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ANNUAL PROGRESS REPORT

EVALUATION OF WATERSHED MANAGEMENT PRACTICES FOR IMPROVING STREAM QUALITY IN THE ILLINOIS WATERSHED PROGRAM

H.R. Dodd, S.L. Kohler, D.H. Wahl, G. F. McIssac, J.H. Hoxmeier, and D. Roseboom

Submitted to
Division of Fisheries
Illinois Department of Natural Resources
Federal Aid Project F-136-R

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Executive Summary

The Pilot Watershed Study contains five jobs: 101.1 Effects of Best Management Practices (BMPs) on physical/chemical indicators of stream quality, 101.2 Effects of BMPs on fish community structure, fish abundance, and population size structure, 101.3 Effects of BMPs on fish growth rates, 101.4 Effects of BMPs on benthic macroinvertebrates community structure and crayfish abundance, and 101.5 Analysis and reporting.

These jobs (except Job 101.5) were completed at each sampling site. In each of the four basins in this study, we monitored four sites: two in the Pilot Watershed (treated with BMPs) and two in the Reference Watershed (control). In the Pilot Watershed, one site is located downstream to assess watershed-scale effects of BMP implementation at a larger drainage area and a second site was sampled upstream in the watershed. In the Reference Watershed, two sites were sampled at similar positions in the watershed as the sites in the Pilot Watershed. The length of each site was defined as 20 times the mean bankfull width (W_{bf}) at the site (see also Lyons 1992, Simonson et al. 1994, Gough 1997).

In Job 101.1, physical and chemical habitat data were collected from the pilot (treated) and reference (control) streams. Habitat variables were divided into two categories: site-scale and transect-scale. Site-scale parameters are considered as habitat characteristics which change very little over the reach of stream (e.g. temperature, discharge, etc.) being sampled and, thus, were collected at one location in the site. Transect-scale variables are those which are expected to vary considerably within a site (e.g. substrate, channel width, etc.) and were measured along 10 transects within the site. Data analysis of both site-scale and transect-scale habitat characteristics is ongoing and will be presented in future reports.

In Jobs 101.2 and 101.3, fish and crayfish were collected in autumn of 1998 with an AC electric seine and structures for aging were taken from all fish caught. Fish community structure in treated and reference streams was evaluated by number of species present and similarity in fish composition between corresponding sites in treated and reference streams. Catch per unit effort (CPUE) was computed for each site sampled and averages were used to detect any differences in fish abundance between treated and reference sites before implementation of BMPs. All fish were measured (total length) and weighed except when numbers of a species were high, then, the first 100 were measured and the remaining fish were counted. Fish greater than 100 mm in total length were measured in the field, while smaller fish were preserved in ethanol and measured in the lab after identification. Average lengths and weights were used to assess size structure differences between treated and reference streams within a basin. Index of Biotic Integrity (IBI) scores were also used to examine the quality of the aquatic resource at study sites. Determination of fish growth rates is ongoing and will be presented in subsequent reports.

In Job 101.4, benthic macroinvertebrates samples were collected in autumn of 1998 and spring of 1999 to evaluate pre-BMP community structure and abundance in treated and reference streams. Samples were collected from soft sediment areas (i.e. silt, sand, very small gravel) using a core sampler and collected from hard substrate areas (i.e. larger gravel and cobble) with a Hess or Surber sampler. Currently, samples are being elutriated and insects are being picked for identification. When possible, individuals will be identified to the species level. Community structure and species abundance will be analyzed after identification.

Job 101.1 Effects of BMPs on physical/chemical indicators of stream quality.

OBJECTIVE

To determine local and watershed-wide responses of physical/chemical factors to the implementation of watershed management practices.

INTRODUCTION

Despite the success of the Clean Water Act in markedly reducing the impacts of point source pollution on freshwater ecosystems, many lotic systems in the United States remain in a degraded condition, largely as a result of nonpoint or diffuse sources of pollution. The majority of water pollution problems in the United States are now attributed to nonpoint sources (USEPA 1990). Sources of diffuse pollution include runoff from agricultural fields, logging activities, and urban areas (e.g., construction sites). The most significant types of nonpoint source pollution include excessive inputs of sediment, nutrients, and pesticides. Nonpoint source pollution from agricultural practices is regarded as the dominant form of pollution currently impacting rivers and lakes in the country (USEPA 1995).

In agricultural landscapes, on-field and off-field techniques (termed best management practices [BMPs]) for reducing nonpoint source pollution are well known (see Gale et al. 1993). Also, instream practices for stabilizing stream banks, increasing habitat diversity, etc., for improving water quality and enhancing fish production have received considerable study, especially in coldwater streams (NRC 1992, Hunt 1993). However, the majority of studies on BMPs were conducted at the plot or field scale, over relatively short time frames (e.g., Magette et al. 1989). Very few studies have addressed the impacts of BMPs at the watershed scale (Muscutt et al. 1993, Tim et al. 1995) or on a large temporal scale (Muscutt et al. 1993, Osborne and Kovacic 1993). The Pilot Watershed Study is designed to examine physical and chemical water quality as well as biotic indicators at the watershed levels across a long temporal scale.

PROCEDURES

Physical/chemical habitat data were collected using two levels of sampling: site-scale and transect-scale. Site-scale parameters (Table 1) were collected at one location in the site (e.g., water temperature, discharge) and are assumed to be representative of the entire site, or are based on maps of the entire site (e.g., total length of riffles, sinuosity). Some variables are assumed to be constant over the duration of the study and were measured only once (Table 1).

Transect-scale variables are those which are expected to vary considerably within a site (Table 2). These variables, which pertain to stream channel morphology, bottom substrate, cover for fish, macrophyte abundance, condition of stream banks, and riparian land use/vegetation, were measured on ten, equally spaced transects perpendicular to the flow. The Stream Assessment Protocol for Ontario (Stanfield et al. 1998) was used to sample these habitat variables. Detailed methods for each parameter are given in Table 2. All transect-scale parameters were measured in autumn of 1998 after fish sampling had been conducted and will be sampled once/year during the study.

Responsibility for site-scale habitat sampling has been divided among the Illinois Natural History Survey (INHS) and the Illinois State Water Survey (ISWS). INHS is responsible for measuring site scale parameters 1- 7 (Table 1). Drainage area, stream order, and site length were measured in 1998. Temperature loggers were installed in spring of 1999. Sinuosity, stream slope, and total length of riffles, runs, and pools have yet to be computed. ISWS is responsible for measuring and analyzing site-scale parameters 8-12 (Table 1). Gauging stations are being installed in 1999 to measure these habitat variables. Transect-scale habitat variables have been measured and recorded.

FINDINGS

Data entry and analysis of the 1998 and 1999 habitat data has not been completed at this point. Analysis will be presented in future annual reports.

RECOMMENDATIONS

Additional collection of pre-BMP habitat data is needed and will be collected during late summer and early autumn of 1999. Gauging stations should be completed and the remaining site-scale water quality data should be obtained this year. These data will be used to assess changes in habitat and chemical parameters following implementation of BMPs.

Job 101.2 Effects of BMPs on fish assemblage structure, fish abundance, and population size structure.

OBJECTIVE

To determine the watershed-wide responses of the stream fish assemblage and fish populations of select species to the implementation of watershed management practices.

INTRODUCTION

Most studies on the effects of BMPs have been implemented on small spatial (e.g. reach-scale) and temporal scales (e.g., Magette et al. 1989). In the few studies that were performed at larger spatial (e.g., watershed) and temporal scales, the emphasis has been on effects of BMP implementation on physical parameters (e.g., nutrient concentration, sediment yield) (see Trimble and Lund 1982, Gale et al. 1993, Walker and Graczyk 1993, Park et al. 1994, Cook et al. 1996, Edwards et al. 1996, Meals 1996, Bolda and Meyers 1997). Responses of the biota to watershed-wide implementation of BMPs have been considered much less frequently, but a number of observational, correlative studies suggest that fish and invertebrates should respond strongly to changes in land use practices within watersheds (Lenat and Crawford 1994, Rabeni and Smale 1995, Richards et al. 1996, Roth et al. 1996, Allan et al. 1997, Barton and Farmer 1997, Wang et al. 1997).

Currently, there is a lack of a conceptual framework for understanding how ecological processes operating at large spatial and temporal scales affect stream fish populations (Schlosser 1995). Most studies of stream fish have been conducted at relatively small spatial scales, but it is clear that processes operating at large scales (e.g., land use in a catchment) can strongly affect the integrity of stream fish communities (Roth et al. 1996).

Implementation of BMPs in watersheds should minimize the impacts of nonpoint source pollution on surface waters. Accomplishing this will require a much greater understanding of the large-scale effects of BMPs on biotic as well as the more traditionally used physical attributes of aquatic systems.

PROCEDURES

At each site, fish and crayfish were collected with a single pass using a standard AC electric seine (Bayley et al. 1989). The length of each site was approximately 20 times the mean bank full width (Lyons 1992, Gough 1997). Block nets were placed at locations upstream and downstream of the site to increase the effectiveness of the sampling. A single pass was used instead of a triple pass depletion method due to the extensive time and labor required for the latter method. Simonson and Lyons (1995) conducted a quantitative comparison of these two types of sampling and found that CPUE provided the same values for species richness and percent species composition as depletion sampling, but captured significantly fewer total fish. However, CPUE sampling took only one quarter the time of depletion sampling. Attempts will be made to use these CPUE values for quantitative estimates of fish abundance using gear calibration methods (Bayley and Dowling 1990).

Fish and crayfish samples were collected in August – November (autumn) 1998 (Table 3). In 1999, samples will be collected in late summer to early autumn. Captured fish and crayfish were identified to species, counted, and lengths and weights were taken. When the number of fish caught of a particular species was high, the first 100 fish were measured and the remaining fish were counted. For selected species, age structures (e.g. scales, fin rays, etc.) for age and growth analysis were collected (see Job 101.3). Fish larger than 10g were processed and released whereas smaller fish were preserved in ethanol and taken to the laboratory for similar processing.

For assessment of fish assemblage structure and differences in structure between treated and reference streams, species richness data and two separate similarity indices were used. The Jaccard Similarity Index (J), based on presence/absence data, was calculated using the formula:

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

where A is the number of species in site A, B is the number of species in site B, and C is the number of species in common. A second similarity index was the Similarity Ratio (SR_{ij}) which takes into account the abundance of each species within the two sites being compared and was calculated using the formula:

$$SR_{ij} = \Sigma_k y_{ki} y_{kj} / (\Sigma_k y_{ki}^2 + \Sigma_k y_{kj}^2 - \Sigma_k y_{ki} y_{kj})$$

where i and j are two sites, y_{ki} is the abundance of the k-th species at site i, and y_{kj} is the abundance of the k-th species at site j. For both similarity indices, a value of one indicates the species composition are exactly the same in both sites and a value of zero indicates no similarity in fish assemblages between the two sites being compared.

To analyze differences in overall fish abundance in treated and reference sites catch per unit effort (CPUE) was computed and tested using a Tukey's Studentized Range test. Evaluating fish size structure, size ranges and average length and weight for each species was computed and compared between corresponding treated and reference sites. The Index of Biotic Integrity (IBI) was calculated using fish community data to estimate the overall health of the aquatic ecosystem at each study site.

FINDINGS

Fish Assemblages

In 1998, a total of 14,784 fish and 58 species were caught among all basins (Table 4). The Embarras basin made up 53% of the total catch and included 32 species (Table 5). All sites in the Embarras basin were similar in numbers caught and species richness with the exception of the Hurricane Upper site which had approximately 2 times more fish and 1.5 times less species than the other sites. The Spoon basin contained 35% of the total fish catch and included 32 species (Table 6). Species richness was relatively similar among the sites in the Spoon basin, but numbers of fish were highest in the Court lower site. The Cache basin contained the fewest number of fish at 12% of the total and included 29 species (Table 7). Within the Cache basin, the lower site of Big Creek contained the fewest number of fish and the fewest species.

Combining upper and lower sites across all treated and reference streams, treated (those which will have BMP implementation) and reference streams were similar in average numbers of species present although reference streams showed a slightly higher species richness at both upper and lower sites (Table 8). As expected, sites lower in the watershed regardless of stream type (treated or reference) contained a few more species on average than sites in the upstream location of the watershed.

To assess similarity in species composition between treated and reference sites, Jaccard's Similarity Index and Similarity Ratios were calculated (Table 9, Table 10). Based on Jaccard's index, the species composition between lower sites of treated and reference streams (striped bars) were highly similar in the Embarras and the Spoon basins with values around 0.75 (Figure 1). The Cache basin had a low similarity value between the lower sites with a Jaccard value of 0.25. In all three basins, the similarity in species composition was relatively high between the upper sites of treated and reference streams (solid bars) with values ranging from 0.52 to 0.60 (Table 9, Figure 1). Combining the three basins into an average Jaccard's Similarity Index for comparisons of upper and lower sites between treated and reference streams, we found that the mean community similarity between lower sites of treated and reference streams (TL v. RL) was highest at a mean similarity of 0.57 (Figure 2). The lowest similarity was between upper and lower sites within the treated streams (TL v. TU). Based on an Analysis of Variance (ANOVA) and a Tukey's Studentized Range test similarity in species composition was not significantly different between the four mean Jaccard index values, indicating that variation in species composition across the two stream types (treated or reference) was similar to the species composition within a stream type ($P = 0.919$, $\alpha = 0.05$). Standard errors of the means were relatively low except for the comparison between lower sites of treated and reference streams due to the low similarity between Big lower and Cypress lower sites.

Similarity Ratios, which take into account abundances of each species, were lower overall than those based on Jaccard's index (Table 10). However, the pattern for comparsion of lower sites between treated and reference streams resembled the results obtained from Jaccard's Similarity Index. Fish composition between the lower sites showed similar values of 0.38 for the Embarras and 0.32 for the Spoon, but the Cache basin had a lower similarity value of 0.10 (Table 10). Comparisons of the upper sites within each basin using Similarity ratios showed a slightly different pattern than that shown by Jaccard's index. With Jaccard's index all three basins had relatively similar index values, but comparing similarity ratios between the upper sites across the three basins, the Spoon basin shows a relatively high similarity in species composition between the two upper sites with a value of 0.45, which is higher than the similarity ratios calculated for comparing the lower sites in each basin. Using abundance of the species present in the upper sites, we find that Court upper and Haw upper sites are the most similar in their fish assemblages.

Fish Abundance

To analyze the pre-BMP conditions in overall fish abundance in treated and reference streams, catch per minute of shocking time was calculated for each site and mean CPUE was used to assess differences between the four sites (treated upper, treated lower, reference upper, reference lower) (Table 11, Figure 3). Reference streams showed a pattern of higher CPUE in the lower sites in all three basins, while treated streams showed no discernible pattern between upper and lower sites across all basins (Table 11). The Cache basin showed the lowest CPUE at all sites, while the Embarras showed the highest CPUE at all sites except the treated lower site (Hurricane lower) (Table 11, Figure 3). At the Hurricane lower site electroshocking effort had to be estimated due to equipment problems which may explain the lower CPUE. Averaging across basins, the treated upper site has the highest CPUE followed by the treated lower site. Although the sites on the reference streams were found to be more species rich on average (Table 8), the two reference sites showed low mean CPUE (Figure 3). However, the differences in mean CPUE between the four sites were found not to be significantly different from each other (ANOVA, $P = 0.520$, $\alpha = 0.05$).

The analysis of species richness, similarity in fish composition, and CPUE between treated sites and their corresponding reference sites indicates that our treated and reference streams are similar and that our pairings are well matched for examining differences in fish assemblages after BMP implementation.

Fish Size Structure

Lengths and weights of each species caught were averaged for each site and lower and upper sites were compared within each basin to determine differences in size structure between treated and reference streams. Comparing the lower sites of the Embarras basin, blackstripe topminnow, bluegill, spotted bass, and striped shiner were found to be on average longer and heavier in Hurricane Creek (treated) than in Kickapoo (reference) (Table 12, Table 13). Central stoneroller, johnny darter, largemouth bass, longear sunfish, and northern hogsucker were smaller and weighed less in Hurricane lower than in Kickapoo lower site. In the two upper sites of the Embarras (Hurricane upper and Kickapoo upper), blackstripe topminnow, redfin shiner, and the silverjaw minnow were larger and heavier in Hurricane, while central stoneroller, orangethroat darter, steelcolor shiner, striped shiner, and suckermouth minnow were smaller and weighed less in Hurricane Creek. For both lower and upper sites in the reference stream of the Spoon basin (Haw Creek), a majority of species were found to be on average either longer and heavier than or similar to those in Court Creek (Table 14, Table 15). In the lower sites of the Cache basin, size structure of most species which were found in both lower sites were similar (Table 16, Table 17). Some exceptions were the pirate perch and the white sucker, which were shorter and weighed less in the treated lower site (Big lower). Largemouth bass, longear sunfish, and mosquitofish were found to be longer and heavier on average in the treated lower site compared to its corresponding reference site (Cypress lower). In the upper sites of the Cache basin, average length and weight of most species were either higher in the treated site (Big upper) or similar between sites. The three species which did show greater length and weight in the reference site (Cypress upper) were bluegill, bluntnose minnow, green sunfish. Overall, there was no consistent pattern in size structure for any individual species across all basins.

Fish Community

To assess the quality of the fish community, the Index of Biotic Integrity (IBI) was computed for each site. Of the 12 sites sampled, three sites attained scores greater than 51 of a possible 60 (Table 18). Seven sites showed scores ranging from 41 to 51, and two sites had scores between 31 and 41. Overall, the sites in the Embarras basin had the highest IBI scores with both reference sites and the treated lower site having very similar IBI scores ranging from 52 to 54. The lower site in Hurricane Creek had a lower score at a value of 46, but this score still suggests that the upper and lower sites within the Embarras basin are similar in overall community health. Court and Haw Creeks in the Spoon basin were also found to be relatively similar in quality with scores ranging from 40 to 50. The lowest score in the Spoon basin occurred in the Haw upper site, in which cattle have access to the stream increasing bank erosion and nutrient loading. However the quality of this site was still found to be similar to the upper site in Court Creek. Sites in the Cache basin were also found to be relatively high in community quality despite their lower species richness and catch per unit effort. Three of the four sites had scores of 48 with the Big Creek lower site having the lowest score at 38. In general, both reference and treated streams within each basin were very similar in IBI scores with most sites showing a high stream quality. Currently IBI metrics used in Illinois streams are being reevaluated and a new IBI scoring criteria will be established. This improved scoring criteria may cause scores to change slightly for some study streams.

RECOMMENDATIONS

To assess the changes in fish assemblage in these treated watersheds, further pre-BMP data will need to be collected and analyzed. Baseline data is key to the Before-After-Control-Impact-Pairs study design (BACIP) 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 (defined as the difference between the average before and after differences between the treatment and control sites), and the variability in the differences between 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. In late summer 1999, additional fish data will be collected and added to the 1998 pre-BMP data.

Job 101.3. Effects of BMPs on fish growth rates.

OBJECTIVE

To determine the local and watershed-wide responses of fish growth rates of select species to the implementation of watershed management practices.

INTRODUCTION

Only a small number of large-scale studies have addressed watershed management practices on fish populations and, thus, a greater understanding of how processes operating at large spatial and temporal scales affect stream fish is necessary. Our study will further examine the impacts of BMPs on fish populations by evaluating differences in growth rates before and after BMP implementation. In addition to species composition, abundance, and size structure of stream fish, growth rates are also a good indicator of improved stream quality. Species composition and abundances may change from year to year within a site, but growth rates can be tracked for the life of a fish providing us with a history of the stream conditions before the study began. Thus, growth rates may be a better measure of improvements in stream quality than species composition and abundances.

PROCEDURES

Growth rate changes will be evaluated for selected fish species associated with the implementation of watershed management practices at each of the sites. Fish for aging analysis will be selected from those collected in Job 101.2. Based on the 1998 fish data, the most common species that are abundant across sites will be chosen for analysis. In 1998, various aging structures (i.e. scales, spines, and otoliths) were collected from all fish to determine which bony structure was most suitable for aging a particular species. A minimum of 30 individuals are being aged for each species and site.

For selected species, about ten scales or the left pectoral spine were removed from each individual for aging and back-calculation. Scales will be impressed on acetate slides and spines sectioned. Radii and interannular distances will be recorded with a digitizing tablet connected to a computer. Replicate measurements from each scale will be averaged for each fish. A subsample will be aged by a second person to verify age estimates. Lengths at each previous year will be backcalculated from the averaged scale measurements using the Fraser-Lee method. Using backcalculated values, age-specific growth rates will be compared before and after implementation of the watershed management practices at both the control and impact sites. In addition, annual size-specific growth will be determined for two sizes for each selected species (Putman et al. 1995). Sizes chosen will encompass the range in which known ontogenetic diet and habitat shifts occur with a small size approximating growth of age-1 fish and large size approximating growth at the onset of maturity. These size-specific growth rates often provide more ecologically meaningful comparisons than age-specific growth rates (Putnam et al. 1995). These estimates will also be used to assess effects of watershed management practices on stream fish growth.

FINDINGS

Age structures collected from fish in 1998 are currently being analyzed. Using the data on distribution and abundance of fish species collected in 1998 as well as the accuracy and ability to age the different types of bony structures (i.e. scales, fin rays, otoliths, etc.), we will decide which fish species as well as the type of age structures to collect for each species for the 1999 field season.

RECOMMENDATIONS

Before particular species can be selected for age and growth analysis, some age structures will need to be analyzed for commonly found species in order to determine the correct age structure to collect. In the 1999 field season, additional structures will need to be taken for pre-BMP growth analysis.

Job 101.4. Effects of BMPs on benthic macroinvertebrate community structure and crayfish abundance.

OBJECTIVE

To determine the local and watershed-wide responses of benthic macroinvertebrates, including crayfish, to the implementation of watershed management practices.

INTRODUCTION

Most studies of stream biota have been conducted at relatively small spatial scales, but it is clear that processes operating at large scales (e.g., land use in a catchment) can strongly affect the integrity of stream fish (Roth et al. 1996) and invertebrate (Richards et al. 1996) assemblages. To further assess the effects of BMPs on stream quality in these Pilot watersheds, benthic macroinvertebrates are being monitored. There are a number of reasons to include benthic invertebrates in a monitoring program. First, because of short generation times and high intrinsic population growth rates, invertebrates should respond more quickly to improvements in water quality than fish. Second, as discussed above, the power of the BACIP design to detect treatment effects strongly depends on the number of sampling dates before and after implementation of BMPs. Because serial correlation associated with frequent sampling should be less of a concern with short-lived invertebrates than with fish (Stewart-Oaten et al. 1992, Osenberg et al. 1994), invertebrates can be sampled more frequently, as we have proposed, to increase the power of the BACIP design. Third, because most stream fish ultimately depend on benthic invertebrates as a food source, invertebrate monitoring will provide a mechanistic understanding of improvements observed in fish assemblage structure (Job 101.2).

PROCEDURES

Benthic macroinvertebrates, other than crayfish, were sampled at each site from riffle, glide, and run habitats in autumn (September – November) of 1998 and spring (May – early June) of 1999 (Table 19). Crayfish were sampled from the entire site by electrofishing as described in Job 101.2. Large gravel – cobble substrates (riffle or run habitats) were sampled using a Surber sampler in 1998 (with exception of Kickapoo Creek) and a Hess sampler in 1999 equipped with a 300 μm mesh net. Fine gravel – sand/silt substrates (run or glide habitats) were sampled with a coring device. Each habitat type was sampled in proportion to its relative availability in the site with a maximum of fifteen samples (cores and hess/surber samples combined) collected at a site. In spring 1999, depth and hydraulic head was also recorded at the location of each sample. Samples were preserved in the field in their entirety with 4% formalin. Benthos samples will be also be taken in summer and autumn of 1999.

Procedures recommended by Wrona et al. (1982) and Thrush et al.(1994) were used in laboratory processing of the samples. All samples collected within the same habitat type (i.e. riffle, run, glide) at a site/date will be pooled. Core samples are elutriated and sorted from organic debris using a dissecting microscope at 10X before pooling and identification of the samples. Hess or Surber samples are also elutriated and then subsampled using an imhoff cone apparatus (Wrona et al. 1982). Subsamples from Hess/Surber samples will then be identified.

Analyses will include trends in the abundance of all invertebrates pooled and individual taxa, and in a number of indices of invertebrate assemblage integrity (e.g., the EPT index and the Macroinvertebrate Biotic Index (MBI) for Illinois streams).

FINDINGS

Three of the four basins were sampled for benthos in autumn 1998 and spring 1999. The fourth basin, Kaskaskia, will be sampled for benthos starting with the summer 1999 sample in early to mid August. Currently, we are elutriating, sorting, and identifying samples in the laboratory. To determine adequacy of our estimates of true macroinvertebrate abundance from core samples, we ran a bootstrap method on two sites using various sample sizes (Figure 4). At the Hurricane lower site, standard error reached 20% of the mean around a sample size of 8.4, suggesting that approximately 9 core samples are sufficient at estimating true abundance in that site (within 20% error). For Kickapoo lower, the standard error of the mean of 100 replicates never reached 20% of the mean. Based on the mean and variance of macroinvertebrate numbers in the cores of the Kickapoo lower site, 15 samples were needed to reach a standard error of 20% of the mean.

RECOMMENDATIONS

Sorting and counting of additional samples will be needed to determine if the number of core samples taken in autumn 1998 and spring 1999 are sufficient to estimate the abundance of the macroinvertebrate community. Collection of additional benthos samples will also be necessary for analysis of pre-BMP communities in both treated and reference streams. Macroinvertebrate samples collected in 1998 and 1999 will be processed and analyzed during the next segment of the study.

Job 101.5. Analysis and reporting.

OBJECTIVE

To prepare annual and final reports that summarize work accomplished and evaluate the effectiveness of watershed management practices for improving water quality.

Data were analyzed and reported within individual jobs of this report (see Job 101.1-101.4).

REFERENCES

Allan, J. D., D. L. Erickson, and J. Fay. 1997. The influence of catchment land use on stream integrity across multiple spatial scales. Freshwater Biology 37:149-161.

Barton, D. R., and M. E. D. Farmer. 1997. The effects of conservation tillage practices on benthic invertebrate communities in headwater streams in southwestern Ontario, Canada. Environmental Pollution 96:207-215.

Bayley, P. B., R. W. Larimore, and D. C. Dowling. 1989. Electric seine as fish sampling gear in streams. Transactions of the American Fisheries Society 118:447-453.

Bayley, P. B., and D. C. Dowling. 1990. Gear efficiency calibrations for stream and river sampling. Illinois Natural History Survey, Technical Report 90/8, Champaign, Illinois, USA.

Bolda, K. S., and W. J. Meyers. 1997. Conducting a long-term water quality monitoring project: a case study on the McCloud River, California. Journal of Soil and Water Conservation 52:49-54.

Cook, M. G., P. G. Hunt, K. C. Stone, and J. H. Canterberry. 1996. Reducing diffuse pollution through implementation of agricultural best management practices: a case study. Water Science and Technology 33:191-196.

Edwards, D. R., T. C. Daniel, H. D. Scott, J. F. Murdoch, M. J. Habiger, and H. M. Burks. 1996. Stream quality impacts of best management practices in a northwestern Arkansas basin. Water Resources Bulletin 32:499-509.

Gale, J. A., D. E. Line, D. L. Osmond, S. W. Coffey, J. Spooner, J. A. Arnold, T. J. Hoban, and R. C. Wimberly. 1993. Evaluation of the experimental rural clean water program. National Water Quality Evaluation Project, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC, USA.

Gough, S. C. 1997. Stream classification and assessment. The Nature Conservancy, Peoria, Illinois Field Office, Peoria, Illinois, USA.

Hunt, R. L. 1993. Trout stream therapy. University of Wisconsin Press, Madison, Wisconsin, USA.

Lenat, D. R., and J. K. Crawford. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. Hydrobiologia 294:185-199.

Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management 12:198-203.

Magette, W. L., R. B. Brinsfield, R. E. Palmer, and J. D. Wood. 1989. Nutrient and sediment removal by vegetated filter strips. Transactions of the ASAE 32:663-667.

Meals, D. W. 1996. Watershed-scale response to agricultural diffuse pollution control programs in Vermont, USA. Water Science and Technology 33:197-204.

Muscutt, A. D., G. L. Harris, S. W. Bailey, and D. B. Davies. 1993. Buffer zones to improve water quality: a review of their potential use in UK agriculture. Agriculture, Ecosystems and Environment 45:59-77.

NRC (National Research Council). 1992. Restoration of aquatic ecosystems: science, technology, and public policy. National Academy Press, Washington, D. C.

Osborne, L. L., and D. A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. Freshwater Biology 29:243-258.

Osenberg, C. W., R. J. Schmitt, S. J. Holbrook, K. E. Abu-Saba, and A. R. Flegal. 1994. Detection of environmental impacts: natural variability, effect size, and power analysis. Ecological Applications 4:16-30.

Park, S. W., S. Mostaghimi, R. A. Cooke, and P. W. McClellan. 1994. BMP impacts on watershed runoff, sediment, and nutrient yields. Water Resources Bulletin 30:1011-1023.

Putnam, J. H., C. L. Pierce, and D. M. Day. 1995. Relationships between environmental variables and size-specific growth rates of Illinois stream fishes. Transactions of the American Fisheries Society 124:252-261.

Rabeni, C. F., and M. A. Smale. 1995. Effects of siltation on stream fishes and the potential mitigating role of the buffering riparian zone. Hydrobiologia 303:211-219.

Richards, C., L. B. Johnson, and G. E. Host. 1996. Landscape-scale influences on stream habitats and biota. Canadian Journal of Fisheries and Aquatic Sciences 53(Suppl. 1):295-311.

Roth, N. E., J. D. Allan, and D. E. Erickson. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecology 11:141-156.

Schlosser, I. J. 1995. Critical landscape attributes that influence fish population dynamics in headwater streams. Hydrobiologia 303:71-81.

Simonson, T. D., and J. Lyons. 1995. Comparison of catch per effort and removal procedures for sampling stream fish assemblages. North American Journal of Fisheries Management 15:419-427.

Stanfield, L., M. Jones, M. Stoneman, B. Kilgour, J. Parish, G. Wichert. 1998. Stream assessment protocal for Ontario. v. 2.1.

Stewart-Oaten, A., W. W. Murdoch, and K. R. Parker. 1986. Environmental impact assessment: "pseudoreplication" in time? Ecology 67:929-940.

Thrush, S. F., R. D. Pridmore, and J. E. Hewitt. 1994. Impacts on soft-sediment macrofauna: the effects of spatial variation on temporal trends. Ecological Applications 4:31-41.

Tim, U. S., R. Jolly, and H. H. Liao. 1995. Impact of landscape feature and feature placement on agricultural non-point-source-pollution control. Journal of Water Resources Planning and Management 121:463-470.

Trimble, S.W. and S.W. Lund. 1982. Soil Conservation and the reduction of erosion and sedimentation in the Coon Creek Basin, Wisconsin. US Geological Survey Professional Paper 1234. Washington, DC, US Printing Office.

USEPA. 1990. The quality of our nation's water: a summary of the 1988 National Water Quality Inventory. U. S. Environmental Protection Agency, EPA Report 440/4-90-005, Washington, D. C.

USEPA. 1995. National water quality inventory: 1994 report to Congress. United States Environmental Protection Agency, EPA 841-R-95-005, Washington, D. C.

Walker, J. F., and D. J. Graczyk. 1993. Preliminary evaluation of effects of best management practices in the Black Earth Creek, Wisconsin, priority watershed. Water Science and Technology **28**:539-548.

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries 22:6-12.

Wrona, F.J., J.M. Culp, and R.W. Davies. 1982. Macroinvertebrate subsampling: a simplified apparatus and approach. Canadian Journal of Fisheries and Aquatic Sciences 39:1051-1054.

Table 1. Summary of site-scale habitat variables. Each site is approximately 20 times the mean bankfull width (W_{bf}) in length (Gough 1997).

Variable	Sample Frequency	Method
1) Drainage area (km^2)	1 time only	1:24,000 topographic maps; GIS
2) Stream order	1 time only	1:24,000 topographic maps
3) Sinuosity	1 time only	1:24,000 topographic maps; GIS
4) Stream slope (m/km)	1 time only	Autolevel and staff rod
5) Site length (m)	Annual	Site length = $20W_{bf}$; see method for W_{bf} (Table 2)
6) Total length of :		
Riffles (m)	Annual	From map of site
Runs (m)	Annual	From map of site
Pools (m)	Annual	From map of site
7) Water temperature (°C)	Continuous	Optic Stowaway temperature logger
8) Discharge (m^3/s)	Continuous	Water level recorders at watershed-scale sites
9) Total P and soluble reactive $PO_4 - P$	Biweekly; Hourly during spates	Ascorbic acid method (APHA 1995); automatic pumping sampler at watershed-scale sites during spates
10) Total N and $NO_3 - N$	Biweekly; Hourly during spates	Cadmium reduction method (APHA 1995); automatic pumping sampler at watershed-scale sites during spates
11) $NH_3 - N$	Biweekly; Hourly during spates	Phenate method (APHA 1995); automatic pumping sampler at watershed-scale sites during spates
12) Suspended sediments	Biweekly; hourly during spates	Depth-integrating DH-48 sampler (Gordon et al. 1992); automatic pumping sampler at watershed-scale sites during spates

Table 2. Summary of transect-scale habitat variables. Ten transects were sampled at each site. All variables will be sampled once/year when fish sampling is conducted.

Variable	Description
Bankfull width (m)	Horizontal distance along transect, measured perpendicular to stream flow, from top of low bank to a point of equal height on opposite bank (Gough 1997). Measured one time only for site length
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 6 equally spaced points along transect
Hydraulic Head (mm)	Measurement of stream velocity at each point along transect. Taken as difference between water height on ruler facing upstream and water height on ruler facing downstream (Stanfield et al. 1998)
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.
Shading (%)	Proportion of densiometer grid squares covered at the center of each transect.
Bank vegetation cover (%)	Proportion of bank which is covered with live vegetation; based on number of 5 X 6.25cm grids out of 16 grids that contain live vegetation.
Undercut bank (mm)	Distance at each side of transect between maximum extent that streamside overhangs channel to furthest point under the bank, to nearest millimeter.
Bank angle	Distance from bank to a tape measure that is strung level and extents 1.5 m on either bank; indicates amount of bank erosion.
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 3. Streams sampled for fish in 1998 for the Illinois Pilot Watershed Study (*Lake Branch was not sampled in 1998 due to the lack of a reference stream). Treated streams are those in which Best Management Practices (BMP) will be instituted.

BASIN	STREAM TYPE	STREAM NAME	SITE NAME	DATE SAMPLED	COUNTY
Embarras	Treated	Hurricane Creek	Lower	8/31/98	Cumberland
	Treated	Hurricane Creek	Upper	8/31/98	Cumberland
	Reference	Kickapoo Creek	Lower	11/16/98	Coles
	Reference	Kickapoo Creek	Upper	11/16/98	Coles
Spoon	Treated	Court Creek	Lower	9/30/98	Knox
	Treated	Court Creek	Upper	9/30/98	Knox
	Reference	Haw Creek	Lower	9/29/98	Knox
	Reference	Haw Creek	Upper	9/29/98	Knox
Cache	Treated	Big Creek	Lower	11/4/98	Union
	Treated	Big Creek	Upper	11/4/98	Union
	Reference	Cypress Creek	Lower	11/5/98	Union
	Reference	Cypress Creek	Upper	11/5/98	Union
Kaskaskia	Treated	Lake Branch	Lower	*	Madison
	Treated	Lake Branch	Upper	*	Madison

Table 4. List of all species collected during the Pilot Watershed Study in 1998.

Common Name	Scientific Name	Total Catch
Banded sculpin	*Cottus carolinae*	149
Bigmouth shiner	*Notropis dorsalis*	139
Black bullhead	*Ameiurus melas*	1
Black crappie	*Pomoxis nigromaculatus*	1
Blacknose dace	*Rhinichthys atratulus*	51
Blackside darter	*Percina maculata*	10
Blackspotted topminnow	*Fundulus olivaceus*	130
Blackstripe topminnow	*Fundulus notatus*	18
Bluegill	*Lepomis macrochirus*	207
Bluntnose darter	*Etheostoma chlorosomum*	1
Bluntnose minnow	*Pimephales notatus*	2993
Brindled madtom	*Noturus miurus*	28
Carp	*Cyprinus carpio*	3
Central stoneroller	*Campostoma anomalum*	755
Channel catfish	*Ictalurus punctatus*	53
Creek chub	*Semotilus atromaculatus*	634
Creek chubsucker	*Erimyzon oblongus*	13
Dusky darter	*Percina sciera*	11
Fantail darter	*Etheostoma flabellare*	56
Fathead minnow	*Pimephales promelas*	4
Fringed darter	*Etheostoma crossopterum*	17
Golden redhorse	*Moxostoma erythrurum*	121
Golden shiner	*Notemigonus crysoleucas*	5
Green sunfish	*Lepomis cyanellus*	44
Greenside darter	*Etheostoma blennioides*	10
Hornyhead chub	*Nocomis biguttatus*	43
Johnny darter	*Etheostoma nigrum*	332
Largemouth bass	*Micropterus salmoides*	48
Longear sunfish	*Lepomis megalotis*	234
Mosquitofish	*Gambusia affinis*	5
Northern hogsucker	*Hypentelium nigricans*	75
Orangethroat darter	*Etheostoma spectabile*	150
Pirate perch	*Aphredoderus sayanus*	23
Quillback	*Carpiodes cyprinus*	31
Rainbow darter	*Etheostoma caeruleum*	113
Red shiner	*Cyprinella lutrensis*	1558
Redear sunfish	*Lepomis microlophus*	7

Table 4. continued.

Common Name	Scientific Name	Total Catch
Redfin shiner	*Lythrurus umbratilus*	432
River carpsucker	*Carpiodes carpio*	12
Sand shiner	*Notropis ludibundus*	1731
Shorthead redhorse	*Moxostoma macrolepidotum*	17
Silver redhorse	*Moxostoma anisurum*	5
Silverjaw minnow	*Notropis buccatus*	1390
Silvery minnow	*Hybognathus nuchalis*	2
Slenderhead darter	*Percina phoxocephala*	2
Slough darter	*Etheostoma gracile*	1
Smallmouth bass	*Micropterus dolomieu*	37
Spotfin shiner	*Cyprinella spiloptera*	1862
Spotted bass	*Micropterus punctulatus*	22
Spotted sucker	*Minytrema melanops*	5
Steelcolor shiner	*Cyprinella whipplei*	471
Stonecat	*Noturus flavus*	34
Striped shiner	*Luxilus chrysocephalus*	364
Suckermouth minnow	*Phenacobius mirabilis*	82
Tadpole madtom	*Noturus gyrinus*	2
Warmouth	*Lepomis gulosus*	8
White sucker	*Catostomus commersoni*	202
Yellow bullhead	*Ameiurus natalis*	30
Total Number		14784
Total Species		58

Table 5. List of fish species collected in downstream (lower) and upstream (upper) sites of Hurricane Creek (Treated) and Kickapoo Creek (Reference) in 1998.

Common Name	Scientific Name	Hurricane Lower	Hurricane Upper	Kickapoo Lower	Kickapoo Upper
Blackside darter	*Percina maculata*	0	0	0	1
Blackstripe topminnow	*Fundulus notatus*	1	1	5	11
Bluegill	*Lepomis macrochirus*	12	0	2	7
Bluntnose minnow	*Pimephales notatus*	361	875	61	137
Brindled madtom	*Noturus miurus*	1	0	10	17
Carp	*Cyprinus carpio*	1	0	0	0
Central stoneroller	*Campostoma anomalum*	29	100	20	63
Creek chub	*Semotilus atromaculatus*	22	348	3	0
Creek chubsucker	*Erimyzon oblongus*	0	0	1	0
Dusky darter	*Percina sciera*	3	0	7	1
Golden redhorse	*Moxostoma erythrurum*	3	0	0	0
Green sunfish	*Lepomis cyanellus*	8	0	1	7
Greenside darter	*Etheostoma blennioides*	0	1	9	0
Johnny darter	*Etheostoma nigrum*	21	230	6	23
Largemouth bass	*Micropterus salmoides*	5	0	1	0
Longear sunfish	*Lepomis megalotis*	64	0	12	8
Northern hogsucker	*Hypentelium nigricans*	43	0	18	0
Orangethroat darter	*Etheostoma spectabile*	7	72	0	22
Rainbow darter	*Etheostoma caeruleum*	0	93	2	18
Redfin shiner	*Lythrurus umbratilus*	48	7	7	14
Sand shiner	*Notropis ludibundus*	65	696	96	132
Silver redhorse	*Moxostoma anisurum*	1	0	0	0
Silverjaw minnow	*Notropis buccatus*	79	708	240	363
Silvery minnow	*Hybognathus nuchalis*	0	0	0	1
Spotfin shiner	*Cyprinella spiloptera*	214	296	1068	284
Spotted bass	*Micropterus punctulatus*	14	0	4	1
Spotted sucker	*Minytrema melanops*	2	0	0	0
Steelcolor shiner	*Cyprinella whipplei*	84	34	234	119
Striped shiner	*Luxilus chrysocephalus*	69	7	4	79
Suckermouth minnow	*Phenacobius mirabilis*	7	2	7	1
White sucker	*Catostomus commersoni*	0	0	0	10
Yellow bullhead	*Ameiurus natalis*	1	0	3	4
Total Numbers		1165	3470	1821	1323
Total Species		26	15	24	23

Table 6. List of fish species collected in downstream (lower) and upstream (upper) sites of Court Creek (Treated) and Haw Creek (Reference) in 1998.

Common Name	Scientific Name	Court Lower	Court Upper	Haw Lower	Haw Upper
Bigmouth shiner	*Notropis dorsalis*	82	50	7	0
Black bullhead	*Ameiurus melas*	0	0	0	1
Blacknose dace	*Rhinichthys atratulus*	23	19	9	0
Bluegill	*Lepomis macrochirus*	10	8	3	3
Bluntnose minnow	*Pimephales notatus*	649	230	250	84
Carp	*Cyprinus carpio*	2	0	0	0
Central stoneroller	*Campostoma anomalum*	43	292	1	7
Channel catfish	*Ictalurus punctatus*	39	0	14	0
Creek chub	*Semotilus atromaculatus*	23	89	15	71
Fathead minnow	*Pimephales promelas*	3	0	1	0
Golden redhorse	*Moxostoma erythrurum*	50	33	18	17
Golden shiner	*Notemigonus crysoleucas*	0	0	0	2
Green sunfish	*Lepomis cyanellus*	6	0	12	2
Hornyhead chub	*Nocomis biguttatus*	3	2	22	16
Johnny darter	*Etheostoma nigrum*	7	40	0	5
Largemouth bass	*Micropterus salmoides*	1	4	5	18
Northern hogsucker	*Hypentelium nigricans*	11	1	2	0
Orangethroat darter	*Etheostoma spectabile*	1	48	0	0
Quillback	*Carpiodes cyprinus*	23	3	5	0
Red shiner	*Cyprinella lutrensis*	1204	75	195	71
Redfin shiner	*Lythrurus umbratilus*	0	9	0	0
River carpsucker	*Carpiodes carpio*	12	0	0	0
Sand shiner	*Notropis ludibundus*	459	104	147	32
Shorthead redhorse	*Moxostoma macrolepidotum*	6	0	11	0
Silver redhorse	*Moxostoma anisurum*	0	0	4	0
Slenderhead darter	*Percina phoxocephala*	2	0	0	0
Smallmouth bass	*Micropterus dolomieu*	6	30	1	0
Stonecat	*Noturus flavus*	1	17	15	1
Striped shiner	*Luxilus chrysocephalus*	0	183	0	22
Suckermouth minnow	*Phenacobius mirabilis*	20	16	27	2
White sucker	*Catostomus commersoni*	1	103	8	54
Yellow bullhead	*Ameiurus natalis*	0	10	2	2
Total Numbers		2687	1366	774	410
Total Richness		26	22	23	18

Table 7. List of fish species collected in downstream (lower) and upstream (upper) sites of Big Creek (Treated) and Cypress Creek (Reference) in 1998.

Common Name	Scientific Name	Big Lower	Big Upper	Cypress Lower	Cypress Upper
Banded sculpin	*Cottus carolinae*	7	142	0	0
Black crappie	*Pomoxis nigromaculatus*	0	0	1	0
Blackside darter	*Percina maculata*	0	0	2	7
Blackspotted topminnow	*Fundulus olivaceus*	32	24	38	36
Bluegill	*Lepomis macrochirus*	9	94	30	29
Bluntnose darter	*Etheostoma chlorosomum*	0	0	1	0
Bluntnose minnow	*Pimephales notatus*	0	76	187	83
Central stoneroller	*Campostoma anomalum*	0	195	0	5
Creek chub	*Semotilus atromaculatus*	0	38	0	25
Creek chubsucker	*Erimyzon oblongus*	0	4	5	3
Fantail darter	*Etheostoma flabellare*	0	56	0	0
Fringed darter	*Etheostoma crossopterum*	2	15	0	0
Golden shiner	*Notemigonus crysoleucas*	0	0	3	0
Green sunfish	*Lepomis cyanellus*	5	2	0	1
Largemouth bass	*Micropterus salmoides*	1	5	3	5
Longear sunfish	*Lepomis megalotis*	48	7	54	41
Mosquitofish	*Gambusia affinis*	3	0	2	0
Pirate perch	*Aphredoderus sayanus*	3	0	3	17
Red shiner	*Cyprinella lutrensis*	0	1	12	0
Redear sunfish	*Lepomis microlophus*	0	1	5	1
Redfin shiner	*Lythrurus umbratilus*	0	11	129	207
Silvery minnow	*Hybognathus nuchalis*	0	0	0	1
Slough darter	*Etheostoma gracile*	0	0	1	0
Spotted bass	*Micropterus punctulatus*	0	2	2	1
Spotted sucker	*Minytrema melanops*	0	0	0	1
Tadpole madtom	*Noturus gyrinus*	0	0	1	1
Warmouth	*Lepomis gulosus*	0	0	8	0
White sucker	*Catostomus commersoni*	0	15	3	8
Yellow bullhead	*Ameiurus natalis*	1	0	0	5
Total Numbers		111	688	490	477
Total Species		10	17	20	19

Table 8. Average fish species richness in treated and reference streams for 1998 (standard error listed in parenthesis).

	Lower	Upper
Treated	20.7 (5.3)	18.0 (2.1)
Reference	22.3 (1.2)	20.0 (1.5)

Table 9. Similarity Index of Jaccard for each site within the three basins sampled in 1998.

Embarras Basin	Hurricane Lower	Hurricane Upper	Kickapoo Lower	Kickapoo Upper
Hurricane Lower	1.000			
Hurricane Upper	0.464	1.000		
Kickapoo Lower	0.724	0.560	1.000	
Kickapoo Upper	0.633	0.520	0.679	1.000

Spoon Basin	Court Lower	Court Upper	Haw Lower	Haw Upper
Court Lower	1.000			
Court Upper	0.655	1.000		
Haw Lower	0.750	0.667	1.000	
Haw Upper	0.467	0.600	0.519	1.000

Cache Basin	Big Lower	Big Upper	Cypress Lower	Cypress Upper
Big Lower	1.000			
Big Upper	0.350	1.000		
Cypress Lower	0.250	0.423	1.000	
Cypress Upper	0.318	0.565	0.500	1.000

Table 10. Similarity Ratios for each site within the three basins sampled in 1998.

Embarras Basin	Hurricane Lower	Hurricane Upper	Kickapoo Lower	Kickapoo Upper
Hurricane Lower	1.000			
Hurricane Upper	0.223	1.000		
Kickapoo Lower	0.381	0.136	1.000	
Kickapoo Upper	0.510	0.288	0.594	1.000

Spoon Basin	Court Lower	Court Upper	Haw Lower	Haw Upper
Court Lower	1.000			
Court Upper	0.180	1.000		
Haw Lower	0.324	0.369	1.000	
Haw Upper	0.209	0.449	0.643	1.000

Cache Basin	Big Lower	Big Upper	Cypress Lower	Cypress Upper
Big Lower	1.000			
Big Upper	0.056	1.000		
Cypress Lower	0.095	0.174	1.000	
Cypress Upper	0.075	0.125	0.716	1.000

Table 11. Catch per minute of shocking time (CPUE) for treated and reference streams in each of the three basins sampled in 1998 (*note: the CPUE in the treated lower site in the Embarras Basin is estimated).

	Treated		Reference	
	Upper	Lower	Upper	Lower
Embarras	68.0	25.9*	18.6	24.9
Spoon	25.3	41.3	8.9	16.8
Cache	9.6	1.8	6.6	8.8

Table 12. Length and weight ranges of species caught in Hurricane Creek in 1998.

Common Name	Hurricane Lower				Hurricane Upper			
	Range Length	Average Length	Range Weight	Average Weight	Range Length	Average Length	Range Weight	Average Weight
Blackstripe topminnow	60-60	60	1.3-1.3	1.3	57-57	57	1.3-1.3	1.3
Bluegill	62-124	87.1	2.3-34.0	9.9				
Bluntnose minnow					29-65	52.8	0.1-1.6	1.0
Brindled madtom	38-73	58.5	0.3-2.6	1.3				
Carp	87-87	87.0	6-6	6.0				
Central stoneroller	42-70	57.4	0.8-2.7	1.6	52-75	65.1	1.2-3.6	2.6
Creek chub	47-192	64.6	0.7-60.0	4.3	47-102	72.4	0.9-9.9	3.5
Golden redhorse	120-132	127.7	15.4-22.3	19.6				
Green sunfish	41-115	70.1	0.8-26.0	6.8				
Greenside darter					70-70	70.0	2.7-2.7	2.7
Johnny darter	40-53	46.9	0.3-1.0	0.7	43-59	52.0	0.5-1.6	1.0
Largemouth bass	151-179	170.0	35-80	58.0				
Longear sunfish	31-151	87.0	0.3-80.0	16.8				
Northern hog sucker	105-172	133.5	12-56	25.3				
Orangethroat darter	39-45	42.3	0.4-0.7	0.5	34-50	45.0	0.4-1.1	0.7
Redfin shiner	35-63	49.9	0.2-1.3	0.6	51-63	56.4	0.6-1.3	1.0
Sand shiner	40-62	47.3	0.3-1.1	0.6	35-68	53.8	0.2-1.8	0.9
Silver redhorse	162-162	162.0	45-45	45.0				
Silverjaw minnow	30-70	50.0	0.1-2.1	0.9	38-75	58.4	0.3-2.5	1.4

Table 12. continued.

Common Name	Hurricane Lower Range Length	Hurricane Lower Average Length	Hurricane Lower Range Weight	Hurricane Lower Average Weight	Hurricane Upper Range Length	Hurricane Upper Average Length	Hurricane Upper Range Weight	Hurricane Upper Average Weight
Spotfin shiner					44-70	54.6	0.5-2.3	1.1
Spotted bass	47-283	134.3	0.8-350.0	73.1				
Spotted sucker	168-195	181.5	56-68	62.0				
Steelcolor shiner	36-82	55.0	0.3-3.3	1.1	37-67	50.2	0.4-1.8	0.8
Striped shiner	40-166	107.2	0.5-140.0	15.2	51-72	64.1	1.1-2.4	1.9
Suckermouth minnow					70-72	71.0	2.1-2.2	2.2
Yellow bullhead	36-255	113.7	0.7-225.0	75.7				

Table 13. Length and weight ranges of species caught in Kickapoo Creek in 1998.

	Kickapoo Lower				Kickapoo Upper			
Common Name	Range Length	Average Length	Range Weight	Average Weight	Range Length	Average Length	Range Weight	Average Weight
Blackside darter					81-81	81	4.6-4.6	4.6
Blackstripe topminnow	25-61	39.2	0.1-1.8	0.6	36-47	40.3	0.3-0.7	0.5
Bluegill	65-75	70.0	2.8-5.4	4.1	36-114	74.7	0.7-27.0	9.0
Bluntnose minnow	25-79	43.2	0.1-4.4	0.8	22-80	46.7	0.1-4.6	1.0
Brindled madtom	32-79	49.6	0.3-5.1	1.5	32-80	50.6	0.3-4.8	1.4
Central stoneroller	64-115	82.6	2.3-15.3	6.1	58-127	88.7	1.6-23.3	8.4
Creek chub	63-90	72.7	2.0-5.0	3.1				
Creek chubsucker	105-105	105.0	12.6-12.6	12.6				
Dusky darter	57-93	74.4	1.2-6.1	3.3	79-79	79.0	3.3-3.3	3.3
Green sunfish	76-76	76.0	6.3	6.3	58-128	77.7	3.0-40.0	10.9
Greenside darter	70-87	80.1	3.2-11.0	6.0				
Johnny darter	52-60	55.7	1.0-1.4	1.2	50-64	56.9	0.8-1.9	1.2
Largemouth bass	240-240	240.0	175-175	175.0				
Longear sunfish	50-132	94.1	1.8-49.0	18.7	109-134	120.3	25-53	37.8
Northern hog sucker	79-229	144.6	4.3-143.0	38.3				
Orangethroat darter					43-61	53.1	0.7-2.3	1.4
Rainbow darter	46-49	47.5	0.7-1.0	0.9	39-62	52.6	0.5-2.7	1.4
Redfin shiner	19-55	36.0	0.04-0.8	0.3	32-57	39.7	0.2-1.2	0.4
Sand shiner	25-64	50.2	0.1-1.9	0.9	25-65	43.8	0.1-1.9	0.7

Table 13. continued.

Common Name	Kickapoo Lower Range Length	Kickapoo Lower Average Length	Kickapoo Lower Range Weight	Kickapoo Lower Average Weight	Kickapoo Upper Range Length	Kickapoo Upper Average Length	Kickapoo Upper Range Weight	Kickapoo Upper Average Weight
Silverjaw minnow	26-73	43.1	0.1-2.7	0.6	18-78	46.5	0.1-4.1	0.8
Silvery minnow					45-45	45.0	834-8.4	8.4
Spotfin shiner					34-82	55.5	0.2-3.7	1.1
Spotted bass	66-76	70.3	2.4-4.0	3.4	80-80	80.0	5.0-5.0	5.0
Steelcolor shiner	29-84	51.9	0.2-4.2	1.0	37-93	63.8	0.3-20.1	2.0
Striped shiner	55-108	81.3	1.1-9.5	5.4	60-207	124.2	1.6-86.0	21.8
Suckermouth minnow	87-97	90.6	4.9-7.9	5.6	96-96	96.0	7.6-7.6	7.6
White sucker					122-170	146.1	16.4-45.0	30.7
Yellow bullhead	155-219	195.7	45-132	26.4	69-180	119.3	4.0-78.0	34.3

Table 14. Length and weight ranges for species caught in Court Creek in 1998.

	Court Lower				Court Upper			
Common Name	Range Length	Average Length	Range Weight	Average Weight	Range Length	Average Length	Range Weight	Average Weight
Bigmouth shiner	35-85	53.4	0.3-5.4	1.2	27-65	54.6	0.1-1.6	1.0
Blacknose dace	38-71	48.3	0.4-3.1	0.9	57-77	67.8	1.5-3.9	2.7
Bluegill	53-121	86.0	2.2-28.6	11.0	61-85	71.1	3.1-9.6	5.4
Bluntnose minnow	7-79	60.2	0.2-4.4	1.9	26-82	60.9	0.2-4.3	1.9
Carp	546-645	595.5	1900-3900	2900.0				
Central stoneroller	49-114	72.2	0.9-14.7	3.9	45-105	74.6	0.8-10.0	3.7
Channel catfish	67-206	84.7	2.2-65.0	6.1				
Creek chub	46-117	85.6	0.6-16.0	5.8	52-220	90.3	1.0-95.0	9.1
Fathead minnow	51-73	58.3	0.9-2..6	1.6				
Golden redhorse	119-312	233.6	16.6-306.0	156.4	105-291	185.7	11.8-256.0	87.7
Green sunfish	49-112	73.0	1.8-23.0	9.6				
Honeyhead chub	56-134	101.7	1.4-23.4	13.0	42-46	44.0	0.6-0.8	0.7
Johnny darter	45-64	57.3	0.9-2.0	1.5	36-61	52.8	0.3-1.7	1.1
Largemouth bass	70-70	70.0	3.1-3.1	3.1	99-131	115.0	9.7-27.0	18.1
Northern hog sucker	160-292	210.5	39-266	107.6	226-226	226.0	115-115	115.0
Orangethroat darter	50-50	50.0	1.1-1.1	1.1	42-62	50.6	0.5-2.7	1.2
Quillback	65-220	128.0	2.7-126.0	44.1	114-201	168.3	18.5-96.0	67.2
Red shiner	43-66	53.7	0.5-2.7	1.2	29-69	52.4	0.2-2.0	1.1
Redfin shiner					50-60	54.3	0.7-1.2	0.9
River carpsucker	63-93	78.0	2.7-9.8	5.8				
Sand shiner	38-65	57.7	0.3-2.0	1.3	25-65	51.6	0.1-1.7	0.9
Shorthead redhorse	113-312	186.0	13.2-278.0	96.2				
Slenderhead redhorse	54-57	55.5	1.2-1.2	1.2				

Table 14. continued.

	Court Lower				Court Upper			
Common Name	Range Length	Average Length	Range Weight	Average Weight	Range Length	Average Length	Range Weight	Average Weight
Smallmouth bass	71-274	171.0	4.6-241.0	106.9	60-352	105.8	2.2-661.0	75.2
Stonecat	59-59	59.0	1.9-1.9	1.9	35-80	57.1	0.3-4.0	1.8
Striped shiner					53-111	84.0	0.9-11.2	5.0
Suckermouth minnow	60-92	83.0	1.8-7.2	5.1	73-95	82.9	3.2-7.5	4.8
White sucker	140-140	140.0	23.8-23.8	23.8	89-280	125.7	4.9-239.0	29.5
Yellow bullhead					45-112	58.0	1.2-16.8	3.3

Table 15. Length and weight ranges for species caught in Haw Creek in 1998.

	Haw Lower				Haw Upper			
Common Name	Range Length	Average Length	Range Weight	Average Weight	Range Length	Average Length	Range Weight	Average Weight
Bigmouth shiner	47-68	57.0	0.5-1.8	1.0				
Blacknose dace	42-83	60.0	0.6-5.0	2.0				
Black bullhead					210-210	210.0	135-135	135.0
Bluegill	87-132	109.5	13-46	29.5	50-84	65.3	1.3-8.1	4.1
Bluntnose minnow					28-90	61.4	0.1-6.4	2.3
Central stoneroller	78-78	78.0	3.9-3.9	3.9	70-129	95.0	2.7-22.3	8.5
Channel catfish	72-87	79.0	2.4-5.3	3.6				
Creek chub	63-127	88.4	1.8-16.0	6.3	59-214	119.2	1.29-86.0	17.5
Fathead minnow	63-63	63.0	1.7-1.7	1.7				
Golden redhorse	127-310	238.1	19.8-304.0	167.6	233-303	271.0	171-314	228.3
Golden shiner					85-87	86.0	4.1-4.1	4.1
Green sunfish	69-130	88.9	4.1-41.0	13.3	100-102	101.0	12.7-14.2	13.5
Hornyhead chub	40-146	93.0	0.4-32.0	10.5	48-155	90.6	0.71-37.0	10.9
Johnny darter					47-71	60.6	0.7-2.8	1.7
Largemouth bass	96-128	104.0	8.7-24.0	12.4	76-103	86.4	4.6-10.2	6.7
Northern hog sucker	106-233	169.5	10.8-143.0	76.9				
Quillback	283-329	301.8	290-467	357.4				
Red shiner	50-77	62.1	0.9-4.3	2.0	27-73	53.4	0.1-3.4	1.4
Sand shiner	29-67	51.7	0.1-1.9	1.0	35-70	58.2	0.2-2.1	1.3
Shorthead redhorse	146-298	200.3	29-273	105.5				
Silver redhorse	151-335	200.3	44-375	128.3				
Smallmouth bass	294-294	294.0	353-353	353.0				
Stonecat	35-130	62.8	0.3-18.6	2.9	50-50	50.0	0.9-0.9	0.9
Striped shiner					99-150	124.0	7.0-29.0	17.1
White sucker	98-351	245.6	8.5-446	216.5	93-333	170.1	6.0-370.0	66.3
Yellow bullhead	64-175	119.5	2.5-76.0	39.2	65-74	69.5	2.5-4.9	3.7

Table 16. Length and weight ranges for species caught in Big Creek.

	Big Lower				Big Upper			
Common Name	Range Length	Average Length	Range Weight	Average Weight	Range Length	Average Length	Range Weight	Average Weight
Banded sculpin	54-110	71.4	1.6-12.5	4	45-104	62.1	0.99-12.5	2.7
Blackspotted topminnow	32-80	50.3	0.2-4	1.3	40-89	65	0.5-6.9	2.8
Bluegill	40-93	59.2	0.7-10.5	3.4	38-137	66.3	0.6-49	6.9
Bluntnose minnow					28-91	56.2	0.2-6.1	1.8
Central stoneroller					48-135	81.0	1.0-23	6.1
Creek chub					37-227	150.5	0.4-109	39.1
Creek chubsucker					102-175	148.8	11.8-62.7	40.6
Fantail darter					32-63	47.1	0.3-2.5	0.9
Fringed darter	40-45	42.5	0.4-0.8	0.6	46-66	53.5	0.7-2.7	1.3
Green sunfish	40-64	53.8	0.9-4.1	2.5	102-115	108.5	16.9-24.0	20.4
Largemouth bass	157-157	157.0	44-44	44.0	88-192	155.6	7.2-88.0	57.0
Longear sunfish	28-155	91.5	0.5-60	16.8	55-142	112.7	2.1-59.0	35.3
Mosquitofish	37-40	39.0	0.5-0.6	0.5				
Pirate perch	69-107	83.0	3.9-15.5	7.8				
Red shiner					67-67	67.0	2.0-2.0	2.0
Redear sunfish					84-84	84.0	8.0-8.0	8.0
Redfin shiner					53-64	59.6	0.7-1.5	1.2
Spotted bass					85-100	92.5	6.2-11.1	8.6
White sucker					211-290	240.4	98-249	146.3
Yellow bullhead	170-170	170.0	57-57	57.0				

Table 17. Length and weight ranges for species caught in Cypress Creek in 1998.

Common Name	Cypress Lower				Cypress Upper			
	Range Length	Average Length	Range Weight	Average Weight	Range Length	Average Length	Range Weight	Average Weight
Black crappie	168-168	168.0	60-60	60.0				
Blackside darter	69-73	71.0	2.3-3.1	2.5	58-68	62.7	1.5-2.1	1.9
Blackspotted topminnow	25-70	49.3	0.1-2.9	1.1	32-84	61.8	0.2-30.2	3.1
Bluegill	37-130	82.6	0.6-35.7	10.8	60-144	86.1	2.5-52.0	12.0
Bluntnose darter	47-47	47.0	0.4-0.4	0.4				
Bluntnose minnow	21-80	58.0	0.04-4.3	1.5	43-82	62.4	.6-4.7	1.9
Central stoneroller					39-109	63.6	1.2-13.5	4.1
Creek chub					78-205	111.9	4.4-81.0	15.4
Creek chubsucker	90-180	136.4	8.3-77.2	35.7	124-138	129.7	21.4-34.3	27.0
Golden shiner	92-103	95.7	5.5-7.6	6.5				
Green sunfish					162-162	162.0	85-85	85.0
Largemouth bass	65-81	74.0	4.0-7.6	6.5	69-156	91.8	3.0-48.0	13.3
Longear sunfish	32-139	59.5	0.4-54.0	5.3	33-148	83.5	0.6-58.0	13.7
Mosquitofish	21-22	21.5	0.2-0.2	0.2				
Pirate perch	84-89	86.7	7.6-8.5	8.0	55-100	70.6	2.3-12.0	5.0
Red shiner	27-58	49.0	0.2-1.4	1.0				
Redear sunfish	72-100	81.2	4.9-15.0	8.0	69-69	69.0	5.4-5.4	5.4
Redfin shiner	25-65	49.3	0.1-1.8	0.7	43-71	53.8	0.4-2.5	0.9
Silvery minnow					106-106	106.0	9.9-9.9	9.9
Slough darter	52-52	52.0	0.8-0.8	0.8				
Spotted bass					60-60	60.0	2.1-2.1	2.1
Spotted sucker	259-307	283.0	175-301	238.0	275-275	275.0	225-225	225.0
Tadpole madtom	81-81	81.0	4.6-4.6	4.6	39-39	39.0	0.5-0.5	0.5
Warmouth	64-182	106.8	3.8-131.0	40.5				
White sucker	322-355	337.7	340-476	417.0	152-317	225.0	32.3-334	133.8
Yellow bullhead					134-252	184.8	26-228	90.4

Table 18. Index of Biotic Integrity (IBI) metric values and actual values (in parenthesis) for each site sampled in 1998 for the Illinois Pilot Watershed Study. Note: all proportions are in percent and number of individuals are catch per hour (CPHr).

	Hurricane Lower	Hurricane Upper	Kickapoo Lower	Kickapoo Upper	Court Lower	Court Upper	Haw Lower	Haw Upper	Big Lower	Big Upper	Cypress Lower	Cypress Upper
Species Richness and Composition												
Number of fish species	5 (26)	3 (15)	5 (24)	5 (23)	5 (26)	5 (22)	5 (23)	5 (18)	3 (10)	5 (17)	5 (20)	5 (19)
Number of darter species	3 (3)	5 (4)	3 (4)	5 (5)	3 (3)	3 (2)	1 (0)	1 (1)	1 (1)	3 (2)	3 (3)	1 (1)
Number of sunfish species	3 (3)	1 (0)	3 (3)	3 (3)	3 (2)	1 (1)	3 (2)	5 (2)	3 (3)	5 (4)	5 (5)	5 (4)
Number of sucker species	5 (4)	1 (0)	1 (2)	1 (1)	5 (6)	3 (4)	5 (6)	3 (2)	1 (0)	3 (2)	5 (3)	5 (3)
Number of intolerant species	5 (8)	3 (5)	5 (8)	5 (9)	5 (7)	3 (5)	5 (6)	1 (1)	3 (3)	3 (4)	1 (2)	3 (3)
Proportion of green sunfish (%)	5 (0.7)	5 (0)	5 (0.1)	5 (0.5)	5 (0.2)	5 (0)	5 (1.6)	5 (0.5)	5 (4.5)	5 (0.3)	5 (0)	5 (0.2)
Trophic Composition												
Proportion of omnivores (%)	3 (31.0)	3 (25.2)	5 (3.3)	5 (10.3)	3 (29.5)	3 (22.1)	3 (35.1)	3 (21.0)	5 (0)	5 (11.0)	3 (38.7)	5 (17.4)
Proportion of insectivores (%)	5 (50.4)	5 (60.5)	5 (91.1)	5 (75.0)	5 (63.6)	3 (35.0)	5 (52.5)	5 (52.2)	1 (0)	1 (7.2)	3 (28.8)	5 (48.6)
Proportion of piscivores (%)	5 (0.4)	5 (0)	5 (0.1)	5 (0)	1 (1.7)	1 (2.5)	1 (2.6)	1 (4.4)	5 (0.9)	5 (0.7)	5 (0.8)	1 (1.0)
Fish Abundance and Condition												
Number of individuals (CPHr)	5 (1556)	5 (4082)	5 (1497)	5 (1118)	5 (2480)	5 (1518)	5 (1010	3 (535)	1 (109)	3 (573)	3 (525)	3 (398)
Proportion of hybrids (%)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)
Proportion of diseased fish (%)	5 (0)	5 (0)	5 (0)	5 (0.3)	5 (0.2)	5 (0.8)	5 (0)	3 (2.7)	5 (0)	5 (0)	5 (0)	5 (0)
Total IBI Score	54	46	52	54	50	42	48	40	38	48	48	48

Table 19. Streams sampled for macroinvertebrates in 1998 and 1999 for the Illinois Pilot Watershed Study. A "0" indicates no sample of that type was taken. A blank indicates that a hess sample substituted for a surber sample and vice versa.

DATE SAMPLED	STREAM NAME	SITE NAME	STREAM TYPE	CORE SAMPLES	SURBER SAMPLES	HESS SAMPLES
11/15/98	Kickapoo	Lower	Reference	9		3
11/15/98	Kickapoo	Upper	Reference	9		3
10/14/98	Hurricane	Lower	Treated	10	2	
10/14/98	Hurricane	Upper	Treated	7	3	
9/29/98	Haw	Lower	Reference	9	4	
9/29/98	Haw	Upper	Reference	9	0	
9/28/98	Court	Lower	Treated	9	2	
9/28/99	Court	Upper	Treated	9	4	
11/4/98	Cypress	Lower	Reference	12	0	
11/4/98	Cypress	Upper	Reference	7	0	
10/29/98	Big	Lower	Treated	12	1	
10/29/98	Big	Upper	Treated	0	7	
5/17/99	Kickapoo	Lower	Reference	12		3
5/17/99	Kickapoo	Upper	Reference	8		5
5/20/99	Hurricane	Lower	Treated	12		3
5/20/99	Hurricane	Upper	Treated	0		9
5/28/99	Haw	Lower	Reference	8		3
5/27/99	Haw	Upper	Reference	11		3
5/27/99	Court	Lower	Treated	10		4
5/28/99	Court	Upper	Treated	11		3
6/10/99	Cypress	Lower	Reference	12		2
6/10/99	Cypress	Upper	Reference	12		2
6/9/99	Big	Lower	Treated	12		2
6/9/99	Big	Upper	Treated	0		10

Figure 1. Similarity Index of Jaccard comparing upper and lower sites between treated and reference streams for each of the basins

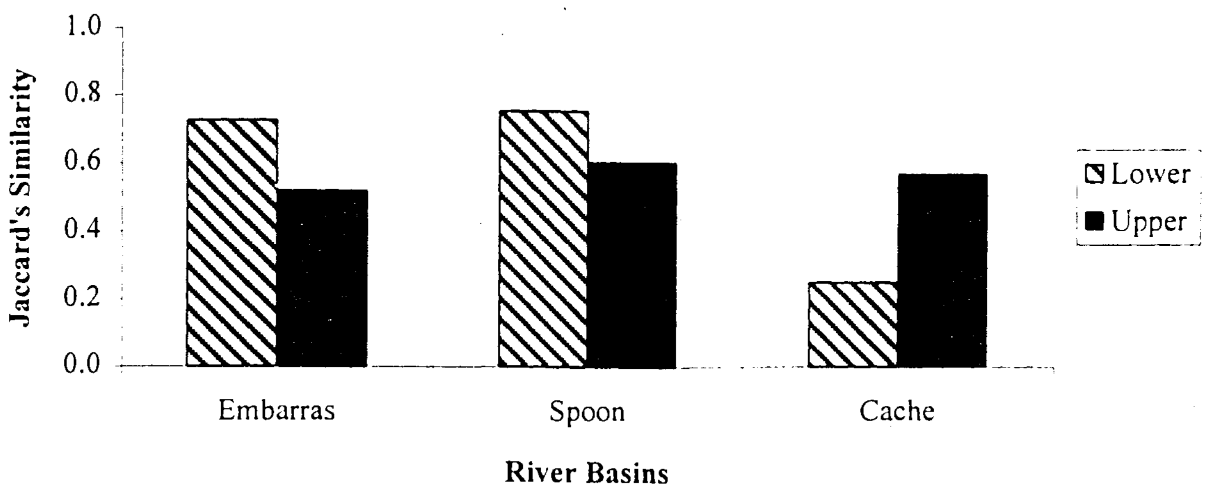

Figure 2. Distribution of the Similary Index of Jaccard comparing species composition between the upper and lower sites (TL= Treated Lower, TU=Treated Upper, RL=Reference Lower, RU= Reference Upper).

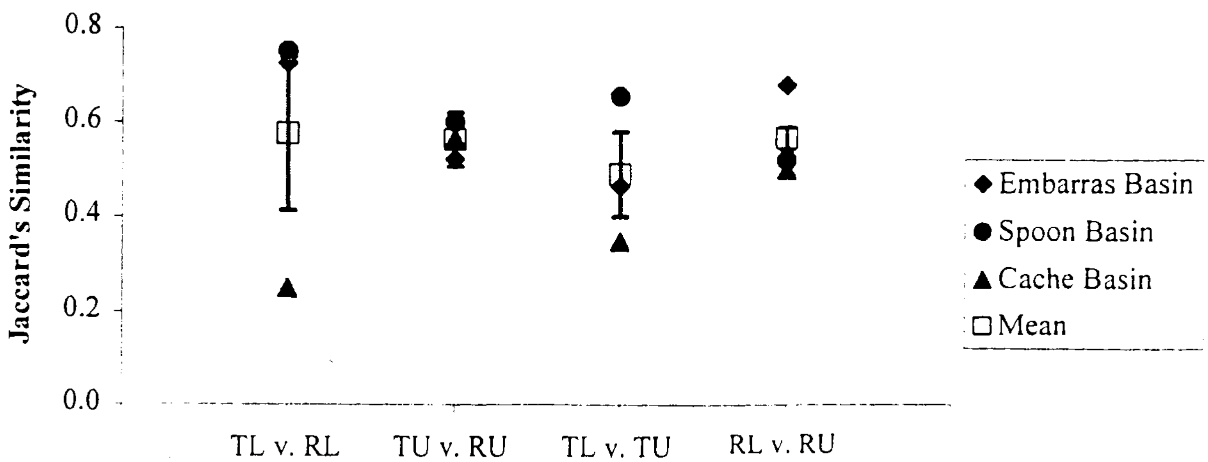

Figure 3. Mean catch per unit effort (± one standard error) for upper (U) and lower (L) sites of treated (T) and reference (R) streams.

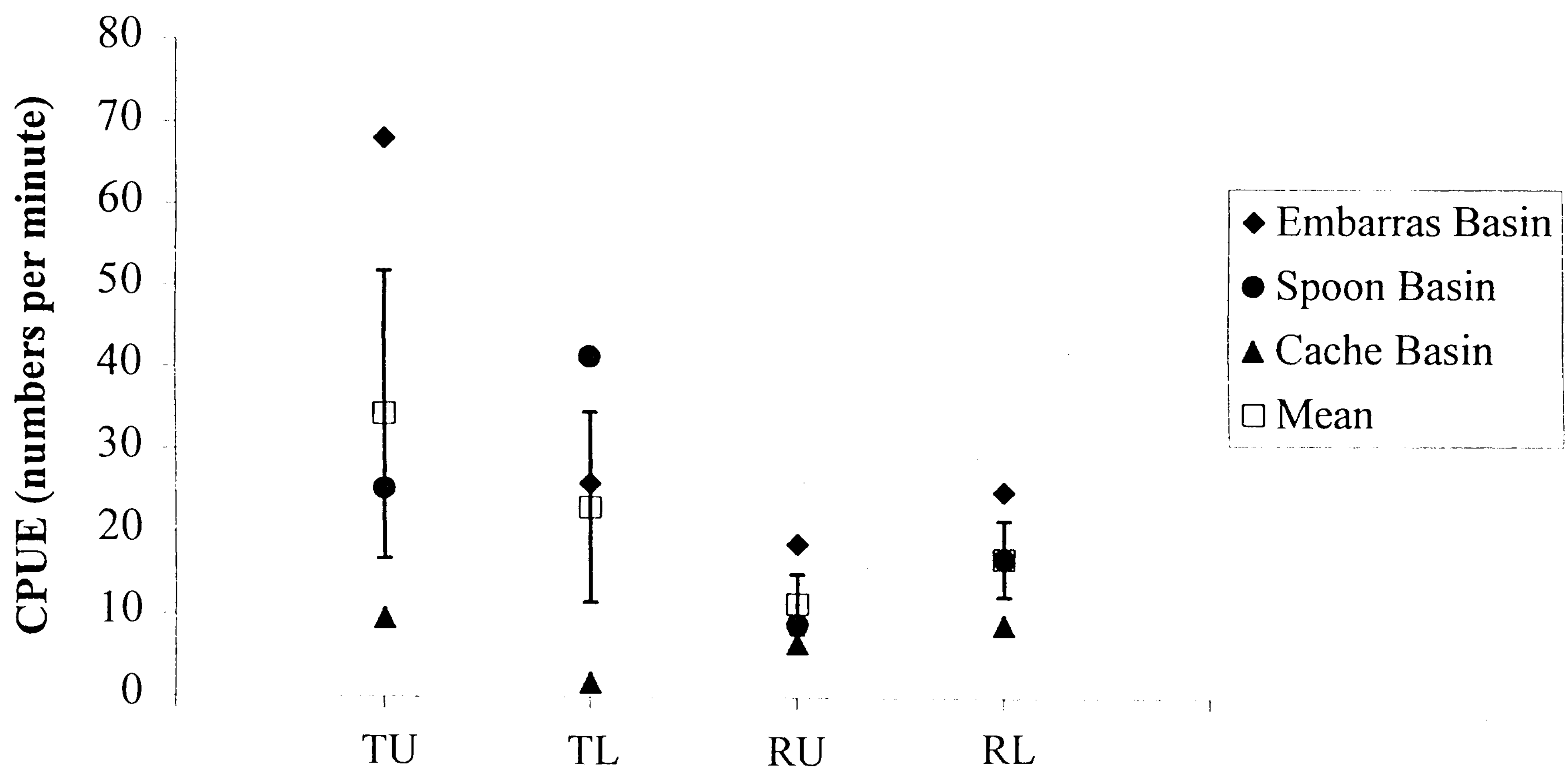

Figure 4. Standard errors based on 100 replicates of core samples taken from the downstream site of Hurricane (top) and the downstream site of Kickapoo (bottom).