replaced with the Qualitative Habitat Evaluation Index (QHEI) starting in 2010 as a more rigorous measure of physical habitat that also incorporates an objective invertebrate sampling.

This overall physical structure provides a base for the ability of the study reach to support diverse life. Routine assessment of characteristic water quality variables combined with substrate characteristics, channel morphology, and bank features help aid in our understanding of stream systems. Analyzing specific physical and chemical variables is essential to understanding the potential for anthropogenic impacts to affect biotic integrity as organisms often exist in narrow ranges of tolerance for these variables. We have compared various physical and chemical features of the Sangamon River sites from 2002-2011. Principle components analysis (PCA) of water quality variables has routinely indicated differences between the upstream and downstream reaches at low discharge (as indicated by the USGS stream gauge at IL Route 48 Bridge). These differences became negligible at discharges exceeding 200 cfs.

Assessment of stream biota was required to determine whether differences observed in the physical and chemical habitat between the stream reaches were reflected across trophic levels. Such an evaluation involved biotic indices based upon macroinvertebrates and fish, taxa that are widely used for biotic assessments. Downstream sites typically were characterized by significantly lower MBI scores, indicating improved habitat quality capable of supporting more diverse macroinvertebrate communities. In contrast, general diversity indices (species richness, evenness) and IBI scores suggest that fish may be relatively insensitive to the environmental gradient that we studied. We concluded that sites downstream of the main treatment plant outfall from the SDD may have increased biotic integrity due to predictable instream flows and increased primary production, due in part to nutrient loading.

Stable and predictable instream flows observed in the reach within 15 miles downstream of the SDD can facilitate development of more diverse biotic communities, as seen in work conducted in other riverine systems (Sanders 1969; Fisher 1983; Peckarsky 1983; Ward & Stanford 1983; Reice 1985; Ross *et al*. 1985; Walde 1986; Resh *et al*. 1988). Drastic reduction of instream flow resulting from routine elimination of reservoir discharge was damaging to habitat quality in the upstream reaches. Differences in the overall nature of the upstream and downstream reaches become less distinct during periods of high reservoir discharge. Overall, results suggested that a flow threshold of 200 cfs exists to maintain a continuum between the upstream and downstream reaches. When flow is below 200 cfs, the reaches have discrete water quality characteristics.

Water quality may be compromised in the upstream reach of the Sangamon River, extending downstream from the dam to the main treatment plant discharge of the Sanitary District of Decatur, as a result of reservoir level maintenance management eliminating outflow. Effective management of the Sangamon River may require a continuous instream flow above the proposed threshold (200 cfs) by discharge from Lake Decatur.

The Tiered Aquatic Life Use (TALU) is a broad measure of the value of habitat and includes both biotic and abiotic values of a given resource. The TALU includes not only historic ecological indices of multiple trophic levels of biota, but economic and recreational value of an aquatic system as well. For example, although sportfish make up a small portion of the fish assemblage they almost always have the greatest economic and recreational value. Additionally, Unionid mussels have shown sensitivity to various assaults on lotic systems. Mussels can be affected by substrate type and flow (Harman 1972; Strayer 1983; Vaughn 1997; Watters 1999), and can be harmed by excessive concentrations of heavy metals, phosphorus, and nitrogen (Beckvar *et al.* 2000; Jacobson et al 1997; Mummert et al 2003; Wang et al 2007). As such, the U.S. Environmental Protection Agency proposed using mussel communities in setting ammonia standards (Great Lakes Environmental Center 2005). Based on this information it is important to include these specific communities in assessment of aquatic systems.

We sought to assess the water quality, as well as the macroinvertebrate, non-game fish, sportfish, and Unionid mussel communities of the Sangamon River near Decatur, Illinois. We sampled the communities in four treatment reaches; two above and two below the Decatur Sanitary District main effluent. Although all of these metrics individually provide some measure of habitat, the combination of all data will provide a more broad analysis of multiple uses as it pertains to the TALU.

METHODS

Water Data Collection and Chemistry Determination

We collected water quality data monthly from April 2012 to March 2013. Sampling began at the Lake Decatur dam and proceeded downstream. In field, we used a YSI model 85 to measure dissolved oxygen, temperature, and specific conductivity, and a YSI model 60 to measure pH. Water samples were collected 0.3 m below the surface, returned to the lab on ice, and analyzed within accepted time limits. All analyses followed the Standard Methods for Examination of Water and Wastewater (APHA, 1995).

Suspended and total solids were determined by drying residue collected on standard glass fiber filters and unfiltered samples at 103-105 °C. We analyzed volatile and suspended solids by weight loss upon ignition at 550 °C. Total oxidized nitrogen (NO_2-N + NO_3-N) was determined using the cadmium reduction method, and ammonia nitrogen was determined with the phenate method. We used the ascorbic acid method to determine total phosphorus (following persulfate digestion) and soluble reactive phosphate (following filtration). A Beckman DU 530 Life Science UV/Vis Spectrophotometer was used for all colorimetric nutrient analyses. Hardness and alkalinity were measured using titration to colormetric endpoint methods. We considered quality control procedures during all analyses, including but not limited to parallel analyses of laboratory standards.

We calculated the averages for each variable for the upstream and downstream reaches. We performed t-tests with a significance level of $P=0.05$ (Zar 1996) to assess differences between upstream and downstream sites. Variables were log transformed where necessary to prevent heteroscedasticity. Principle components analysis was conducted for 16 variables after individually log transforming and normalizing the data. All analyses were performed using Primer 6.1.14 (Clarke and Warwick 2001). Variables that were highly correlated to another and thus redundant were eliminated from the analysis.

Assessment of Physical Habitat

We assessed physical habitat at low flow in summer 2012 using Ohio's Qualitative Habitat Evaluation Index: QHEI (Rankin 1996) at two sites above the Lake Decatur dam, four sites below the dam and above the effluent, three sites within 15 miles downstream of the effluent, and two sites 25+ miles downstream of the effluent (Figure 1). Each 100 m site was divided into six evenly-spaced transects. We measured substrate type and depth every five meters along the width of each transect. Between each transect, we estimated the percent of each instream cover type, the channel morphology, the amount of riparian zone and bank erosion, and the pool and riffle quality. Each section was scored out of 20, making a total possible maximum score of 100.

Assessment of Macroinvertebrate Community

Macroinvertebrates were sampled during summer 2012 using IEPA's multihabitat 20-jab method. We sampled two sites above the Lake Decatur dam, four sites below the dam and above the effluent, three sites within 15 miles downstream of the effluent, and two sites 25+ miles downstream of the effluent (Figure 1). The proportion of jabs in a specific substrate type was based on relative proportions in the Qualitative Habitat Evaluation Index (QHEI) calculated that year. We preserved the macroinvertabrates in 70% ethanol and transported them to the EIU Fisheries and Aquatic Research Lab for identification and enumeration. Macroinvertebrates were moved to fresh 70% ethanol within a week of collection to prevent degradation of the samples. We identified all macroinvertebrates to the lowest taxonomic group possible using Merritt and Cummins (1996). Voucher specimens were catalogued into the EIU invertebrate collection.

We assessed the taxonomic richness, Simpson's diversity (D), Shannon-Weiner diversity (H'), percent Ephemeroptera, Pleucoptera, and Trichoptera (EPT) taxa, and macroinvertebrate index of biotic integrity (MIBI) based on taxon-specific environmental sensitivity values using standard River watch and EPA protocols. The Simpson's diversity (D) was calculated using the formula:

$$D = \frac{1}{\Sigma p_i^2}$$

Where:

1. p_i = is the proportion of the total number of individuals comprised by species i

We calculated Shannon-Weiner diversity (H') using the formula:

$$H' = -\sum (p_i \times ln(p_i))$$

Where:

2. p_i = is the proportion of the total number individuals comprised by species i

We performed t-tests with a significance level of P=0.05 (Zar 1996) to assess differences between upstream and downstream sites.

Relative abundance of taxa was assessed using multidimensional scaling (MDS) based on Bray-Curtis similarity matrices (BC). Data were square root transformed to down-weight the influence of abundant taxa. Similarity of assemblages among sample sites was portrayed in scatter plots of the first two ordination axes. Multivariate analysis of similarity (ANOSIM) was used to determine significant differences between reaches. All analysis were performed using Primer 6.1.14 (Clarke and Warwick 2001), and significance level was set at P = 0.10.

Assessment of Unionid Mussel Community

Mussel assemblages were sampled during summer 2012 using timed hand searches. We sampled three sites above the Lake Decatur dam and four sites 25+ miles downstream of the effluent (Figure 1). Four people spread out and searched within the 100 m site at random for one hour, creating four total man hours of effort. Searches were conducted visually and tactilely. All mussels were collected in mesh bags and identified to species according to Cummings and Mayer (1992). We took length measurements in field and returned all live mussels to the river. Dead shells collected for vouchers were taken back to the lab for identification conformation and cataloging.

We calculated species richness (S), Simpson's diversity (D), Shannon-Weiner diversity (H'), and catch per unit effort (CPUE) for the mussel assemblages. Simpson's diversity and Shannon-Weiner diversity were calculated using the same formulas as outlined above. We performed one-way ANOVAs with a significance level of P=0.05 (Zar 1996) to assess differences among reaches. The below effluent reach was not included in ANOVA analyses due to the high number of zero samples. Catch per unit effort was determined as individual mussels caught per hour for the timed hand searches, and individual mussels caught per square meter for the substrate sieves.

Relative abundance of species present was examined using MDS and ANOSIM as outlined above. All analysis were performed using Primer 6.1.14 (Clarke and Warwick 2001), and significance level was set at $P = 0.10$.

Assessment of Sportfish Community

Conductivity was much higher in the below effluent reach (above effluent = 585.8 mS cm^{-1}, below effluent = 2015.4 mS cm^{-1}), causing electrofishing gear to be an ineffective sampling method. We attempted to sample fishes using trap nets, but it was unsuccessful. As a result, seines were used to sample all sites to compare relative densities of fishes. We sampled four treatment reaches (above the dam, above the effluent, below the effluent, and 25+ miles below the effluent) during spring 2012 using 50 foot seines (Figure 1). The above the Lake Decatur Dam reach data was excluded from all comparisons because this reach is separated from the lower reaches by the reservoir.

Kick and pull seine methods were used to sample fish in each site beginning in mid-June 2012. In the absence of a riffle, we performed 2 pull seines, which required one person to hold one end of the seine near shore, staying in place, while a second person pulled the seine out into the middle of the river and continued upstream, wrapping around to meet the person near shore. When a riffle was present we performed 1 pull and 1 kick seine. The kick seine method requires two people hold the seine downstream of the riffle, while a third person kicks beginning upstream moving in a downstream manner until the seine is reached. An estimate of relative density was calculated as catch per unit effort (CPUE) as number of fish captured per seine pull or kick. All fishes were weighed to the nearest gram and measured in total length to the nearest mm. Fish that could not be identified to species in the field were taken back to the laboratory for identification.

During high water at the end of April 2013 we were able to use alternating current (AC) boat electrofishing because the conductivity dropped to around 300 mS cm^{-1}. We were able to sample three sites in the above the effluent reach, and 3 sites in the below the effluent reach. At each site we conducted two 15 minute electrofishing runs on each shoreline for a total of 30 minutes of effort. A measure of relative density was calculated as catch per unit effort (CPUE) as fish per hour.

RESULTS

Water Data Collection and Chemistry Determination

A total of nineteen water quality variables were determined for eleven sites along the Sangamon River (Table 1). An overall pattern of parameters increasing downstream of the effluent was seen, similar to previous years. Individual t-tests indicated that temperature, conductivity, hardness, nitrates, ammonia, phosphates, and solids all increased significantly downstream of the effluent (Table 1). Suspended solids did not increase significantly downstream of the effluent, thus dissolved solids, consisting of anions, cations, and nutrients, were the main contribution to elevated total solids below the effluent.

Principle Components Analysis extracted six factors that explained 87% of the total variation in water quality of the Sangamon River during the sampling period. Upstream and downstream sites occupy discrete regions, with upstream sites showing more variation (Figure 2). Sites also grouped based on discharge and season. Upstream and downstream samples taken when flow, as measured from the Route 48 Bridge, was greater than 200 cfs grouped close together. Solids, phosphates, conductivity, and dissolved oxygen tended to vary based on reach. Temperature, ammonia, pH, and alkalinity tended to vary based on season. Hardness and nitrates tended to vary based on both reach and season. ANOSIM revealed significant differences between reaches ($R = 0.44$, $p = 0.10$) and between high and low flow regimes ($R = 0.45$, $p = 0.10$).

Assessment of Physical Habitat

Qualitative habitat scores ranged from 44 to 65 out of 100 (Figure 3). The above dam and below effluent reaches had average ratings of "good", while the above effluent and 25+ miles below effluent reaches had average ratings of "fair". Above effluent scores were significantly lower than scores in the above dam and below effluent reaches ($F_{3,7} = 8.99$, $p = 0.008$). Main differences between reaches included the amount of siltation and the number of riffles.

Assessment of Macroinvertebrate Community

A total of 32 different families were identified in the combined reaches sampled (Table 2). There was no significant difference between the 4 reaches for taxonomic richness, Simpson's diversity, Shannon-Weiner diversity, percent EPT taxa, or MIBI scores (Table 3, $p > 0.05$). The reach upstream of the dam had scores indicating a higher quality assemblage for all parameters. The above-dam reach and below-effluent reach had percent EPT taxa scores a magnitude higher than the other two reaches. The above-effluent reach and 25+ below effluent reach had MIBI scores in the "very poor" category, while the above-dam reach and below-effluent reach had "poor" scores.

Multidimensional scaling revealed relative differences in taxonomic composition among the reaches (Figure 4). Clustering occurred (2D stress: 0.07) within treatment reaches and significant separation occurred among reaches (ANOSIM, R = 0.77, p = 0.1). The above dam and 25+ miles below effluent reaches were more similar to each other, as were the above effluent and below effluent reaches.

Assessment of Unionid Mussel Community

A total of 16 native species and one introduced species (*Corbicula fluminea*) were recovered (Table 4). The most common species found was *Quadrula pustulosa*, and this species, along with *Tritogonia verrucosa, Potamilus ohiensis, Lampsilis cardium,* and *Lasmigona complanata* make up 74.5% of the total individuals found. Three *Arcidens confragosus,* an uncommon species in Illinois, were found above the dam (Table 4). Relative density (CPUE) was significantly higher above the dam than 25+ miles below the effluent, but CPUE above the effluent was not significantly different from either reach (Table 5, Figure 5). Above the dam had significantly higher species richness than the above effluent and 25+ miles below effluent reaches. Simpson's and Shannon-Weiner diversity indices were not significantly different among the reaches (Table 5).

Multidimensional scaling revealed relative differences in species composition among the reaches (Figure 6). Clustering occurred (2D stress: 0.09) within treatment reaches and significant separation occurred among reaches (ANOSIM, R = 0.77, p = 0.1). The above effluent reach and 25+ miles below effluent reach did cluster together for some sites.

Assessment of Sportfish Community

We sampled a total of 11 sites, 6 upstream sites, and 5 downstream sites using seines. We sampled 2442 individuals and 25 species using seineing methods (Table 6), and 910 individuals and 28 species with AC electrofishing (Table 7). The most dominant non-sportfish species sampled were: Gizzard Shad, juvenile cyprinidae species, Sand Shiners, Bluntnose Minnows, Red Shiners, and Mosquitofish. The majority of the sportfish community was comprised of: Bluegill, Channel Catfish, Green Sunfish, White Crappie, Largemouth Bass, and Yellow Bullhead; with bluegill and channel catfish being the most numerically abundant (Table 6 and 7).

Relative density (CPUE) of all fishes using the seine was highest in the Riverton downstream site and lowest in upstream site 8 (Table 8). There was no difference in relative density of fishes among the 3 reaches below the Lake Decatur Dam ($P>0.05$). A total of 120 sportfish were sampled using seines (Table 9). The average relative density of sportfishes in the Sangamon River below the Lake Decatur Dam was 4.80 ± 1.69 fish/hour. The relative density of sportfishes was highest at site 1 (15.5 fish/hr) and the lowest was at site 14 (0 fish/hr) (Table 10).

When using AC electrofishing to sample fishes at high flow, we captured a total of 910 individuals (Table 11). Relative density using electrofishing was highest in upstream sites 3 and 5 and the lowest was at site 9 and 12 (Table 11). The average CPUE was much higher in the upstream reach (above effluent reach), but the variance was large, so there was statistically no significant difference in relative densities between the reaches ($P>0.05$) (Table 11). When comparing the relative density of fishes sampled between AC electrofishing and seining, we found that AC electrofishing was able to sample more fish per hour ($P<0.05$). However, AC electrofishing was unable to sample the smaller fishes such as minnows and shiners, which kick and pull seines were able to collect.

DISCUSSION

The primary difference between the upstream and downstream reaches is likely attributable to metrics related to reservoir discharge and inputs from the SDD main discharge. Outflow from

Lake Decatur is the primary input to the upstream reach, which is compromised as a result of management to maintain reservoir levels by eliminating outflow. The discharge from the main treatment plant of the SDD alters instream water chemistry, especially during periods of low reservoir discharge. Consistent flow downstream of the SDD's main outfall, during periods of low reservoir discharge, helps maintain the overall QHEI scores and physical habitat quality. The changes in water quality below the sanitary effluent were more pronounced this year than in previous years due to the national drought of 2012. The discharge from the dam was below 10 cfs for eight out of the twelve months sampled, and only went above 500 cfs once. This lowered flow led to ammonia and hardness, two water quality parameters that usually do not differ between reaches, to increase significantly downstream of the SDD's sanitary effluent. Sites downstream of the SDD may have greater potential for instream primary productivity, as a result of nutrient loading, particularly at low flow. This elevated productivity, as indexed by higher levels of dissolved solids, conductivity, oxidized nitrogen, and phosphorus, could in turn support more diverse macroinvertebrate and fish assemblages. Consistent high reservoir discharge would allow these factors, along with the others parameters that change downstream, to remain relatively homogenous as seen in previous years.

The macroinvertebrate communities were dominated by aquatic midges and oligochaete worms. Both taxa are common in organic rich habitats, and midges are often the most abundant taxa (Rabeni and Wang 2000). The increased abundance of aquatic worms is likely due to the drought and consequentially lowered flow in the Sangamon River. Aquatic worms have been shown to thrive in low-flow and drought conditions (Dumnicka and Koszalka 2005, Sloreid 1994). While not significant, both parameters that measured sensitive taxa, percent EPT and MIBI scores, improved above the dam and below the effluent; corresponding with significantly higher QHEI scores. Macroinvertebrate communities are typically correlated with habitat scores (Hammer and Linke 2003) and are likely responding to the improved physical habitat below the effluent as in previous years. The drought, however, led to an overall decrease in macroinvertebrate quality and quantity, and overshadowed other factors affecting community structure. Although there were large differences between reaches, using sensitive EPT taxa, there was enough variability between sites within a reach that these differences were only marginally significant. Comparison of samples from specific microhabitats, during normal flow, may allow for more detailed comparisons.

Mussel community structure above the dam was significantly different than reaches below the dam. The reduction in flow and physical barrier from upstream waters likely led to a decrease in relative density and species richness in mussel communities below the dam. This was follwed by local extinctions below the effluent. Mussel communities began to recover downstream of the effluent in species richness, diversity, and density measures. Additional input of several tributaries diluted the SDD's main effluent's effects and allowed mussel communities to return. The exact causes of this pattern, whether from inadequate dispersal or water quality conditions, requires further study.

The diversity of fish species was comparable to other Midwestern streams (Colombo unpublished data), with Sand Shiners, Blutnose Minnows, Red Shiners, Gizzard Shad, and Mosquitofish being the most numerically abundant non-game species and Bluegill, Channel Catfish, Green Sunfish, Largemouth Bass, and Yellow Bullhead being the most abundant sportfish species. Fairly small individuals dominated the sportfish population of the Sangamon River when using seining methods, while AC boat electrofishing sampled larger fish species such as Walleye, Gar, and Buffalo. Because of the 2012 drought, the conductivity was extremely high below the Sanitary District of Decatur effluent, making it impossible to use electrofishing gear types, until recently. Higher water caused the conductivity to drop enough (301 mS cm^{-1}) to use alternating current electrofishing. We sampled fishes with electrofishing that we were unable to collect using seines, such as Smallmouth Bass, and Freshwater Drum. Because of our differential success of sampling a wide range of species using both AC boat electrofishing and seining methods, we will continue to conduct fish sampling using various gear types during 2013 to more accurately assess all sportfishes in the Sangamon River.

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TABLES AND FIGURES

Table 1. Measured water quality variables for eleven Sangamon River sites associated with the Sanitary District of Decatur. Variables below the detection limit are indicated with a < .

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
4.2012	1	12.5	18.5	8.1	537	489.1	237.3	0.05	0.24	0.19	<	20.5	11.5	9	308.8	144.5	164.3	329.3	156	173.3
5.2012	1	4	21.8	8.5	527	379.6	223.4	0.17	0.96	0.38	0.14	39	15	24	355.7	199.7	156	394.7	214.7	180
6.2012	1	3.9	22.7	8.3	521	197.1	223.4	0.46	2.77	0.33	0.19	32.7	10.7	22	199.3	122.7	76.7	232	133.3	98.7
7.2012	1	2.8	27.5	8.4	740	146	307.1	0.16	18.43	1.55	0.92	85.9	43.5	42.4	410.1	239.1	171	496	282.7	213.3
8.2012	1	1.9	24.7	8.8	644	259.2	265.2	0.61	<	0.67	0.39	12	4	8	536	66.7	469.3	548	70.7	477.3
9.2012	1					211.7	<	0.02	0.09	0.34	0.04	30	20.7	9.3	391.3	168.7	222.7	421.3	189.3	232
10.2012	1	3.5	17.2	8.4	455	230	<	0.09	<	0.21	0.02	16	5	11	318.7	177.7	141	334.7	182.7	152
11.2012	1	2.9	11.6	8.5	2725	237.3	<	0.28	<	0.16	0.03	14	8	6	235.3	30.7	204.7	249.3	38.7	210.7
12.2012	1					288.4	<	0.16	0.11	0.13	<									
1.2013	1	2.5	0.6	9.3	316	262.8	14	3.88	0.19	0.15	<	10.4	4.7	5.7	338.9	6	332.9	349.3	10.7	338.7
2.2013	1	5.2	4	9.5	374	281.1	27.9	11.4	0.06	0.14	0.04	9.6	6	3.6	166.4	46	120.4	176	52	124
3.2013	1	2.5	4.1	9.2	376	277.4	27.9	9.25	0.04	0.17	0.03	16.8	8.8	8	109.9	116.5		126.7	125.3	1.3
4.2012	3	4.4	16.9	6.9	691	372.3	223.4	0.02	0.06	0.22	<	19.5	10	9.5	335.2	98	237.2	354.7	108	246.7
5.2012	3	5.1	22.1	8.4	526	244.6	279.2	0.27	0.66	0.28	0.11	31	12	19	169	182.7	<	200	194.7	5.3
6.2012	3	4	21.7	8.2	530	120.5	237.3	0.43	2.36	0.28	0.2	23.3	4.7	18.7	206	110	96	229.3	114.7	114.7
7.2012	3	0.8	26.5	8.1	775	164.3	293.2	0.05	5.23	0.78	0.42	32	26	6	437.3	178	259.3	469.3	204	265.3
8.2012	3	1.8	23.5	8.1	650	262.8	265.2	0.12	0.06	0.43	0.11	11.9	6	5.9	520.1	32.7	487.4	532	38.7	493.3
9.2012	3					233.6	<	0.22	0.66	0.24	<	19.3	16.7	2.7	404.7	178	226.7	424	194.7	229.3
10.2012	3	1.6	18.2	8	477	215.4	<	0.19	<	0.29	0.07	11	9	2	346.3	161.7	184.7	357.3	170.7	186.7
11.2012	3	3.1	9.2	8.5	383	284.7	<	0.51	<	0.13	<	15	9	6	341	39	302	356	48	308
12.2012	3					313.9	14	0.45	0.04	0.09	<									
1.2013	3	2.9	0.9	9	339															
2.2013	3	4.9	3.8	9	379	284.7	27.9	11.4	0.14	0.11	0.03	9.2	7.2	2	234.8	10.1	224.7	244	17.3	226.7
3.2013	3	2	4	9	383	292	27.9	9.46	0.1	0.21	0.04	17.2	8	9.2	140.1	142.7		157.3	150.7	6.7

Table 1 cont.

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO$_2$/NO$_3$ mg L^{-1}	NH$_4$ mg L^{-1}	PO$_4$ total mg L^{-1}	PO$_4$ SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
4.2012	4	6.1	16.5	7.2	657	321.2	293.2	0.26	0.51	0.19	0.05	6.5	4	2.5	354.8	93.3	261.5	361.3	97.3	264
5.2012	4	4.2	22.3	8.1	532	244.6	251.3	0.14	0.82	0.27	0.11	34	9	25	314	171	143	348	180	168
6.2012	4	3.8	23	8.2	526	116.8	223.4	0.41	2.24	0.31	0.17	33.3	7.3	26	212	110	102	245.3	117.3	128
7.2012	4	3.4	27.1	8.2	680	120.5	223.4	<	0.23	0.29	0.19	13.5	9.5	4	386.5	205.2	181.3	400	214.7	185.3
8.2012	4	1.8	24.1	8	408	157	153.6	0.06	0.26	0.35	0.2	5	4	1	333.7	9.3	324.3	338.7	13.3	325.3
9.2012	4					219	<	<	0.19	0.27	<	24	18.7	5.3	412	144	268	436	162.7	273.3
10.2012	4	1.3	17.9	8	378	182.5	<	0.28	0.15	0.33	0.16	5	4	1	249.7	124	125.7	254.7	128	126.7
11.2012	4	3.1	9.5	8.3	504	281.1	<	0.32	0.85	0.18	0.08	8	6	2	325.3	51.3	274	333.3	57.3	276
12.2012	4					324.9	<	0.23	0.1	0.2	0.03									
1.2013	4	2.9	0.3	8.9	337	270.1	14	5.33	0.18	0.12	<	12.5	4.7	7.8	344.8		346.9	357.3	2.7	354.7
2.2013	4	5.2	3.6	9	379	262.8	27.9	8.8	0.13	0.14	0.03	8.4	3.2	5.2	248.9	20.8	228.1	257.3	24	233.3
3.2013	4	2.1	4	9.1	384	281.1	27.9	9.25	0.08	0.18	0.04	16.8	6.8	10	283.2	222.5	60.7	300	229.3	70.7
4.2012	5	3.8	16.2	7.3	651	335.8	279.2	0.26	0.54	0.21	0.07	5.5	3	2.5	371.8	109	262.8	377.3	112	265.3
5.2012	5	5.2	22.2	8.5	535	244.6	237.3	0.24	0.93	0.33	0.12	32	<	32	304	224	80	336	224	112
6.2012	5	4.1	21.7	8.2	537	127.8	251.3	0.41	1.91	0.3	0.19	30	8.7	21.3	195.3	95.3	100	225.3	104	121.3
7.2012	5	4.1	27	8.2	677	116.8	237.3	0.03	0.16	0.28	0.23	12	6.5	5.5	378.7	200.2	178.5	390.7	206.7	184
8.2012	5	1.9	23	7.8	370	146	153.6	0.1	0.47	0.58	0.38	4	<	4	289.3	25.3	264	293.3	25.3	268
9.2012	5					208.1	<	<	0.22	0.23	<	21.3	15.3	6	381.3	112.7	268.7	402.7	128	274.7
10.2012	5	1.2	17.6	7.9	380	167.9	<	0.19	0.47	0.54	0.23	6	3	3	260.7	111.7	149	266.7	114.7	152
11.2012	5	2.5	8	8.2	472	262.8	<	2.45	0.66	0.21	0.11	9	7	2	324.3	65	259.3	333.3	72	261.3
12.2012	5					317.6	27.9	0.03	0.05	0.2	<									
1.2013	5	2.9	0.7	8.9	337	277.4	14	3.56	0.15	0.13	0.02	9.1	4.4	4.7	342.9	3.6	339.3	352	8	344
2.2013	5	5	3.7	8.9	380	324.9	<	13.54	0.14	0.13	0.03	12	8.4	3.6	273.3	36.9	236.4	285.3	45.3	240
3.2013	5	1.9	3.9	9.1	386	284.7	27.9	9.32	0.09	0.17	0.05	16	5.2	10.8	293.3	225.5	67.9	309.3	230.7	78.7

Table 1 cont.

Date	**Site**	**DO mg L^{-1}**	**Temp (°C)**	**pH**	**Spec. Cond. mS cm^{-1}**	**Hard. mg L^{-1}**	**Total Alk. mg L^{-1}**	**NO_2/NO_3 mg L^{-1}**	**NH_4 mg L^{-1}**	**PO_4 total mg L^{-1}**	**PO_4 SRP mg L^{-1}**	**TSS mg L^{-1}**	**FSS mg L^{-1}**	**VSS mg L^{-1}**	**TDS mg L^{-1}**	**FDS mg L^{-1}**	**VDS mg L^{-1}**	**TS mg L^{-1}**	**TFS mg L^{-1}**	**TVS mg L^{-1}**
4.2012	6	3.3	17.5	7.4	570	452.6	223.4	0.24	0.5	0.21	0.09	4.5	1.5	3	282.2	155.8	126.3	286.7	157.3	129.3
5.2012	6	5.6	22	8.4	539	288.4	223.4	0.19	0.94	0.29	0.12	37	5	32	319	292.3	26.7	356	297.3	58.7
6.2012	6	4.2	22.2	8.2	540	87.6	237.3	0.44	2.44	0.34	0.17	26	4.7	21.3	188.7	20.7	168	214.7	25.3	189.3
7.2012	6	2.2	27.6	7.8	798	167.9	293.2	0.05	0.81	0.2	0.07	13	7	6	565.7	167.7	398	578.7	174.7	404
8.2012	6	1.6	25.2	7.7	565	200.8	209.4	0.09	<	0.3	0.18	5.3	2	3.3	356	3.3	352.7	361.3	5.3	356
9.2012	6					182.5	<	<	0.46	0.18	<	18	12.7	5.3	295.3	116.7	178.7	313.3	129.3	184
10.2012	6	0.9	17.7	8.2	370	167.9	<	0.43	0.61	0.3	0.16	8	7	1	220	62.3	157.7	228	69.3	158.7
11.2012	6	2.7	7.7	8.1	468	233.6	<	0.39	0.45	0.18	0.04	6	5	1	314	69.7	244.3	320	74.7	245.3
12.2012	6					324.9	<	0.11	0.09	0.17	<									
1.2013	6	2.5	0.3	8.9	337															
2.2013	6	4.9	3.8	9	379	284.7	14	13.24	0.1	0.12	0.02	13.2	6.4	6.8	288.1	6.9	281.2	301.3	13.3	288
3.2013	6	2	4	9	385	284.7	27.9	7.92	0.21	0.16	0.05	16.4	4.8	11.6	348.9	220.5	128.4	365.3	225.3	140
4.2012	7	7.4	18.4	7.9	480	361.4	209.4	0.19	0.32	0.24	<	28	6.5	21.5	238.7	73.5	165.2	266.7	80	186.7
5.2012	7	4.9	23	8.4	460	292	251.3	0.41	0.16	0.45	0.1	51	15	36	335.7	137	198.7	386.7	152	234.7
6.2012	7	3.7	23.3	8.2	516	138.7	237.3	0.37	1.87	0.26	0.09	54	9.3	44.7	167.3	10.7	156.7	221.3	20	201.3
7.2012	7	3.7	26	8	685	157	293.2	<	0.42	0.19	0.09	10.5	5	5.5	489.5	123	366.5	500	128	372
8.2012	7	2	25.7	8.2	564	230	265.2	0.03	0.63	0.24	0.13	2	0.7	1.3	368.7	4.7	364	370.7	5.3	365.3
9.2012	7					167.9	<	0.02	0.11	0.19	<	47.3	8.7	38.7	235.3	82	153.3	282.7	90.7	192
10.2012	7	4.1	19	8.3	408	193.5	<	0.55	0.38	0.24	<	33	16	17	259	78.7	180.3	292	94.7	197.3
11.2012	7	2.8	8.4	8.1	426	204.4	<	0.28	0.22	0.12	0.03	43	2	41	214.3	84.7	129.7	257.3	86.7	170.7
12.2012	7					266.5	<	0.27	0.05	0.12	0.04									
1.2013	7	3.1	0.2	9	326	277.4	14	3.72	0.2	0.14	<	14	6.7	7.3	322	16	306	336	22.7	313.3
2.2013	7	4.9	3.7	9.1	380	262.8	<	14.77	0.11	0.13	0.05	15.6	6.8	8.8	295.1	31.9	263.2	310.7	38.7	272
3.2013	7	2.2	3.8	9	386	255.5	27.9	7.71	0.1	0.17	0.04	18.4	6	12.4	336.3	202	134.3	354.7	208	146.7

Table 1 cont.

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
4.2012	8	4.2	18	7.8	501	292	209.4	0.2	0.33	0.29	0.13	14.5	7.5	7	278.8	92.5	186.3	293.3	100	193.3
5.2012	8	5	22.4	8.4	522	251.9	237.3	0.56	0.21	0.28	0.07	39	15	24	313	110.3	202.7	352	125.3	226.7
6.2012	8	3.6	22.5	8	535	94.9	237.3	0.47	2.81	0.28	0.15	26	6	20	176.7	179.3	<	202.7	185.3	17.3
7.2012	8	3.3	27.3	8	992	164.3	335	0.21	0.58	1.23	0.7	16	7.5	8.5	608	155.2	452.8	624	162.7	461.3
8.2012	8	1.8	24.8	8.1	843	237.3	265.2	0.22	0.53	0.47	0.3	9.3	2	7.3	402.7	12.7	390	412	14.7	397.3
9.2012	8					189.8	<	0.17	1.4	0.2	0.06	12.7	8.7	4	319.3	255.3	64	332	264	68
10.2012	8	2.1	17.7	8.2	403	189.8	<	0.5	0.27	0.17	<	12	8	4	254.7	144	110.7	266.7	152	114.7
11.2012	8	2.8	8.4	8.1	375	204.4	<	0.22	0.36	0.15	0.04	11	6	5	238.3	99.3	139	249.3	105.3	144
12.2012	8					233.6	<	0.43	0.14	0.14	0.03									
1.2013	8	2.9	0.2	9	312	237.3	14	3.72	0.21	0.2	0.02	11.3	4.7	6.7	356.7	30	326.7	368	34.7	333.3
2.2013	8	5.1	3.7	9.1	380	259.2	14	14	0.15	0.12	0.03	16	6	10	344	60.7	283.3	360	66.7	293.3
3.2013	8	2	4	9	386	273.8	14	7.78	0.29	0.18	0.04	18.4	5.6	12.8	348.3	197.1	151.2	366.7	202.7	164
4.2012	9	7.3	23.6	7.6	3088	321.2	460.7	12.05	0.37	3.75	3.9	11.5	7.5	4	1863.2	180.5	1682.7	1874.7	188	1686.7
5.2012	9	5.5	24.2	8.3	1827	346.8	293.2	10.85	0.38	3.97	5.01	34	13	21	1303.3	149.7	1153.7	1337.3	162.7	1174.7
6.2012	9	3.6	25.6	8.1	2499	208.1	488.6	12.32	0.29	4.36	4.36	24	4	20	1408	286.7	1121.3	1432	290.7	1141.3
7.2012	9	4.2	29.8	8.1	4285	248.2	670.1	5.74	0.39	6.36	3.97	13	8.5	4.5	2503	319.5	2183.5	2516	328	2188
8.2012	9	1.8	29.8	8.2	4170	354.1	628.2	10.43	1.46	4.22	7.2	4.5	0.5	4	2664.8	135.5	2529.3	2669.3	136	2533.3
9.2012	9					259.2	<	8.09	3.8	5.55	6.31	13.3	7.3	6	2276	395.3	1880.7	2289.3	402.7	1886.7
10.2012	9	2.5	24.7	8.2	3150	284.7	<	16.25	0.61	2.7	5.53	11	8	3	1943.7	241.3	1702.3	1954.7	249.3	1705.3
11.2012	9	2.4	7.9	8.1	364	310.3	<	6.02	0.13	0.45	1.23	16	8	8	2358.7	181.3	2177.3	2374.7	189.3	2185.3
12.2012	9					324.9	<	5.93	0.2	3.45	3.37									
1.2013	9	2.3	4.6	8.7	890	240.9	14	5.33	0.23	0.96	1.29	35.8	3.6	32.1	456.2	44.4	411.9	492	48	444
2.2013	9	5.2	4.1	8.9	459	284.7	14	11.24	0.13	0.35	0.24	16.4	8	8.4	379.6	85.3	294.3	396	93.3	302.7
3.2013	9	1.8	4.2	9	403	255.5	14	8.55	0.05	0.36	0.2	18.8	6	12.8	393.2	211.3	181.9	412	217.3	194.7

Table 1 cont.

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
4.2012	11	7.2	23.5	7.6	2985	467.2	474.6	12.54	0.53	3.34	3.42	12	6.5	5.5	1842.7	301.5	1541.2	1854.7	308	1546.7
5.2012	11	5.3	24.3	8.3	2107	321.2	418.8	7.42	0.51	3.86	3.91	36	12	24	1280	328	952	1316	340	976
6.2012	11	3.9	25.7	8.1	2365	182.5	488.6	12.13	10.24	4.79	4.19	91.3	5.3	86	1311.3	305.3	1006	1402.7	310.7	1092
7.2012	11	4.3	30	8.1	4263	262.8	670.1	7.4	0.33	5.2	0.74	10	5	5	2696.7	323	2373.7	2706.7	328	2378.7
8.2012	11	1.8	29.9	8.2	4165	390.6	628.2	12.84	1.46	5.68	4.22	6	2	4	2588.7	95.3	2493.3	2594.7	97.3	2497.3
9.2012	11					328.5	<	7.78	4.38	6.07	6.58	12	6	6	2281.3	346	1935.3	2293.3	352	1941.3
10.2012	11	4.6	25	8.2	3228	335.8	<	18.6	0.81	3.16	3.82	10	6	4	1996.7	228.7	1768	2006.7	234.7	1772
11.2012	11	2.4	21.3	8.2	3604	321.2	<	7.21	0.15	1.61	4.43	9	3	6	2371	198.3	2172.7	2380	201.3	2178.7
12.2012	11					313.9	<	5.16	0.19	3.06	3.59									
1.2013	11	3.7	2.5	8.8	696	257.3	<	6.13	0.3	3.44	1.96	8.9	3.1	5.7	701.8	72.9	629	710.7	76	634.7
2.2013	11	5.2	4.3	8.9	443	281.1	14	11.09	0.16	0.78	0.67	16.4	8	8.4	411.6	38.7	372.9	428	46.7	381.3
3.2013	11	1.9	4.6	8.9	452	273.8	14	9.81	0.1	0.8	0.63	18.4	5.6	12.8	437.6	203.7	233.9	456	209.3	246.7
4.2012	12	7.2	22.1	7.8	2519	394.2	446.7	13.9	0.87	4.28	4.5	20	6	14	1556	282	1274	1576	288	1288
5.2012	12	5.1	25.1	8.3	2257	335.8	460.7	9.34	0.82	2.95	3.3	27	9	18	1423.7	315	1108.7	1450.7	324	1126.7
6.2012	12	3.6	26.1	8.2	2189	222.7	446.7	6.66	1.3	5.24	4.56	28.7	3.3	25.3	1259.3	244.7	1014.7	1288	248	1040
7.2012	12	5.2	29.1	8.3	4085	313.9	670.1	4.88	0.46	3.91	4.5	19	6	13	2609	294	2315	2628	300	2328
8.2012	12	1.9	28.3	8.3	4187	430.7	991.2	17.33	0.68	5.11	4.86	19	2	17	2713	134	2579	2732	136	2596
9.2012	12					354.1	<	9.85	3.27	5.81	4.83	25.3	8.7	16.7	2184	346	1838	2209.3	354.7	1854.7
10.2012	12	2.8	23	8.3	2578	303	<	13.72	0.78	2.11	3.66	10	9	1	1675.3	224.3	1451	1685.3	233.3	1452
11.2012	12	2.5	21.6	8.3	3578	321.2	<	6.83	0.14	4.37	4.15	16	3	13	2294.7	202.3	2092.3	2310.7	205.3	2105.3
12.2012	12					328.5	<	4.93	0.17	3.59	3.68									
1.2013	12	2.2	3	8.8	738	295.7	<	6.46	0.36	2.35	1.96	14.7	5.3	9.3	724	48	676	738.7	53.3	685.3
2.2013	12	5.2	4.9	9	463	310.3	27.9	13.08	0.09	0.65	0.6	15.2	6.8	8.4	419.5	59.9	359.6	434.7	66.7	368
3.2013	12	2.1	4.7	8.9	474	270.1	14	8.83	0.12	0.77	0.68	19.6	5.2	14.4	457.7	216.1	241.6	477.3	221.3	256

Table 1 cont.

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
4.2012	14	8	19.5	8	1948	292	349	7.07	3.98	3.19	4.01	25.5	7	18.5	1166.5	255.7	910.8	1192	262.7	929.3
5.2012	14	5.3	23.8	8.3	1923	350.4	404.8	7.29	0.48	3.86	4.29	34	8	26	1182	274.7	907.3	1216	282.7	933.3
6.2012	14	3.8	23.9	8.3	2310	219	474.6	9.39	2.73	3.56	5.13	168	5.3	162.7	1269.3	278.7	990.7	1437.3	284	1153.3
7.2012	14	8.8	27.7	8.6	3984	270.1	600.3	5.45	0.23	4.91	4.21	27	12.5	14.5	2595.7	328.8	2266.8	2622.7	341.3	2281.3
8.2012	14	2.3	24.6	8.6	4288	401.5	725.9	15.78	0.15	7.84	4.35	25.3	3.3	22	2744	152.7	2591.3	2769.3	156	2613.3
9.2012	14					332.2	41.9	6.12	1.31	6.46	2.94	34.7	12.7	22	2525.3	394	2131.3	2560	406.7	2153.3
10.2012	14	2.5	20.8	8.3	1980	248.2	<	7.31	0.59	3.03	4.25	25	11	14	1327	189	1138	1352	200	1152
11.2012	14	2.9	17.9	8.4	3107	332.2	<	6.09	0.23	4.37	4.1	25	6	19	2335	196.7	2138.3	2360	202.7	2157.3
12.2012	14					343.1	<	3.38	0.16	3.68	2.89									
1.2013	14	2.3	2	8.8	761	313.9	7	6.05	0.35	2.21	2.28	26.1	5.9	20.1	784.6	59.4	725.2	810.7	65.3	745.3
2.2013	14	5.1	5.1	9	486	270.1	27.9	12.93	0.1	0.85	0.74	20.8	8.4	12.4	461.9	95.6	366.3	482.7	104	378.7
3.2013	14	2	5	8.9	486	281.1	14	8.27	0.36	0.76	0.59	28.8	6	22.8	464.5	191.3	273.2	493.3	197.3	296
Upstream	Mean	3.4	14.9	8.4	524	240.9	166.5	2.4	0.8	0.3	0.1	19.3	8.2	11.3	312.9	109.6	216.7	332.2	116.1	216.1
Downstream	Mean	3.9	18.2	8.4	2244.6	306.4	354.6	9.2	1	3.4	3.4	24.6	6.5	18.1	1582.8	214.9	1367.9	1607.4	221.4	1385.9
p-value		0.079	0.012*	0.88	<0.001*	<0.001*	0.15	<0.001*	0.032*	<0.001*	<0.001*	0.09	0.39	0.012*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

* Denotes significant differences between reaches.

Table 2. Summary of macroinvertebrates sampled in four reaches of the Sangamon River in summer 2012.

	Above Dam		**Above Effluent**				**Below Effluent**			**25+ Miles Below**		
	1	**3**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**15**	**16**	
Classification												**Total**
Amphipoda	8											8
Oligochaeta	2	3	13	199	15	10	2	19	31	2	13	309
Asellidae	1											1
Baetidae	13					2		3			2	20
Baetiscidae	1											1
Caenidae	20	10		2		5	1		1	1	5	45
Ceratopogonidae		1										1
Chironomidae	79	76	144	258	448	362	317	235	383	5	175	2482
Coenagrionidae	11			2		1		4			1	19
Corduliidae		1		1		2		1				5
Corixidae	2	200	125	57	24	25		1	4	435	435	1308
Dytiscidae			1									1
Elmidae	52	9						2	2		6	71
Ephemeridae		1										1
Sphaeriidae	3										1	4
Gerridae					1							1
Gomphidae	2						5	1	1		1	10
Haliplidae			1									1
Heptageniidae	6											6
Hirudinea				1		1						2
Hydrachnidiae				1								1
Hydrophilidae			1	1								2
Hydropsychidae	66						7	15	72		6	166
Hydroptilidae							1					1
Leptohyphidae	10								30		2	42
Libellulidae		1										1
Macromiidae	1											1
Physidae		2	14	9	1	1		10	2	1		40
Planorbidae			1	1				1		1		4
Polycentropodidae							2	3	2		1	8
Scirtidae	3											3
Veliidae	1											1

Table 3. Comparison of four reaches upstream and downstream of the Lake Decatur dam and SDD's sanitary effluent in the Sangamon River using aquatic macroinvertebrate community indices.

	Above Dam		**Above Effluent**		**Below Effluent**		**25+ Miles Below Effluent**		
Parameter	**Mean**	***S.E.***	**Mean**	***S.E.***	**Mean**	***S.E.***	**Mean**	***S.E.***	***P-Value***
Species Richness	14.00	*4.00*	8.25	*1.25*	9.67	*1.45*	9.00	*3.00*	*p = 0.503*
Simpson's Diversity	3.78	*1.77*	1.87	*0.37*	1.49	*0.20*	1.48	*0.43*	*p = 0.284*
Shannon-Weiner Diversity	1.52	*0.53*	0.77	*0.19*	0.71	*0.09*	0.52	*0.38*	*p = 0.236*
Percent EPT Taxa	22.45	*18.83*	0.52	*0.41*	10.09	*5.02*	1.34	*1.12*	*p = 0.056*
River Watch MIBI[a]	5.72	*0.27*	6.63	*0.38*	6.13	*0.09*	6.64	*0.46*	*p = 0.326*

[a] – lower values suggest a higher quality assemblage.

Table 4. Summary of mussels sampled using timed hand searches in two reaches of the Sangamon River during summer 2012.

	Above Dam			25+ Miles Below Effluent					
	1	2	3	12	13	14	15	16	
Species									**Total**
Amblema plicata	2	1	4						7
Arcidens confragosus	2	1							3
Fusconaia flava	6	5	1						12
Lampsilis cardium	1	16	9						26
Lasmigona complanata	8	6	3				1	6	24
Leptodea fragilis	5	6	2		5	1	1		20
Obliquaria reflexa	5	1	1				1		8
Pleurobema sintoxia	7	10	5						22
Potamilus alatus	3	2	5						10
Potamilus ohiensis	1	1		8	1	11	4	3	29
Pyganodon grandis							1	2	3
Quadrula pustulosa	142	41	31				5		219
Quadrula quadrula	6	6	2			1	1		16
Tritogonia verrucosa	40	7	16		1		1		65
Truncilla donaciformis	3	1	1						5
Truncilla truncata	13	4	1						18

Table 5. Comparison of reaches upstream and downstream of the Lake Decatur dam and SDD's sanitary effluent in the Sangamon River using Unionid mussel community indices. Below effluent reach was not included in analyses. All data were analyzed using F-test with a P = 0.05 level of significnance. Parameters with different letters indicate significant differences between reaches.

Parameter	**Above Dam**		**Above Effluent**		**Below Effluent**		**25+ Miles Below Effluent**			
	Mean	***S.E.***	**Mean**	***S.E.***	**Mean**	***S.E.***	**Mean**	***S.E.***	***F-Statistic***	***P-Value***
Species Richness	14.33^{a}	*0.67*	7.5^{b}	*1.71*	0.67	*0.67*	3.6^{b}	*1.17*	$14.99_{2,9}$	*p = 0.001**
Catch per Unit Effort	36.08^{a}	*12.61*	13.5^{a,b}	*5.9*	0.17	*0.17*	2.7^{b}	*0.37*	$6.86_{2,9}$	*p = 0.015**
Simpson's Diversity	4.21	*0.77*	3.28	*0.86*	0.67	*0.67*	2.29	*0.67*	$1.48_{2,9}$	*p =0.279*
Shannon-Weiner Diversity	1.86	*0.16*	1.41	*0.21*	0.23	*0.23*	0.83	*0.29*	$3.94_{2,9}$	*p =0.059*

*Denotes significantly different means at α = 0.05.

Table 6. Number of species sampled at each site in the Sangamon River in 2012 using pull and kick seines. Upstream and downstream is in relation to the Sanitary District of Decatur effluent.

	Above Dam	**Above Effluent**					**Below Effluent**			**25+ Miles Below Effluent**		
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**15**	**16**	
Species												**Total**
Blackstripe Topminnow (*Fundulus notatus*)		6										6
Bluegill (*Lepomis macrochirus*)		30	34	19	4	2	1	2				92
Bluntnose Minnow (*Pimephales notatus*)		3	5	97	15	2	26	3	39		263	453
Brook Silverside (*Labidesthes sicculus*)				2					5		11	18
Bullhead Minnow (*Pimephales vigilax*)			1						1	14		16
Centrarchidae Spp. Juvenile										7		7
Channel Catfish (*Ictalurus punctatus*)										4	18	22
Cyprinidae Spp.Juvenile		12	2	4	3					388	207	616
Dusky Darter (*Percina sciera*)							1					1
Emerald Shiner (*Notropis atherinoides*)			2									2
Gizzard Shad (*Dorosoma cepedianum*)		3	22	9	1							35

	Above Dam	**Above Effluent**					**Below Effluent**			**25+ Miles Below Effluent**		
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**15**	**16**	
Species												**Total**
Green Sunfish (*Lepomis cyanellus*)				1								1
Johnny Darter (*Etheostoma nigrum*)			1							5		6
Largemouth Bass (*Micropterus salmoides*)							2					2
Logperch (*Percina caprodes*)		1										1
Longear Sunfish (*Lepomis megalotis*)			1									1
Mosquito Fish (*Gambusia affinis*)	44		2		53		31			24	83	237
Orangespotted Sunfish (*Lepomis humilis*)		1		1								2
Red Shiner (*Cyprinella lutrensis*)		4	34	2	19	1	38	27	113	41	169	448
Redfin Shiner (*Lythrurus umbratilis*)		4	2									6
Sand Shiner (*Notropis ludibendus*)		3			14		439		9			465

	Above Dam		**Above Effluent**				**Below Effluent**			**25+ Miles Below Effluent**		
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**15**	**16**	
Species												**Total**
Spotted Bass (*Micropterus punctulatus*)							1	1				2
White Sucker (*Catostomus commersonii*)							1					1
Yellow Bullhead (*Ameiurus natalis*)											1	1
Longear Orangespotted Sunfish Hybrid (*Lepomis megalotis X Lepomis humilis*)		1										1
Total	44	68	106	135	109	5	540	33	167	483	752	2442

Table 7. Number of species sampled at each site in the Sangamon River in 2013 using AC electrofishing. Upstream and downstream is in relation to the Sanitary District of Decatur effluent.

	Above Effluent			Below Effluent			
	5	6	7	9	10	11	
Species							**Total**
Bighead Carp (*Hypophthalmichthys nobilis*)					1	1	2
Bigmouth Buffalo (*Ictiobus cyprinellus*)			1				1
Black Crappie (*Pomoxis nigromaculatus*)	2	2	1	1			6
Blackstripe Topminnow (*Fundulus notatus*)			1				1
Bluegill (*Lepomis macrochirus*)	5	18	8	8	9	1	49
Bluntnose Minnow (*Pimephales notatus*)				2			2
Brook Silverside (*Labidesthes sicculus*)	9	2	3	1	3		18
Bullhead Minnow (*Pimephales vigilax*)	1						1
Channel Catfish (*Ictalurus punctatus*)					2		2
Common Carp (*Cyprinus carpio*)					1		1
Freshwater Drum (*Aplodinotus grunniens*)	1	1	2	2	6	4	16

Table 7 cont.

	Above Effluent			**Below Effluent**			
	5	**6**	**7**	**9**	**10**	**11**	
Species							**Total**
Gizzard Shad (*Dorosoma cepedianum*)	278	189	77	53	85	49	731
Green Sunfish (*Lepomis cyanellus*)		5	10	1		4	20
Highfin Carpsucker				1			1
Longear Sunfish (*Lepomis megalotis*)					1	2	3
Longnose Gar (*Lepisosteus osseus*)			1				1
Orangespotted Sunfish (*Lepomis humilis*)	1						1
Red Shiner (*Cyprinella lutrensis*)				1			1
River Carpsucker (*Carpiodes carpio*)	1			2	1	3	7
Shortnose Gar (*Lepisosteus platostomus*)			1	4			5
Smallmouth Bass (*Micropterus dolomieu*)						1	1
Smallmouth Buffalo (*Ictiobus bubalus*)	2	1	2	1	3	6	15
Striped Bass (*Morone saxatilis*)		1					1

Table 7 cont.

	Above Effluent			**Below Effluent**			
	5	**6**	**7**	**9**	**10**	**11**	
Species							**Total**
Walleye (*Sander vitreus*)			1	1			2
White Bass (*Morone chrysops*)	2						2
White Crappie (*Pomoxis annularis*)	2	4	5	2	2	1	16
White/Striped Bass (*Morone chrysops/Morone saxatilis*)			1	1			2
Yellow Bass (*Morone mississippiensis*)	2			1			3
Total	306	223	114	82	114	71	910

Table 8. Relative density estimated for all fishes by fish per seine pull and total catch per site for seines on the Sangamon River during spring 2012.

Reach	Site	Total Catch	Relative Density
Above Dam	3	44	22
Above Effluent	4	68	34
	5	106	53
	6	135	67.50
	7	109	54.50
	8	5	2.5
Below Effluent	9	540	180
	10	33	11
	11	167	55.67
25+ Miles Below Effluent	15	752	376
	16	483	241.50
Total		2442	
Average ± Standard Error			99.79 ± 35.39

Table 9. Number of sport fish and non-sport fish sampled using seineing at each site in the Sangamon River in 2012. Upstream and downstream are in relation to the Sanitary District of Decatur effluent.

Reach	Site	Non-Sport fish	Sport fish	Total
Above Dam	3	44	0	44
Above Effluent	4	37	31	68
	5	72	34	106
	6	115	20	135
	7	105	4	109
	8	3	2	5
Below Effluent	9	537	3	540
	10	30	3	33
	11	167	0	167
25+ Miles Below Effluent	15	479	4	483
	16	733	19	752
Total		2322	120	2442

Table 10. Relative density estimated for sport fishes by fish per seine pull and total catch per site for seines on the Sangamon River during spring 2012.

Reach	Site	Total Catch	Relative Density
Above Dam	3	0	0
Above Effluent	4	31	15.5
	5	34	11.33
	6	20	10
	7	4	2
	8	2	0.67
Below Effluent	9	3	1
	10	3	1.50
	11	0	0
25+ Miles Below Effluent	15	19	9.5
	16	4	1.33
Total		120	
Average ± Standard Error			4.80 ± 1.69

Table 11. Total catch and relative density (fish/hour) using AC boat electrofishing in Spring 2013.

Reach	Site	Total Catch	Relative Density
Above Effluent	5	306	612
	6	223	446
	7	114	228
Below Effluent	9	82	164
	10	114	228
	11	71	142
Total		910	
Average ± Standard Error			303.33 ± 75.81

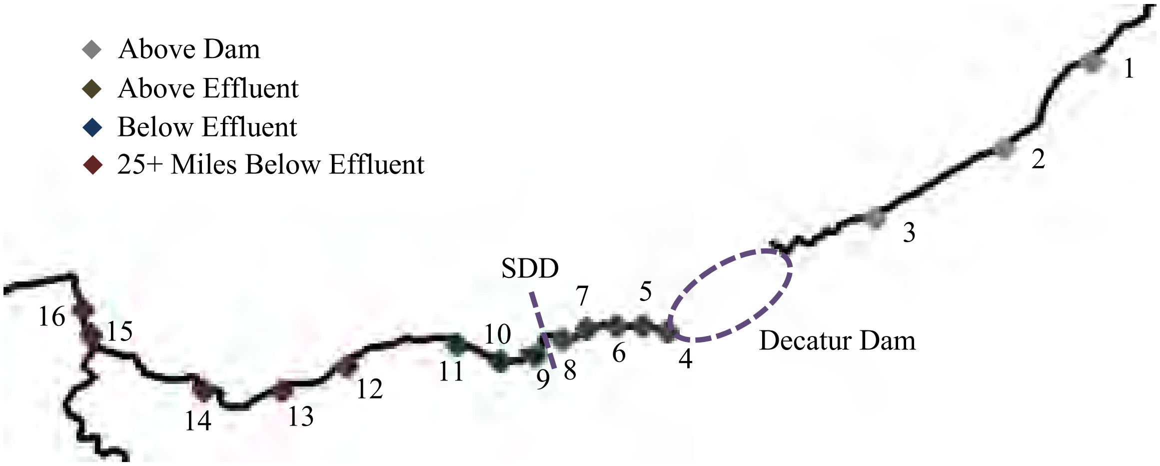

Figure 1. Map of Sangamon River sampling sites for summer 2012.

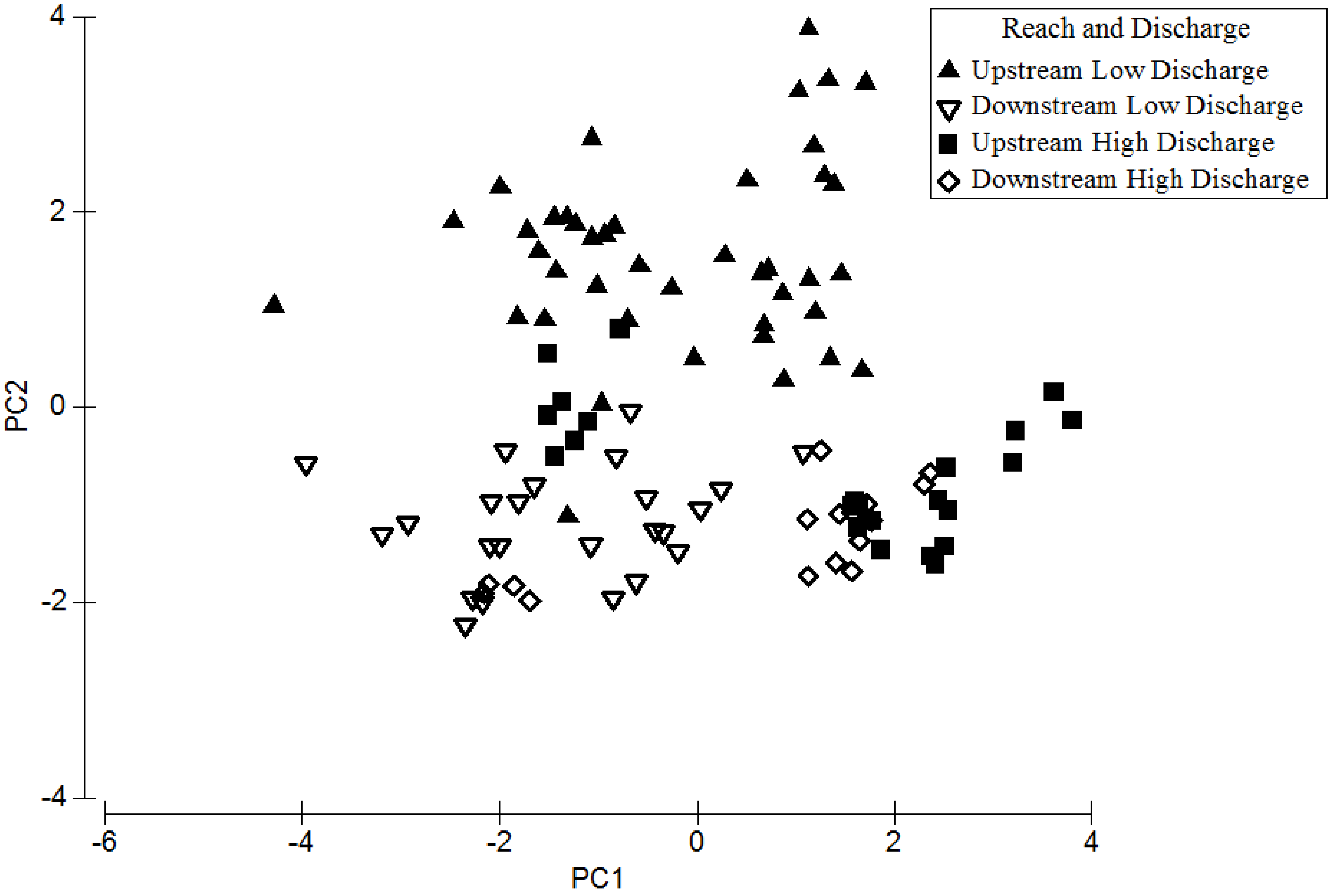

Figure 2. Principle components analysis of water quality data sampled during 2011-2012 from all mainstem sites of the Sangamon River.

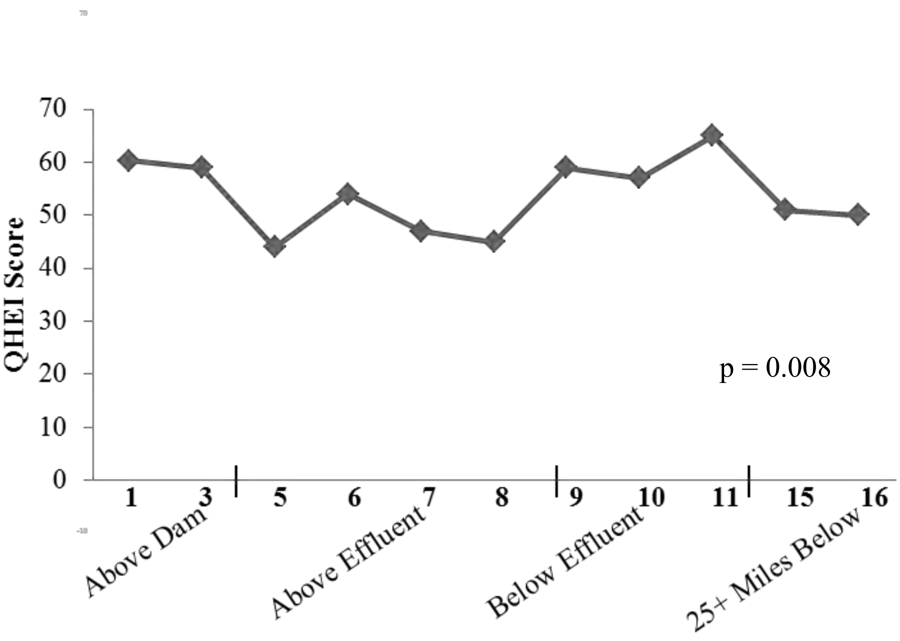

Figure 3. Qualitative Habitat Evaluation Index (QHEI) scores for four reaches upstream and downstream of the Lake Decatur dam and SDD’s sanitary effluent in the Sangamon River. Habitat is scored out of 100. Reaches were tested for significant differences using a one-way ANOVA with $p<0.05$ significance level.

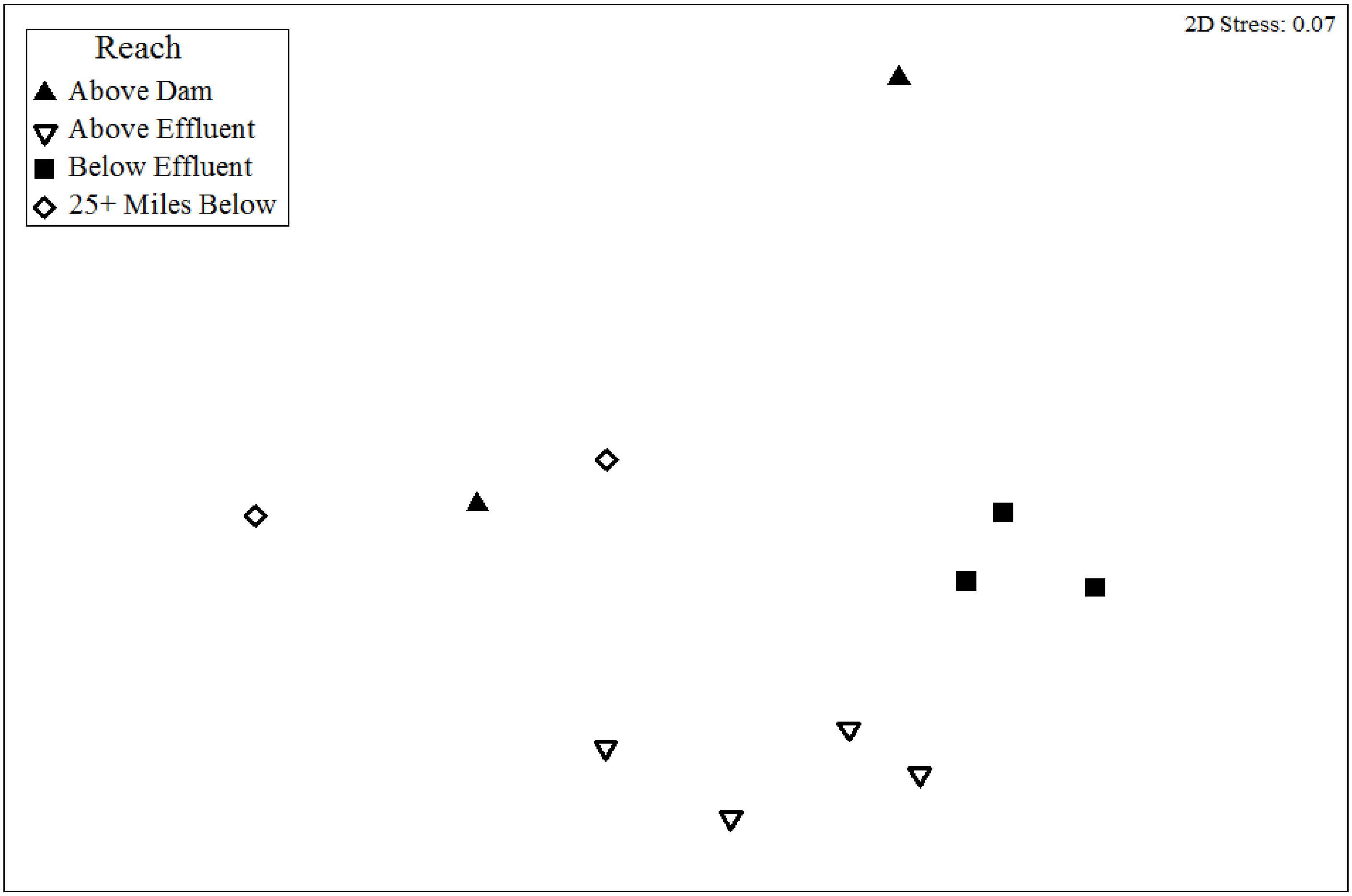

Figure 4. Multidimensional scaling plot of macroinvertebrate communities based on Bray-Curtis similarity (2D stress = 0.07). The four reaches were significantly different (ANOSIM, $p < 0.05$).

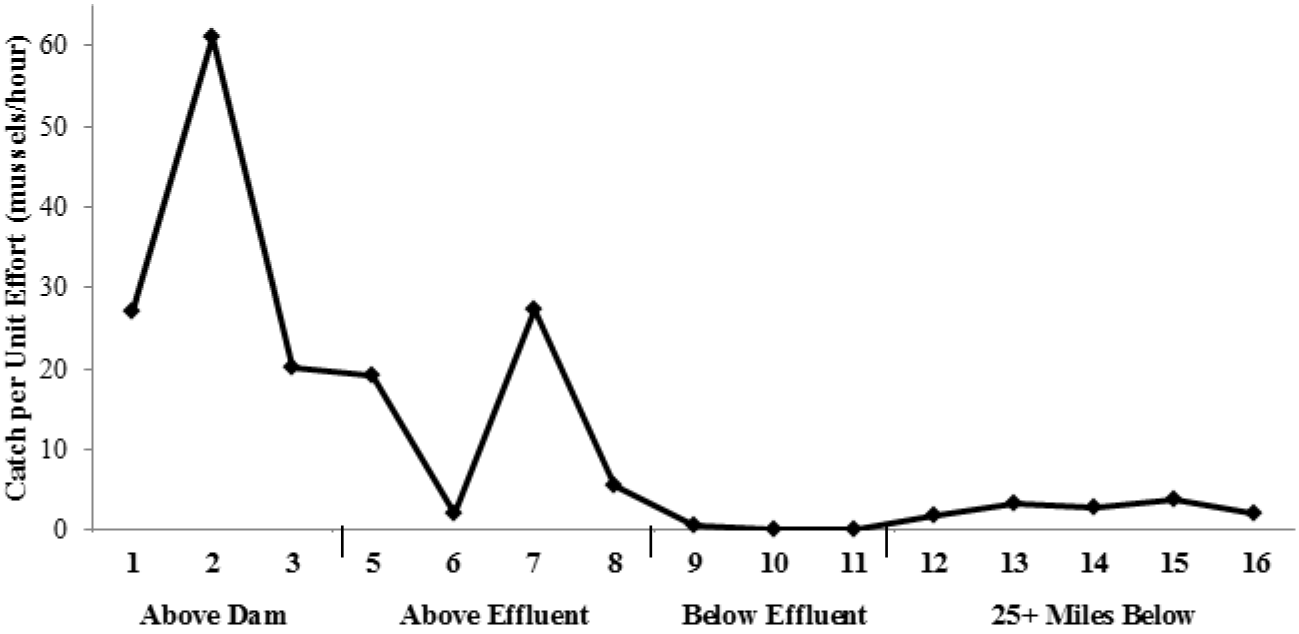

Figure 5. Relative density as estimated by catch per unit effort (CPUE) of all mussels sampled at four reaches on the Sangamon River during summer 2011 and 2012. Catch per unit effort is mussels per hour.

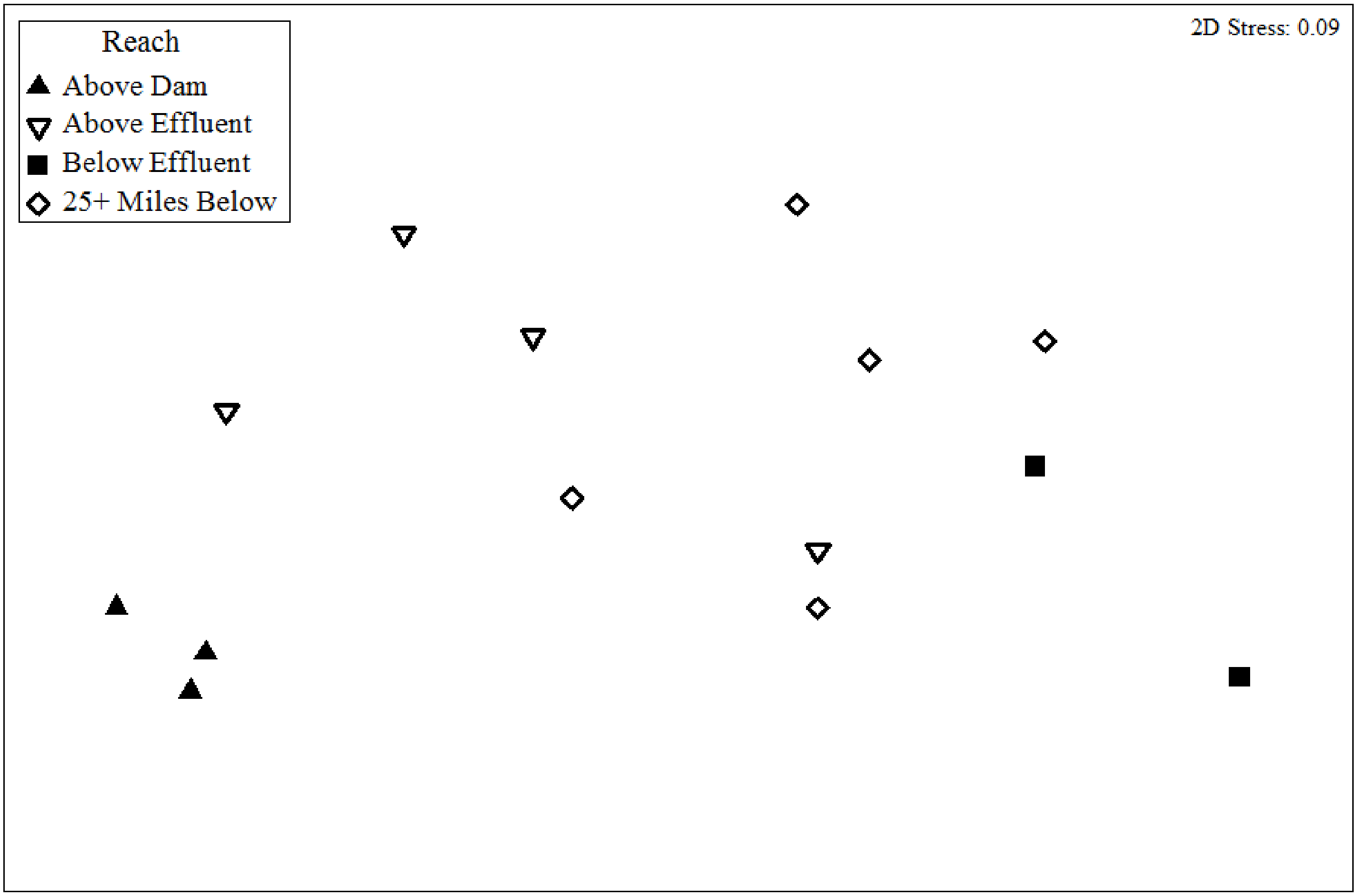

Figure 6. Multidimensional scaling plot of mussel communities based on Bray-Curtis similarity (2D stress = 0.09). The different reaches were significantly different (ANOSIM, $p < 0.05$).

Exhibit 37

Exhibit 37

Biotic assessment of water quality in a stretch of the Sangamon River receiving effluent from the Sanitary District of Decatur: Focusing on chemical assessment, mussel assemblage, tiered-aquatic life use, and the sport fishery

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EXECUTIVE SUMMARY

We sampled two treatment reaches of the Sangamon River for water quality, macroinvertebrate, mussel, and sportfish diversity. The two treatment reaches were upstream of the Decatur Sanitary District main discharge and downstream of the main discharge. We sampled eleven sites monthly for water quality; seven sites located in the upstream reach, which extends from the Lake Decatur Dam to the discharge of the main treatment plant of the Sanitary District of Decatur (SDD), and four sites located downstream of the SDD. Seven sites were designated to sample annually for macroinvertebrate, mussel, sportfish, and non-game fish diversity; four sites located in the upstream reach and three located in the downstream reach (Appendix 1).

Water quality in the upstream and downstream reaches differed during periods when discharge, measured at the Route 48 Bridge, was below 10 cfs. Macroinvertebrate diversity as estimated by Simpson's D and Shannon-Weiner H' showed no difference between the two reaches ($p > 0.05$). River watch MIBI scores showed no difference ($p > 0.05$), however, the upstream range was much larger, reflecting variation in habitat due to inconsistent flow. A future study comparing only high quality habitat in each reach will be conducted in summer and fall 2012.

A total of 14 mussels species were found in the upstream reach of the river. Relative density, estimated by catch per unit effort, fluctuated between upstream sites and dropped to zero in the downstream sites. Mussel diversity as estimated by Simpson's D and Shannon-Weiner H' showed significant differences between the two reaches ($p < 0.05$). Additionally, mussels showed a clumped distribution pattern within treatment reaches. We would need to sample upstream of the reservoir and further downstream to determine how our upstream sites compare to a baseline, and where mussel populations recover.

Within both treatment reaches of the Sangamon River, twenty-seven species of fish were sampled; six sportfish species were found. Sampling for channel catfish began under high water conditions (a necessity of boat AC electrofishing). During this high water event, fish were distributed throughout both treatment reaches; to provide an assessment of habitat use during periods of low to moderate flows, a tracking study could be initiated. Channel catfish were the most numerically abundant sportfish sampled and found in good condition. Sampling for all sportfish using boat AC electrofishing will take place in spring 2012. Because of high conductivity below the effluent, DC barge electrofishing was ineffective; seines were used to resample all downstream sites for a more accurate fish assessment. These findings and the sampling we will conduct summer 2012 will be used to assess the Sangamon River in regards to the Tiered Aquatic Life use (TALU).

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INTRODUCTION

Impoundments of rivers are constructed and operated for a variety of purposes including residential, commercial, and agricultural water supply; flood and debris control; and hydropower production (Kondolf 1997). Impoundments, however, may impact downstream aquatic systems and their surrounding terrestrial habitats. They can affect riverine systems by altering the flow regime, changing the sediment and nutrient loads, and modifying energy flow (Lignon *et al.* 1995). In addition, impoundments can cause diminished water quality and availability, closures of fisheries, extirpation of species, and groundwater depletion for surrounding areas (Abramovitz 1996, Collier *et al.* 1996, Naiman *et al.* 1995). As a result of impoundments, downstream reaches may no longer be able to support native species, which will be reflected by reduced integrity of biotic communities (Naiman *et al.* 1995, NRC 1992).

A critical aspect for sustaining ecosystem integrity and native biodiversity in rivers is a natural flow regime (Poff *et al.* 1997). Depending on the purpose for which the dam was built, it may have varying effects on downstream aquatic habitats. Impoundments used for urban water supplies cause a reduction in flow rates downstream the dam throughout the entire year (Finlayson *et al*. 1994), as well as increase daily and seasonal variability in flow regime (Finlayson *et al*. 1994, McMahon & Finlayson 2003). In addition, abiotic variables including temperature, dissolved oxygen, turbidity, pH, conductivity, and solids concentrations are altered in the downstream river system (Finlayson *et al.* 1994).

Along with stream and river impoundments, point source and non-point source pollution can have profound effects on the ecological integrity of the system. Non-point sources of pollution may include agriculture, livestock grazing, and urbanization, while sanitary discharge and industrial waste are considered point source pollutions. In order to reduce point source pollution, the Water Quality Act of 1972 encouraged wastewater treatment plants to upgrade their systems. As a result, many communities were forced to build advanced tertiary water treatment facilities (Karr *et al.* 1985). Although, they built advanced tertiary water treatment facilities, they still export high concentrations of nutrients into rivers. Carpenter and Waite (2000) documented that concentrations of phosphorus were highest in streams draining agricultural basins and at sites influenced by wastewater discharges, while Twichell et al (2002) reported that sewage effluent inputs had elevated nitrate levels. The enhanced nutrient inputs can be expected to increase productivity within a river because primary productivity and detrital processing usually are limited by low ambient stream nutrient concentrations (Stockner and Shortreed 1978, Elwood et al 1981, Winterbourn 1990).

The Sangamon River immediately below Lake Decatur is influenced by impoundment, altered flow regime, and point source discharges. The river runs for approximately 400 km in central Illinois, and its 14,000 km^2 watershed extends to 18 counties. Streams converging with the Sangamon run through glacial and alluvial deposits, creating a low gradient stream with sand and gravel substrates. The Sangamon basin has experienced multiple point and non-point source impacts throughout the years. Land use around the river system is currently 80% agricultural of which 85% is corn or soybeans. Bloomington, Decatur, and Springfield, with a combined population of over 500,000 people, are the main cities along the river. Lake Taylorville, Lake Sangchris, Lake Springfield, Clinton Lake, and Lake Decatur were all created by impounding the Sangamon River or its tributaries.

Due to multiple anthropogenic influences, the biotic integrity of the Sangamon River is in constant flux. An intensive sampling program, beginning in 1998-99 and continuing from 2001-2010, was conducted to document temporal and spatial heterogeneity of an 8.5 km urban reach of the Sangamon River. Sampling began directly below the Lake Decatur Dam and continued downstream to incorporate discharges from the Sanitary District of Decatur (SDD). These studies (Fischer & Pederson 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010) were intended to characterize stream habitat quality and assess impacts from ongoing reservoir and urban management by evaluating biotic integrity at various trophic levels in the context of the physical and chemical nature of the Sangamon River.

All sampling locations were associated with operation of SDD that were easily identified by landmarks within the city of Decatur, Illinois, USA (Appendix 1). Sites were established in 1998 in conjunction with combined sewage overflow (CSO) facilities and the main treatment plant. Sites are located in the mainstem of the Sangamon River extending from directly below the Lake Decatur dam to the Lincoln Memorial Highway Bridge, located five miles southwest of Decatur. Sites 1, 3, 4, 5, 6, 7, and 8 extend from the dam to directly above the discharge of the main treatment plant in the upstream reach, and sites 9, 11, 12, and 14 extend from the main treatment discharge to a point approximately 8 river miles downstream near Lincoln Trail Homestead State Park.

The Stream Habitat Assessment Procedure (SHAP), which assesses lotic habitat quality using features considered important to biotic integrity, was performed in 1998, 2001, and 2002. At each site, two individuals assessed metrics relating to substrate and instream cover, channel morphology and hydrology, and riparian and bank features to one of four habitat quality types, following guidelines established by the Illinois Environmental Protection Agency (1994). The mean total score of the 15 metrics forms the basis of an overall habitat quality rating for the stream reach under consideration. Habitat quality of the upstream and downstream reaches was categorized as “fair” quality stream reaches indicating that the physical structure of the stream is homogenous.

This overall physical structure provides a base for the ability of the study reach to support diverse life. Routine assessment of characteristic water quality variables combined with substrate characteristics, channel morphology, and bank features can aid in understanding the functioning of stream systems. Analyzing certain physical and chemical variables is essential to understanding the potential for anthropogenic impacts to decrease biotic integrity as organisms often exist in narrow ranges of tolerance for these variables. We began routine analyses of various physical and chemical features of the Sangamon River sites from 2002-2011. Principle components analysis (PCA) of water quality variables has routinely indicated differences between the upstream and downstream reaches at low discharge (as indicated by the USGS stream gauge at IL Route 48 Bridge), which have become negligible at discharges exceeding 400 cfs.

Assessment of stream biota was required to determine whether differences observed in the physical and chemical habitat between the two stream reaches were reflected in multiple trophic levels. Such an evaluation involved biotic indices based upon macroinvertebrates and fish, taxa that are widely used for biotic assessments. Downstream sites typically were characterized by significantly lower MBI scores, indicating improved habitat quality capable of supporting more diverse or environmentally sensitive macroinvertebrate communities. In contrast, general diversity indices (species richness, evenness) and IBI scores suggest that fish may be insensitive to the environmental gradient that we studied. We concluded that sites downstream of the main treatment plant outfall from the SDD may have increased biotic integrity due to predictable instream flows and increased primary production, due in part to nutrient loading.

Stable and predictable instream flows observed in the reach downstream of the SDD can facilitate development of more diverse biotic communities, as seen in work conducted in other riverine systems (Sanders 1969; Fisher 1983; Peckarsky 1983; Ward & Stanford 1983; Reice 1985; Ross *et al*. 1985; Walde 1986; Resh *et al*. 1988). Differences in the overall nature of the upstream and downstream reaches become less distinct during periods of high reservoir discharge. Drastic reduction of instream flow, resulting from routine elimination of reservoir discharge, is damaging to habitat quality in the upstream reach. Overall, water quality results suggest that a flow threshold of 400 cfs exists to maintain a continuum between the upstream and downstream reaches. When flow is below 400 cfs, the two reaches have discrete habitat quality characteristics. Water quality may be compromised in the upstream reach of the Sangamon River, extending downstream from the dam to the main treatment plant discharge of the Sanitary District of Decatur, as a result of reservoir level maintenance management eliminating outflow. Effective management of the Sangamon River may require a continuous instream flow above the proposed threshold (400 cfs) by discharge from Lake Decatur.

Biotic assessment can be used as a stand-alone measure or as part of a larger scope. For example, Unionid mussels have shown sensitivity to various assaults on lotic systems. Mussels are affected by substrate type and flow (Harman 1972; Strayer 1983; Vaughn 1997; Watters 1999), and can be harmed by excessive concentrations of heavy metals, phosphorus, and nitrogen (Beckvar *et al.* 2000; Jacobson et al 1997; Mummert et al 2003; Wang et al 2007). As such, the U.S. Environmental Protection Agency is proposing using mussel communities in setting ammonia standards (Great Lakes Environmental Center 2005). Based on this information it is important to include these specific communities in assessment of aquatic systems. The Tiered Aquatic Life Use (TALU) is a broad measure of the value of habitat and includes both biotic and abiotic values of a given resource. The TALU includes not only historic ecological indices of multiple trophic levels of biota, but economic and recreational value of an aquatic system as well. For example, although sportfish make up a small portion of the fish assemblage they almost always have the greatest economic and recreational value.

We sought to assess the water quality, as well as the macroinvertebrate, non-game fish, sportfish, and Unionid mussel communities of the Sangamon River below the Lake Decatur Dam. We sampled the communities in two treatment reaches above and below the Decatur Sanitary District main effluent. Although, all of these metrics individually provide some measure of habitat, the combination of all data will provide a more broad analysis of multiple uses as it pertains to the TALU.

METHODS

Water Data Collection and Chemistry Determination

Water quality data were collected monthly from May 2011 to March 2012. We began sampling at the Lake Decatur dam and proceeded downstream. In field, we determined abiotic variables including dissolved oxygen, temperature, pH, and conductivity using a Eureka field multiprobe and amphibian field display. Water samples were collected 0.3 m below the surface, returned to the lab on ice, and analyzed within accepted time limits. All analyses followed the Standard Methods for Examination of Water and Wastewater (APHA, 1995).

We determined suspended and total solids by drying residue collected on standard glass fiber filters and unfiltered samples at 103-105 ^{o}C. Volatile and suspended solids were determined by weight loss upon ignition at 550 ^{o}C. Total oxidized nitrogen (NO_2-N + NO_3-N) was determined using the cadmium reduction method, and ammonia nitrogen was determined with the phenate method. The ascorbic acid method was used to determine total phosphorus (following persulfate digestion) and soluble reactive phosphate (flowing filtration). We determined colorimetry of all nutrient analyses using a Beckman DU 530 Life Science UV/Vis Spectrophotometer. We measured hardness and alkalinity using titration to colormetric endpoint methods. We considered quality control procedures during all analyses, including but not limited to parallel analyses of laboratory standards.

Averages of each variable were calculated for the upstream and downstream reaches. Principle components analysis was conducted for 16 variables after individually log transforming and normalizing the data. All analyses were performed using Primer 6.1.14 (Clarke and Warwick 2001). Variables that were highly correlated to another and thus redundant were eliminated from the analysis.

Benthic Algae and Diatoms

Benthic algae will be collected from naturally occurring substrates in late summer 2011and Diatom Species Proportional Counts as described in Standard Methods for Examination of Water and Wastewater, 19th Edition (APHA-AWWA-WEF) will be performed. Appropriate indices based on relative tolerance of diatom genera will be calculated along with standard community-level variables.

Assessment of Macroinvertebrate Community

We sampled macroinvertebrates during summer 2011 using IEPA's multihabitat 20-jab method. The proportion of jabs in a specific substrate type was based on relative proportions in the Qualitative Habitat Evaluation Index (QHEI) originally calculated in spring 2010 and reestimated in 2011. Macroinvertebrates were preserved in 70% ethanol and taken back to the EIU Fisheries and Aquatic Research Lab for identification and enumeration. We moved the macroinvertebrates to fresh 70% ethanol within a week of collection to prevent degradation of the samples. All macroinvertebrates were identified to the lowest taxonomic group possible. Specimens were fixed and catalogued into the EIU invertebrate collection.

We assessed the species richness (S), Simpson's diversity (D), Shannon-Weiner diversity (H'), and macroinvertebrate index of biotic integrity (MBI) based on taxon-specific environmental sensitivity values using standard River watch and EPA protocols. The Simpson's diversity (D) was calculated using the formula:

$$D = \frac{1}{\sum p_i^2}$$

Where:

- p_i = is the proportion of the total number of individuals comprised by species i

We calculated Shannon-Weiner diversity (H') using the formula:

$$H' = -\sum \left(p_i \times ln(p_i)\right)$$

Where:

- p_i = is the proportion of the total number individuals comprised by species i

We performed t-tests with a significance level of P=0.05 (Zar 1996) to assess differences between upstream and downstream sites.

Assessment of Unionid Mussel Community

Mussel assemblages were sampled during summer 2011 using timed hand searches. Four people spread out and searched within the 100 m site at random for one hour, creating four total man hours of effort. Searches were conducted visually and tactilely. We sieved the substrate with a clam rake for smaller species and juveniles. Twenty scoops were taken at each site, targeting substrates with sand, small gravel, and clay. All mussels were collected in mesh bags and identified to species according to Cummings and Mayer (1992). We took length measurements in field and returned all live mussels to the river. Dead shells collected for vouchers were taken back to the lab for identification conformation and cataloging.

We calculated species richness (S), Simpson’s diversity (D), Shannon-Weiner diversity (H’), and catch per unit effort (CPUE) for the mussel assemblages. Simpson’s diversity and Shannon-Weiner diversity were calculated using the same formulas as outlined above. We performed t-tests with a significance level of P=0.05 (Zar 1996) to assess differences between upstream and downstream sites. Catch per unit effort was determined as individual mussels caught per hour for the timed hand searches, and individual mussels caught per square meter for the substrate sieves. Relative abundance of species present was examined using multidimensional scaling (MDS) based on Bray-Curtis similarity matrices (BC). Data were square root transformed to down-weight the influence of abundant taxa. Similarity of assemblages among sample sites was portrayed in scatter plots of the first two ordination axes. Multivariate analysis of similarity

(ANOSIM) was used to determine significant differences between upstream and downstream assemblages. All analysis were performed using Primer 6.1.14 (Clarke and Warwick 2001), and significance level was set at P = 0.10.

Assessment of Sportfish Community

We sampled two treatment reaches (upstream and downstream) during Spring 2011 using three gear types including; three phase alternating current (AC) electrofishing using an unbalanced three dropper electrode array, direct current (DC) electrofishing using three anodes, and 50 foot seines. Sampling using AC electrofishing was used to target channel catfish and began in mid-April at the most upstream site, sampling randomly in a downstream manner until the most downstream sight was reached. In early-August all fish were sampled using DC electrofishing at the most upstream site continuing downstream until all possible designated sites were sampled. Conductivity was much higher in the downstream reach (upstream= 585.8 mS cm^{-1}, downstream= 2015.4 mS cm^{-1}), causing the electrofishing gear to be an ineffective sampling method. As a result, seines were used to re-sample all sites in the downstream reach to compare relative densities of each gear. As an estimate of relative density for electrofishing (AC and DC), we calculated catch per unit effort (CPUE) as number of fish captured per electrofishing hour.

Kick and pull seine methods were used to sample fish in each site the downstream reach beginning in mid-August. In the absence of a riffle, we performed 2 pull seines, which required one person to hold one end of the seine near shore, staying in place, while a second person pulled the seine out into the middle of the river and continued upstream, wrapping around to meet the person near shore. When a riffle was present we performed 1 pull and 1 kick seine. The kick seine method requires two people hold the seine downstream of the riffle, while a third person kicks beginning upstream moving in a downstream manner until the seine is reached. For seining we calculated catch per unit effort (CPUE) as catch per seine pull/kick.

All fishes sampled using DC electrofishing and seine methods that could not be identified to species in the field were taken back to the laboratory for identification.

Channel catfish sampled using AC electrofishing were weighed to the nearest gram and measured to the nearest millimeter total length (TL). The left pectoral spine was removed using a disarticulation process for all catfish over 200 mm to estimate age. Spines were let dry for 24 hours, and then cleaned to prepare for cutting. At least three sections of the articulating process were cut at a width of approximately 750 microns with a Buehler IsoMet Low Speed saw. The sections were placed in mineral oil and observed under low magnification with reflected light on a dissecting microscope. The age of each fish was estimated by counting annuli in the cross section of the spine. Two independent researchers estimated the age of each catfish and disagreements in ages were reconciled by consensus.

As an index of condition, relative weight (W_r) was calculated for channel catfish. We did not include two outliers in our calculation of average relative weight. Relative weight estimates the condition of individuals based on a length specific standard weight for a species. Relative weight is calculated from the equation (Anderson and Neumann 1996):

$$W_r = \frac{W}{Ws} \times 100$$

Where:

- W = weight of an individual
- Ws = length-specific standard weight

The standard weight equation for an individual species is based on the 75th percentile of different populations throughout each species range (Anderson and Neumann 1996). Relative weight scores of less than 100 suggest overabundance, while scores greater than 100 suggest poor use of available prey (Anderson and Neumann 1996).

RESULTS

Water Data Collection and Water Chemistry Determination

Nineteen variable levels were determined for eleven mainstem sites in 2011-12 (Table 1). As in previous sampling years, a general pattern of higher values at the downstream sites was apparent. Specific conductivity was significantly higher in the downstream reach, possibly related to an increase in total dissolved solids and salts. Contributions to elevated solids included nutrient loads (nitrogen and phosphorus).

PCA analysis extracted seven factors, which explained 83% of the variation in water quality observed within the Sangamon River during the sampling period. Upstream and downstream sites occupy discrete regions in the ordination space created by PCA factors 1 and 2, with lowflow samples differing by a greater degree than highflow samples (Figure 1). Ammonia, alkalinity, and suspended solids tended to vary by flow, while phosphates, total nitrogen, specific conductivity, and dissolved solids tended to vary based on the reach. ANOSIM revealed significant differences between upstream and downstream reaches at times when discharge at the Route 48 Bridge was less than 10 cfs ($\rho = 0.597$, $P = 0.01$).

Assessment of Macroinvertebrate Community

A total of 13 orders of macroinvertebrates were found at the upstream and downstream sites sampled on the Sangamon. No significant differences were found between the upstream and downstream reaches for species richness, biotic integrity, Simpson's diversity, and Shannon-Weiner diversity (Table 2, $p > 0.05$). River watch MIBI scores varied more in the upstream reach, indicating stream quality from "very poor" to "fair", while all downstream sites were in the "fair" category. Original QHEI scores tended to vary more between upstream sites. However, upstream MIBI scores did not correlate with QHEI scores, but rather with the presence or absence of riffles.

Assessment of Unionid Mussel Community

A total of 14 species of native mussels (Table 3) and 1 introduced species (*Corbicula* sp.) were recovered. The most abundant species was threeridge, and this species along with fawnsfoot, fragile papershell, pink papershell and giant floater made up 83% of total individuals found (Table 3). One rock pocketbook, an uncommon species in Illinois, was found at site 7 (Table 3). The relative density (CPUE) was highest at site 7 and lowest at site 5 among the upstream sites and dropped to zero in the downstream sites (Figure 2). The timed hand search CPUE (mussels/hour) and substrate sieve CPUE (mussels/m^2) follow the same pattern across sites, indicating even juvenile and adult recruitment (Figure 2). Species richness, Simpson's D, and Shannon-Weiner H' were all significantly higher in the upstream reach (Table 4, $p < 0.05$).

MDS revealed differences in relative abundance of species present. Clustering occurred (2D stress: 0.0) within the treatment reaches (Figure 3) as well as significant separation between the two reaches (ANOSIM, $\rho = 0.963$, $p < 0.05$).

Assessment of Sportfish Community

We sampled a total of 7 sites, 4 upstream sites, and 3 downstream sites using DC barge electrofishing and seines. In the sites, we sampled a total of 26 species (Table 5). The five most dominant species sampled were: red shiner, bullhead minnow, juvenile cyprinidae species, and gizzard shad (Table 5). The sportfish community was comprised of: bluegill, channel catfish, hybrid striped bass, and largemouth bass; with bluegill and channel catfish being the most numerically abundant (Table 5).

Relative density (CPUE) of all fishes using the seine was highest in site 7 and lowest in site 3, while relative density using DC electrofishing was highest in site 8 and lowest in site 4 (Table 6). Channel catfish in the Sangamon River were found to be in good condition, with an average relative weight of 92.19 ± 1.10 (N=164). Relative density for the channel catfish population was 29.126 fish per hour (N=166). Channel catfish had an average length of 343.21 ± 6.22 mm with a maximum of 660 mm and a minimum of 172 mm (N=166) (Figure 4.). The average age of channel catfish in the Sangamon River was 5.07 years ± 0.11, with the oldest fish being 10 years old, and the youngest being 2 years old**.** Average percent error (APE) for channel catfish ages between the two independent agers was 8.23 %. There was an 89.02% chance that the agers were within one year difference and a 34% chance that the agers agreed 100% of the time. Channel catfish need to be sampled again in order to show a complete representation of age structure of the population, but based on current data, the population is aging normally (Figure

5.). Among four sites (site 3, site 8, site 11, and site 12) 22 sportfish were sampled using a seine at an average catch of 2.23 ± 1.13 fish/hour (Table 7.). The relative density of sportfish using the seine was at site 11, while the lowest was at site 3. The average relative density for sportfish using the seine was low (2.23 ± 1.13 fish/hour), while DC electrofishing was higher (61.15 ± 33.40 fish/hour, N=138) (Table 7). Relative density of sportfish using DC electrofishing was highest at site 7, and lowest at site 11 (among a total of 6 sites: site 3, site 5, site 7, site 8, site 11, site 14) (Table 7).

DISCUSSION

The primary difference between the upstream and downstream reaches is likely attributable to metrics related to reservoir discharge and inputs from the SDD main discharge. Outflow from Lake Decatur is the primary input to the upstream reach, which is compromised as a result of management to maintain reservoir levels by eliminating outflow. Sites downstream of the SDD may have greater potential for instream primary productivity as a result of nutrient loading as indexed by higher levels of dissolved solids, conductivity, oxidized nitrogen, and phosphorus. This elevated productivity could in turn support more diverse macroinvertebrate and fish assemblages.

The discharge from the main treatment plant of the SDD alters instream water chemistry, especially during periods of low reservoir discharge. Consistent flow downstream of the SDD's main outfall, during periods of low reservoir discharge, helps maintain the overall QHEI scores and physical habitat quality. During high reservoir discharge, however, water quality over the entire study reach is relatively homogenous. This indicates that high flow can compensate for the elevated nutrient inputs.

The macroinvertebrate community was dominated by aquatic midges; a group that is indicative of organic rich habitats, and are often the most abundant taxa (Rabeni and Wang 2000). Macroinvertebrate communities are typically correlated with habitat scores (Hammer and Linke 2003). Upstream River watch MBI scores had a greater range, reflected by a greater variation in the habitat due to inconsistent flow. Future assessment of high quality benthic habitats in the two reaches will provide further insight into the effect of impoundment on the macroinvertebrate community.

The relative density of Unionid mussels in the Sangamon River varied among the upstream sites, and dropped to zero in the downstream reach. Unlike the other biota sampled, mussels showed a greater sensitivity to the effects related to the discharge of the main treatment plant of the Sanitary District of Decatur. The upstream reach was dominated by few species, and lost diversity originally present upstream of the Lake Decatur dam in historic data. We will sample further downstream of the main discharge in summer or fall 2012 to determine where mussel populations return, and upstream of the dam to assess species richness and diversity loss from the impoundment.

The diversity of fish species was comparable to other Midwestern streams (Colombo unpublished data), with red shiners, bullhead minnows, multiple cyprinidae species, and gizzard shad being the most numerically abundant non-game species and bluegill, channel catfish, hybrid striped bass, and largemouth bass being the most abundant sportfish species. Fairly small and young channel catfish dominated the sportfish population of the Sangamon River. The community of catfish was found to have a higher relative abundance compared to other Midwestern river systems (Colombo unpublished data). Although density was high, age structure did not suggest a completely unexploited system. We expected to see a population comprised of large, old fish, indicative of an unharvested population. Although no catfish was measured to be greater than 660 mm, fish tended to be in good condition, suggesting an adequate food supply for growth. Future sampling using multiple gears will allow a more accurate estimation of age structure of channel catfish; these data will be used to determine the economic value and best management strategy for the fishery in the Sangamon River. We will be conducting additional sampling during the spring of 2012 to more accurately assess all sportfishes in the Sangamon River.

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TABLES AND FIGURES

Table 1. Measured water quality variables for eleven Sangamon River sites associated with the Sanitary District of Decatur. Variables below the detection limit are indicated with a < .

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
5.13.2011	1	9.0	22.0	8.6	462	449	112	4.31	0.18	0.04	0.11	12.8	6.0	6.8	393.9	143.3	250.5	406.7	149.3	257.3
6.09.2011	1	8.2	26.4	8.9	429	314	112	4.97	<	0.19	0.03	18.0	15.2	2.8	424.7	134.1	290.5	442.7	149.3	293.3
7.28.2011	1	4.0	30.3	9.1	628	325	168	0.07	0.10	0.29	0.06	6.0	3.2	2.8	247.3			253.3		
8.18.2011	1	7.7	28.3	8.8	628	219	181	0.17	0.13	0.16	0.13	6.4	3.2	3.2	396.3	222.1	174.1	402.7	225.3	177.3
9.28.2011	1	12.9	2.0	9.2	628	237	195	0.05	0.07	0.06	0.05	<	0.4	<	407.7	300.9	106.8	405.3	301.3	104.0
10.25.2011	1	11.0	13.1	8.2	682	288	195	<	0.04	0.04	<	3.6	0.8	2.8	277.7	<	287.9	281.3	<	290.7
11.30.2011	1	9.5	5.1	5.5	584	223	251	0.06	0.01	0.08	<	0.0	3.5	<	302.7	283.2	19.5	302.7	286.7	16.0
12.16.2011	1	12.5	6.9	6.2	536	172	140	0.08	0.04	0.07	<	6.5	3.5	3.0	134.8	<	305.0	141.3	<	308.0
2.16.2012	1	29.4	2.0	8.5	555	277	168	0.31	0.06	0.16	0.01	21.0	10.5	10.5	356.3	86.8	269.5	377.3	97.3	280.0
3.20.2012	1	15.8	19.1	8.2	541	256	98	0.11	<	0.08	0.40	16.0	5.5	10.5	198.7	533.2	<	214.7	538.7	<
5.13.2011	3	8.2	21.5	8.6	524	314	126	4.71	0.04	0.05	0.09	16.0	6.5	9.5	400.0	125.5	274.5	416.0	132.0	284.0
6.09.2011	3	8.2	26.5	9.0	430	438	140	4.76	0.01	0.28	0.04	14.8	10.8	4.0	431.9	187.9	244.0	446.7	198.7	248.0
7.28.2011	3	2.5	26.6	8.7	760	206	161	<	0.12	0.37	0.08	<	<	3.2	328.3			266.7		
8.18.2011	3	4.1	23.5	8.6	682	234	195	0.15	0.13	0.29	0.15	14.8	5.6	9.2	411.9	189.1	222.8	426.7	194.7	232.0
9.28.2011	3	12.7	2.0	9.2	628	197	168	0.33	0.19	0.18	0.05	1.0	2.5	<	233.7	146.8	86.8	234.7	149.3	85.3
10.25.2011	3	4.5	13.0	7.9	771	358	168	0.18	0.30	0.12	<	0.8	1.6	<	368.5	<	398.1	369.3	<	397.3
11.30.2011	3	8.3	4.8	7.3	456	234	181	0.43	0.20	0.08	0.02	<	<	<	237.8	49.0	188.8	233.3	48.0	185.3
12.16.2011	3	11.8	9.7	7.3	420	212	112	0.26	0.10	0.05	<	22.0	10.0	12.0	79.3	<	246.7	101.3	<	258.7
2.16.2012	3	19.5	2.0	8.1	552	248	181	0.60	0.03	0.16	<	27.5	13.0	14.5	352.5	161.7	190.8	380.0	174.7	205.3
3.20.2012	3	5.5	18.5	8.1	698	285	195	0.03	0.00	0.13	0.03	22.0	11.5	10.5	294.0	504.5	<	316.0	516.0	<
5.13.2011	4	9.0	22.3	8.8	476	263	154	4.89	0.22	0.04	0.09	21.5	9.5	12.0	425.2	162.5	262.7	446.7	172.0	274.7
6.09.2011	4	8.2	26.5	9.0	432	219	140	6.49	<	0.19	0.01	14.5	10.3	4.2	424.2	209.7	214.5	438.7	220.0	218.7
7.28.2011	4	3.2	28.8	8.2	730	188	175	<	0.18	0.30	0.16	6.0	2.8	3.2	258.0			264.0		
8.18.2011	4	5.3	24.3	8.2	735	259	195	0.19	0.13	0.33	0.23	13.2	4.4	8.8	510.8	280.9	229.9	524.0	285.3	238.7
9.28.2011	4	12.6	2.1	9.4	629	146	140	0.58	0.93	0.21	0.05	3.5	3.0	0.5	115.2	77.0	38.2	118.7	80.0	38.7
10.25.2011	4	7.9	12.1	8.0	538	252	126	0.09	0.18	0.10	<	4.0	2.0	2.0	208.0	<	223.3	212.0	<	225.3
11.30.2011	4	9.4	4.4	7.9	476	223	195	0.36	0.43	0.11	0.03	<	1.5	<	240.5	66.5	174.0	240.0	68.0	172.0
12.16.2011	4	20.7	8.7	7.4	554	230	154	0.24	0.26	0.06	<	16.0	6.5	9.5	177.3	<	334.5	193.3	<	344.0
2.16.2012	4	19.0	2.4	8.3	560	252	154	0.78	0.03	0.15	0.10	29.5	13.0	16.5	343.8	200.3	143.5	373.3	213.3	160.0
3.20.2012	4	9.6	18.7	8.2	727	336	168	0.08	0.24	0.06	<	10.0	5.3	4.7	292.7	502.7	<	302.7	508.0	<

Table 1. Cont.

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
5.13.2011	5	8.8	22.3	8.8	482	420	126	4.71	0.13	0.05	0.10	17.5	8.5	9.0	398.5	127.5	271.0	416.0	136.0	280.0
6.09.2011	5	8.1	26.5	9.0	431	383	140	5.91	0.02	0.21	0.01	13.1	12.0	1.1	440.2	213.3	226.9	453.3	225.3	228.0
7.28.2011	5	2.4	28.2	8.0	699	224	175	0.01	0.43	0.30	0.10	<	7.2	<	430.3			266.7		
8.18.2011	5	5.8	24.7	8.6	735	248	195	0.19	0.24	0.36	0.22	13.6	6.0	7.6	434.4	258.0	176.4	448.0	264.0	184.0
9.28.2011	5	12.6	20.9	9.4	630	153	112	0.45	0.24	0.20	0.05	5.0	<	6.0	140.3	170.3	<	145.3	169.3	<
10.25.2011	5	8.8	11.5	7.9	577	259	126	0.08	0.17	0.14	<	6.0	7.5	<	264.7	1.8	262.8	270.7	9.3	261.3
11.30.2011	5	9.5	3.7	7.9	463	168	195	0.36	0.41	0.15	0.05	<	<	<	351.9	96.5	255.4	240.0	96.0	144.0
12.16.2011	5	10.8	8.7	7.5	569	223	154	0.27	0.27	0.06	<	10.0	4.0	6.0	223.3	<	315.3	233.3	<	321.3
2.16.2012	5	24.7	2.2	8.1	553	281	154	0.89	0.03	0.23	0.03	33.5	15.0	18.5	333.2	193.0	140.2	366.7	208.0	158.7
3.20.2012	5	7.3	18.2	8.0	732	256	168	0.07	0.22	0.06	<	11.3	4.7	6.7	376.7	483.3	<	388.0	488.0	<
5.13.2011	6	8.7	22.4	8.7	491	394	126	4.50	0.22	0.03	0.10	16.5	9.5	7.0	383.5	110.5	273.0	400.0	120.0	280.0
6.09.2011	6	8.0	26.5	8.9	431	208	140	7.35	0.16	0.25	0.02	13.7	10.0	3.7	427.7	219.3	208.3	441.3	229.3	212.0
7.28.2011	6	4.6	29.8	7.9	875	195	195	<	0.18	0.27	0.07	9.6	6.0	3.6	307.7			317.3		
8.18.2011	6	7.7	24.4	7.9	811	299	209	0.15	0.17	0.22	0.10	10.0	6.0	4.0	543.3	191.3	352.0	553.3	197.3	356.0
9.28.2011	6	12.7	2.0	9.3	633	226	195	0.21	0.25	0.23	0.05	20.5	<	22.5	303.5	320.7	<	324.0	318.7	5.3
10.25.2011	6	8.8	12.6	7.8	543	241	98	0.52	0.04	0.23	<	8.0	7.5	0.5	266.7	68.5	198.2	274.7	76.0	198.7
11.30.2011	6	8.5	5.3	7.8	441	157	168	0.36	0.29	0.18	0.08	3.0	<	3.5	237.0	352.5	<	240.0	352.0	<
12.16.2011	6	11.3	8.3	7.6	601	252	168	0.23	0.53	0.04	<	11.5	5.0	6.5	265.8	<	329.5	277.3	<	336.0
2.16.2012	6	19.5	2.3	8.2	563	241	168	0.80	0.04	0.20	<	28.5	12.0	16.5	322.2	157.3	164.8	350.7	169.3	181.3
3.20.2012	6	8.0	19.5	7.9	716	266	154	0.03	0.06	0.09	<	19.3	8.0	11.3	358.0	388.0	<	377.3	396.0	<
5.13.2011	7	11.5	21.6	9.0	444	369	112	3.70	0.17	<	0.07	13.0	11.0	2.0	368.3	101.0	267.3	381.3	112.0	269.3
6.09.2011	7	9.2	26.5	9.0	431	168	112	5.34	0.08	0.32	0.02	15.0	11.3	3.7	434.3	198.0	236.3	449.3	209.3	240.0
7.28.2011	7	3.9	30.3	7.9	771	217	175	<	0.08	0.29	<	18.0	6.4	11.6	234.0			252.0		
8.18.2011	7	10.4	25.2	8.5	621	208	181	0.60	0.22	0.20	0.00	22.0	9.2	12.8	396.7	222.8	173.9	418.7	232.0	186.7
9.28.2011	7	12.8	1.9	9.3	632	263	251	0.41	0.62	0.18	0.05	0.0	<	6.0	333.3	183.3	150.0	333.3	177.3	156.0
10.25.2011	7	7.2	14.1	8.0	580	266	140	0.34	0.13	0.11	<	15.3	6.0	9.3	299.3	52.7	246.7	314.7	58.7	256.0
11.30.2011	7	10.3	6.0	8.0	500	186	195	0.80	0.40	0.10	0.01	2.5	1.5	1.0	308.2	151.8	156.3	310.7	153.3	157.3
12.16.2011	7	10.9	6.7	7.8	673	299	209	0.35	0.54	<	<	3.0	3.5	<	329.0	<	357.8	332.0	<	357.3
2.16.2012	7	20.7	2.4	8.3	562	241	140	0.82	0.04	0.16	0.00	32.7	11.3	21.3	326.0	272.7	53.3	358.7	284.0	74.7
3.20.2012	7	13.8	19.4	8.6	594	219	140	<	0.00	0.16	<	167.3	22.7	144.7	208.7	326.7	<	376.0	349.3	26.7

Table 1. Cont.

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
5.13.2011	8	11.2	21.4	8.9	444	427	98	3.41	0.12	0.00	0.06	14.0	11.5	2.5	366.0	124.5	241.5	380.0	136.0	244.0
6.09.2011	8	8.3	26.5	9.0	430	113	154	6.20	0.04	0.23	0.02	16.7	42.9	<	432.6	177.1	255.5	449.3	220.0	229.3
7.28.2011	8	3.9	29.3	7.9	781	217	168	<	0.17	0.25	<	178.8	5.6	173.2	30.5			209.3		
8.18.2011	8	10.2	23.9	8.5	654	208	140	0.33	0.37	0.19	0.01	13.5	4.5	9.0	450.5	283.5	167.0	464.0	288.0	176.0
9.28.2011	8	12.8	1.8	9.3	633	223	265	0.60	0.73	0.11	0.05	<	<	2.7	312.7	267.3	45.3	309.3	261.3	48.0
10.25.2011	8	7.8	12.2	8.0	591	234	154	0.25	<	0.04	<	11.3	8.7	2.7	304.7	131.3	173.3	316.0	140.0	176.0
11.30.2011	8	8.7	4.9	7.9	549	266	237	0.45	0.54	0.08	0.02	<	2.0	<	315.0	224.7	90.3	312.0	226.7	85.3
12.16.2011	8	19.5	2.6	8.4	557	266	140	0.61	0.30	<	<	<	6.5	<	395.2	512.2	<	310.7	518.7	<
2.16.2012	8	12.3	7.8	7.9	547	230	154	0.96	0.12	0.21	<	36.7	12.7	24.0	323.3	238.0	85.3	360.0	250.7	109.3
3.20.2012	8	11.9	19.3	8.5	585	226	154	0.03	0.01	0.11	<	<	768.0	<	369.3	<	868.0	297.3	269.3	28.0
5.13.2011	9	10.6	21.9	8.7	889	485	140	4.42	0.18	1.01	0.79	55.0	26.5	28.5	578.3	102.8	475.5	633.3	129.3	504.0
6.09.2011	9	8.2	26.5	8.9	446	150	126	6.87	0.07	0.59	0.32	15.6	12.0	3.6	464.4	234.7	229.7	480.0	246.7	233.3
7.28.2011	9	5.3	31.2	7.9	3445	237	237	<	0.07	4.13	3.52	6.8	2.8	4.0	1586.5			1593.3		
8.18.2011	9	6.4	29.2	8.4	3138	245	293	9.98	0.11	2.53	3.52	5.6	<	7.2	2130.4	261.6	1868.8	2136.0	260.0	1876.0
9.28.2011	9	11.7	5.0	9.2	1112	245	363	6.39	0.77	2.16	2.48	<	<	<	1326.7	354.7	972.0	1318.7	349.3	969.3
10.25.2011	9	6.8	24.5	7.8	3561	369	293	6.44	0.17	0.53	2.24	37.3	27.3	10.0	2225.3	255.3	1970.0	2262.7	282.7	1980.0
11.30.2011	9	7.8	15.4	7.6	2069	285	419	2.71	0.34	3.00	2.27	<	3.5	<	1326.8	353.8	973.0	1325.3	357.3	968.0
12.16.2011	9	9.4	17.6	7.6	2334	285	279	4.88	0.61	2.51	2.38	9.5	7.0	2.5	1455.8	531.7	924.2	1465.3	538.7	926.7
2.16.2012	9	16.3	6.4	8.1	1231	263	209	2.86	0.09	1.80	2.41	26.7	10.7	16.0	733.3	386.7	346.7	760.0	397.3	362.7
3.20.2012	9	9.8	22.0	8.0	2972	303	307	<	0.08	0.56	2.38	23.3	12.0	11.3	1802.0	750.7	1051.3	1825.3	762.7	1062.7
5.13.2011	11	10.4	21.9	8.7	842	347	140	3.27	0.24	0.73	0.93	36.0	16.5	19.5	586.7	82.2	504.5	622.7	98.7	524.0
6.09.2011	11	8.2	25.8	8.9	528	142	126	7.45	<	0.64	0.41	51.6	17.8	33.8	511.1	246.2	264.9	562.7	264.0	298.7
7.28.2011	11	0.6	32.1	8.0	3456	224	216	<	0.09	3.59	3.84	52.4	8.8	43.6	1566.3			1618.7		
8.18.2011	11	6.8	29.2	8.5	3135	234	321	10.06	0.08	2.74	3.07	6.4	<	8.0	2205.6	249.6	1956.0	2212.0	248.0	1964.0
9.28.2011	11	11.8	4.4	9.2	1076	248	363	14.29	1.61	2.84	2.42	2.6	7.7	<	1372.1	326.9	1045.2	1374.7	334.7	1040.0
10.25.2011	11	7.2	24.0	7.9	3549	358	293	7.65	0.20	0.50	2.52	10.8	5.6	5.2	2189.2	249.1	1940.1	2200.0	254.7	1945.3
11.30.2011	11	8.1	15.1	7.7	2060	237	377	3.40	0.28	3.32	2.44	3.0	4.5	<	1309.0	415.5	893.5	1312.0	420.0	892.0
12.16.2011	11	15.2	17.7	7.7	2435	299	279	4.50	0.64	2.43	2.71	13.5	8.0	5.5	1535.8	462.7	1073.2	1549.3	470.7	1078.7
2.16.2012	11	17.8	5.7	8.1	1076	248	168	2.64	0.06	2.64	1.95	34.7	15.3	19.3	657.3	211.3	446.0	692.0	226.7	465.3
3.20.2012	11	10.0	23.3	8.3	3018	321	251	<	0.03	0.55	2.73	12.0	5.3	6.7	1892.0	660.0	1232.0	1904.0	665.3	1238.7

Table 1. Cont.

Date	Site	DO mg L^{-1}	Temp (°C)	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk. mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	FSS mg L^{-1}	VSS mg L^{-1}	TDS mg L^{-1}	FDS mg L^{-1}	VDS mg L^{-1}	TS mg L^{-1}	TFS mg L^{-1}	TVS mg L^{-1}
5.13.2011	12	9.0	22.0	8.5	709	405	126	4.06	0.15	0.52	0.72	25.5	11.0	14.5	534.5	173.0	361.5	560.0	184.0	376.0
6.09.2011	12	7.9	26.3	8.9	495	131	126	7.83	0.07	0.67	0.42	28.7	13.5	15.3	516.6	245.2	271.4	545.3	258.7	286.7
7.28.2011	12	4.3	29.7	8.0	3090	224	237	<	0.19	4.22	3.74	18.8	4.4	14.4	1393.2			1412.0		
8.18.2011	12	7.5	28.8	8.6	3092	219	293	13.69	0.17	2.55	3.43	11.2	<	12.4	2112.8	258.5	1854.3	2124.0	257.3	1866.7
9.28.2011	12	11.9	3.2	9.1	1080	219	293	17.59	0.88	0.34	2.44	13.0	<	14.5	983.0	285.5	697.5	996.0	284.0	712.0
10.25.2011	12	6.9	20.8	8.0	3459	350	279	8.20	0.25	0.57	3.52	16.5	6.0	10.5	2151.5	227.3	1924.2	2168.0	233.3	1934.7
11.30.2011	12	10.0	10.2	7.7	1464	259	321	2.37	0.36	2.60	2.39	4.0	4.0	0.0	894.7	328.0	566.7	898.7	332.0	566.7
12.16.2011	12	7.5	13.3	7.2	1786	332	251	2.58	0.36	2.64	2.21	19.5	8.5	11.0	1113.8	334.2	779.7	1133.3	342.7	790.7
2.16.2012	12	20.6	6.3	7.9	1237	274	209	2.50	0.07	2.22	2.08	32.7	14.0	18.7	744.7	242.0	502.7	777.3	256.0	521.3
3.20.2012	12	10.7	22.7	8.0	2673	325	209	<	<	0.60	2.41	14.0	8.7	5.3	1670.0	639.3	1030.7	1684.0	648.0	1036.0
5.13.2011	14	7.9	22.1	8.5	748	449	140	3.92	0.17	0.58	0.88	16.5	12.0	4.5	576.8	154.7	422.2	593.3	166.7	426.7
6.09.2011	14	7.4	26.4	8.8	496	135	140	6.30	<	0.70	0.51	27.2	15.6	11.6	547.5	273.7	273.7	574.7	289.3	285.3
7.28.2011	14	4.5	30.3	8.2	2570	219	230	<	0.01	4.10	4.69	18.8	7.6	11.2	1137.2			1156.0		
8.18.2011	14	9.2	25.8	9.0	3104	259	265	9.41	0.01	2.55	3.20	17.5	0.0	17.5	2126.5	265.3	1861.2	2144.0	265.3	1878.7
9.28.2011	14	12.6	3.0	9.3	1078	230	530	10.72	0.50	1.99	2.77	16.5	<	19.5	2188.8	595.0	1593.8	2205.3	592.0	1613.3
10.25.2011	14	9.3	15.5	8.2	2984	332	307	6.35	0.13	0.59	2.72	18.7	2.0	16.7	1820.0	262.0	1558.0	1838.7	264.0	1574.7
11.30.2011	14	9.7	9.4	7.9	1802	266	321	5.00	0.36	2.69	2.24	9.0	4.5	4.5	1073.7	276.8	796.8	1082.7	281.3	801.3
12.16.2011	14	7.4	12.0	7.7	2956	365	293	4.02	0.62	2.67	2.03	38.5	8.5	30.0	1893.5	380.8	1512.7	1932.0	389.3	1542.7
2.16.2012	14	12.8	5.4	8.1	1124	281	195	2.38	0.04	2.35	1.91	36.0	11.3	24.7	685.3	183.3	502.0	721.3	194.7	526.7
3.20.2012	14	12.4	22.3	8.2	2298	307	237	0.01	0.00	0.52	1.98	39.3	15.3	24.0	1378.0	516.7	861.3	1417.3	532.0	885.3
Upstream	Mean	10.3	15.4	8.3	585.8	254.2	161.7	1.4	0.2	0.2	0.1	19.0	20.1	13.0	323.1	214.9	224.9	332.2	223.1	204.8
Downstream	Mean	9.4	18.9	8.3	2015.4	277.7	255.1	6.2	0.3	1.9	2.3	21.7	9.9	14.0	1324.9	327.1	987.1	1345.3	335.5	998.7

Table 2. Comparison of the upstream and downstream reaches of the Sangamon River using macroinvertebrate community indices. All data were analyzed using t-test with a P = 0.05 level of significance.

Parameter	Upstream		Downstream		
	Mean	*S.E.*	Mean	*S.E.*	*P-Value*
Species Richness	6	*2.0*	7.5	*0.5*	*p = 0.54*
Simpson's Diversity	1.59	*0.34*	1.85	*0.02*	*p =0.53*
Shannon-Weiner Diversity	0.45	*0.03*	0.57	*0.09*	*p = 0.29*
River Watch MIBI[a]	7.14	*1.16*	5.52	*0.17*	*p = 0.30*

[a] – lower values suggest a higher quality assemblage.

Table 3. Summary of the mussels sampled using timed hand searches and substrate sieves on seven sites of the Sangamon River during summer 2011.

	Upstream				Downstream			
Species	Site 3	Site 5	Site 7	Site 8	Site 11	Site 12	Site 14	Total
3 ridge (*Amblema plicata*)	24	1	67	13				105
fawnsfoot (*Truncilla donaciformis*)	16	2	18	2				38
fragile papershell (*Leptodea fragilis*)	11	6	12	2				31
pink papershell (*Potamilus ohiensis*)	14	2	1	4			1	22
giant floater (*Anodonta grandis*)	9		3	2			1	15
mapleleaf (*Quadrula quadrula*)			10					10
white heelsplitter (*Lasmigona complanata*)	4		5					9
deertoe (*Truncilla truncata*)	2		5	1				8
3 horn wartyback (*Obliquaria reflexa*)	4		2	1				7
pistolgrip (*Tritogonia verrucosa*)			4					4
pimpleback (*Quadrula pustulosa*)			2					2
lilliput (*Toxolasma parvus*)	1							1
rock pocketbook (*Arcidens confragosus*)			1					1
Wabash pigtoe (*Fusconaia flava*)			1					1

Table 4. Comparison of the upstream and downstream reaches of the Sangamon River using Unionid mussel community indices. All data were analyzed using t-test with a P = 0.05 level of significance.

Parameter	Upstream		Downstream		
	Mean	*S.E.*	Mean	*S.E.*	*P-Value*
Species Richness	8.25	*1.9*	0.67	*0.67*	*p = 0.02**
Simpson's Diversity	3.71	*0.68*	0.67	*0.67*	*p =0.03**
Shannon-Weiner Diversity	1.55	*0.15*	0.23	*0.23*	*p =0.004**

*Denotes significantly different means at α = 0.05.

Table 5. Summary of the fishes sampled using DC electrofishing and seining on seven sites of the Sangamon River during spring 2011.

	Upstream				Downstream			
Species	Site 3	Site 5	Site 7	Site 8	Site 11	Site 12	Site 14	Total
Bluegill (*Lepomis macrochirus*)	3		7		3	6		19
Bluntnose Minnow (*Pimephales notatus*)			12	2	2	1		17
Brook Silverside (*Labidesthes sicculus*)	12		5	6	9	3		35
Bullhead Minnow (*Pimephales vigilax*)	2	21	123	378			18	542
Centrarchidae Spp. Juvenile				7				7
Channel Catfish (*Ictalurus punctatus*)			5	1	1	1	5	13
Cyprinidae Spp.Juvenile				1		224	4	229
Dusky Darter (*Percina sciera*)						1		1
Freshwater Drum (*Aplodinotus grunniens*)	2		15					17
Gizzard Shad (*Dorosoma cepedianum*)	1	32	9		123			165
Green Sunfish (*Lepomis cyanellus*)					2	1	1	4
Hybrid Striped Bass (*Morone saxatilis* X *Morone chrysops*)		1						1
Largemouth Bass (*Micropterus salmoides*)	1					1		2
Logperch (*Percina caprodes*)			1	1		4		6
Longear Sunfish (*Lepomis megalotis*)	1							1
Mosquito Fish (*Gambusia affinis*)	1		1	2				4
Quillback (*Carpiodes cyprinus*)					1			1

Table 5. Continued

	Upstream				Downstream			
Species	Site 3	Site 5	Site 7	Site 8	Site 11	Site 12	Site 14	Total
Red Shiner (*Cyprinella lutrensis*)	28	74	199	8	13	79	199	600
River Carpsucker (*Carpiodes carpio*)					1			1
River Shiner (*Notropis blennius*)							1	1
Sand Shiner (*Notropis ludibendus*)	7	35	20	26	7	3		98
Shortnose Gar (*Lepisosteus platostomus*)		1						1
Spotfin Shiner (*Cyprinella spiloptera*)			8					8
Suckermouth Minnow (*Phenacobius mirabilis*)						3	1	4
Tadpole Madtom (*Noturus gyrinus*)							2	2
Yellow Bass (*Morone mississippienis*)				1				1
Total	58	164	405	433	162	327	231	1780

Table 6. Relative density estimated for all fishes by fish per seine pull using seining and fish per hour using DC electrofishing, as well as total catch per site for each gear type on seven sites on the Sangamon River during spring 2011.

	Seine		DC Electrofishing	
Site	CPUE (Fish/seine)	Total Catch	CPUE (Fish/hr)	Total Catch
3	29.00	58	0.037	12
5	82.00	164	0.020	110
7	197.00	394	0.048	235
8	144.33	433	0.276	23
11	75.00	150	0.147	12
12	65.40	327	N/A	N/A
14	110.50	221	0.214	19
Mean ± *S.E.*	100.46 ± 21.08		0.124 ± 0.043	
Sum		1747		411

Table 7. Relative density estimated for all sportfishes by fish per seine pull using seining and fish per hour using DC electrofishing, as well as total catch per site for each gear type on seven sites on the Sangamon River during spring 2011.

	Seine		DC Electrofishing	
Site	CPUE (Fish/Seine)	Total Catch	CPUE (Fish/hr)	Total Catch
3	0.25	12	23.33	7
5	N/A	N/A	65.46	24
7	N/A	N/A	223.20	93
8	8.00	1	30.87	8
11	5.50	2	9.93	2
12	1.71	7	N/A	N/A
14	N/A	N/A	14.12	4
Mean ± *S.E.*	2.23 ± 1.27		61.15 ± 33.40	
Sum		22		138

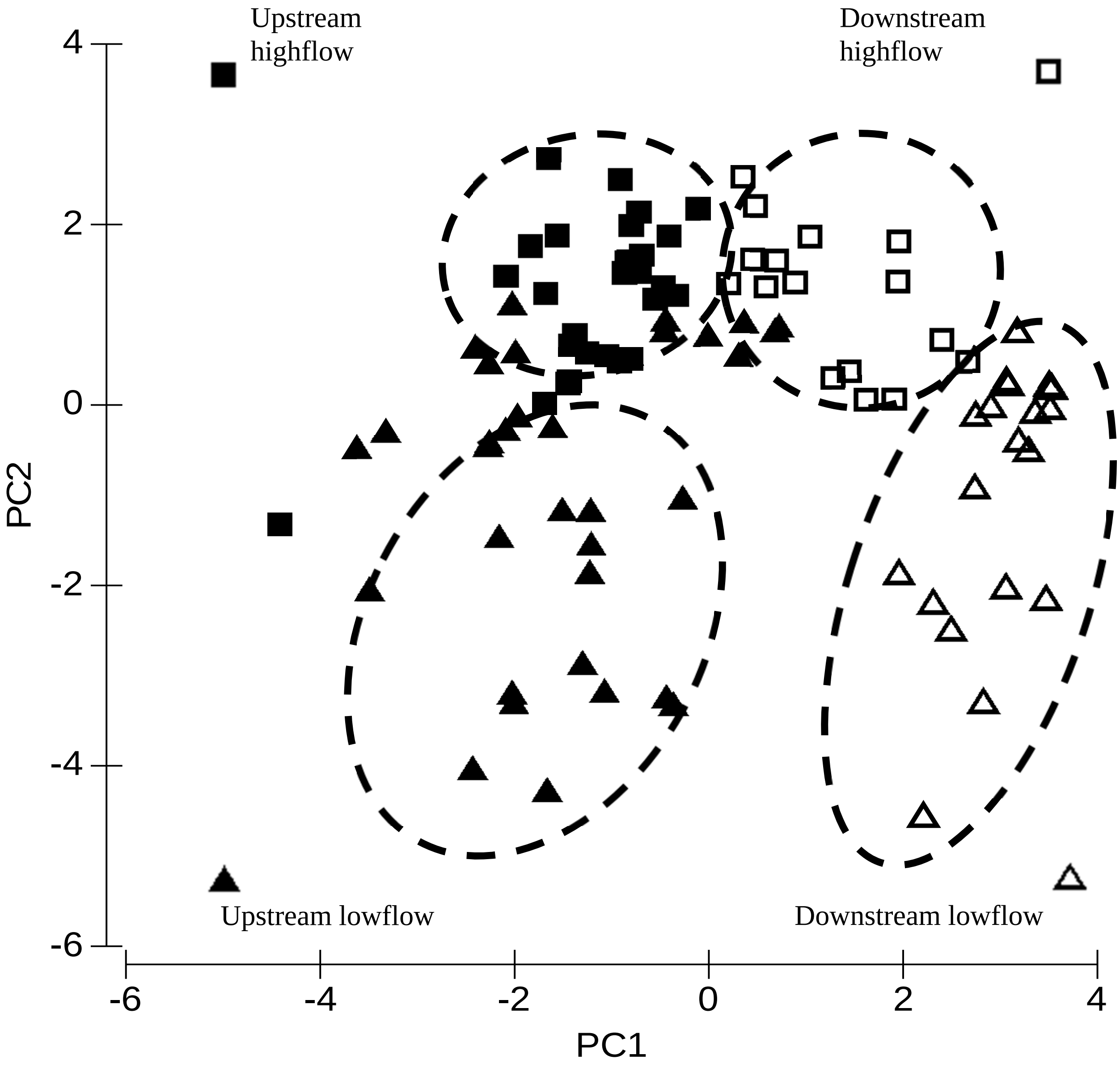

Figure 1. Principle components analysis of water quality data sampled during 2011-2012 from all mainstem sites of the Sangamon River.

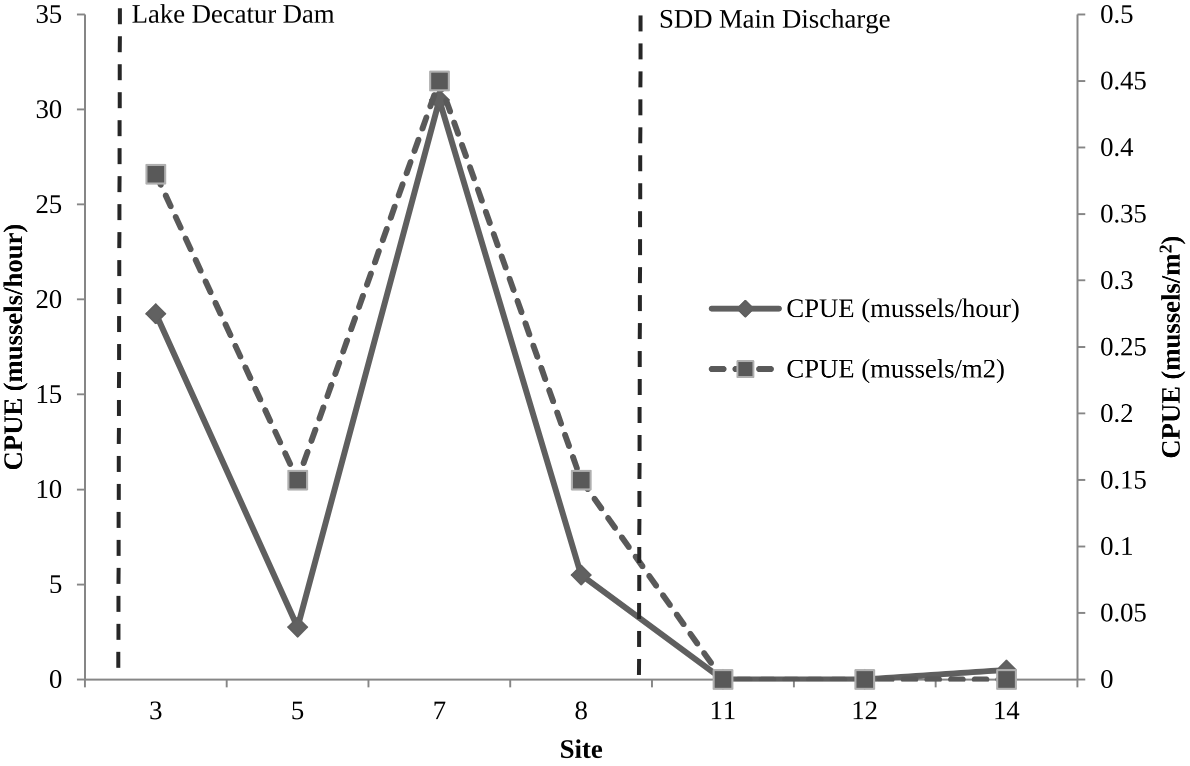

Figure 2. Relative density as estimated by catch per unit effort (CPUE) of all mussels sampled at seven sites on the Sangamon River during summer 2011. Timed hand searches are represented with mussels per hour, and substrate sieves are represented by mussels per square meter.

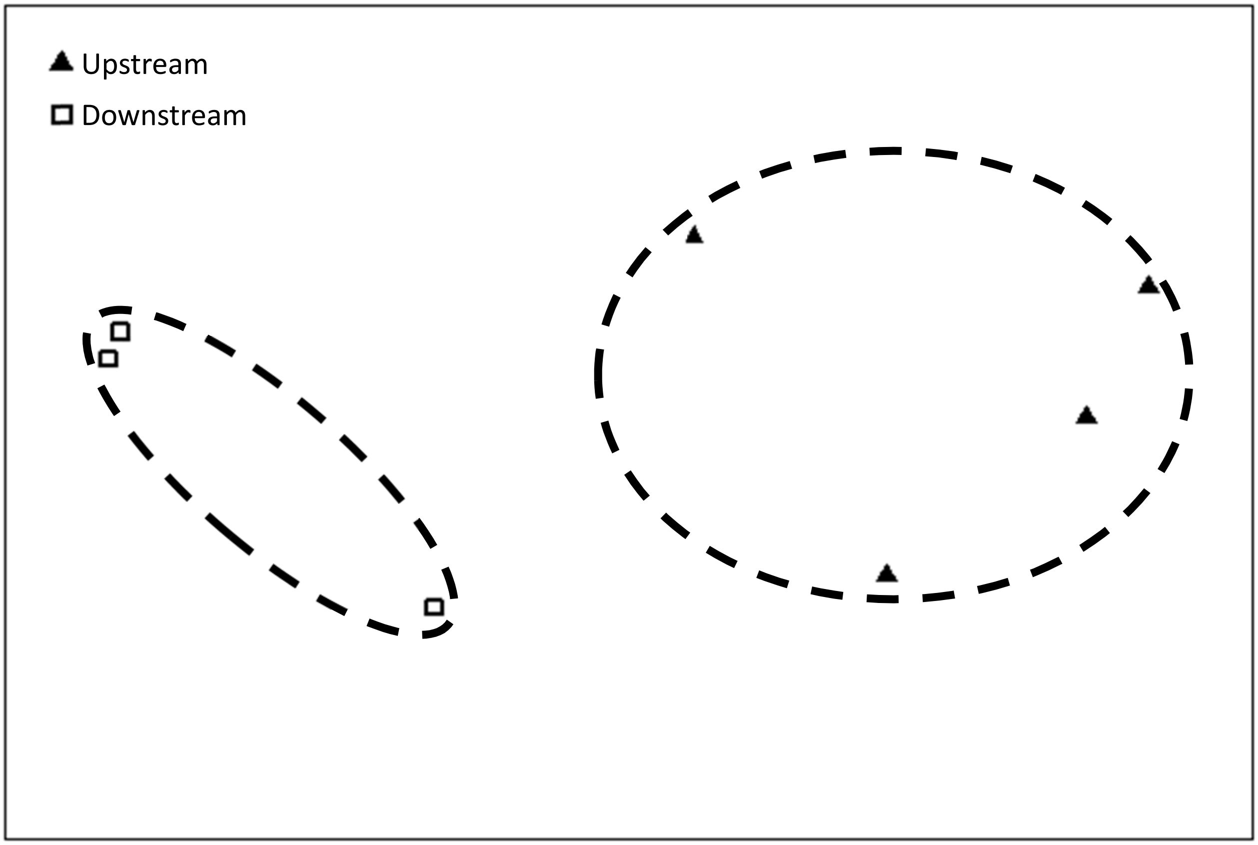

Figure 3. Multidimensional scaling plot based on Bray-Curtis similarity (2D stress = 0.0). The two different reaches were significantly different (ANOSIM, $p < 0.05$).

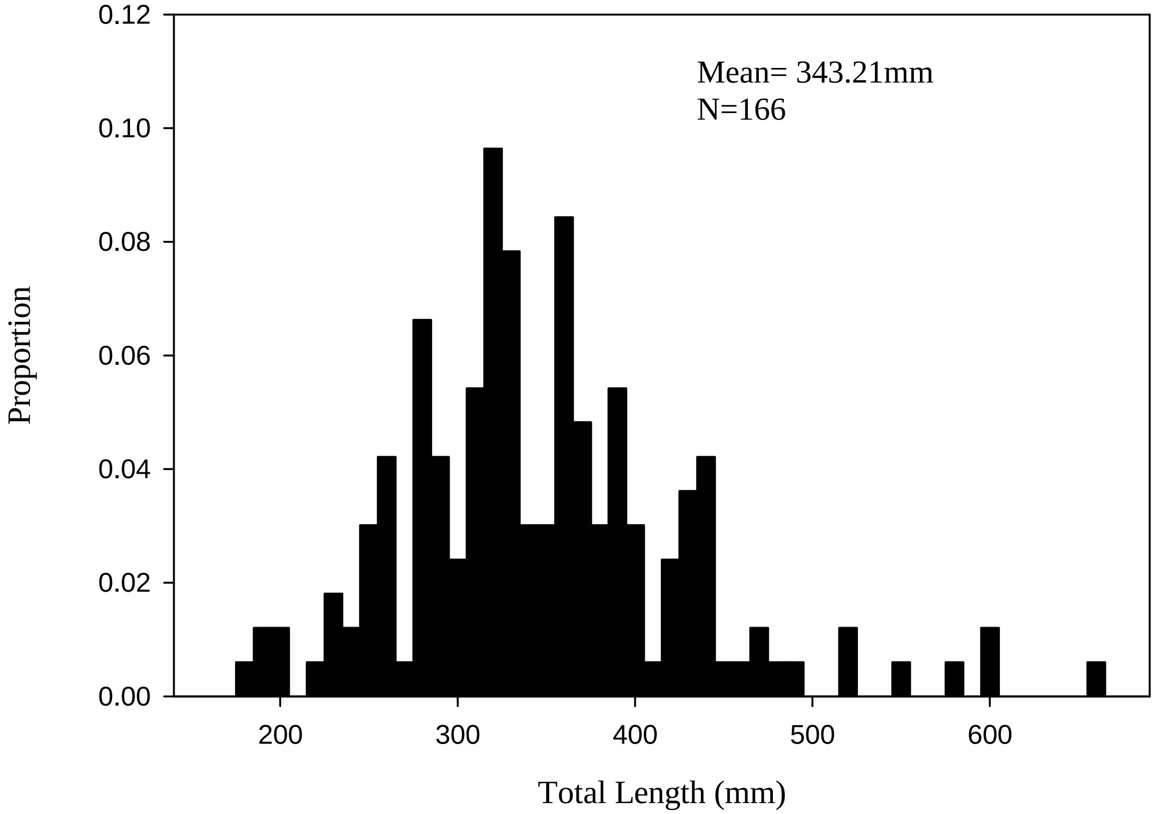

Figure 4. Length frequency histogram for channel catfish sampled using AC electrofishing on the Sangamon River during spring 2011.

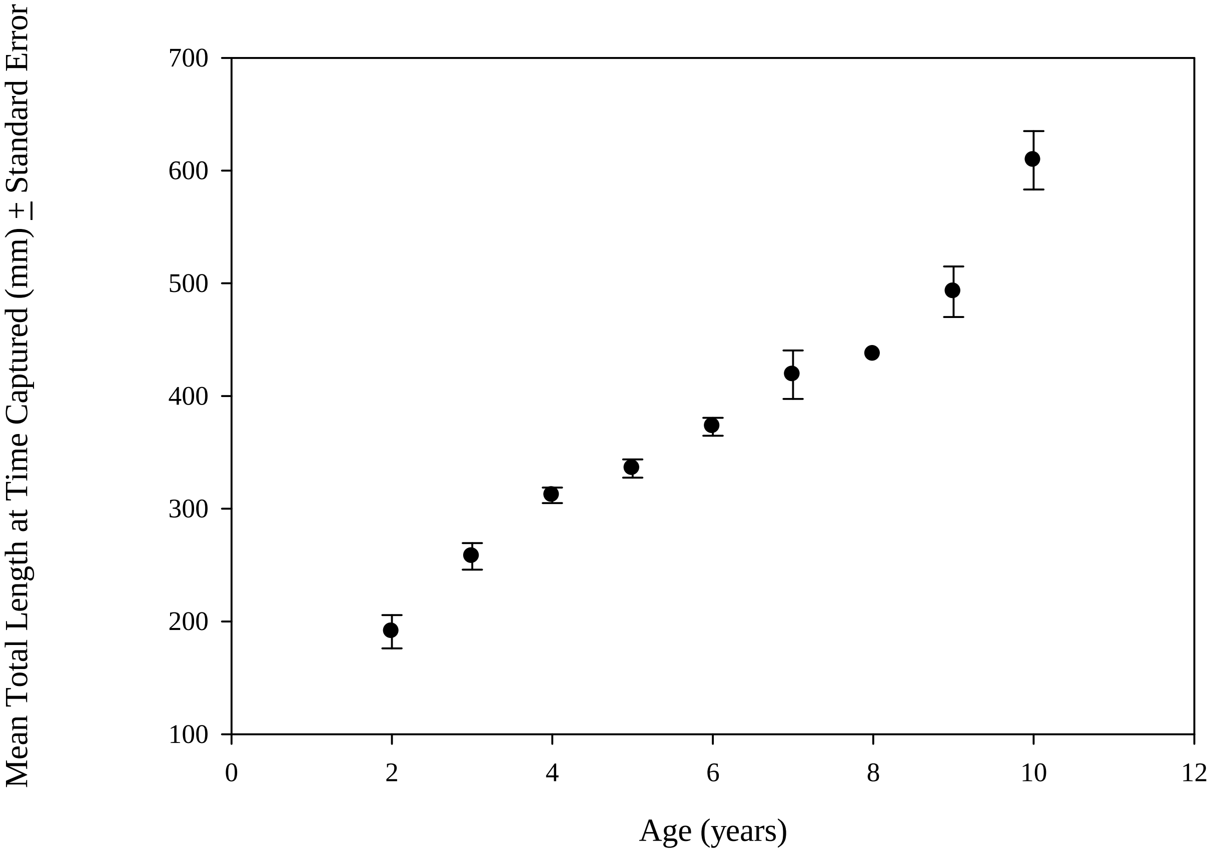

Figure 5. Mean total length at age for all channel catfish sampled using AC electrofishing on the Sangamon River during spring 2011 (N=164).

APPENDIX 1
SANGAMON RIVER SITES

Sangamon River Sampling sites (Site # based on previously completed studies)

Site 1 – Lincoln Park CSO – above outfall
Site 3 – Lincoln Park CSO – below outfall
Site 4 – Oakland CSO (Lincoln Park) - above outfall
Site 5 – Oakland CSO (Lincoln Park) – below outfall
Site 6 – 7th Ward CSO (End Sunset Dr.) – above outfall
Site 7 – 7th Ward CSO (End Sunset Dr.) - below outfall
Site 8 – Main Treatment Plant (Off Main street) – upstream of main outfall
Site 9 – Main Treatment Plant (Off Main street) –down stream of main outfall
Site 10 – Sangamon River at mouth of Stevens Creek
Site 11 – Sangamon River directly downstream of Stevens Creek
Site 12 – Bridge on Wyckles Road
Site 14 – Lincoln Trail Homestead State Park

Routine collections for water quality assessment will be conducted at all sites.

Intensive sampling for fish, macroinvertebrate, mussel, and benthic diatoms will be conducted at Sites 3, 5, 7, 8, 11, 12, and 14.

Exhibit 38

Exhibit 38

Biotic assessment of water quality in a stretch of the Sangamon River Receiving Effluent from the Sanitary District of Decatur: Focusing on qualitative habitat assessment, mussel assemblage, tiered-aquatic life use, and the sport fishery

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May, 2011

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EXECUTIVE SUMMARY

We sampled two treatment reaches of the Sangamon River for water and habitat quality, macroinvertebrate, mussel, and sportfish diversity. The two treatment reaches were upstream of the Decatur Sanitary District main discharge and downstream of the main discharge. We sampled eleven sites monthly for water quality and designated eight sites (Appendix 1) to be sampled annually for habitat quality, macroinvertebrate, mussel, sportfish, and non-game fish diversity. Four sites were located in the reach extending from the dam which impounds Lake Decatur to the discharge of the main treatment plant of the Sanitary District of Decatur (SDD). The other four sites were located downstream of SDD.

Water quality in the upstream and downstream reaches differed only during periods when discharge, measured at the Route 48 Bridge was below 10 cfs. Habitat quality as determined by the Qualitative Habitat Evaluation Index (QHEI) was higher in the downstream reaches compared to the upstream reaches ($p < 0.05$), duein part to continuous flow provided by the sanitary district effluent. Macroinvertebrate diversity wasestimated by Simpson’s D and Shannon-Weiner H’ ($p < 0.05$); however, there was no difference in the River watch MBI between river reaches. We found a significant relationship between QHEI and macroinvertebrate Simpson’s D ($p < 0.10$). Additionally, macroinvertebrate communities showed clear clustering within treatment reaches and significant separation between reaches ($p < 0.10$). We will complete a second quantitative assessment of the macroinvertebrate community during fall 2011. Qualitative assessment of the mussel community found evidence of thirteen different species of mussels in the Sangamon. A quantitative assessment of the mussel

community will be completed during summer 2011 and 2012.

A total of five sampling sites (4 upstream; 1 downstream) was sampled for sportfish. High water prevented us from completing the sportfish sampling. We will conclude sportfish sampling as soon as the USGS route 48 gauge reaches eight feet. We sampled eight different species of sportfishes in the two treatment reaches of the Sangamon. Channel catfish were the dominant species of sportfish and relative abundance of catfish in the Sangamon was higher than in other Midwestern river systems. Sampling for sportfish began under high water conditions (a necessity of the gear). During this high water event fish were distributed throughout the treatment reaches, to provide an assessment of the habitat use during periods of low to moderate flows a tracking study could be initiated. Sampling for sportfish using boat AC electrofishing will be conducted again during spring 2012. We will complete an assessment of the non-game fish using a combination of two-man seines and DC barge shocking during summer 2011 and 2012.

In addition to these preliminary findings we will use the sampling conducted during summer 2011 and 2012 to assess the Sangamon in regards to Tiered Aquatic Life Use (TALU).

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INTRODUCTION

Impoundment of rivers to create reservoirs used for irrigation purposes, as urban water supplies, and recreation, is commonplace. However, impoundments may impact downstream aquatic systems and their surrounding terrestrial habitats. Diminished water quality and availability, closures of fisheries, extirpation of species, groundwater depletion, and more frequent and intense flooding are increasingly distinguished as consequences of current river management associated with impoundments (Abramovitz 1996, Collier *et al* 1996, Naiman *et al* 1995). Specifically, dams can affect riverine systems by altering flow regime, changing nutrient and sediment loads, and modifying energy flow (Ligon *et al* 1995). As a result, river reaches downstream from a dam may no longer able to support native species, which will be reflected by reduced integrity of biotic communities. (Naiman *et al* 1995, NRC 1992).

A natural flow regime is critical for sustaining ecosystem integrity and native biodiversity in rivers (Poff, *et al*. 1997). Dams can have varying effects on downstream aquatic habitats depending on the purpose for which the dam was built. Impoundments used for urban water supplies reduce flow rates below the dam throughout the entire year (Finlayson et al. 1994) as well as increased daily and seasonal variability in flow regime (Finlayson et al. 1994, McMahon & Finlayson 2003). In addition, abiotic variables including temperature, dissolved oxygen, turbidity, pH, conductivity, and solids concentrations are altered in the downstream river system (e.g., (Finlayson et al. 1994).

Along with stream impoundments, point source and non-point source pollution can have profound effects on the ecological integrity of river systems. Non-point sources of pollution may include agriculture, livestock grazing, and urbanization while sanitary discharge and industrial waste are examples of point source pollution. To reduce point source pollution, the Water Quality Act of 1972 encouraged wastewater treatment plants to upgrade their systems and, as a result, many communities were forced to build advanced tertiary water treatment facilities (Karr et al 1985). Yet these treatment facilities still export high concentrations of nutrients into rivers. Carpenter and Waite (2000) documented that concentrations of phosphorus were highest in streams draining agricultural basins and at sites influenced by wastewater discharges, while Twichell et al (2002) reported that sewage effluent inputs had elevated nitrate levels. These enhanced nutrient inputs can be expected to increase productivity within a river because primary productivity and detrital processing usually are limited by low ambient stream nutrient concentrations (Stockner and Shortreed 1978, Elwood et al 1981, Winterbourn 1990).

Physical habitat (e.g., flow regime, bottom substrate composition, instream cover, etc.) and chemical water quality must be suitable for support of individual species in lotic systems and maintenance of the integrity of aquatic communities. The Sangamon River immediately below the dam which impounds Lake Decatur is influenced by impoundment, altered flow regime, as well as point source discharges. The Sangamon River Basin is a 14,000 km^2 watershed covering all or portions of eighteen counties in central Illinois. More than 3540 km of streams within the basin course through glacial and alluvial deposits creating typically low gradient stream with sand and gravel substrates. Streams within the basin have been impacted for most of the past century, receiving inputs from both point and non-point sources. Current land use is 80%

agricultural of which 85% is corn or soybeans. Major metropolitan areas associated with the Sangamon River are Bloomington, Decatur, and Springfield representing a combined population of more than 500,000 residents. Impoundments associated with urbanization include Lake Taylorville, Lake Sangchris, and Lake Springfield on the tributaries South Fork of the Sangamon; Clinton Lake on Salt Creek; as well as Lake Decatur.

In this context, the biotic integrity of the Sangamon River system is in constant flux. In 1998-99 and continuing from 2001-2010, an intensive sampling program was conducted to document temporal and spatial heterogeneity of an 8.5 km urban reach of the Sangamon River beginning just below the Lake Decatur Dam and extending downstream to incorporate discharges from the Sanitary District of Decatur (SDD). These studies (Fischer & Pederson 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010) were intended to characterize stream habitat quality and to assess impacts resulting from ongoing municipal and reservoir management by evaluating biotic integrity at various trophic levels in the context of the physical and chemical nature of the Sangamon River.

All sampling locations were associated with operation of SDD that were easily identified by prominent landmarks within the City of Decatur, Illinois, USA (Appendix 1). Sites were established initially in 1998 during an assessment of potential impacts of discharges from combined sewage overflow (CSO) facilities as well as the main treatment plant. All sites were located in the mainstem of the Sangamon River extending from just downstream of the dam, which impounds Lake Decatur to the Lincoln Memorial Highway bridge approximately five miles southwest of Decatur. Sites 1, 3, 4, 5, 6, 7, and 8 are within the upstream reach extending from the dam to the discharge of the main treatment plant, and Sites 9, 11, 12, 13 and 14 are located in the downstream reach which extends from the main treatment plant discharge to the a point near the Lincoln Trail Homestead State Park.

The Stream Habitat Assessment Procedure (SHAP), which evaluates lotic habitat quality using features considered important to biotic integrity, was performed in 1998, 2001, and 2002. At each stream site, two individuals independently assigned metrics related to substrate and instream cover, channel morphology and hydrology and riparian and bank features to one of four habitat quality types using guidelines established by the Illinois Environmental Protection Agency (1994). The mean total score of the 15 metrics forms the basis of an overall habitat quality rating for the stream reach under consideration. Habitat quality of the upstream and downstream reaches was categorized as "fair" quality stream reaches indicating that the physical structure of the stream is homogeneous.

This overall physical structure provides a backdrop for the ability of the study reach to support a diverse flora and fauna. Routine assessment of characteristic water quality variables superimposed on substrate characteristics, channel morphology and bank features can aid in understanding the functioning of stream systems. Given that organisms exist within often-narrow ranges of tolerance for certain physical and chemical characteristics of their environment, analysis of these variables is imperative for understanding the potential for anthropogenic impacts to decrease biotic integrity of natural systems. As a result, we began routine analyses of various physical and chemical features of the Sangamon River sites from 2002 -2010. Principle components analysis (PCA) of water quality variables has routinely indicated differences between upstream and downstream reaches at relatively low discharge (as indicated by the USGS stream gauge at IL Route 48 Bridge). Overall differences between upstream and downstream reaches are negligible when discharge measured at the Route 48 Bridge exceeds 400 cfs.

Qualitative evaluation of the two stream reaches required assessment of stream biota to determine whether or not differences in the two stream reaches were reflected by higher trophic levels. Such an evaluation of overall stream habitat quality involved biotic indices based upon macroinvertebrates and fish, taxa that have become widely used for biotic assessments. Downstream sites typically were characterized by significantly lower MBI scores, indicative of improved habitat quality capable of supporting diverse biota and a variety of different trophic levels. In contrast, general diversity indices (species richness, evenness) and IBI scores suggest that fish may be insensitive to the environmental gradient that we studied. Conclusions were that sites associated with the main treatment plant outfall from the SDD may have increased biotic integrity due to predictable instream flows and increased autochthonous primary production due in part to nutrient loading.

Stable and predictable instream flows observed in the reach downstream of the SDD facilitate development of more diverse biotic communities as confirmed by work conducted in other riverine systems (Sanders 1969; Fisher 1983; Peckarsky 1983; Ward & Stanford 1983; Reice 1985; Ross *et al*. 1985; Walde 1986; Resh *et al*. 1988). Difference in the overall nature of the upstream and downstream reaches becomes less distinct during periods of high reservoir discharge. Drastic reduction of instream flow resulting by routine elimination of reservoir discharge is detrimental to habitat quality in the upstream. Overall, results suggest that a threshold exists with respect to flow, i.e. periods when discharge is less than 400 cfs. When flow is below this threshold, the upstream and downstream reaches are discrete while they appear to behave as a continuum when discharge exceeds 400 cfs. This suggests that water quality is compromised in the reach of the Sangamon River extending downstream from the dam to the discharge of the main treatment plant of the Sanitary District of Decatur as a result of management to maintain reservoir levels by eliminating outflow. In contrast, effective management of Sangamon River may require maintenance of instream flow above the proposed threshold (400 cfs) by continuous discharge from Lake Decatur.

The Tiered Aquatic Life Use (TALU) is a broad measure of the value of habitat and includes both biotic and abiotic values of a given resource. In addition to historic ecological indices of macroinvertebrate and non-game fishes diversity, the TALU also includes measures of the economic and recreational value of an aquatic system. For example, although sportfish make up a small portion of the fish assemblage they almost always have the greatest economic and recreational value. Additionally, Unionid mussels are only a portion of the macroinvertebrate community; however, mussels have been shown to be sensitive to ecological impacts. As such the U.S. Environmental Protection Agency is proposing using mussel communities in setting ammonia standards (Great Lakes Environmental Center 2005). Based on this information it is important to include these specific communities in assessment of aquatic systems.

We have begun to assess the habitat quality using the Qualitative Habitat Evaluation Index (QHEI) (Rankin 1989). The QHEI was designed to quantify lotic habitats essential to biotic communities. Additionally, the QHEI has been shown to correlate with both fish IBI (Rankin 1989) and macroinvertebrate MCI (Hammer and Linke 2003). This may provide a better assessment of habitat quality for inclusion in the TALU.

We sought to assess the water and habitat quality, as well as the macroinvertebrate, non-game fish, sportfish, and unionid mussel communities of the Sangamon River. We sampled these communities in two treatment reaches above and below the Decatur Sanitary District main effluent. Although, all of these metrics individually provide some measure of habitat, the combination of all data will provide a broader analysis of multiple uses as it pertains to the TALU.

METHODS

Water Data Collection and Chemistry Determination

Water quality data were collected monthly from September 2010 to April, 2011. Sampling was initiated at the Lake Decatur dam and proceeded downstream. While in the field, abiotic variables were determined, such as dissolved oxygen, pH, conductivity, and temperature using a Eureka field multiprobe. Water samples were collected at 0.3 m below the surface and returned to the laboratory on ice and analyzed within generally accepted time limits. All sampling and analyses were conducted according to Standard Methods for Examination of Water and

Wastewater (APHA, 1995).

In the laboratory, suspended and total solids determinations were made by drying residue collected on standard glass fiber filters as well as unfiltered samples at 103-105 ^{o}C. Volatile and suspended solids fractions were determined by weight loss upon ignition at 550 ^{o}C. Total phosphorus (following persulfate digestion) and soluble reactive phosphorus (utilizing filtered, undigested, sample aliquots) were determined using the ascorbic acid method. The phenate method was used for determination of ammonia nitrogen, and total oxidized nitrogen (NO_2-N + NO_3-N) was determined via the cadmium reduction method. Colorimetry of all nutrient analyses was determined using a Beckman DU 530 Life Science UV/Vis Spectrophotometer. Alkalinity and hardness were measured by titration to colorimetric endpoint methods. For all chemical analyses, due consideration was given to quality control and quality assurance procedures, including but not limited to parallel analyses of laboratory standards.

Benthic Algae and Diatoms

Benthic algae will be collected from naturally occurring substrates in late summer 2011and Diatom Species Proportional Counts as described in Standard Methods for Examination of Water and Wastewater, 19th Edition (APHA-AWWA-WEF) will be performed. Appropriate indices based on relative tolerance of diatom genera will be calculated along with standard community-level variables.

Habitat Assessment Using the Qualitative Habitat Evaluation Index (QHEI)

We assessed the habitat quality of 8 sites (4 upstream and 4 downstream) using the Ohio EPA Qualitative Habitat Assessment Index (QHEI) (Rankin 1989). The QHEI ranks habitat on a scale from 0 to 100 with higher scores signifying better habitat quality. The ranking is based on six metrics: substrate type, instream cover, channel morphology, riparian zone, pool/riffle quality, and gradient (Rankin 1989, Rankin 2006). Each 150m site was split into eleven equidistant transects, and all 6 metrics were measured in all transects.

Assessment of Macroinvertebrate Community

Macroinvertebrates were sampled during fall 2010 using *IEPA's multihabitat 20- jab* method. The proportion of jabs in specific substrate types was based on their relative proportions in the QHEI. Macroinvertebrates were preserved in 95% ethanol and brought to the EIU Fisheries and Aquatic Research Lab for species identification and enumeration. Within one week of sampling, we exchanged the ethanol in the sample containers to ensure quality fixation. All macroinvertebrates were identified to lowest possible taxonomic group, enumerated, and referenced. Specimens were fixed and catalogued into the EIU invertebrate collection.

We assessed the species richness (S), Simpson's diversity (D), Shannon-Weiner diversity (H'), and macroinvertebrate index of biotic integrity based on standard River watch protocols. The Simpson's diversity (D) was calculated using the formula:

$$D = \frac{1}{\sum p_i^2}$$

Where:

- p_i = is the proportion of the total number individuals comprised by species i

We calculated Shannon-Weiner diversity (H’) using the formula:

$$H' = -\sum\left(p_i \times ln(p_i)\right)$$

Where:

- p_i = is the proportion of the total number individuals comprised by species i

Differences between upstream and downstream sites were compared using t-tests with a significance level was of P = 0.05 (Zar 1996). Relative abundance of species present was examined using multidimensional scaling (MDS) based on Bray-Curtis similarity matrices (BC). Data were square root transformed to down-weight the influence of abundant taxa. Similarity of assemblages among sample sites was portrayed in scatter plots of the first 2 ordination axes. Multivariate analysis of similarity (ANOSIM) was used to determine significance of upstream and downstream assemblages. All analyses were performed using Primer 6.3.1. (Clarke and Warwick 2001), and significance level was set at the P = 0.10. We used a linear regression to determine if QHEI was related to macroinvertebrate Simpson’s D with significance set at P = 0.10.

Assessment of Unionid Mussel Community

The mussel assemblage was assessed qualitatively by visual inspection of exposed portions of the stream bed. Representative examples of dead shells (relic or recent dead) were collected from individual upstream and downstream reaches which had been evaluated using QHEI. Dead shells were returned to the EIU Fisheries and Aquatic Research Lab for identification. Live mussels were identified and returned to the stream. All identifications were to species, according to Cummings and Mayer (1992). Upstream and downstream reaches were compared based on the presence or absence of mussel species.

Assessment of Sportfish Community

We sampled two treatment reaches (Upstream and Downstream) during spring 2011 with three-phase alternating current electrofishing using a balanced three dropper electrode array. Sampling began during mid-April at the most upstream site and continued downstream until all possible designated sampling sites were sampled. At each site, sportfish were sampled along each shoreline in a downstream manner until a 200 m of stream bank was sampled, leading to about 10 minutes of effort per shoreline. As an estimate of relative density, we calculated catch per unit effort (CPUE) as number of fish captured per electrofishing hour (pedal time).

All fish species captured were weighed to the nearest g and measured to the nearest mm total length (TL). To numerically describe the size structure of the population we used proportional and relative stock density indices. The proportional stock density (PSD) is calculated by the equation:

$$PSD = \frac{Number\ \geq\ Quality\ Length}{Number \geq Stock\ Length} \times 100$$

Where:

- Stock Length = 20-26% of the world record length

- Quality Length = 36-41% of the world record length

The relative stock density (RSD) is calculated form the equation:

$$RSD = \frac{Number\ \geq Specified\ Length\ (Preferred, Memorable, or\ Trophy)}{Number\ \geq Stock\ Length} \times 100$$

Where:

- Stock Length = 20-26% of the world record length
- Specified Length = Preferred (45-55%), Memorable (59-64%), or Trophy (74-80%)

As an index of condition, relative weight (W_r) was calculated for each sportfish species (largemouth bass, bluegill, green sunfish, white and black crappie, walleye, hybrid striped bass, and channel and flathead catfish). Relative weight estimates the condition (plumpness) of individuals based on a length specific standard weight for a species. Relative weight is calculated from the equation (Anderson and Neumann 1996):

$$Wr = \frac{W}{Ws} \times 100$$

Where:

- W = weight of an individual
- Ws = length-specific standard weight

The standard weight equation for an individual species is based on the 75th percentile of different populations throughout each species range (Anderson and Neumann 1996). Relative weight scores of less than 100 suggests overabundance while scores greater than 100 suggests poor use of available prey (Anderson and Neumann 1996).

For largemouth bass, bluegill, green sunfish, hybrid striped bass, and black and white crappie the sagittal otoliths were removed. Two independent researchers will estimate the age of these fishes in double blind fashion. We will estimate fish age from the otolith with a dissecting microscope equipped with a top-mounted digital camera. For channel catfish, we will estimate the age from annual rings on the pectoral spine. From each channel catfish the articulating process of the spine will be sectioned to 0.5 mm with a Beuhler low speed isomet saw and used to estimate age. Disagreements in age estimates for all species will be reconciled by consensus between the two readers. In a small percentage of fish artifacts on the otolith or spine prevent that structure from being used for aging. If disagreements cannot be reconciled the sample will be discarded. Due to small sample sizes all walleye were released unharmed.

RESULTS

Field Data Collection and Water Chemistry Determination

Levels of 19 separate water quality variables were determined for eleven mainstem sites in 2011 (Table 1). The trend established in prior sampling years continued throughout this recent sampling period, with levels for each of the variables being generally higher in downstream locations. Aggregate measures of solids, both suspended and dissolved, were elevated as a result of discharge from the main treatment plant. Higher concentrations of fixed dissolved solids downstream of the SDD discharge were confirmed by elevated specific conductance. Primary contributors to the elevated solids content include plant macronutrients (nitrate, ammonia, and different forms of phosphate) as well as other minerals, e.g., calcium and magnesium measured as hardness.

Given that some measures were determined to be redundant or uninformative, they were eliminated from multivariate analysis (e.g., conductivity and total dissolved solids are highly correlated). PCA analysis was conducted using 12 measured variables. PCA analysis extracted 5 factors, which explained a total of 86 % of the variation in water quality observed within the Sangamon River during the sampling period. Upstream and downstream sites occupy discrete regions in the ordination space created by PCA Factors 1 and 2 (Figure 1). ANOSIM revealed significant differences between the upstream and downstream reaches at times when discharge at the Route 48 Bridge was less than 10 cfs ($\rho = .639$, $P < 0.0001$).

Habitat Assessment Using the Qualitative Habitat Assessment Index (QHEI)

The QHEI scores ranged from 42 (poor) to 65.5 (good) with the highest quality habitat occurring in the site directly downstream of the effluent and the lowest quality habitat occurring in the site directly upstream of the effluent (Figure 2). Overall, habitat quality based on QHEI scores was higher in the downstream treatment reach compared to the upstream reach (Figure 3; $p < 0.05$). Whereas the average QHEI in the upstream reach suggests fair habitat quality, the average QHEI in the downstream reach suggests good habitat quality (Rankin 2006).

Assessment of Macroinvertebrate Community

A total of 25 different taxa of macroinvertebrates comprising ten different orders was sampled from the eight different sites on the Sangamon. Although, there was no significant difference in the species richness ($p > 0.05$) and biotic integrity ($p > 0.05$) between the two reaches (Upstream and Downstream) both Simpson's D ($p < 0.05$) and Shannon-Weiner H' ($p < 0.05$) were higher in the downstream reach (Table 2). Additionally, there were significant differences in the relative abundance of species present. We found clear clustering (2D Stress: 0.05) within treatment reaches (Figure 4) and significant separation between the two reaches (ANOSIM, $p < 0.10$). Additionally, macroinvertebrate diversity (Simpson's D) increased linearly with habitat quality as estimated by QHEI (Figure 4; $P < 0.10$).

Assessment of Unionid Mussel Community

A total of 13 species of native mussels (Table 3) and 1 introduced species (*Corbicula* sp.) were recovered. Of these, there were 6 unique species in the upstream sites and 1 unique species in the downstream sites (Table 3).

Assessment of Sportfish Community

We sampled a total of 4 upstream sites and 1 downstream site using three phase AC electrofishing before high water prevented access. The three remaining sites (12, 13 and 14) will be completed as soon as the USGS Route 48 gauge (USGS 05573540) reaches 8 feet. In the five completed sites we sampled a total of 22 different species of fishes (Table 4). The five most dominant fish species were: channel catfish, gizzard shad, bluegill, freshwater drum, and smallmouth buffalo (Table 4). The sportfish community was comprised of: black crappie, bluegill, channel and flathead catfish, green sunfish, hybrid striped bass, largemouth bass, longear sunfish, walleye, and white crappie; with channel catfish and bluegill being the most numerically abundant (Table 4).

The relative density (CPUE) of all fishes was highest in site 7 and lowest in site 11 (Table 5). Sportfish relative density averaged 107.0 fish/hour with the highest density of sportfish occurring at site 3 (Table 5). Due to small sample sizes of all sportfish species except channel catfish, only relative weight was calculated (Table 6). Excluding largemouth bass the relative weight for all species of sportfish suggested fish in average condition; however, largemouth bass were in above average condition (Table 6). Average channel catfish CPUE was high (44.8 catfish/hr), with the highest relative density in site 7 and the lowest relative density in site 5 (Table 5). Although, the majority (67%) of channel catfish were of harvestable size (> 280 mm) there was a small proportion greater than quality size (PSD = 28) and no catfish greater than preferred length (610 mm) (Figure 6).

DISCUSSION

The primary difference between upstream and downstream reaches is attributable indirectly to metrics related to reservoir discharge and input of dissolved solids from the SDD main discharge. Outflow from Lake Decatur is the primary input to the upstream reach, which is compromised as a result of management to maintain reservoir levels by eliminating outflow. Sites downstream of the SDD main discharge may have greater potential for instream primary productivity as a result of nutrient loading as indexed by higher levels of dissolved solids, conductivity, total alkalinity, oxidized nitrogen, and phosphorus. This elevated autochthonous primary productivity may in turn support more diverse macroinvertebrate and fish assemblages.

These results are reflected by the QHEI values which showed that downstream reach habitat was of higher quality than that of the upstream reach. This most likely is a function of a more continuous flow which is critical for maintaining high quality substrate and instream cover in lotic systems. Discharge from the main treatment plant of the Sanitary District of Decatur alters instream water chemistry during periods of low reservoir discharge. However, the entire study reach is relatively homogeneous during periods of high discharge from the dam which impounds Lake Decatur. As a result, the stability of instream flows at downstream locations compensates for the elevated nutrient inputs. During fall 2011, we will repeat the habitat assessment of the eight sampling sites on the Sangamon River.

Overall, the macroinvertebrate community was dominated by aquatic midges. This group is indicative of organic rich habitats, but they are often the most abundant taxa (Rabeni and Wang 2000). Macroinvertebrate communities are typically correlated with habitat scores (Hammer and Linke 2003). Based on preliminary data, that would seem to be the case in this study. Although the MBI scores and number of taxa (richness) were not significantly different between reaches, the diversity (Simpson's D and Shannon-Weiner H'), which takes into account both abundance and number of taxa, increased downstream. Overall, sites in the downstream reach clustered together, and separate from upstream sites. This suggests that communities were similar within reaches, but differed between reaches. Unionid mussels were collected from upstream and downstream reaches. At low water, we will do a quantitative assessment of the unionid mussel community during summer of 2011. Additionally, we will repeat the IEPA 20-jab macroinvertebrate sampling during fall 2011.

The relative density of both large non-game and sport fishes in the Sangamon was high compared to other Midwestern rivers (Colombo unpublished data). Further, the diversity of fish species was comparable to other Midwestern systems (Colombo unpublished data). The sportfish community of the Sangamon River was dominated by channel catfish. This population of catfish has higher relative abundance compared to other Midwestern river systems (Colombo 2007). Based on the density and condition of these catfish it would seem that this is an underexploited resource. Once age structure is developed for this population we can determine the economic value and best management strategy channel catfish fishery in the Sangamon. Sample sizes of all other sportfishes were low. We will be conducting additional sampling during spring 2011 and 2012 to develop a more accurate assessment of the sportfish community. Additionally, we will conduct an assessments of the non-game fish community of that are not vulnerable to the boat shocking gear during summer 2011 and 2012. These data will allow correlations to be made between the macroinvertebrate, unionid and fish communities.

One aspect that was revealed with the incorporation of sportfish data into the sampling regime is during high water flows the sportfish community is free to access both reaches of the Sangamon. It therefore becomes important to know the low water refugia that sportfish use. This can be determined using an ultrasonic tracking study. Tracking data could then be used to assess the critical habitats of the Sangamon River and to assess the extent of the home ranges for sportfish.

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TABLES AND FIGURES

Table 1. Measured water quality variables for 11 Sangamon River sites associated with the Sanitary District of Decatur.

Date	Site	Temp	DO	pH	Spec. Cond.	Hard.	Total Alk	NO_2/NO_3	NH_4	PO_4 total	PO_4 SRP	TSS	VSS	FSS	TDS	VDS	FDS	TS	TVS	TFS
		(°C)	mg L^{-1}		mS cm^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}
9/14/2010	1					256	307	0.53	0.13	0.36	0.18	13.1	4.6	8.6	381.5	92.8	288.8	394.7	97.3	297.3
10/26/2010	1	18.3	8.3	8.1	464	383	195	0.75	0.32	0.44	0.83	40.0	22.0	18.0	362.7	126.0	236.7	402.7	148.0	254.7
11/14/2010	1	9.3	9.2	8.7	752	423	363	0.04	0.07	0.18	0.13	10.4	4.8	5.6	548.3	116.5	431.7	558.7	121.3	437.3
1/18/2011	1	2.0	12.9	9.2	628	511	251	0.04	0.07	0.18	0.13	6.6	2.8	3.8	362.7	226.5	136.2	369.3	229.3	140.0
2/20/2011	1	2.9	12.8	9.2	640	292	181	4.08	0.13	0.07	0.04	6.3	5.7	0.6	393.7	111.6	282.1	400.0	117.3	282.7
3/28/2011	1	8.0	11.4	9.6	567	270	147	4.12	0.01	0.02	0.00	10.4	4.8	5.6	548.3	116.5	431.7	558.7	121.3	437.3
4/17/2011	1	13.4	10.4	8.3	469	234	147	4.46	0.24	0.12	0.05	28.0	19.0	9.0	424.0	198.3	225.7	452.0	217.3	234.7
9/14/2010	3					318	342	0.34	0.00	0.26	0.15	12.7	5.7	7.0	426.0	101.0	325.0	438.7	106.7	332.0
10/26/2010	3	17.8	7.9	8.4	561	391	265	0.17	0.20	0.49	0.27	45.0	14.0	31.0	407.0	130.0	277.0	452.0	144.0	308.0
11/14/2010	3	10.2	7.1	8.6	794	445	377	0.06	0.04	0.28	0.09	18.8	10.4	8.4	498.5	113.6	384.9	517.3	124.0	393.3
1/18/2011	3	2.0	12.7	9.2	628	365	293	0.06	0.04	0.28	0.09	4.6	2.4	2.2	404.7	213.6	191.1	409.3	216.0	193.3
2/20/2011	3	2.8	12.8	9.2	642	310	237	3.66	0.15	0.05	0.01	8.8	6.0	2.8	375.2	116.7	258.5	384.0	122.7	261.3
3/28/2011	3	8.0	11.1	9.9	568	267	154	6.22	0.00	0.09	0.00	18.4	4.4	14.0	430.9	126.3	304.7	449.3	130.7	318.7
4/17/2011	3	13.4	10.3	8.7	470	281	126	4.46	0.17	0.17	0.01	29.5	19.0	10.5	462.5	234.3	228.2	492.0	253.3	238.7
9/14/2010	4	20.9	8.4	8.0	574	263	335	0.68	0.08	0.20	0.08	7.1	3.1	4.0	424.9	98.2	326.7	432.0	101.3	330.7
10/26/2010	4	16.7	9.7	8.5	720	442	384	0.11	0.00	0.66	0.15	13.3	9.0	4.3	506.7	128.3	378.3	520.0	137.3	382.7
11/14/2010	4	10.4	11.5	8.7	795	569	426	0.12	0.21	0.41	0.07	8.3	3.0	5.3	529.0	115.7	413.3	537.3	118.7	418.7
1/18/2011	4	2.1	12.6	9.4	629	420	307	0.12	0.21	0.41	0.07	5.2	2.0	3.2	389.5	195.3	194.1	394.7	197.3	197.3
2/20/2011	4	2.9	12.6	9.2	641	256	98	4.90	0.09	0.08	0.02	7.2	6.0	1.2	378.1	92.7	285.5	385.3	98.7	286.7
3/28/2011	4	8.3	11.2	9.8	566	336	154	6.01	0.04	0.08	0.00	21.2	6.8	14.4	425.5	127.9	297.6	446.7	134.7	312.0
4/17/2011	4	13.6	10.4	9.0	470	391	147	4.11	0.24	0.12	0.04	30.5	19.0	11.5	469.5	254.3	215.2	500.0	273.3	226.7
9/14/2010	5	20.7	8.0	8.0	574	296	328	0.68	0.06	0.20	0.09	6.0	3.0	3.0	432.7	105.0	327.7	438.7	108.0	330.7
10/26/2010	5	16.8	7.6	8.5	755	507	384	0.07	0.00	0.62	0.16	17.0	11.0	6.0	507.0	123.7	383.3	524.0	134.7	389.3
11/14/2010	5	8.5	7.0	8.6	799	836	426	0.09	0.17	0.22	0.11	7.3	3.3	4.0	515.4	115.4	400.0	522.7	118.7	404.0
1/18/2011	5	20.9	12.6	9.4	630	650	405	0.09	0.17	0.22	0.11	4.6	2.8	1.8	379.4	158.5	220.9	384.0	161.3	222.7
2/20/2011	5	3.0	12.5	9.2	638	292	168	5.18	0.09	0.12	0.03	17.2	8.8	8.4	388.1	116.5	271.6	405.3	125.3	280.0
3/28/2011	5	8.3	11.2	9.7	569	263	154	4.93	0.21	0.09	0.00	51.0	16.0	35.0	393.0	114.7	278.3	444.0	130.7	313.3
4/17/2011	5	13.6	10.2	8.9	470	329	140	4.04	0.18	0.15	0.02	29.0	18.0	11.0	447.0	226.0	221.0	476.0	244.0	232.0

Table 1. Continued

Date	Site	Temp (°C)	DO mg L^{-1}	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	VSS mg L^{-1}	FSS mg L^{-1}	TDS mg L^{-1}	VDS mg L^{-1}	FDS mg L^{-1}	TS mg L^{-1}	TVS mg L^{-1}	TFS mg L^{-1}
9/14/2010	6	22.0	8.3	7.9	577	325	300	0.66	0.04	0.22	0.07	6.0	1.5	4.5	438.0	91.8	346.2	444.0	93.3	350.7
10/26/2010	6	16.5	7.5	8.7	816	518	419	0.24	0.00	0.08	0.00	14.0	7.0	7.0	554.0	125.0	429.0	568.0	132.0	436.0
11/14/2010	6	9.8	9.4	8.4	861	920	454	0.07	0.20	0.30	0.05	14.4	4.4	10.0	576.3	120.9	455.3	590.7	125.3	465.3
1/18/2011	6	2.0	12.7	9.3	633	657	307	0.07	0.20	0.30	0.05	5.2	2.8	2.3	394.8	138.5	256.3	400.0	141.3	258.7
2/20/2011	6	5.2	12.7	9.5	634	329	168	4.35	0.11	0.12	0.05	9.2	8.0	1.2	393.5	116.0	277.5	402.7	124.0	278.7
3/28/2011	6	8.4	11.2	9.0	571	223	161	4.43	0.00	0.07	0.00	18.0	13.5	4.5	416.7	113.2	303.5	434.7	126.7	308.0
4/17/2011	6	13.7	10.2	8.9	471	252	147	4.27	0.18	0.10	0.00	32.0	19.5	12.5	438.7	197.8	240.8	470.7	217.3	253.3
9/14/2010	7	24.0	9.8	8.4	546	380	314	0.35	0.05	0.19	0.04	21.7	7.2	14.5	375.6	78.1	297.5	397.3	85.3	312.0
10/26/2010	7	17.5	10.4	8.6	645	515	356	0.13	0.00	0.11	0.00	23.2	10.8	12.4	404.8	94.5	310.3	428.0	105.3	322.7
11/14/2010	7	10.3	10.0	8.5	682	1073	394	0.14	0.40	0.19	0.05	12.3	4.7	7.7	439.7	92.7	347.0	452.0	97.3	354.7
1/18/2011	7	1.9	12.8	9.3	632	712	307	0.14	0.40	0.19	0.05	6.8	3.8	3.0	406.5	150.9	255.7	413.3	154.7	257.7
2/20/2011	7	5.2	12.3	9.4	636	347	168	6.49	0.09	0.11	0.05	19.3	4.0	15.3	384.7	116.0	268.7	404.0	120.0	284.0
3/28/2011	7	8.6	11.3	9.8	569	299	140	5.29	0.02	0.08	0.00	22.0	11.6	10.4	395.3	111.1	284.3	417.3	122.7	294.7
4/17/2011	7	13.8	10.4	9.3	472	369	147	4.00	0.21	0.10	0.00	31.0	18.0	13.0	449.0	216.7	232.3	480.0	234.7	245.3
9/14/2010	8	24.2	8.8	8.1	544	332	314	0.36	0.01	0.14	0.01	15.7	5.7	10.0	377.6	85.0	292.7	393.3	90.7	302.7
10/26/2010	8	17.2	6.0	8.5	801	515	433	0.61	0.01	0.49	0.55	14.3	9.3	5.0	548.3	98.7	449.7	562.7	108.0	454.7
11/14/2010	8	9.9	6.7	8.4	670	657	349	0.11	0.48	0.14	0.05	8.0	3.3	4.7	418.7	83.3	335.3	426.7	86.7	340.0
1/18/2011	8	1.8	12.8	9.3	633	566	293	0.11	0.48	0.14	0.05	6.6	3.8	2.8	408.1	196.2	211.9	414.7	200.0	214.7
2/20/2011	8	3.2	13.5	9.2	636	402	293	4.01	0.16	0.10	0.03	6.9	6.0	0.9	374.5	123.3	251.1	381.3	129.3	252.0
3/28/2011	8	8.7	11.2	9.6	570	245	140	5.15	0.08	0.09	0.05	21.5	16.5	5.0	399.8	123.5	276.3	421.3	140.0	281.3
4/17/2011	8	13.8	10.1	9.2	472	292	133	3.88	0.15	0.11	0.00	30.5	19.5	11.0	442.8	227.2	215.7	473.3	246.7	226.7

Table 1. Continued

Date	Site	Temp (°C)	DO mg L^{-1}	pH	Spec. Cond. mS cm^{-1}	Hard. mg L^{-1}	Total Alk mg L^{-1}	NO_2/NO_3 mg L^{-1}	NH_4 mg L^{-1}	PO_4 total mg L^{-1}	PO_4 SRP mg L^{-1}	TSS mg L^{-1}	VSS mg L^{-1}	FSS mg L^{-1}	TDS mg L^{-1}	VDS mg L^{-1}	FDS mg L^{-1}	TS mg L^{-1}	TVS mg L^{-1}	TFS mg L^{-1}
9/14/2010	9	27.7	7.0	8.0	545	398	489	3.81	0.01	3.28	3.25	4.9	2.9	2.0	1896.4	182.4	1714.0	1901.3	185.3	1716.0
10/26/2010	9	25.1	6.8	8.4	3197	632	510	5.09	0.08	8.08	7.53	8.0	6.2	1.8	2144.0	239.2	1904.8	2152.0	245.3	1906.7
11/14/2010	9	22.9	7.7	8.5	3432	537	565	2.37	0.74	3.27	2.92	9.7	5.3	4.3	2279.7	241.3	2038.3	2289.3	246.7	2042.7
1/18/2011	9	5.0	11.7	9.2	1112	708	335	2.37	0.74	3.27	2.92	12.0	8.2	3.8	688.0	158.5	529.5	700.0	166.7	533.3
2/20/2011	9	4.5	11.8	9.1	765	387	168	3.19	0.09	0.33	0.27	18.0	7.1	10.9	390.0	120.9	269.1	408.0	128.0	280.0
3/28/2011	9	9.6	10.9	9.5	802	347	168	6.08	0.09	0.93	0.91	24.0	16.0	8.0	522.7	102.7	420.0	546.7	118.7	428.0
4/17/2011	9	13.9	10.3	9.2	496	340	140	3.38	0.17	1.96	1.61	28.0	16.5	11.5	497.3	239.5	257.8	525.3	256.0	269.3
9/14/2010	11	27.7	7.2	8.0	2442	409	440	3.12	0.10	3.66	3.64	8.5	3.3	5.2	1379.5	136.8	1242.8	1388.0	140.0	1248.0
10/26/2010	11	25.2	6.4	8.4	3388	453	496	7.13	0.07	8.20	7.84	16.4	8.2	8.2	2198.3	245.1	1953.1	2214.7	253.3	1961.3
11/14/2010	11	22.2	7.4	8.5	3395	413	503	2.55	0.11	3.27	3.06	16.3	10.0	6.3	2221.0	226.0	1995.0	2237.3	236.0	2001.3
1/18/2011	11	4.4	11.8	9.2	1076	365	321	2.55	0.11	3.27	3.06	8.0	5.2	2.8	658.7	133.5	525.2	666.7	138.7	528.0
2/20/2011	11	3.7	12.8	9.1	697	398	154	4.43	0.12	0.48	0.41	15.7	6.0	9.7	389.6	122.0	267.6	405.3	128.0	277.3
3/28/2011	11	9.7	10.8	9.5	843	329	168	4.00	0.03	2.14	1.04	25.0	17.5	7.5	559.0	123.8	435.2	584.0	141.3	442.7
4/17/2011	11	14.5	10.2	9.4	665	325	140	3.84	0.20	1.95	1.41	29.5	20.5	9.0	595.8	231.5	364.3	625.3	252.0	373.3
9/14/2010	12	25.9	8.6	8.0	2058	445	440	3.31	0.11	3.49	3.47	16.7	3.3	13.5	1463.2	151.4	1311.8	1480.0	154.7	1325.3
10/26/2010	12	21.0	7.7	8.6	2487	496	475	5.46	0.05	8.06	5.54	13.7	4.2	9.5	1625.0	223.8	1401.2	1638.7	228.0	1410.7
11/14/2010	12	17.4	8.0	8.7	2957	420	377	2.15	0.09	3.52	3.05	17.7	5.3	12.3	1961.0	230.7	1730.3	1978.7	236.0	1742.7
1/18/2011	12	3.2	11.9	9.1	1080	478	391	2.15	0.09	3.52	3.05	8.4	4.8	3.6	638.3	143.2	495.1	646.7	148.0	498.7
2/20/2011	12	4.0	12.9	9.3	668	329	140	4.01	0.12	0.67	0.57	70.0	16.5	53.5	376.7	102.2	274.5	446.7	118.7	328.0
3/28/2011	12	8.8	12.3	9.0	723	310	181	4.65	0.00	1.18	0.96	22.8	12.0	10.8	554.5	116.0	438.5	577.3	128.0	449.3
4/17/2011	12	13.7	9.5	9.2	718	358	154	4.84	0.16	1.09	0.85	33.0	18.5	14.5	575.0	226.8	348.2	608.0	245.3	362.7
9/14/2010	14	23.5	7.8	8.1	1660	376	468	2.83	0.14	3.27	3.07	14.6	2.0	12.6	1164.1	115.3	1048.8	1178.7	117.3	1061.3
10/26/2010	14	18.8	8.0	8.6	2953	559	482	3.28	0.04	8.25	8.18	23.3	6.9	16.4	1976.7	215.8	1760.9	2000.0	222.7	1777.3
11/14/2010	14	11.9	9.1	8.9	2865	653	503	1.62	0.08	3.19	2.94	22.7	5.7	17.0	1929.3	193.0	1736.3	1952.0	198.7	1753.3
1/18/2011	14	3.0	12.6	9.3	1078	697	363	1.62	0.08	3.19	2.94	6.6	2.8	3.8	362.7	226.5	136.2	369.3	229.3	140.0
2/20/2011	14	4.4	12.9	9.0	661	420	140	3.46	0.42	0.95	0.76	39.2	9.6	29.6	455.5	106.4	349.1	494.7	116.0	378.7
3/28/2011	14	8.7	12.2	8.6	707	318	181	5.51	0.08	1.07	0.99	21.6	12.8	8.8	533.1	117.9	415.2	554.7	130.7	424.0
4/17/2011	14	13.6	9.3	9.2	711	372	168	4.73	0.22	1.09	0.87	41.8	14.9	26.9	551.5	211.8	339.8	593.3	226.7	366.7
Upstream	Mean	10.9	10.4	8.9	618.8	418.7	264.7	2.1	0.1	0.2	0.1	16.7	8.5	8.1	433.7	136.7	297.0	450.3	145.2	305.1
Downstream	Mean	14.1	9.8	8.8	1577.9	438.2	323.3	3.7	0.2	3.1	2.8	20.6	9.0	11.6	1092.4	174.4	918.0	1113.0	183.4	929.5

Table 2. Comparison of the Upstream and Downstream reaches of the Sangamon River using macroinvertebrate community indices. All data were analyzed using t-test with a P = 0.05 level of significance.

	Upstream		Downstream		
Parameter	Mean	*S.E.*	Mean	*S.E.*	*P-value*
Species Richness	10	*1.5*	13.5	*1.9*	$p = 0.100$
Simpson's Diversity	1.66	*0.29*	2.69	*0.21*	$p < 0.010$*
Shannon-Weiner Diversity	0.82	*0.16*	1.5	*0.09*	$p < 0.004^*$
River watch MIBI[a]	6.64	*0.45*	6.06	*0.25*	$p = 0.156$

*Denotes significantly different means at $\alpha = 0.05$.[a] – lower values suggest a higher quality assemblage.

Table 3. Summary of the Unionid mussel community sampled from eight 200 m sampling sites on the Sangamon River during fall 2010.

	Upstream				Downstream			
Species	Site 3	Site 5	Site 7	Site 8	Site 11	Site 12	Site 13	Site 14
3 horn wartyback (*Obliquaria reflexa)*		X		X				
pistolgrip (*Tritogonia vurrucosa)*		X						
3 ridge (*Amblyma plicata)*		X		X				
deertoe (*Truncilla truncate*)		X		X	X		X	
fawnsfoot (*Truncilla donaciformis)*		X						
plain pocketbook (*Lampsilis cardium)*		X			X			
giant floater (*Pyganodon grandis)*		X		X				
fragile papershell (*Leptodea fragilis)*		X		X	X			
pink papershell (*Potamilus ohiensis)*		X			X			
yellow sandshell (*lampsilis teres)*		X		X				
pimpleback (*Quadrula pustulosa)*				X				
mapleleaf (*Quadrula quadrula)*				X	X			
white heelsplitter (*Lasmigona complanata*)					X			

Table 4. Summary of the fishes sampled using three-phase AC electrofishing on five sites of the Sangamon River during spring 2011.

Species	S3	S5	S7	S8	S9	Total
Bigmouth Buffalo (*Ictiobus cyprinellus*)	7	3	5	1	1	17
Black Crappie (*Pomoxis nigromaculatus*)	1	1				2
Bluegill (*Lepomis macrochirus*)	16	11	12	5	6	50
Channel Catfish (*Ictalurus punctatus*)	14	10	24	16	14	78
Common Carp (*Cyprinus carpio*)	4	2	4	1	2	13
Flathead Catfish (*Pylodictis olivaris*)					1	1
Freshwater Drum (*Aplodinotus grunniens*)	4	4	24	10	5	47
Gizzard Shad (*Dorosoma cepedianum*)	20	20	1	2	10	53
Golden Redhorse (*Moxostoma erythrurum*)		1		1	2	4
Green Sunfish (*Lepomis cyanellus*)	13	4	1			18
Highfin Carpsucker (*Carpiodes velifer*)				1		1
Hybrid Striped Bass (*Morone saxatilis x M. chrysops*)		6		1		7
Largemouth Bass (*Micropterus salmoides*)	7	4		2		13
Longear sunfish (*Lepomis megalotis*)	2		2		5	9
Quillback (*Carpiodes cyprinus*)			1	1		2
River Carpsucker (*Carpiodes carpio*)	1	2	7	1	1	12
Shorthead Redhorse (*Moxostoma macrolepidotum*)		1	6	5		12
Shortnose Gar (*Lepisosteus platostomus*)			3	2	1	6
Silver Carp			1			1

(*Hypophthalmichthys molitrix*)						
Smallmouth Buffalo (*Ictiobus bubalus*)	4	8	18	5	3	38
Walleye (*Sander vitreus*)		2	1	1		4
White Crappie (*Pomoxis annularis*)	2					2

Site	CPUE (Fish/hr) All Fishes	Sportfishes	Channel Catfish
S3	282.64	163.64	41.65
S5	237.00	114.00	30.00
S7	292.25	106.27	63.76
S8	162.70	73.95	47.33
S11	150.86	76.91	41.41
Mean ± *S.E.*	225.09 ± 29.5	106.95 ± 16.3	44.83 ± 5.5

Table 5. Relative density as estimated by catch per unit of effort (CPUE) of all fishes, sportfishes, and channel catfish sampled with three-phase AC electrofishing on five sites on the Sangamon River during spring 2010.

Table 6. Mean relative weight of sportfish sampled from five sampling sites on the Sangamon River during spring 2011.

Species	n	Wr	*S.E.*
Black Crappie	2	89.1	5.93
Bluegill	43	84.6	2.12
Channel Catfish	78	84.7	1.00
Green Sunfish	16	85.0	2.33
Hybrid Striped Bass	7	82.6	2.84
Largemouth Bass	11	111.0	2.96
Walleye	4	88.9	7.06
White Crappie	2	81.1	12.6

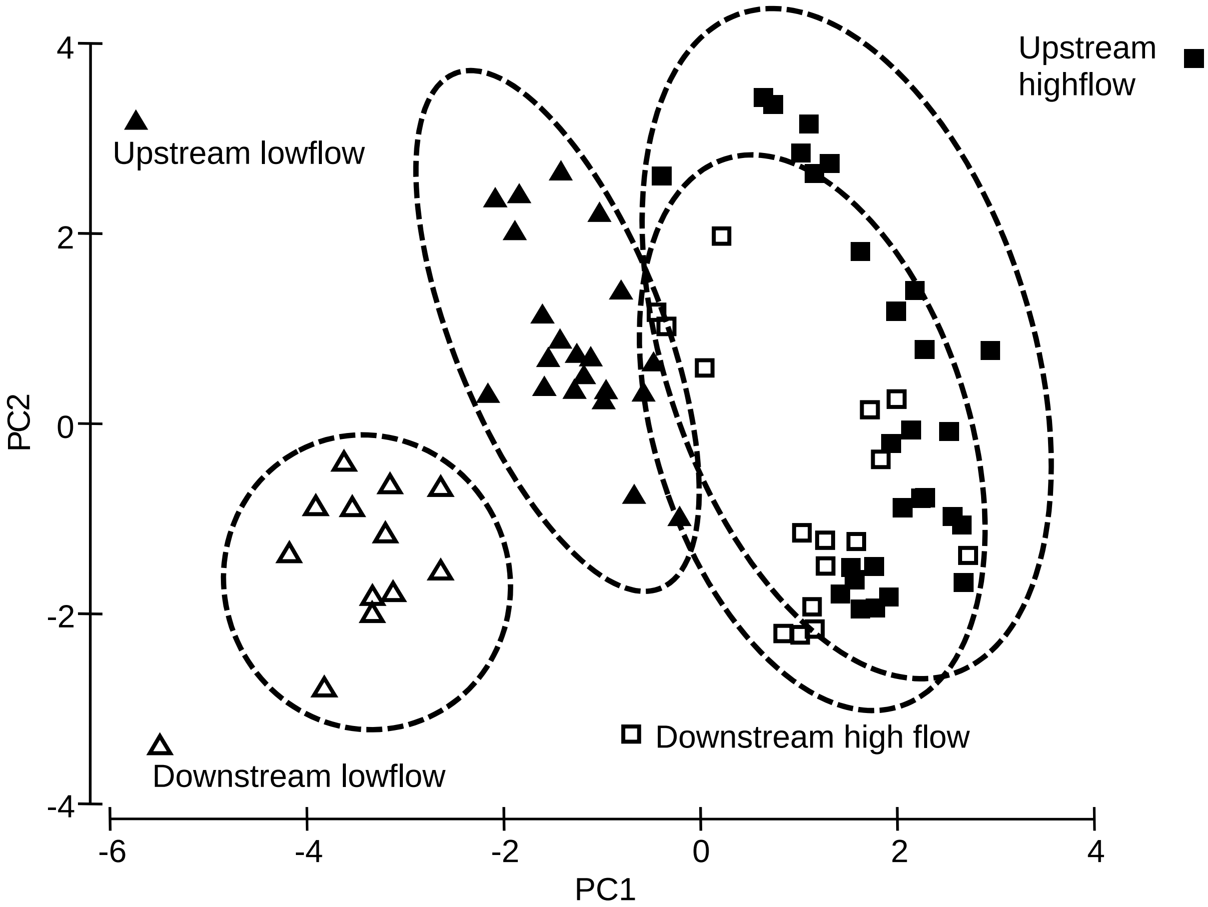

Figure 1. Principle components analysis of water quality data sampled during 2010 – 2011 from all mainstem sites of the Sangamon River.

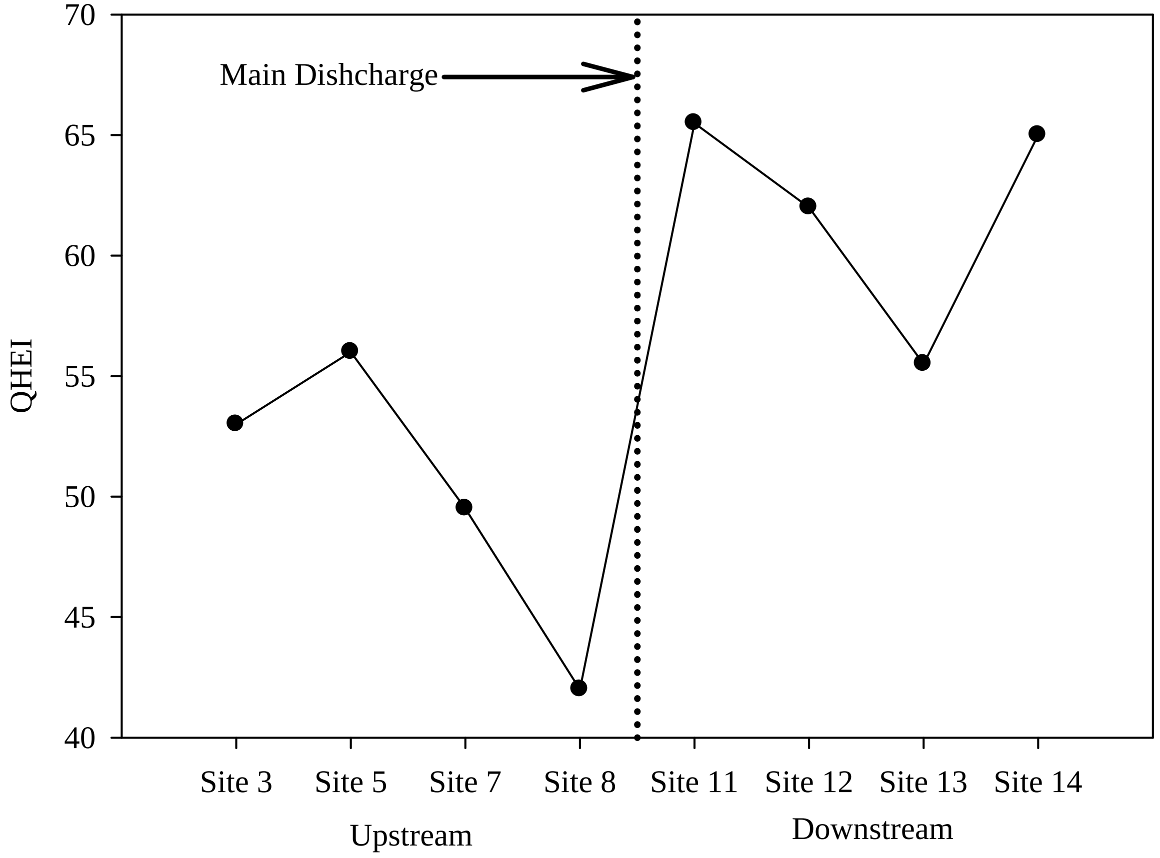

Figure 2. Qualitative habitat evaluation index (QHEI) as a function of sampling site for eight sampling sites in the two treatment reaches (Upstream and Downstream) of the Sangamon River sampled during fall 2010

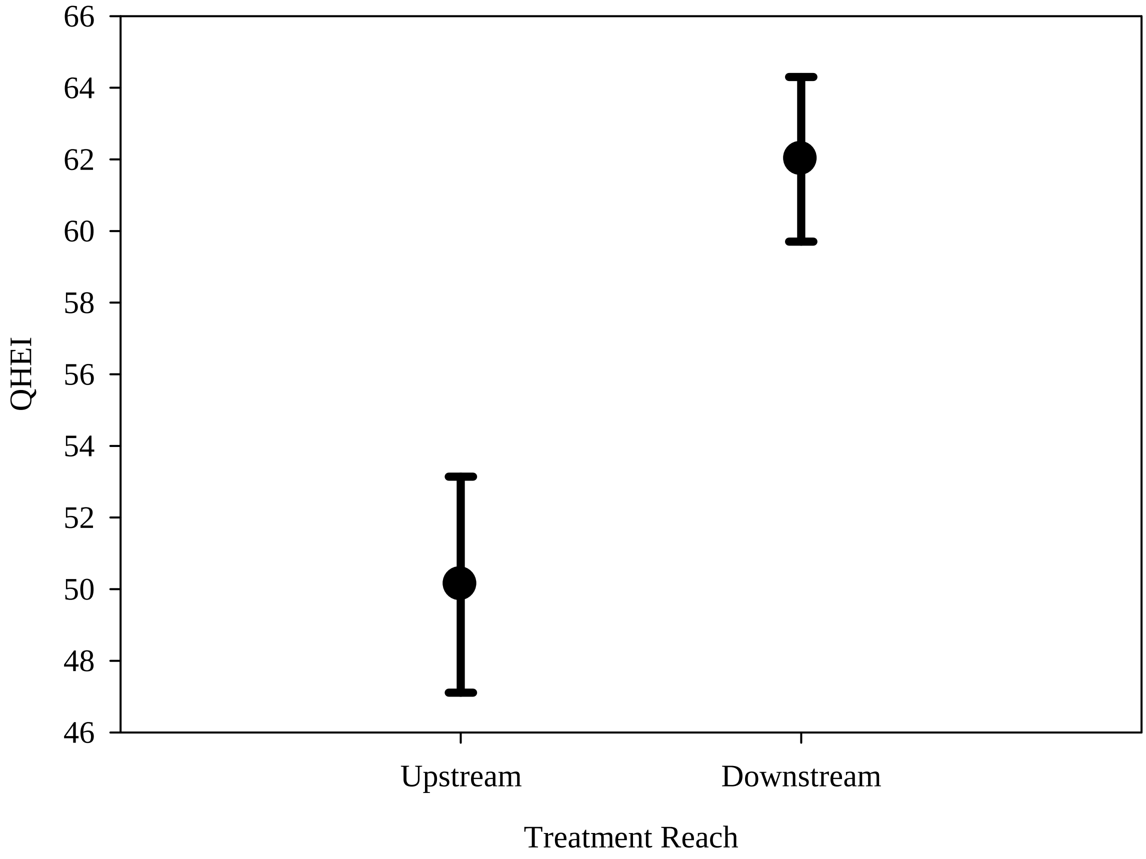

Figure 3. Average QHEI ± S.E. for the two different treatment reaches of the Sangamon River sampled during fall 2010. Habitat as estimated by QHEI was significantly higher in the reach below the effluent (Downstream) compared to the upstream reach ($p < 0.05$)

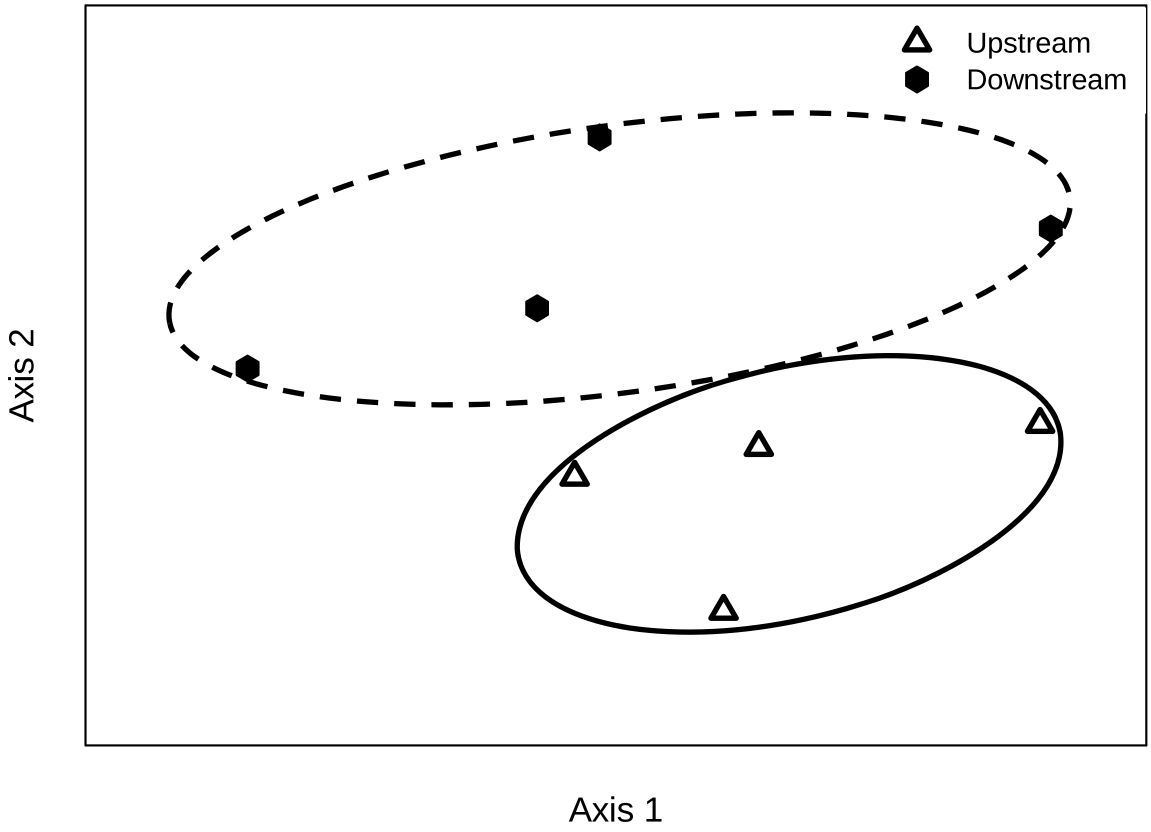

Figure 4. Multidimensional scaling plot based on Bray-Curtis similarity (2D stress = 0.08). The two different reaches were significantly different (ANOSIM, $p < 0.10$).

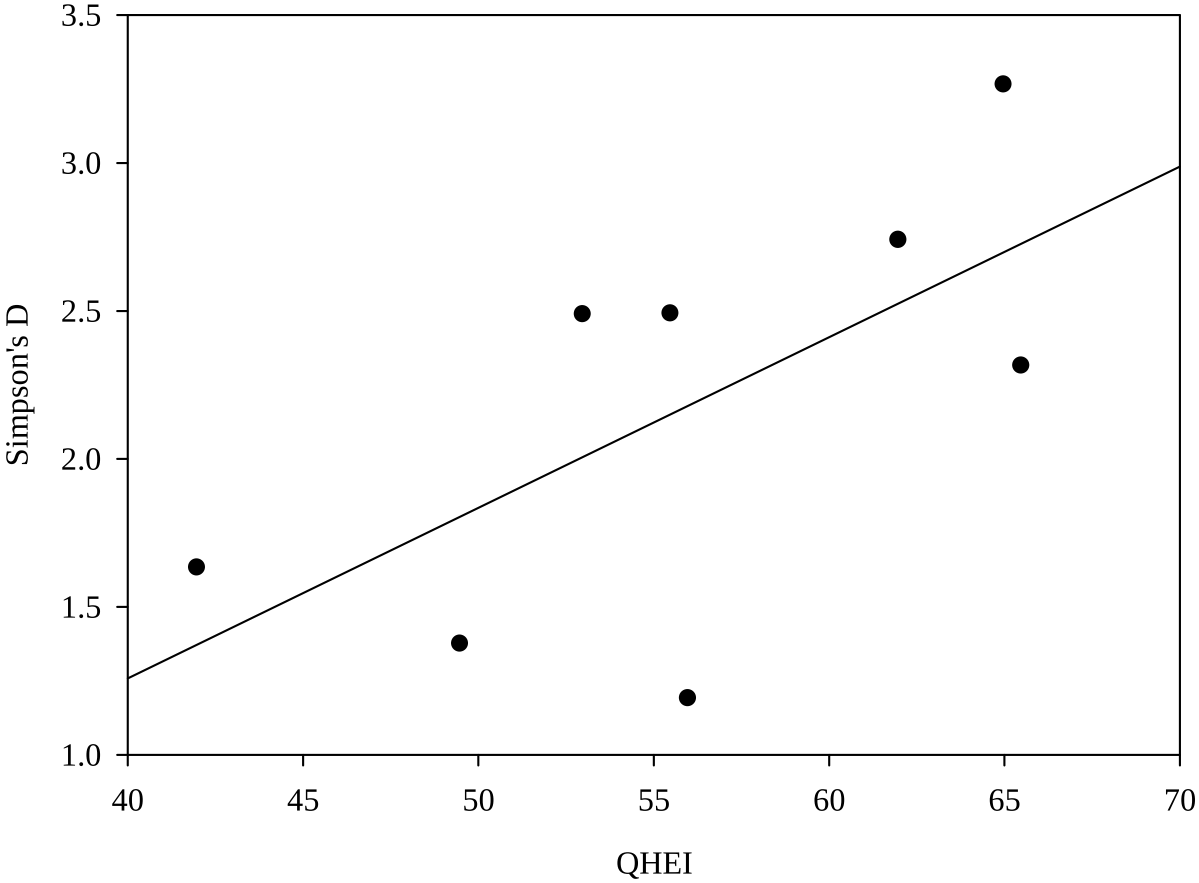

Figure 5. Regression showing a significant ($p < 0.10$) positive relationship between habitat quality as estimated by QHEI and macroinvertebrate species diversity as estimated by Simpson's D for eight sites on the Sangamon River. Simpson's D = -1.05 + 0.05 * QHEI; ($r^2 = 0.4169$).

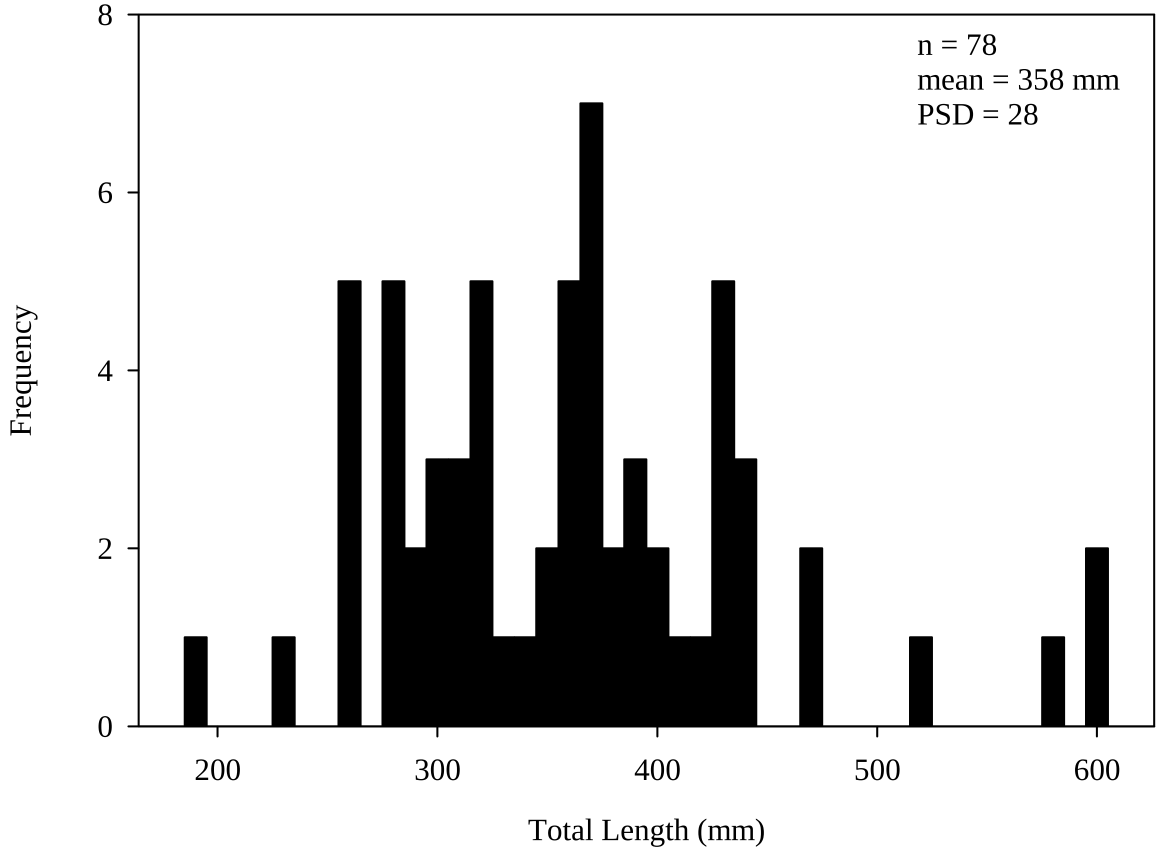

Figure 6. Length frequency histogram for channel catfish sampled from five sites on the Sangamon River during spring 2011.

APPENDIX 1
SANGAMON RIVER SITES

Sangamon River Sampling sites (Site # based on previously completed studies)

Site 1 – Lincoln Park CSO – above outfall
Site 3 – Lincoln Park CSO – below outfall
Site 4 – Oakland CSO (Lincoln Park) - above outfall
Site 5 – Oakland CSO (Lincoln Park) – below outfall
Site 6 – 7th Ward CSO (End Sunset Dr.) – above outfall
Site 7 – 7th Ward CSO (End Sunset Dr.) - below outfall
Site 8 – Main Treatment Plant (Off Main street) – upstream of main outfall
Site 9 – Main Treatment Plant (Off Main street) –down stream of main outfall
Site 10 – Sangamon River at mouth of Stevens Creek
Site 12 – Bridge on Wyckles Road
Site 13 – Bridge at Route 51
Site 14 – Lincoln Trail Homestead State Park

Routine collections for water quality assessment will be conducted at all sites.

Assessment by QHEI as well as intensive sampling for fish, macroinvertebrate, mussel, and benthic diatoms will be conducted at Sites 3, 5, 7, 8, 11, 12, 13, and 14.

Exhibit 39

Exhibit 39

Biotic assessment of water quality in a reach of the Sangamon River receiving effluent from the Sanitary District of Decatur

REPORT - 2010

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Introduction

Impoundment of rivers to create reservoirs used for irrigation purposes, as urban water supplies, and recreation is commonplace. However, impoundments may impact downstream aquatic systems and their surrounding terrestrial habitats. Diminished water quality and availability, closures of fisheries, extirpation of species, groundwater depletion, and pronounced hydrologic variability are increasingly distinguished as consequences of current river management associated with impoundments (Abramovitz 1996, Collier *et al.* 1996, Naiman *et al.* 1995). Specifically, dams affect riverine systems by altering flow regime, changing nutrient and sediment loads, and modifying energy flow (Ligon *et al.* 1995). As a result, river reaches downstream from a dam may no longer support intolerant native species, reflected by a reduction in the integrity of biotic communities. (Naiman *et al.* 1995, NRC 1992).

A natural flow regime is critical for sustaining ecosystem integrity and native biodiversity in rivers (Poff *et al.* 1997). Dams can have varying effects on downstream aquatic habitats depending on the purpose for which the dam was built. Impoundments used for urban water supplies reduce flow rates below dams throughout the entire year, but increase daily and seasonal variability in flow regime (Finlayson *et al.* 1994, McMahon and Finlayson 2003). Due to the flow regime, abiotic variables including temperature, dissolved oxygen, turbidity, pH, conductivity and solids concentrations are altered in the downstream river system (e.g., (Finlayson *et al.* 1994).

Along with stream impoundments, point source and non-point source inputs of particulate and dissolved substances can have profound effects on the ecological integrity of riverine systems. Water chemistry is often directly impacted by human disturbance, such as nutrient enrichment resulting from agriculture and wastewater treatment plants (McCormick and O'Dell 1996, Pan *et al.* 1996). Non-point sources of pollution may include agriculture, livestock grazing, and urbanization while sanitary discharge and industrial waste are examples of point source pollution. To reduce point source pollution, the Water Quality Act of 1972 encouraged wastewater treatment plants to upgrade their systems and, as a result, many communities were forced to build advanced tertiary water treatment facilities (Karr *et al.* 1985). Yet these treatment facilities still export high concentrations of nutrients into rivers. Carpenter and Waite (2000) documented that concentrations of phosphorus were highest in streams draining agricultural basins and at sites influenced by wastewater discharges, while Twichell *et al.* (2002) reported that sewage effluent inputs had elevated nitrate levels. These enhanced nutrient inputs can be expected to increase productivity within a river because primary productivity and detrital processing usually are limited by low ambient stream nutrient concentrations (Stockner and Shortreed 1978, Elwood *et al.* 1981, Winterbourn 1990).

Distribution and abundance of individual species and the composition of aquatic communities in lotic systems largely are governed by geographically related physiochemical variables. Desirable physical habitat (e.g., flow, current velocity, bottom substrate composition, cover, etc.) and suitable chemical water quality must exist to meet specific requirements of individual species. While the physical and chemical characteristics of a stream are set by local conditions, human activities alter these components. Routine monitoring of river conditions traditionally incorporates chemical as well as biological analyses. Chemical analyses are essential to ensure that levels of nutrients, metals, pesticides, etc. are kept below recommended levels, whereas biocriteria are necessary to evaluate overall effects of the chemical input on organisms (Round 1991).

Passage of the Clean Water Act of 1977 (PL 95-217) and more recently, the Water Quality Act of 1987 (PL 100-4) has emphasized protection and assessment of biotic integrity in aquatic environments. Assessment of biotic integrity using fish has received increased emphasis in recent years (Stauffer *et al.* 1976, Hocutt 1981, Karr 1981, Karr *et al.* 1986). And the Illinois Environmental Protection Agency has emphasized use of fish communities as an indicator of stream quality for assessments required by Section 305(b) of the Clean Water Act and as the primary biotic metric of the Illinois EPA/IDNR Interagency Biological Stream Characterization (BSC) process (Hite and Bertrand 1989). Water quality conditions that significantly affect lower levels of the food web also may alter the abundance, species composition, and condition of the fish community. Because fish occupy upper trophic levels, they are affected directly and indirectly by physical and chemical changes in the environment. Condition of a fishery is the index of water quality most meaningful to the general public (Weber 1973).

Benthic macroinvertebrates may be better suited for biomonitoring because they are sensitive and respond quickly to reduced water quality and their use in evaluating aquatic habitat is well established (Cairns and Dickson 1971, Barbour *et al.* 1999). Each macroinvertebrate species is dependent on specific ranges of environmental conditions (e.g., water quality, habitat, flow) throughout its lifespan. Unlike fish they are sessile, and upon collection, macroinvertebrates can be assumed to have integrated information regarding environmental conditions over the preceding weeks and months. This makes the macroinvertebrate community especially useful under conditions of mild or intermittent perturbation when altered water quality is not readily detectable by conventional chemical surveys (Chutter 1972). Good water quality typically supports a diverse community containing largely intolerant taxa, while various types of pollution may increase density of tolerant species and reduce species richness (Keup *et al.* 1967).

Benthic algae are important to riverine ecology when considering their role as primary producers and transformers of inorganic nutrients into organic forms that are ready to be used by other organisms (Lamberti 1996, Mulholland 1996). Algae also stabilize substrate and create mats that may form habitat for fish and invertebrates (Bott 1996). Along with fish and macroinvertebrates, benthic diatoms have been used for biological assessment of rivers (Growns 1999) and may represent an extremely useful taxonomic group for studying ecosystem perturbation. Although often neglected in monitoring programs due to the lack of available taxonomic expertise in many agencies, diatoms are easily identified due to the unique ornamentation of their frustules (Round 1993). Diatom assemblages are useful for evaluating different forms of pollution, such as organic enrichment downstream of sewage discharges (Cox 1991), and they respond quickly to environmental change due to their relatively short life cycles. Many studies have related changes in diatom assemblages to altered water chemistry, specifically phosphorus, nitrogen, and pH (Carrick *et al.* 1988, Pan *et al.* 1996, Winter and Duthie 2000). Diatom communities vary with substratum type (Leland 1995) and overall habitat heterogeneity (Robinson *et al.* 1994). Diatom community structure likely varies according to reach scale morphological features that coincide with land use and geologic variation among basins (Kutka and Richards 1996). That said, sampling of benthic algae in streams may be more difficult than sampling of macroinvertebrates and fish.

Physical habitat (e.g., flow regime, bottom substrate composition, instream cover, etc.) and chemical water quality must be suitable for support of individual species in lotic systems and maintenance of the integrity of aquatic communities. Since 2001, we have studied these relationships in the a stream influenced by impoundment as well as point source discharges - the Sangamon River. The Sangamon River Basin is a 14,000 km^2 watershed covering all or portions of eighteen counties in central Illinois. More than 3540 km of streams within the basin course through glacial and alluvial deposits creating typically low gradient stream with sand and gravel substrates. Streams within the basin have been impacted for most of the past century, receiving inputs from both point and non-point sources. Current land use is over 80% agricultural of which 85% is corn or soybeans. The great expanses of prairie that once existed in Illinois have been reduced to isolated hill and sand prairies coupled with remnants along highway and railroad right-of-ways and native deciduous woodlands now are limited to stream riparian areas. Major metropolitan areas associated with the Sangamon River basin are Bloomington, Decatur, and Springfield representing a combined population of more than 500,000 residents. Impoundments associated with urbanization include Lake Taylorville, Lake Sangchris, and Lake Springfield on the South Fork of the Sangamon; Clinton Lake on Salt Creek; as well as Lake Decatur.

Considerable development and habitat alteration within the watershed may impact biotic integrity of the Sangamon River system. In 2001, an intensive sampling program was initiated to document temporal and spatial heterogeneity of an 8.5 km reach of the Sangamon River beginning just below the Lake Decatur Dam and extending downstream to incorporate discharges from the Sanitary District of Decatur (SDD). The 8.5 km urban reach can be divided into two reaches that have received profoundly different inputs. The upstream reach extends upstream from the SDD to the dam that impounds Lake Decatur and is influenced mainly by reservoir discharge, while downstream sites, occur downstream of the SDD and receive treated sanitary effluent from the Sanitary District of Decatur.

Sampling Sites

We utilize sampling locations associated with operation of SDD that were easily identified by prominent landmarks within the City of Decatur, Illinois, USA and have logged GPS coordinates for those sites (Table 1). Sites were established initially in 1998 during an assessment of potential impacts of discharges from combined sewage overflow (CSO) facilities as well as the main treatment plant. All sites were located in the mainstem of the Sangamon River extending from just downstream of the dam, which impounds Lake Decatur to a site located near the Lincoln Trail Homestead Park. Sites 1, 3, 4, 5, 6, 7, and 8 are within the upstream reach extending from the dam to the discharge of the main treatment plant, and Sites 9, 11, 12 and 14 are located in the downstream reach which extends from the SDD main treatment plant discharge.

Table 1. List of the 11 sites utilized by the Department of Biological Sciences for studies conducted on reaches of the Sangamon River associated with the Sanitary District of Decatur.

Site #1 - Lincoln Park - above CSO outfall
Site #3 - Lincoln Park - below CSO outfall
Site #4 - Oakland (Lincoln Park Drive) - above CSO outfall
Site #5 - Oakland (Lincoln Park Drive) - below CSO outfall
Site #6 - 7th Ward - upstream of CSO outfall
Site #7 - 7th Ward - downstream of CSO outfall
Site #8 - SDD Main Treatment Plant - upstream of main outfall
Site #9 - SDD Main treatment Plant - downstream of main outfall
Site #11 - Sangamon River - downstream of Stevens Creek
Site #12 - Sangamon River at Wyckles Road
Site # 14 - Sangamon Rivernear the Lincoln Trail Homestead State Park, 1km north of the intersection of CR 600E and CR 800N

Physical Habitat Assessment

The Stream Habitat Assessment Procedure (SHAP), which evaluates lotic habitat quality using features considered important to biotic integrity, was performed by us in early project years. At each stream site, two individuals independently assigned metrics related to substrate and instream cover, channel morphology and hydrology, and riparian and bank features to one of four habitat quality types using guidelines established by the Illinois Environmental Protection Agency (1994). The mean total score of the 15 metrics (Table 2) forms the basis of an overall habitat quality rating for the stream reach under consideration. Habitat quality of the **upstream** and **downstream** reaches were categorized on the basis of its SHAP score as follows: <59 = Very Poor; 59 - 100 = Fair; 100 - 142 = Good; > 142 = Excellent. Average SHAP scores for **upstream** and **downstream** sites were 82 and 93, respectively (Table 3). Nonetheless, physical habitat structure based on SHAP still results in classification of all mainstem sites as "fair" quality stream reaches indicating that the physical structure of the stream is homogeneous.

This overall physical structure provides a backdrop for the ability of the study reach to support a diverse flora and fauna. Routine assessment of characteristic water quality variables superimposed on substrate characteristics, channel morphology and bank features can aid in understanding the functioning of stream systems. Given that organisms exist within often-narrow ranges of tolerance for certain physical and chemical characteristics of their environment, analysis of these variables is imperative for understanding the potential for anthropogenic impacts to decrease biotic integrity of natural systems. As a result, we incorporated routine analyses of various physical and chemical features of the Sangamon River sites studied during 2002, which based on principal components analysis, revealed significant differences between the upstream and downstream reaches. Monitoring of relevant variables has continued through 2009.

Field data collection and water chemistry determination

Methods

Water quality data were collected every two to four weeks from April 2009 to April 2010. Sampling was initiated at the Lake Decatur dam and proceeded downstream. While in the field, additional abiotic variables (dissolved oxygen, pH, conductivity, and temperature were determined) using Eureka Amphibian and Manta multiprove. Surface water samples were collected at 0.3 m below the surface and returned to the laboratory on ice and analyzed within generally accepted time limits. All sampling and analyses were conducted according to Standard Methods for Examination of Water and Wastewater (APHA, 1995).

In the laboratory, suspended and total solids determinations were made by drying residue collected on standard glass fiber filters as well as unfiltered samples placed into tared porcelain crucibles at 103-105 °C. Total dissolved solids were calculated by difference. Total phosphorus (following persulfate digestion) and soluble reactive phosphorus (utilizing filtered, undigested, sample aliquots) were determined using the ascorbic acid method. The phenate method was used for determination of ammonia nitrogen, and total oxidized nitrogen (NO_2-N + NO_3-N) was

Table 2. Parameters and values for the Stream Habitat Assessment Procedure (SHAP).

METRIC	Excellent	Good	Fair	Poor
Substrate and Instream Cover				
Bottom Substrate	16-20	11-15	6-10	1-5
Deposition	10-12	7-9	4-6	1-3
Substrate Stability	13-16	9-12	5-8	1-4
Instream Cover	10-12	7-9	4-6	1-3
Pool Substrate	16-20	11-15	6-10	1-5
Channel Morphology and Hydrology				
Pool Quality	13-16	9-12	5-8	1-4
Pool Variability	13-16	9-12	5-8	1-4
Channel Alteration	7-8	5-6	3-4	1-2
Channel Sinuosity	10-12	7-9	4-6	1-3
Width/Depth Ratio	13-16	9-12	5-8	1-4
Hydrologic Diversity	10-12	7-9	4-6	1-3
Riparian and Bank Features				
Canopy Cover	10-12	7-9	4-6	1-3
Bank Vegetation	13-16	9-12	5-8	1-4
Immediate Land Use	7-8	5-6	3-4	1-2
Flow-Related Refugia	10-12	7-9	4-6	1-3

Table 3. The habitat parameters scores and the overall SHAP score for the 12 sites sampled in the Sangamon River Basin.

Habitat Parameters	Site #1	Site #2	Site #3	Site #4	Site #5	Site #6	Site #7	Site #8	Site #9	Site #10	Site #11	Site #12
Bottom Substrate	11	4	11	6	6	15	11	11	9	16	13	11
Deposition	7	3	9	10	10	10	10	7	10	9	8	7
Substrate Stability	5	4	5	5	5	5	5	6	6	12	9	8
Instream Cover	4	1	5	9	6	4	4	7	4	7	6	7
Pool Substrate	6	1	6	6	6	6	6	6	6	12	6	6
Pool Quality	4	0	4	4	4	5	5	5	5	8	4	4
Pool Variablity	4	1	4	4	4	4	4	4	4	9	4	4
Canopy Cover	4	4	7	9	9	4	4	6	6	11	7	9
Bank Vegetation	4	1	4	4	4	4	4	2	2	9	4	4
Top of Bank Land Use	4	4	5	6	6	6	4	6	6	4	7	7
Flow-Related Refugia	6	1	6	4	6	4	4	5	5	8	5	5
Channel Alteration	3	1	5	6	6	6	6	7	7	7	6	6
Channel Sinuosity	4	1	5	4	4	3	3	6	6	7	4	5
Width/Depth Ratio	8	10	6	5	5	5	5	5	5	11	5	5
Hydrologic Diversity	4	1	5	5	5	5	4	5	5	9	5	4
Total SHAP Score	**78**	**36**	**87**	**87**	**86**	**86**	**79**	**88**	**86**	**129**	**93**	**92**

determined via the cadmium reduction method. Colorimetry of all nutrient analyses was determined using a Beckman DU 530 Life Science UV/Vis Spectrophotometer. Hardness and alkalinity were measured by titration to colorimetric endpoint methods. For all chemical analyses, due consideration was given to quality control and quality assurance procedures, including but not limited to parallel analyses of laboratory standards.

Results

Levels of 13 separate water quality variables were determined for eleven mainstem sites in 2009 – 2010 (Table 4). The trend established in prior sampling years continued throughout this recent sampling period, with levels for each of the variables being generally higher in DOWNSTREAM locations. Most notably, higher concentrations of forms of phosphorus and nitrogen were observed along with a general trend of elevated conductivity, presumably resulting from discharge from the main treatment plant of the Sanitary District of Decatur. Water chemistry continued to be relatively homogeneous over the entire study reach during periods of high discharge from the dam which impounds Lake Decatur.

Benthic algal (diatom) samples

Methods and Results

Artificial substrates were deployed at 11 sites in the main channel of the Sangamon River 9 June 2009. Substrates were 1 x 3 inch clean glass microscope slides suspended at the surface of the stream in commercially available periphytometers (Wildco, Inc.). Difficulties with thie sampling protocol were similar to those in the 2008 sampling season, as substrates were lost at all sites due either to natural occurrence (i.e., high discharge events) or due to vandalism. As such, further analysis of diatom assemblages was not pursued. Given the inherent difficulties of deployment of artificial substrates for collection of benthic algae, future efforts will focus on collection of materials from naturally occurring substrates.

Macroinvertebrates

Methods and Results

As in past years, we attempted to collect macroinvertebrate samples using modified multiplate samplers (Hester and Dendy 1962). Substrates were placed on the stream bottom for periods of six weeks, beginning 9 June 2009 to allow colonization. All samplers were lost or displaced, likely due to high stream discharge (although vandalism remains as a potential source of disruption). Samplers were not redeployed, as water levels remained routinely high throughout much of the 2009 summer period. Loss of samplers precluded analysis of macroinvertebrates.

Relatively greater success had been realized in previous years, and data from 2001 – 2008 are informative. Upon collection and after sorting, macroinvertebrates were identified to the lowest

Table 4. Levels of water quality variables for 11 mainstem sites in the Sangamon River associated with the SDD.

Date	Site	D.O. ppm	Temp. °C	pH	Cond µmho	Hardness ppm	total Alkalinity ppm	TON ppm	NH4 ppm	TP ppm	SRP ppm	TSS ppm	TS ppm	TDS ppm
04.28.09	1	10.6	17.3	8.4	572	306	307	3.94	0.06	0.13	0.02	22.7	398.7	376.0
05.28.09	1	8.2	21.1	7.8	469	257	237	3.28	0.07	0.26	0.14	29.2	301.3	272.1
06.09.09	1	9.4	22.6	9.5	563	301	265	5.73	0.14	0.21	0.01	44.0	433.3	389.3
07.29.09	1	9.0	26.0	9.7	525	308	328	5.84	0.05	1.90	1.80	44.0	710.7	666.7
08.11.09	1	9.1	28.3	9.8	485	251	237	1.55	0.00	0.13	0.02	14.0	321.3	307.3
09.29.09	1	12.4	17.6	9.1	692	314	314	0.11	0.05	0.23	0.09	13.5	385.3	371.8
10.20.09	1	11.9	13.5	9.6	488	242	251	0.55	0.02	0.21	0.14	20.5	320.0	299.5
11.10.09	1	12.3	11.6	7.7	404	295	254	3.04	0.05	0.22	0.18	35.0	308.0	273.0
1.26.10	1					277	272	2.97	0.13	0.18	0.10	24.0	90.7	66.7
2.27.10	1	17.6	1.0	0.0	7.78	208	230	2.64	0.45	0.42	0.41	19.0	260.0	188.5
3.31.10	1	17.2	10.9	8.8	529	252	293	5.24	0.00	0.15	0.06	27.5	418.7	319.2
4.28.10	1	10.5	16.7	9.0	431			1.65	0.41	0.08	0.01			
04.28.09	3	10.1	17.3	8.4	573	306	279	3.86	0.13	0.13	0.03	23.7	412.0	388.3
05.28.09	3	8.4	20.9	8.4	471	240	223	3.21	0.05	0.25	0.14	31.2	306.7	275.5
06.09.09	3	9.7	22.6	9.5	565	277	286	6.64	0.14	0.22	0.00	47.3	434.7	387.3
07.29.09	3	8.6	26.0	9.7	526	279	251	3.75	0.09	0.14	0.02	21.2	376.0	354.8
08.11.09	3	8.8	29.0	9.7	488	236	223	1.36	0.00	0.09	0.01	13.2	336.0	322.8
09.29.09	3	7.3	17.1	9.1	742	346	328	0.43	0.01	0.20	0.07	12.0	440.0	428.0
10.20.09	3	10.6	13.6	9.6	537	263	251	0.68	0.00	0.21	0.11	21.5	354.7	333.2
11.10.09	3	11.6	11.6	7.8	404	255	216	2.78	0.05	0.30	0.18	38.0	301.3	263.3
1.26.10	3					256	279	2.80	0.12	0.18	0.10	25.5	97.3	71.8
2.27.10	3	15.8	0.9	8.0	460	215	230	0.40	0.56	0.51	0.39	14.8	269.3	254.5
3.31.10	3	14.6	10.9	8.7	529	263	293	5.15	0.01	0.14	0.06	25.5	418.7	393.2
4.28.10	3	10.4	16.7	9.1	432			1.99	0.33	0.13	0.00			

Table 4. (continued)

Date	Site	D.O. ppm	Temp. °C	pH	Cond µmho	Hardness ppm	total Alkalinity ppm	TON ppm	NH4 ppm	TP ppm	SRP ppm	TSS ppm	TS ppm	TDS ppm
04.28.09	4	10.4	17.3	8.4	573	322	279	3.94	0.05	0.15	0.04	22.4	421.3	398.9
05.28.09	4	8.1	19.7	7.8	501	248	230	0.31	0.06	0.13	0.29	19.5	367.5	348.0
06.09.09	4	9.0	22.7	9.6	566	295	272	7.23	0.14	0.16	0.00	45.3	429.3	384.0
07.29.09	4	9.2	26.3	9.7	527	259	335	3.04	0.01	0.18	0.03	28.5	317.3	288.8
08.11.09	4	12.1	27.9	9.7	503	275	265	1.46	0.05	0.13	0.01	27.2	345.3	318.1
09.29.09	4	7.3	15.9	9.0	707	342	342	0.41	0.01	0.12	0.07	12.0	394.7	382.7
10.20.09	4	15.2	13.2	9.5	550	277	265	0.78	0.07	0.14	0.11	16.0	368.0	352.0
11.10.09	4	11.9	11.6	7.9	405	224	244	3.89	0.05	0.21	0.16	42.0	286.7	244.7
1.26.10	4					263	279	3.77	0.11	0.14	0.10	26.5	96.0	69.5
2.27.10	4	15.0	1.0	8.1	462	259	237	3.05	0.52	0.45	0.42	20.4	260.0	239.6
3.31.10	4	14.5	11.0	8.6	529	256	279	5.15	0.01	0.14	0.05	27.1	418.7	391.6
4.28.10	4	10.2	16.8	9.1	431			1.39	0.36	0.05	0.01			
04.28.09	5	10.3	1.3	8.4	575	304	307	4.32	0.02	0.14	0.03	26.8	450.7	423.9
05.28.09	5	8.3	20.1	7.8	516	255	237	2.15	0.15	0.28	0.09	107.7	392.0	284.3
06.09.09	5	9.0	22.7	9.6	566	283	265	6.29	0.14	0.20	0.01	48.7	449.3	400.7
07.29.09	5	9.2	26.3	9.7	526	291	216	2.69	0.08	0.16	0.03	25.0	1441.3	1416.3
08.11.09	5	9.5	28.3	9.7	504	220	251	1.54	0.00	1.11	0.01	16.8	353.3	336.5
09.29.09	5	7.4	16.3	9.0	712	342	356	0.44	0.00	0.17	0.07	9.3	405.3	396.0
10.20.09	5	15.3	13.1	9.5	542	271	265	0.72	0.18	0.23	0.11	17.0	360.0	343.0
11.10.09	5	11.1	11.6	7.8	406	224	244	3.51	0.05	0.24	0.18	44.0	314.7	270.7
1.26.10	5					270	279	1.23	0.16	0.20	0.11	4.5	28.5	24.0
2.27.10	5	14.8	1.0	8.2	465	215	216	0.91	0.58	0.46	0.40	22.4	330.7	308.3
3.31.10	5	14.5	10.9	8.6	532	270	286	5.34	0.03	0.14	0.05	25.5	422.7	397.2
4.28.10	5	10.3	16.8	9.1	432			1.65	0.36	0.11	0.01			

Table 4. (continued)

Date	Site	D.O. ppm	Temp. °C	pH	Cond µmho	Hardness ppm	total Alkalinity ppm	TON ppm	NH4 ppm	TP ppm	SRP ppm	TSS ppm	TS ppm	TDS ppm
04.28.09	6	10.3	17.2	8.3	575	301	279	4.32	0.07	0.15	0.03	28.4	452.0	423.6
05.28.09	6	8.1	20.6	7.8	493	248	230	2.71	0.10	0.25	0.11	51.3	342.7	291.3
06.09.09	6	10.2	22.7	9.6	568	271	321	6.43	0.14	0.21	0.01	43.3	442.7	399.3
07.29.09	6	9.0	26.2	9.6	529	279	258	4.67	0.03	0.15	0.02	25.6	377.3	351.7
08.11.09	6	11.3	28.3	9.7	522	244	251	1.15	0.05	0.08	0.01	12.0	358.7	346.7
09.29.09	6	11.7	18.0	8.8	794	350	370	0.20	0.03	0.14	0.02	7.7	450.7	443.0
10.20.09	6	14.5	13.3	9.5	504	234	265	0.70	0.00	0.24	0.12	18.5	325.3	306.8
11.10.09	6	11.2	1.6	7.8	406	204	244	3.37	0.05	0.31	0.17	43.3	297.3	254.0
1.26.10	6					270	272	3.77	1.74	0.17	0.09	31.5	104.0	72.5
2.27.10	6	14.9	1.0	8.1	464	245	230	1.73	0.53	0.51	0.40	20.8	289.3	268.5
3.31.10	6	13.5	11.0	8.7	529	248	286	5.34	0.02	0.13	0.05	27.0	422.7	395.7
4.28.10	6	10.1	16.8	9.2	432			1.69	0.35	0.13	0.00			
04.28.09	7	10.2	17.2	8.4	575	316	293	4.09	0.08	0.15	0.03	30.0	477.3	447.3
05.28.09	7	9.4	20.1	8.2	451	234	209	2.57	0.08	0.16	0.04	23.4	314.7	291.2
06.09.09	7	8.8	22.7	9.9	566	287	279	6.67	0.13	0.21	0.02	48.0	460.0	412.0
07.29.09	7	17.9	26.1	9.6	532	267	251	3.57	0.04	0.16	0.01	25.5	389.3	363.8
08.11.09	7	10.1	28.6	9.8	489	232	251	1.68	0.00	0.11	0.03	30.8	353.3	322.5
09.29.09	7	9.9	16.4	9.1	702	295	363	0.03	0.03	0.17	0.00	30.5	422.7	392.2
10.20.09	7	8.9	13.3	9.3	418	230	230	0.72	0.03	0.13	0.05	18.5	325.3	306.8
11.10.09	7	10.9	11.6	7.8	411	224	258	3.48	0.05	0.29	0.15	38.0	312.0	274.0
1.26.10	7					285	286	3.87	0.14	0.20	0.10	30.0	126.7	96.7
2.27.10	7	14.8	1.0	8.2	465	241	230	1.11	0.60	0.49	0.41	20.8	286.7	265.9
3.31.10	7	17.6	11.0	8.7	530	281	293	5.10	0.00	0.14	0.05	26.0	442.7	416.7
4.28.10	7	10.0	16.9	9.4	433			1.39	0.39	0.09	0.01			

Table 4. (continued)

Date	Site	D.O. ppm	Temp. °C	pH	Cond µmho	Hardness ppm	total Alkalinity ppm	TON ppm	NH4 ppm	TP ppm	SRP ppm	TSS ppm	TS ppm	TDS ppm
04.28.09	8	10.1	17.2	8.4	575	318	279	4.17	0.01	0.15	0.04	32.4	469.3	436.9
05.28.09	8	9.3	20.1	8.2	453	234	209	2.78	0.00	0.18	0.03	26.1	316.0	289.9
06.09.09	8	8.5	22.8	9.7	567	283	272	6.29	0.12	0.19	0.01	49.3	449.3	400.0
07.29.09	8	8.5	26.2	9.6	530	271	265	3.64	0.01	0.16	0.02	23.6	373.3	349.7
08.11.09	8	12.2	28.6	9.7	481	275	237	1.65	0.00	0.10	0.03	22.4	344.0	321.6
09.29.09	8	9.8	16.8	9.1	689	326	349	0.00	0.00	0.14	0.02	19.3	382.7	363.3
10.20.09	8	11.3	13.4	9.2	479	263	237	0.65	0.02	0.12	0.06	17.0	317.3	300.3
11.10.09	8	11.8	11.6	7.9	405	259	244	2.83	0.05	0.23	0.17	43.3	317.3	274.0
1.26.10	8					285	286	3.53	0.15	0.18	0.12	33.0	116.0	83.0
2.27.10	8	14.7	1.1	8.2	467	237	223	1.18	0.56	0.42	0.44	21.6	278.7	257.1
3.31.10	8	18.6	11.0	8.7	528	281	293	5.15	0.02	0.14	0.05	28.5	442.7	414.2
4.28.10	8	10.0	16.9	9.3	433			1.87	0.49	0.12	0.01			
04.28.09	9	10.0	17.2	8.4	578									
05.28.09	9	9.1	20.6	8.0	813	249	223	2.43	0.01	0.24	1.49	25.1	477.3	452.2
06.09.09	9	8.5	22.9	9.6	688	275	272	6.29	0.13	0.86	0.67	44.7	550.7	506.0
07.29.09	9	8.2	26.5	9.6	845	283	293	6.09	0.03	1.53	1.52	28.5	549.3	520.8
08.11.09	9	19.4	29.6	9.3	2048	299	363	8.42	0.13	2.60	2.98			
09.29.09	9	10.7	25.8	9.1	3509	381	489	25.41	0.02	2.79	2.59			
10.20.09	9	8.0	16.6	9.0	1254	238	265	5.73	0.13	1.66	1.93	18.0	813.3	795.3
11.10.09	9	11.0	12.1	7.8	508	196	251	4.16	0.05	0.65	0.72	44.7	376.0	331.3
1.26.10	9					314	265	3.20	0.17	0.40	0.32	31.0	77.3	46.3
2.27.10	9	14.7	1.2	8.1	495	252	237	3.59	0.57	0.77	0.69	22.0	364.0	342.0
3.31.10	9	13.3	11.1	8.6	723	285	286	5.78	0.01	0.76	0.64	28.0	473.3	453.3
4.28.10	9	9.9	17.0	9.3	492			1.69	0.59	0.65	0.50			

Table 4. (continued)

Date	Site	D.O. ppm	Temp. °C	pH	Cond µmho	Hardness ppm	total Alkalinity ppm	TON ppm	NH4 ppm	TP ppm	SRP ppm	TSS ppm	TS ppm	TDS ppm
04.28.09	11	9.9	17.2	8.3	610	310	293	3.79	0.08	0.64	0.47	27.6	522.7	495.1
05.28.09	11	9.1	20.5	8.0	761	259	223	3.07	0.06	0.43	1.15	24.0	489.3	537.4
06.09.09	11	8.4	22.9	9.6	760	318	272	7.47	0.12	1.21	1.11	44.0	598.7	554.7
07.29.09	11	6.4	26.6	9.5	953	281	293	6.16	0.01	1.45	1.69	30.0	598.7	568.7
08.11.09	11	8.7	29.4	9.3	1955									
09.29.09	11	10.1	24.8	9.1	3456	416	503	19.71	0.06	2.98	3.38			
10.20.09	11	8.3	16.5	9.0	1190	269	265	5.80	0.09	1.94	2.08	23.0	742.7	719.7
11.10.09	11	11.1	11.8	7.8	460	220	237	3.99	0.05	0.63	0.44	42.7	341.3	298.7
1.26.10	11					296	265	4.43	0.15	0.53	0.42	33.5	92.0	58.5
2.27.10	11	14.5	1.7	8.1	549	277	230	0.01	0.50	0.87	0.80	30.4	340.0	318.4
3.31.10	11	13.4	11.3	8.5	632	285	293	4.90	0.01	0.70	0.59	26.5	505.3	478.8
4.28.10	11	9.8	17.2	9.3	527			2.06	0.43	0.58	0.54			
04.28.09	12	9.3	16.4	8.1	598	291	293	5.00	0.33	0.65	0.43	81.5	557.3	475.8
05.28.09	12	8.6	19.9	7.9	729	261	251	3.28	0.00	0.27	1.22	37.3	508.0	470.7
06.09.09	12	8.2	21.6	8.2	699	291	265	6.18	0.11	0.73	0.58	50.7	549.3	498.7
07.29.09	12	8.1	26.0	8.3	1077	303	342	6.16	0.13	1.82	1.81	33.2	714.7	681.5
08.11.09	12	7.9	28.3	8.0	1738	310	307	3.03	0.02	2.25	2.90	30.0	1137.3	1107.3
09.29.09	12	5.7	20.4	7.8	3222	389	475				3.25	34.3	2089.3	2055.0
10.20.09	12	9.5	14.5	7.9	877	251	279	5.89	0.13	1.30	1.60	19.2	562.7	543.5
11.10.09	12	11.1	11.7	7.8	449	220	230	3.45	0.05	0.59	0.41	50.7	338.7	288.0
1.26.10	12					292	293	3.40	0.63	0.34	0.40	25.6	65.3	39.7
2.27.10	12													
3.31.10	12													
4.28.10	12													

Table 4. (continued)

Date	Site	D.O. ppm	Temp. °C	pH	Cond µmho	Hardness ppm	total Alkalinity ppm	TON ppm	NH4 ppm	TP ppm	SRP ppm	TSS ppm	TS ppm	TDS ppm
04.28.09	14	8.9	16.6	8.1	573	269	237	3.33	0.44	0.72	0.49	133.8	588.0	545.2
05.28.09	14	7.9	20.3	7.9	575	249	237	3.49	0.05	0.69	2.91	60.7	448.0	387.3
06.09.09	14	8.7	21.7	8.2	651	287	272	6.60	0.08	0.93	0.78	53.3	592.0	538.7
07.29.09	14	8.9	25.9	8.3	1067	308	328	5.84	0.05	1.90	1.80	44.0	710.7	666.7
08.11.09	14	9.4	27.6	8.4	1329	273	293	2.51	0.01	2.19	2.54	28.8	856.0	827.2
09.29.09	14	7.0	17.2	8.1	2894	373	489	18.55	0.03	2.65	3.12	17.3	1882.7	1865.3
10.20.09	14	10.7	12.8	8.2	712	229	251	3.00	0.05	1.19	1.19	22.5	468.0	445.5
11.10.09	14	10.6	12.2	7.9	522	207	251	4.10	0.05	0.88	0.69	110.0	424.0	314.0
1.26.10	14					343	279	3.77	0.18	0.32	0.30	60.7	156.0	95.3
2.27.10	14	14.2	1.9	8.8	531	285	258	0.61	0.45	0.69	0.59	30.4	349.3	318.9
3.31.10	14	14.9	11.5	8.3	593	259	286	5.34	0.01	0.47	0.34	38.5	490.7	452.7
4.28.10	14	9.7	16.9	9.3	535			1.17	0.42	0.64	0.51			

possible taxonomic level and data were used to calculate a Macroinvertebrate Biotic Index (MBI) according to Hilsenhoff (1982). In this method, each taxon is assigned a pollution tolerance value ranging from zero to eleven based on available literature and previous field experience. Based on present assessment methods, MBI values reflect water quality as follows (IEPA 1988): < 5.0 - Excellent; 5.0 - 6.0 - Very good; 6.1 - 7.5 - Good/Fair; 7.6 - 10.0 - Poor; > 10.0 - Very Poor. Macroinvertibrate Biotic Index scores for during this time frame indicate that the Sangamon River downstream of the SDD main discharge warrants a ranking of at least "very good" where as quality of the upstream reach is somewhat compromised (Table 5).

Fish

Methods

Fish were collected by hand seining on 17-18 September 2009, with attempts to standardize sampling effort at each site. Fish were identified to species, counted and returned to the stream alive when possible, although voucher specimens were preserved and retained. When field identifications were not practical, specimens were preserved in ten percent formalin and returned to the laboratory. Fish assemblage data were used to determine the community-based Index of Biotic Integrity (IBI), which uses twelve metrics in three categories to appraise fish communities (Karr et al., 1986). Values of 1, 3, and 5 are assigned for each metric, and the values for the individual metrics are then summed to generate a score from 12 to 60. Calculation of IBI values was performed using an interactive program written in Basic for use on an IBM-PC (Bickers et al., 1988). The utility of IBI scores is that they enable qualitative characterization of streams, as follows: 51-60 – excellent; comparable to best situations without human disturbance, 41-50.9 – good; good fishery for gamefish: species richness may be below expectations, 31-40.9 – fair; bullheads, sunfish, and carp predominate; diversity and intolerants reduced, 21-30.9 – poor; fish dominated by omnivores and tolerant forms; diversity notably reduced, <21 – very poor; few fish of any species present, no sport fishery exists.

A total of 2721 fish representing 20 unique species were collected at 11 sites during July 2003 (Table 6). As in previous years, the fish assemblage again was dominated by the family Cyprinidae (minnows and carp). Stream quality in the Sangamon River basin as evaluated by fish population samples and the Index of Biotic Integrity ranged from 28 (Site 4) to 36 (Sites 11 and 12). Overall mean IBIs for data pooled from 2001-2009 were 31.6 and 35.1 for the upstream and downstream reaches, respectively (Table 7) – values which are typical of a "fair" stream habitat.

Discussion

Overall, the Sangamon River extending from the dam, which impounds Lake Decatur to the Wyckles Road Bridge, can be considered a fair quality aquatic system with minimal habitat variety. Although there is significant variation in physical habitats upstream and downstream of the SDD, variability in SHAP ratings were primarily dependent upon such factors as substrate stability, pool variability and quality due to stream flow, and loss or reduction of riparian zone

Table 5. Mean MBI Scores for Sangamon River sites upstream and doenstream of the main discharge from the Sanitary District of Decatur Treatment Plant

Year	Upstream Reach	Downstream Reach
2001	7.3	5.9
2002	7.7	6.2
2003	7.1	5.6
2004	6.3	6.1
2005	6.8	5.7
2006	6.9	5.9
2007	6.8	5.9
2008	6.7	----
2009	----	----
overall mean	**7.0**	**5.9**

Table 6. Fish assemblage data and calculated IBI's for 11 mainstem sites in the Sangamon River associated with SDD.

Common Name	**Scientific Name**	**Site #1**	**Site #3**	**Site #4**	**Site #5**	**Site #6**	**Site #7**	**Site #8**	**Site #9**	**Site #11**	**Site #12**	**Site #14**
Mosquitofish	*Gambusia affinis*	37	0	6	0	0	129	7	5	2	7	0
Spotted bass	*Micropterus punctulatus*	1	0	0	0	0	0	1	4	1	4	0
Johnny darter	*Etheostoma nigrum*	2	0	0	1	0	0	1	0	0	0	0
Bluegill	*Lepomis macrochirus*	1	15	1	3	2	0	4	0	0	3	0
Bluntnose minnow	*Pimephales notatus*	44	81	13	47	4	6	131	0	8	0	0
Red shiner	*Cyprinella lutrensis*	396	4	53	19	6	232	3	22	467	9	249
Channel catfish	*Ictalurus punctatus*	0	0	0	0	0	6	0	1	0	0	0
Striped shiner	*Luxilus crysocephalus*	0	0	0	0	0	0	0	2	3	0	2
Sand shiner	*Notropis ludibundus*	64	0	8	10	1	25	0	18	253	20	3
Common shiner	*Luxilus cornutus*	0	0	0	0	102	0	0	3	0	47	1
Brook silverside	*Labidesthes sicculus*	36	1	13	39	0	0	0	0	0	1	0
Blackside darter	*Percina maculata*	0	1	0	0	0	0	0	0	0	0	0
Gizzard shad	*Dorosoma cepedianum*	1	0	0	1	0	6	0	0	0	0	0
Spotfin shiner	*Cyprinella spiloptera*	2	1	0	1	0	7	0	0	0	0	0
Smallmouth bass	*Micropterus dolomieu*	0	1	0	0	0	0	0	0	0	0	0
Creek chub	*Semotilus atromaculatus*	0	0	0	0	0	0	0	0	1	0	1
Freshwater drum	*Aplodinotus grunniens*	0	0	0	0	0	1	0	0	0	0	0
Golden redhorse	*Moxostoma erythrurum*	0	0	0	0	0	1	0	0	0	0	0
Suckermouth minnow	*Phenacobius mirabilis*	0	0	0	0	0	0	0	0	5	0	0
Longear sunfish	*Lepomis megalotis*	1	0	0	0	0	0	0	0	0	0	0
	Total	585	104	94	121	115	413	147	55	740	91	256
	Richness (# of taxa)	11	7	6	8	5	9	6	7	8	7	5
	IBI	32	30	28	32	33	34	34	37	36	36	34

mean UPSTREAM IBI = 31.86

mean DOWNSTREAM IBI = 35.75

Table 7. Meab IBI scores for Sangamon River sites upstream and downstream of the main dischsrge from the Sanitary District of Deactur Treatment Plant

Year	Upstream Reach	Downstream Reach
1998	29	33
2001	32	33
2002	30	34
2003	30	35
2004	30	31
2005	34	34
2006	34	40
2007	31	39
2008	34	36
2009	32	36
overall mean	**31.6**	**35.1**

vegetation that had occurred at each specific site. The primary difference between upstream and downstream reaches is attributable indirectly to metrics related to flow. The downstream reach receives continuous flow from SDD, whereas upstream flow varies greatly due to unpredictable reservoir discharges. Such alterations have lead to simplification of stream habitat with concomitant reduction in species diversity and biotic integrity and an overall decline in quality of the aquatic resource.

Based on physical habitat structure as measured by SHAP, the reaches of the Sangamon River, which we studied, are indistinguishable. Discharge from Lake Decatur is the primary input to the upstream reach, resulting in our observation of relatively higher variability in flow and nutrient concentrations in the upstream reach. Conversely, stable and predictable instream flows observed in the reach downstream of the SDD facilitate development of more diverse biotic communities as confirmed by work conducted in other riverine systems (Sanders 1969; Fisher 1983; Peckarsky 1983; Ward & Stanford 1983; Reice 1985; Ross *et al.* 1985; Walde 1986; Resh *et al.* 1988). Difference in the overall nature of the upstream and downstream reaches becomes less distinct during periods of high reservoir discharge.

We also believe that drastic reduction of instream flow resulting by routine elimination of reservoir discharge is detrimental to habitat quality in the upstream reach. Overall, we suggest that a threshold exists with respect to flow, i.e. periods when discharge is less than 400 cfs. When flow is below this threshold, the upstream and downstream reaches are discrete while they appear to behave as a continuum when discharge exceeds 400 cfs. This suggests that water quality is compromised in the reach of the Sangamon River extending downstream from the dam to the discharge of the main treatment plant of the Sanitary District of Decatur as a result of management to maintain reservoir levels by eliminating outflow. In contrast, effective management of Sangamon River may require maintenance of instream flow above the proposed threshold (400 cfs) by continuous discharge from Lake Decatur.

Sites downstream of SDD are characterized by lower pH, perhaps resulting from addition of CO_2 due to respiratory breakdown of organic matter in the wastewater treatment process. These sites may also have greater potential for instream primary productivity as a result of nutrient loading as indexed by higher levels of dissolved solids, conductivity, total alkalinity, oxidized nitrogen, and phosphorus. Elevated concentrations of suspended solids that occur in the upstream sites indicate that suspended organic material (including phytoplankton algae) derived from the reservoir may be supporting heterotrophs in the upstream reach. In contrast, downstream sites are maintained by autochthonous primary productivity that is supported by relatively higher concentrations of plant nutrients derived from the sanitary discharge. We conclude that SDD discharge may be facilitating a shift from a stream system that relies on allochthonous input of algae to one that relies on autochthonous instream primary productivity.

Qualitative evaluation of the two stream reaches requires assessment of stream biota to determine whether or not differences in the two stream reaches are reflected by higher trophic levels. Such an evaluation of overall stream habitat quality can be made via biotic indices involving macroinvertebrates and fish, taxa that have become widely used for biotic assessments. downstream sites are distinguished by significantly lower MBI scores and higher IBI values, indicative of improved habitat quality capable of supporting diverse biota and a variety of different trophic levels. Downstream sites associated with the main treatment plant outfall from the SDD may have increased integrity due to predictable instream flows and increased autochthonous primary production due in part to nutrient loading.

When comparing our observations made during the 2009 sampling period with data collected in 1992 (IEPA report), 1998 (Sanitary District of Decatur) and 2001-2008 (Sanitary District of Decatur) both IBI and MBI values for downstream sites associated with the main treatment plant outfall were generally similar or slightly improved compared to values obtained during all previous sampling periods. Thus the upgrades performed to the main plant in 1990 and the Lincoln CSO in 1992 by SDD have lead direct to improvement of the water quality of the Sangamon River which has been maintained over recent years. Additionally, there has been no reduction in the quality of the Sangamon River section located near the Sanitary District of Decatur in the last 20 years.

Future Direction

To better assess restoration efforts, biologists need a repeatable index to assess aquatic habitats. Instream habitat has been measure several different methods (SHAP, Habitat Suitability, Habitat diversity); however, these methods are often too expensive or overly simplistic. The Ohio EPA sought to resolve this with the development of the Qualitative Habitat Evaluation Index (QHEI). The index uses a group of six metrics (Substrate; Instream Cover; Channel Moprphology; Riparian Zone and Bank Erosion; Pool/Glide and Riffle/Run Quality; and Gradient) that are important in describing the fish and macroinvertebrate communities in wadable streams (Rankin 1989). One desirable aspect of the QHEI is that scores from the index correlate well with fish IBI. Additionally, the QHEI's ease of data collection and repeatability of the results have lead to the widespread adoption of index throughout the Midwestern United States. Recently, the Illinois Environmental Agency has adopted the use of the QHEI to assess instream physical attributes of all wadeable streams.

Results of the QHEI are a necessary prerequisite to utilization of a more robust sampling method for collection of macroinvertebrates. Based on QHEI scores, stream sites should be sampled for macroinvertebrates using the IEPA 20 jab method as described by the USEPA 2007). The results of these assessments could support a wider range of regulatory and non-regulatory activities in that they provide the basis for i) assessing and reporting aquatic life use support under Sections 303(d) and 305(b) of the Clean Water act, ii) for evaluating the impacts of nonpoint source pollution under section 319 of the Clean Water Act, and iii) for review of permit requirements under the National Pollution Discharge Elimination System.

Mollusks in general, and bivalves in particular, are very sensitive to a number of pollutants, especially heavy metals (Keller, 91) and ammonia (Augspurger et al, 2003). Mussels have proven to be much more sensitive to ammonia than are most fish, which has prompted the USEPA to propose new ammonia criteria based on whether or not mussels are present in a stream (federal register 2009). These guidelines are being reviewed, and it is unclear if these criteria will remain as developed or be modified. At this time the criteria are based solely on presence or absence, apparently without regard to mussel species diversity. Since different species may have variable ammonia sensitivities, it is in the interest of agencies to know the mussel assemblages in impacted waters to comply with proposed regulations, but also to assess the potential of using more species-specific standards. Incorporation of an assessment of mussel assemblages in the Sangamon River may be prudent, as individual species may or may not be impacted by elevated levels of ammonia. A survey of the Sangamon River Basin was conducted from 1987-89 (Schanzle and Cummings, 1991). They sampled from 57 sites within the entire river basin and collected live specimens from 33 different species. Only 2 of their sites were proximate and downstream from the treatment facility, and only 4 species were found in these sites. Because the current status of mussel populations in the study reach is unknown, this effort could be useful for establishing compliance with new ammonia criteria and determination as to whether SDD operations impact mussel populations.

Routine evaluation of fish assemblages by hand seining has proved to be the most consistent and reliable method for biotic assessment of the study reach, and should be continued. However, a large number of anglers exploit the Sangamon River near Decatur daily. Nonetheless, limited information can be determined regarding this resource based on seining. Efforts to assess the sport fish (e.g., sunfishes, catfish, walleye, and temperate basses) assemblages using boat electrofishing may prove useful. Evaluation of age structure, growth, and condition of all sport fishes sampled in the Sangamon River would permit comparisons with the sport fish assemblages from the Sangamon to other Midwestern River systems (i.e. Embarass) and extend our ability to evaluate potential impacts of SDD operations.

Finally, utility of benthic diatoms for biological monitoring was confirmed by our extensive analysis of communities, which developed on artificial substrates during 2002 and 2003 (Thomas 2004). However, as with macroinvertebrates, collection of samples using artificial substrates should to be reconsidered . Excessive loss of samplers due to extreme discharge events or vandalism compromises the utility of this methodology. Attempts should be made in the future to utilize collections from naturally occurring substrates.

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