ILLINOIS NATURAL HISTORY SURVEY
CENTER FOR AQUATIC ECOLOGY

ANNUAL PROGRESS REPORT

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

H.R. Dodd, J.W. Neisler, A.M. Holtrop, and D.H. Wahl

Submitted to
Division of Fisheries
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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 macroinvertebrate community structure and crayfish abundance, and 101.5 Analysis and reporting.

These jobs were completed for each sampling site. Four basins were selected for this study: the Embarras, Spoon, Cache, and the Kaskaskia (Figure1, Table 1). 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 stream with minimum BMPs). 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 is sampled upstream in the watershed. In the Reference Watershed, two sites were sampled at positions similar to those 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). All basins were sampled in 1998-2000 except the Kaskaskia basin in which only downstream sites were first sampled in 1999 due to problems with locating a suitable reference watershed in 1998 and low water levels at upstream sites in 1999.

In Job 101.1, physical and chemical habitat data were collected from the pilot (treated) and reference (control) streams. Habitat consisted of site-scale and transect – scale variables. Site-scale parameters are habitat characteristics which change very little over the reach of stream (e.g. temperature, discharge, etc.) and, thus, were collected at one location in the site. Transect-scale variables are those attributes 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 pre-BMP site-scale and transect-scale habitat characteristics is ongoing and baseline data from 1998-2000 are presented in this report.

In Jobs 101.2 and 101.3, fish were collected in late summer or early autumn of 1998-2000 with an AC electric seine. Structures for aging were taken from all fish caught in 1998 and from selected species in 1999 and 2000. 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 formalin, identified and measured in the laboratory. In general, fish community structure in pilot and reference streams was similar and consistent across years with a few exceptions in certain basins and years. Number of species collected in pilots were comparable to their respective reference sites with the exception of the Hurricane Upper (pilot) site and Big Lower (pilot) site in 1998 and 1999 and Lake Branch Lower (pilot) in 2000 which showed lower species richness than their references. Similarity indices showed fish composition was also comparable between pilot and reference streams with most sites having relatively high similarity in fish assemblage structure across years. Analysis of catch per unit effort (CPUE) detected little difference between relative fish abundance between upper and lower sites of pilot and reference watersheds before implementation of BMPs with the exception of the upper Embarras sites in 1998 and 1999. To examine the quality of the aquatic resource before BMPs, Index of Biotic Integrity (IBI) scores were computed and found to be relatively high at most pilot and reference sites, indicating good stream quality with the exception of the Kaskaskia basin. Age structure of selected species was examined and differences in mean ages analyzed. Determination of fish growth rates is ongoing and preliminary age data from selected fish species indicated that growth of was similar among pilot and reference watersheds with no apparent differences in population age structure for any species examined across basins.

In Job 101.4, benthic macroinvertebrates samples were collected in autumn of 1998 and spring, summer, and autumn of 1999 and 2000 to evaluate pre-BMP community structure and abundance in pilot and reference streams. A stratified random sampling design was used where riffle, run, and glide/pool habitats were sampled in proportion to their occurrence at the sites. A core sampler was used to collect macroinvertebrates from glide/pool areas with soft sediments while a Hess sampler was used in riffle or run habitats with hard substrates (i.e. larger gravel and cobble). In the laboratory, samples were elutriated through various sizes of sieves to separate the sediment from the organisms. When possible, most macroinvertebrates are being identified to the family taxonomic level with the more sensitive families (Ephemeroptera, Plecoptera, Trichoptera) being identified to genus. Identification of samples from 1998 and 1999 are ongoing, but baseline data from glide/pool habitats of most sites sampled in 1998 and 1999 are presented in this report. Taxa richness was relatively high in glide/pool habitats with similar numbers of taxa between pilot and reference sites within a season. Catch per area (CPA) was computed to examine baseline differences in relative abundance of all taxa at a site and date. Across basins, there was no clear trend in CPA, although within basins some trends were apparent. Percentage of individuals in Ephemeroptera, Plecoptera, and Trichoptera (%EPT) families was low in most glide/pool habitats at the study sites. To assess stream quality, Hilsenhoff's Family Biotic Index (FBI) was calculated for each site, date, and habitat type (i.e. glide/pool, run, or riffle) (Hilsenhoff 1987, Hilsenhoff 1988). Although fish IBI scores indicated relatively good stream quality at most sites, FBI scores showed poor to very poor stream quality in pool habitats at these sites. However, most riffle and run habitats in these sites have not been analyzed and FBI scores are likely to change with further invertebrate identification in these habitats.

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 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 non-point sources of pollution (USEPA 1990). Sources of non-point pollution include runoff from agricultural fields, logging activities, and urban areas. In predominately agricultural systems, the most significant types of pollution include excessive inputs of sediment, nutrients (from fertilizers, livestock, etc.), 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). As a result of heavy agricultural land use in Illinois, non-point source pollution is a major problem for Illinois watersheds.

In agricultural landscapes, on-field and off-field techniques, termed best management practices (BMPs), for reducing non-point source pollution are well known (see Gale et al. 1993). Also, in-stream 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 these 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 Illinois Pilot Watershed Study is designed to examine physical and chemical water quality as well as biotic indicators at the watershed level 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 2) were collected at one location in the site (e.g., water temperature, discharge) or are based on maps of the entire site (e.g., drainage area, stream order) and are assumed to be representative of the entire site. Some variables are assumed to be constant over the duration of the study and were measured only once (Table 2).

Transect-scale variables are those which are expected to vary considerably within a site (Table 3). 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 3. All transect-scale parameters were measured in autumn of 1998 and late summer 1999 and 2000 after fish sampling had been conducted with the exception of the Kaskaskia basin which was only sampled in 1999 and 2000 due to lack of a suitable reference watershed in 1998. We will continue to sample transect-scale characteristics 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- 4 (Table 2). Drainage area, stream order, and site length were measured in 1998. Temperature loggers were installed in spring of 1999 at all sites except in the Kaskaskia Basin which were installed in autumn of 1999. ISWS is responsible for measuring and analyzing site-scale parameters 5-9 (Table 2). Gauging stations were installed in 1999 to measure these habitat variables except at lower Kickapoo. Beginning in summer 2001, point samples of these site scale parameters are being collected to coincide with macroinvertebrate and fish sampling.

FINDINGS

Site-scale characteristics

Pilot and reference sampling sites in each basin were located according to their position in the watershed based on drainage area. In two of the basins, upstream sites were located at a drainage area approximately 10 sq. mi., and downstream sites were placed at approximately 20 sq. mi (Table1). Upstream and downstream sites in the remaining two basins were located at about 25 sq. mi. and 60 sq. mi., respectively. For upstream sites, stream order ranged from 3-4 while downstream sites ranged from 4-5.

In general, average monthly temperature was similar between pilot and reference watersheds with highest average temperatures in July-August. Due to failure or loss of temperature data loggers, temperature data are unavailable from Lower Kickapoo and Upper Big sites; therefore, temperature data for the lower Embarras and the upper Cache sites are omitted from this report. In the upper sites of the Embarras, the pilot site (Hurricane) was slightly cooler on average than the reference in summer 1999 but was slightly warmer in spring and early summer of 2000 with the largest difference in temperature of 3 °C in August 1999 (Figure 2). The warmer summer temperatures at the upper reference site (Kickapoo Upper) may be due to either less canopy cover in that reach allowing sunlight to penetrate and increase temperature or due to effluent from a waste water treatment plant located upstream. In the Spoon basin, pilot and reference sites were similar in average monthly temperature (Figure 3). Summer temperatures were highest in August with the upper site of the pilot (Court) being slightly cooler than the reference (Haw Creek), whereas lower Court was warmer than the reference. At the lower sites in the Cache basin, we see a similar pattern with the lower pilot site (Big) having a slightly higher average temperature than the reference site (Cypress) in late summer months (Figure 4). As with the other basins, average temperatures between the lower sites in the Kaskaskia basin were also similar with August having the highest temperatures in both the pilot (Lake Branch) and reference (Lost) (Figure 5). In addition to our temperature loggers, the ISWS is also collecting temperature at gaging stations. Temperature data reported here were collected from both temperature loggers and gaging stations. Data on other site-scale parameters (e.g. discharge, nutrient and sediment data) are being collected by the ISWS. Due to dry conditions, ISWS were unable to collect data for the first 1.5 years. As they collect additional data, we will incorporate their water quality findings with the analysis of our data on fish and macroinvertebrates.

Transect-scale characteristics

Channel Morphology

At each site, in-stream channel morphology measurements were taken to assess differences between pilot and reference watersheds prior to intensive implementation of BMPs through IDNR funded grants. Evaluation of stream channel morphological characteristics were based upon the differences between the pilot and its respective reference station. Differences were calculated by subtracting the reference site from the pilot where a positive difference indicates the pilot is greater than the reference and a negative difference indicates the pilot is less than the reference.

In the Embarras, upper sites were similar in average width and velocity (with the exception of 1999) showing consistency across years. Average depth was greater in Kickapoo Upper (reference) for all three years, and was consistently different in 1999 and 2000 (Figure 6). Average point particle sizes were much larger in Hurricane Upper in 1998 and slightly larger in 2000 but was similar in 1999. Mean maximum particle sizes were larger in the upper pilot sites all three years but were consistent from 1999 to 2000 (Figure 7). This large difference in both point and maximum particle sizes in 1998 can be explained by the large amount of bedrock at the upper site on Hurricane. However, in 1999 we observed an increase in sand deposition over the bedrock, thus, changing the streambed composition from mostly bedrock in 1998 to mostly sandy sediment in 2000. Lower sites of the Embarras were less similar and less consistent in their mean width, depth, and velocity across years than the upper sites, but lower sites were more similar and consistent in particle sizes (Figure 6 and 7). Hurricane Lower (pilot) was narrower and shallower than Kickapoo (with the exception of 1999) with slower flow in all years. However, there is some stability of these differences with average depth and velocity being different between pilot and reference in 1998 and 2000. Average point and maximum particle sizes were similar between the lower Embarras sites and differences were stable across all years.

Although the Spoon basin generally showed similar channel characteristics between the two upper and two lower sites and between years within a site (Figure 6,

Figure 7), the upper sites tended to be less similar than the two lower sites for all channel morphology characteristics we measured. On average, Court Upper (pilot) was wider than Haw Upper in all three years, but differences in average width were fairly consistent in 1998 and 2000 (Figure 6). Average depth, velocity, and point and maximum particle sizes were similar between the upper Spoon sites and were stable across years. For the lower sites, all channel morphology characteristics were similar between sites and stable across years with average depth the most variable across years and showing a trend of from slightly shallower in the pilot in 1998 to deeper in the pilot in 2000. As BMPs are put into practice in this basin in 2001, we will continue to monitor depth to determine if this trend will continue during the implementation phase.

As in the Spoon, most channel morphology characteristics of the Cache basin were similar between the upper and lower sites with the lower sites more similar and less variable across years. Big Upper (pilot) was wider and shallower on average than the reference, but has similar average velocity and substrate size for all years. For the lower sites of the Cache, average depth was the most dissimilar between the two sites with the pilot deeper than the reference for all years.

For the Kaskaskia basin, the upper sites tended to be more similar and consistent in channel morphology than lower sites (Figure 6 and 7). However, since only one year of data has been collected on the upper sites, this will need additional monitoring. Most morphological characteristics were very similar between the upper sites with the exception of mean depth (Figure 6). For the lower sites in the Kaskaskia, Lake Branch (pilot) was narrower and shallower than Lost Creek, but was similar in average velocity and substrate sizes across all years (Figure 6, Figure 7).

In general, average depth and width were the habitat variables most dissimilar between pilot and reference sites and the least consistent across years. Because we are concerned with detecting changes in habitat after BMP implementation, it is necessary to know with-in site variability and how accurately we are measuring the habitat within a stream reach. It is also important to understand how this within site variability affects our variability from year to year. Because our study design combines data across years in the pre- and the post-implementation phases for comparison, the more variability in our pre-BMP data the more difficult is will be to detect a change after BMPs.

In order to estimate our within site accuracy, we intensively sampled (40 transects per site) habitat and are performing a bootstrap and power analysis on two of our study reaches: a stream reach with diverse habitat (Kickapoo Upper) and one with uniform habitat (Lost Lower). Presented in this report are the bootstrap analysis results for the channel morphology measurements for both stream reaches. For each channel morphology characteristic at the Kickapoo site, we ran two bootstrap methods: a bootstrap based on all transects randomly selected and a bootstrap where the first transect was randomly selected and the others were then equally spaced throughout the site. For all five channel morphology characteristics, equally spacing the transects provides greater accuracy than randomly selected transects (Figures 8-11). For mean width, we would need to measure habitat at 3 transects for 20% standard error (SE) of the true mean (mean based on 40 transects), 12 transects for 10% SE, and 40 transects for 5% SE if we randomly selected transects (Figure 8), but if we use equal spacing, then we only need 15 transects to get 5% SE of the true mean (Figure 9). Because our protocol uses 10 equally spaced transects per site, we will focus our examination on the bootstraping of the equally spaced transects for both the diverse and uniform site. Based on the standard errors for upper Kickapoo in Figures 9 and 11, our protocol of 10 transects gets us within **at least** 20% SE of the true mean for average depth, width, and maximum particle size (within 10% SE for the latter two) and close to 20% SE for mean hydraulic head (measure of velocity). In our more uniform site, we found that most of our channel morphology characteristics were less variable and more close to our true mean of 40 transects (Figures 12 and 13). For average width and depth, 10 transects gave us less than 10% SE of the true mean. Hydraulic head was constant throughout the lower Lost Creek site giving us no with-in site variability which would allow us to detect small amounts of change. Accuracy of mean point particle size was the same for both the diverse and the uniform site (27 transects to reach 20% SE) while average maximum particle size for the uniform site was less accurate (27 transects at Lost and 10 transects at Kickapoo). From this bootstrap analysis, we believe that with our 10 equally spaced transects we are accurately describing a majority of our stream channel morphology characteristics. Substrate is our most variable channel morphology characteristic in both diverse and uniform sites. Although adding additional transects would give more accuracy, there are tradeoffs between time spent collecting the data and the increase in accuracy. One approach which may decrease variability in average substrate size but not cost a great amount of time would be collection of point and maximum particle sizes between transects along the thalweg in addition to those along the transects.

We are also interested in annual variability and our ability to detect changes in channel morphology across time. To determine how annual variability affects our ability to detect changes in stream quality after BMPs, we performed a power analysis on channel morphology characteristics for all study reaches. For this analysis, we assumed that our annual variability would be similar between the pre- and post-BMP time period. Therefore, we used the standard deviation of the mean from our 3 years of baseline data and used a range of years of post-BMP collection to obtain differences we could detect post-BMP. As the number of years of post-BMP collection increase, the detectable difference for each habitat variable decreases (Table 4-7). By increasing the number of years sampled after BMP implementation from 1 to 4 years, we can detect a change half as small. Similar relationships exist for increases in number of years of sampling from 4 to 10 years post-BMP. For stream width, four years of data collection will allow us to detect a change of 1m or less for most sites and 0.5m or less after 10 years (Table 4). Differences in average depth that can be detected post-BMP was also small for most sites (Table 4). With 4 years of post-BMP data collection, we can detect a change in average depth of 100mm (approximately 4 inches) in nine out of the twelve sites and a difference of 70mm after 10 years.

Substrate sizes were found to be the most variable channel morphology characteristics within both uniform and diverse sites (Figures 11 and 13). Annual variability for point and maximum particle size was high at some sites, such as upper Hurricane, making it difficult to detect a small change in substrate. However, this large detectable difference at Hurricane upper is due to the shift in predominately bedrock in 1998 to mostly sand/small gravel in 1999 and 2000. Although we are unable to detect small changes at a few sites, we can detect a difference of 15 mm or less in point particle sizes at a majority (8 of 12) of the sites. This degree of detection would allow us to separate out fines (clay, silt and sand) from courser substrate (medium gravel).

Hydraulic head (a measure of velocity) was less variable within both diverse and uniform habitat sites (Figures 9 and 12) as well as across years for most of our sampling sites, thus, allowing us to detect small changes in velocity after BMPs (Table 6). With 1 year of post-BMP collection, we can detect a difference in hydraulic head of 5 mm or less (approximately 1 m/s) in 10 of 12 sites (Table 6). If we sample an additional 3 years post-BMP, we can detect a change in hydraulic head of 2 mm or less (about 0.04 m/s) in three fourths of the sites and about 1 mm after 10 years of post-BMP sampling.

From this power analysis on channel morphology characteristics, it appears that with a moderate amount of post-BMP data collection (4 or 5 years), it is possible to detect small changes in habitat as a result of improved stream quality. We will continue to look at other habitat measurements in addition to channel morphology characteristics as well as examine how alternative methods for collecting point-transect data (i.e. taking points only in the thalweg) will affect the accuracy of our habitat measurements.

In-stream habitat

With flooding a common event in these flashy systems resulting in inputs of upland sediment and shifting streambed substrate, channel structure can often change in these watersheds. We examined differences in habitat types between pilot and reference watershed sites and examined annual variability. In the Embarras basin, the upper sites were similar in percent habitat types (i.e. pool, riffle, run). Upper sites were dominated by pool area (73% in Hurricane Upper, 62% in Kickapoo Upper) with 13% run habitat and similar amounts of slow riffles (Figure 14). Both upper sites changed across years. In 1999, Hurricane Upper was less diverse than in 2000 with 22% islands and 78% pool while Kickapoo Upper was more diverse with larger amounts of slow (17%) and fast riffles (17%) (See Figure 4 in Dodd et al. 2000, Annual Progress Report). In 2000, lower sites of the Embarras were less similar to each other than upper sites. Kickapoo Lower had far less pool habitat (30%) than Hurricane (67%), almost twice a much run habitat, and three times as much slow riffles (Figure 14). Kickapoo Lower is also more consistent in percent habitat composition over time than Hurricane Lower which had 95% of it habitat as pool in 1999 (See Figure 4 in Dodd et al. 2000, Annual Progress Report).

In the Spoon basin, differences in habitat composition between upper sites and between years within upper sites were less evident than for lower sites (Figure 14). In the upper sites, percentage of pools were similar between Court Upper (81%) and Haw Upper (72%) in 2000 although Haw Upper had twice the percent run habitat as Court Upper. From 1998 to 2000, percent pool habitat slightly decreased for both upper sites while percent run increased (See Figure 5 in Dodd et al. 2000). Lower sites of the Spoon basin were dissimilar in habitat composition in 2000. Court Lower had 22% less pool and twice as much run and fast riffle habitat than Haw Lower. Court Lower was more variable across years, shifting from predominantly pool habitat (73% in 1998) to less pool habitat and more run habitat (40% and 37% in 2000) (See Figure 5 in Dodd et al. 2000). Haw Lower was more consistent across years, but also showed a shift from pool to more run and fast riffle habitat.

Habitat in the Cache basin was dominated by pool areas in both upper and lower sites in 2000 (Figure 15). However, Big Upper did have 7% percent island and 3% run habitat. Lower sites were also dominated by pools with a very small amount of run habitat in both sites. Across years, upper and lower sites were consistent in habitat composition (See Figure 6 in Dodd et al. 2000). Like the Cache basin, the upper and lower sites in the Kaskaskia basin were completely dominated by slow flowing deeper pool areas (Figure 15) and did not change habitat composition over time (See Figure 7 in Dodd et al. 2000). Overall, habitat types were found to be similar between the pilot and reference watersheds with the lower Embarras and lower Spoon showing the most variability between sites and the Kaskaskia showing the least variability.

Since depth and hydraulic head within a site determines the type of habitat (i.e. riffle, run, pool), we also examined how annual variability of these two characteristics combined affect the amount of change we can detect in types of habitat post-BMP. We can detect a change of 20% in pool habitat in 10 of 12 sites based on four years of post-BMP data collection (Table 6) whereas a 20% change in riffle and run habitat can be detected in all sites (Table 7). For riffle and run habitat, we can detect a change as small as 10% in 11 and 9 of the12 sites if we sample at least 4 years after BMP implementation (Table 7). If we sample for 10 years post-BMP, we can detect this same amount of change (10%) in all sites for riffle habitat and 11 of 12 sites for run habitat. Although the two habitat parameters in which we derive percent habitat types showed some annual variability, we are confident that we can combine depth and hydraulic head to get an accurate estimate of percent habitat type and detect small amounts of change after BMPs.

As part of our baseline in-stream survey, we measured the amount of in-stream cover and vegetation. All basins showed little in-stream cover and vegetation (Figures 16-19). In the Embarras, most in-stream cover was unembedded and consisted mostly of wood. In the upper sites, Hurricane had no in-stream cover, while Kickapoo contained wood (5%) and flat rock (2%) cover in 2000 (Figure 16). At lower sites, both Hurricane and Kickapoo had 5% unembedded wood cover, but Kickapoo also had 3% unembedded round rock and unembedded and embedded flat rock. Cover in the Spoon basin consisted of unembedded and embedded cover as well as a small amount of macrophytes (Figure 17). Upper sites were similar in overall percent cover with Haw Upper having more woody cover (4% unembedded, 2% embedded). As with the upper sites, lower sites of the Spoon had very little in-stream cover, but the types of cover in each of the lower sites were different, with Court having unembedded wood (2%) and flat rock (2%) and Haw Lower having macrophyte cover (2%).

Sites in the Cache and Kaskaskia basins had the most in-stream cover. In the Cache basin, cover in upper and lower sites were dominated by unembedded wood and unembedded flat and round rock cover (Figure 18). Upper sites were comparable in cover, but Cypress Upper contained about 5% more unembedded wood. At lower sites, unemebbed wood cover was higher in Big Creek with a small amount of unembedded flat rock cover. Like the Cache, the Kaskaskia basin was also dominated by wood (Figure 19). In the upper sites, Lake Branch had 6% more unembedded wood cover than Lost and a small amount of unembedded flat rock (3%). For the lower sites, percent cover composition was similar between pilot and reference, but Lake Branch (pilot) had more wood cover. Overall, there were low amounts of in-stream cover in all basins. Within basins, categories of cover varied slightly between pilot and reference sites, but overall percent cover was generally comparable between pilot and reference watersheds.

Bank Conditions

In these watersheds bank erosion has been identified as a major concern. Consequently, it is anticipated that in-stream and on-field BMPs will be used to reduce erosion. Therefore we examined pre-BMP bank conditions (bank vegetation, overstory cover, and bank height) to assess changes in bank stability and shading of the stream as

BMPs are implemented in the pilot watersheds. Land from water's edge to 2m on either side of the stream (0-2m) was usually dominated by herbaceous vegetation or was bare in all basins (Figures 20-23). Moving out to 100 m, we found a general progression from herbaceous to mature trees to cultivated fields. Most sites had a very narrow buffer strip of grasses and/or trees, but agricultural land use was usually within 100m of the stream. This pattern was evident in the Embarras (Figure 20). For both upper and lower sites, the reference stream (Kickapoo) tended to have more herbaceous vegetation near the water and more quickly became dominated by cultivated fields in the 10 to 100m buffers, while the pilot had a wider buffer of trees. In the upper sites, overstory cover was higher in the pilot indicating more tree cover near the stream, while in the lower sites, the reference had a greater percent cover indicating higher number of trees along the stream edge (Figure 24). This pattern is also true for the upper sites of the Spoon (Figure 21) with the pilot (Court) predominantly herbaceous at water's edge and becoming dominated by trees throughout most of the 100m buffer, while the upper site of the reference is mostly herbaceous and becomes predominately cultivated after 30m due to a cattle pasture located adjacent to both sides of the stream. This is also reflected in the percent overstory cover of the upper sites, whereby the pilot site has a slightly higher percent overstory cover (Figure 24). Lower sites were much more similar in riparian vegetation, although the reference stream tends to have more trees in its 30-100m buffer area and a higher percent overstory cover for all years.

For the Cache, all sites follow the pattern from herbaceous to trees to cultivated riparian area. However, in the upper sites, Big has trees closer to the stream (2-10m buffer) more often than Cypress (Figure 22) although this is not evident in the overstory cover which suggests more tree cover near the stream in Cypress (Figure 24). In the lower sites, the opposite pattern for riparian vegetation and overstory cover is true where the reference tends to have more trees in the riparian buffer but less overstory cover (Figures 22 and 24). For upper sites of the Kaskaskia, latitudinal trends in riparian areas are more dissimilar than those in the lower sites (Figure 23). The upper site of the pilot (Lake Branch) is mostly herbaceous near water's edge with a very narrow buffer of trees (Figure 23), while the reference site has a wider buffer of trees and higher percent overstory cover (Figure 24). For the lower sites, the opposite is true where the pilot has a larger riparian area of trees (Figure 23) although overstory cover near the stream was similar between the pilot and the reference (Figure 24).

Bank height measurements were collected as a measure of bank stability where a high bank stability rating indicates more stable banks. The Embarras had similar bank stability ratings between both upper and lower sites with similarity of upper sites more consistent across all years (Figure 24). Lower sites were less similar in 1998 with increased similarity in bank stability from 1998-2000. However, we should note that bank height was estimated in 1998 and not directly measured as in 1999 and 2000, thus, bank stability rating may not be as accurate in 1998. Like the Embarras, the lower site of the pilot (Court) in the Spoon basin was found to have slightly less stable banks than the reference with a trend of increasing similarity across time (Figure 24). In 1998, bank stability in the upper sites was much lower in the pilot (Court) than corresponding reference site (Haw), while in 1999 and 2000 bank stability tended to be more similar between Court and Haw. Again, these differences may be due to a categorization of bank angle in 1998, therefore, these may not be an accurate representation of the apparently large changes in stability.

In both the Cache and Kaskaskia, the pilot sites showed higher stability than their corresponding reference sites with the exception of the lower sites of the Kaskaskia in 2000 (Figure 24). Between the upper sites of the Cache in 1998, we found a large difference in bank stability with Big Upper (pilot) having more stable banks; but in 1999 and 2000 there was very little difference in bank stability. In the lower sites of the Cache, the difference in stability between Big and Cypress was fairly consistent across years with Big Lower having higher bank stability.

RECOMMENDATIONS

From our baseline data collected in 1998-2000, differences in channel morphology between pilot and reference streams was somewhat variable in terms of average width and depth, but substrate and velocity was similar between pilot and reference watersheds. Channel structure was generally similar within basins with the exception of the lower Embarras and lower Spoon basins where habitat diversity was high and varied between sites more so than in other basins. In-stream cover was low in all basins and latitudinal trends in bank vegetation was comparable between sites and across basins. In general, our baseline data indicates that the majority of in-stream habitat characteristics and bank vegetation conditions were similar between pilot and reference watersheds. Bootstrap analysis indicated that most of our channel morphology parameters were consistent within diverse and uniform habitat sites, with substrate size the most variable component. In general, 10 transects were sufficient to assess site characteristics, although characterization of substrate in a stream reach may need additional substrate points taken between transects. Power analysis on all sites with at least 3 years of baseline data showed that with 4 to 10 years of post-BMP sampling, we can detect increasingly small changes in our in-stream habitat parameters. At most sites, detectable changes increase from moderate to very small over these time scales. For our power analysis, we assumed that our annual variability after BMPs would be similar to pre-BMP variability, therefore, our estimates of detectable change after BMPs is dependent on the number of baseline samples. The best assessments of annual variation in habitat between pilot and reference watersheds will be obtained with additional collection of pre-BMP habitat data. Additional baseline data will provide a better assessment of annual variability in these systems allowing us to better assess the potential to detect changes after BMPs. In the next segments of the study, we will examine additional in-stream, bank, and riparian habitat measurements and compare our estimates of detectable change in habitat characteristics to those in the literature to determine if our ability to detect changes in habitat are within a reasonable range of change that we may expect due to BMP implementation. As part of our analysis, we will also investigate how habitat variability within both diverse and uniform sites changes with slightly different collection methods (i.e. taking measurements at points within the thalweg only or with two points on either side of the thalweg) and how these methods affect our ability to detect changes after BMPs.

To help assess annual variability in stream habitat and how this will affect our ability to detect changes after BMPs, additional baseline data will be collected during late summer 2001 in all basins except the Spoon. In this basin, BMPs are being implemented in the pilot and we will begin collecting data during the implementation phase this year.

Gaging stations were installed in or near both upstream and downstream sites in the pilots and in or near the downstream site in the reference watersheds. Two exceptions are the Kaskaskia basin where the pilot has only one gaging station and the Embarras where the reference station is located at the upstream site. Data from gaging stations will be analyzed by ISWS to assess changes in chemical parameters following implementation of BMPs and INHS will incorporate the chemical parameters with biotic variables to help define mechanisms of impacts these BMPs have on the biota.

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. A number of observational, correlative studies suggest that fish and invertebrates should respond strongly to changes in land use practices within watersheds through changes in nutrient and sediment loading, hydrology, and in-stream shading and cover (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 understanding on 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 were collected with a single pass using a standard AC electric seine (Bayley et al. 1989; Bayley and Dowling 1990). 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) found that CPUE provided the same values for species richness and percent species composition as depletion sampling and took only one quarter the time required for depletion sampling. Fish samples were collected in late summer of 2000 from August to September. Captured fish were identified to species, counted, and lengths and weights were recorded. 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 100mm were processed and released whereas smaller fish were fixed in 10% formalin and preserved in 70% ethanol in the laboratory for processing.

For assessment of fish assemblage structure and differences in structure between pilot 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 relative abundance of the k-th species at site i, and y_{kj} is the relative 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 pilot and reference sites, catch per unit effort (CPUE) was computed. Evaluating fish size structure, average weight and biomass for each species was computed and compared between corresponding pilot and reference sites. Using fish community data, we calculated the Index of Biotic Integrity (IBI) to estimate the overall health of the aquatic ecosystem at each study site.

FINDINGS

Fish Assemblages

Species Richness

In 2000, a total of 21,350 fish encompassing 65 species were caught among all basins. The Embarras basin made up 60% (56% in 1999 and 52% in 1998) of the total catch and included 37 (36 in 1999 and 32 in 1998) species (Table 8). All sites in the Embarras basin were fairly similar in species richness ranging from 23 to 31 species. The largest difference in species richness was between the upper sites with Kickapoo Upper yielding five more species than Hurricane Upper (Table 8, Figure 25). Both upper and lower sites on Hurricane held higher numbers of individuals in 2000 (Table 8), but the difference in total catch was not consistent across years for both upper or lower sites of the Embarras (Figure 25). The Spoon basin contained 17% (15% in 1999 and 35% in 1998) of the total fish catch and included 30 species (36 in 1999 and 32 in 1998) (Table 9). Species richness was similar between the lower sites of the Spoon basin but less consistent across years than the upper sites, while the upper sites were less similar with the pilot containing 6 more species than the reference (Figure 25). Differences in numbers of fish were also more consistent across time in the upper sites, while the lower sites show a decrease across years.

The Cache basin contained 20% (25% in 1999 and 12% in 1998) of the total catch and included 31 species (32 in 1999 and 29 in 1998) (Table 10). In 2000, species richness was extremely similar between upper and lower sites in the Cache. Examining species richness across years, differences between the upper sites were more similar across all years, whereas the lower sites had large differences in species richness in 1998 and 1999 (Figure 25). Numbers of individuals were not comparable between upper or lower sites in 2000, but lower sites were more similar across years than upper sites. The Kaskaskia basin had the lowest number of individuals making up only 3% of the total catch (3% in 1999) (Table 11). Both upper and lower sites of the Kaskaskia basin were comparable in numbers of fish caught, but species richness was lower in Lake Branch for both upper and lower sites.

Assemblage Composition

To assess similarity in species composition between pilot and reference sites, Jaccard's Similarity Index and Similarity Ratios were calculated with a value of one indicating complete similarity between sites (Table 12, Figure 26). Based on Jaccard's index, the species composition between upper and lower sites of the Embarras was similar with a value of 0.76 and 0.69, respectively. Lower sites in the Embarras remained consistent across years, but fish communities in upper sites increased in similarity in 2000. The Spoon basin had higher similarity between the lower sites (0.54) in 2000 than the upper sites (0.48) (Table 12), but similarity between upper sites are more consistent across years (Figure 26). The Cache basin had moderate similarity in assemblage composition between upper and lower sites with a similarity of 0.50 for both sites (Table 12). Across years, Jaccard's similarity index between the lower sites of the Cache increased from that in 1998, while the assemblage similarity index for the upper site remained comparable to 1998 and 1999 (Figure 26). In the Kaskaskia, both the upper and lower sites had poor community similarity due to the low number of species caught in the pilot in 2000.

Similarity Ratios, which take into account abundances of each species, were lower overall but showed similar trends to Jaccard's similarity index (Table 12, Figure 26). The two exceptions were the upper sites in the Embarras in 2000 and the lower sites in the Cache in 1999 (Figure 26). As with Jaccard's index, the upper sites of the Embarras showed an increase in Similarity Ratio across years, but the magnitude of the increase in 2000 was much greater for Similarity Ratios than for Jaccard's index. For the Cache, we found a high Similarity Ratio for lower sites in 1999 compared to 1998 and 2000, but the Jaccard's index was similar between 1999 and 2000 (Table 12, Figure 26). Overall, sites were fairly similar in assemblage composition and consistent across years but were less similar when taking into account relative abundances (Similarity Ratio).

Fish Abundance

To analyze the pre-BMP conditions in overall fish abundance in pilot and reference streams, catch per hour of electroshocking time was calculated for each site (Table 13, Figure 27). In the pilot watersheds, a pattern of higher CPUE in both upper and lower sites was observed with the exception of the lower sites in the Spoon and the upper and lower sites of the Kaskaskia (Table 13). The Kaskaskia basin showed the lowest CPUE at all sites, while the Embarras showed the highest CPUE at all sites except in the lower reference (Table 13). Similarity in CPUE between upper and lower sites was not consistent across all years within any particular basin (Figure 27). The upper Embarras sites were dissimilar in their CPUE but consistent across 1998 and 1999, while the lower sites show an upward trend of increasing dissimilarity (Figure 27). For the lower sites of the Spoon, we found an increase in similarity of CPUE across time, while the upper sites remained relatively stable across years. In the Cache, upper sites of the pilot tended to have consistently higher CPUE than the reference for all years, but the lower site showed a fluctuation from lower CPUE in the pilot in 1998 and 1999 to higher CPUE in 2000. Although the Kaskaskia had the lowest CPUE of all basins and was the most dissimilar in terms of species richness, CPUE was similar between the upper and lower sites.

Fish Size Structure

Weights of each species caught were averaged for each site and comparisons of biomass and percent composition of biomass were made between upper and lower sites within each basin to determine differences in size structure between pilot and reference streams. Comparing the upper sites of the Embarras, the reference site (Kickapoo) has eight times greater fish biomass per area than the pilot and is dominated by steelcolor (25.9%) and spotfin shiners (29.5 %), while the pilot is dominated by central stonerollers (28.3%)(Table 14). In the lower sites, total biomass was similar with both sites achieving about 14% of their biomass from longear sunfish (Table 15). In the Spoon basin, the upper sites were more similar in total biomass, although the reference (Haw Upper) did have almost twice the biomass (9.7 g/m^2) as the pilot (5.1 g/m^2) (Table 16). Biomass in Court Upper was dominated by carp, while Haw Upper contained high biomass of white suckers. Lower sites of the Spoon were more dissimilar in total biomass than upper sites with the pilot having almost five times as much biomass (Table 17). Court Lower was dominated by central stoneroller (34.1%) while Haw Lower was dominated by red shiner (41.4%) with both sites obtaining a high percentage of their biomass from golden redhorse (21.8% in Court, 26.9% in Haw).

In the Cache basin, creek chubsucker comprised 34.4% of the biomass in the pilot (Big) and 18% in the reference (Cypress) (Table 18). Lower sites were not as similar as the upper sites in total biomass. The pilot had three times more fish biomass than the reference (Table 19), but both lower sites had high percent of their biomass from bluntnose minnow (30% in Big, and 18.6% in Cypress). White sucker also make up about 30% of the biomass in Big Lower while creek chubsucker made up 21.6% in Cypress Lower. Like the Cache, the upper sites of the Kaskaskia were similar in total biomass, but the composition was different between the two sites. Brown bullhead, green sunfish, and gizzard shad made up most of the biomass in Lake Branch while bluegill made up most of the biomass in Lost (Table 20). By comparison, at the lower sites, total biomass was four times greater in the reference but composition was fairly similar with common carp making up most of the biomass in both sites (Table 21).

Fish Community

To assess the quality of the fish community, the Index of Biotic Integrity (IBI) was computed for each site. Of the 16 sites sampled in 2000, two sites attained a score greater than 51 of a possible 60 (Table 22). Seven sites showed scores ranging from 41 to 50, five sites had scores between 31 and 40, and two ranged from 21 to 30. Overall, the sites in the Embarras basin had high IBI scores with scores ranging from 50 to 52. Differences in IBI scores between upper and lower sites of the Embarras were variable across years with a decreasing trend in the lower sites (Figure 28). Court and Haw Creeks in the Spoon basin had scores ranging from 36 to 50. Upper sites in this basin were found to be more similar (difference of 4) in quality than the lower sites, although lower sites had better quality. The lowest score in the Spoon basin occurred in the Haw upper site, due to cattle having access to the stream increasing bank erosion, nutrient loading and turbidity. However, the quality of this site was still found to be relatively high. As with the Embarras, differences in IBI scores were not consistent across years. Sites in the Cache basin were also found to be relatively high in community quality with three of the four sites having scores greater than 41. Big Lower contained the lowest quality with a score of 40. Examining differences in IBI scores for the Cache, we found a increased similarity in both upper and lower sites across years. Of all four basins, the Kaskaskia had the lowest stream quality with scores ranging from 26 to 40. The upper sites of the Kaskaskia were found to be the most dissimilar in IBI scores of all basins.

In general, most sites showed good stream quality. However, 3 of the 8 comparisons in IBI scores between upper and lower sites revealed a difference in scores greater than 4 points. 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.

As with in-stream habitat, we were also interested in the ability to detect changes in fish assemblage composition, abundance, and quality of the fish community after BMP implementation. Species richness is a good indicator of stream with higher species richness usually meaning better stream habitat conditions. Most sites showed low annual variability in number of species caught resulting in the ability to detect a change in five species or less for three fourths of our sites based on sampling four years post-BMP (Table 23). After 10 years, changes of three species or less could be detected. Lower Big and upper Hurricane had the most annual variability of the 12 sites and, thus, we can only detect changes of eight and seven species after four years. These two sites also had high fluctuations in catch per unit effort (CPUE) between years resulting in a larger difference needed between pre- and post-BMP years in order for us to detect a change in abundance (Table 23). Our ability to detect only large changes at the upstream site of Hurricane Creek is probably linked to the shift in substrate from bedrock in 1998 to sand/gravel in 2000. In 2000, we caught species such as sunfish and suckers that were more adapted to finer substrates and were not previously found at this site in 1998 and 1999 (Table 8). At the lower site of Big Creek we also see an increase in both species richness and CPUE from 1998 to 2000 (Tables 10 and 13; see previous Annual Reports for 1998 and 1999 data). At this time, it is not clear what is driving this increase in species richness and CPUE; changes in in-stream habitat have been consistent across years at this site. By incorporating water quality data from ISWS with our fish data, we may find a relationship between the amount or type of nutrients coming into the system and the fish assemblage. CPUE was the most variable fish assemblage characteristic we measured which indicates that this parameter may not be a good measure of change as stream conditions improve.

In a comparison of fish assemblages between pilot and reference watersheds, we were able to detect a change in similarity of 20% between upper and lower sites with Jaccard's index which is based on presence/absence (Table 24). When taking into account abundance as well as species richness (Similarity Ratio (SR)), we found that a larger difference is needed in the upper Embarras and lower Cache in order to detect a change in assemblage similarity (Table 24). This is due to the annual fluctuations in CPUE in upper Hurricane and lower Big Creek (Table 13; see previous Annual reports for 1998 and 1999 data). However, similarity comparisons between upper and lower sites in the remaining watersheds had low annual variability; thus, we are able to detect changes of 20% or less in assemblage similarity using SR.

For IBI scores which indicate overall quality of the fish community, we can detect a change in score of five or less in eight of the 12 sites based on four years of post-BMP collection and three or less after 10 years (Table 25). With the current modification of IBI metrics for Illinois streams, reevaluation of these sites with the new IBI scoring criteria may stabilize scores across years allowing for improved detection of changes in fish assemblages.

RECOMMENDATIONS

The analysis of species richness, community composition and CPUE between pilot sites and their corresponding reference sites indicates that most of our pilot and reference watersheds are similar, but not necessarily consistent across years. With the exception of the upper sites in the Embarras basin where most species were larger in the reference and lower sites of the Spoon where most species were larger in the pilot, size structure of most fish species was comparable between pilot and corresponding reference watersheds. Although the quality of the fish community was different in three of the eight comparisons between upper and lower sites, most sites were comparable in IBI scores.

From our analysis of composition, abundance, and size structure we found that there is variability among years especially in CPUE, but that our pairings are well matched for examining differences in fish assemblage composition and size after BMP implementation.

To assess the changes in fish assemblage in these pilot watersheds, further pre-BMP data will need to be collected and analyzed. Baseline data are 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 treatment and control sites in each period (Osenberg et al. 1994). As with our habitat data, additional baseline fish data is needed to improve our predictions on the amount of changes we can detect in fish assemblages after BMPs. In the next segments of the study, we will attempt to compare our estimates of detectable change against studies that have monitored stream restoration at small scales in other regions to determine if our ability to detect changes in fish assemblages is within an adequate range. Obtaining sufficient numbers of pre-treatment samples is critical, because additional before samples cannot be obtained after the treatment is implemented. This is especially important in the Kaskaskia where we have been unable to sample the upstream reaches the past two years of this study. In late summer 2001, additional baseline fish data will be collected at all basins except the Spoon where BMPs will be implemented beginning in summer of 2001.

In the Spoon basin, we are monitoring changes in fish assemblages during the implementation phase through watershed-scale monitoring and site-scale monitoring at locations where individual BMPs are being implemented. We are currently monitoring a Newbury weir site in the Court Creek watershed where we have two pre-BMP sampling dates (one in mid-Oct. 2000 and one in late May 2001) and one post-BMP date (late August). We will continue to monitor this site as well as additional BMP sites. In Big Creek, monitoring began in 2000 at a location also designated for Newbury weir construction, however, it is not clear when these weirs will be constructed.

Job 101.3. Effects of BMPs on fish growth rates.

OBJECTIVE

To determine the local and watershed-wide responses of fish growth rates of selected 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 (Schlosser 1995). Our study will further examine the impacts of BMPs on fish populations by evaluating differences in growth rates before and after BMP implementation. Growth is a useful metric for evaluating habitat suitability, prey availability, fish health, and management practices because it results from the effects of both endogenous and exogenous conditions (DeVries and Frie 1996). Species composition, abundance, and size structure have historically been used to describe the population dynamics of stream fish communities, but the results of these metrics offer little insight into the factors regulating them. A species appearing in the population only means that the habitat falls into a range of conditions that allows the species to exist. It does not give an indication of how well the habitat meets the needs of the species. For example, high abundance may indicate that reproductive potential and survival are not limited by the habitat, but abundance fails to account for the health and sustainability of the existing population. Size structure alone is not an adequate indicator of how well the habitat meets a species needs because it does not provide information about the time it took for the individuals in a population to reach their current size. Growth rates will also likely respond more quickly to changes in habitat and invertebrate populations, providing a more sensitive response variable to BMPs than fish community variables. By examining growth rates, our understanding of the mechanisms regulating stream fish communities (Schlosser 1987) and traditional evaluation metrics will be improved because growth plays an important role in regulating population dynamics of fishes

(Werner and Gilliam 1984). Therefore, we will determine the growth rates of individual species in addition to species composition, abundance, and size structure of stream fish in an effort to detect changes in stream quality. As we observed from our 1998-2000 data, species composition, abundance, and size structure 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 more effective measure of improvements in stream quality than species composition and abundances as well as help us to understand the factors regulating species composition, abundance, and size structure.

PROCEDURES

Changes in growth rate will be evaluated for selected fish species associated with the implementation of watershed management practices at each of the sites. Based on the 1998 fish data, the most common species that were abundant across sites were chosen for analysis. These were: largemouth bass, smallmouth bass, bluegill, longear sunfish, green sunfish, creek chub, white sucker, golden redhorse, central stoneroller, and yellow bullhead. 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. Scales were used for aging *Micropterus* spp., *Lepomis* spp., creek chub, central stoneroller, and golden redhorse collected in 1998 and 1999. For fish collected in 2000, scales were used to age *Micropterus* spp., *Lepomis* spp. ≤ 150 mm, creek chub, central stoneroller, and golden redhorse. Otoliths were used for aging *Lepomis* spp. > 150 mm collected in 2000. Pectoral fin rays/spines will be used for aging white sucker and yellow bullhead. Fish larger than 100 mm were identified to species, weighed, measured for total length, and released after the proper aging structures were removed. *Lepomis* spp. > 150 mm were returned to the lab and frozen for otolith extraction. Other fish species smaller than 100 mm were preserved in 10% formalin and returned to the lab. Preserved samples were processed in the lab using the same protocol as those in the field. We hope to obtain a minimum of 30 individuals per species and site for age and growth analysis. 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. A subsamble 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 pilot and reference sites. In addition, annual size-specific growth will be determined for two sizes for each selected species (Putnam 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

Scales and otoliths collected from centrarchids and golden redhorse in 1998, 1999, and 2000 have been aged. Measurement of the interannular distances will be conducted in future segments. Creek chub and central stoneroller scales, along with white sucker and yellow bullhead fin rays/spines, will be processed, aged, and measured as well. An assessment of population age structure and growth trends of the species that have been aged from pilot and reference watersheds will be given in this report.

The average age of largemouth bass showed the most variation of all species between pilot and reference sites within each basin (Table 26). The Embarras and Kaskaskia basins particularly displayed a difference between pilot and reference sites, while largemouth bass in the upper and lower sites of pilot and reference streams in the Cache and Spoon basins were similar in average age. For all basins, growth of largemouth bass between upper and lower pilot and reference sites in streams were similar. However, the relationships were slightly less similar in the Cache and Kaskaskia basins than in the Embarras with differences in average length between sites for each age class possibly caused by small sample sizes from the reference streams (Figure 29).

Smallmouth bass were collected in frequent numbers only from the pilot stream of the Spoon basin (Figure 30). Average age of bluegill differed very little between pilot and reference sites in each basin with the exception of the lower pilot site of the Embarras (Table 26). Bluegill growth was similar between the pilot and reference sites of each basin although some variation began to occur with the older age classes likely due to low numbers of older individuals being collected (Figure 31). Within each basin, the average age and growth of longear sunfish were similar between upper and lower pilot and reference sites of watersheds. Longear sunfish from the lower pilot site of the Cache had a smaller average length than the lower reference site despite averaging one year older (Table 26, Figure 32). No longear sunfish were collected from the Spoon basin or the pilot stream of the Kaskaskia basin. As with the other sunfish species we examined, green sunfish had similar average ages for most pilot and reference sites within a basin (Table 26). In the Embarras basin, individuals collected from the reference sites were slightly older than those collected from the pilot sites. One exception is the Spoon basin where difference in average age between upper and lower sites was at least one year, however, this is probably attributable to small sample size for the pilot sites (N=1). Growth was also similar for green sunfish within each basin (Figure 33). We found similar average age and growth for golden redhorse between upper and lower pilot and reference sites in streams within each basin (Table 26, Figure 34). Golden redhorse were collected from only one site of the Embarras and Cache basins and no sites of the Kaskaskia basin.

RECOMMENDATIONS

From our preliminary analysis, population age structure and growth of largemouth bass, smallmouth bass, bluegill, longear sunfish, green sunfish, and golden redhorse appeared similar for upper and lower pilot and reference sites within each basin. As bony structures are aged for the remaining species and radii and interannular distances are measured for all species, we will be able to better assess pre-BMP population age structure and growth rates. In the 2001 field season, additional structures were taken for more pre-BMP growth analysis in the Embarras, Cache, and Kaskaskia basins. Once these data are collected and analyzed, we will conduct power analysis to determine the magnitude of changes in growth rates that we can detect as a result of BMP implementation. Implementations of BMP's have begun in the Spoon basin and changes in growth during this phase will begin to be analyzed.

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 seasonally 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) and growth (Job 101.3).

PROCEDURES

Benthic macroinvertebrates were sampled at each site from riffle, glide/pool, and run habitats in fall (September – November) of 1998 and spring (May – early June), summer (July), and fall (October) 1999 and 2000. At most sites 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 and 2000 equipped with a 300 μm mesh net. Fine gravel – sand/silt substrates (run or glide/pool 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 1999 and 2000, depth and hydraulic head was also recorded at the location of each sample to help categorize habitat types. Samples were preserved in the field in their entirety with 4% formalin.

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. Samples were elutriated using various size sieves and sorted from organic debris using a dissecting microscope at 10X magnification. Samples with a large number of organisms were sub-sampled and macroinvertebrates identified to the family level with more sensitive taxa (Ephemeroptera, Plecoptera, and Trichoptera) identified to genus using various taxonomic keys (Wiederholm 1983; Thorp and Covich 1991; Merritt and Cummins 1996)

All samples from 1998 and 1999 have been processed and are currently being identified. Data presented in this report are from glide/pool habitats. In addition, few riffle samples from 1999 have been identified and are included in this report. To analyze the community structure in glide/pool habitats we examined trends in taxa richness, %EPT, and macroinvertebrate abundance. We also assessed stream quality through Hilsenhoff's Family Biotic Index (Hilsenhoff, 1988).

FINDINGS

In general, glide/pool habitats were dominated by chironomids and oligocheates in all basins (Tables 27-30). In the Embarras basin, taxa richness was similar in both upper and lower sites of fall 1998 and spring 1999. Total catch per area (CPA) differed among upper and lower sites with the pilot sites having greater CPA than reference (Table 27). For the Spoon basin, upper and lower sites in all years and seasons were similar in taxa richness with the exception of the upper sites in fall 1998 (Table 28). In the fall samples, catch per area was higher in both upper and lower sites of Court, while Haw had higher CPA in the spring 1999 samples.

Taxa richness and relative abundance for the Cache differed between the upper sites in fall 1998 and spring 1999 with Big Upper yielding higher taxa richness but lower CPA than Cypress Upper (Table 29). Lower sites were similar in taxa richness for fall 1998 and spring 1999, although CPA greatly differed between the sites in fall 1998 (Table 29). Spring and Fall riffle samples at the upper pilot site (Big) did not have higher species richness than the glide/pool habitats, but did have higher numbers of Ephemeroptera, Trichoptera, and Amphipoda taxa (Table 31). In the Kaskaskia, only one site in one season has been identified and analyzed. However, comparing the lower site of Lake Branch with those of other basins suggests that taxa richness is relatively high (Table 30).

To further assess community structure as well as water quality, we computed FBI (Hilenshoff 1988; Lenat 1993) and %EPT scores. In general, FBI scores were high and %EPT was low for glide/pool habitat in all basins and seasons, indicating poor water quality (Table 32). In the Embarras, upper sites were similar in FBI and %EPT in fall 1998, while in the lower sites, the macroinvertebrate community was very poor in the reference but only fairly poor in the pilot. In the Kickapoo Lower site in spring 1999, %EPT was high compared to Hurricane although FBI scores indicated both sites were poor quality. In the Spoon basin, the upper and lower reference sites had higher FBI and lower %EPT scores (except Haw Lower in fall 1998) than the pilot in both fall and spring samples, indicating lower water quality in the reference. Sites in the Cache were very poor quality in all seasons, with the upper and lower pilot sites having slightly better quality than their respective reference sites. Examining the riffle samples in the upper site of the pilot (Big) in spring and fall 1999 shows good quality and higher %EPT taxa then glide habitats in that basin. Percent similarity, which compares FBI scores between upper and lower sites, was high in all basins, indicating that pilot watersheds were very similar in FBI scores to their corresponding reference watershed (Table 33).

As with habitat and fish assemblages, we are also interested in understanding the sensitivity of our sampling methods to detect changes in macroinvertebrate assemblages using our current sampling methods. In order to examine accuracy of our samples in describing the benthic community for a stream reach, we performed a bootstrap analysis on number of core samples needed to obtain 20% SE of the mean in spring and summer samples. From our analysis, we found that for most sites, we are collecting adequate number of core samples in both spring and summer to reach 20% SE (Figures 35-38). All but one site in which the standard errors did not reach 20% of the mean had only one season where this was the case. Court Upper was the only site where both spring and summer samples did not reach 20% SE. From this preliminary analysis, we feel we are accurately characterizing benthic invertebrates in the glide/pool habitat in our study reaches. We intend to analyze samples from glide/pool habitats from the fall as well as samples taken in riffles in order to determine if our sampling methods are accurate enough to detect changes in benthic communities for various seasons and habitat types.

RECOMMENDATIONS

Baseline data from 1998 and 1999 revealed similar macroinvertebrate composition between pilot and reference watersheds with most glide/pool habitats dominated by chironomids and oligocheates. FBI scores were high and % EPT was low for glide/pool habitats at all sites suggesting poor water quality and opportunities for improved stream quality after BMP implementation.

Our preliminary bootstrap analysis in pool/glide habitats indicate that our sampling protocol gives us a sufficient estimate of total numbers of benthic macroinvertebrates within a stream reach. Ongoing processing of 2000 samples and identification of 1998 and 1999 samples will continue in subsequent segments. From this additional data, we will examine within site variability in macroinvertebrate abundance and richness for different seasons and types of habitat. We will examine our annual variability in benthic invertebrate communities and our ability to detect changes in benthic macroinvertebrate communities after BMPs.

In order to improve our ability to detect a change following BMP implementation, collection of additional benthos samples will be necessary to quantify pre-BMP conditions in macroinvertebrate communities in pilot and reference watersheds. We will continue to monitor pre-BMP conditions in the Embarras, Cache, and Kaskaskia basins. In the Spoon basin, we have begun monitoring changes in macroinvertebrate assemblages as BMPs are implemented in the pilot watershed at both the watershed-scale and at specific sites were BMPs are being installed. We are monitoring changes in macroinvertebrate communities at the same Newbury weir site in Court Creek where we are monitoring changes in fish assemblages and habitat. For macroinvertebrates, we have two pre-BMP sampling dates (corresponding to fish sampling) and one post-BMP sampling date (early Oct. 2001). As additional site specific BMPs are identified, we will collect pre- and post-BMP data to assess the effects of specific types of BMPs on the macroinvertebrate community.

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).

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Table 1. Location, drainage area, and channel morphology features of study sites in the Pilot and Reference watersheds.
"P" denotes Pilot watersheds and "R" denotes Reference watersheds.

Stream	Site		Station Code	Latitude	Longitude	Drainage Area (sq. mi)	Ave. Sample Area (m^2)	Ave. Width (m)	Ave. Depth (mm)	Width/Depth Ratio	Ave. Substrate Size (mm)	Ave. Velocity (m/s)
Hurricane	Upper	P	BEL-03	39 22 35.90	-88 04 59.05	32.2	2450	9.0	78.8	113.7	103.1	0.04
Kickapoo	Upper	R	BEN-02	39 27 54.55	-88 13 48.46	26.5	1790	8.3	246.6	33.5	20.5	0.09
Hurricane	Lower	P	BEL-01	39 18 26.19	-88 08 20.57	53.4	2930	9.0	235.2	37.5	2.5	0.07
Kickapoo	Lower	R	BEN-01	39 27 44.81	-88 11 35.39	63.8	3770	11.8	311.0	37.9	22.3	0.17
Court	Upper	P	DJJB-03	40 57 40.72	-90 12 34.65	26.5	2550	9.8	238.6	40.9	2.5	0.03
Haw	Upper	R	DJH-03	40 50 59.22	-90 15 41.11	19.8	1110	5.6	300.8	18.7	6.8	0.04
Court	Lower	P	DJJ-04	40 55 46.28	-90 08 21.95	72.0	3010	9.2	317.6	28.9	6.1	0.15
Haw	Lower	R	DJH-04	40 47 38.21	-90 14 02.32	55.2	1980	10.5	240.5	43.4	5.6	0.11
Big	Upper	P	IXJ-02	37 24 39.82	-89 09 51.28	7.7	1760	7.3	171.9	42.5	26.4	0.03
Cypress	Upper	R	IXM-05	37 24 40.94	-89 06 29.70	8.5	809	3.9	342.1	11.3	90.8	0.00
Big	Lower	P	IXJ-01	37 21 42.27	-89 08 37.97	20.4	924	4.8	347.0	13.9	1.6	0.00
Cypress	Lower	R	IXM-04	37 23 21.68	-89 03 24.55	21.3	791	4.4	219.3	20.1	1.5	0.01
Lake Branch	Upper	P	OHA-05	38 38 02.36	-89 34 19.86	7.7	1250	7.4	498.0	14.8	2.3	0.00
Lost	Upper	R	OJB-03	38 36 55	-89 11 25	0.7	1100	6.1	171.9	35.7	1.6	0.00
Lake Branch	Lower	P	OHA-01	38 33 15	-89 37 35	20.4	983	5.2	346.8	15.1	0.01	0.00
Lost	Lower	R	OJB-04	38 35 13.12	-89 15 14		1550	7.6	380.4	20.0	5.8	0.00

Table 2. 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) Site length (m)	Annual	Site length = $20W_{bf}$; see method for W_{bf} (Table 3)
4) Water temperature (°C)	Continuous	Optic Stowaway temperature logger; Gaging Stations (ISWS)
5) Discharge (m^3/s)	Continuous	Gaging Stations (ISWS)
6) Total P and soluble reactive $PO_4 - P$	Once/week; Hourly during spates	Ascorbic acid method (APHA 1995); automatic pumping sampler at Gaging Stations (ISWS)
7) Total N and $NO_3 - N$	Once/week; Hourly during spates	Cadmium reduction method (APHA 1995); automatic pumping sampler at Gaging Stations (ISWS)
8) $NH_3 - N$	Once/week; Hourly during spates	Phenate method (APHA 1995); automatic pumping sampler at Gaging Stations (ISWS)
9) Suspended sediments	Once/week; hourly during spates	Depth-integrating DH-48 sampler (Gordon et al. 1992); automatic pumping sampler at Gaging Stations (ISWS)

Table 3. 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 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 4. Relationship between the number of years sampled after BMPs and the difference in average width and depth that was detectable at alpha = 0.05 and beta = 0.20. Only sites with three years of baseline data were included.

	No. of Years Post-BMP											
	Ave. Width (mm)						Ave. Depth (mm)					
Stream Reach	1	2	3	4	5	10	1	2	3	4	5	10
Hurricane Upper	2.0	1.4	1.1	1.0	0.9	0.6	39.7	28.1	22.9	19.8	17.7	12.5
Kickapoo Upper	2.0	1.4	1.1	1.0	0.9	0.6	149.5	105.7	86.3	74.8	66.9	47.3
Hurricane Lower	4.8	3.4	2.8	2.4	2.2	1.5	220.5	155.9	127.3	110.2	98.6	69.7
Kickapoo Lower	2.6	1.8	1.5	1.3	1.2	0.8	224.9	159.0	129.8	112.4	100.6	71.1
Court Upper	3.5	2.5	2.0	1.8	1.6	1.1	29.9	21.1	17.3	15.0	13.4	9.5
Haw Upper	0.7	0.5	0.4	0.4	0.3	0.2	114.1	80.7	65.9	57.1	51.0	36.1
Court Lower	1.9	1.3	1.1	1.0	0.9	0.6	73.7	52.1	42.6	36.9	33.0	23.3
Haw Lower	0.6	0.4	0.3	0.3	0.3	0.2	109.5	77.4	63.2	54.7	48.9	34.6
Big Upper	1.5	1.1	0.9	0.8	0.7	0.5	94.6	66.9	54.6	47.3	42.3	29.9
Cypress Upper	2.0	1.4	1.1	1.0	0.9	0.6	110.6	78.2	63.9	55.3	49.5	35.0
Big Lower	1.9	1.3	1.1	0.9	0.8	0.6	297.2	210.1	171.6	148.6	132.9	94.0
Cypress Lower	2.3	1.6	1.3	1.1	1.0	0.7	140.1	99.1	80.9	70.1	62.7	44.3

Table 5. Relationship between the number of years sampled after BMPs and the difference in average point and maximum particle size that was detectable at alpha = 0.05 and beta = 0.20. Only sites with three years of baseline data were included.

	No. of Years Post-BMP											
	Ave. Point Particle (mm)						Ave. Maximum Particle (mm)					
Stream Reach	1	2	3	4	5	10	1	2	3	4	5	10
Hurricane Upper	339.0	239.7	195.7	169.5	151.6	107.2	416.1	294.2	240.2	208.1	186.1	131.6
Kickapoo Upper	25.5	18.0	14.7	12.7	11.4	8.1	54.8	38.7	31.6	27.4	24.5	17.3
Hurricane Lower	0.9	0.6	0.5	0.4	0.4	0.3	7.0	5.0	4.1	3.5	3.1	2.2
Kickapoo Lower	26.0	18.4	15.0	13.0	11.6	8.2	62.3	44.1	36.0	31.2	27.9	19.7
Court Upper	45.6	32.2	26.3	22.8	20.4	14.4	35.6	25.2	20.6	17.8	15.9	11.3
Haw Upper	6.1	4.3	3.5	3.0	2.7	1.9	26.4	18.7	15.2	13.2	11.8	8.3
Court Lower	3.1	2.2	1.8	1.5	1.4	1.0	14.6	10.3	8.4	7.3	6.5	4.6
Haw Lower	23.9	16.9	13.8	11.9	10.7	7.6	82.5	58.4	47.7	41.3	36.9	26.1
Big Upper	40.8	28.9	23.6	20.4	18.3	12.9	109.1	77.2	63.0	54.6	48.8	34.5
Cypress Upper	76.6	54.1	44.2	38.3	34.2	24.2	96.6	68.3	55.8	48.3	43.2	30.5
Big Lower	2.6	1.8	1.5	1.3	1.2	0.8	10.6	7.5	6.1	5.3	4.7	3.3
Cypress Lower	2.0	1.4	1.1	1.0	0.9	0.6	3.8	2.7	2.2	1.9	1.7	1.2

Table 6. Relationship between the number of years sampled after BMPs and the difference in average hydraulic head and percent pool habitat that was detectable at alpha = 0.05 and beta = 0.20. Only sites with three years of baseline data were included.

	No. of Years Post-BMP											
	Ave. Hydraulic Head (mm)						Pool Habitat (%)					
Stream Reach	1	2	3	4	5	10	1	2	3	4	5	10
Hurricane Upper	2.1	1.5	1.2	1.0	0.9	0.7	16.9	11.9	9.7	8.4	7.6	5.3
Kickapoo Upper	4.0	2.9	2.3	2.0	1.8	1.3	23.8	16.8	13.7	11.9	10.6	7.5
Hurricane Lower	4.7	3.3	2.7	2.4	2.1	1.5	40.8	28.8	23.6	20.4	18.2	12.9
Kickapoo Lower	7.6	5.4	4.4	3.8	3.4	2.4	35.0	24.7	20.2	17.5	15.7	11.1
Court Upper	1.4	1.0	0.8	0.7	0.6	0.5	14.6	10.3	8.4	7.3	6.5	4.6
Haw Upper	0.9	0.6	0.5	0.4	0.4	0.3	17.8	12.6	10.3	8.9	8.0	5.6
Court Lower	6.9	4.9	4.0	3.5	3.1	2.2	47.0	33.3	27.2	23.5	21.0	14.9
Haw Lower	3.8	2.7	2.2	1.9	1.7	1.2	29.9	21.2	17.3	15.0	13.4	9.5
Big Upper	0.0	0.0	0.0	0.0	0.0	0.0	3.2	2.3	1.9	1.6	1.4	1.0
Cypress Upper	0.0	0.0	0.0	0.0	0.0	0.0	4.3	3.0	2.5	2.1	1.9	1.4
Big Lower	0.4	0.3	0.2	0.2	0.2	0.1	12.6	8.9	7.3	6.3	5.6	4.0
Cypress Lower	0.6	0.4	0.3	0.3	0.3	0.2	11.3	8.0	6.5	5.7	5.1	3.6

Table 7. Relationship between the number of years sampled after BMPs and the difference in percent riffle and run habitat that was detectable at alpha = 0.05 and beta = 0.20. Only sites with three years of baseline data were included.

	No. of Years Post-BMP											
	Riffle Habitat (%)						Run Habitat (%)					
Stream Reach	1	2	3	4	5	10	1	2	3	4	5	10
Hurricane Upper	11.3	8.0	6.5	5.7	5.1	3.6	18.4	13.0	10.6	9.2	8.2	5.8
Kickapoo Upper	32.3	22.8	18.6	16.1	14.4	10.2	5.6	4.0	3.2	2.8	2.5	1.8
Hurricane Lower	18.6	13.2	10.8	9.3	8.3	5.9	25.1	17.7	14.5	12.5	11.2	7.9
Kickapoo Lower	19.1	13.5	11.0	9.5	8.5	6.0	26.0	18.4	15.0	13.0	11.6	8.2
Court Upper	2.8	2.0	1.6	1.4	1.3	0.9	14.8	10.5	8.6	7.4	6.6	4.7
Haw Upper	3.2	2.3	1.9	1.6	1.4	1.0	18.0	12.7	10.4	9.0	8.1	5.7
Court Lower	11.6	8.2	6.7	5.8	5.2	3.7	36.1	25.5	20.9	18.1	16.2	11.4
Haw Lower	12.8	9.1	7.4	6.4	5.7	4.1	13.2	9.4	7.6	6.6	5.9	4.2
Big Upper	0.0	0.0	0.0	0.0	0.0	0.0	4.3	3.0	2.5	2.1	1.9	1.4
Cypress Upper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Big Lower	3.2	2.3	1.9	1.6	1.4	1.0	7.1	5.0	4.1	3.5	3.2	2.2
Cypress Lower	0.0	0.0	0.0	0.0	0.0	0.0	7.1	5.0	4.1	3.5	3.2	2.2

Table 8. List of fish species and numbers collected in upper and lower sites of the Embarras Basin in 2000.

Species	Scientific Name	Hurricane Upper	Kickapoo Upper	Hurricane Lower	Kickapo Lower
Catostomidae					
Creek chubsucker	Erimyzon oblongus	0	0	0	1
Golden redhorse	Moxostoma erythrurum	0	0	4	0
Highfin carpsucker	Carpiodes velifer	0	0	12	1
Northern hogsucker	Hypentelium nigricans	1	15	25	21
Quillback	Carpiodes cyprinus	0	0	4	0
River carpsucker	Carpiodes carpio	0	4	12	3
White sucker	Catostomus commersoni	4	21	3	6
Centrarchidae					
Bluegill	Lepomis macrochirus	27	109	10	11
Green sunfish	Lepomis cyanellus	5	16	4	3
Largemouth bass	Micropterus salmoides	0	5	17	4
Longear sunfish	Lepomis megalotis	3	60	215	63
Longear sunfish x Green sunfish	Lepomis megalotis x L. cyanellus	0	2	0	0
Spotted bass	Micropterus punctulatus	1	3	2	3
Clupeidae					
Gizzard shad	Dorosoma cepedianum	0	0	3	0
Cyprinidae					
Bluntnose minnow	Pimephales notatus	250	334	1344	287
Bullhead minnow	Pimephales vigilax	0	9	0	0
Central stoneroller	Campostoma anomalum	466	422	291	60
Creek chub	Semotilus atromaculatus	223	200	67	36
Pugnose shiner	Notropis anogenus	0	0	1	0
Redfin shiner	Lythrurus umbratilus	5	7	49	1
Sand shiner	Notropis ludibundus	652	518	1356	364
Silverjaw minnow	Notropis buccatus	534	381	243	92
Silvery minnow	Hybognathus nuchalis	19	29	97	7
Spotfin shiner	Cyprinella spiloptera	691	411	539	269
Steelcolor shiner	Cyprinella whipplei	221	336	241	355
Striped shiner	Luxilus chrysocephalus	1	13	34	0
Suckermouth minnow	Phenacobius mirabilis	71	1	4	8
Cypriodontidae					
Blackstripe topminnow	Fundulus notatus	0	0	5	0
Esocidae					
Grass pickerel	Esox americanus	0	1	0	3
Ictaluridae					
Brindled madtom	Noturus miurus	11	18	0	30
Channel catfish	Ictalurus punctatus	0	0	0	1
Yellow bullhead	Ameiurus natalis	0	4	8	4
Percidae					
Dusky darter	Percina sciera	1	3	2	6
Greenside darter	Etheostoma blennioides	3	3	10	14
Johnny darter	Etheostoma nigrum	136	14	39	0
Orangethroat darter	Etheostoma spectabile	91	34	21	3
Rainbow darter	Etheostoma caeruleum	114	0	19	4
Total Catch		3530	2973	4681	1660
Species Richness		23	28	31	28

Table 9. List of fish species and numbers collected in upper and lower sites of the Spoon Basin in 2000.

Species	Scientific Name	Court Upper	Haw Upper	Court Lower	Haw Lower
Catostomidae					
Golden redhorse	Moxostoma erythrurum	8	10	15	2
Northern hogsucker	Hypentelium nigricans	1	0	2	1
Quillback	Carpiodes cyprinus	0	0	9	0
River carpsucker	Carpiodes carpio	0	0	2	0
Silver redhorse	Moxostoma anisurum	0	0	4	0
White sucker	Catostomus commersoni	7	53	1	0
Centrarchidae					
Bluegill	Lepomis macrochirus	0	3	7	2
Green sunfish	Lepomis cyanellus	0	1	0	4
Largemouth bass	Micropterus salmoides	4	5	2	2
Smallmouth bass	Micropterus dolomieu	6	0	5	0
Cyprinidae					
Bigmouth shiner	Notropis dorsalis	51	0	29	0
Blacknose dace	Rhinichthys atratulus	8	0	4	2
Bluntnose minnow	Pimephales notatus	617	35	199	50
Carp	Cyprinus carpio	2	0	1	0
Central stoneroller	Campostoma anomalum	98	2	24	10
Creek chub	Semotilus atromaculatus	28	19	10	6
Hornyhead chub	Nocomis biguttatus	0	5	0	1
Red shiner	Cyprinella lutrensis	184	41	403	850
Redfin shiner	Lythrurus umbratilus	5	1	0	0
Sand shiner	Notropis ludibundus	295	7	195	105
Striped shiner	Luxilus chrysocephalus	1	3	0	0
Suckermouth minnow	Phenacobius mirabilis	0	0	0	3
Ictaluridae					
Channel catfish	Ictalurus punctatus	0	0	3	6
Stonecat	Noturus flavus	3	1	1	0
Yellow bullhead	Ameiurus natalis	2	0	2	1
Percidae					
Johnny darter	Etheostoma nigrum	34	0	7	7
Orangethroat darter	Etheostoma spectabile	14	0	0	0
Rainbow darter	Etheostoma caeruleum	4	0	0	0
Slenderhead darter	Percina phoxocephala	0	0	3	3
Total Catch		1372	186	928	1055
Species Richness		20	14	22	17

Table 10. List of fish species and numbers collected in upper and lower sites of the Cache Basin in 2000.

Species	Scientific Name	Big Upper	Cypress Upper	Big Lower	Cypress Lower
Catostomidae					
Black redhorse	Moxostoma duquesnei	0	0	1	0
Creek chubsucker	Erimyzon oblongus	2	38	7	16
Golden redhorse	Moxostoma erythrurum	0	0	6	0
Spotted sucker	Minytrema melanops	0	1	0	1
White sucker	Catostomus commersoni	12	16	41	2
Centrarchidae					
Bluegill	Lepomis macrochirus	37	22	10	3
Green sunfish	Lepomis cyanellus	16	6	3	0
Largemouth bass	Micropterus salmoides	8	1	8	8
Longear sunfish	Lepomis megalotis	18	91	152	18
Redear sunfish	Lepomis microlophus	5	0	0	0
Redear sunfish x Green sunfish	Lepomis microlophus x L. cyanellus	2	0	0	0
Warmouth	Lepomis gulosus	0	2	0	0
White crappie	Pomoxis annularis	0	0	0	1
Cottidae					
Banded sculpin	Cottus carolinae	405	0	15	0
Cyprinidae					
Bluntnose minnow	Pimephales notatus	291	43	1072	188
Central stoneroller	Campostoma anomalum	376	24	4	27
Creek chub	Semotilus atromaculatus	229	48	10	9
Golden shiner	Notemigonus crysoleucas	0	0	0	25
Red shiner	Cyprinella lutrensis	0	1	22	0
Redfin shiner	Lythrurus umbratilus	97	28	226	71
Cypriodontidae					
Blackspotted topminnow	Fundulus olivaceus	13	44	58	33
Esocidae					
Grass pickerel	Esox americanus	0	0	0	7
Ictaluridae					
Tadpole madtom	Noturus gyrinus	2	0	8	7
Yellow bullhead	Ameiurus natalis	1	3	1	19
Percidae					
Blackside darter	Percina maculata	0	6	0	10
Bluntnose darter	Etheostoma chlorosomum	0	0	0	15
Fantail darter	Etheostoma flabellare	46	0	1	0
Fringed darter	Etheostoma crossopterum	15	0	2	0
Slough darter	Etheostoma gracile	0	2	0	30
Percopsidae					
Pirate perch	Aphredoderus sayanus	0	40	3	105
Poeciliidae					
Mosquitofish	Gambusia affinis	0	0	6	6
Total Catch		1575	416	1656	601
Species Richness		18	18	21	21

Table 11. List of fish species and numbers collected in upper and lower sites of the Kaskaskia Basin in 2000.

Species	Scientific Name	Lake Branch Upper	Lost Upper	Lake Branch Lower	Lost Lower
Catostomidae					
Creek chubsucker	Erimyzon oblongus	0	0	0	1
White sucker	Catostomus commersoni	0	0	0	4
Centrarchidae					
Bluegill	Lepomis macrochirus	13	47	12	13
Flier	Centrarchus macropterus	0	0	1	0
Green sunfish	Lepomis cyanellus	67	4	37	60
Largemouth bass	Micropterus salmoides	8	21	4	8
Longear sunfish	Lepomis megalotis	0	3	0	11
Longear sunfish x Green sunfish	Lepomis megalotis x L. cyanellus	0	0	0	1
Clupeidae					
Gizzard shad	Dorosoma cepedianum	7	1	8	30
Cyprinidae					
Bluntnose minnow	Pimephales notatus	0	2	0	2
Carp	Cyprinus carpio	1	0	27	3
Creek chub	Semotilus atromaculatus	0	4	0	2
Golden shiner	Notemigonus crysoleucas	16	0	1	18
Redfin shiner	Lythrurus umbratilus	0	6	0	15
Sand shiner	Notropis ludibundus	0	2	0	0
Silverjaw minnow	Notropis buccatus	0	2	0	0
Cypriodontidae					
Blackstripe topminnow	Fundulus notatus	41	83	0	16
Ictaluridae					
Brown bullhead	Ameiurus nebulosus	3	0	0	0
Tadpole madtom	Noturus gyrinus	0	1	0	1
Yellow bullhead	Ameiurus natalis	0	12	2	8
Percidae					
Blackside darter	Percina maculata	0	0	0	1
Slough darter	Etheostoma gracile	0	2	0	3
Percopsidae					
Pirate perch	Aphredoderus sayanus	0	6	0	50
Poeciliidae					
Mosquitofish	Gambusia affinis	9	0	17	0
Total Catch		165	196	109	247
Species Richness		9	15	9	19

Table 12. Jaccard's similarity index and similarity ratio between upper and lower sites of each basin from 1998 to 2000.

Jaccard's Index

	Embarras	Spoon	Cache	Kaskaskia
Upper 98	0.52	0.60	0.57	
Upper 99	0.56	0.60	0.50	
Upper 00	0.76	0.48	0.50	0.26
Lower 98	0.72	0.75	0.25	
Lower 99	0.66	0.43	0.50	0.47
Lower 00	0.69	0.54	0.50	0.33

Similarity Ratio

	Embarras	Spoon	Cache	Kaskaskia
Upper 98	0.29	0.45	0.13	
Upper 99	0.35	0.33	0.17	
Upper 00	0.90	0.16	0.18	0.35
Lower 98	0.38	0.32	0.10	
Lower 99	0.24	0.17	0.89	0.31
Lower 00	0.25	0.41	0.25	0.42

Table 13. Catch per hour of electroshocking time (CPUE) for upper and lower sites in each basin sampled in 2000.

	Upper		Lower	
Basin	Pilot	Reference	Pilot	Reference
Embarras	3069.6	1644.4	2530.3	930.8
Spoon	1779.9	253.4	868.1	1184.3
Cache	1011.8	308.1	1483.0	735.9
Kaskaskia	202.0	379.4	186.9	269.5
Mean	1515.8	646.3	1267.1	780.1
Std. Error	609.9	333.7	497.4	193.4

Table 14. Average weight, biomass per area, and percent composition for each species in the upper sites of the Embarras in 2000.

Species	Hurricane Upper Ave. Wt (g)	Hurricane Upper Biomass/Area (g/m^2)	Hurricane Upper % Comp.	Kickapoo Upper Ave. Wt (g)	Kickapoo Upper Biomass/Area (g/m^2)	Kickapoo Upper % Comp
Catostomidae						
Northern hogsucker	7.0	0.003	0.1	118.1	0.989	6.6
River carpsucker				49.0	0.161	1.1
White sucker	3.3	0.005	0.2	71.9	0.028	0.2
Centrarchidae						
Bluegill	0.5	0.005	0.2	2.4	0.143	1.0
Green sunfish	3.4	0.007	0.2	15.6	0.140	0.9
Largemouth bass		0.000		351.3	0.981	6.6
Longear sunfish	2.6	0.003	0.1	14.7	0.493	3.3
Longear x Green sunfish		0.000		21.6	0.024	0.2
Spotted bass	1.4	0.001	0.0	22.4	0.003	0.0
Cyprinidae						
Bluntnose minnow	2.2	0.222	8.0	2.0	0.371	2.5
Bullhead minnow						
Central stoneroller	4.1	0.785	28.3	5.8	1.378	9.3
Creek chub	3.6	0.329	11.9	8.7	0.968	6.5
Redfin shiner	1.2	0.003	0.1	1.3	0.004	0.0
Sand shiner	1.1	0.288	10.4	1.1	0.378	2.5
Silverjaw minnow	1.5	0.334	12.1	1.3	2.398	16.1
Silvery minnow	7.3	0.056	2.0	11.3	0.013	0.1
Spotfin shiner	1.2	0.349	12.6	0.8	0.339	2.3
Steelcolor shiner	1.5	0.134	4.8	1.5	5.862	39.3
Striped shiner	11.6	0.005	0.2	31.2	0.031	0.2
Suckermouth minnow	3.5	0.101	3.6	4.3	0.019	0.1
Esocidae						
Grass pickerel		0.000		34.0	0.019	0.1
Ictaluridae						
Brindled madtom	3.9	0.018	0.6	5.0	0.051	0.3
Yellow bullhead				17.7	0.076	0.5
Percidae						
Dusky darter	2.4	0.001	0.0	34.0		
Greenside darter	4.3	0.005	0.2	3.0	0.005	0.0
Johnny darter	1.0	0.053	1.9	0.9	0.007	0.0
Orangethroat darter	0.7	0.027	1.0	0.9	0.017	0.1
Rainbow darter	0.8	0.036	1.3			
Total Biomass/Area (g/m^2)		2.770			14.898	

Table 15. Average weight, biomass per area, and percent composition for each species in the lower sites of the Embarras in 2000.

	Hurricane Lower			Kickapoo Lower		
	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp.	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp
Catostomidae						
Creek chubsucker				1.0	0.000	0.0
Golden redhorse	50.0	0.068	1.9			
Highfin carpsucker	16.4	0.067	1.8	18.0	0.005	0.4
Northern hogsucker	37.4	0.319	8.7	26.5	0.147	13.3
Quillback	33.8	0.046	1.3			
River carpsucker	22.3	0.091	2.5	23.7	0.019	1.7
White sucker	39.9	0.041	1.1	24.8	0.040	3.6
Centrarchidae						
Bluegill	2.4	0.008	0.2	1.2	0.003	0.3
Green sunfish	9.1	0.012	0.3	13.0	0.010	0.9
Largemouth bass	52.8	0.307	8.4	1.8	0.002	0.2
Longear sunfish	7.2	0.525	14.4	9.2	0.154	13.9
Spotted bass	109.0	0.074	2.0	58.0	0.046	4.2
Clupeidae						
Gizzard shad	37.3	0.038	1.0			
Cyprinidae						
Bluntnose minnow	1.3	0.587	16.1	1.6	0.124	11.2
Central stoneroller	1.9	0.193	5.3	2.4	0.039	3.5
Creek chub	1.2	0.028	0.8	3.8	0.037	3.3
Pugnose shiner	0.6	0.000	0.0			
Redfin shiner	0.7	0.012	0.3	1.3	0.000	0.0
Sand shiner	0.6	0.287	7.9	1.2	0.116	10.5
Silverjaw minnow	1.1	0.094	2.6	1.9	0.046	4.1
Silvery minnow	8.3	0.276	7.6	10.3	0.019	1.7
Spotfin shiner	0.6	0.110	3.0	0.8	0.057	5.1
Steelcolor shiner	1.2	0.096	2.6	1.6	0.147	13.2
Striped shiner	19.1	0.222	6.1			
Suckermouth minnow	2.0	0.003	0.1	7.9	0.017	1.5
Cypriodontidae						
Blackstripe topminnow	1.3	0.002	0.1			
Esocidae						
Grass pickerel				24.3	0.019	1.7
Ictaluridae						
Brindled madtom				5.5	0.044	4.0
Channel catfish				2.3	0.001	0.1
Yellow bullhead	41.5	0.113	3.1	2.4	0.002	0.2
Percidae						
Dusky darter	2.2	0.001	0.0	2.8	0.004	0.4
Greenside darter	3.3	0.011	0.3	3.2	0.012	1.1
Johnny darter	0.8	0.010	0.3			
Orangethroat darter	0.5	0.004	0.1	0.7	0.001	0.1
Rainbow darter	0.6	0.004	0.1	0.8	0.001	0.1
Total Biomass/Area (g/m^2)		3.654			1.112	

Table 16. Average weight, biomass per area, and percent composition for each species in the upper sites of the Spoon in 2000.

	Court Upper			Haw Upper		
Species	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp.	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp
Catostomidae						
Golden redhorse	211.8	0.664	13.0	317.3	2.859	42.0
Northern hogsucker	35.0	0.014	0.3			
White sucker	171.0	0.470	9.2	125.7	6.000	88.2
Centrarchidae						
Bluegill				8.7	0.024	0.3
Green sunfish				36.0	0.032	0.5
Largemouth bass	3.3	0.005	0.1	3.4	0.015	0.2
Smallmouth bass	308.2	0.725	14.2			
Cyprinidae						
Bigmouth shiner	1.5	0.031	0.6			
Blacknose dace	1.9	0.006	0.1			
Bluntnose minnow	2.3	0.546	10.7	2.2	0.069	1.0
Carp	2700.0	2.118	41.4			
Central stoneroller	4.5	0.175	3.4	1.9	0.003	0.1
Creek chub	5.1	0.056	1.1	23.5	0.402	5.9
Hornyhead chub				18.8	0.085	1.2
Red shiner	1.6	0.115	2.2	1.8	0.068	1.0
Redfin shiner	1.0	0.002	0.0	8.7	0.008	0.1
Sand shiner	1.1	0.130	2.5	1.7	0.011	0.2
Striped shiner	70.0	0.027	0.5	32.7	0.088	1.3
Ictaluridae						
Stonecat	11.4	0.013	0.3	0.6	0.001	0.0
Yellow bullhead	3.7	0.003	0.1			
Percidae						
Johnny darter	0.9	0.012	0.2			
Orangethroat darter	1.0	0.005	0.1			
Rainbow darter	1.0	0.002	0.0			
Total Biomass/Area (g/m^2)		5.119			6.806	

Table 17. Average weight, biomass per area, and percent composition for each species in the lower sites of the Spoon in 2000.

Species	Court Lower Ave. Wt (g)	Court Lower Biomass/Area (g/m^2)	Court Lower % Comp.	Haw Lower Ave. Wt (g)	Haw Lower Biomass/Area (g/m^2)	Haw Lower % Comp
Catostomidae						
Golden redhorse	223.3	1.113	21.8	324.5	0.328	36.9
Northern hogsucker	151.1	0.100	2.0	279.0	0.141	15.8
Quillback	227.0	0.679	13.3			
River carpsucker	12.8	0.009	0.2			
Silver redhorse	225.0	0.299	5.9			
White sucker	2.6	0.001	0.0			
Centrarchidae						
Bluegill	6.1	0.014	0.3	4.5	0.004	0.5
Green sunfish				10.3	0.021	2.3
Largemouth bass	2.6	0.002	0.0	2.8	0.003	0.3
Smallmouth bass	120.4	0.200	3.9		0.000	0.0
Cyprinidae						
Bigmouth shiner	0.8	0.008	0.2			
Blacknose dace	2.4	0.003	0.1	0.9	0.001	0.1
Bluntnose minnow	1.4	0.092	1.8	1.6	0.041	4.6
Carp	1750.0	0.581	11.4			
Central stoneroller	218.8	1.744	34.1	2.4	0.012	1.3
Creek chub	5.8	0.019	0.4	1.6	0.005	0.5
Hornyhead chub				16.0	0.008	0.9
Red shiner	1.1	0.145	2.8	1.2	0.504	56.7
Sand shiner	1.0	0.066	1.3	1.4	0.074	8.3
Suckermouth minnow				1.4	0.002	0.2
Ictaluridae						
Channel catfish	2.3	0.002	0.0	18.4	0.056	6.3
Stonecat	13.1	0.004	0.1			
Yellow bullhead	37.5	0.025	0.5	14.6	0.007	0.8
Percidae						
Johnny darter	0.7	0.002	0.0	1.3	0.005	0.5
Slenderhead darter	1.5	0.001	0.0	3.9	0.006	0.7
Total Biomass/Area (g/m^2)		5.111			0.889	

Table 18. Average weight, biomass per area, and percent composition for each species in the upper sites of the Cache in 2000.

	Big Upper			Cypress Upper		
Species	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp.	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp
Catostomidae						
Creek chubsucker	14.5	0.016	0.5	7.4	0.348	15.3
Spotted sucker				10.2	0.013	0.6
White sucker	11.2	0.077	2.1	21.7	0.129	5.7
Centrarchidae						
Bluegill	9.6	0.201	5.6	6.5	0.177	7.8
Green sunfish	8.4	0.076	2.1	3.5	0.026	1.1
Largemouth bass	4.7	0.021	0.6	2.5	0.003	0.1
Longear sunfish	12.9	0.132	3.7	5.8	0.653	28.8
Redear sunfish	6.7	0.019	0.5			
Redear x Green sunfish	75.9	0.086	2.4			
Warmouth				3.9	0.010	0.4
Cottidae						
Banded sculpin	1.5	0.336	9.4			
Cyprinidae						
Bluntnose minnow	1.9	0.319	8.9	2.9	0.155	6.8
Central stoneroller	4.2	0.899	25.1	5.6	0.165	7.3
Creek chub	9.5	1.231	34.4	8.0	0.472	20.8
Red shiner				2.1	0.003	0.1
Redfin shiner	1.8	0.097	2.7	1.7	0.058	2.5
Cypriodontidae						
Blackspotted topminnow	3.2	0.024	0.7	2.8	0.153	6.7
Ictaluridae						
Tadpole madtom	5.4	0.006	0.2			
Yellow bullhead	16.2	0.009	0.3	6.7	0.025	1.1
Percidae						
Blackside darter				3.2	0.023	1.0
Fantail darter	0.8	0.020	0.6			
Fringed darter	1.5	0.013	0.4			
Slough darter				0.7	0.002	0.1
Percopsidae						
Pirate perch				4.2	0.206	9.1
Total Biomass/Area (g/m^2)		3.582			2.272	

Table 19. Average weight, biomass per area, and percent composition for each species in the lower sites of the Cache in 2000.

Species	Big Lower Ave. Wt (g)	Big Lower Biomass/Area (g/m^2)	Big Lower % Comp.	Cypress Lower Ave. Wt (g)	Cypress Lower Biomass/Area (g/m^2)	Cypress Lower % Comp
Catostomidae						
Black redhorse	64.0	0.069	1.0			
Creek chubsucker	30.1	0.228	3.2	31.7	0.641	21.6
Golden redhorse	50.7	0.329	4.6			
Spotted sucker				193.0	0.244	8.2
White sucker	48.3	2.142	29.7	105.1	0.266	8.9
Centrarchidae						
Bluegill	5.5	0.060	0.8	4.0	0.015	0.5
Green sunfish	5.5	0.018	0.2			
Largemouth bass	31.7	0.274	3.8	5.9	0.060	2.0
Longear sunfish	6.9	1.135	15.7	0.7	0.016	0.5
White crappie				7.1	0.009	0.3
Cottidae						
Banded sculpin	1.9	0.030	0.4			
Cyprinidae						
Bluntnose minnow	1.9	2.163	30.0	2.3	0.553	18.6
Central stoneroller	8.0	0.034	0.5	2.0	0.068	2.3
Creek chub	17.7	0.191	2.6	5.6	0.063	2.1
Golden shiner				3.0	0.095	3.2
Red shiner	1.3	0.032	0.4			
Redfin shiner	0.7	0.170	2.4	1.2	0.111	3.7
Cypriodontidae						
Blackspotted topminnow	2.2	0.138	1.9	1.9	0.079	2.7
Esocidae						
Grass pickerel				21.0	0.186	6.3
Ictaluridae						
Tadpole madtom	6.5	0.056	0.8	3.7	0.032	1.1
Yellow bullhead	90.0	0.097	1.3	4.7	0.113	3.8
Blackside darter				2.2	0.028	0.9
Bluntnose darter				0.5	0.009	0.3
Fantail darter	0.5	0.001	0.0			
Fringed darter	0.7	0.002	0.0			
Slough darter				0.5	0.020	0.7
Percopsidae						
Pirate perch	13.6	0.044	0.6	2.7	0.360	12.1
Poeciliidae						
Mosquitofish	0.4	0.003	0.0	0.4	0.003	0.1
Total Biomass/Area (g/m^2)		7.216			2.972	

Table 20. Average weight, biomass per area, and percent composition for each species in upper sites of the Kaskaskia in 2000.

	Lake Branch Upper			Lost Upper		
Species	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp.	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp
<u>Centrarchidae</u>						
Bluegill	11.8	0.123	11.0	9.9	0.424	72.9
Green sunfish	4.0	0.216	19.4	11.2	0.041	7.0
Largemouth bass	9.3	0.059	5.3	6.0	0.114	19.5
Longear sunfish				30.0	0.082	14.1
<u>Clupeidae</u>						
Gizzard shad	39.7	0.222	19.9	23.0	0.021	3.6
<u>Cyprinidae</u>						
Bluntnose minnow				0.5	0.001	0.1
Carp	54.0	0.043	3.9			
Creek chub				1.9	0.007	1.2
Golden shiner	11.6	0.148	13.3			
Redfin shiner				2.4	0.013	2.3
Sand shiner				0.6	0.001	0.2
Silverjaw minnow				0.5	0.001	0.2
<u>Cypriodontidae</u>						
Blackstripe topminnow	0.8	0.025	2.3	2.0	0.152	26.1
<u>Ictaluridae</u>						
Brown bullhead	166.0	0.398	35.7			
Tadpole madtom				9.4	0.009	1.5
Yellow bullhead				11.4	0.124	21.4
<u>Percidae</u>						
Slough darter				0.5	0.001	0.2
<u>Percopsidae</u>						
Pirate perch				3.0	0.016	2.8
<u>Poeciliidae</u>						
Mosquitofish	0.4	0.003	0.3			
Total Biomass/Area (g/m^2)		1.116			0.581	

Table 21. Average weight, biomass per area, and percent composition for each species in lower sites of the Kaskaskia in 2000.

	Lake Branch Lower			Lost Lower		
Species	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp.	Ave. Wt (g)	Biomass/Area (g/m^2)	% Comp
Catostomidae						
Creek chubsucker				5.6	0.004	0.1
White sucker				89.6	0.231	4.9
Centrarchidae						
Bluegill	4.4	0.054	6.3	5.6	0.047	1.0
Flier	5.9	0.006	0.7			
Green sunfish	5.0	0.190	22.1	10.8	0.420	8.9
Largemouth bass	44.0	0.179	20.8	26.4	0.136	2.9
Longear sunfish				15.9	0.113	2.4
Longear x Green sunfish				35.0	0.023	0.5
Clupeidae						
Gizzard shad	18.3	0.149	17.3	41.3	0.800	17.0
Cyprinidae						
Bluntnose minnow				2.6	0.003	0.1
Carp	9.4	0.259	30.2	1190.0	2.303	48.9
Creek chub				33.0	0.043	0.9
Golden shiner	7.0	0.007	0.8	9.2	0.107	2.3
Redfin shiner				1.4	0.014	0.3
Cypriodontidae						
Blackstripe topminnow				1.8	0.019	0.4
Ictaluridae						
Tadpole madtom				5.4	0.003	0.1
Yellow bullhead	2.5	0.005	0.6	62.7	0.324	6.9
Percidae						
Blackside darter				0.4	0.000	0.0
Slough darter				0.5	0.001	0.0
Percopsidae						
Pirate perch				3.8	0.124	2.6
Poeciliidae						
Mosquitofish	0.6	0.010	1.2			
Total Biomass/Area (g/m^2)		0.859			4.714	

Table 22. Index of Biotic Integrity scores, individual metric values and actual values for each metric (in parenthesis) for all sites sample in 2000. Proportions are percents and number of individuals are catch per hour.

	Hurr. Upper	Kick. Upper	Hurr. Lower	Kick. Lower	Court Upper	Haw Upper	Court Lower	Haw Lower	Big Upper	Cypress Upper	Big Lower	Cypress Lower	Lk. Br. Upper	Lost Upper	Lk. Br. Lower	Lost Lower
Species Richness and Composition																
Number of fish species	5 (23)	5 (28)	5 (31)	5 (28)	5 (20)	3 (14)	5 (22)	3 (18)	5 (18)	5 (18)	5 (21)	5 (21)	3 (9)	3 (15)	3 (9)	5 (19)
Number of darter species	5 (5)	5 (4)	5 (5)	3 (4)	3 (3)	1 (0)	3 (2)	3 (2)	3 (2)	3 (2)	1 (2)	3 (3)	1 (0)	1 (1)	1 (0)	3 (2)
Number of sunfish species	3 (3)	3 (3)	3 (3)	3 (3)	1 (0)	5 (2)	1 (1)	3 (2)	5 (4)	5 (4)	3 (3)	3 (3)	3 (2)	5 (3)	3 (2)	5 (3)
Number of sucker species	3 (2)	3 (3)	5 (6)	5 (5)	3 (3)	3 (2)	5 (6)	1 (2)	3 (2)	5 (3)	5 (4)	5 (3)	1 (0)	1 (0)	1 (0)	3 (2)
Number of intolerant species	5 (10)	5 (10)	5 (11)	5 (11)	5 (6)	1 (1)	5 (6)	3 (3)	3 (4)	1 (2)	3 (5)	1 (2)	1 (0)	1 (1)	1 (0)	3 (2)
Proportion of green sunfish	5 (0.1)	5 (0.5)	5 (0.1)	5 (0.2)	5 (0)	5 (0.5)	5 (0)	5 (0.4)	5 (1)	5 (1.4)	5 (0.2)	5 (0)	1 (41)	5 (2)	1 (34)	1 (24)
Trophic Composition																
Proportion of omnivores	5 (7.1)	5 (12)	3 (29)	5 (18)	1 (49)	5 (19)	3 (26)	5 (5)	5 (18)	5 (10)	1 (65)	3 (35)	5 (15)	5 (1.5)	3 (33)	3 (21)
Proportion of insectivores	5 (68)	5 (63)	5 (54)	5 (68)	3 (37)	3 (41)	5 (66)	5 (91)	3 (21)	1 (19)	1 (15.6)	1 (13)	1 (0)	1 (7)	1 (0)	1 (7)
Proportion of piscivores	1 (0)	1 (0.2)	1(0.4)	1(0.5)	1 (0.7)	3 (2.7)	3 (1.1)	1 (0.7)	1 (0.5)	1 (0.2)	1 (0.5)	3 (2.7)	3 (5)	5(11)	3 (4)	3 (3)
Fish Abundance and Condition																
Number of individuals	5 (3070)	5 (1644)	5 (2530)	5 (931)	5 (1780)	1 (253)	5 (868)	5 (1184)	5 (1002)	3 (308)	5 (1483	5 (736)	1 (202)	3 (379)	1 (187)	1 (269)
Proportion of hybrids	5 (0)	3 (0.03)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	3 (0.06)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	3 (0.4)
Proportion of diseased fish	5 (0)	5 (0)	3 (0.02)	5 (0)	3 (0.07)	1 (1.6)	5 (0)	3 (0.1)	1 (1)	5 (0)	5 (0)	5 (0)	5 (0)	5 (0)	3 (0.9)	1 (1.6)
Total IBI Score	52	50	50	52	40	36	50	42	42	44	40	44	30	40	26	32

Table 23. Relationship between number of years sampled post-BMP and the difference in species richness and catch per hour eletrofishing (CPUE) that was detectable at alpha = 0.05 and beta = 0.20. Only those sites with three years of baseline data are included.

	No. Years Post-BMP											
	Species Richness						CPUE					
Stream Reach	1	2	3	4	5	10	1	2	3	4	5	10
Hurricane Upper	12.9	9.1	7.5	6.5	5.8	4.1	2059	1456	1189	1029	921	651
Kickapoo Upper	7.4	5.2	4.3	3.7	3.3	2.3	784	554	453	392	351	248
Hurricane Lower	7.4	5.2	4.3	3.7	3.3	2.3	1373	971	792	686	614	434
Kickapoo Lower	7.4	5.2	4.3	3.7	3.3	2.3	790	559	456	395	353	250
Court Upper	3.2	2.3	1.9	1.6	1.4	1.0	1059	749	611	529	473	335
Haw Upper	6.5	4.6	3.8	3.2	2.9	2.1	396	280	229	198	177	125
Court Lower	9.8	6.9	5.7	4.9	4.4	3.1	2496	1765	1441	1248	1116	789
Haw Lower	8.6	6.1	4.9	4.3	3.8	2.7	1067	755	616	534	477	337
Big Upper	1.6	1.1	0.9	0.8	0.7	0.5	1225	866	707	613	548	387
Cypress Upper	1.6	1.1	0.9	0.8	0.7	0.5	466	329	269	233	208	147
Big Lower	15.4	10.9	8.9	7.7	6.9	4.9	1925	1361	1111	963	861	609
Cypress Lower	10.6	7.5	6.1	5.3	4.7	3.4	908	642	524	454	406	287

Table 24. Relationship between number of years sampled post-BMP and the difference in Jaccard's Similarity Index and Similarity Ratio that was detectable at alpha = 0.05 and beta = 0.20. Only those sites with three years of baseline data are included.

	No. Years Post-BMP											
	Jaccard's Index						Similarity Ratio					
Stream Reach	1	2	3	4	5	10	1	2	3	4	5	10
Embarras Upper	0.4	0.3	0.2	0.2	0.2	0.1	1.0	0.7	0.5	0.5	0.4	0.3
Embarras Lower	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.1
Spoon Upper	0.2	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.2	0.2	0.2	0.1
Spoon Lower	0.4	0.3	0.3	0.2	0.2	0.1	0.3	0.2	0.2	0.2	0.2	0.1
Cache Upper	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Cache Lower	0.4	0.3	0.2	0.2	0.2	0.1	1.2	0.8	0.7	0.6	0.5	0.4

Table 25. Relationship between number of years sampled post-BMP and the difference in Index of Biotic Integrity (IBI) that was detectable at alpha = 0.05 and beta = 0.20. Only those sites with three years of baseline data are included.

	No. Years Post-BMP					
	IBI					
Stream Reach	1	2	3	4	5	10
Hurricane Upper	14.8	10.5	8.6	7.4	6.6	4.7
Kickapoo Upper	5.6	4.0	3.2	2.8	2.5	1.8
Hurricane Lower	0.0	0.0	0.0	0.0	0.0	0.0
Kickapoo Lower	5.6	4.0	3.2	2.8	2.5	1.8
Court Upper	14.8	10.5	8.6	7.4	6.6	4.7
Haw Upper	3.2	2.3	1.9	1.6	1.4	1.0
Court Lower	14.6	10.3	8.4	7.3	6.5	4.6
Haw Lower	11.6	8.2	6.7	5.8	5.2	3.7
Big Upper	3.2	2.3	1.9	1.6	1.4	1.0
Cypress Upper	8.6	6.1	4.9	4.3	3.8	2.7
Big Lower	9.7	6.9	5.6	4.8	4.3	3.1
Cypress Lower	3.2	2.3	1.9	1.6	1.4	1.0

Table 26. Mean age of fish species collected from each site in 1998 - 2000 combined. Sample size for each species and site is shown in parenthesis.

	Embarras Basin				Cache Basin			
Species	Hurricane Upper	Hurricane Lower	Kickapoo Upper	Kickapoo Lower	Big Upper	Big Lower	Cypress Upper	Cypress Lower
Largemouth bass		1.9 (31)	3.0 (8)	0.6 (8)	0.5 (39)	1.0 (12)	1.0 (7)	1.8 (23)
Smallmouth bass								
Bluegill	0.0 (93)	1.2 (120)	0.3 (100)	0.4 (38)	1.7 (159)	1.4 (57)	1.9 (88)	1.5 (95)
Longear sunfish	1.0 (3)	1.6 (296)	1.9 (79)	1.5 (101)	2.2 (29)	1.9 (253)	1.8 (153)	0.9 (218)
Green sunfish	1.0 (5)	1.4 (26)	1.9 (26)	2.2 (11)	2.0 (22)	1.2 (9)	1.6 (12)	1.0 (5)
Golden redhorse		2.1 (18)				1.0 (2)		

	Spoon Basin				Kaskaskia Basin			
Species	Court Upper	Court Lower	Haw Upper	Haw Lower	Lake Branch Upper	Lake Branch Lower	Lost Upper	Lost Lower
Largemouth bass	0.0 (41)	0.0 (5)	0.6 (27)	0.0 (8)	2.1 (8)	2.3 (24)	0.5 (21)	1.5 (10)
Smallmouth bass	2.0 (22)	2.4 (8)		5.0 (1)				
Bluegill	1.6 (19)	1.3 (41)	1.7 (8)	1.8 (9)	1.8 (13)	2.0 (35)	1.6 (47)	1.4 (55)
Longear sunfish							2.3 (3)	2.2 (11)
Green sunfish	2.0 (2)	1.0 (7)	3.0 (3)	2.5 (23)	1.1 (18)	1.7 (78)	1.8 (4)	2.1 (107)
Golden redhorse	2.4 (61)	3.4 (72)	3.8 (34)	4.0 (26)				

Table 27. List of taxa collected in glide/pool habitats in upper and lower sites of the Embarras Basin in 1998 and 1999. Values for each taxa are in numbers per square meter.

Taxa		Fall 98				Spring 99			Spring 99
		Hurricane Upper	Kickapoo Upper	Hurricane Lower	Kickapoo Lower	Kickapoo Upper	Hurricane Lower	Kickapoo Lower	Hurricane Lower Run Habitat
Bivalvia					20957.4				
Bivalvia	Corbiculidae							467.8	
Calanoidia				56.1					
Coleoptera				112.3					
Coleoptera	Elmidae		62.4	56.1	124.7			46.8	
Coleoptera	Hydrophilidae						102.1		
Cyclopoida		80.2		3143.6	62.4	46.8	1888.2	46.8	
Diptera		160.4			62.4		612.4		
Diptera	Ceratopogonidae	160.4	187.1	2020.9	2307.8		255.2	280.7	
Diptera	Chironomidae	86609.7	37922.9	187213.4	44409.8	6689.5	9645.2	2666.5	42102.0
Diptera	Culicidae						51.0		
Diptera	Empididae				62.4				
Ephemeroptera				112.3				421.0	
Ephemeroptera	Baetidae			280.7	187.1		459.3		
Ephemeroptera	Caenidae			336.8	62.4				
Ephemeroptera	Heptageniidae			56.1	62.4		51.0	561.4	
Ephemeroptera	Heptageniidae/ Leptophlebiidae								561.4
Ephemeroptera	Isonychiidae							46.8	
Gastropoda	Aneylidae		2120.7		2931.5				
Harpacicoida							663.4		
Hydrachnida					62.4				
Nematoda				56.1					
Nematoda	Rhabdiasidae						51.0		
Odonata	Calopterygidae			56.1					
Odonata	Gomphidae					46.8			
Oligocheata		9302.5	10665.8	1796.4	36925.0	6596.0	8930.7	7017.0	111710.5
Ostracoda					4116.6	46.8			
Plecoptera		80.2							
Plecoptera	Nemouridae							46.8	
Trichoptera			62.4	56.1					
Trichoptera	Hydropsychidae			112.3		46.8		93.6	
Total CPA (no./m^2)		96393.4	51021.3	195465.3	112334.3	13472.6	22709.5	11695.0	154373.8
Taxa Richness		6	6	15	14	6	11	11	3

Table 28. List of taxa collected in glide/pool habitats in upper and lower sites of the Spoon Basin in 1998 and 1999. Values for each taxa are in numbers per square meter.

Taxa		Fall 98				Spring 99				Fall 99	
		Court Upper	Haw Upper	Court Lower	Haw Lower	Court Upper	Haw Upper	Court Lower	Haw Lower	Court Upper	Haw Upper
Bivalvia							204.1				56.1
Calanoida								56.1			112.3
Cladocera											2301.6
Coleoptera	Elmidae		436.6	187.1	686.1		153.1			153.1	842.0
Coleoptera	Hydrophilidae						51.0				
Collembola	Isotomidae				62.4						
Collembola	Poduridae					51.0					
Cyclopoida		2432.6	623.7	374.2	187.1		204.1		62.4	918.6	3368.2
Diptera				187.1						102.1	
Diptera	Ceratopogonidae	686.1	873.2			102.1	51.0				
Diptera	Chironomidae	26695.8	9293.6	87422.4	1995.9	2041.3	1479.9	1178.9	3680.0	23577.1	8083.6
Diptera	Empididae	62.4	62.4								56.1
Diptera	Simuliidae					51.0					
Diptera	Tabanidae		187.1								
Diptera	Tipulidae						51.0	112.3			
Ephemeroptera						102.1	51.0				
Ephemeroptera	Baetidae		124.7			51.0	51.0			51.0	
Ephemeroptera	Caenidae	374.2			62.4					663.4	
Ephemeroptera	Ephemerellidae		62.4								
Ephemeroptera	Ephemeridae	187.1			124.7						
Ephemeroptera	Heptageniidae	124.7	62.4								
Ephemeroptera	Isonychiidae							56.1			
Ephemeroptera	Tricorythidae		124.7								
Ephemeroptera/Odonata/Plecoptera								56.1			
Gastropoda			249.5								
Gastropoda	Ancylidae		873.2								
Harpacticoida				748.5							
Hemiptera	Corixidae	187.1	187.1	873.2	1684.1					714.5	
Hirudinoidea	Glossiphoniidae		62.4								
Hydrachnida					62.4	51.0	51.0				
Mysidacea	Mysidae					51.0			62.4		

Table 28 continued.

Taxa		Fall 98				Spring 99				Fall 99	
		Court Upper	Haw Upper	Court Lower	Haw Lower	Court Upper	Haw Upper	Court Lower	Haw Lower	Court Upper	Haw Upper
Odonata	Coenagrionidae	62.4									
Oligocheata		1933.6	14907.2	6299.7	3742.4	2347.5	14493.3	1178.9	3680.0	6379.1	11283.3
Ostracoda		7297.7	124.7	187.1	62.4		51.0			102.1	168.4
Plecoptera			62.4			51.0					
Trichoptera			62.4								
Trichoptera	Hydropsychidae	62.4	124.7			51.0					168.4
Trichoptera	Leptoceridae	249.5			124.7						
Total CPA (no./m^2)		40355.5	28504.6	96279.4	8794.6	4950.2	16891.8	2638.4	7484.8	32660.9	26440.0
Taxa Richness		13	19	8	11	11	12	6	4	9	10

Table 29. List of taxa collected in glide/pool habitats in upper and lower sites of the Cache Basin in 1998 and 1999. Values for each taxa are in numbers per square meter.

Taxa		Fall 98				Spring 99				Summer 99	Fall 99
		Big Upper	Cypress Upper	Big Lower	Cypress Lower	Big Upper	Cypress Upper	Big Lower	Cypress Lower	Cypress Upper	Cypress Lower
Amphipoda		12.5				524.0					
Amphipoda	Gammaridae	399.7				561.9		172.7			
Annelida								86.4			
Bivalvia					280.7	6.3		43.2	561.4	93.6	5847.5
Braciopoda								43.2			
Calanoida		12.5								140.3	
Cladocera	Chydoridae	12.5			46.8				46.8		
Coleoptera	Elimdae	50.0	80.2	140.3	421.0	63.1		259.1	140.3	46.8	46.8
Coleoptera	Sphaeriidae				93.6		93.6		46.8	327.5	
Coleoptera/Megaloptera/Plecoptera								259.1			
Collembola		25.0			46.8						
Collembola	Onychiuridae								46.8		
Copepoda						6.3					
Cyclopoida		1811.1	320.8	467.8	46.8	669.2	233.9	604.5	233.9		140.3
Decapoda	Cambaridae	25.0				12.6					
Diptera				46.8		63.1		86.4			
Diptera	Ceratopogonidae	12.5		93.6	374.2			259.1	140.3		795.3
Diptera	Chironomidae	1423.9	12510.3	40043.6	3695.6	1243.8	9636.7	5786.3	5987.8	2198.7	2151.9
Diptera	Simuliidae	174.9				12.6	46.8				
Diptera	Stratiomydae	12.5					46.8				
Diptera	Tabanidae		80.2				93.6				
Diptera	Tipulidae	25.0	80.2								
Ephemeroptera		50.0						86.4			
Ephemeroptera	Baetidae	62.5	80.2	140.3	46.8	50.5					
Ephemeroptera	Caenidae	99.9	160.4	233.9	467.8			43.2	187.1		46.8
Ephemeroptera	Ephemerellidae							43.2			
Ephemeroptera	Heptageniidae	687.0		46.8	233.9	50.5			93.6		
Emphemeroptera	Heptageniidae/ Leptophlebiidae					31.6	46.8				
Gastropoda	Ancylidae	12.5									
Gastropoda	Physidae								46.8		
Harpacticoida						6.3					
Hirudinoidea						75.8					
Hirudinoidea	Glossiphoniidae										46.8

Table 29 continued.

		Fall 98				Spring 99				Summer 99	Fall 99
Taxa		Big Upper	Cypress Upper	Big Lower	Cypress Lower	Big Upper	Cypress Upper	Big Lower	Cypress Lower	Cypress Upper	Cypress Lower
Hemiptera	Corixidae										654.9
Hydrachnida		62.5		46.8		18.9	46.8	129.5	46.8		
Isopoda	Asellidae	87.4				126.3	46.8	129.5	46.8		
Megaloptera	Sialidae			46.8		12.6		215.9	280.7		
Nematoda	Mermithidae						93.6				
Tylenchia	Tylenchidae						46.8				
Odonata	Coenagrionidae			233.9							
Oligocheata		5021.1	8099.6	12162.8	14080.8	2651.7	17074.7	18611.2	24091.7	31389.3	18665.2
Ostracoda		50.0		140.3		18.9	140.3		233.9	46.8	467.8
Plecoptera		324.7			46.8		46.8		93.6		
Plecoptera	Perlodidae		240.6								46.8
Trichoptera		12.5									
Tricoptera	Hydropsychidae		80.2	46.8	46.8	6.3					
Trichoptera	Hydroptilidae							86.4			
Tricoptera	Polycentropodidae			93.6							
Total CPA (no./m^2)		10466.8	21732.6	53984.1	19928.3	6212.6	27693.7	26945.3	32324.9	34242.9	28910.0
Taxa Richness		24	10	15	14	21	14	18	17	7	11

Table 30. List of taxa collected in glide/pool habitats in the lower site of Lake Branch in the Kaskaskia Basin in 19
Numbers of each taxa are in numbers per square meter.

Taxa		Fall 99 Lake Branch Lower
Bivalvia		421.0
Coleoptera	Scirtidae	46.8
Cyclopoida		280.7
Diptera	Ceratopogonidae	1730.9
Diptera	Chaoboridae	187.1
Diptera	Chironomidae	935.6
Megaloptera		46.8
Megaloptera	Sialidae	46.8
Nematoda	Mermithidae	46.8
Odonata	Anisoptera	46.8
Odonata	Corduliidae	46.8
Oligocheata		18103.8
Ostracoda		5239.4
Total CPA (no./m^2)		27179.2
Taxa Richness		13

Table 31. List of taxa collected in riffle habitats in upper sites of the Cache Basin in 1999. Values for each taxa are in numbers per square meter.

		Spring 99	Fall 99
		Big	Big
Taxa		Upper	Upper
Amphipoda			315.7
Amphipoda	Gammaridae	2860.6	789.2
Coleoptera	Elmidae	62.4	63.1
Coleoptera	Psephenidae		31.6
Coleoptera/Megaloptera			31.6
Collembola		7.8	
Cyclopoida		7.8	
Diptera	Chironomidae	912.0	7008.1
Diptera	Empididae	7.8	63.1
Diptera	Simuliidae	444.3	
Diptera	Tipulidae	15.6	284.1
Ephemeroptera		7.8	157.8
Ephemeroptera	Baetidae	709.3	63.1
Ephemeroptera	Heptageniidae		94.7
Gastropoda	Ancylidae		221.0
Harpacticoida		15.6	63.1
Hydrachnida		93.5	221.0
Isopoda		116.9	
Nematoda		7.8	
Oligocheata		569.0	378.8
Ostracoda			31.6
Platyhelminthes		77.9	126.3
Plecoptera			442.0
Trichoptera			1010.2
Trichoptera	Hydropsychidae	101.3	3946.0
Trichoptera	Hydroptilidae	7.8	3219.9
Trichoptera	Philopotamidae		
Total CPA (no./m^2)		6025.2	18561.9
Taxa Richness		18	21

Table 32. Family Biotic Index (FBI) and Percent Emphemeroptera, Plecoptera, and Tricoptera (%EPT) for glide habitats at each site. Indices left blank are those sites in which macroinvertebrates have not yet been identified.

	Fall 98		Spring 99		Summer 99		Fall 99	
Site	FBI	%EPT	FBI	%EPT	FBI	%EPT	FBI	%EPT
Hurricane Upper	6.58	0.26						
Kickapoo Upper	6.5	0.12	6.97	0.35				
Hurricane Lower	6.05	0.5	6.96	2.25				
Kickapoo Lower	7.43	0.61	6.96	10				
Court Upper	6.86	3.7	6.78	5.15			6.82	3.42
Haw Upper	7.12	2.18	7.71	0.6			7.23	0.64
Court Lower	6.78	0	6.78	2.17				
Haw Lower	7.26	3.55	6.98	0				
Big Upper	6.88	11.8	6.91	2.23				
Cypress Upper	6.7	2.58	7.25	0.34	7.83	0		
Big Lower	7.07	2.34	7.39	0.97				
Cypress Lower	7.38	4.23	7.52	1.16			7.8	0.32
Lake Branch Lower							7.75	0
Lost Lower								
Hurricane Lower (Run)			7.44	0.36				
Big Upper (Riffle)			4.7	13.71			4.86	48.21

Water Quality based on FBI Scores*

FBI	Water Quality
0.00 - 3.75	Excelllant
3.76 - 4.25	Very Good
4.26- 5.00	Good
5.01 - 5.75	Fair
5.76 - 6.50	Fairly Poor
6.51 - 7.25	Poor
7.26 - 10.00	Very Poor

* from Hilsenhoff (1988)

Table 33. Percent Similarity values for upper and lower sites within each basin. Similarity based on FBI. Values left blank can not be computed due to one or both sites within a basin not containing an FBI index value.

Basin	Fall 98	Spring 99	Fall 99
Embarras Upper	98.7		
Embarras Lower	123.0	100.0	
Spoon Upper	96.4	113.8	106.0
Spoon Lower	107.2	103.0	
Cache Upper	97.4	105.0	
CacheLower	104.4	101.7	

% Similarity	Condition
>= 85%	Very Similar
70-84%	Moderately Similar
50-69%	Slightly Similar
< 50%	Different

* modified from Plafkin (1989)

Figure 1. Location of Pilot and Reference watersheds. *Map produced by IDNR Watershed Management Section.

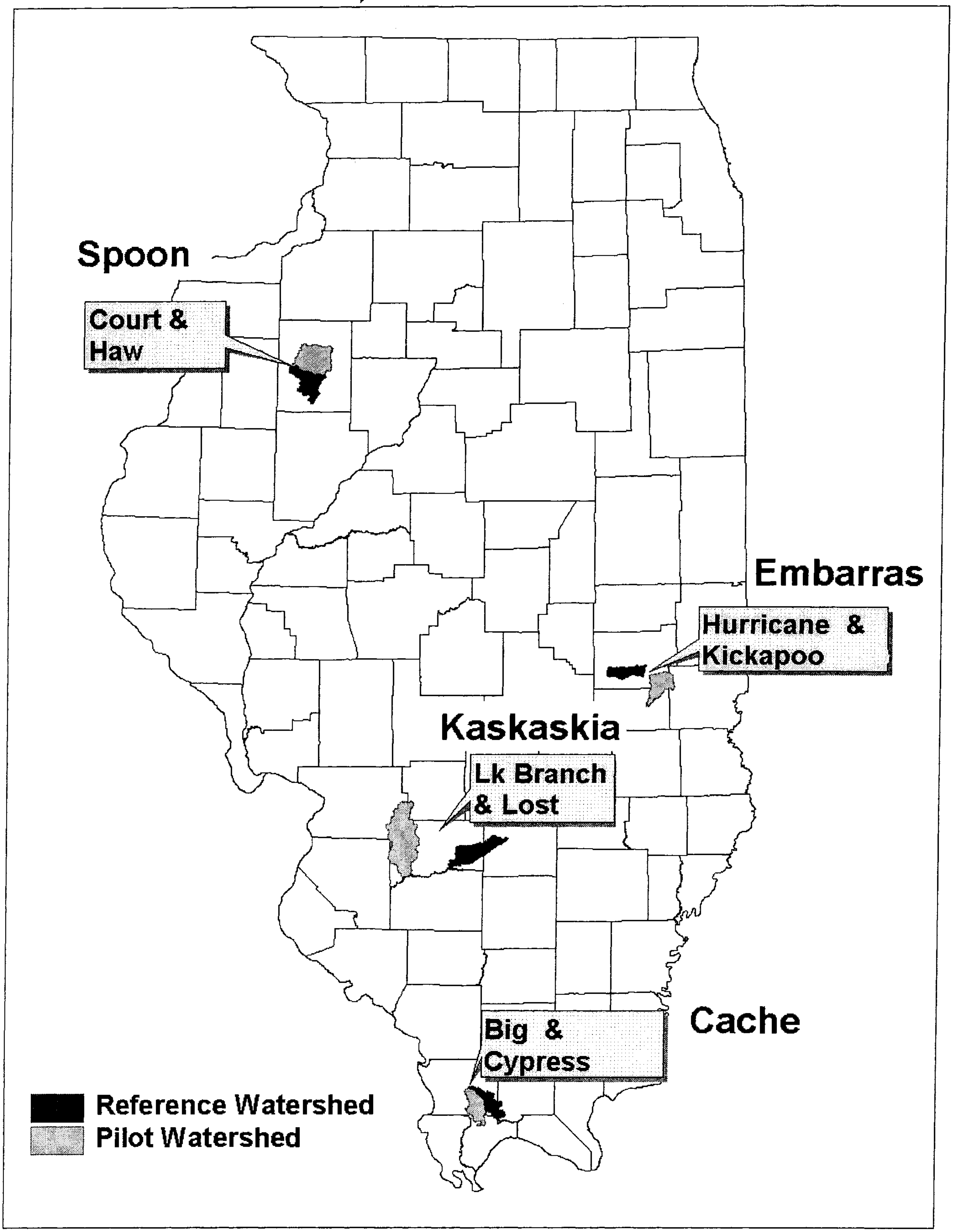


Figure 2. Average monthly temperature (+- one standard deviation) for upper sites of the Embarras Basin. The pilot site is the striped bar and the reference is the solid bar.

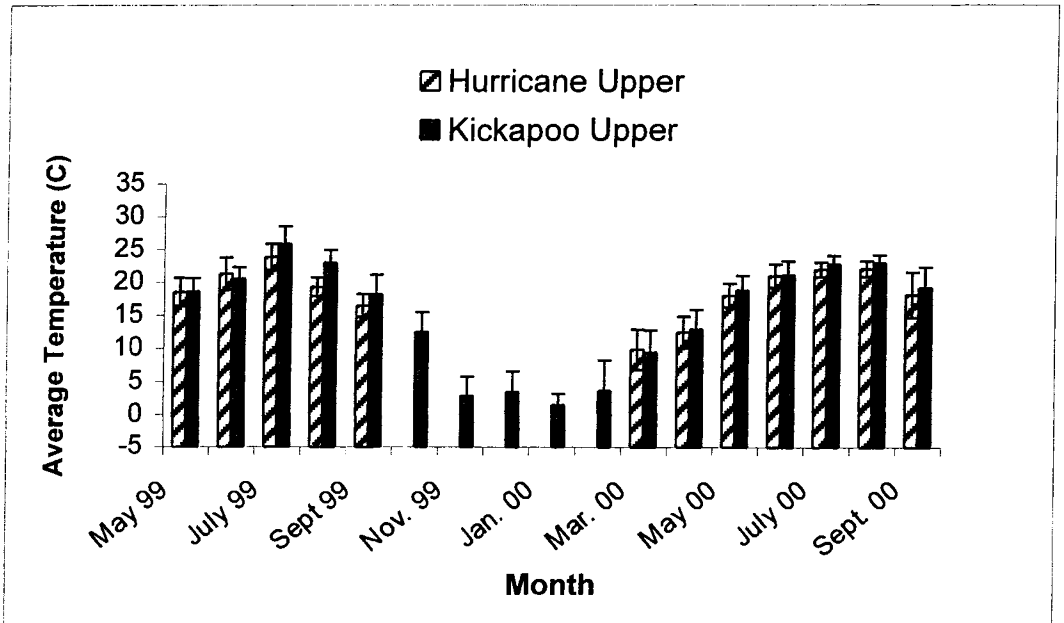
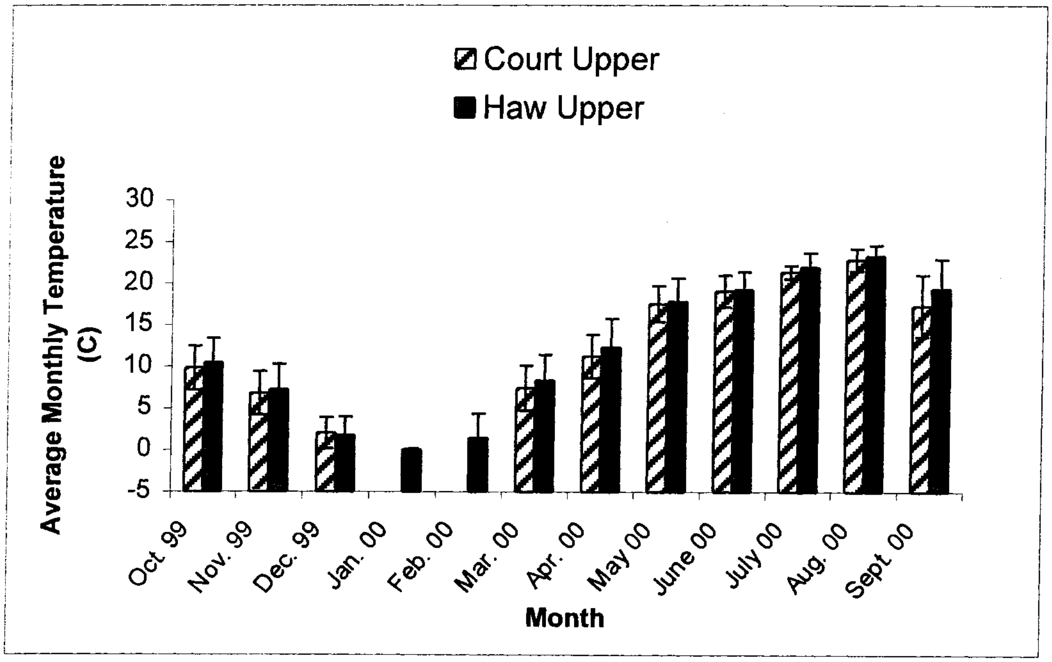


Figure 3. Average monthly temperature (+- one standard deviation) for upper and lower sites of the Spoon Basin.



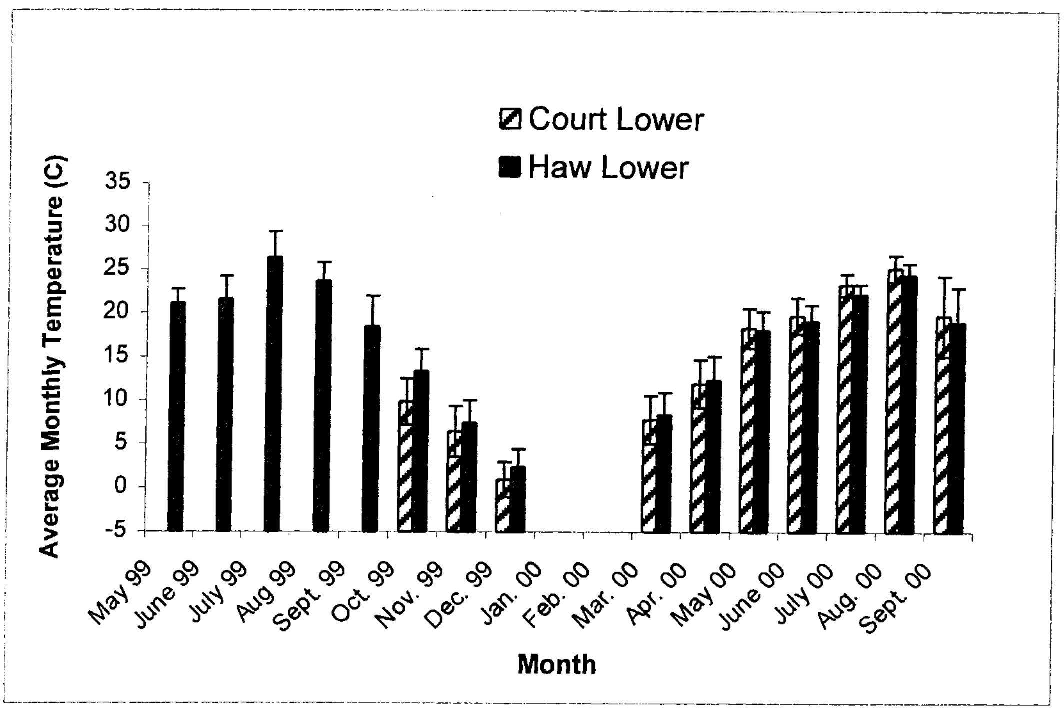


Figure 4. Average monthly temperature (+- one standard deviation) for lower sites of the Cache Basin.

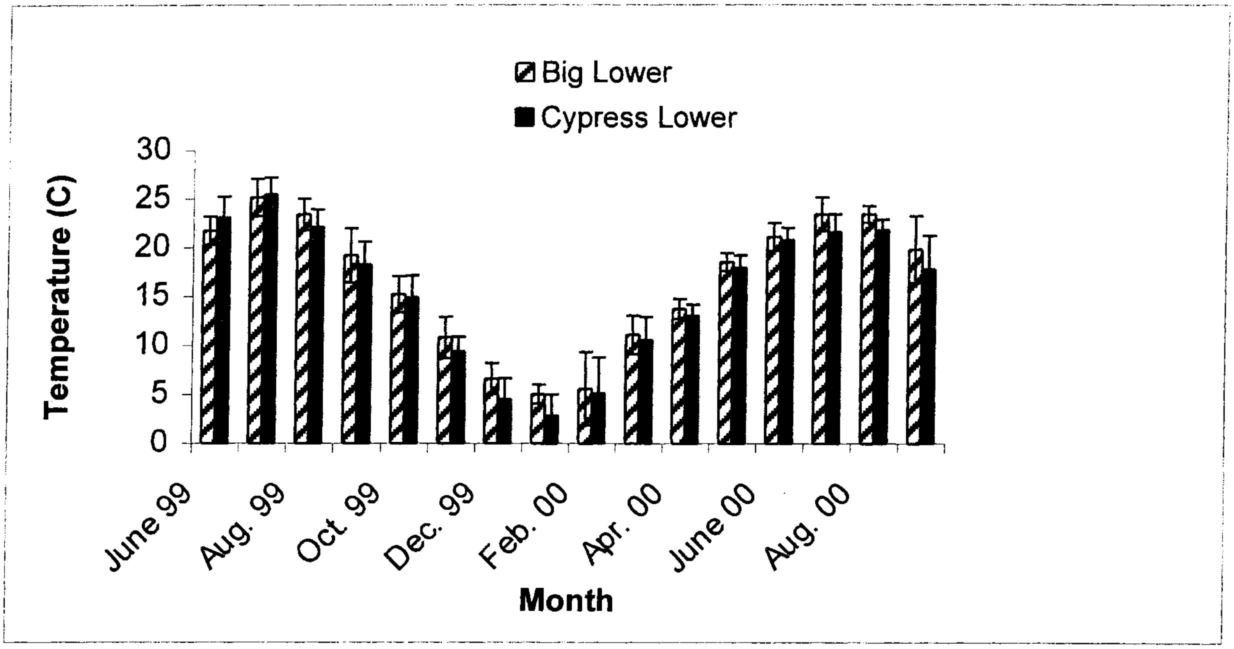
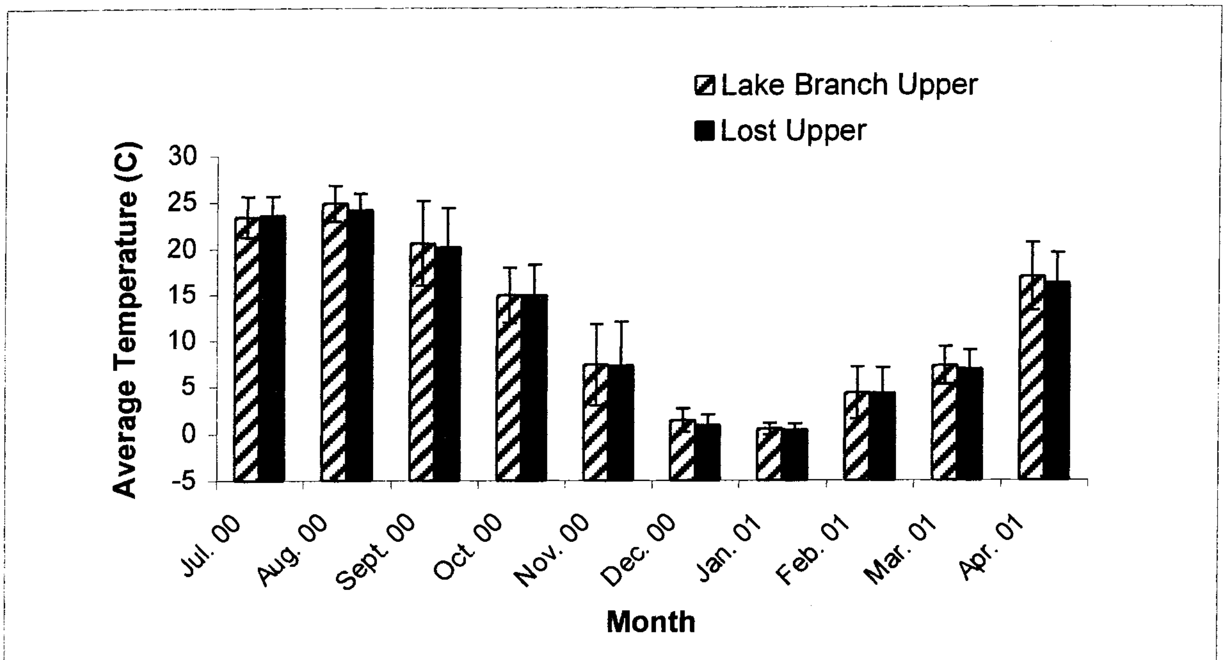


Figure 5. Average monthly temperature (+- one standard deviation) for upper and lower sites of the Kaskaskia Basin.



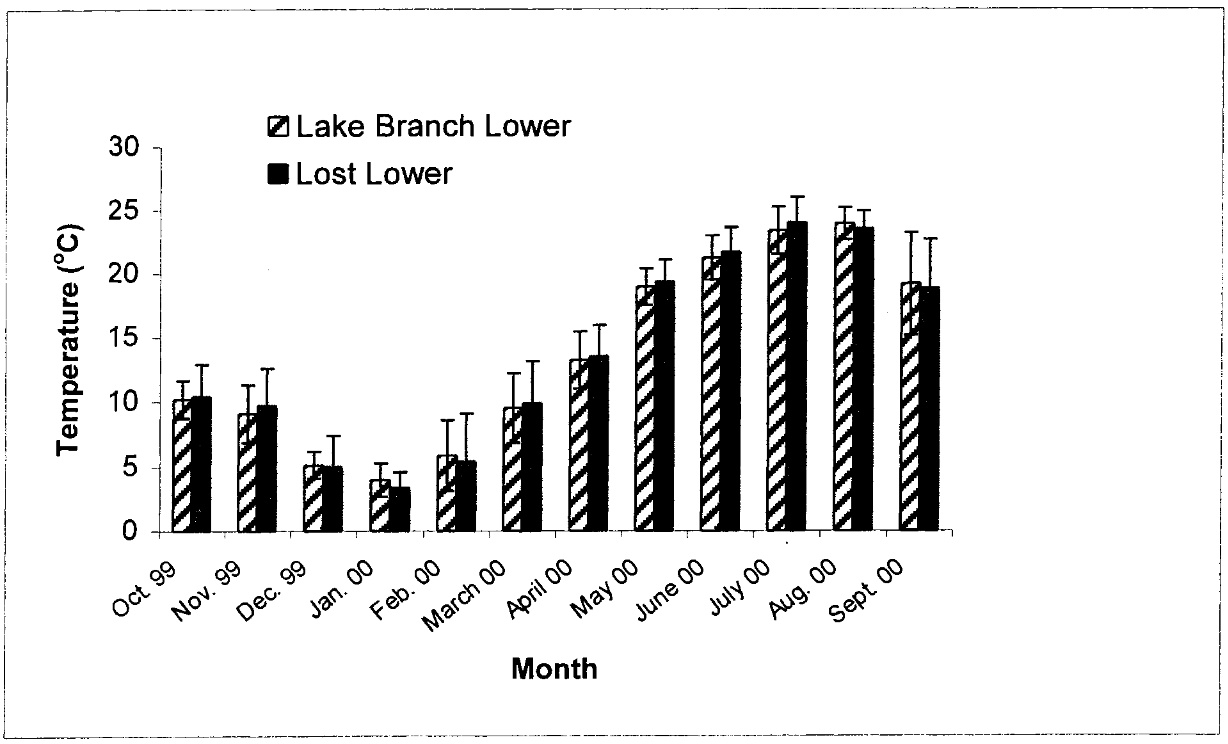


Figure 6. Difference in average width, depth, and velocity between the Pilot and Reference sites in each study basin. Difference = Pilot - Reference.

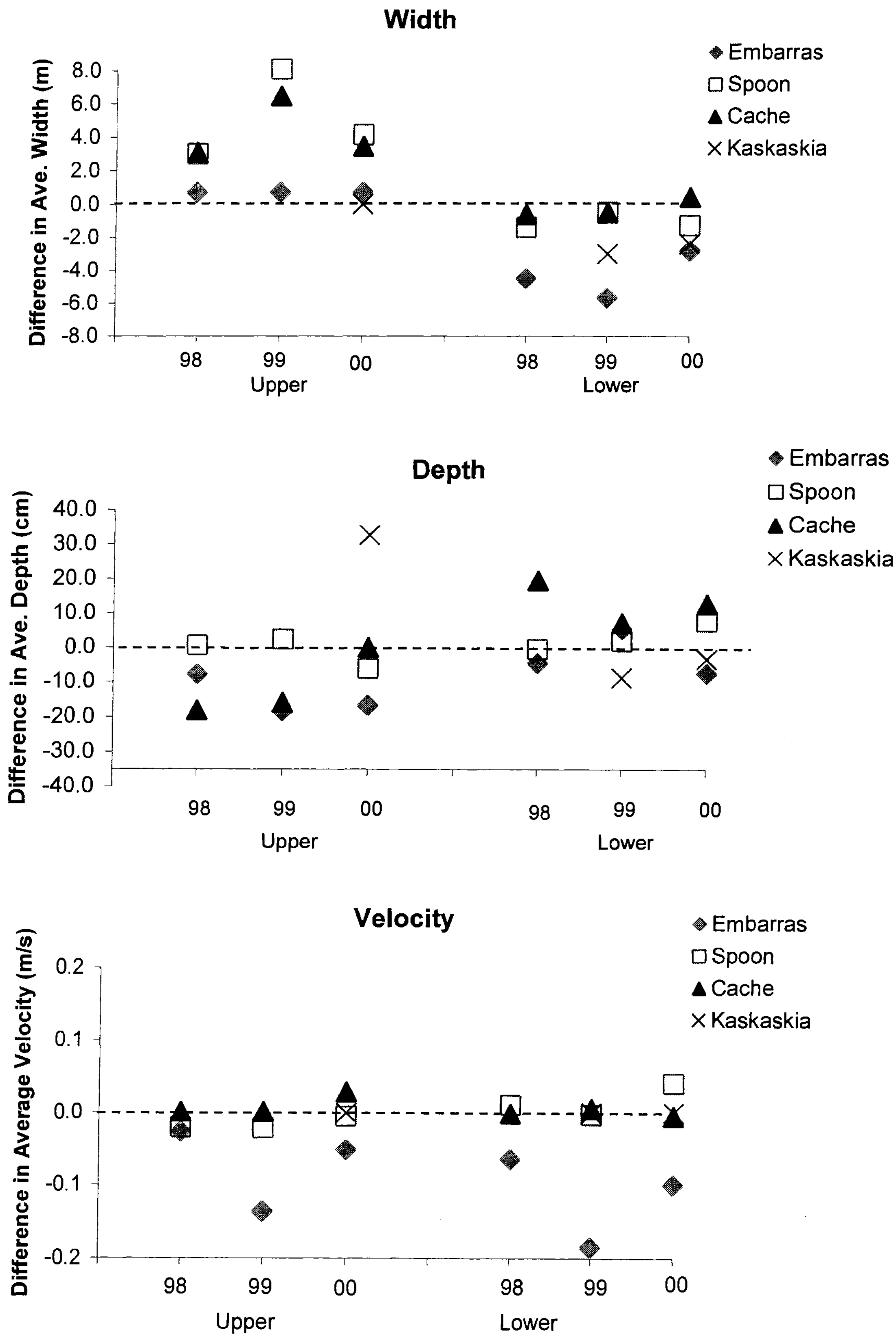
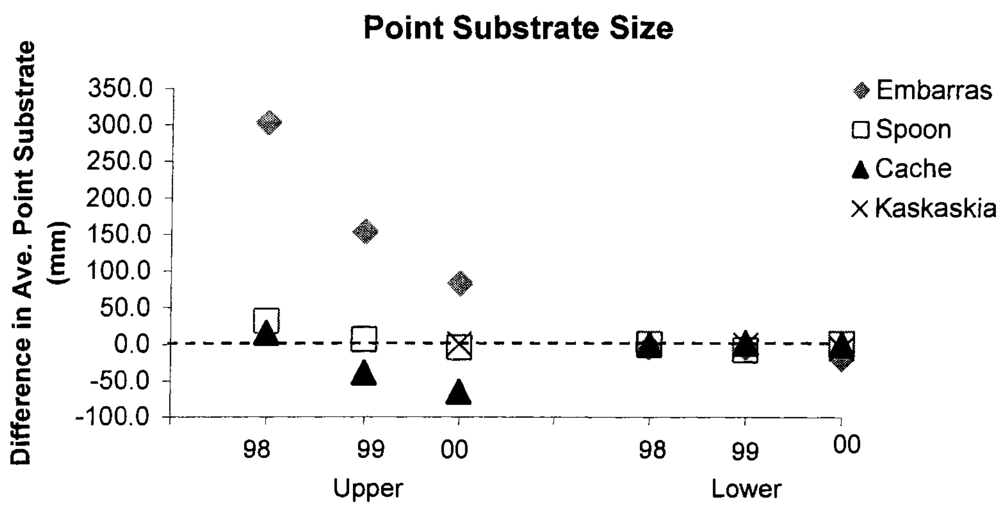


Figure 7. Diffference in average point particle and maximum substrate size between Pilot and Reference sites in each study basin. Difference = Pilot - Reference.



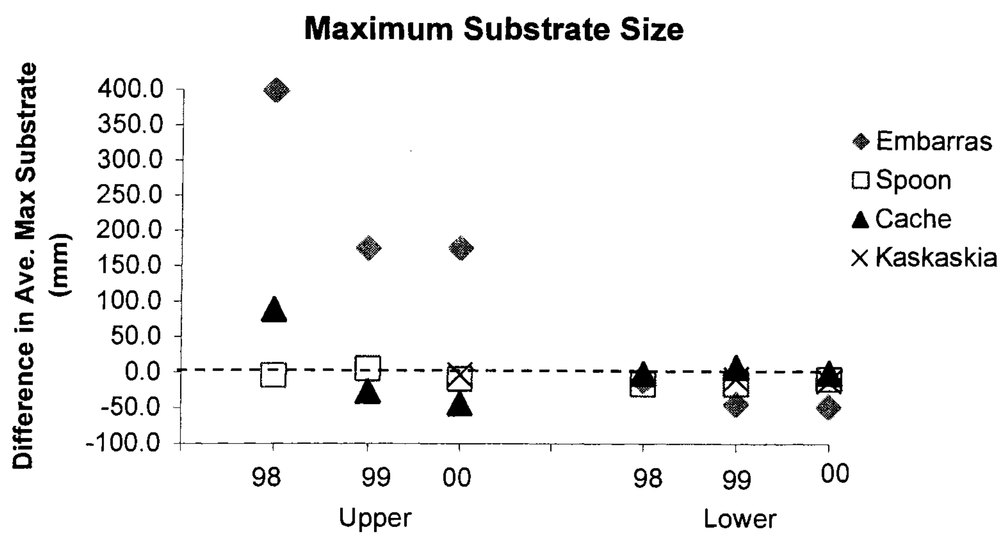


Figure 8. Bootstrap analysis of randomly selected transects for mean width, mean depth, and mean velocity in upper Kickapoo (diverse site).

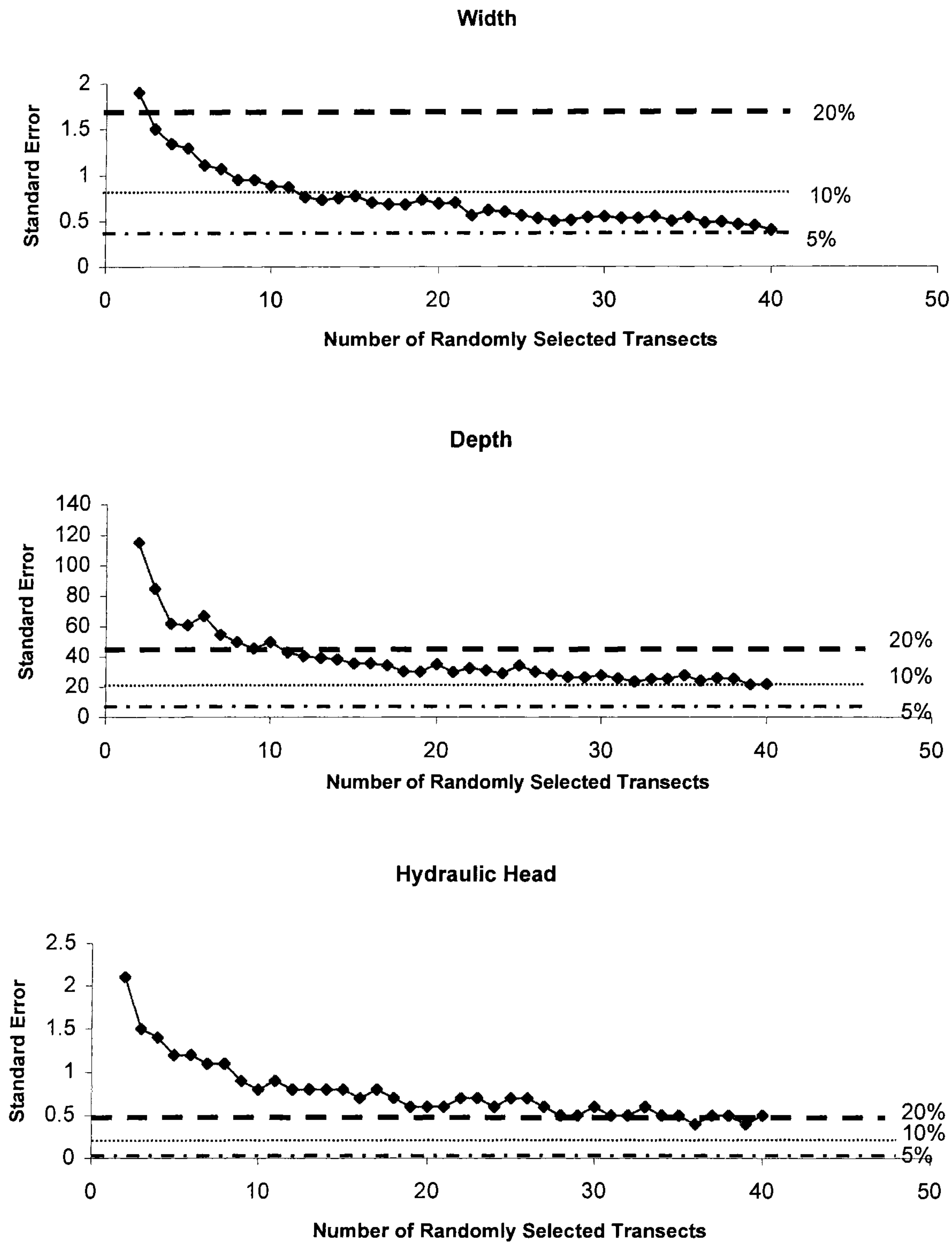


Figure 9. Bootstrap analysis of equally spaced transects for mean width, depth, and velocity (hydraulic head) in upper Kickapoo (diverse site).

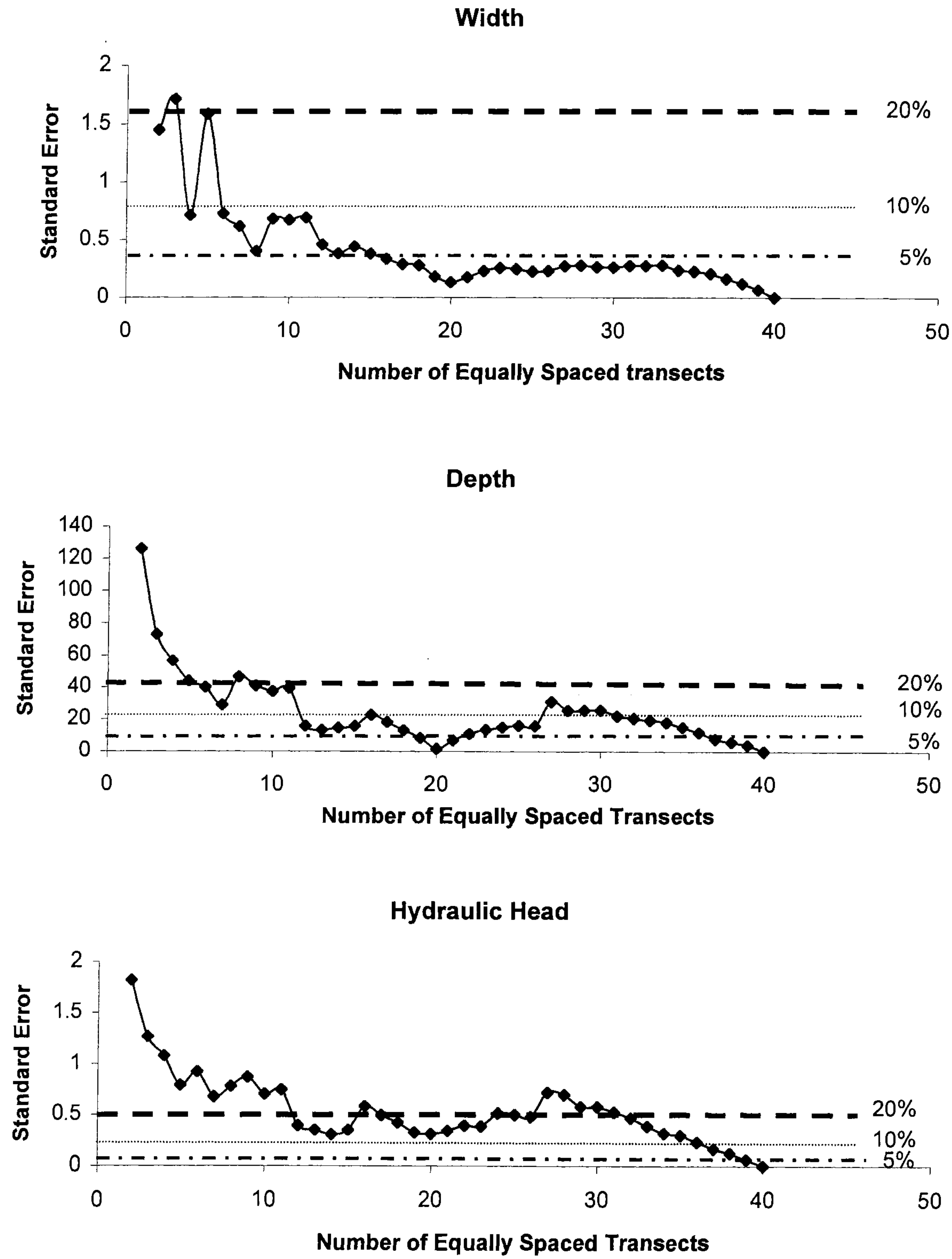
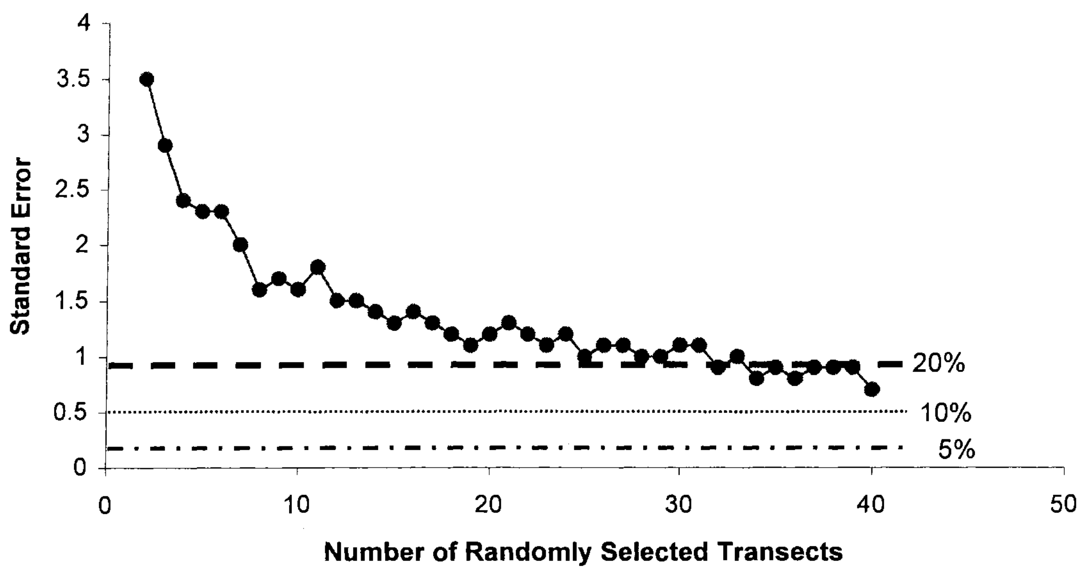


Figure 10. Bootstrap analysis of randomly selected transects for mean point particle and mean maximum particle sizes in upper Kickapoo (diverse site).

Point Particle Size



Maximum Particle Size

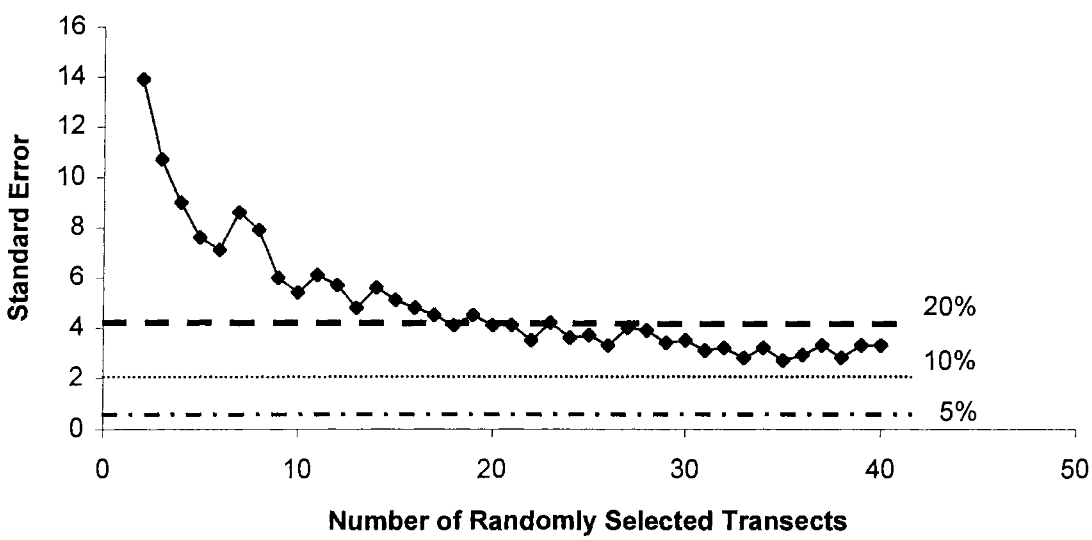
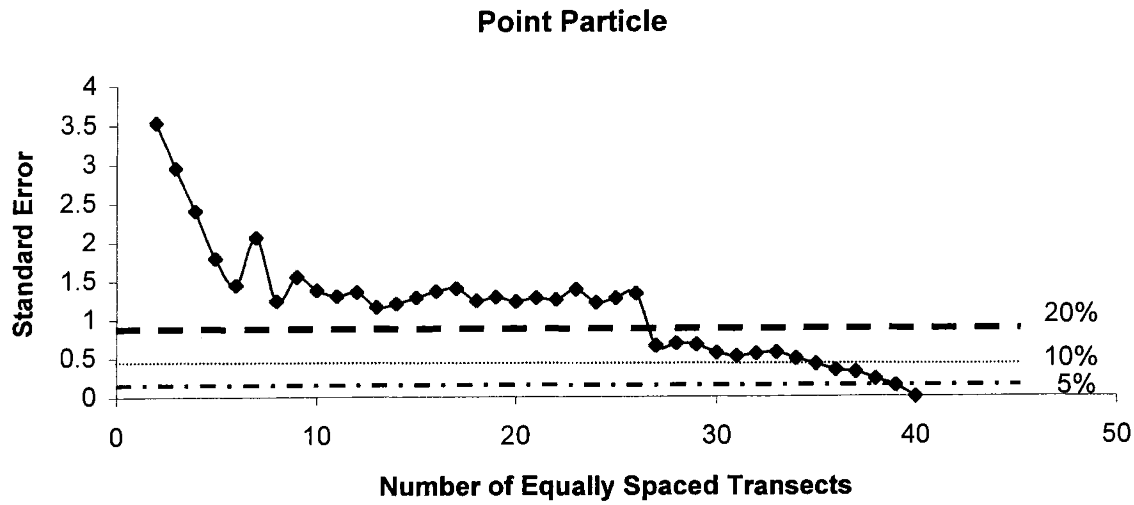


Figure 11. Bootstrap analysis of equally spaced transects for mean point particle and mean maximum particle sizes in upper Kickapoo (diverse site).



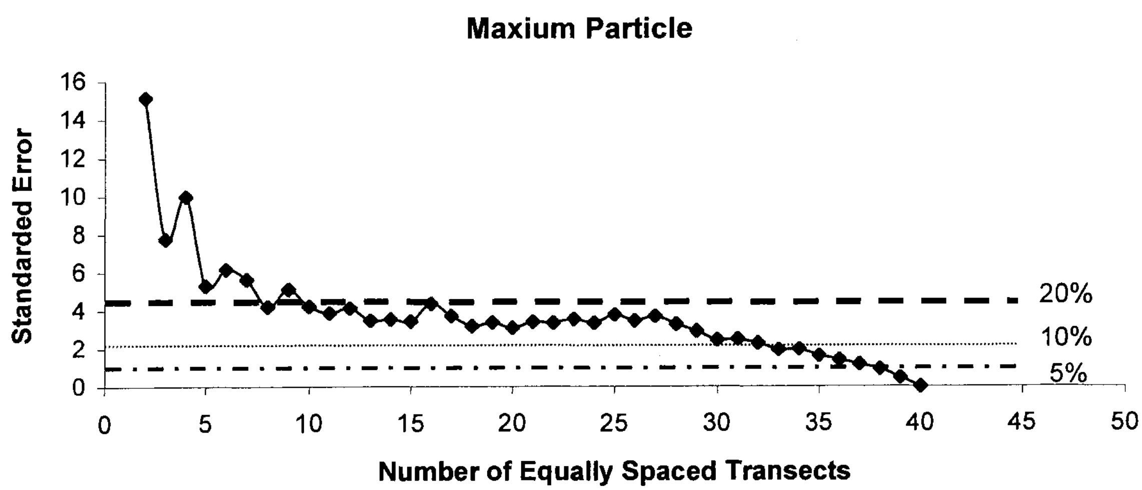
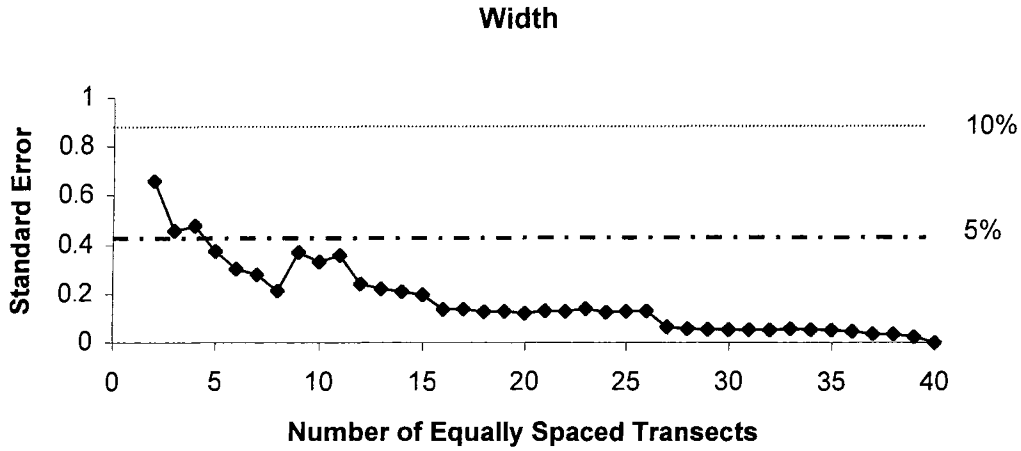
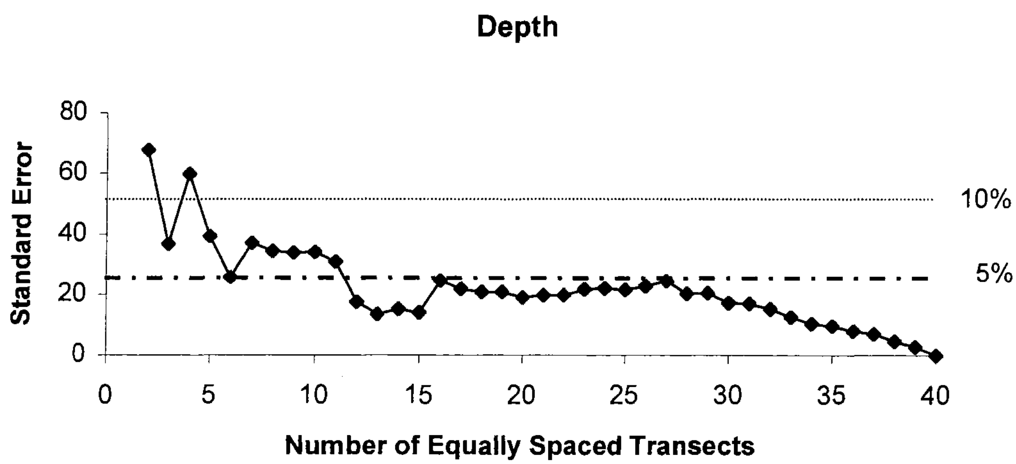


Figure 12. Bootstrap analysis of equally spaced transects for mean width, depth, and velocity (hydraulic head) in lower Lost (uniform site).





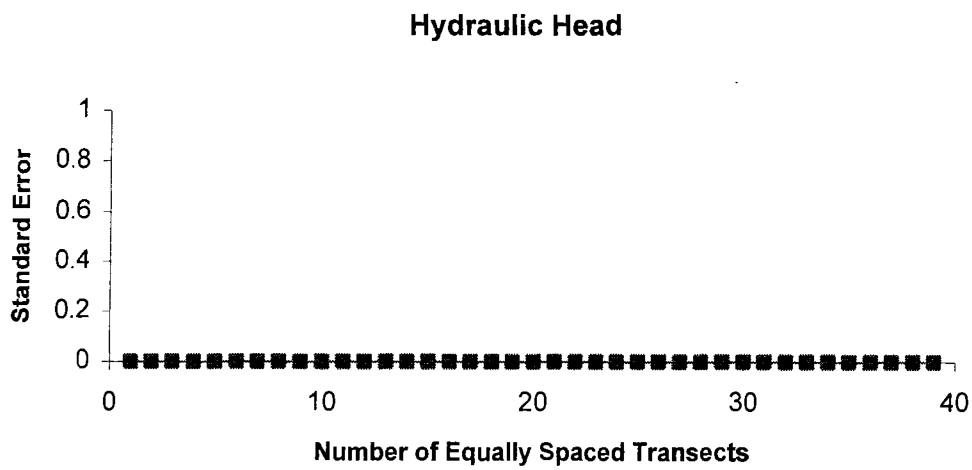
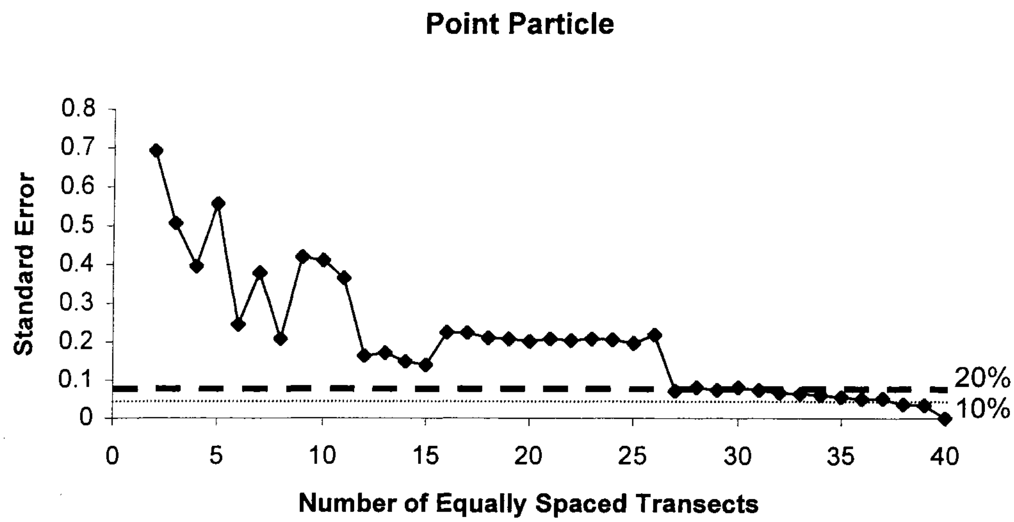


Figure 13. Bootstrap analysis of equally spaced transects for point particle and mean maximum particle sizes in lower Lost (uniform site).



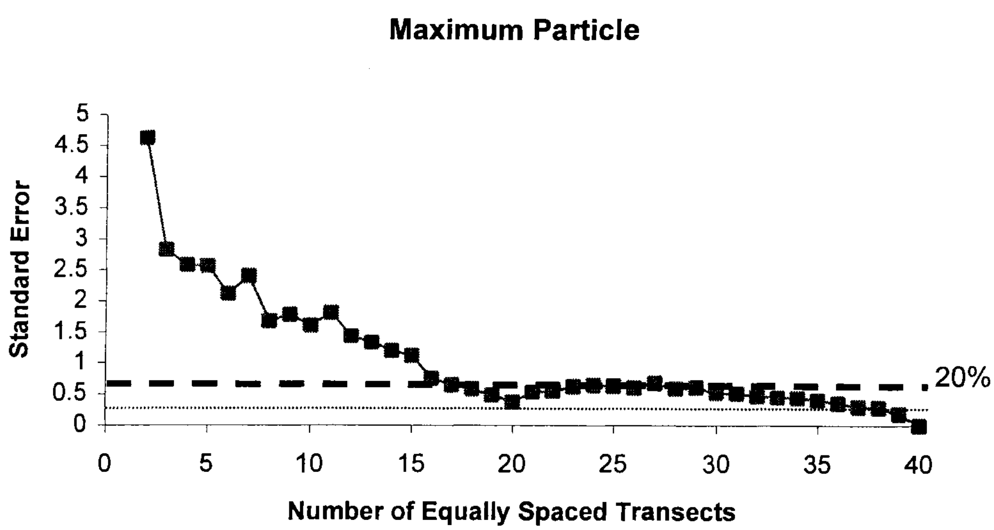


Figure 14. Percent habitat composition for upper and lower sites of the Embarras and Spoon Basins in 2000.

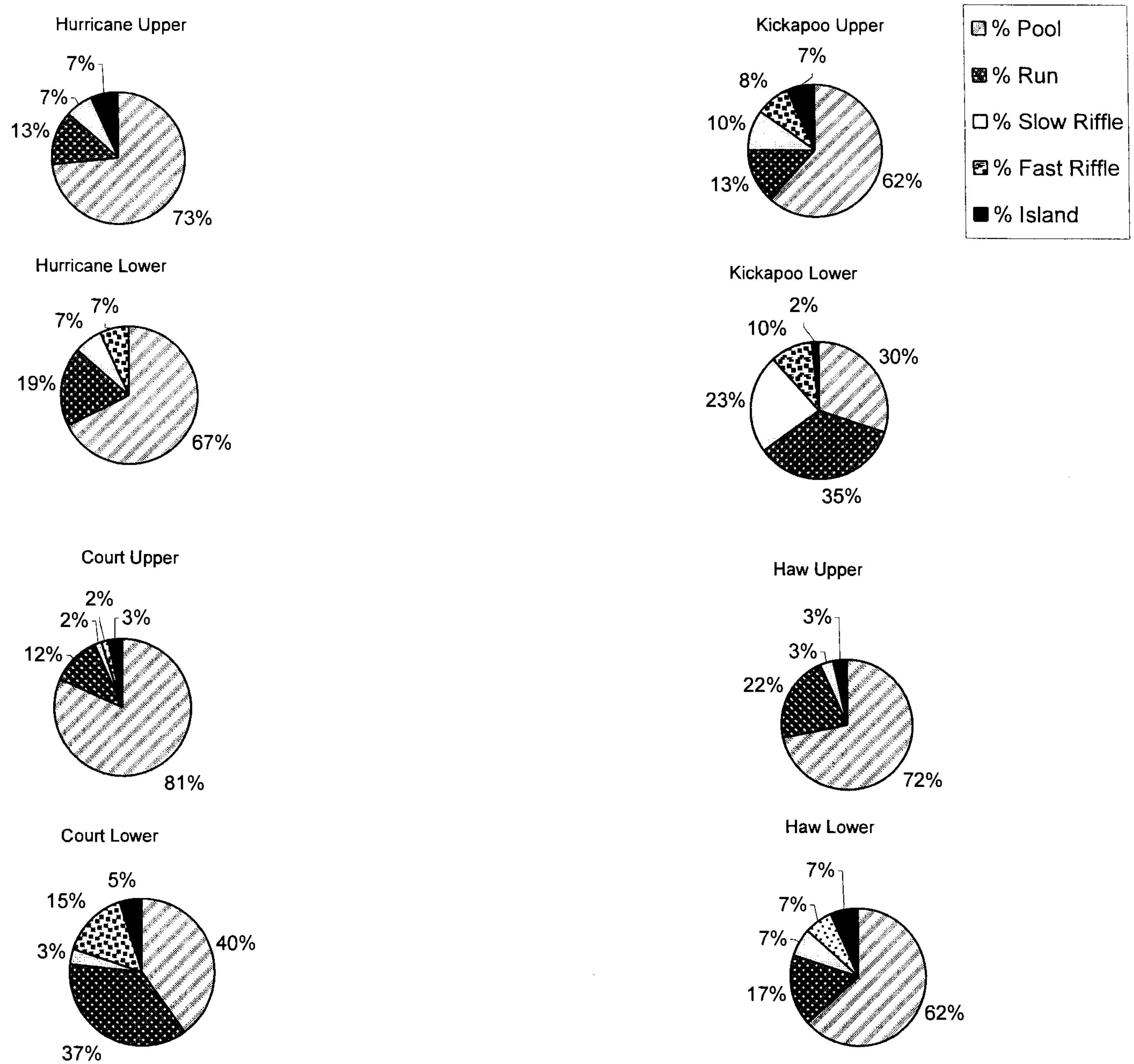


Figure 15. Percent habitat composition for upper and lower sites of the Cache and Kaskaskia Basins in 2000.

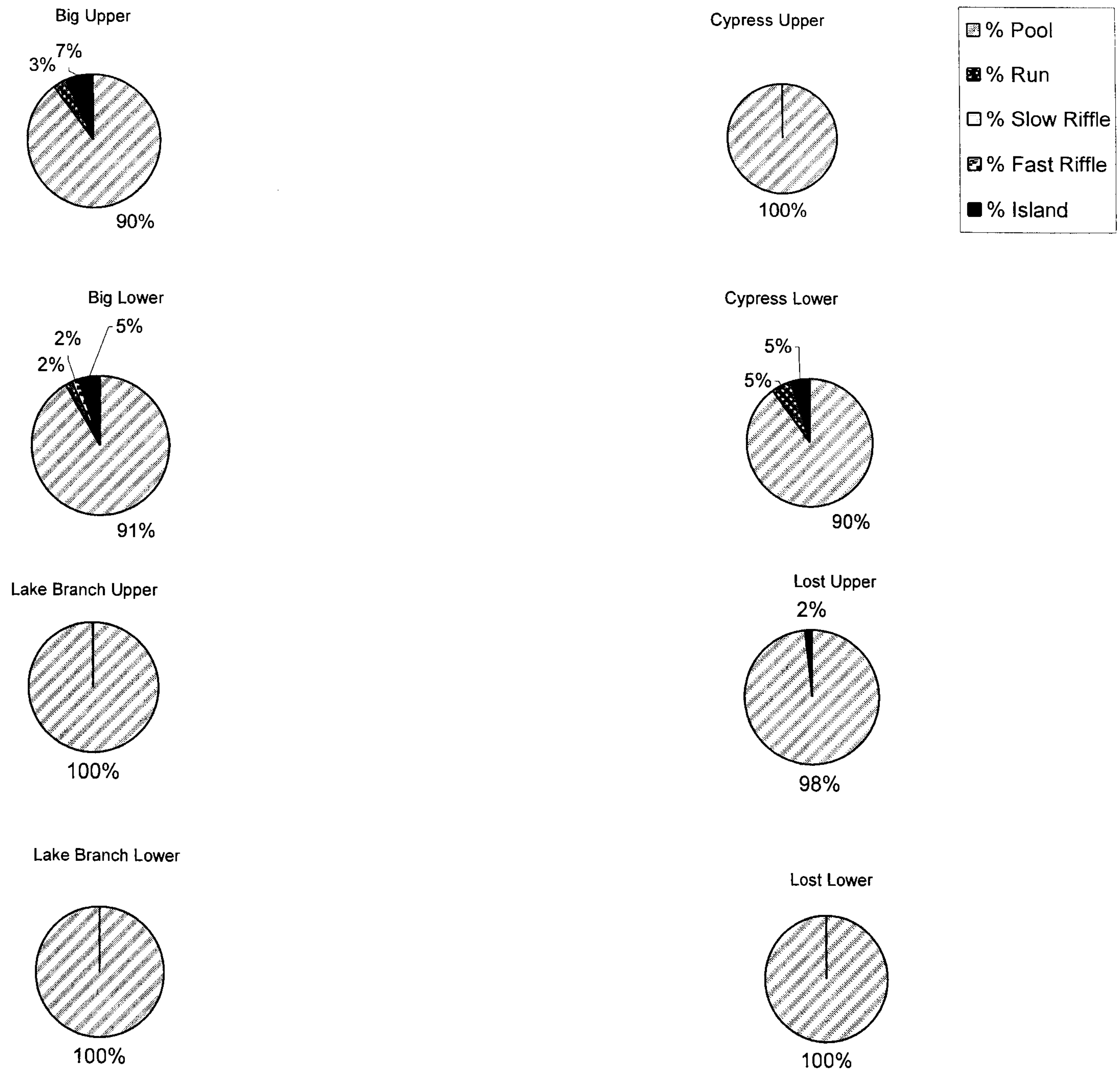


Figure 16. Percent in-stream cover for upper and lower sites of the Embarras basin in 2000. U represents unembedded cover and E represents embedded cover.

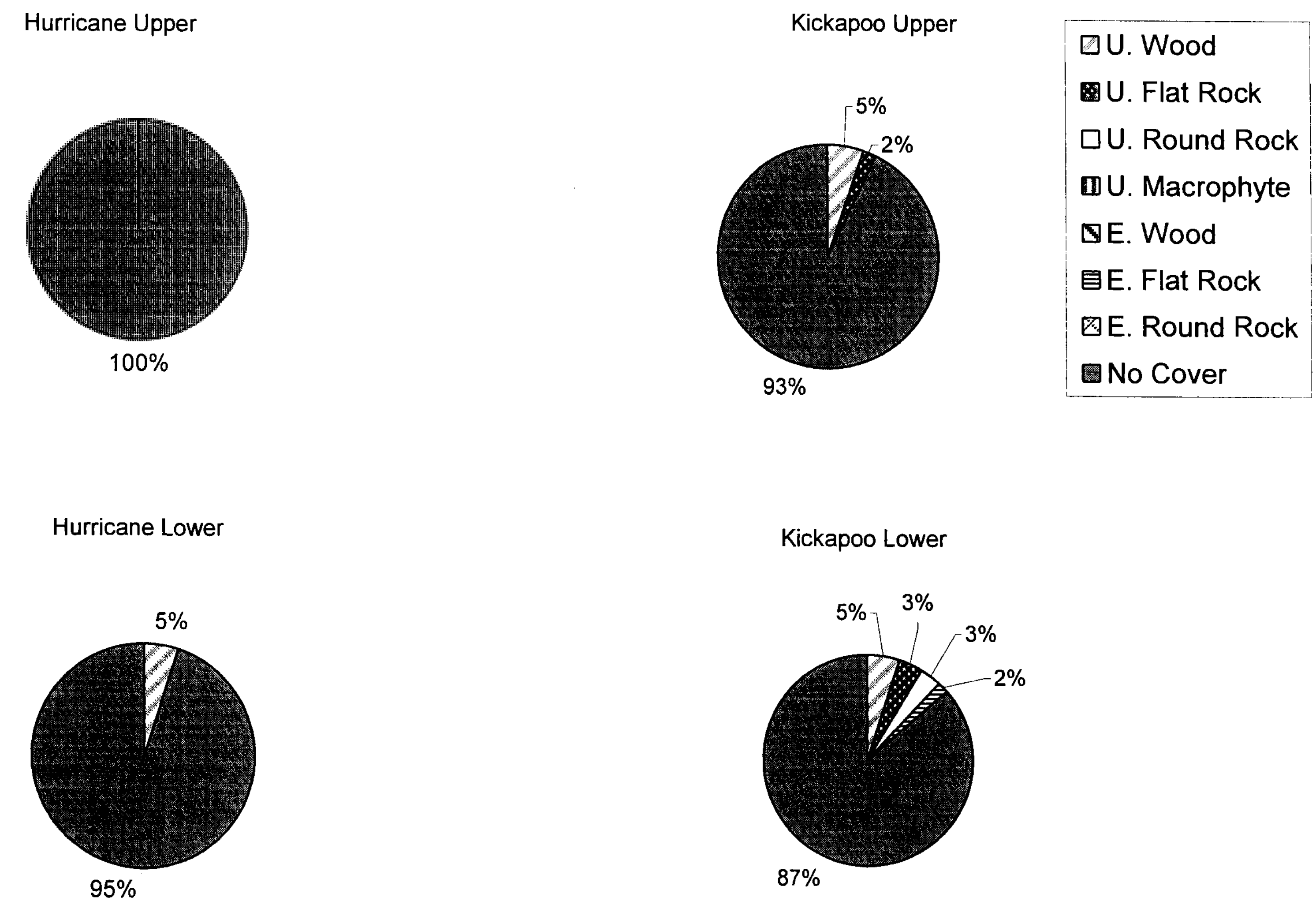


Figure 17. Percent in-stream cover for upper and lower sites of the Spoon basin in 2000. U represents unembedded cover and E represents embedded cover.

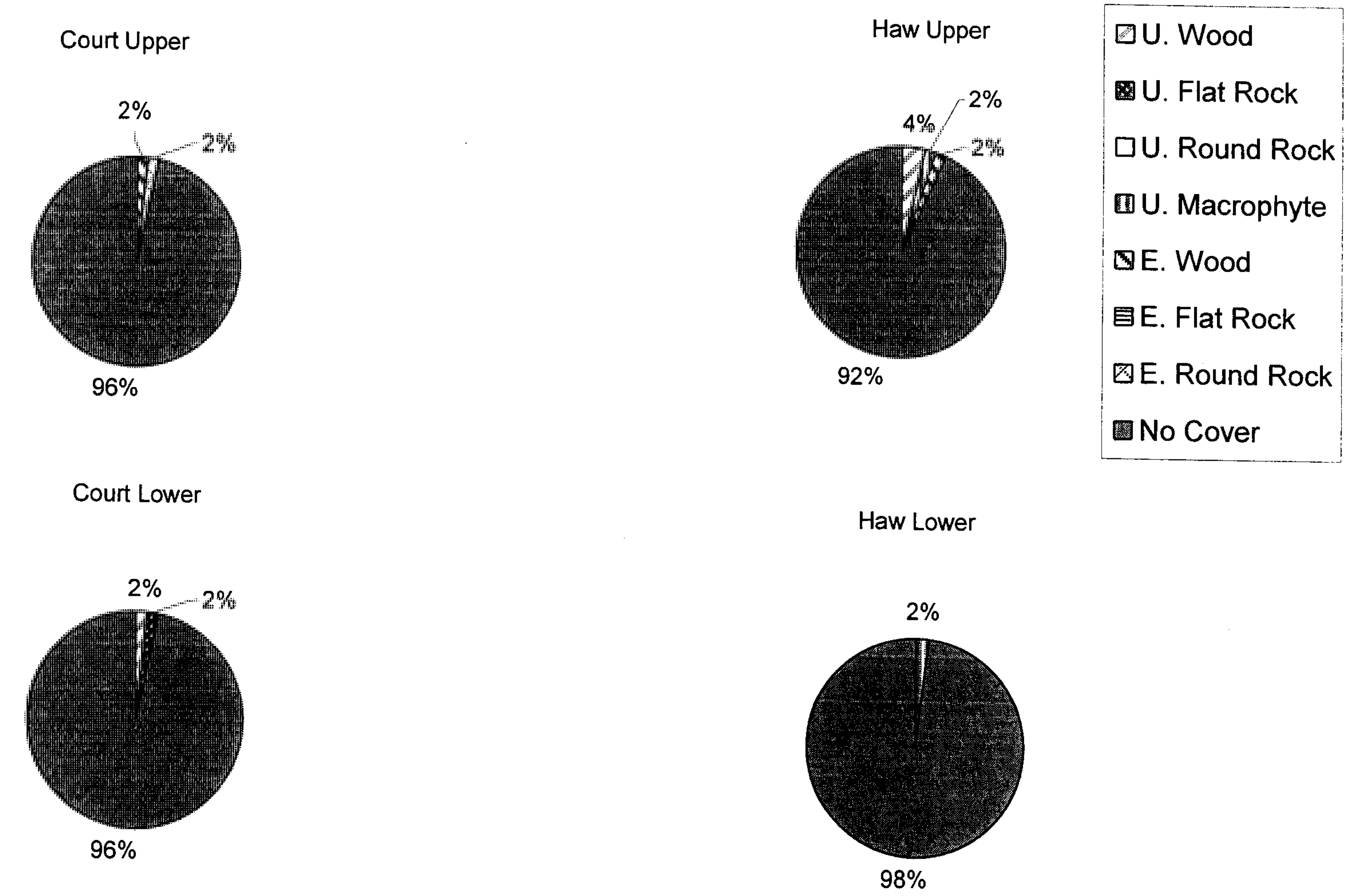


Figure 18. Percent in-stream cover for upper and lower sites of the Cache basin in 2000. U represents unembedded cover and E represents embedded cover.

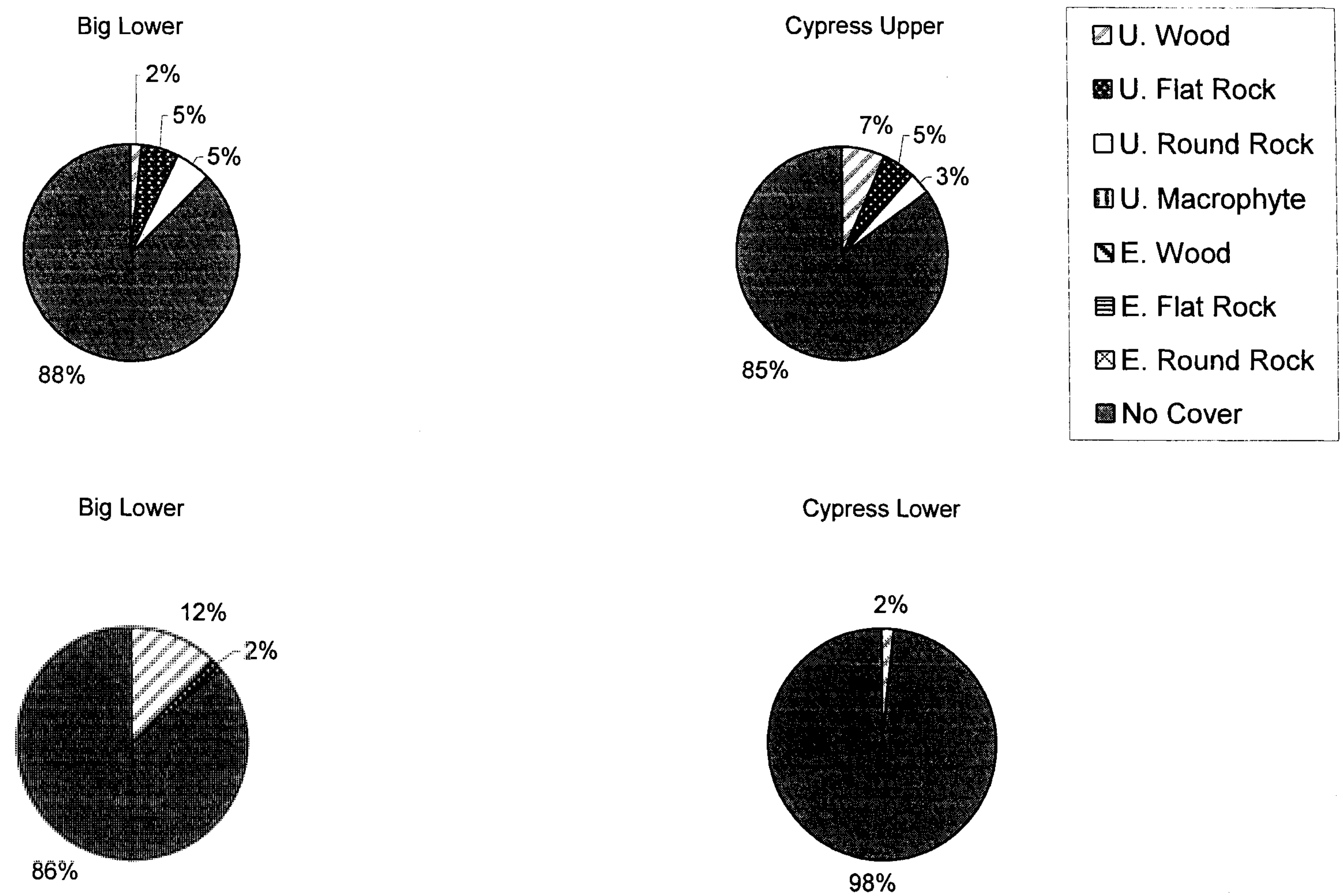


Figure 19. Percent in-stream cover for upper and lower sites of the Kaskaskia basin in 2000. U represents unembedded cover and E represents embedded cover.

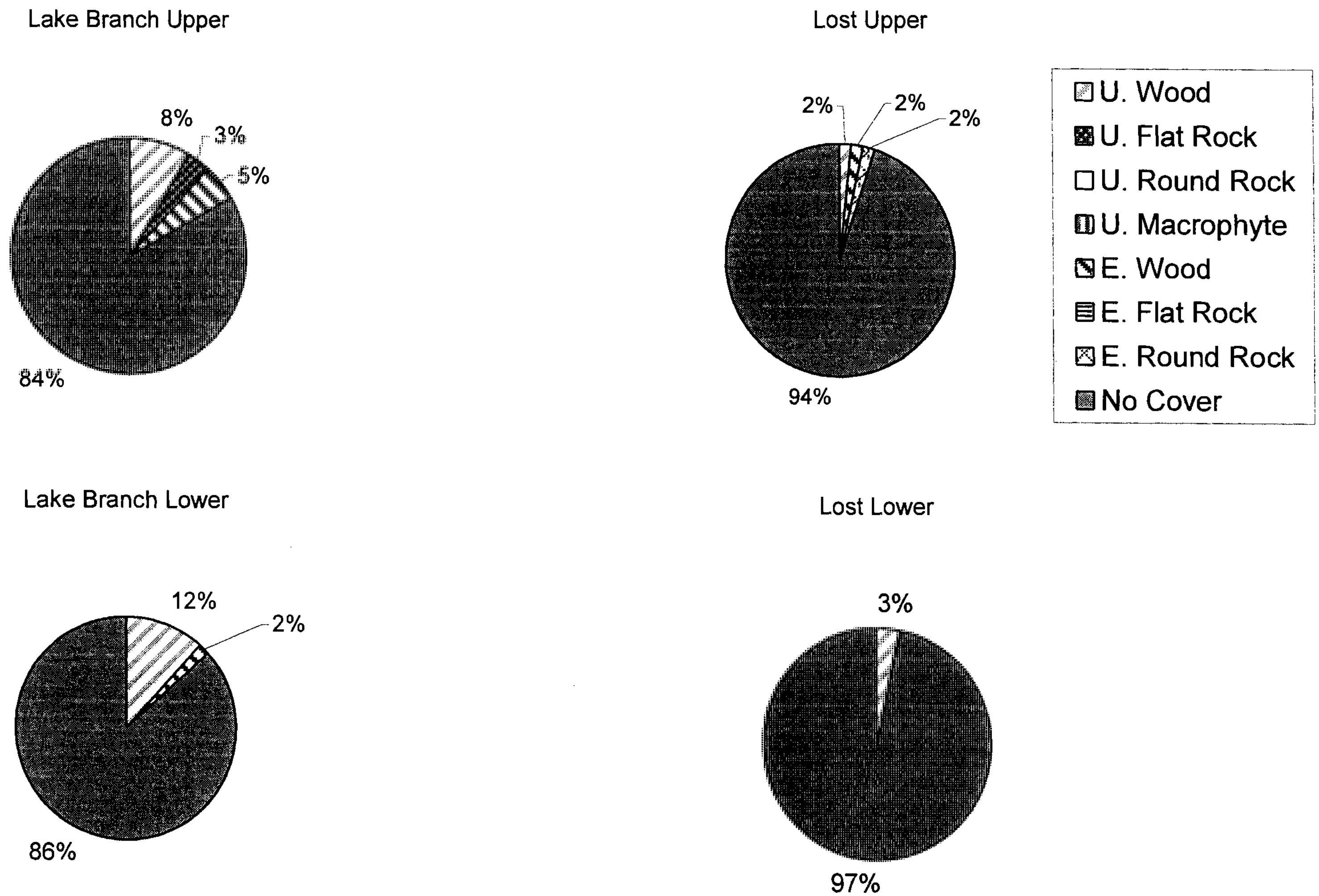


Figure 20. Occurrence of riparian vegetation categories in the Embarras Basin from water's edge to 100m. A observation is made at the left and right bank of each transect for a total of 20 observations per site.

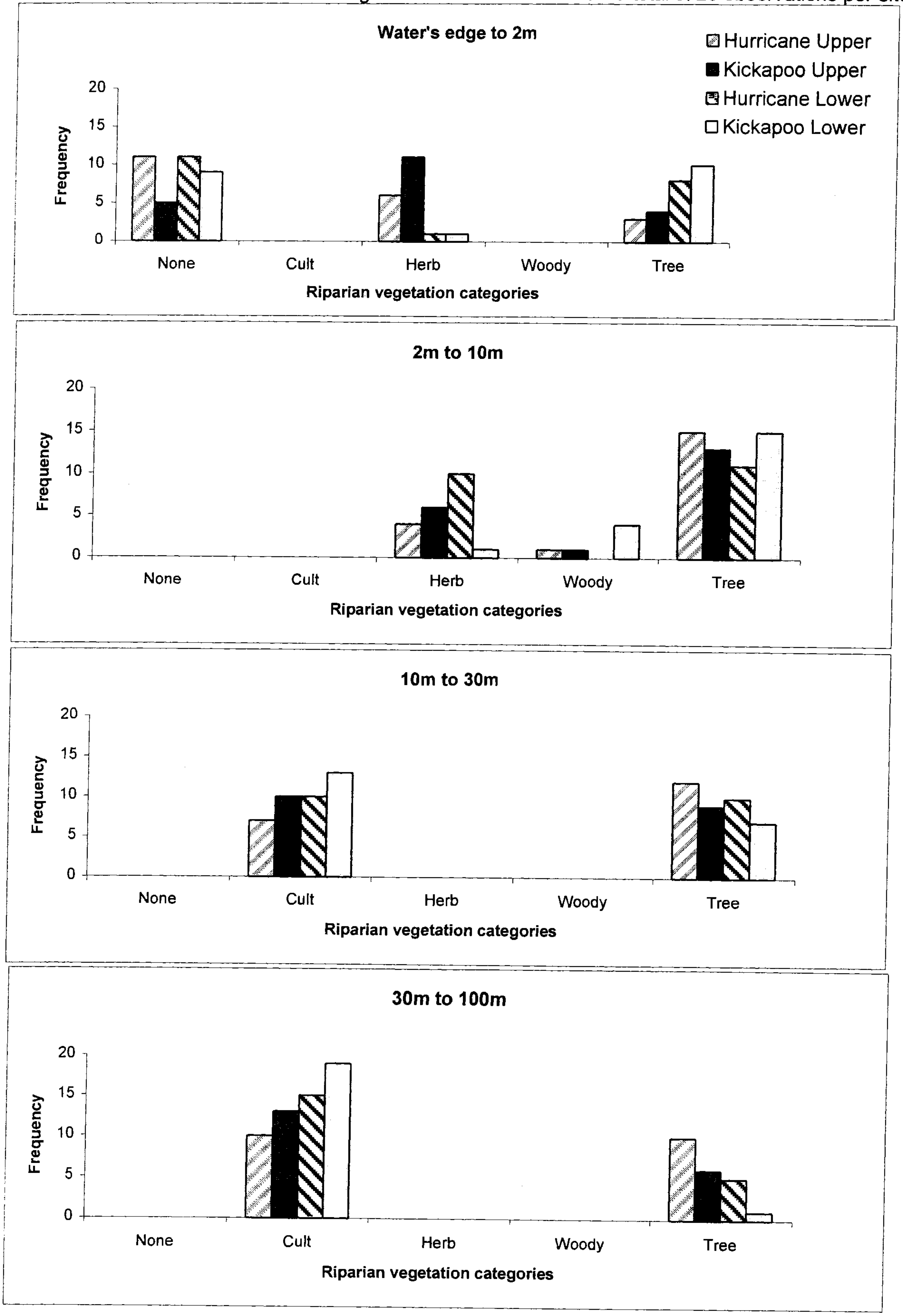


Figure 21. Occurrence of riparian vegetation categories in the Spoon Basin from water's edge to 100m. An observation is made at the left and right bank of each transect for a total of 20 observations per site.

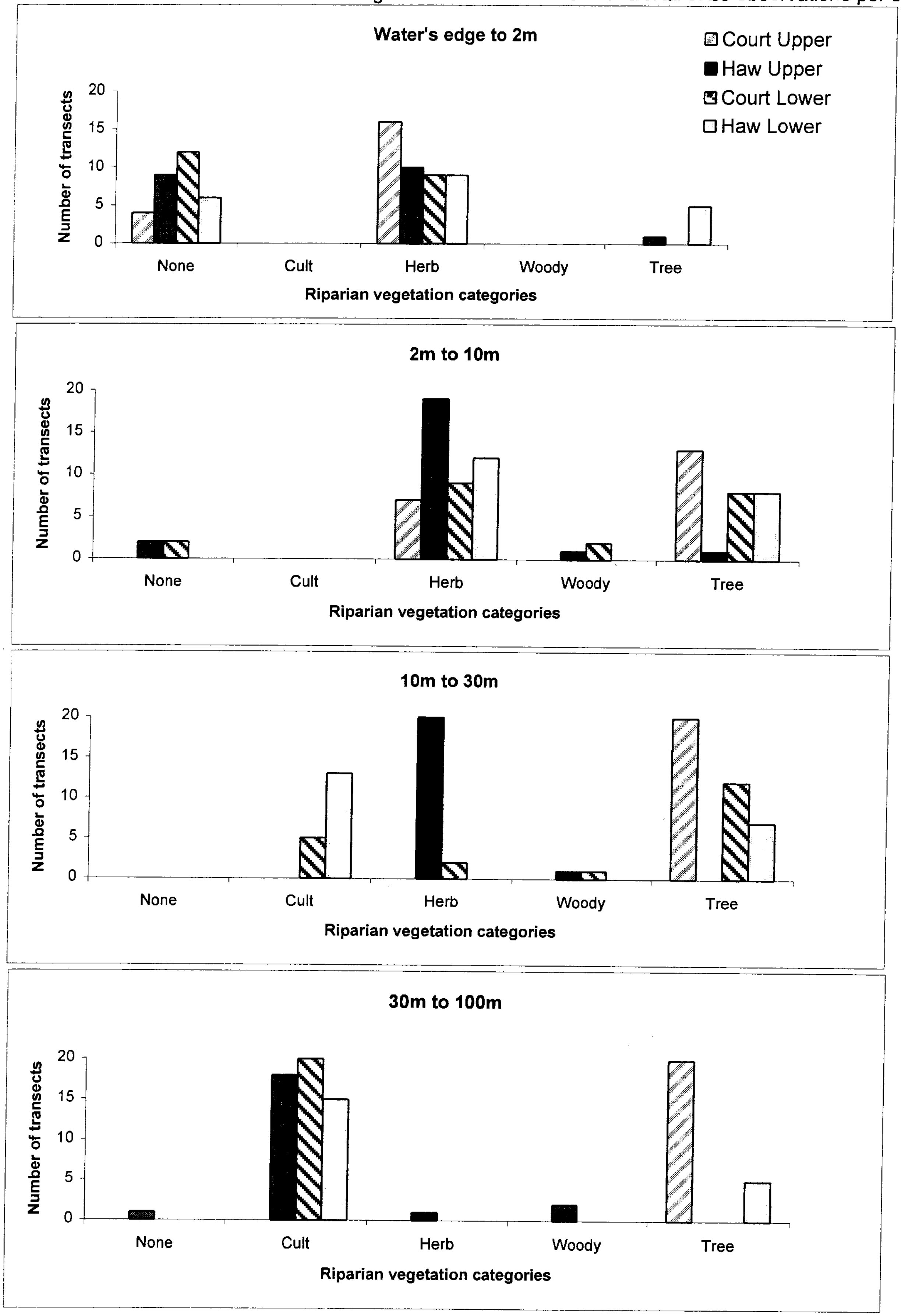


Figure 22. Occurrence of riparian vegetation categories in the Cache Basin from water's edge to 100m. An observation is made at the left and right bank of each transect for a total of 20 observations per site.

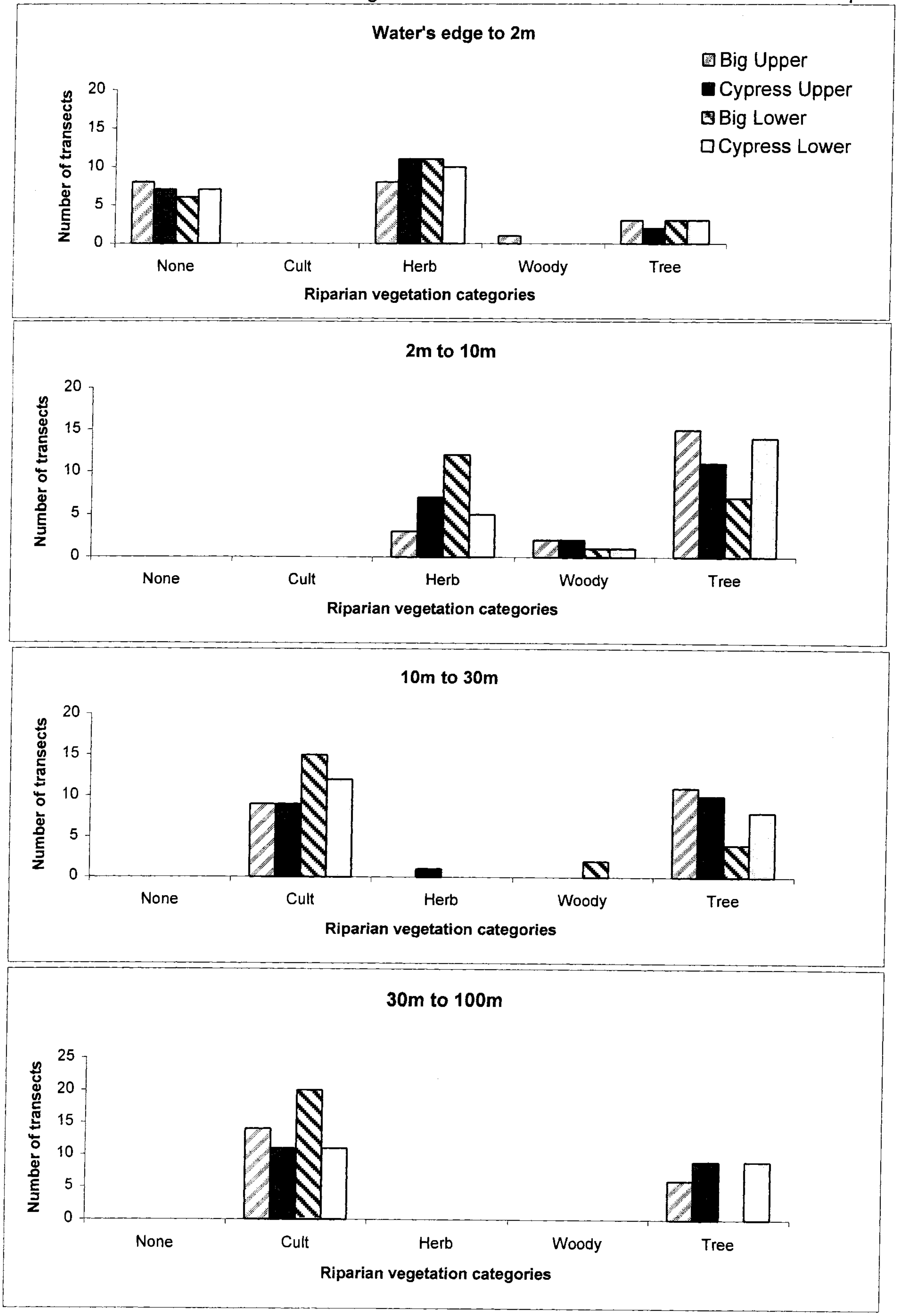


Figure 23. Occurrence of riparian vegetation categories in the Kaskaskia Basin from water's edge to 100m. An observation is made at the left and right bank of each transect for a total of 20 observations per site.

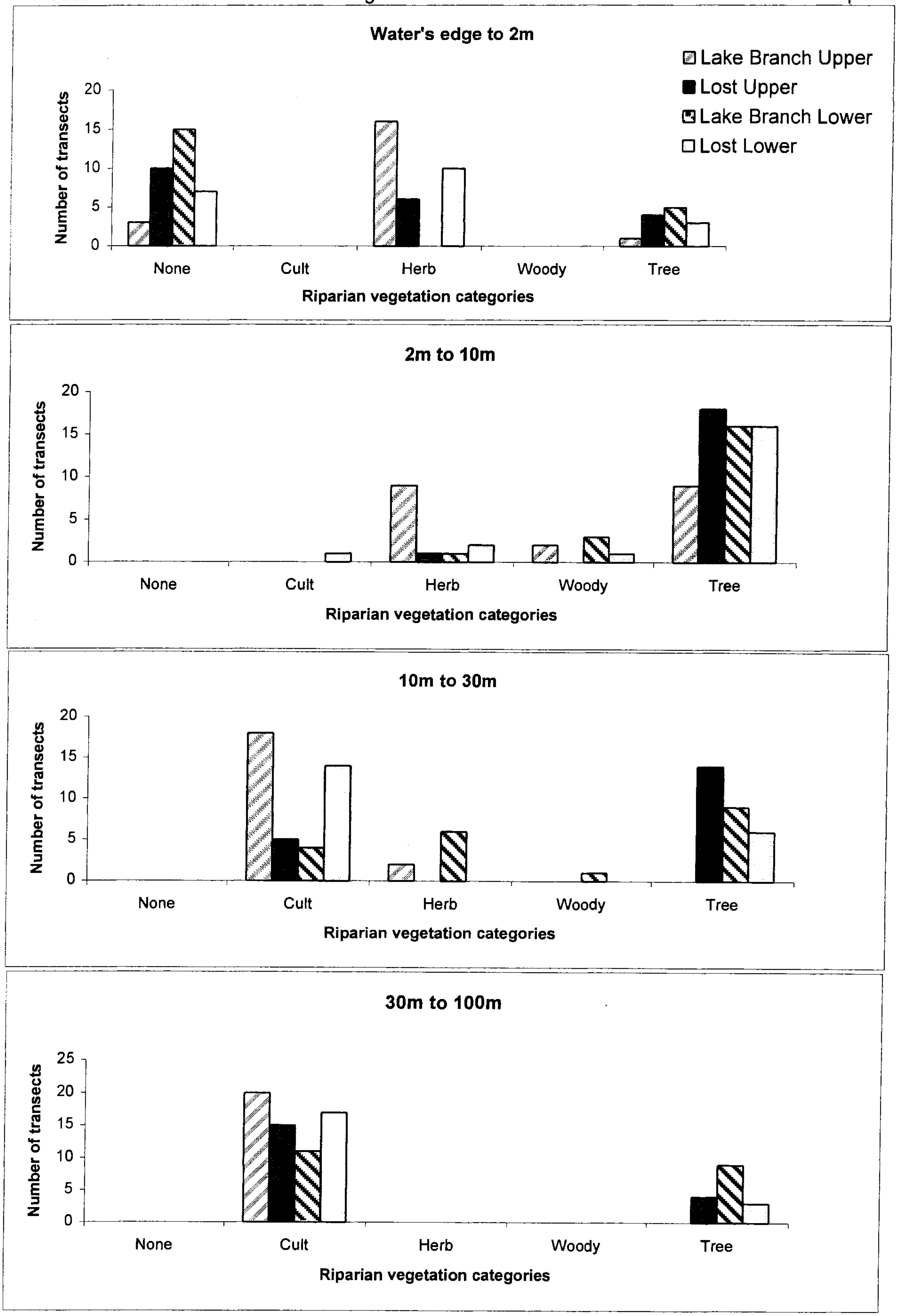
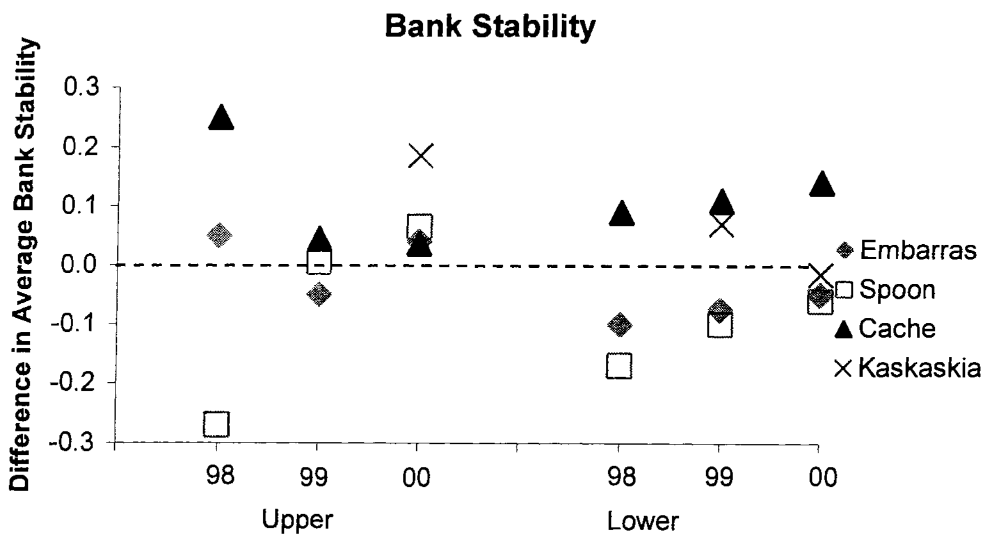


Figure 24. Difference in average bank stability and overstory cover between Pilot and Reference sites in each study basin. Difference = Pilot - Reference.



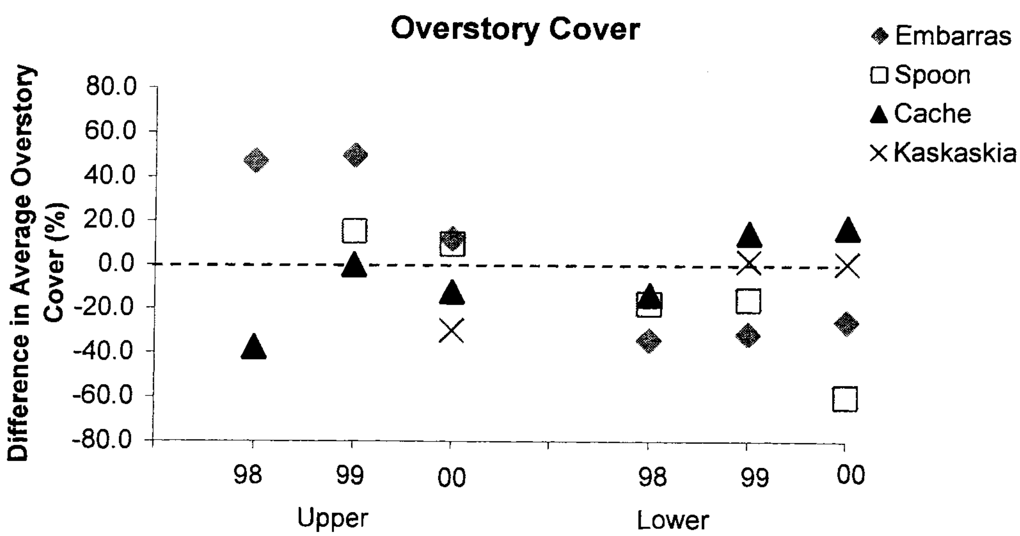
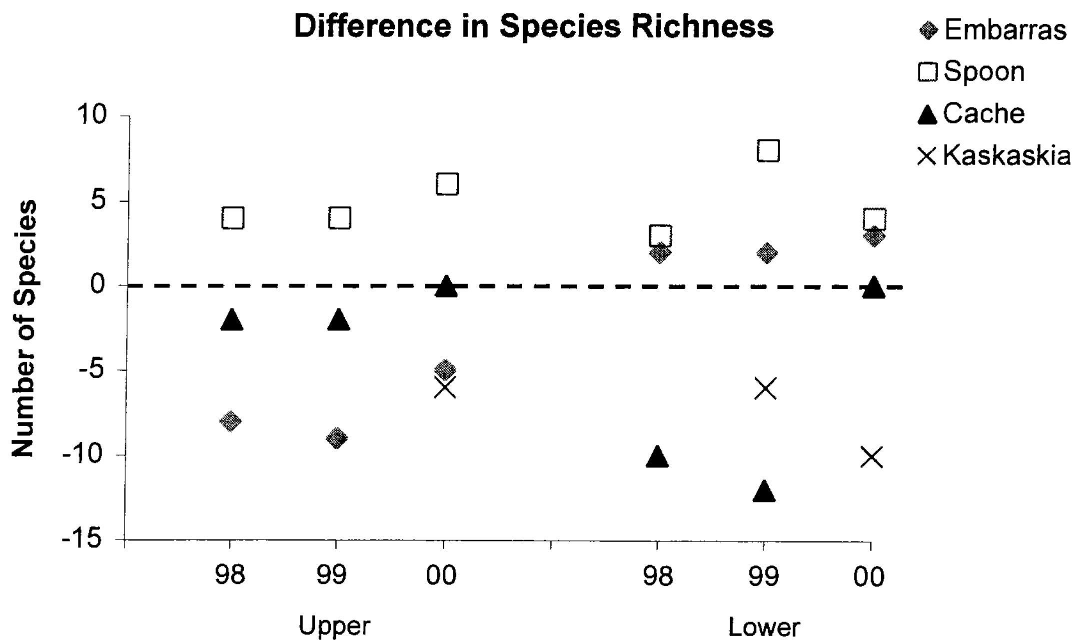


Figure 25. Difference in species richness and total catch between Pilot and Reference sites in each study basin from 1998 to 2000. Difference = Pilot - Reference.



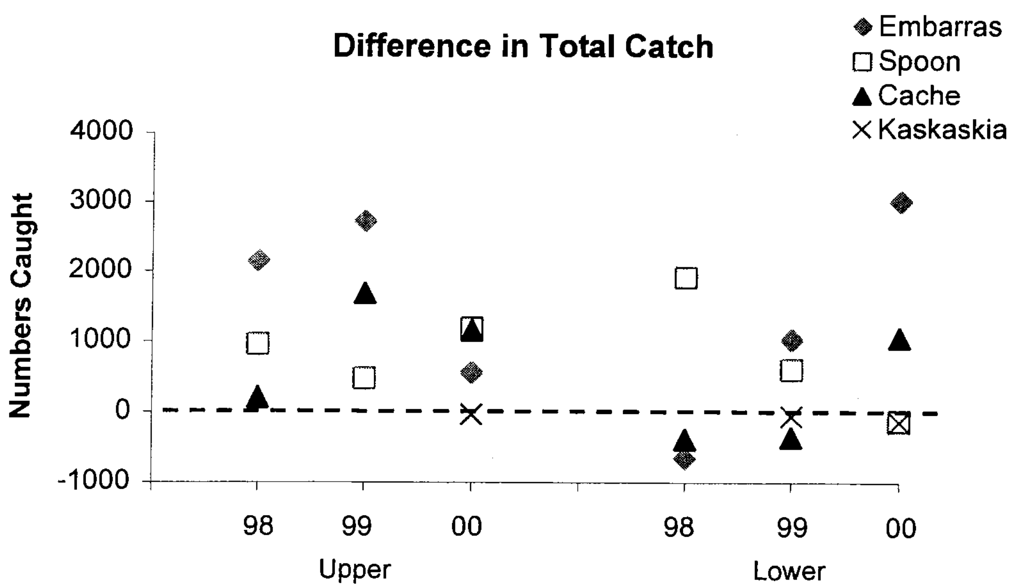


Figure 26. Jaccard's similarity index and Similarity Ratio between Pilot and Reference sites in each study basin from 1998 to 2000. Difference = Pilot - Reference.

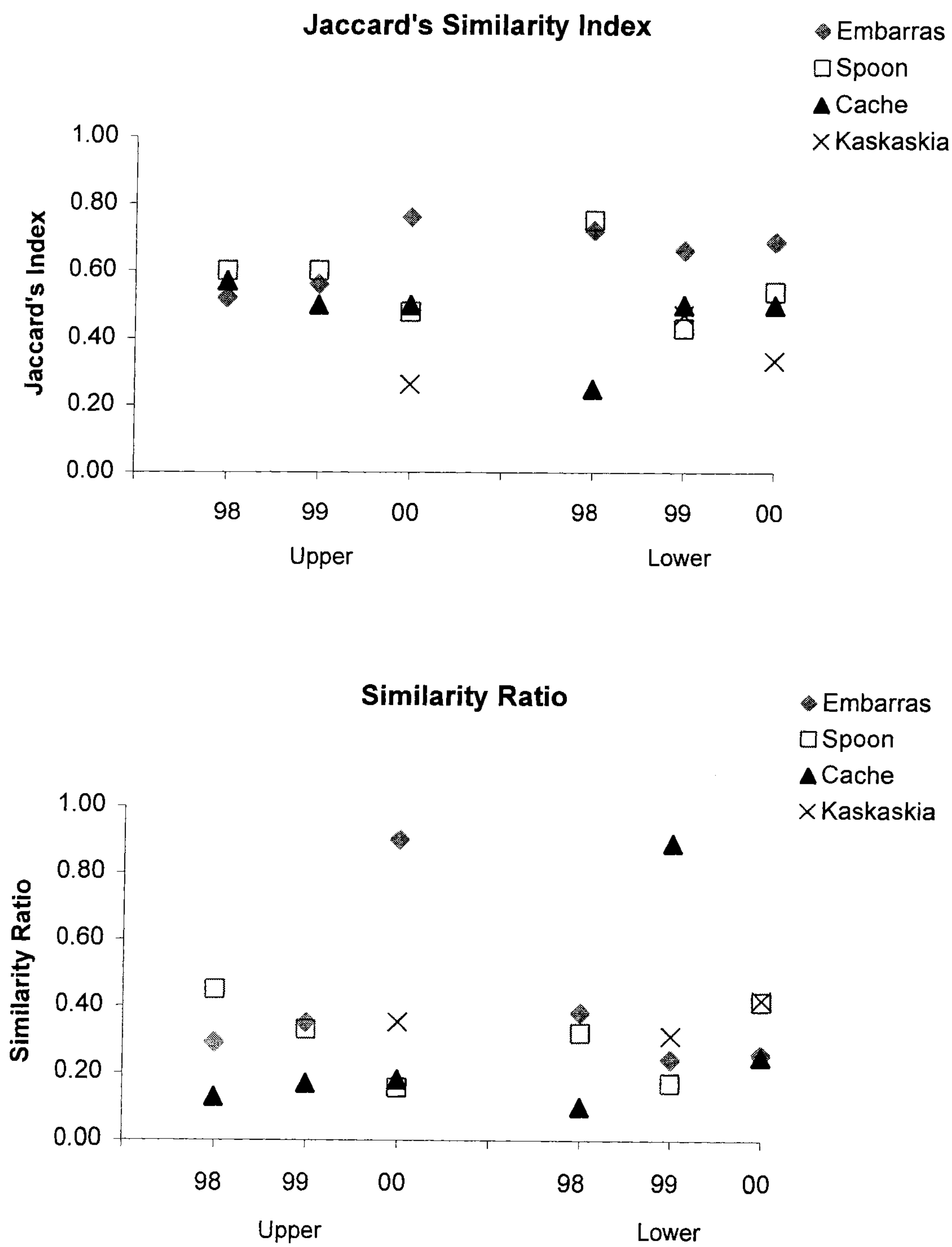


Figure 27. Difference in catch per hour of electroshocking time (CPUE) between Pilot and Reference sites in each basin from 1998 to 2000. Difference = Pilot - Reference.

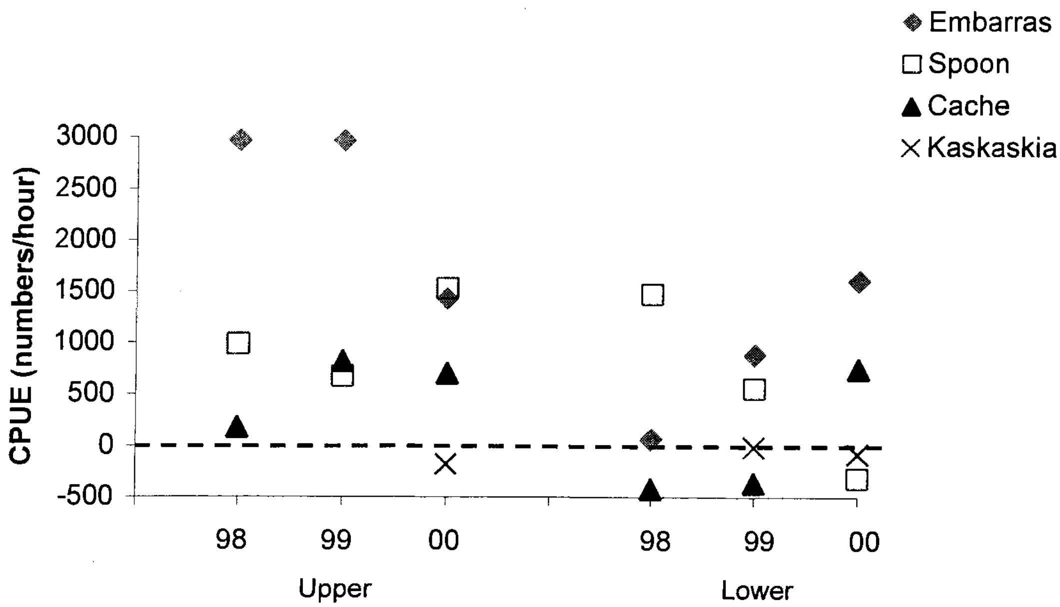


Figure 28. Difference in IBI scores between Pilot and Reference sites in each basin from 1998 to 2000. Difference = Pilot - Reference.

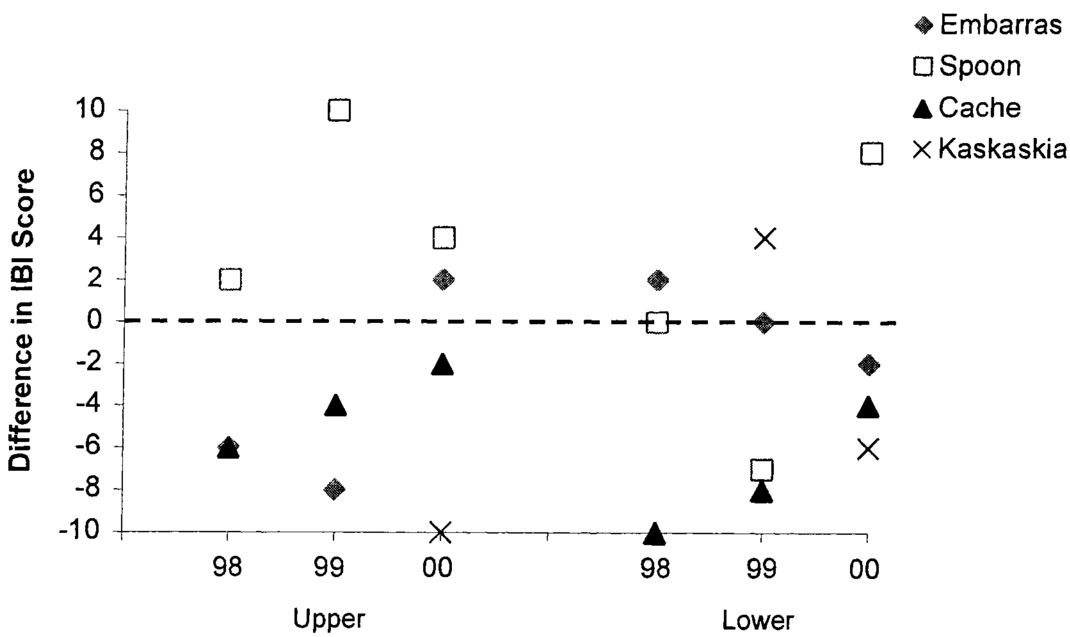


Figure 29. Growth curves for largemouth bass collected from the Embarras, Cache, Spoon, and Kaskaskia basins in 1998, 1999, and 2000 combined. No largemouth bass were collected from the upper site of Hurricane Creek.

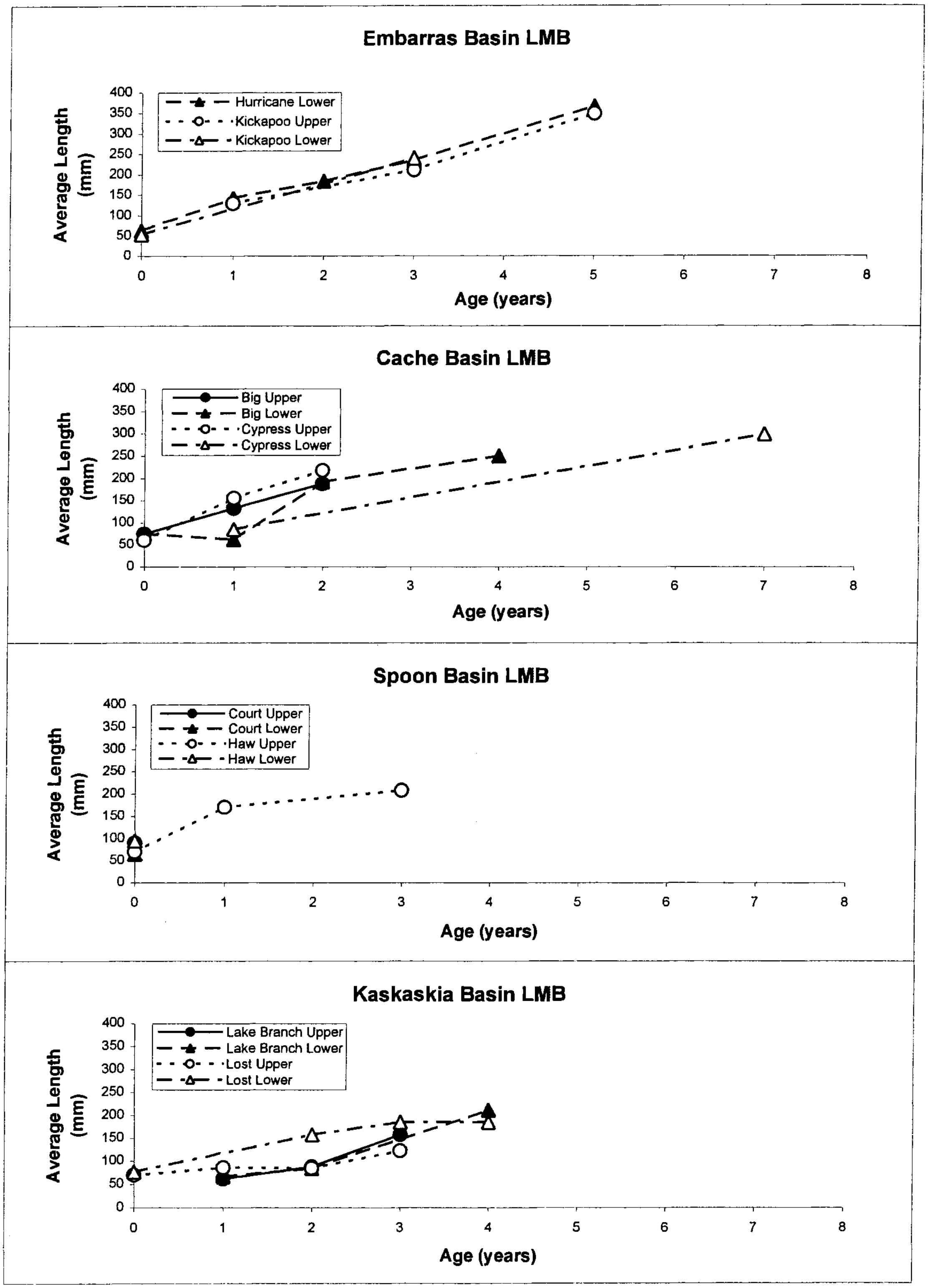


Figure 30. Growth curve for smallmouth bass collected from the Spoon basin in 1998, 1999, and 2000 combined. No smallmouth bass were collected from the upper site of Haw Creek or the Embarras, Cache, and Kaskaskia basins.

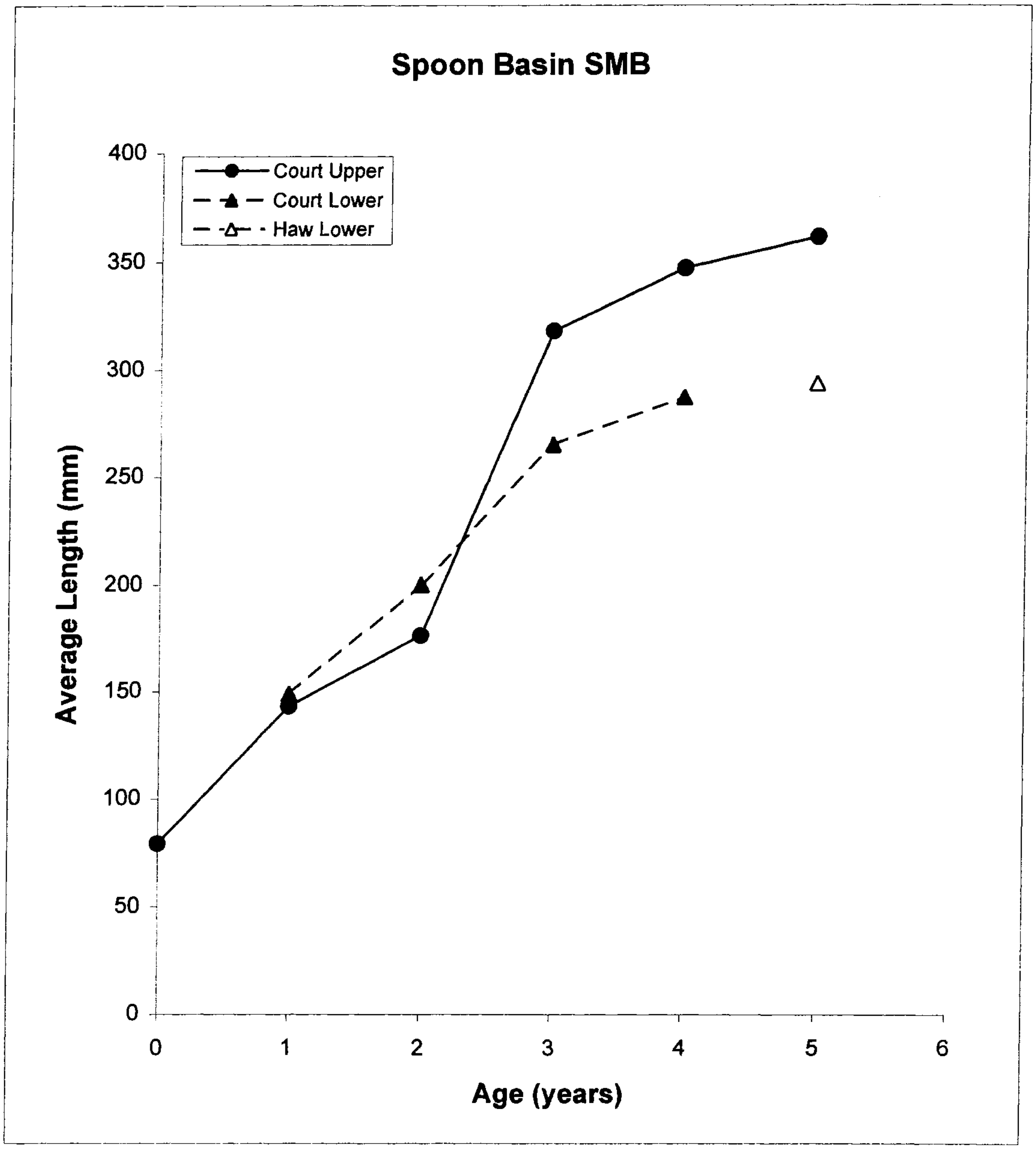


Figure 31. Growth curves for bluegill collected from the Embarras, Cache, Spoon, and Kaskaskia basins in 1998, 1999, and 2000 combined.

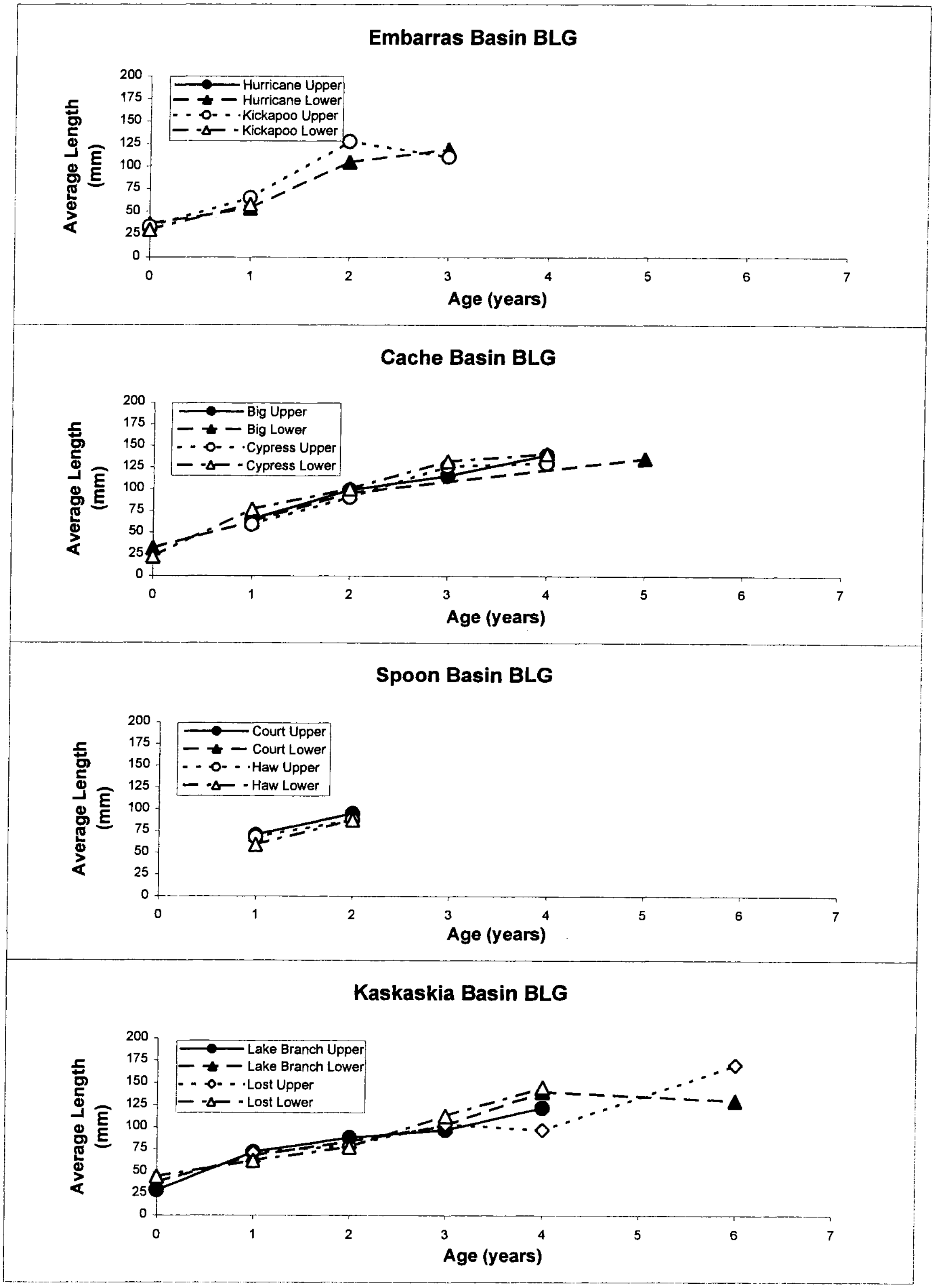


Figure 32. Growth curves for longear sunfish collected from the Embarras and Cache basins in 1998, 1999, and 2000 combined. No longear sunfish were collected from the Spoon basin or Lake Branch Creek.

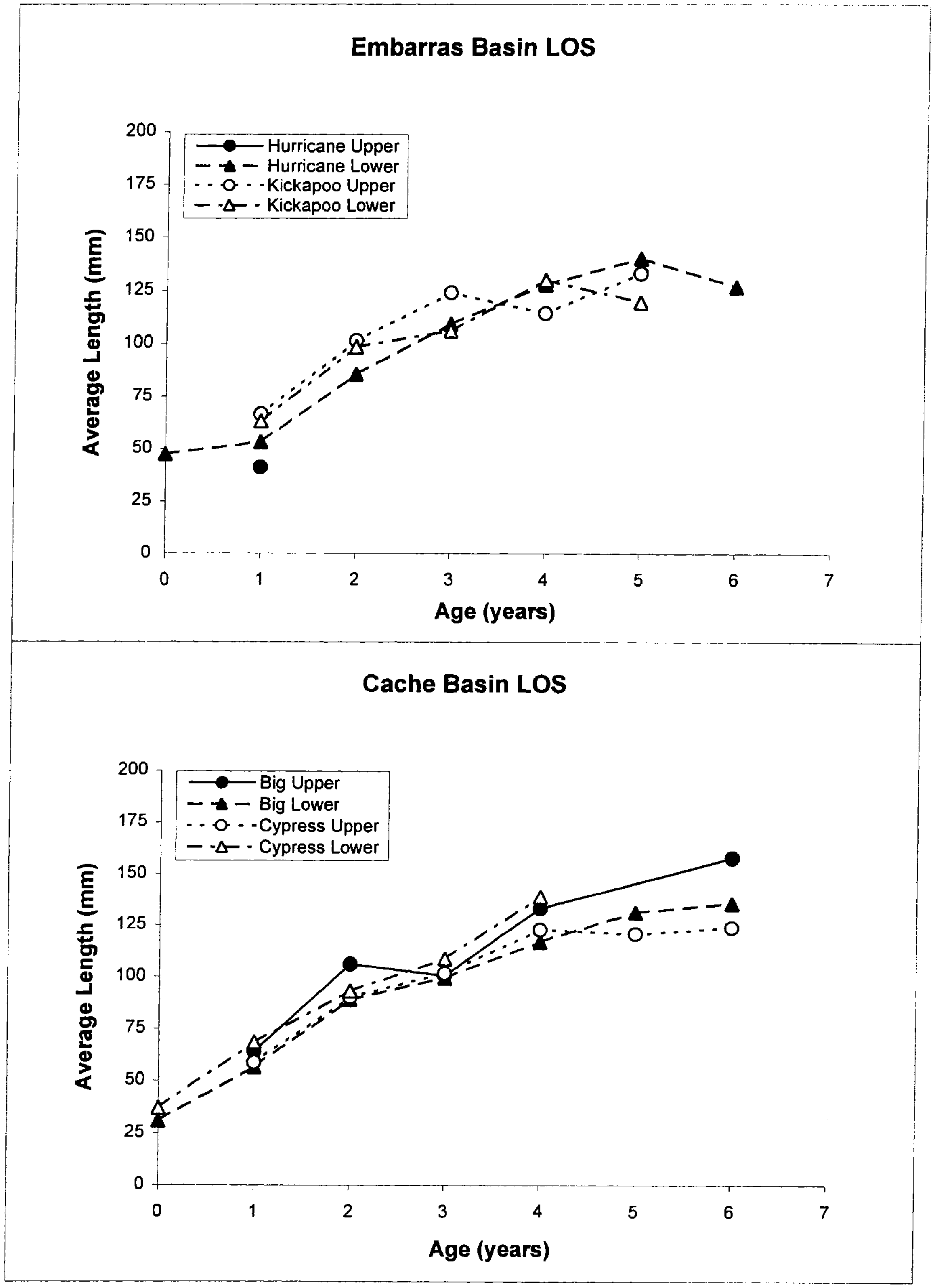


Figure 33. Growth curves for green sunfish collected from the Embarras, Cache, and Kaskaskia basins in 1998, 1999, and 2000 combined.

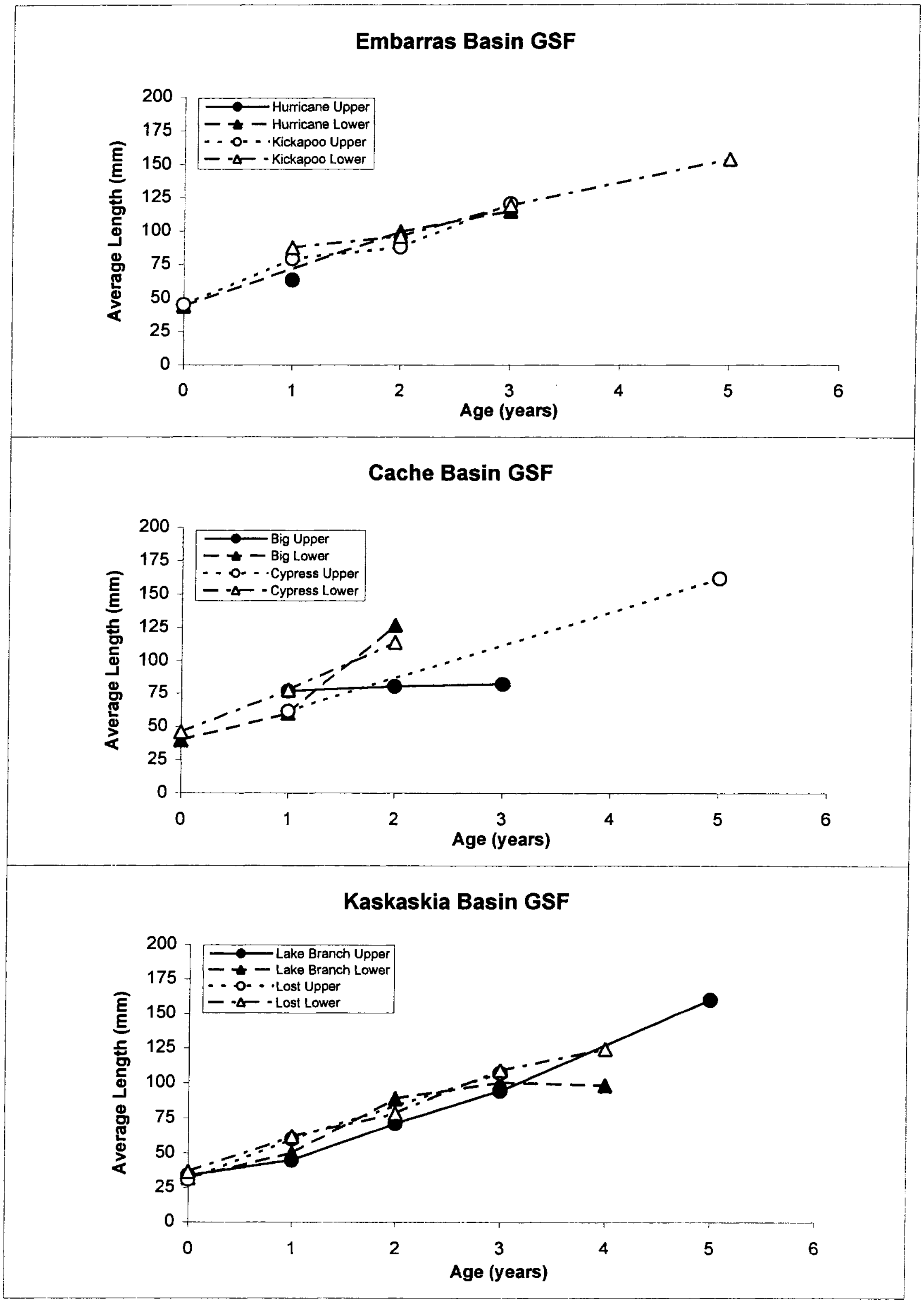


Figure 34. Growth curve for golden redhorse collected from the Spoon basin in 1998, 1999, and 2000 combined. None were collected from the Kaskaskia basin or three sites in each of the Embarras and Cache basins.

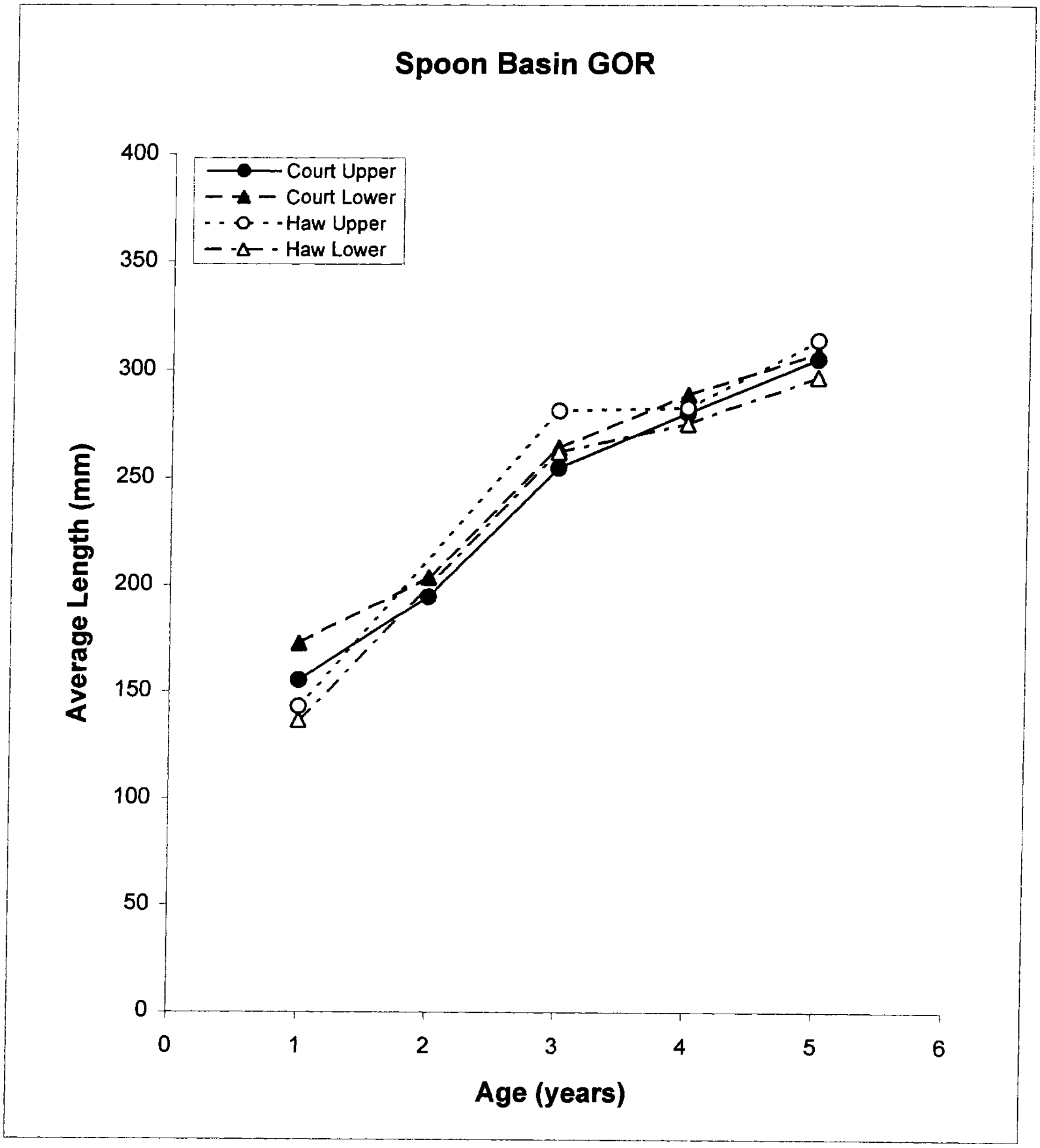
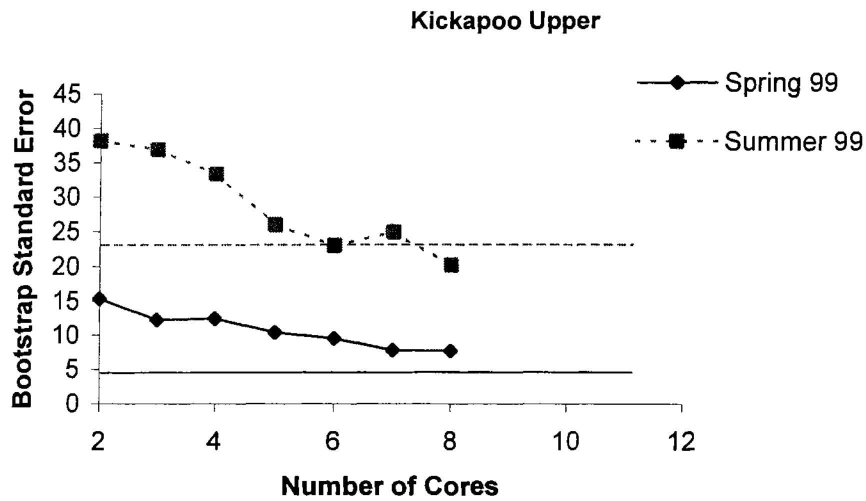
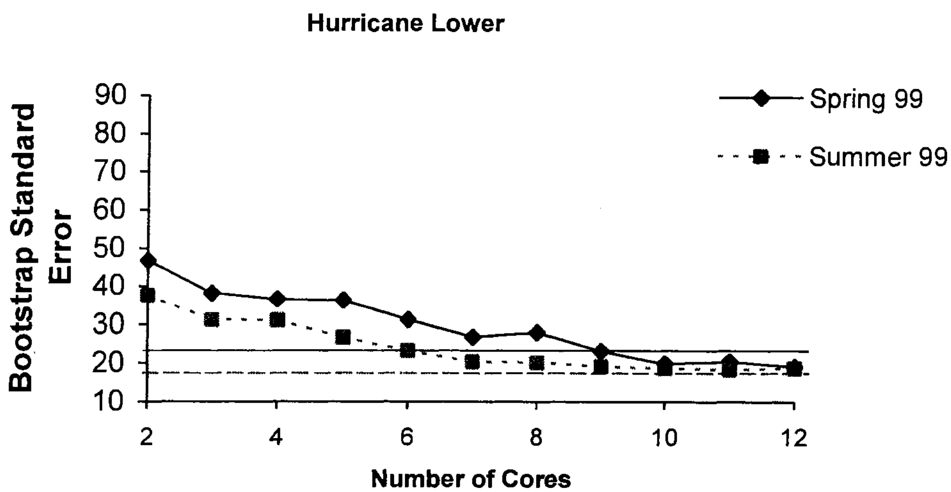


Figure 35. Bootstrap analysis of number of individuals in core samples taken in glide/pool habitats at the upper and lower sites of the Embarras.Hurricane Upper is not included due to this site being sampled entirely with the hess sampler.





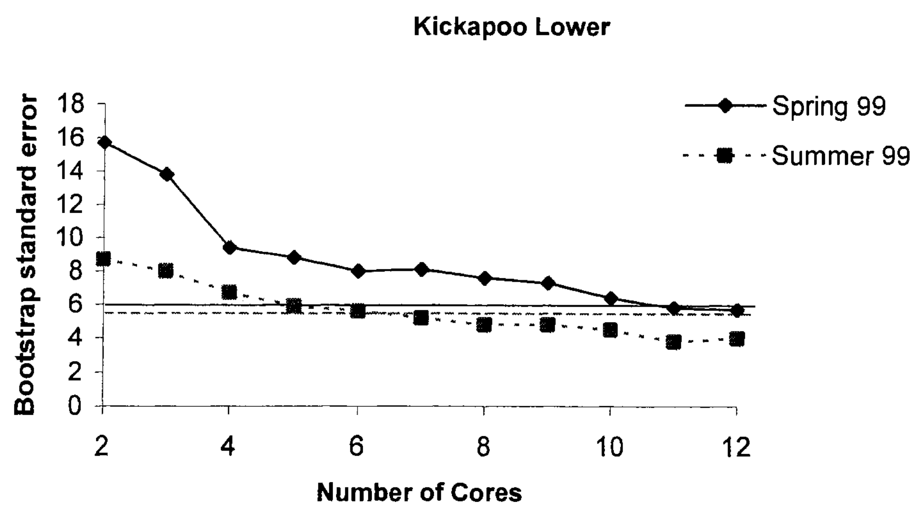
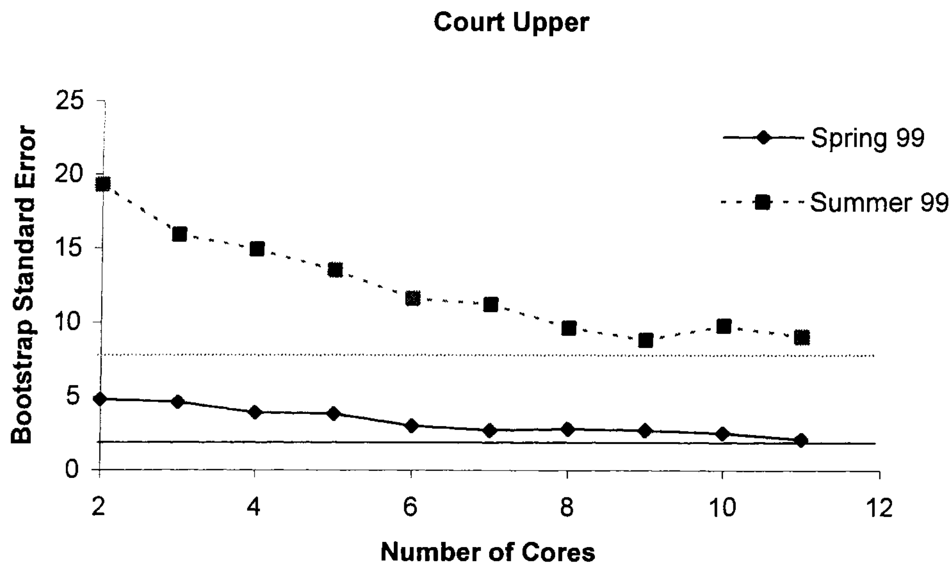


Figure 36. Bootstrap analysis of number of individuals in core samples taken in glide/pool habitats at the upper sites of the Spoon.



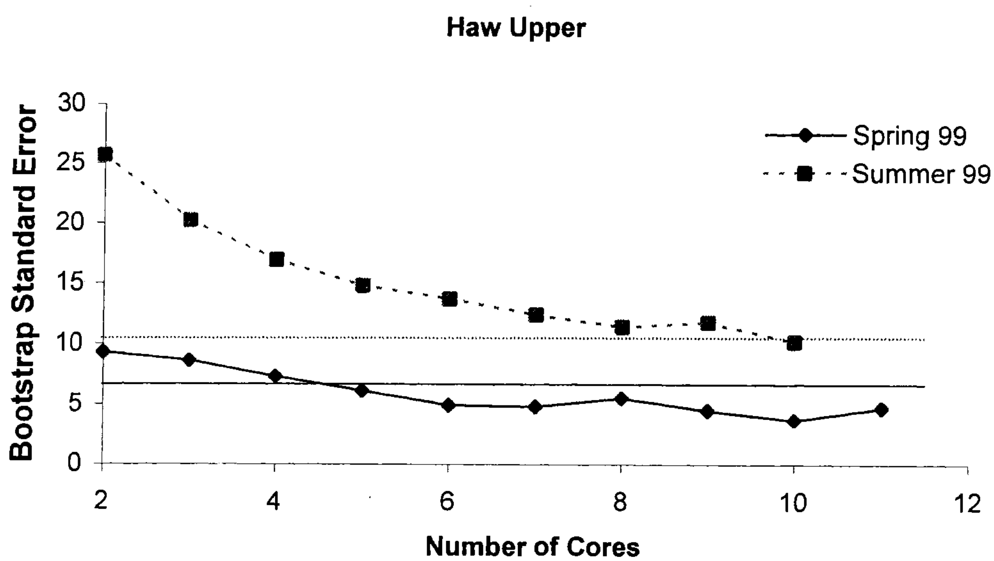
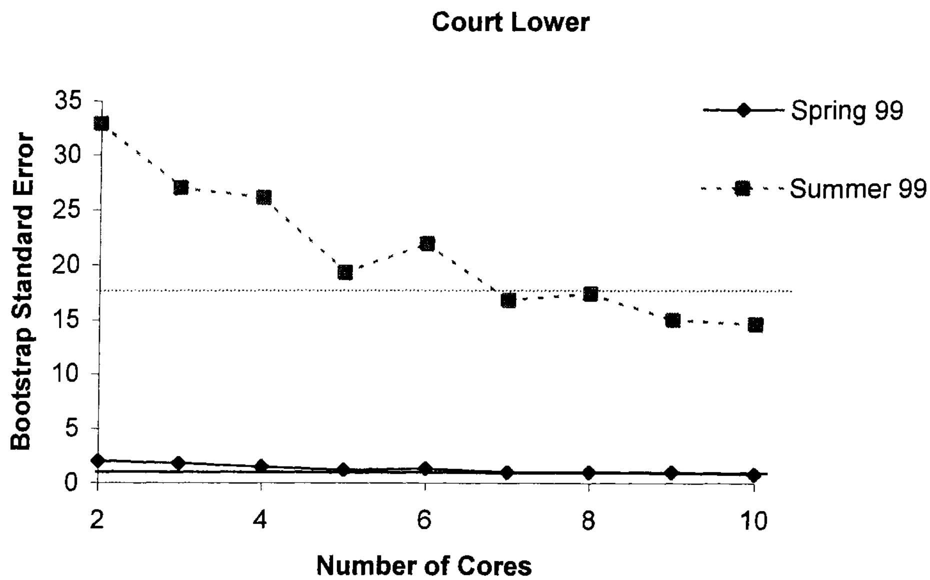


Figure 37. Bootstrap analysis of number of individuals in core samples taken in glide/pool habitats at the lower sites of the Spoon.



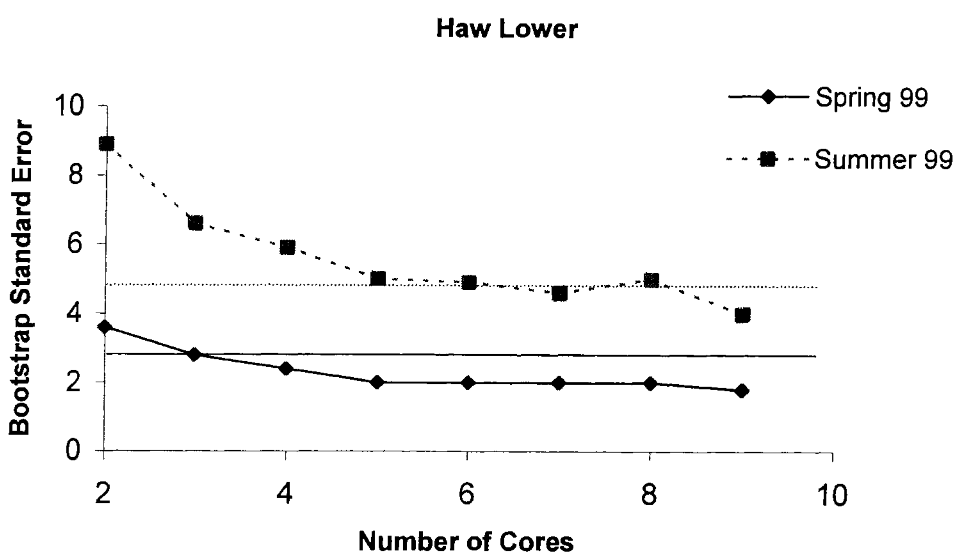


Figure 38. Bootstrap analysis of number of individuals in core samples taken in glide/pool habitats at the upper and lower sites of the Cache. Big Upper is not included due to this site being sampled entirely with the hess sampler.