ILLINOIS NATURAL HISTORY SURVEY
CENTER FOR AQUATIC ECOLOGY

PROGRESS REPORT

Evaluation of Modification of the Upper Batavia Dam on the Fox River, Illinois

H.R. Dodd, S.E. Butler, and D.H. Wahl

Submitted to
Office of Water Resources
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Submitted to
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August 2004

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INTRODUCTION

In the past, point source pollution has been a problem in the Fox River Watershed resulting in poor water quality, fish, and macroinvertebrate communities including mussel populations (Muench 1965; Brown et al. 1973; Bertrand et al. 1982; Sallee and Bergmann 1986; Day et al. 1992; IDNR 1998; Pescitelli, unpublished data). However, recent prevention of point source pollution in the Fox River has improved water quality resulting in partial recovery in the biota, yet there are currently 15 low-head dams located on the mainstem of the Fox River that likely limit further improvements in the biota. To continue improvement of the watershed, the Fox River Ecosystem Partnership (FREP) has identified dam removal or modification as an important management tool to improve water quality and habitat, thus, improving biotic communities (IDOT 1976).

Dams have detrimental impacts on aquatic systems causing habitat loss and fragmentation. Impounded areas lack the habitat diversity needed for a variety of life stages of many lotic fauna (including fish and macroinvertebrates) by creating a homogenous slow flowing pool with fine sediment bottoms. Dams also affect the water quality of the system by increasing water temperature and decreasing dissolved oxygen below lethal levels for some organisms especially benthic fish, mussels and macroinvertebrates (Butts and Evans 1978).

Dam removal or modification is a relatively new idea in Illinois. Although there are several documented cases of successful dam removals in other states, most have focused either on the dam removal process or the effects of dam removal on water quality (American Rivers et al. 1999). Only a few studies have evaluated the performance of post-modification or removal on physical habitat or stream/river biota (Schuman 1995; Kanehl 1997; Klomp 1998; Mistak 2000; Stanely et al. 2002; Doyle et al. 2003; Stanely and Doyle 2003; Manatawny Dam Removal Project) with most studies focusing on cool or coldwater streams or streams in coastal states (American Rivers et al. 1999; Klomp 1998; Mistak 2000). Because of the potential changes dam removal/modification can have on water quality and channel morphology/physical habitat, it is important to include monitoring of fish assemblages and macroinvertebrates in any study which evaluates dam modification or removal.

For fishes, little is known about their responses to dam removal/modification, particularly changes in composition, abundance, size structure, growth and movement. Species composition, abundance, and size structure are useful for describing shifts or changes in fish assemblages due to dam removal/modification. Because growth is influenced by environmental conditions (DeVries and Frie 1996, Moyle and Cech 2000), information on fish growth combined with an understanding of habitat availability, habitat utilization, and prey availability will allow us to better understand which factors associated with dam modification have the greatest effect on the fish community of the Fox River.

To further assess direct effects of dams and dam removal on fishes, we are collecting data on seasonal movements and habitat selection by selected species in the Fox River. The impacts of dams on highly migratory species are well established (Hynes 1970, Nehlsen et al. 1991, National Research Council 1996, Benstead et al. 1999), but there is an accumulating body of evidence that indicates dams also affect resident stream fishes (Winston et al. 1991, Martinez et al. 1994, Helfrich et al 1999). Dams may impede movement necessary at different life stages and at different times of year restricting fishes to discrete areas in which required habitats may be limited or unavailable (Sule and Skelly 1985, Schlosser 1987, Todd and Rabeni 1989, Langhurst and Schoenike 1990, Lobb and Orth 1991, Matheney and Rabeni 1995, Beaumont et al. 1997). Dam removal is expected to restore movement of fishes throughout a river, but the extent to which various species take advantage of restored passage is uncertain. By monitoring passage and overall movements of fishes in the Fox River, we hope to determine how dam modification may affect various species with different seasonal movement patterns and habitat preferences.

Although there have been a few studies on dam removal and it's effect on fish (Kanehl 1997; Klomp 1998; Mistak 2000), even less information is known about the effects of dam removal/modification on macroinvertebrate communities (Stanley 2002). By examining abiotic parameters in conjunction with several response parameters of fish assemblages and macroinvertebrate communities, we can better understand the mechanisms linking changes among habitat and water quality to changes in macroinvertebrates (prey) and fish assemblages (consumers). There are a number of reasons to include benthic invertebrates in a monitoring program. First, mussels and certain aquatic insects such as mayflies, stoneflies, and caddisflies are important indicators of water quality and, thus, we can assess the post-modification performance in terms of changes in benthic organisms. Second, because of short generation times and high population growth rates, macroinvertebrates should respond more quickly to improvements in water quality and physical habitat than fish increasing our ability to evaluate the success of dam removal/modification. Third, because most river fish ultimately depend on benthic invertebrates as a food source, invertebrate monitoring will provide a mechanistic understanding of improvements observed in fish assemblage structure and growth.

Previous dam removal/modification studies have also failed to gauge changes in habitat and/or biota against a reference or control area thereby limiting the inference by failing to assess temporal changes (for exceptions see: Schuman 1995; Klomp 1998; American Rivers et al. 1999; Mistak 2000; Stanely et al. 2002; Doyle et al. 2003). A sound experimental design is essential to document the performance of post-removal/post-modification on stream quality. The basic design advocated by Spooner and Line (1993) and Wang et al.(1996) involves the use of paired sites, in which only one of the two areas receives a "treatment" (i.e. dam removal/modification). The paired sites should be as similar as possible in large-scale characteristics such as climate, geology, drainage area, aquatic thermal regimes, land use, and stream gradient. This experimental design for assessing the impacts of unreplicated perturbations is referred to as the Before-After-Control-Impact-Pairs (BACIP) design (Stewart-Oaten et al. 1986, 1992) whereby paired samples are taken simultaneously (as nearly as possible) at the Impact site (i.e., dam removal site) and a nearby "Control" site. Because replication is achieved by collecting paired samples Before and After the treatment has been applied in the Impact site, it is necessary to collect as many samples before the treatment in order to accurately reflect baseline conditions in water quality, physical habitat, and biotic communities. Our study of the modification of the North Batavia Dam (also called Upper Batavia Dam) is designed to gauge changes at the impacted reach by monitoring "control" or "reference reaches" at other locations on the Fox River.

OBJECTIVE 1. Monitor the short- and long-term changes in physical/chemical habitat quality to modification of a low-head dam.

PROCEDURES

Physical habitat data was collected in August 2002 using two levels of sampling: site-scale and transect-scale (Tables 1.1 and 1.2). In order to account for temporal variability and aid in detection of habitat changes after dam removal/modification, we sampled sites in the impounded and free-flowing reaches of the North Batavia Dam (treated) and the Geneva Dam (reference) (Figure 1.1). Due to the removal of the South Batavia Dam and the impacts this may have on physical habitat in the free-flowing section downstream of the North Batavia Dam (i.e. potential head cut), we also measured physical habitat in impounded and free-flowing reaches of the South Batavia Dam (treated) and the North Aurora Dam (reference) (Figure 1.1). Site-scale parameters were collected at one location in the site (e.g., water quality) and are assumed to be representative of the entire site, or are based on maps of the entire site (e.g., sinuosity, stream slope) (Table 1.1). Some variables are assumed to be constant over the duration of the study and will be measured only once (e.g. drainage area, stream order, site length). Water quality variables (dissolved oxygen, pH, conductivity, total phosphorous, and chlorophyll *a*) were not sampled in 2002 due to delays in equipment arrival, but were sampled hourly throughout summer months (June – August) in 2003. In subsequent field seasons, we will continue to collect water temperature, dissolved oxygen, pH, and conductivity at the impounded and free-flowing sites of North Batavia Dam (i.e. treated sites). At impounded and free-flowing sites of the Geneva (reference) and South Batavia Dams (treated), we will collect water temperature hourly and collect dissolved oxygen, pH, and conductivity biweekly. Total Phosphorus and chlorophyll *a* will be measured biweekly at impounded and free-flowing sites of Geneva, North Batavia, and South Batavia Dams.

Transect-scale variables are those which are expected to vary considerably within a site. These variables, which pertain to stream channel morphology, bottom substrate, cover for fish, macrophyte abundance, and condition of stream banks were measured at 3 equally spaced transects perpendicular to the flow (Orth 1983; Stanfield et al. 1998;

Table 1.2). All transect-scale parameters were measured in August 2002 and 2003 and will be measure once a year in subsequent field seasons with the exception of the dam removal/modification period, in which habitat will be sampled more frequently.

Along with collecting quantitative habitat measures, we also assessed physical habitat in August 2002 through qualitative methods established by Illinois EPA's Stream Habitat Assessment Procedures (SHAP; IEPA 1994) and Ohio EPA's Qualitative Habitat Evaluation Index (QHEI; Ohio EPA 1989). These quantitative habitat procedures have been used in past studies on the Fox River (IEPA 1987; V. J. Santucci and Gephard 2003); therefore, we used these procedures to compare our results after dam removal/modification to historical data in the pre-dam removal/modification period. Qualitative habitat assessment methods were used at each site in which quantitative habitat was collected (i.e. from the impounded reach at Geneva Dam to the free-flowing reach below North Aurora Dam).

FINDINGS

Site-scale characteristics

Water Quality

To assess differences between impounded and free flowing sites, we collected water quality parameters upstream and downstream of the Geneva, North Batavia, and South Batavia dams during summer and fall of 2003. We found that dissolved oxygen and total phosphorus were highest in September and October and did not differ between free flowing and impounded sites during summer and early fall in 2003 (Figure 1.2). This data was based on biweekly collection during the day and, thus, may not be often enough to detect differences between impounded and free flowing sections. During summer 2003, we also installed YSI datasondes above and below the North Batavia Dam to collect temperature, dissolved oxygen, conductivity, and pH every half hour. This data will give a more accurate assessment of fluctuations in water quality for impounded and free flowing sites. We are currently in the process of analyzing temperature, conductivity, pH and chlorophyll *a* data from study sites and will report our findings in future reports.

Transect-scale characteristics

Channel Morphology

At each site, in-stream channel morphology measurements were taken to assess differences between impounded and free-flowing sites and between treated and reference sites, prior to dam removal/modification. In general, average width, depth, velocity, and substrate size was substantially different between impounded and free-flowing sites (Table 1.3). On average, impounded sites were twice as wide and approximately three times deeper than free flowing sites. Comparing impounded sites with their corresponding free-flowing sites at each dam, we find that impounded sites ranged from 1 to 4 times wider and 2 to 4 times deeper than their free-flowing sites. South Batavia impounded and free flowing sites were the most similar in terms of average width and depth.

Average velocity and substrate showed an opposite trend, where substrate at free-flowing sites was 3 times larger and velocity was seven times higher on average than impounded sites (Table 1.3). However, when comparing impounded and corresponding free-flowing sites at each dam, we found that impounded sites of North Batavia and South Batavia Dams had higher substrate sizes then their free-flowing sites. This is due to the high content of bedrock along the shoreline of the North Batavia impoundment and the high gravel content of the substrate at South Batavia impoundment. Average velocity was always higher in the free flowing sites with velocity being 3-29 times higher in free-flowing versus their respective impounded site.

Because we are using reference sites to account for temporal variability during this study, we also compared channel morphology measurements between treated and reference sites. Comparing Geneva impounded and free-flowing sites (reference) to North Batavia sites (treated), we found that the free-flowing reference site was about 30 m wider and 15 cm shallower than the North Batavia free-flowing site, but that substrate and velocity were similar between the two sites (Table 1.3). For the impounded reaches, Geneva impoundment was only slightly wider (14.1 m) and shallower (16.7 cm) than the North Batavia Impoundment, but average substrate was much larger (approximately 98 mm) and velocity was much faster (0.08 m/s difference) in North Batavia impoundment. For comparisons between South Batavia (treated) and North Aurora (reference) sites, we found that the free-flowing reaches differed by 88.5 m in width, 30.6 cm in depth, 285 mm in substrate size, and 0.15 m/s in velocity. The impounded sections above the South Batavia and North Aurora Dams were more similar than their free-flowing sections. North Aurora impoundment (reference) was approximately 48 m wider and 42 cm deeper than South Batavia impoundment, however, South Batavia impoundment had larger average substrate (approximately 19 mm larger) and higher average velocity (0.09 m/s).

In-stream habitat

To determine the similarity in macrohabitat between impounded and free flowing sites and between sites that will be modified by dam removal (treated) and those which will not be modified (reference), we examined differences in percent riffle, run, and pool habitat types between sites. As expected, impounded sites, on average, consisted of predominately run (56.3%) and pool (41.1%) habitat on average; while free flowing sites consisted mostly of riffle (49.6%) and run (40.1%) habitat (Table 1.3). The reason for this large percent run habitat in the impoundments is probably due to the fact that these are low-head run-of-the-river dams with low retention times (Santucci and Gephard 2003); and therefore, these impoundments have some detectable flow.

Comparing treated to reference sites, we found that the free flowing site at Geneva (reference) had about 33% more riffle habitat than North Batavia (treated) (Table 1.3). Based on macrohabitat composition, impounded sites at Geneva (reference) and North Batavia (treatment) were different in habitat composition, although these sites had fairly similar average width and depth. The Geneva impoundment consisted predominately of pool habitat (93.5%), while North Batavia impoundment consisted mostly of run habitat (85.9%). Free flowing sites at South Batavia (treated) and North Aurora (reference) were fairly similar in terms of percent riffle (difference of 23%) and pool (difference of 2%) habitat composition although they differed substantially in terms of average width, depth, substrate, and velocity. For impounded sites, South Batavia was predominately run habitat (85.2%), while North Aurora had equal amounts of run and pool habitat (47.5%).

As part of our habitat survey, we measured the amount of in-stream cover and vegetation. Impounded sites had less diversity of in-stream cover than free flowing sites (Figure 1.3). Overall, impounded sites were fairly similar in terms of diversity and abundance of cover types with the exception of the South Batavia impoundment which had a higher percentage of embedded round rock cover (11%). For free flowing sites, composition and abundance of in-stream cover was similar between North Batavia, South Batavia, and North Aurora, but the Geneva free flowing site had little in-stream cover (20% for all types combined) compared to the other 3 free flowing sites. Comparing impounded sites to free flowing sites at each dam, we found greater percent of unembedded round and flat rock cover in free flowing sites with the exception of the Geneva Dam where percent unembedded rock cover was similar between the impounded (3% flat rock, 5% round rock) and free flowing site (7% flat rock). Percent embedded rock cover (round and flat rock) and percent wood cover (embedded and unembedded) were similar between free flowing and impounded sites.

Similar to the results for instream cover, all the impounded sites had little or no vegetation with small amounts of filamentous algae and terrestrial vegetation at the Geneva impoundment and some macrophytes and terrestrial vegetation at the South Batavia and North Aurora impoundments (Figure 1.4). Conversely, free flowing sites consisted of large amounts of filamentous algae, particularly at Geneva and North Batavia where more than half of the stream bottom consisted of filamentous algae.

Quantitative Habitat Assessment

To indicate overall habitat quality at each sampling site, we used two qualitative assessment methods (QHEI and SHAP). Both use a ranking system of various stream characteristics (substrate, flow, streambed slope, etc.) to calculate an overall habitat rating score. Using both QHEI and SHAP, we found that impounded sites had lower overall habitat rating scores ranging from 38.5 to 55.5 for QHEI and 68 to 96 for SHAP criteria indicating that these sites are in a degraded condition (Table 1.4). The free flowing sites had much higher overall habitat quality score (69.0 to 86.0 for QHEI; 104 to 147 for SHAP) and rated as having good or excellent habitat conditions. Based on our quantitative assessment and these overall habitat condition scores, we found that impoundments had poor habitat conditions (silt and sand substrate, low flow, little cover) for biotic communities, while free flowing sites had a much higher quality habitat for fish and invertebrates (coarser and more stable substrate, variety of flows, larger amount of rock cover).

OBJECTIVE 2. Document the quantitative short- and long-term responses of fish assemblage structure and growth to removal/modification of a low-head dam.

PROCEDURES

Fish communities were sampled once in late summer 2002 and 2003 with a pulsed-D.C. boat shocker and a D.C. backpack shocker for assessment of assemblage composition and abundance. Because fish are able to move between impounded and free flowing sites, we are using entire reaches between dams for impacted and reference sites for assessment of fish assemblages (Figure 2.1). Because the St. Charles, Geneva, North Aurora, and Stolp Island Dams will not be removed or modified during this study, we sampled the free flowing and impounded sites between St. Charles and Geneva (Reference 1) and between North Aurora and Stolp Island (Reference 2) as our reference reaches. These references will be compared against our three treated reaches (which include both impounded and free flowing sites) between Geneva and North Aurora dams (Figure 2.1) to assess baseline conditions and detect changes due to dam modification. We also combined fish data by habitat type to compare assemblages between impounded and free flowing habitats as well as comparing impounded and free flowing sites at each dam to indicate current conditions and fish assemblage quality.

All sites (impounded and free flowing) within each reach were long enough to accommodate 30 min. boat electroshocking runs, or about 730 m in length. Both sides of the river were sampled for a total shocking time of 60 min. per site. Backpack shocking was used to target wadable habitat (riffles and shoreline areas) for a period of 30 min. per site. All fish larger than 100 mm total length were identified, measured, and weighed in the field and returned to the river; smaller fish were preserved in 10% buffered formalin and taken to the laboratory for identification and measurement.

A critical component to the evaluation of post-construction performance is to determine if dam modification will affect the stream in a way we might expect from an environmental perspective. Species composition (richness and diversity), relative abundance, size structure, and the Index of Biotic Integrity (IBI) were used to determine baseline conditions in impounded and free flowing sites in treated and reference reaches and will be used to detect shifts in fish assemblage composition due to changes in habitat above the modified dams. Because of limitations of both boat and backpack electrofishing gear (i.e. boat is effective in deeper pools and runs, backpack more effective in shallow riffles and near-shore areas), we combined fish caught with both gear types at each site in order to get a better representation of overall assemblage composition and abundance of individual species. To justify our decision to combine gear types for data analysis, we compared richness and CPUE between the two gear types at each site. In free flowing sites, we found that the backpack electrofisher collected more species and had a higher CPUE than the boat, but IBI scores based on data from both gears were similar (Table 2.1). For impounded sites, backpack electrofishing gear collected more fish species but had similar CPUE to the boat (except at Geneva impoundment) and IBI scores based on gear type varied depending on the site. Comparisons of fish composition and abundance based on gear types indicated that using only boat electrofishing gear would greatly underestimate species richness in both free flowing and impounded sites and underestimate CPUE in the free flowing areas, therefore, we combined data from both gears at each site for analysis.

To further assess fish composition, we examined the number of species caught (richness) as well as the Simpson's diversity index (Attrill 2002) which takes into account the relative abundance of each species. Simpson's diversity index (S) is calculated by:

$$S = \Sigma((n^2 - n)/(N^2 - N))$$

where S is Simpon's diversity index, n = number of individuals of *i*th species, and $N = \Sigma n$. Simpson's diversity index ranges from 0 to 1 with 0 indicating excellent diversity and 1 indicating poor diversity.

To compare fish composition between the impounded sites and free flowing sites in treated and reference reaches, we used Jaccard's Similarity Index (Attrill 2002) which uses presence/absence data to compare the fish assemblage structure. The Jaccard Similarity Index (J), was calculated using the formula:

$$J = C / (A+B-C)$$

where A and B is the number of species in site A or site B, respectively, and C is the number of species in common. A value of one indicates species composition are exactly the same in both sites and a value of zero indicates no similarity in fish assemblages between the two sites.

For relative abundance, Catch per hour of electroshocking time (CPUE) was used. IBI scores, which give an indication of overall stream quality based on fish assemblages, were calculated following the new IBI criteria (Smoger, IEPA unpublished data) based on work by Karr 1981 and Karr et al. 1986.

Hard structures to be used in fish growth analysis were collected at the same sites as fish community sampling (Figure 2.1) from fish collected for evaluation of assemblage composition and for mark-recapture analysis (Objective 3). Approximately ten scales were removed from each smallmouth bass, walleye, and common carp. A pectoral spine was removed from each channel catfish (Hubert 1999) and pectoral fin rays were removed from golden redhorse, silver redhorse, shorthead redhorse, and river redhorse. We attempted to collect structures from at least 30 individuals from each site sampled in 2002.

We are currently processing hard structures for age analysis. Scales will be impressed onto polycarbonate slides and spines and fin rays will be sectioned using a Dremel® tool with a cutting-blade attachment. Prepared hard structures will be viewed under a dissecting microscope and radii and interannular distances will be recorded with a digitizing pad connected to a microcomputer. A subsample will be aged by a second person to verify age estimates. Lengths at previous years will be back-calculated from averaged interannular measurements using the Fraser-Lee method for smallmouth bass, common carp, walleye, and redhorse species. Back-calculation will be accomplished via the direct proportion method for channel catfish (DeVries and Frie 1996). Using back-calculated values, age-specific growth rates will be compared between treatment and reference reaches before and after dam modification. Additionally, we will determine annual size-specific growth for two sizes for each species. Sizes chosen will encompass the range in which known ontogenetic diet and habitat shifts occur (Putnam et al. 1995). These size-specific growth rates often provide more ecologically meaningful comparisons than age-specific growth rates (Larkin et al. 1957, Gerking and Raush 1979, Werner and Gilliam 1984). Size-specific growth rates will be compared between sites and time periods as for age-specific growth rates.

FINDINGS

Fish Assemblage Composition and Abundance

In 2002, CPUE (with combined gear types) was eight and a half times greater in free flowing sites compared to impounded sites with twice as many species present (Table 2.2). The impounded sites consisted primarily of common carp (*Cyprinus carpio*) and some sunfish species (Centrarchids), while free flowing sites were more diverse and consisted of more intolerant species such as redhorse, smallmouth bass, and darters as well as greater diversity of minnow species and larger numbers of channel catfish. Based on species presence/absence, fish composition between all impounded and free flowing sites combined was low with a Jaccard's Index of 0.40.

To assess the baseline conditions of the free flowing river and compare these to the impounded sites, we compared richness, CPUE, diversity and IBI scores at each site located directly above (impounded) and below (free flowing) each dam. In general, free flowing sites contained more species (range of 10-18 more species) and had higher relative abundances (range of 235 – 888 more fish/hour) (Table 2.3). At each dam, free flowing sites also showed higher fish diversity (i.e. lower diversity score) than their corresponding impounded sites and higher IBI scores indicating higher overall quality of the river in free flowing sites. Because of these large differences in fish richness, we found that free flowing sites and their corresponding impoundment at each dam had low similarity of fish assemblage composition (based on presence/absence data) ranging from 29 to 33% similarity.

To account for temporal variability and increase our ability to detect changes at sites affected by dam modification/removal, we also examined fish assemblage structure in our treated compared to reference sections. We found that for treated and reference free flowing sites richness, CPUE, and diversity was within range of the treated free flowing sites (Table 2.3). Richness at both St. Charles and North Aurora (reference) free flowing sites (22 species) was at the lower end of the range for treated sites (23-27 species), but CPUE and IBI scores at these reference sites were within the range for treated sites (CPUE: 348-996 fish/hour; IBI: 45-48). For impounded areas, the two reference sites were on either end of the range for treated sites in terms of richness (8-11 species), CPUE (40-108 fish/hour), and IBI scores1(8-23), with Geneva impoundment being at the high end of the range for all three fish community parameters and Stolp Island being at the low end of the range. From these comparisons of fish composition and abundance in reference and treated sites, we feel that these sites are well matched for detecting changes in treated areas after dam modification.

Fish Weights and Size Structure

Weights of each species were averaged and comparisons of biomass and percent composition were made between free flowing and impounded sections of the Fox River. As with relative abundance, biomass in impounded sites consisted primarily of large common carp (86.2%) with some fish biomass composed of freshwater drum (*Aplodinotus grunniens*) and quillback (*Carpiodes cyprinus*) (Table 2.4). In free flowing sites, fish biomass was more evenly distributed among taxa; however, sucker species (Catostomids) composed over 52% of the biomass consisting primarily of silver redhorse (*Moxostoma anisurum*) and quillback. Minnow species (Cyprinids) composed over 25% of fish biomass and channel catfish composed about 11% of the overall biomass of free flowing sites. As we found with the CPUE data, fish assemblage structure in impoundments consisted primarily of common carp with few other fish species making up a large proportion of the community (in terms of abundance or biomass) (Table 2.4). Similar to the CPUE data in free flowing areas, we found that biomass was also more evenly distributed across fish taxa compared to impoundments with higher biomass of intolerant (redhorse) and game fish (channel catfish) (Table 2.4).

Age and Growth Analysis

During July, September, and October 2002, hard structures were removed from eight fish species for age and growth analysis. We collected samples from 282 common carp, 207 smallmouth bass, 195 channel catfish, 32 walleye, 107 silver redhorse, 52 golden redhorse, 66 shorthead redhorse, and 8 river redhorse. Preparation and back-calculation of these samples is ongoing. We have found scales of common carp from the Fox River to contain a high proportion of reabsorbed or otherwise unreadable scales. In future work of this study, we will attempt to determine alternative hard structures appropriate for aging common carp from the Fox River.

Pectoral spines from channel catfish captured at the St. Charles free-flowing site have been sectioned, interannular distances measured, and lengths-at-age back-calculated. We have determined that channel catfish at this site reach mean lengths of 271, 392, and 444 mm for ages 3, 5, and 7, respectively (Figure 2.2). These lengths-at-age are all above average for this species (Hubert 1999), suggesting that channel catfish are growing faster in the Fox River compared to other populations across North America. We will continue to age pectoral spines from other sites on the Fox River in order to allow for comparison of growth rates among reaches with varying habitat.

OBJECTIVE 3. Monitor changes in fish movement and habitat utilization in response to removal/modification of a low-head dam.

PROCEDURES

Mark/recapture techniques are being used to determine overall movements of fish above and below dams, the ability of fish to pass dam sites, and use of altered habitat by different species following dam modification. Eight species of fish are being marked at each free-flowing and impounded site (Table 3.1). Sites below the North Aurora dam and above the Geneva dam will serve as reference sites, whereas sites between the North Aurora dam and the Geneva dam will be considered treatment sites (Figure 2.1).

During July 2002, target species were collected from the Fox River during fish community sampling as described under Objective 2. All target fish were measured, weighed, and subcutaneously injected with a site-specific colored elastomer tag (Northwest Marine Technology ®) prior to being released. During September and October 2002, additional boat electrofishing was conducted in order to recapture marked fish, and additional fish were given site-specific tags at this time.

In addition to mark/recapture techniques, radiotelemetry is being used to monitor seasonal movements and habitat utilization of smallmouth bass, channel catfish, and common carp. Using this technique, fish movements are being monitored below the South Batavia Dam (treatment), above the North Batavia Dam (treatment), and above the Geneva Dam (reference). Fish are being tracked using an Advanced Telemetry Systems ® model R2000 receiver and a bi-directional loop antenna. All fish are located once a week during six week periods in spring, summer, and fall. In winter, only two weeks of tracking is being conducted, as we anticipate activity during this period to be minimal. During normal and low flow conditions, fish are tracked by wading in free-flowing areas and by canoe in impounded areas. During periods of ice cover and during high flows, fish are located by triangulation from shore. Fish locations are recorded on aerial photographs, and habitat variables (depth, flow, substrate, cover, and macrohabitat) are recorded for each location whenever time and safety permit.

Within each reach, ten smallmouth bass and ten common carp were surgically implanted with radio-transmitters between September 26 and October 11, 2002. All but one smallmouth bass was released in free-flowing habitat, due to the lack of use of impoundment habitat by this species. Within each reach, five common carp from free-flowing habitats and five from impoundment habitats were given transmitters, in order to determine and account for any potential behavioral differences between fish from these different habitats. Five channel catfish from each site were implanted with transmitters from October 16-18. Channel catfish from below the South Batavia dam and above the Geneva dam were released in free-flowing habitats. Those between the North Batavia dam and the Geneva dam were released in impoundment habitat.

We attempted to locate all fish once a week from October 23 to December 6. Due to logistical constraints, habitat data associated with fish locations was only recorded during November 21 and 22 during the 2002 fall tracking period.

FINDINGS

In 2002, 948 fish were marked with elastomer tags in the Fox River (Table 3.1). During boat electrofishing efforts in September and October 2002, five tagged fish of three species were recaptured (Table 3.1). Only one common carp was recaptured outside of its marking site in 2002, although this recapture was within the same reach.

From October 23 to December 6, 75 fish were tracked by radiotelemetry, resulting in 432 observations of fish locations. One hundred seventy-two locations were recorded for smallmouth bass. Approximately 77 % of smallmouth bass remained in free-flowing habitat through the end of the fall tracking period. Only four individuals (13 %) moved into downstream impoundments to over-winter. Two smallmouth bass were recorded passing upstream of dam sites. One is thought to have been transported over the Geneva Dam by an angler or avian predator; the other likely passed through the breech in the South Batavia Dam that was formed by an early fall flood event. In general, smallmouth bass moved very little during the fall 2002 tracking period (Figure 3.1). Most individuals remained within small home ranges and rarely wandered from these areas. Smallmouth bass were found in water with a mean depth of 98 cm and 89 % were located over gravel or cobble substrates. Approximately 53 % were located in close proximity to cover, with boulders being the most common (33 %).

One hundred seventy-two locations were recorded for common carp. All individuals originally released in impoundment habitat remained in the same impoundment through the duration of fall tracking in 2002. Ten of the fifteen common carp (67 %) released in free-flowing habitat had moved into downstream impoundments to over-winter by the end of tracking in December. Common carp tracked during fall 2002 did not display evident associations with individual home areas, and underwent much larger weekly movements than did smallmouth bass (Figure 3.2). Individuals remaining in free-flowing habitats, however, did display substantially less movement than those located in impoundments. Mean depth used by common carp was 148.0 cm. Approximately 71 % were located over silt substrate. Few carp (21 %) were located in close proximity to cover.

Eighty-eight locations were observed for channel catfish. All individuals had moved into downstream impoundments by early November 2002. The majority (87 %) had moved prior to the beginning of tracking on October 23. Channel catfish displayed sporadic movement patterns during fall 2002 (Figure 3.3). Some individuals remained relatively stationary for a period of time, followed by periods of increased movement, possibly in response to environmental cues (flow, temperature, etc.). Others seemingly wandered at random, as for common carp. Towards the end of the fall tracking period, channel catfish tended to congregate in small areas within impoundments. Mean depth used by channel catfish was 190.5 cm and 86 % were located over silt or sand substrates. Twenty percent of channel catfish were found in close proximity to cover.

OBJECTIVE 4. Evaluate the short- and long-term responses of invertebrate community structure to removal/modification of a low-head dam.

PROCEDURES

Benthic macroinvertebrates were sampled in summer (June) and fall (September) 2002 and 2003 at the same sites sampled for fish. Due to time constraints, we were unable to sample mussels in 2002. However, in 2003 and subsequent field seasons, we will sample mussel populations to assess current conditions of mussel assemblages as well as to determine shifts in mussel populations due dam modification. Invertebrates (excluding mussels) were sampled from wadable habitats using both quantitative and semi-quantitative techniques. A Hess sampler (quantitative technique using a standard area) was used at three locations along shoreline areas of the impoundments and in run/riffle habitats in free flowing areas. In conjunction with using a Hess sampler at three wadeable locations in free flowing and impounded areas, we also used kick nets with hand picking (semi-quantitative technique using a standard time) for 10 minutes per kick net sample (a total of 30 minutes of kick net sampling per site). The Hess sampler was a metal cylinder with a diameter of 16.5 cm equipped with a 300 μm mesh net and the kick net was a 25 by 46cm rectangular steel framed net with 500 μm mesh. Forceps were used when hand picking the kick nets and during removal of organisms from the Hess sampler. In the impoundments, we also collected invertebrate samples in deep-water areas using a petite ponar dredge (15 X 15 cm opening) deployed from a boat at 3 locations (left, right, and mid channel) along 2 transects (total of 6 ponar grabs). Habitat types were sampled in relative proportion to their abundance at each free flowing and impounded site. All invertebrate samples were preserved in 4% buffered formalin and returned to the laboratory for processing and identification. Samples were elutriated using a two sieve series and sorted from organic debris using a dissecting microscope at 10X magnification. Samples with a large number of organisms were sub-sampled.

To assess effects of dam modification, taxa richness, relative abundance, and the Macroinvertebtrate Biotic Index (MBI) will be compared between treated and reference sites across years. We will also compare invertebrate composition and abundance in impounded versus free flowing areas to determine baseline conditions of the invertebrate community and how communities differ based on the type of reach sampled. We will also compare our data with historical data to expand on pre-removal/modification invertebrate community assessments.

FINDINGS

In 2002 and 2003, we collected invertebrate samples from all impounded and free flowing sites extending from the free flowing reach below St. Charles Dam to the impoundment above the Stolp Island Dam. At each of the five impounded sites, we collected three Hess and three kick net samples along the shoreline and 6 ponar samples in deeper water. At the five free flowing sites, we collected three Hess and three kick net samples in riffle and run habitats. All 2002 samples have been sorted through a 2 sieve series to separate organisms into large (> 1mm) rare taxa and small (250 – 1mm) abundant taxa. We are currently in the process of identifying these samples and will present these results in subsequent reports.

RECOMMENDATIONS

From our baseline data collected in 2002, we found that physical habitat in the impoundments was much different and of lower quality than habitat in the free flowing sections. Impounded sites were deeper and wider areas with softer substrate and consisted primarily of pool and run habitat, while free flowing areas were much narrower and shallower on average with larger substrate and consisted of run and riffle habitat. In general, treated (both impounded and free flowing sites which will be affected by dam modification) and corresponding reference sites were fairly similar in channel morphology, habitat composition, in-stream cover and vegetation, indicating that these sites will make good pairings for assessing changes in physical habitat due to dam modification.

From our analysis on various fish assemblage parameters, we found that community composition (richness and diversity), abundance, and size structure (biomass) differed between free flowing and impounded sites. IBI scores showed a much lower quality of fish assemblages in the impoundments compared to free flowing sites. We did find that our reference sites in both free flowing and impounded areas were within the range of fish composition parameters (richness, abundance, diversity) for our treated sites and that IBI scores were similar. This suggests that our reference sites are good matches for our treated sites and, thus, will increase our likelihood of detecting significant changes in fish communities once the dams are modified/removed. In subsequent years, additional boney structures for age and growth analysis will need to be collected in order to account for intrinsic variability in growth between years prior to dam modification. Following dam modification, this process will need to be repeated to provide for comparisons of growth rates against pre-modification conditions. Because many carp scales could not be analyzed due to regeneration of scales, alternative hard structures from common carp may need to be evaluated in order to determine the appropriate structure that will provide accurate growth data for this species from the Fox River. Due to low sample sizes, some species (walleye, river redhorse) may be excluded from further analysis.

In 2002, only five fish were recaptured using mark/recapture techniques.

Additional recapture efforts will need to be conducted in future years to provide estimates of population-level movement of fishes in relation to dams and dam modification. Furthermore, additional marking should be conducted in order to obtain a larger pool of marked fish from which to sample. Following dam modification, mark/recapture information will become critical in determining the extent to which fish are capable of passing dam sites. It will also help us to examine the level of recolonization of the former impoundment by fishes from outside of this habitat. Radiotelemetry will also need to be continued over time to monitor the movements and habitat selection of individual fish. A minimum of six weeks of tracking during each season (with the exception of winter in which only two weeks are necessary) will be conducted in future field seasons to account for seasonal movement patterns. In 2003, five additional channel catfish at each site were implanted with radiotransmitters. Additional habitat data in conjunction with radiotelemetry observations will need to be collected in future years to determine which habitat characteristics are utilized by each species during different seasons.

We recommend continuance of benthic macroinvertebrate sampling to obtain a more accurate picture of baseline conditions in treated and reference sites of impounded and free flowing reaches. In 2003, we also collected mussels at each treated and reference sites to obtain baseline data on mussel populations. Historical data and data from recent studies (Santucci and Gephard 2003) on the Fox River will also be incorporated into our analysis of macroinvertebrate communities prior to dam modification.

In the next year, we will continue to monitor physical habitat, fish assemblage structure, growth, and movement, as well as macroinvertebrate communities at all treated and reference sites in impounded and free flowing sections. In late fall 2002, a large breach was created at the South Batavia Dam due to high river flows. Thus, we will begin monitoring changes in physical habitat, water quality, fish, and macroinvertebrates as a result of this breach and determine any effects this may have on the free flowing reach below the North Batavia Dam (particularly fish movement between free flowing sections of the North and South Batavia Dams). In subsequent reports, we will compare these changes in habitat and biotic conditions to those before the breach occurred. At the North Batavia (treated sites) and Geneva (reference sites) Dams, we will continue monitoring baseline conditions of physical habitat and biotic communities during the next year and add water quality monitoring to our assessment at all treated and reference sites.

Because we are using a Before-After-Control-Impact paired (BACIP) design to assess changes after dam modification, additional baseline data is essential because the ability of the design to detect effects of a treatment depends strongly on the number of sampling dates before and after the treatment is initiated, the size of the treatment effect, and the variability in the treatment and control sites in each period (Osenberg et al. 1994). Obtaining sufficient numbers of pre-treatment samples is critical because additional before samples cannot be obtained after the treatment is implemented. Additional data collection will also increase the accuracy of our baseline assessment giving us greater ability to detect significant changes in chemical/physical habitat and biota as a result of dam modification. To increase the amount of pre-dam modification data, we will also be combining our data with those of previous studies on the Fox River (Santucci 1994; Santucci and Gephard 2003). In order to assess potential effects of the breach at the South Batavia Dam on the removal of the North Batavia Dam, it is particularly critical to incorporate historical data since we currently have only one year of data before the breach.

Other states have begun either removing dams or installing fishways (American Rivers et al. 1999), however, dam removal or modification is a relatively new idea in Illinois. As part of evaluating the overall performance of dam removal/modification, it is not only necessary to examine the success from an economic and social standpoint but also from an ecosystem perspective. By monitoring several biotic and abiotic parameters of a lotic ecosystem (chemical/physical habitat, fish, mussels and macroinvertebrates) collectively, we can better understand how removal of a dam may affect different parameters differently and allow us to identify the mechanisms linking changes among parameters. This study will improve our knowledge of immediate and long-term impacts of dam removal on medium-sized warmwater rivers. Information from this study will aid resource managers and stakeholders in decision making processes and help justify and guide future dam removal projects. Documentation of the positive effects of dam removal/modification on river communities will also help increase public awareness of the benefits of dam removal.

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Table 1.1. Summary of site-scale habitat variables used to assess water quality at impounded and free flowing sites in our study area of the Fox River, Illinois.

Variable	Sample Frequency	Method
Drainage area (km^2)	1 time only	1:24,000 topographic maps; GIS
Stream order	1 time only	1:24,000 topographic maps
Water temperature (°C)	Continuous – spring to fall	YSI Datasonde; Optic Stowaway temperature logger
Dissolved Oxygen	Continuous- summer	YSI Datasonde
	Biweekly -summer	YSI 55 handheld meter
pH and Conductivity	Continuous - summer	YSI Datasonde (at North Batavia only)
Total P and Chlorophyll *a*	Biweekly -summer	Water samples collected from subsample of water column

Table 1.2. Summary of transect-scale habitat variables. Three equally spaced transects were sampled at each site. All variables are sampled once/year in summer when fish sampling is conducted.

Variable	Description
Bankfull width (m)	Horizontal distance along transect, measured perpendicular to stream flow, from top of bank (Gough 1997).
Stream width (m)	Horizontal distance along transect, measured perpendicular to stream flow from bank to bank at existing water surface
Depth (mm)	Vertical distance from water surface to stream bottom, measured at 5 m intervals along transect
Velocity (m/s)	Measurement of stream velocity at each point along transect.
Bottom substrate type	Composition of stream bed measured at each point and in a 30 cm circle around each point where stream depth is measured; particle diameters in each category are: Clay: ≤0.004 mm Silt: 0.004 – 0.062 mm Sand: >0.062 – 2 mm Gravel: >2 – 64 mm Cobble: >64 – 256 mm Small boulder: >256 – 512 mm Large boulder: >512 mm
Cover (%)	Object(s) that are 10 cm wide along median axis and blocks greater than 75% of sunlight; the largest object which is partially or wholly within a 30 cm circle around each point along the transect are measured.
Bank vegetation cover	Dominate cover on the bank within a 1 X 2 m area from water's edge. Categories are: None, Cultivated, Herbaceous, Woody, Mature Trees, and Tree Roots
Undercut bank (mm)	Distance at each side of transect between maximum extent that streamside overhangs channel to furthest point under the bank, to nearest centimeter.
Bank height	Height from water's edge to top of bank; indicates amount of incision.
Riparian land use (left and right bank)	Composition of riparian zone at distances of 1.5-10 m, 10-30 m, and 30-100 m along each transect: largest land use category is recorded and is estimated visually; categories are: Cultivated, Herbaceous, Woody, Mature Trees, Tree Roots.

Table 1.3. Average geomorphology characteristics (width, depth, substrate, and velocity) and percent habitat (riffle, run, pool, islands) for free flowing and impounded sites. Dams listed in bold are being removed.

	Free Flowing				Impoundment			
Dams	Width (m)	Depth (cm)	Substrate (mm)	Velocity (m/s)	Width (m)	Depth (cm)	Substrate (mm)	Velocity (m/s)
GENEVA	93.8	36.3	36.3	0.29	181.3	144.7	2.4	0.01
N. BATAVIA	61.7	51.4	37.1	0.28	167.2	161.4	90.3	0.09
S. BATAVIA	143.5	40.2	18.5	0.48	151.3	102.3	24.0	0.13
N. AURORA	55.0	70.8	303.8	0.63	199.0	143.9	5.1	0.04
Average	88.5	49.7	98.9	0.42	174.7	138.1	30.4	0.06

	Free Flowing				Impoundment			
Dams	% Riffle	% Run	% Pool	% Islands	% Riffle	% Run	% Pool	% Islands
GENEVA	72.7	23.7	3.6	0.0	0.0	6.5	93.5	0.0
N. BATAVIA	40.0	45.7	14.3	0.0	0.0	85.9	14.1	0.0
S. BATAVIA	54.3	25.2	1.2	19.3	0.0	85.2	9.1	5.7
N. AURORA	31.3	65.6	3.1	0.0	0.0	47.5	47.5	5.0
Average	49.6	40.1	5.6	4.8	0.0	56.3	41.1	2.7

Table 1.4. Qualitative habitat scores and habitat quality rating for impounded and free flowing sites in the Fox River using QHEI and SHAP scoring criteria. QHEI ranges from Severely Degraded to Good. SHAP ranges from Poor to Excellent. Dams listed in bold are being removed.

	Free Flowing				Impoundment			
Dams	QHEI	Rating	SHAP	Rating	QHEI	Rating	SHAP	Rating
GENEVA	70.8	Good	104	Good	42.0	Severely Degraded	68	Fair
N. BATAVIA	78.5	Good	128	Good	49.3	Degraded	89	Fair
S. BATAVIA	86.0	Good	147	Excellent	55.5	Degraded	96	Fair
N. AURORA	69.0	Good	115	Good	38.5	Severely Degraded	75	Fair
Average	76.1		123.5		46.3		82.0	

QHEI Criteria	
Good	>60
Degraded	46-60
Severely Degraded	<46

SHAP Criteria	
Excellent	>= 142
Good	100-141
Fair	59-99
Poor	<59

Table 2.1. Species richness, catch per hour of electrofishing (CPUE), and Index of Biotic Integrity (IBI) for free flowing and impounded sites for both boat and backpack electrofishing gear. Dams listed in bold are being removed.

	Free Flowing						Impoundment					
	Boat			Backpack			Boat			Backpack		
Dams	Richness	CPUE	IBI	Richness	CPUE	IBI	Richness	CPUE	IBI	Richness	CPUE	IBI
ST. CHARLES	10	96	24	15	374	24						
GENEVA	11	122	33	19	226	31	12	77	22	5	36	16
N. BATAVIA	14	115	38	18	666	39	4	31	12	7	44	18
S. BATAVIA	16	172	43	17	824	36	6	40	17	8	68	17
N. AURORA	11	88	36	14	556	34	4	18	15	6	22	17
AURORA							3	23	6	4	20	12

Table 2.2. List of fish species, numbers caught (Catch), and numbers caught per hour of electrofishing (CPUE) for Free Flowing and Impounded sections of the Fox River. Both backpack and boat electrofishing data is combined in this table.

			Free Flowing		Impoundment	
Family	Common Name	Scientific Name	Catch	CPUE	Catch	CPUE
Catostomidae	Golden redhorse	*Moxostoma erythrurum*	36	36	0	0
	Northern hog sucker	*Hypentelium nigricans*	6	6	0	0
	Quillback	*Carpiodes cyprinus*	88	96	9	9
	River carpsucker	*Carpiodes carpio*	1	1	1	1
	Shorthead redhorse	*Moxostoma macrolepidotum*	25	25	0	0
	Silver redhorse	*Moxostoma anisurum*	58	58	1	1
	White sucker	*Catostomus commersoni*	12	12	0	0
Centrarchidae	Black crappie	*Pomoxis nigromaculatus*	3	6	0	0
	Bluegill	*Lepomis macrochirus*	68	132	38	64
	Bluegill x Green sunfish hybrid	*Lepomis macrochirus x L. cyanellus*	2	4	3	6
	Green sunfish	*Lepomis cyanellus*	44	87	25	42
	Largemouth bass	*Micropterus salmoides*	32	64	20	40
	Longear sunfish	*Lepomis megalotis*	1	2	4	4
	Orangespotted sunfish	*Lepomis humilis*	35	70	1	1
	Pumpkinseed	*Lepomis gibbosus*	0	0	1	1
	Pumpkinseed x Green sunfish hybrid	*Lepomis gibbosus x L. cyanellus*	1	2	0	0
	Smallmouth bass	*Micropterus dolomieu*	118	149	8	12
Cyprinidae	Bluntnose minnow	*Pimephales notatus*	189	378	6	8
	Bullhead minnow	*Pimephales vigilax*	1	2	1	1
	Carp	*Cyprinus carpio*	57	60	112	121
	Creek chub	*Semotilus atromaculatus*	3	6	0	0
	Emerald shiner	*Notropis atherinoides*	2	4	0	0
	Fathead minnow	*Pimephales promelas*	6	12	0	0
	Golden shiner	*Notemigonus crysoleucas*	5	10	0	0
	Hornyhead chub	*Nocomis biguttatus*	1	1	0	0
	River shiner	*Notropis blennius*	0	0	1	2
	Sand shiner	*Notropis ludibundus*	160	318	0	0
	Spotfin shiner	*Cyprinella spiloptera*	376	741	4	8
	Spottail shiner	*Notropis hudsonius*	3	6	0	0
	Suckermouth minnow	*Phenacobius mirabilis*	30	60	0	0

Table 2.2. Continued

Cypriodontidae	Blackstripe topminnow	*Fundulus notatus*	0	0	1	2
Ictaluridae	Channel catfish	*Ictalurus punctatus*	140	145	2	2
	Flathead catfish	*Pylodictis olivaris*	10	12	5	5
	Stonecat	*Noturus flavus*	3	6	0	0
	Tadpole madtom	*Noturus gyrinus*	12	24	1	2
	Yellow bullhead	*Ameiurus natalis*	14	28	4	8
Moronidae	White bass	*Morone chrysops*	7	9	0	0
Percidae	Banded darter	*Etheostoma zonale*	282	564	0	0
	Johnny darter	*Etheostoma nigrum*	2	4	0	0
	Logperch	*Percina caprodes*	1	2	0	0
	Slenderhead darter	*Percina phoxocephala*	11	22	0	0
	Walleye	*Stizostedion vitreum*	15	15	0	0
Poeciliidae	Mosquitofish	*Gambusia affinis*	1	2	0	0
Sciaenidae	Freshwater drum	*Aplodinotus grunniens*	55	58	36	39
Total			1916	3239	284	379
Species Richness			41		22	
Similarity = 0.40						

Table 2.3. Species richness, catch per hour of electrofishing (CPUE), diversity, and index of biotic integrity for free flowing and impounded sites of the Fox River. Jaccard's similarity index gives the proportion of fish composition similar between the impounded and free flowing site at each dam. Those sites left blank were not sampled in this study and dams listed in bold are those being removed.

	Free Flowing				Impoundment				Jaccard's
Dams	Richness	CPUE	Diversity	IBI	Richness	CPUE	Diversity	IBI	Similarity
ST. CHARLES	22	470	0.081	36					
GENEVA	23	348	0.094	45	13	113	0.146	22	0.333
N. BATAVIA	26	781	0.150	48	8	75	0.211	18	0.308
S. BATAVIA	27	996	0.117	47	11	108	0.277	23	0.310
N. AURORA	22	644	0.115	48	9	40	0.264	18	0.292
AURORA					6	43	0.494	13	

Table 2.4. Total weight and percent composition for each species caught in free flowing and impounded areas of the Fox River between St. Charles and Aurora. NW denotes species which were caught but were not weighed.

			Free Flowing		Impoundment	
Family	Common Name	Scientific Name	Weight (g)	% Comp	Weight (g)	% Comp
Catostomidae	Golden redhorse	*Moxostoma erythrurum*	27403.6	5.8		
	Northern hog sucker	*Hypentelium nigricans*	1682.0	0.4		
	Quillback	*Carpiodes cyprinus*	70233.5	14.9	9217.5	4.0
	River carpsucker	*Carpiodes carpio*	1210.0	0.3	742.0	0.3
	Shorthead redhorse	*Moxostoma macrolepidotum*	26611.7	5.6		
	Silver redhorse	*Moxostoma anisurum*	116936.8	24.8	2126.2	0.9
	White sucker	*Catostomus commersoni*	2258.6	0.5		
Centrarchidae	Black crappie	*Pomoxis nigromaculatus*	210.0	0.0		
	Bluegill	*Lepomis macrochirus*	1315.0	0.3	479.0	0.2
	Bluegill x Green sunfish hybrid	*Lepomis macrochirus x L. cyanellus*	70.0	0.0	23.0	0.0
	Green sunfish	*Lepomis cyanellus*	486.0	0.1	456.0	0.2
	Largemouth bass	*Micropterus salmoides*	193.0	0.0	1245.0	0.5
	Longear sunfish	*Lepomis megalotis*	5.0	0.0	47.0	0.0
	Orangespotted sunfish	*Lepomis humilis*	327.0	0.1	8.0	0.0
	Pumpkinseed	*Lepomis gibbosus*			15.0	0.0
	Pumpkinseed x Green sunfish hybrid	*Lepomis gibbosus x L. cyanellus*	29.0	0.0		
	Smallmouth bass	*Micropterus dolomieu*	20211.1	4.3	349.0	0.1
Cyprinidae	Bluntnose minnow	*Pimephales notatus*	338.0	0.1	6.0	0.0
	Bullhead minnow	*Pimephales vigilax*	2.0	0.0	7.0	0.0
	Carp	*Cyprinus carpio*	117589.9	24.9	200909.9	86.2
	Creek chub	*Semotilus atromaculatus*	40.0	0.0		
	Emerald shiner	*Notropis atherinoides*	NW			
	Fathead minnow	*Pimephales promelas*	8.0	0.0		
	Golden shiner	*Notemigonus crysoleucas*	15.0	0.0		
	Hornyhead chub	*Nocomis biguttatus*	51.0	0.0		
	River shiner	*Notropis blennius*			7.0	0.0
	Sand shiner	*Notropis ludibundus*	262.0	0.1		
	Spotfin shiner	*Cyprinella spiloptera*	955.0	0.2	22.0	0.0
	Spottail shiner	*Notropis hudsonius*	18.0	0.0		
	Suckermouth minnow	*Phenacobius mirabilis*	247.0	0.1		

Table 2.4. Continued

Cypriodontidae	Blackstripe topminnow	*Fundulus notatus*			NW	
Ictaluridae	Channel catfish	*Ictalurus punctatus*	50317.8	10.7	899.9	0.4
	Flathead catfish	*Pylodictis olivaris*	7002.1	1.5	3312.0	1.4
	Stonecat	*Noturus flavus*	43.0	0.0		
	Tadpole madtom	*Noturus gyrinus*	51.0	0.0	NW	
	Yellow bullhead	*Ameiurus natalis*	380.0	0.1	9.0	0.0
Moronidae	White bass	*Morone chrysops*	1144.4	0.2		
Percidae	Banded darter	*Etheostoma zonale*	136.0	0.0		
	Johnny darter	*Etheostoma nigrum*	2.0	0.0		
	Logperch	*Percina caprodes*	11.0	0.0		
	Slenderhead darter	*Percina phoxocephala*	43.0	0.0		
	Walleye	*Stizostedion vitreum*	4157.1	0.9		
Poeciliidae	Mosquitofish	*Gambusia affinis*	NW			
Sciaenidae	Freshwater drum	*Aplodinotus grunniens*	20413.2	4.3	13094.9	5.6
Total weight (g)			472408.8		232975.4	

Table 3.1. Numbers of marked fish released and recaptured from the Fox River, Illinois during 2002. Includes markings from July, September, and October 2002. Recaptures are from sampling efforts in September and October 2002. Common carp recaptured at N. Batavia FF was originally marked at S. Batavia Imp. FF = Free-flowing, Imp = Impoundment. CAP = Common Carp, SMB = Smallmouth Bass, WAE = Walleye, CCF = Channel Catfish, GOR = Golden Redhorse, SVR = Silver Redhorse, SHR = Shorthead Redhorse, RVR = River Redhorse.

	Number marked									Number recaptured			
Site	CAP	SMB	WAE	CCF	GOR	SVR	SHR	RVR	Totals	CAP	CCF	WAE	Totals
St. Charles FF	38	22	4	49	1	0	0	0	114	0	0	0	0
Geneva Imp	19	2	0	3	0	0	0	0	24	0	0	0	0
Geneva FF	15	39	5	58	16	25	0	0	158	1	0	0	1
N. Batavia Imp	35	4	0	0	0	0	0	0	39	0	0	0	0
N. Batavia FF	33	52	2	24	2	21	0	0	134	1	0	0	1
S. Batavia Imp	55	1	0	1	0	0	0	0	57	0	0	0	0
S. Batavia FF	12	39	9	73	15	24	12	3	187	0	1	1	2
N. Aurora Imp	34	0	0	1	4	1	2	2	44	0	0	0	0
N. Aurora FF	17	18	9	27	9	27	44	2	153	0	0	0	0
Aurora Imp	25	8	0	0	1	1	1	2	38	1	0	0	1
Totals	283	185	29	236	48	99	59	9	948	3	1	1	5

Figure 1.1. Impacted and reference sites for the evaluation of dam modification on physical habitat/water quality in the Fox River, Illinois. IMP = impoundment, FF = Free Flowing.

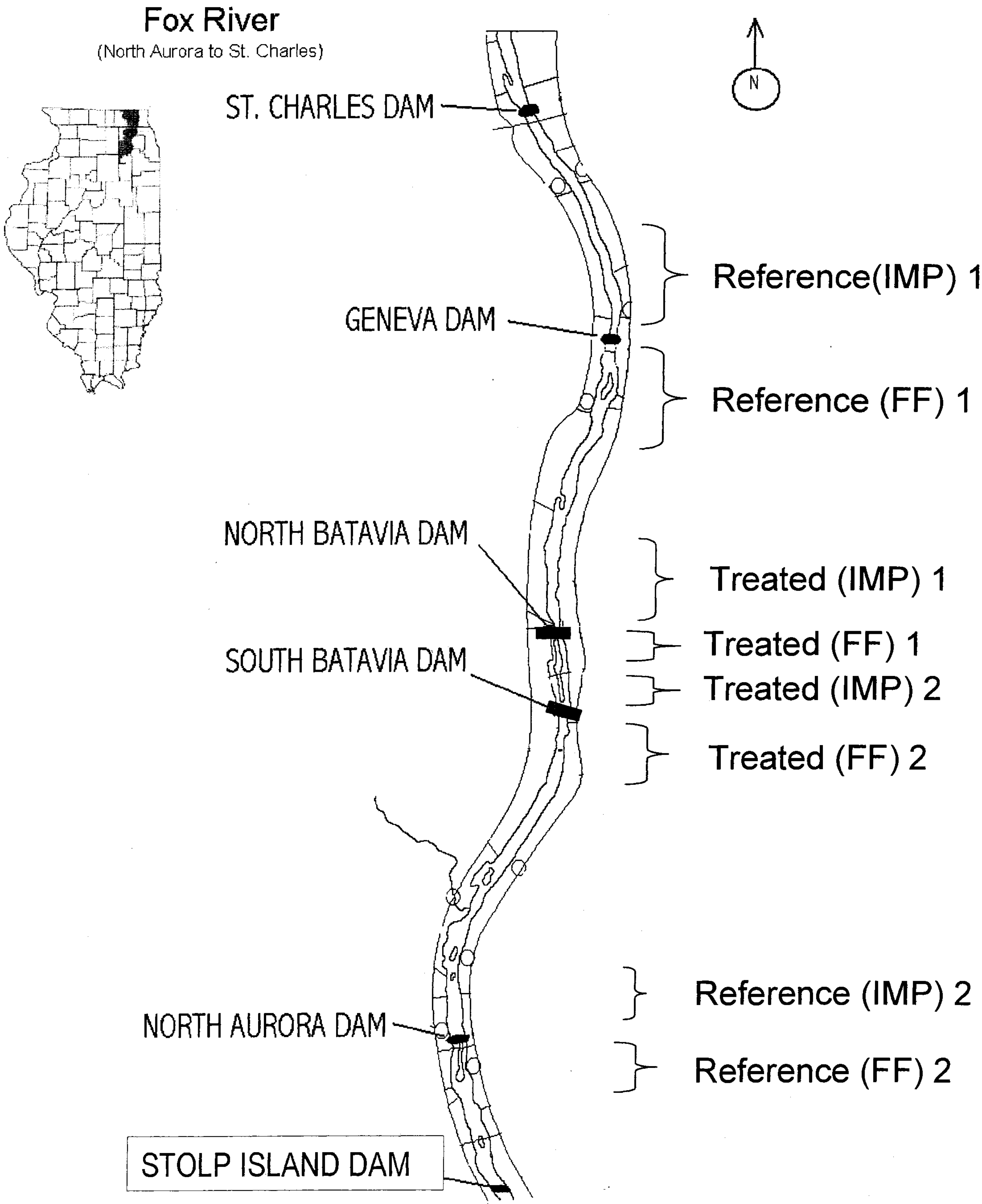
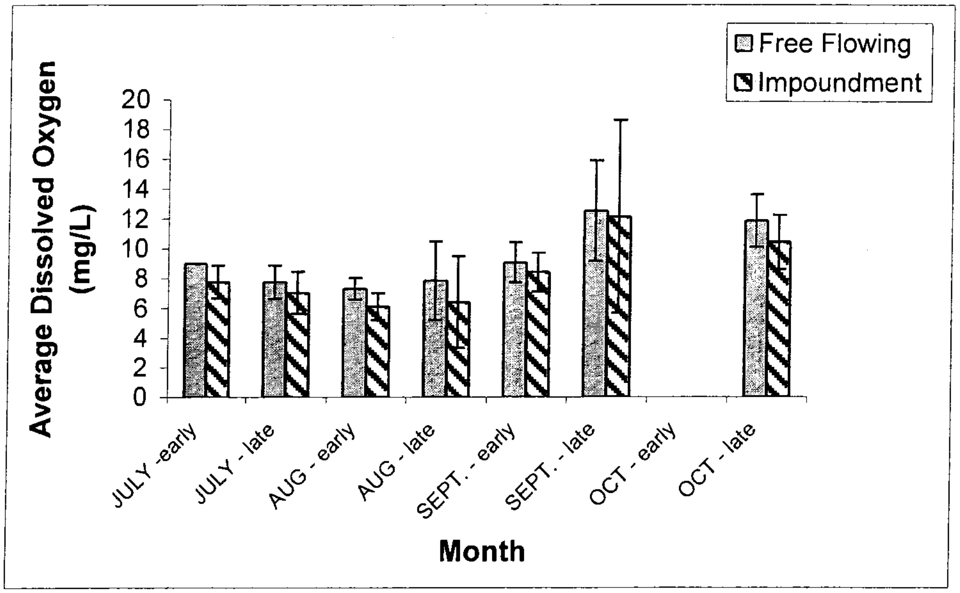


Figure 1.2 Average dissolved oxygen and total phosphorus for free flowing and impouded sites in our study area of the Fox River, Illinois.



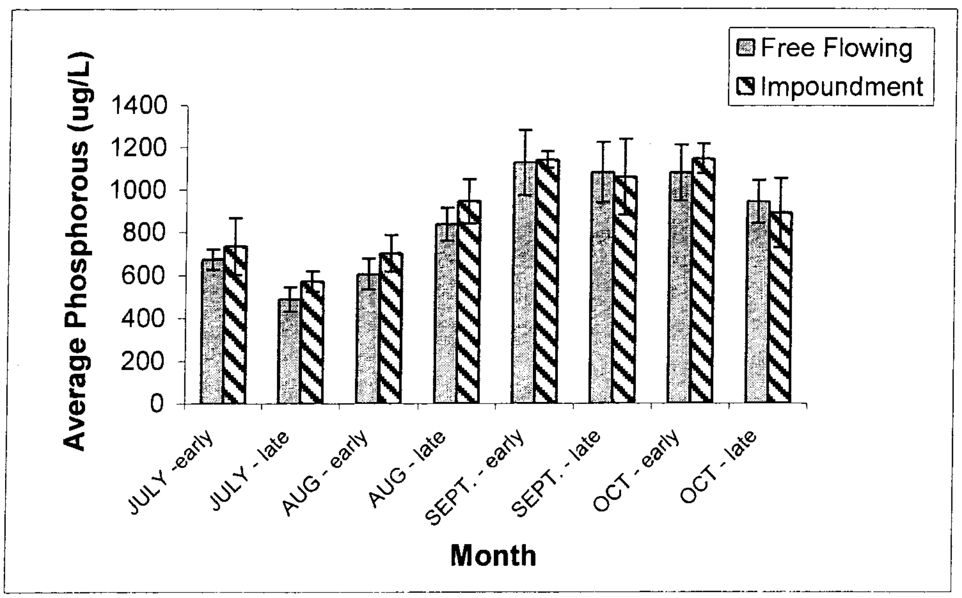


Figure 1.3. Percent unembedded (U) and embedded (E) in-stream cover for impounded (IMP) and free flowing (FF) sites of our study area in the Fox River.

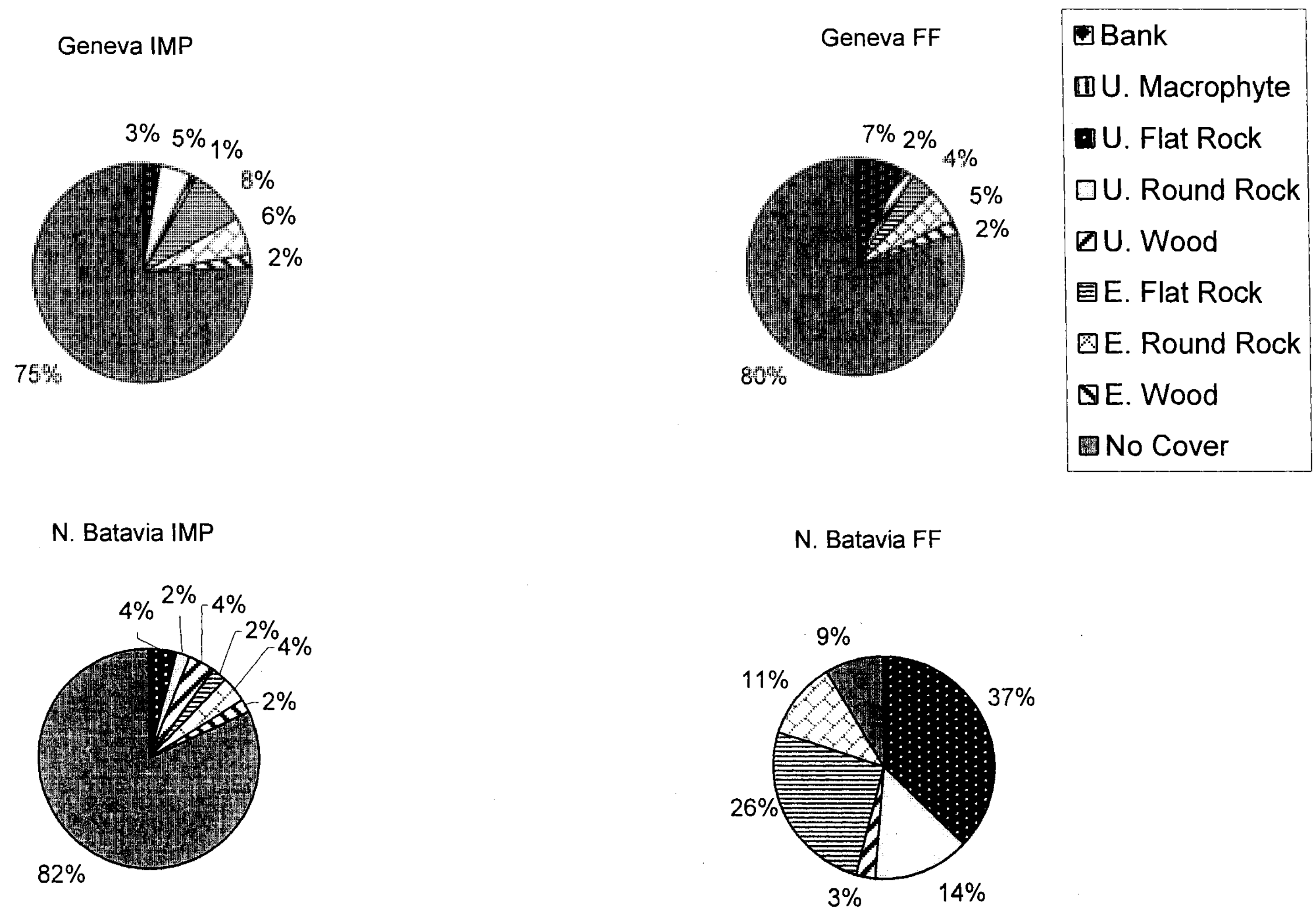


Figure 1.3. Continued.

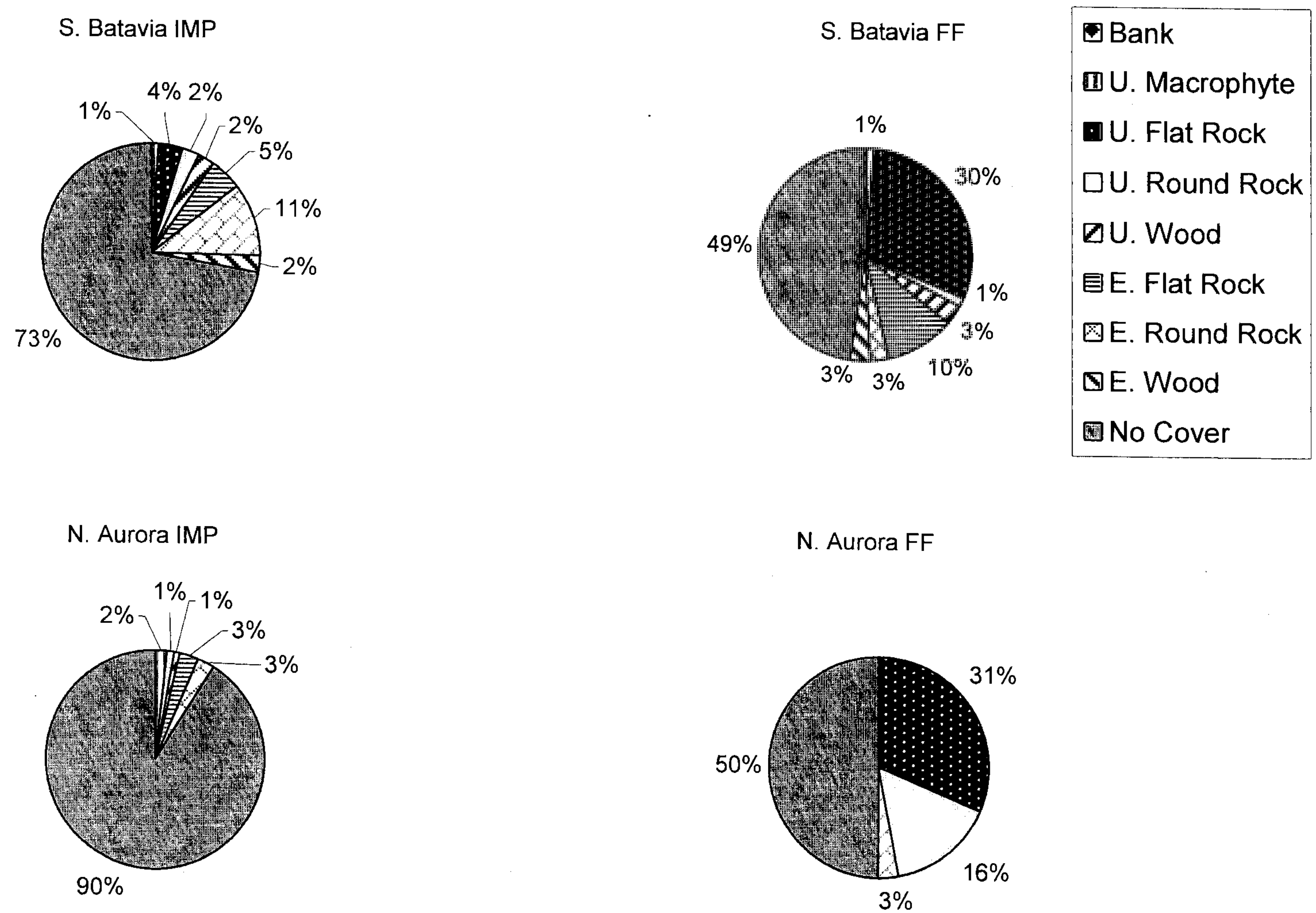


Figure 1.4. Percent in-stream vegetation for impounded and free flowing sites in our study area of the Fox River, Illionis.

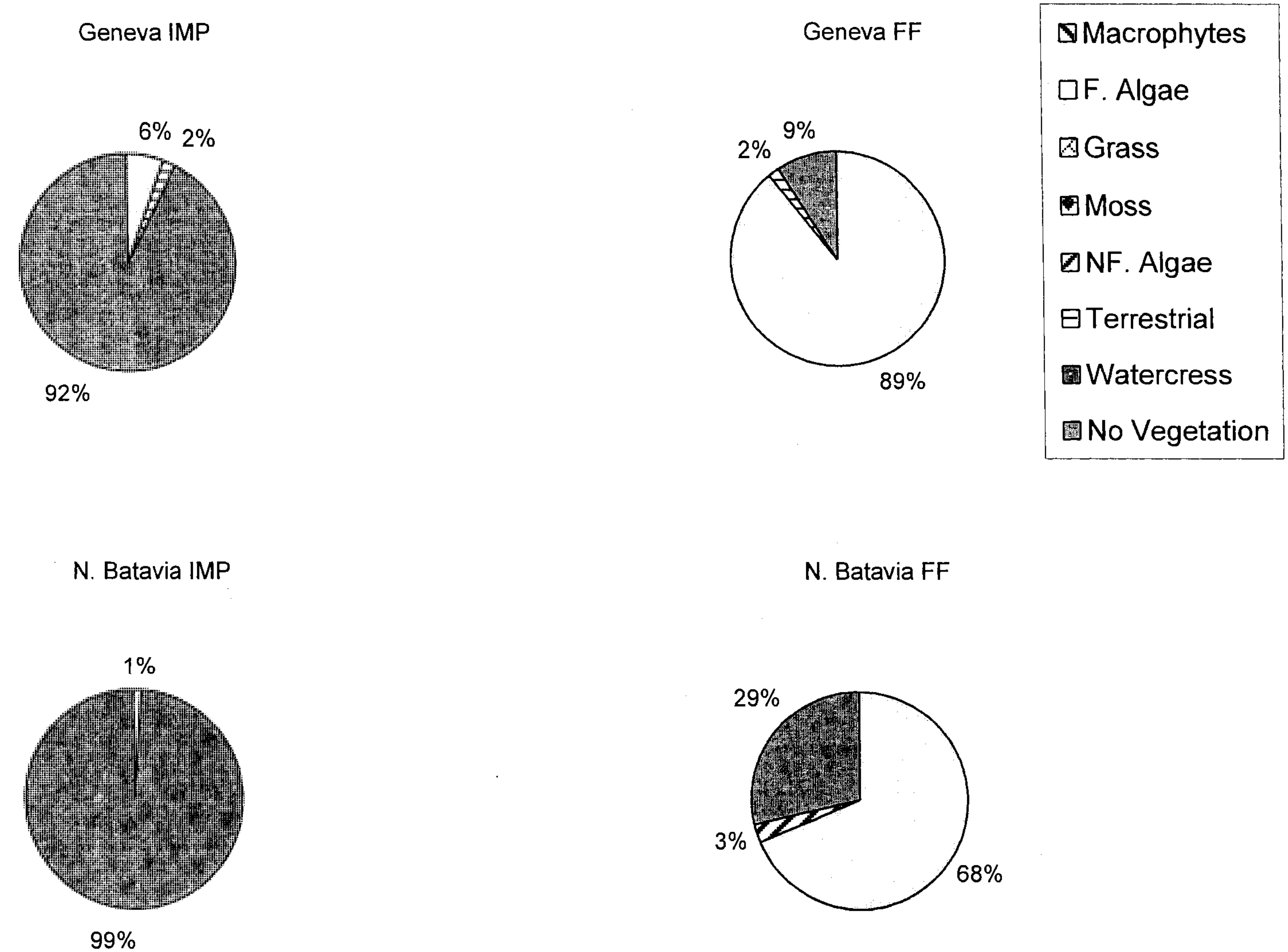


Figure 1.4. Continued.

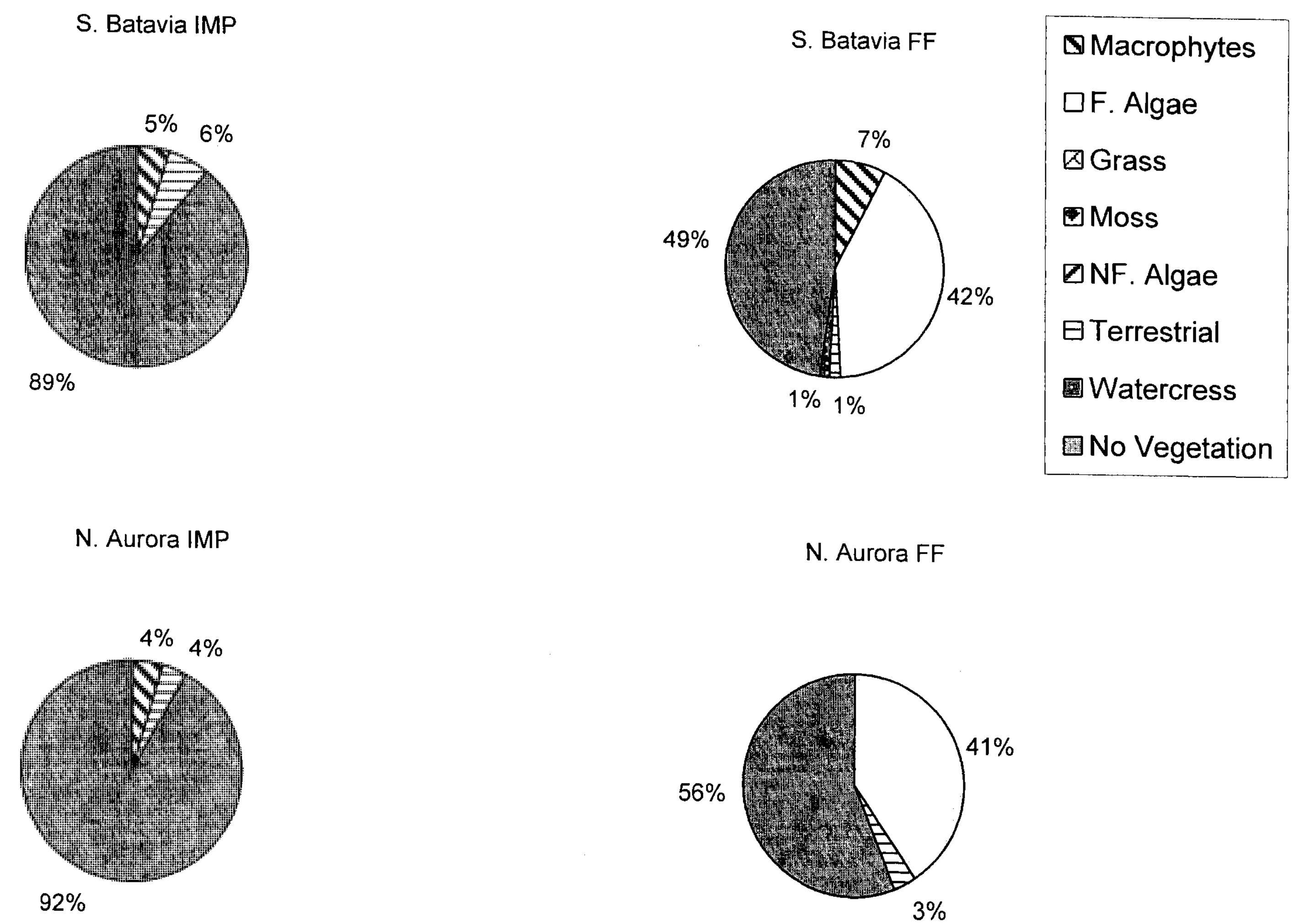


Figure 2.1. Impacted and reference reaches for the evaluation of dam modification on fish and macroinvertebrates in the Fox River, Illinois. IMP = Impoundment, FF = Free Flowing.

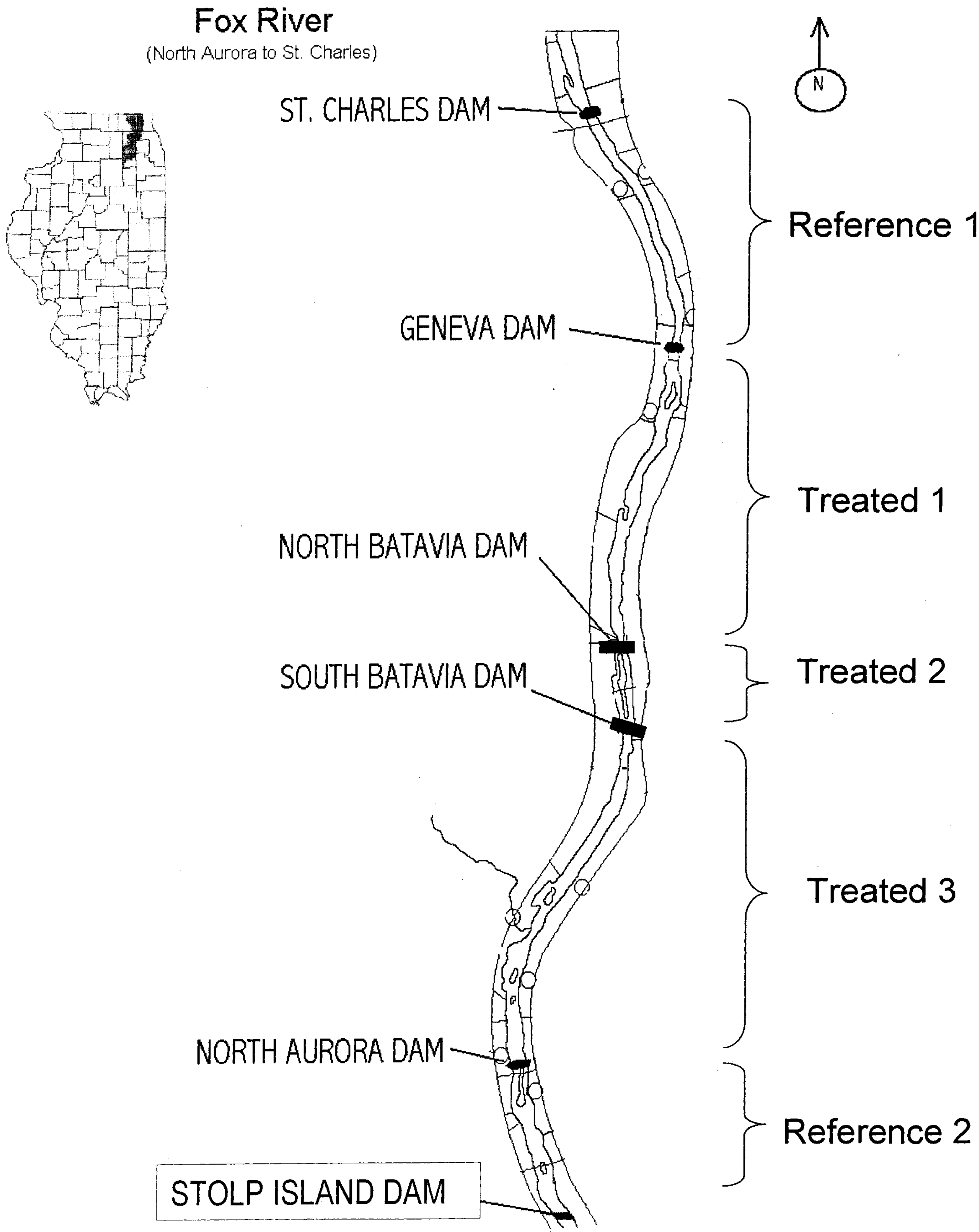


Figure 2.2. Growth of channel catfish from the Fox River at St. Charles, IL. Error bars represent one standard deviation.

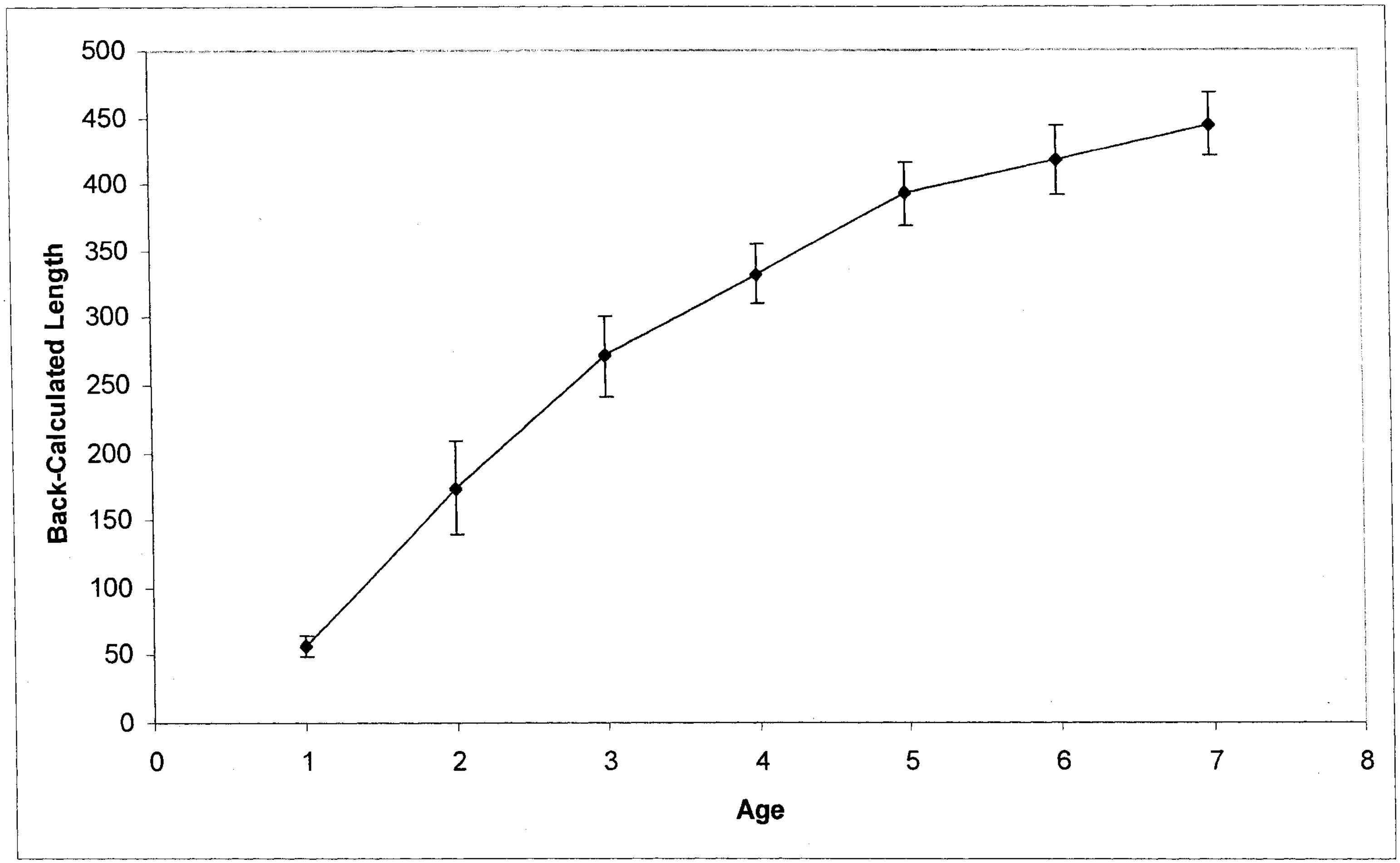


Figure 3.1. Locations of three smallmouth bass in the St. Charles free-flowing site (control site) during the fall 2002 tracking period.

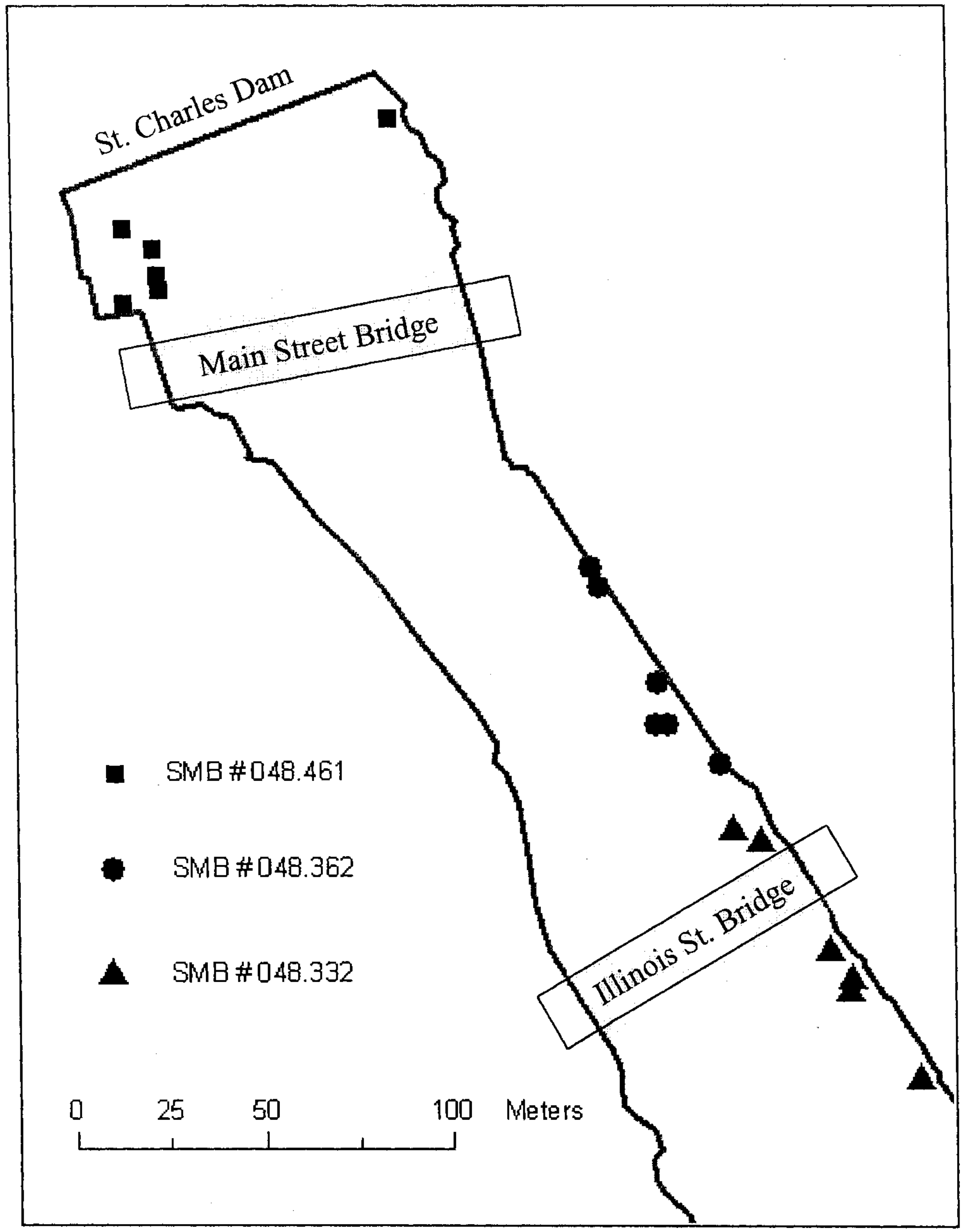


Figure 3.2. Locations of three common carp between the St. Charles free-flowing and Geneva impoundment sites (control sites) during the fall 2002 tracking period.

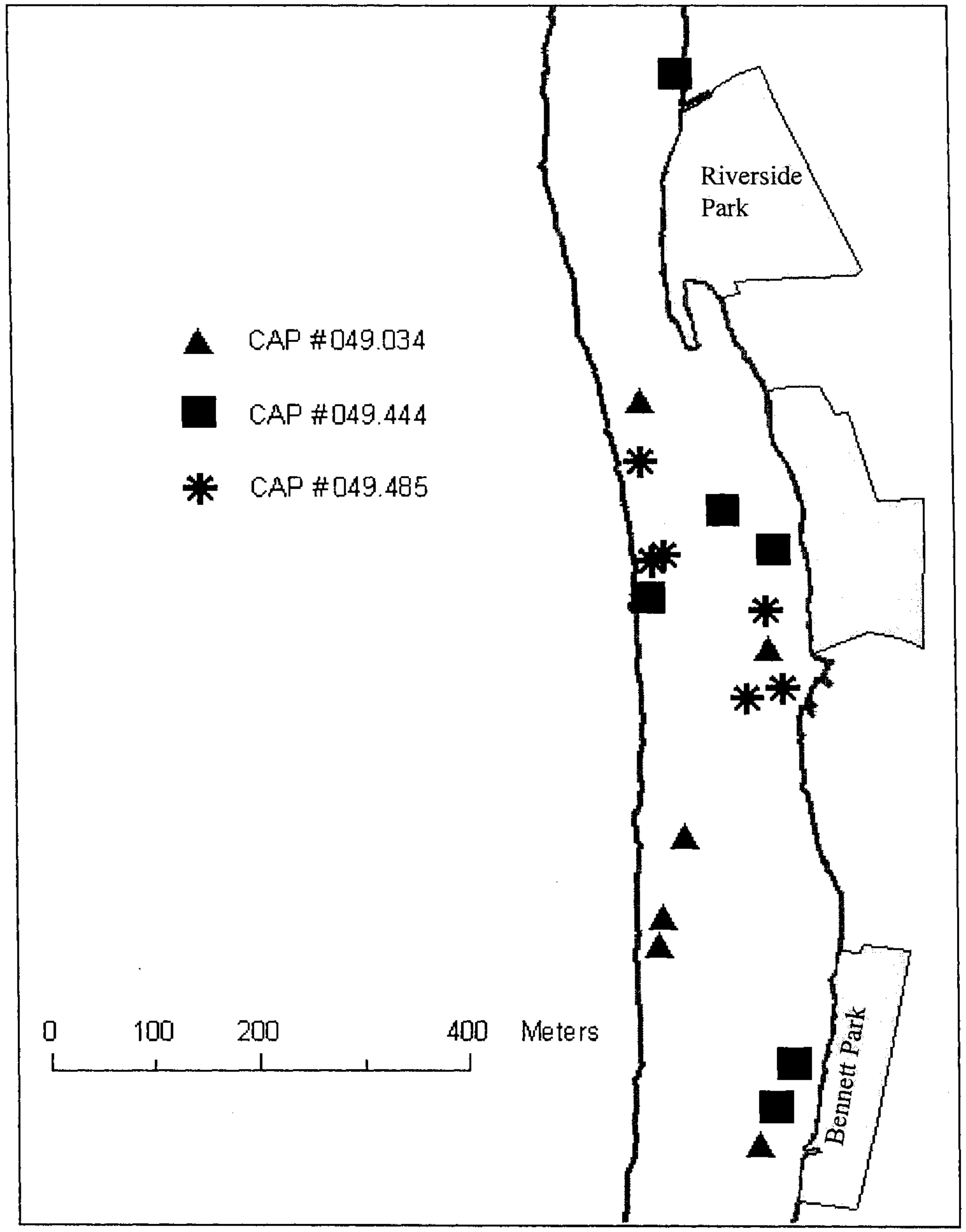


Figure 3.3. Locations of three channel catfish between the St. Charles free-flowing and Geneva impoundment sites (control sites) during the fall 2002 tracking period.