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MANAGEMENT AND DEVELOPMENT OF AQUATIC HABITAT
IN AGRICULTURAL DRAINAGE SYSTEMS

by

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ABSTRACT

Drainage improvements in agricultural watersheds have extensively modified midwestern streams and rivers and the flora and fauna associated with these water resources. The alteration of low order streams in Central Illinois has been particularly severe. This study is designed to support better management of these agricultural drainage systems through an improved understanding of the type and quantity of habitat required for maintenance of high quality fisheries and aquatic resources.

Fisheries resources in two watersheds, the Middlefork of the Vermilion River in northeastern Champaign County, and the Embarras River in south central Champaign County were evaluated. The potential for a high quality fisheries was demonstrated. Additional analyses involved the assessment of habitat conditions in these basins with the objective of identifying modifications of existing drainage district maintenance procedures which would enhance environmental quality and fishery potential while meeting engineering requirements for channel hydraulic capacity, and flood stage elevation and duration. Three management options were evaluated: 1) maintenance of riparian vegetation, 2) development of instream cover as a habitat enhancement, and 3) increasing the number and depth of pools. The preferred option, considering both fish species habitat needs and impact on existing drainage district maintenance practices, was increasing the number and depth of pools. Although an increase in instream cover would be expected to improve fisheries habitat, the expected hydraulic consequences may limit the application of this option. Maintenance of riparian vegetation would be expected to provide positive benefits to fisheries, but the improvement in overall habitat quality is more strongly related to instream habitat modifications.

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Channel Morphology

1. INTRODUCTION/STUDY OBJECTIVES

Drainage improvements in agricultural watersheds have extensively modified midwestern streams and rivers and the flora and fauna associated with these water resources. The alteration of low order streams in Central Illinois has been particularly severe. Because existing management practices only consider hydraulic capacity and flood stage duration, the provision of suitable habitat for fisheries and other aquatic resources is typically ignored. Designs and management practices which integrate habitat requirements of aquatic organisms with drainage district maintenance procedures would lead to improved environmental quality in the watershed.

This study is designed to support better management of agricultural drainage systems through an improved understanding of the type and quantity of habitat required for maintenance of high quality fisheries and aquatic resources. The primary study objective is to identify modifications of existing drainage district maintenance procedures in order to enhance the environmental quality and fishery potential of modified low order midwestern stream systems. This research identifies aquatic habitat which may be developed while still meeting engineering requirements for channel hydraulic capacity, and flood stage elevation and duration. The study is divided into four sections: 1) identifying current maintenance and management approaches as well as the history of past maintenance activities, 2) conducting a biological analysis of the state and condition of the fishery and biotic communities within the proposed study sites, 3) determining the habitat components required to support a diverse and sustainable fish community, and 4) evaluating drainage system management alternatives.

2. STUDY SITE SELECTION AND DESCRIPTION

Study sites were selected to provide settings which would allow evaluation of fisheries condition in relation to distance from high quality colonization sources or the influence of streambank vegetation. The location of study sites is given in Table 2.1. The selection of sampling locations within each study site was based on the following criteria:

- 1) stream order/watershed location - low order, headwater locations, or locations at defined distances from potential colonization sources,
- 2) existing morphology - including channel and substrate stability,
- 3) general habitat quality - including riparian vegetation and channel cover, depth, and water quality,
- 4) drainage district management and maintenance approaches and history,
- 5) availability of background data - both engineering design information and aquatic resource information.

2.1 Middlefork River Drainage Basin

The first site (Site I) is located on the Middlefork River Drainage Basin in northeast Champaign County, Illinois (Figure 2.1). The drainage area for the Middlefork River in Champaign County is presented in Table 2.2. Site I was primarily chosen to determine what type of fishery could exist in a first order drainage system which is a tributary to a high order receiving system with a high quality fishery. Two locations were chosen for sampling fish. The first location is an extended reach on the main stem of the Middlefork just northeast of Penfield. The second location is a first order drainage ditch which empties directly into the Middlefork of the Vermilion River 4.8 km north of Penfield. As is typical of many drainage ditches, no name could be identified for this small intermittent stream. For purposes of this study it is called Farm Creek.

Middlefork River

The Middlefork was sampled in a reach approximately one kilometer upstream and downstream from its confluence with Farm Creek. In this reach riparian vegetation was well developed. Substrate materials varied from sand/silt areas to well developed riffles with medium cobble. Average width varied between 30 and 50 m. Depth varied between pools and riffles with an average depth of 0.75 m. Collection records on the Middlefork indicate that a diverse fishery is found there with some potential for a sport fishery, including catfish and Smallmouth bass fishing. The Bluebreast darter, an endangered species, has only been found in Illinois in the upper reaches of the Middlefork. The Middlefork River Forest Preserve, a local natural and recreation area, is located just north and upstream of this study site.

Table 2.1 Formal description of location of collection sites in Champaign County and the abbreviations used in fisheries data sheets.

Illinois Natural History Survey Site No.	This Study Site No.
<hr/>	
Embarras River (EC-01 to 04, East Branch & EC-05 to 08, Main Branch)	
1031	EC-01 (T17N, R9E, 15NE) EC-02 (T17N, R9E, 23NW) (one mile south of 1031) EC-03 (T17N, R9E, 27NE) (two miles south of 1031)
1034	EC-04 (T17N, R9E, 28SE)
1035	EC-05 (T17N, R9E, 33NE) EC-06 (T17N, R9E, 21S) (one mile north of 1035) EC-07 (T17N, R9E, 21NW) (two miles north of 1035) EC-07-I,II,III (T17N, R9E, 16SW) (upstream of bridge) EC-07-IV,V (T17N, R9E, 21NW) (downstream of bridge)
1030	EC-08 (T17N, R9E, 4SW) (new bridge 1987)

Middlefork River

1156	(T22N, R14W, 28SE) Both samples north of bridge
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Farm Creek (Tributary of Middlefork)

1147	Our sampling sites (FC-01 to FC-03) are about 1.5 miles downstream of 1147 at T22N, R14W, 20NE. Note that plunge pool at 1147 has been modified by the drainage district and no longer provides the deep pool habitat once unique to this site.
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Abbreviations used on fisheries data sheets describing site or collection methods.

FE-fixed electrodes	SH-seine haul
ES-electro-seine	AS-artificial shade site
ASC-artificial shade control	BEF-backpack electrofisher

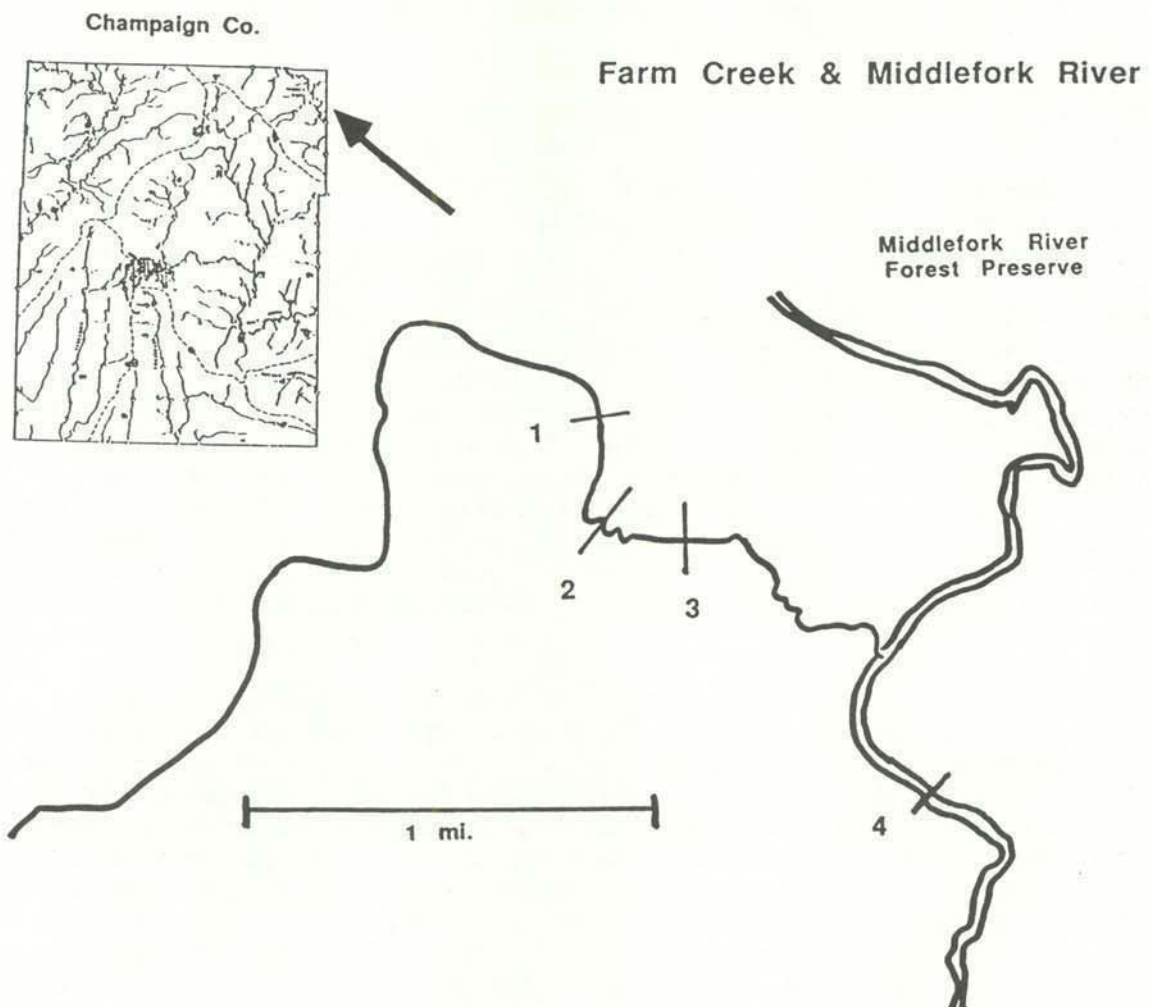


Figure 2.1. Study sites on Farm Creek

Table 2.2 Drainage area of Embarras and Middlefork Basin within Champaign County.

Embarras Drainage	
Larimore and Smith, 1963.	138 sq miles
This study, 1988.	160 sq miles
Middlefork Drainage	
Larimore and Smith, 1963.	69 sq miles
This study, 1988.	80 sq miles

Farm Creek

Farm Creek offers a combination of undisturbed areas of natural vegetation, a natural stream channel, and channelized areas typical of current drainage system design. As a tributary to the Middlefork, Farm Creek has the potential to support a fishery which includes migrants from the Middlefork. In 1987 the flow in Farm Creek originated in a plunge pool downstream from a concrete structure which contained several tile field drainage outlets. This plunge pool provided habitat with a 1.5 to 2 m depth. Surface drainage at this location was affected by runoff from the town of Gifford just southwest of this sampling location. In 1988, this area was modified and the plunge pool was eliminated as was deep water fish habitat associated with it. Farm Creek is shown on USGS topographic maps as an intermittent stream although continuous flow was observed in 1987. Discharge varied with rainfall. During periods of extended rainfall, saturated soils and associated field tile drainage maintained high flow levels. The response to rain was rapid with sharp hydrograph peaks which returned rapidly to "base flow" conditions. Due to drought conditions, Farm Creek was reduced to a series of shallow isolated pools in the summer of 1988.

Three areas were selected for intensive study within the Farm Creek drainage ditch (FC01-FC03). All areas were located in the lower 1.5 km of the stream. Area 1 was furthest upstream. The channel in Area 1 (1.5 km upstream from the confluence with the Middlefork) was modified and straightened, had steep, 1 m banks, no defined pool/riffle conditions and a depth of 0.2 to 0.4 m. Area 2 (approximately 150 m downstream from Area 1) was located in a relatively undisturbed, natural, and highly vegetated channel. Farm Creek in Area 2 was meandering and included a deep pool/riffle sequence and undercut banks. Area 3, a modified and straightened reach, was located approximately 0.75 km upstream from the confluence with the Middlefork. The channel in Area 3 included a shallow pool/riffle sequence. The channel in areas 1 and 2 remained unchanged over the two-year study period. Steep grassy banks along Area 3 had begun to slough into the channel in 1988, initiating the development of a meandering stream channel and more distinct pool/riffle sequence.

2.2 Embarras River Drainage Basin

The second site (Site II) is located in the Embarras River Basin in south-central Champaign County, Illinois (Figure 2.2). The drainage area for the Embarras River in Champaign County is presented in Table 2.2. Study areas were located on the East Branch of the Embarras and the Embarras River. The East Branch of the Embarras River has been modified for agricultural drainage although the reach near the study area had a relatively natural channel flowing through a well developed riparian vegetation. In contrast, the main branch of the Embarras consists of highly modified stream channel with minimal riparian vegetation. The origin of the East Branch of the Embarras is found in largely agricultural drainage near St. Joseph, Illinois. The East Branch flows southwest to the confluence with the Embarras upstream from Villa Grove, Illinois. The Embarras originates from a series of ditches which drain southern sections of Champaign and Urbana, Illinois. The Embarras flows south to its confluence with the East Branch. The Embarras River is known to support an excellent fisheries. USGS topographic maps indicate continuous flow for both the East Branch and the Embarras river in the sampling areas. Flow is variable, the Embarras is affected by stormwater runoff from the urbanized area in its headwaters. During the drought of 1988 no flow was observed in both the Embarras and the East Branch (Appendix VI, Table 1). Habitat consisted of a series of pools isolated by dry or shallow riffles. Pool measurements for two one-mile sections of the East Branch of the Embarras River are presented in Tables 2.3a and 2.3b.

Eight areas were selected for sampling. A range of habitat conditions are provided in these sampling areas. Four areas were sampled on the East Branch (EC01-EC04) and the Embarras (EC05-EC08). Area EC07 was extensively studied. This area was located in a meandering reach with a series of deep pools separated by riffles. A portion of Area EC07 was used for artificial shade experiments.

The Embarras study areas were selected in 1987 because patches of riparian vegetation existed along this reach. Drainage district maintenance activity in 1988 removed vegetation in Areas EC05 through EC08. Channel maintenance, including dredging and vegetation removal, occurred near EC08 in late 1988 and early 1989.

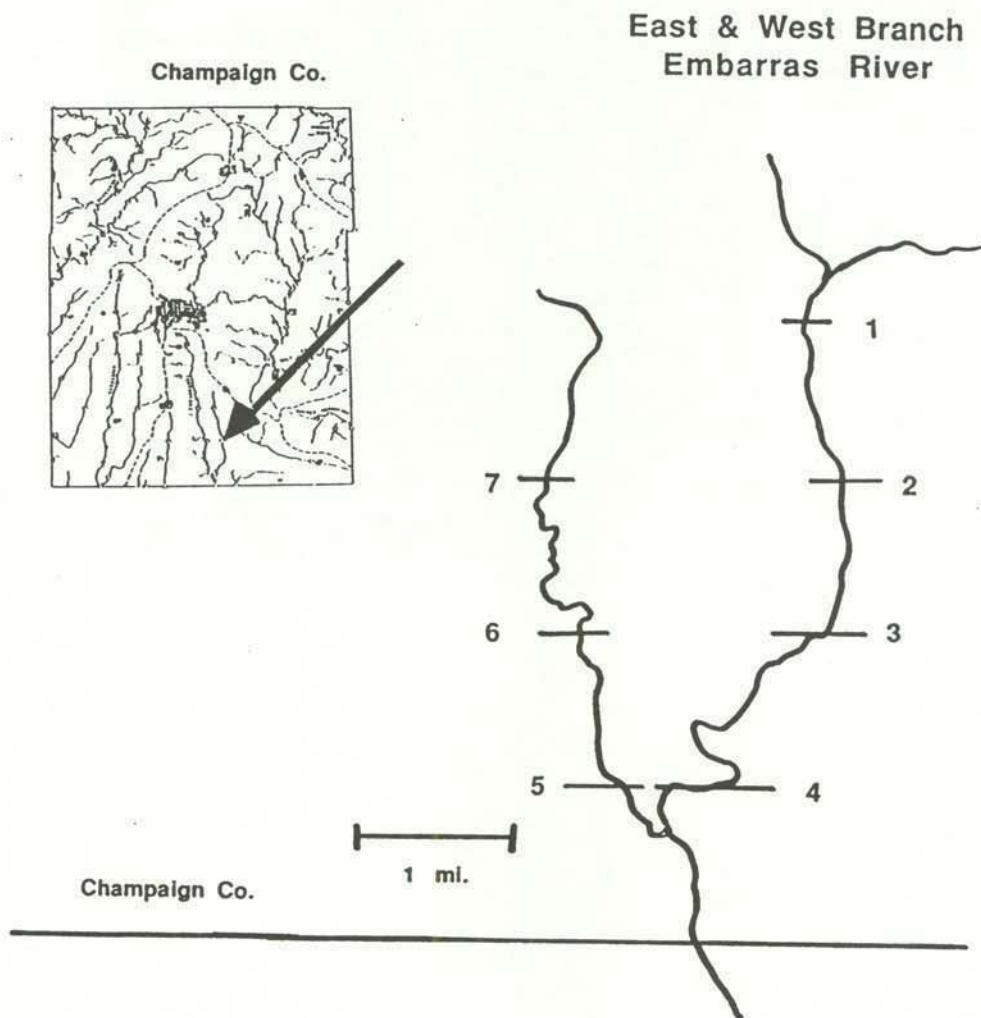


Figure 2.2. Study sites on Embarras River

Table 2.3a. Pool measurements taken along a one-mile stretch of the Embarras River on 8/27/88 between EC-07 and EC-08.*

Pool No.	Max Depth (in)	Width (ft)	Length (ft)	Substrate	% Cover	Bank	Comments
1	6	12	12	mud	none	2 steep	upstream
2	12	8	30	mud	none	1 steep	
3	12	10	20	clay/gravel	none	2 steep	fish
4	24	16	90	clay	none	moderate	dredged
5	24	16	50	clay	none	moderate	
6	8	6	70	silt/gravel	none	steep	
7	12	10	50	silt	none	steep	
8	12	11	20	silt	none	moderate	
9	21	14	50	silt	60%	gentle	large fish
10	10	10	80	silt	none	gentle	
11	24	20	100	silt	none	1 steep	
12	15	20	50	silt	none	2 steep	downstream
Avg	15.00	12.75	51.83				

* no deep pools were observed in extensive sections of riparian vegetation

Table 2.3b. Pool measurements taken along a one-mile stretch of the Embarras River on 9/26/88 between EC-07 and EC-06.

Pool No.	Max Depth (in)	Width (ft)	Length (ft)	Substrate	Bank	Comments
1	18	20	50	silt/clay	none	upstream
2	36	25	70	silt/clay	none	artificial shade site
3	24	15	50	silt/clay	none	shade control
4	12	10	26	silt/clay	none	
5	18	18	112	silt/clay	none	
6	12	11	48	silt/clay	none	
7	12	17	48	silt/clay	none	
8	24	19	64	silt/clay	none	
9	18	30	97	silt/clay	20% trees	
10	12	22	62	silt/clay	none	
11	12	18	43	silt/clay	none	
12	12	14	62	silt/clay	none	downstream
Avg	17.5	18.25	61.0			

3. METHODS AND PROCEDURES

The following discussion of methods and procedures is divided into sections dealing with field sampling and data collection, and data analysis and interpretation.

3.1 Field Sampling

Initial study site selections were made following an aerial reconnaissance. Photographs and topographic map locations were compared and potential sites were examined and sampled. After final selection of sampling locations, detailed study sites in each site were selected based on criteria reviewed in site selection discussions. Thus, each area was subject to different sampling intensity depending on experimental design.

Fish sampling ranged from annual samples on the Middlefork to weekly sampling in intensive study areas. The objective of sampling was to identify resident species and periods of fish movement. Intensive sampling in some areas augmented the regular sampling schedule. The overall sampling program included seasonal sampling with an emphasis on spawning periods in spring and summer.

Larger fish and important game species were processed in the field and released. Smaller specimens were preserved in formalin and identified in the laboratory. Lengths were measured for all fish and weights determined for all larger specimens. Although scales were collected from large specimens the low number of large fish collected did not allow use of this data in an age-growth analysis.

Fish were marked with finclips and later with numbered floy tags. In 1988, 317 fish were finclipped and six fish were tagged with numbered floy tags. Additional fish were tagged in the spring of 1989. Low returns of marked fish prevented direct assessment of movement or dispersal.

Fish Sampling Techniques

Sampling procedures were selected to provide methods and gear most appropriate for each study site. Four techniques were used; a conventional minnow seine, a backpack electroshocker, an electro-seine, and fixed electrodes. Visual observations of fish and habitat use were also made when water conditions were suitable.

Conventional Minnow Seine - Seining was used to supplement electrofishing and provide a basis for evaluation of electrofishing effectiveness and selectivity. Pools and channels isolated by blocknets were seined using a 50 foot 1/4 inch mesh bag seine.

Backpack Electrofishing - A Smith-Root Type VII direct-current backpack electrofisher was used during periods of low flow for focal habitat sampling. Blocknets were placed upstream and downstream in the sampling reach and several passes through the reach were made. Because of difficulties carrying the backpack unit in soft substrates, the positive and negative electrodes were extended 15 m from the unit which was placed on shore. Focal habitat sampling included aquatic plants, woody debris, rocks, riparian vegetation, and small isolated pools.

Electro-seine - An electro-seine, designed by R. W. Larimore and INHS personnel, was constructed for use in larger streams and during periods of higher flow than could be accommodated by the backpack unit. Electro-seining, which proved to be the most flexible method for diverse water conditions, was the primary method used for collecting fish in this study. The sampling procedure and its absolute efficiency in Central Illinois streams has been previously discussed in detail by Larimore (1961) and Schlosser (1982). Following Larimore (1961), two seine passes were made through a stream segment isolated by upstream and downstream blocknets.

Fixed Electrodes - Fixed-electrodes were installed in two areas on the Embarras (EC-07-I and EC-07-IV) and in the three study areas on Farm Creek (FC-01, FC-02, and FC-03). Fixed electrodes were placed in selected habitats (selected based on depth, cover, or observed fish use). Fixed electrodes allowed sampling of limited areas under a variety of flow conditions and allowed sampling without disturbing fish. Fixed electrodes were installed in early spring and remained in place until late fall.

Several designs for fixed electrodes were used. Two types of fixed electrodes and their efficiency in obtaining microhabitat data for various warmwater stream fish were described by Larimore and Garrels (1985). Larimore's general electrode design has been adopted for this study, with modifications. Fixed electrodes consisted of two 50 foot lengths of 12-gage bare copper wire which were connected to a two-conductor insulated cable and locking twist-plug. Initially 12-gauge insulated cables capable of withstanding low temperatures of 20 degrees F were installed, however, cold weather and icy water conditions in the early spring cracked the insulating material. These cables were replaced by 16-gage, all-weather, insulated cable which retained flexibility at low temperatures of 0 degrees F.

The power cable was suspended from bank to bank and above the high water level to reduce debris accumulation (Fig. 3.1). A positive and negative electrode suspended from the power cable to the water surface could be adjusted to accommodate different flows and depths. Both electrodes were extended parallel to the shoreline approximately one-third the water column depth from the stream bottom (Fig. 3.2). Each was suspended from height-adjustable, plastic, electric fence insulators attached to metal stakes. The electrode cable was connected to a 115-V, 1500-W, alternating current, Honda generator which was placed on shore at a distant location to avoid disturbing fish.

Immediately after switching on the generator from shore, two individuals would enter the water and extend a minnow seine across the stream. The stream current would wash stunned fish into the net while others were gathered by dipnet. Many of the small minnows remained stunned for several minutes after the current was switched off. In early spring, when water temperatures were near zero C, some larger specimens such as Hognosed suckers and White suckers never revived.

The area of the active electric field depends on electrical power available, water conductance, and habitat type. This arrangement of electrodes provided an active field limited to the area between the electrodes. Field characteristics were verified visually by observation of stunned fish occurring only between electrodes. Larimore and Garrels (1985) rated efficiencies as good for eleven groups of fish species, poor for catfish species, good for large and small fish, good for shallow, clear, cold water conditions, and poor for deep, turbid, fast water conditions. Observations during this study support these efficiency ratings.

Weekly sampling by fixed electrode in the spring when high, fast water conditions predominated yielded mixed results. Generally few fish were collected. Debris accumulating on the submerged sections of the initial fixed electrode design tended to interfere with sampling efficiency and alter the nature of the habitat being sampled. The initial fixed-electrode design was modified to improve efficiency in high, flowing water. The final and most effective design is illustrated in Figures 3.1 and 3.2. Efficiency during clear, low water conditions was much greater as stunned fish were more easily observed.

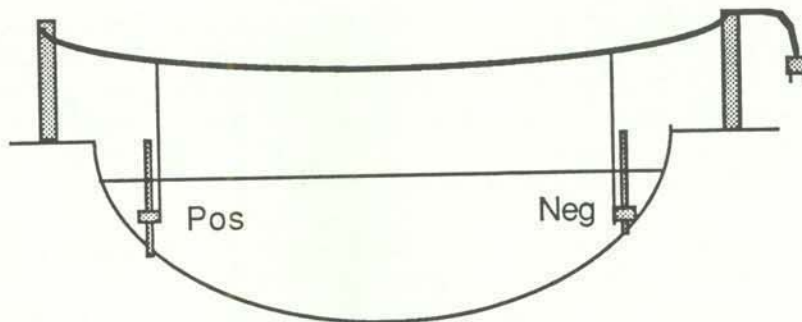


Figure 3.1. Cross section profile of fixed electrodes on Farm Creek.

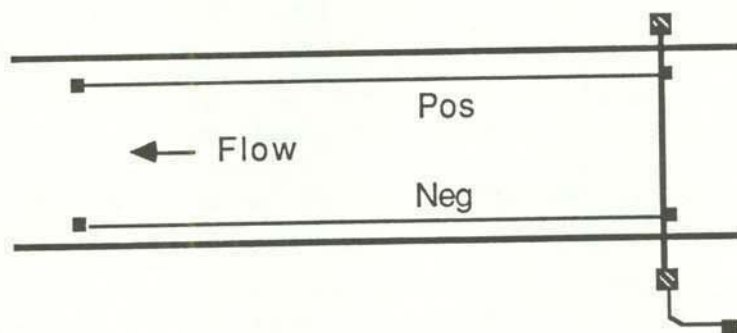


Figure 3.2. Overhead view of fixed electrodes on Farm Creek.

3.2 Data Analysis

Fisheries data were analyzed using a number of techniques designed to both identify the general structure of the fish community in study sites and determine quality and condition of the observed fishery. Field data analysis was supplemented by a review of historical fisheries sampling data. Fisheries data was integrated into management analysis through the use of Habitat Suitability Index (HSI) methods available from the U. S. Fish and Wildlife Service (1981).

Fish Community Structure

Seasonal changes in the fish population were assessed for Farm Creek and the Embarras River. Species composition was determined during three seasonal periods, spring, summer, and fall. Seasonal periods were chosen based on a knowledge of migration characteristics and spawning activity for key species. April through May samples comprised the spring season, June through August the summer season, and September through October the fall season.

Several analytical methods were used to identify seasonal patterns in species composition. A qualitative analysis uses species lists to assess seasonal changes in the fishery. Several species are considered separately, and seasonal observations for key species are described in detail.

A quantitative analysis includes both species presence and relative abundance of each species. Because sample size differed between collections, a rarefaction analysis (James and Rathbun 1981) was used to produce analysis units of equal size. With samples of equal size it is possible to make a direct comparison of richness values. Total numbers of fish were used to calculate diversity indices (Shannon and Weaver 1963). Trends in this index are identified.

Similarity indices were also used to compare fisheries communities. Binary data (presence/absence) were used to calculate a Jaccard Coefficient of similarity (Hubalek 1982 and Janson and Vegelius 1981). The use of presence/absence data is effective where sample sizes are different, but general sampling effort is equal. The Chord Distance Index of Dissimilarity, described in Ludwig and Reynolds (1988), was also calculated. This distance measure uses abundance data to determine dissimilarity between data sets. Cluster analysis was also used to group seasonal data. In the cluster analysis the results of the Chord Distance test were linked using the unweighted centroid method Pielou (1984a). All statistics were calculated using software provided by Ludwig and Reynolds (1988).

Further comparisons of community composition was made through the use of Random Skewers Analysis (RSA) (Pielou 1984b). RSA is an analysis method which can be used to determine if a trend in species distribution follows an environmental gradient. The analysis identifies trends in either species composition or abundance. The test is distribution free (non-parametric) thus, for ecological applications, it has an advantage over parametric tests which assume a normal distribution for the data. The environmental gradient must be of known direction, such as a pollution gradient. In cases where two or more independent environmental factors vary along the gradient, the test itself can not discriminate among them. Random Skewers Analysis (RSA) does not require data transformation, thus species

specific information is retained. Pielou recommends the test as a useful preliminary to direct gradient analysis or ordination techniques. RSA was applied to data for the East Branch Embarras, the Embarras, and Farm Creek. The utility of RSA applied to fishery data is supported by analyzing data sets with known fishery gradients.

Fish Community Condition and Quality

The condition or quality of a fish community can be assessed using a number of techniques. A condition index or factor is often calculated using length and weight information to assess individual organism and population health. Unless long term comparative data is available, condition factors do little more than validate subjective observations. Subjective observations were made about health, parasitism, etc. in field notes and used in general qualitative analysis of community condition and quality.

A quantitative technique for condition or quality assessment was also applied to fisheries data. The Index of Biotic Integrity (IBI) (Karr et. al. 1986) was calculated for the Middlefork Basin, the Embarras River Basin, and for individual sites on the Embarras and Middlefork Rivers. Where information was available, scores were compared to published basin results. Sample IBI refers to IBI scores for one-time samples collected on a specific date and location. Station IBI refers to scores for individual sample sites. Basin IBI refers to the arithmetic mean of IBI estimates from all sample stations on the river. The IBI was calculated in a procedure as recommended by Karr et. al. (1986) using a Macintosh personal computer and Excel Spreadsheet software. No major modifications of the general structure of the published procedure was required since Karr's version was developed for the zoogeographic region characteristic of this study area.

Determination of an IBI is dependent on the quality of data used in determining metrics. Karr et. al. (1986) recommends using a single collection where the relative abundance of each species is accurate. He also recommends that samples should not be combined for an IBI analysis. Sampling design issues have been discussed in depth by Angermeier and Karr (1986), Karr et. al. (1987), and Fausch et. al. (1984). More recent studies, however, indicate that the IBI appears to be relatively robust with regard to sampling requirements (Steedman 1988). In this study, the analysis was performed on both single collections and combined site data.

Management Option Development and Analysis

Management options were developed from an analysis of field data and the use of Habitat Suitability Index (HSI) models. Models for fish species common to the Middlefork or Embarras watersheds, or species which have characteristics which provided useful management comparisons were selected from the HSI model library. HSI models were converted for spreadsheet use.

The use of spreadsheet models allowed rapid evaluation of the importance of specific parameters in final index determination. A sensitivity analysis was performed to determine how a change in a single habitat variable affected the final HSI. From field observations it was possible to relate fish presence and abundance with habitat conditions and evaluate the importance of those habitat conditions with HSI models. Using this procedure a set of management options were identified and the expected change in habitat conditions, and expected fishery, were evaluated.

4. RESULTS AND DISCUSSION

4.1 Historical Fishery of the Middlefork and Embarras Rivers

An analysis was made of historical fisheries collections to establish "reference" fish communities for the Vermilion (Middlefork) River and Embarras River Drainage systems. This information was also reviewed to identify changes species composition over the past 30 years. The data reviewed include: 1) basin fisheries lists compiled by Herricks and Himelick (1981a & b), 2) Illinois Natural History Survey and Illinois Department of Conservation collection records, and 3) Champaign County records from 1889, 1929, and 1959 as reported by Larimore and Smith (1963). These records provided a reasonably comprehensive listing for comparative purposes.

Historical data records were analyzed to identify fish species expected in low order streams (Section 4.1.1 and Appendix I, Tables 1 and 2) and basin specific fisheries (Section 4.1.2 and Appendix I, Tables 3 and 4). Appendices I-1 and I-2 list species expected in highly modified low order streams. Tables I-3 and I-4 lists species in larger streams and rivers which can serve as a source for organisms in headwaters or low order streams. These lists do not include miscellaneous minnows and hybrid species from the published data. Since fish populations may vary widely from year to year and sampling method may differ, comparisons between historical records and collections made in this study are used to identify trends in species composition and abundance, not to make direct comparisons of relative fisheries quality.

4.1.1 Comparison of Fisheries in the Middlefork and Embarras Rivers in Champaign County

The headwaters of four river systems originate in Champaign County (Salt Fork, Embarras, Kaskaskia, and Little Vermilion). These headwaters provide habitat for a diverse fish fauna. Collection records from as early as the late 1800's are available for Champaign County. Forbes and Richardson (1908) sampled 48 locations in the county in 1899 and identified 65 species. Thompson and Hunt (1930) sampled 132 sites in 1928 and 1929 and identified 75 species. As of 1959 Larimore and Smith (1963) recorded a cumulative total of 90 species of fish which have occurred in Champaign County streams. A total of 74 species were represented countywide in 1959.

The Middlefork River, Champaign County

In the Middlefork River (Appendix I, Table 1) a total of 54 species were reported up to 1959 (Larimore and Smith 1963) with 48 species reported in 1959 collections. Our collections in 1987-88 produced 39 species in the Middlefork drainage. The following changes have been observed in fish distributions since 1959, based on information published by Larimore and Smith (1963).

1. River redhorse, Silver redhorse, and Shorthead redhorse carpsuckers have been commonly collected in the Middlefork River prior to 1959, but not in the upper Champaign County reaches. Silver and Shorthead redhorse were commonly captured in the Champaign County reach of the Middlefork in this study and one River redhorse was captured in Farm Creek. Thus, it appears that ranges for these fish have been extended further upstream than previously recorded.

2. The Red shiner was not reported in the Embarras or Middlefork in 1959, but was reported in the westward neighboring Kaskaskia and Sangamon drainages. It appears the range of this fish has extended eastward as it was collected, although in low abundance, in the Embarras and Middlefork Rivers in this study.

3. In 1959 bluegill were relatively abundant throughout the state, however they were not recorded in Champaign County collections. In this study bluegill were commonly collected in the Embarras and Middlefork, but not in as high numbers as other centrarchids.

4. Gizzard shad have become increasingly abundant in all Illinois streams. Gizzard shad were represented prior to 1959 in downstream reaches of the Middlefork and are currently well represented in Champaign County in both the Embarras and Middlefork Rivers. It appears ranges have been extended further upstream than previously recorded.

5. Seventeen species collected from the Middlefork watershed in 1959 were not collected in this study (Table 4.1.1). Several factors contribute to the absence of noted species. Our sampling effort was concentrated on a first order tributary (Farm Creek) which reduces the probability of collecting Middlefork or large river specimens. Drought conditions in 1988 encouraged larger or deep water species to migrate downstream thereby reducing the probability of collecting typical large river specimens as found in the Middlefork. Also, many of the species listed in Table 4.1.1 were not highly represented in past collections, suggesting a relatively uncommon status.

Table 4.1.1 Species not collected from the Middlefork watershed (Middlefork River and Farm Creek) in this study but reported in 1959. (17 species)

1	Longnose gar
2	Hornyhead chub
3	Emerald shiner
4	Bigmouth shiner
5	Rosyface shiner
6	Mimic shiner
7	Steelcolor shiner
8	Flathead catfish
9	Brindled madtom
10	Spotted bass
11	Orangespotted sunfish
12	White crappie
13	Logperch
14	Slenderhead darter
15	Eastern sand darter
16	Fantail darter
17	Orangethroat darter

6. Six species were collected in this study which were not reported in 1959 (Table 4.1.2). All species have been regularly collected in the drainage basin during recent studies. This may indicate a decided increase in occurrence since 1959. Changes in the status of these fish are most likely associated with recent changes in aquatic habitat.

Table 4.1.2 Species collected from the Middlefork watershed (Middlefork River and Farm Creek) in this study but not reported in 1959 (6 species).

1	Gizzard shad (2)
2	Grass pickerel (19)
3	Red shiner (31)
4	Silver redhorse (5)
5	Shorthead redhorse (18)
6	Bluegill (2)

7. Table 4.1.3 lists six species collected only in the Middlefork Drainage but not collected in the Embarras Drainage. In Illinois, many species are considered basin-specific due to unique habitat conditions. This list aids in identifying distinctive habitat types through an analysis of the habitat requirements of each basin specific species. Extensions of these species outside known ranges often indicates changes in habitat conditions in adjoining basins.

Table 4.1.3 Species collected in Middlefork drainage (Middlefork River and Farm Creek) but not the Embarras based on historic information. (6 species)

1	Silver redhorse
2	Channel catfish
3	Flathead catfish
4	Stonecat
5	Smallmouth bass
6	Rock bass

8. In 1928, 20.6 species per station were reported in the Middlefork River (Table 4.1.4). In 1959 the number of reported species increased to 31.4 per station and during this study 26 species per station were collected. The number of species per station is highly dependent on season, sampling technique, and efficiency thus few valid comparisons between this data can be made. It is evident, however, that species richness has not changed significantly on the Middlefork since 1959.

Table 4.1.4 Average number of species collected per station.

Site	Year	No. species per station
Middlefork	1928	20.6
Middlefork	1959	31.4
Middlefork	1988	26
Farm Creek	1988	18.6

In 1962 Lopinot (1962) sampled a site on the Middlefork of the Vermilion River in Champaign County which corresponds to a collection site for this study. A total of twenty-two groups of fish were reported (Table 4.1.5). Because several groups of fish were not reported to the species level (eg. minnows, darters, carpsuckers, and madtoms) it is likely that more than twenty-two species were collected. Without species identification, no direct comparison of the number of species collected at this station could be made. It should be noted that all except one species has been previously reported in either 1959 or this study. The additional species identified in 1962, the Yellow bass, is not common in Champaign County. The Yellow bass is typically associated with reservoirs and small lakes and its occasional presence in streams primarily results from individuals dispersing from nearby lakes.

Table 4.1.5 List of species collected in summer of 1962 by Lopinot (1962) in Middlefork of the Vermilion River at one station near Penfield, IL by rotenone sample and seine haul. (22+ species)

1	Misc. minnows
2	Darters
3	Yellow bullhead
4	Longear sunfish
5	White sucker
6	Green sunfish
7	Madtoms
8	Hognose sucker
9	Golden redhorse
10	Carp suckers
11	Blackstripe topminnow
12	Grass pickerel
13	Rock bass
14	Smallmouth bass
15	Spotted bass
16	White crappie
17	Channel catfish
18	Orangespotted sunfish
19	Spotfin shiner
20	Steel color shiner
21	Bluntnose minnow
22	Yellow bass

Conclusions - With a cumulative total of 61 species of fish reported in Champaign County up to 1988, this stream is rich in species and has supported a diverse fish fauna. Thirty-nine of these 61 species have been collected in this study. The species composition is probably not greatly different now than in the past with the exception that the ranges of several species have apparently been extended to the headwater region in Champaign County.

Embarras River, Champaign County

In the Embarras River (Appendix I, Table 2) a total of 35 species were reported up to 1959 (Larimore and Smith 1963) with 32 species reported in 1959 collections. Our collections in 1987-88 produced 42 species in the Embarras drainage. From this information it appears that species richness is greater today than in the past. The following changes have been observed in fish distributions since 1959, based on information published by Larimore and Smith (1963).

1. The River, Quillback, and Highfin carpsuckers have extended their ranges to the headwaters of the Embarras. These species were not collected in Champaign County in 1959. They have been previously collected in the lower reaches of the Embarras. These three species are now relatively common in the upper reaches, often contributing a large portion of the total collection in both numbers and biomass at several sites during this study.
2. In 1959, the Bigmouth shiner was reported to occur only in the western basins of the county. This fish has extended its range eastward. It was not reported in the Embarras in 1959 but commonly occurs there now.
3. The Red shiner was not reported in the Embarras or Middlefork in 1959, but was reported in the Kaskaskia and Sangamon drainages. It appears the range of this fish has also extended eastward as it was collected, although in low abundance, in the Embarras and Middlefork Rivers in this study.
4. The Slender madtom was not reported in 1959. Four specimens were collected at one site on the Embarras during this study. Although present, they are not very abundant.
5. In 1959, Bluegill were relatively abundant throughout the state, however, they were not present in Champaign County collections. In this study, Bluegill were commonly collected in the Embarras and Middlefork, although numbers were less than other centrarchids.
6. The Dusky darter, previously reported in downstream locations on the Embarras, was not collected in Champaign County in 1959. Its presence in high numbers at three out of seven Embarras collection sites during this study suggests an upstream extension of its range.
7. The Hornyhead chub has never been common in the Embarras drainage, but was often collected from other headwaters in close proximity. Only two specimens were collected in this study from an intensively sampled collection site on the Embarras. Although present, they appear to be relatively uncommon in this drainage area.
8. Orangespotted sunfish were not collected in 1959. Only two Orangespotted sunfish were collected from one site on the Embarras. Although this species is present it is not common within the upper reaches of this drainage system.
9. Gizzard shad have become increasingly abundant in all Illinois streams. Gizzard shad were represented prior to 1959 in downstream reaches of the Middlefork and is currently well represented in Champaign County in both the Embarras and Middlefork Rivers. The evidence suggests that ranges have been extended further upstream than previously recorded.
10. Fourteen species collected in this study were not reported in 1959 (Table 4.1.6). Many of these species have been recorded in downstream sections of the drainage basin, thus ranges have evidently been extended to the upstream reaches of the Embarras for many of these species.

Table 4.1.6. Additional species collected from the Embarras River during this study which were not reported in 1959 in Champaign County. (14 species)

1	Hornyhead chub (2)
2	Bigmouth shiner (10)
3	Red shiner (2)
4	River carpsucker (6)
5	Quillback carpsucker (157)
6	Highfin carpsucker (6)
7	Shorthead redhorse (1)
8	Spotted sucker (62)
9	Slender madtom (4)
10	Largemouth bass (13)
11	Orangespotted sunfish (3)
12	Bluegill (263)
13	White crappie (2)
14	Dusky darter (5)

11. Three species reported in 1959 were not collected in this study (Table 4.1.7). Recent fish surveys indicate that these species are sporadic and increasingly uncommon in occurrence throughout the State.

Table 4.1.7. Species not collected from the Embarras River during this study but reported in 1959 in Champaign County. (3 species)

1	Steelcolor shiner
2	Log perch
3	Orangethroat darter

In 1928, 6.8 species per station were recorded in the Embarras River (Table 4.1.8). In 1959 the number of reported species increased to 14.3 per station and in this study 18.5 species per station were collected. Few valid comparisons between this data can be made since the number of species per station is highly dependent on season, collection technique, and efficiency. The evidence does support, however, an increase in species richness in the Champaign County section of the Embarras.

Table 4.1.8. Average number of fish species collected per station on the Embarras River.

Site	Year	Avg. No. species per station
Embarras	1928	6.8
Embarras	1959	14.3
Embarras	1988	18.5

Conclusions - With a cumulative total of 48 species of fish collected, the Embarras River supports a diverse fish fauna. An overall increase in species richness has been noted in Champaign County with three species being lost and fourteen new species introduced. Introductions are primarily the result of the ranges of several species being extended from the lower reaches to the headwater region in Champaign County. It is expected that this shift reflects drainage modifications as well as possible improvement in water quality in the Embarras. Species which are both tolerant and intolerant of poor water quality are more widely distributed than reported in the past.

4.1.2 Comparison of Fisheries Collected at Study Sites to Basin Fisheries Lists

Further analysis of historical data was conducted to provide an assessment of the contribution of low order systems to the integrity of the basinwide fishery. Two sources of information were utilized in compiling sub-basin fishery lists. Herricks and Himelick (1981 a & b) provided a comprehensive listing of basin fisheries as part of the biological component of the Water Quality Management Information System (WQMIS). The data used to develop the WQMIS fish listing was obtained from three sources: 1) Illinois Department of Conservation, 2) Illinois Natural History Survey, and 3) Department of Civil Engineering, University of Illinois. WQMIS listings were available for a range of drainage area sizes for both pre-1965 and post-1965 collections. For this study only post-1965 data was used in preparing the sub-basin listings. The second source of information was a recent basin fisheries survey performed by the Illinois Department of Conservation (DOC) for the Embarras River basin (Price 1975), and the Middlefork River Basin (Lopinot 1964).

Middlefork

Using DOC basin report data, 65% (34 of 52) of the species known to occur in the Vermilion watershed in 1962 were collected in the headwater reaches of Champaign County. According to WQMIS data, 56 species have been reported in the Vermilion River basin since 1965. Seventy percent (39 of 56) of the species reported basinwide by WQMIS have been collected from study sites during this study. Combining WQMIS and DOC data identifies 70 species represented in the Vermilion River basin. Fifty-six percent (39 of 70) of all species reported by the DOC and WQMIS occur in headwaters. In stream basins of less than 200 square miles a total of 41 species have been reported since 1965. Since the Middlefork River watershed in Champaign County is less than 200 square miles, (69 square miles as reported by Larimore and Smith 1963) samples collected in this study can most closely be compared with stream basin listings for less than 200 square miles. In Champaign County 81% (33 of 41) of species reported in streams of less than 200 square miles by WQMIS have been collected during this study.

Many species identified in previous studies are identified as rare or atypical species. From the combined DOC and WQMIS data, a list of commonly occurring (typical) species in the Vermilion basin was prepared (Appendix I, Table 3). A species was considered common if it was represented at more than one site for 1962 DOC data, occurred in two or more categories for WQMIS data, and/or was relatively abundant in any given sample. A total of 58 of 70 species (79%) were identified as commonly occurring within the basin. When considering only the most commonly collected species in the watershed, 60% (39 of 58) of the common species present in the watershed were collected from the headwaters of Champaign County. All 41 species expected in drainage areas of less than 200 square

miles were identified as common. When considering data collected from waterways of less than 200 square miles, 71% (41 of 58) of the common species are represented in the Champaign County headwaters. Depending on the data set used, a range of 56% to 81% of basin species utilize low order drainage ditches.

Embarras

The DOC collected 76 species in the Embarras watershed between 1962 and 1974. Fifty-five species (72%) were collected in 1962, 63 species (83%) were collected in 1967, and 67 species (88%) were collected in 1974. Increases in the total number of species collected during successive years was a result of different collection techniques and an increase in the number of stations sampled in progressive years.

This historical data can be used to estimate the relative contribution of low order systems to the basin fishery. Using DOC data a total of 51% (39 of 76) of the species known to occur in the Embarras watershed since 1962 currently were collected in headwater reaches of Champaign County. Using WQMIS data, 80 species were represented throughout the Embarras River basin. Forty-nine percent (39 of 80 species) were collected in this study. In small watersheds of less than 200 square miles, 63 species are expected. In Champaign County 67% (42 of 63) species basin-wide have been collected. Forty-nine species commonly occur in the basin (Appendix I, Table 4). When considering only the most commonly collected species in the watershed as many as 80% (39 of 49) of the common species present in the watershed inhabit the headwaters of Champaign County. When comparing this study with WQMIS expectations, 85% (39 of 46) of the common species are represented in the Champaign County headwaters. Depending on the data set used a range of 49% to 85% of basin species utilize low order tributaries on the Embarras.

4.2 Analysis of Fish Collections from the Middlefork and Embarras Rivers

4.2.1 Basin Fisheries

Middlefork Basin

The results of collections from Farm Creek and the Middlefork River are contained in Appendix II, Table 1 and Table 4.2.1. Thirty-seven species were collected in 26 samples from six sampling areas between June 24, 1987 and October 6, 1988. Common species are identified from the percent occurrence tabulations for the six collection sites (Table 4.2.1). Seven species were collected at all six sites, six species at five of six sites (83%), six species at four of six sites (67%), and two species at three of six sites (50%). Twenty-one species occurred at 50% or more sites while eighteen species occurred at less than 50% of sites sampled. In general, the most commonly collected species were also collected in greatest abundance. The Shannon-Weaver diversity index for these collections was 1.07.

Fish were grouped in one of three categories (game, commercial, or forage) according to guidelines as presented by Lopinot (1964), (Table 4.2.2 and Appendix II, Table 3). Although ratios between these categories are often used to implement management plans, this information is used here to identify differences between fish communities at different sites. Ratios have been calculated using both the number of species and the number of individuals captured.

For the Middlefork watershed the percent of game, commercial, forage species was 27%, 22%, 51%, respectively (Table 4.2.2). The ratio for numbers of fish collected was 7%, 8%, 86%. Game and commercial species are well represented and a good forage base exists.

Table 4.2.1. Species collected in Middlefork River Basin (listed in order of percent occurrence at five sites on Farm Creek and one site on the Middlefork, six sites total).

	Species	% Occurrence	Total No Collected
1	Grass pickerel	100%	19
2	Striped shiner	100%	181
3	Spotfin shiner	100%	63
4	Redfin shiner	100%	181
5	Silverjaw minnow	100%	162
6	Bluntnose minnow	100%	873
7	Longear sunfish	100%	133
8	Creek chub	83%	280
9	Red shiner	83%	31
10	Common stoneroller	83%	290
11	Quillback carpsucker	83%	49
12	White sucker	83%	44
13	Creek chubsucker	83%	11
14	Sand shiner	67%	79
15	Northern hog sucker	67%	33
16	Yellow bullhead	67%	9
17	Rainbow darter	67%	22
18	Johnny darter	67%	40
19	Carp	50%	3
20	Suckermouth minnow	50%	30
21	Green sunfish	50%	8
22	Highfin carpsucker	33%	6
23	Golden redhorse	33%	46
24	Black bullhead	33%	3
25	Largemouth bass	33%	3
26	Gizzard shad	17%	2
27	Golden shiner	17%	1
28	Silver redhorse	17%	5
29	Shorthead redhorse	17%	18
30	Channel catfish	17%	1
31	Stonecat	17%	6
32	Blackstripe topminnow	17%	25
33	Smallmouth bass	17%	3
34	Bluegill	17%	2
35	Rock bass	17%	1
36	Blackside darter	17%	9
37	Greensided darter	17%	3
38	Hornyhead chub	0%	0
39	Emerald shiner	0%	0
40	Bigmouth shiner	0%	0
41	River carpsucker	0%	0
42	Spotted sucker	0%	0
43	Slender madtom	0%	0
44	Brindled madtom	0%	0
45	Orangespotted sunfish	0%	0
46	White crappie	0%	0
47	Dusky darter	0%	0

Table 4.2.2. Ratios of game, commercial, and forage fish collected in this study.

	Farm Cr. All sites 24 samples	Midfk. All dates 2 samples	Farm Cr. and Midfk. 26	East Branch Emb. 10 samples	West Branch Emb. 25 samples	Total for East and West Branches samples
No. Species	28	32	37	31	39	42
% of all species	76%	86%	100%	74%	93%	100%
No. Fish	2029	646	2675	986	5352	6338
% of all numbers	76%	24%	100%	9%	91%	100%
Number Forage Species	15	16	19	14	24	24
% forage species	54%	50%	51%	45%	62%	57%
Number Forage Fish	1874	415	2289	675	4429	5104
% numbers forage	92%	64%	86%	68%	83%	81%
No. Commercial Species	6	8	8	9	7	9
% commercial species	21%	25%	22%	29%	18%	21%
Number Commercial Fish	57	147	204	160	124	284
% numbers commercial	3%	23%	8%	16%	2%	4%
Number Game Species	7	8	10	8	8	9
% game species	25%	25%	27%	26%	21%	21%
Number Game Fish	98	84	182	151	799	950
% numbers game	5%	13%	7%	15%	15%	15%

Embarras River Basin

Fish collections from the East and West branches of the Embarras River are used to identify fish communities representative of this area of the Embarras River Basin. The results of collections from the East and West Branches are contained in Appendix II, Table 2 and Table 4.2.3. Forty-two species were collected in thirty-five samples from seven sites on twenty dates between June 24, 1987 and October 22, 1988. Two species occurred at all seven sites, five species at six of seven sites, three species at five of seven sites, and seven species at four of seven sites. A total of twenty-three species occurred at four or more sites while nineteen species occurred at less than four sites. The most commonly collected species were also represented in greatest abundance. The Shannon-Weaver Diversity Index for these collections was 0.84.

For the Embarras watershed the percent of game, commercial, forage species was 21%, 21%, 57% (Table 4.2.2). Of the 6,338 fish collected the ratio for numbers of fish was 15%, 4%, 81%. This indicates that game and commercial species are well represented, accounting for nearly half the species present, and a good forage base exists. The numbers of game fish may be biased by large numbers of young-of-the-year sunfish collected in samples.

Typical fish communities in the Embarras include small minnows, shiners, and small sunfish. Larger species may be found in areas where habitat (mainly depth conditions) are suitable. At several sampling sites adult carp, carpsuckers, and suckers dominated the community.

Middlefork and Embarras Comparisons

The fisheries of the Middlefork and Embarras basins are comparable. The ratios of game/commercial/forage fish were similar. Differences in species composition were observed, but species diversity and richness is high in both areas. Tables 4.2.4 and 4.2.5 lists the fish species collected in each basin. While no Spotted suckers or Brindled madtoms were collected in the Middlefork, both species were collected in the Embarras (Table 4.2.4). Historical data indicates that these species have occurred in the Middlefork Basin in the past (Appendix I, Tables 1 & 3). The occurrence in the Embarras may be due to an actual preference for habitat conditions or be an artifact of sampling design/effort in the Middlefork.

Although the sample size limits interpretation, it is possible, using historical data for the remaining species in Tables 4.2.4 and 4.2.5, to use differences in distribution to infer habitat preference. For example, historical data has not identified the Bigmouth shiner or Slender madtom as a common Middlefork species. Similarly, historical data has not identified the Silver redhorse, Stonecat, and Smallmouth bass as common in the Embarras.

Table 4.2.3. Species collected in Embarras River Basin (listed in order of percent occurrence at seven sites on the East and West Embarras Rivers).

	Species	% Occurrence	Total number fish collected
1	Redfin shiner	100%	3519
2	Blackstripe topminnow	100%	3880
3	Striped shiner	86%	235
4	Spotfin shiner	86%	261
5	Bluntnose minnow	86%	388
6	Creek chubsucker	86%	138
7	Longear sunfish	86%	1132
8	Grass pickerel	71%	40
9	Sand shiner	71%	68
10	Bluegill	71%	263
11	Gizzard shad	57%	98
12	Quillback carpsucker	57%	157
13	Golden redhorse	57%	60
14	Yellow bullhead	57%	43
15	Brindled madtom	57%	34
16	Green sunfish	57%	168
17	Johnny darter	57%	60
18	Carp	43%	72
19	Creek chub	43%	88
20	Common stoneroller	43%	51
21	Spotted sucker	43%	62
22	Blackside darter	43%	11
23	Dusky darter	43%	5
24	Emerald shiner	29%	11
25	Highfin carpsucker	29%	6
26	Northern hog sucker	29%	29
27	White sucker	29%	17
28	Black bullhead	29%	6
29	Largemouth bass	29%	13
30	Golden shiner	14%	2
31	Hornyhead chub	14%	2
32	Suckermouth minnow	14%	10
33	Bigmouth shiner	14%	10
34	Red shiner	14%	2
35	Silverjaw minnow	14%	2
36	River carpsucker	14%	6
37	Shorthead redhorse	14%	1
38	Slender madtom	14%	4
39	Orangespotted sunfish	14%	3
40	White crappie	14%	2
41	Greensided darter	14%	2
42	Rainbow darter	14%	2
43	Silver redhorse	0%	0
44	Channel catfish	0%	0
45	Stonecat	0%	0
46	Smallmouth bass	0%	0
47	Rock bass	0%	0

Table 4.2.4. List of species found only in the Embarras Basin.

1	Hornyhead chub	2
2	Emerald shiner	11
3	Bigmouth shiner	10
4	River carpsucker	6
5	Spotted sucker	62
6	Slender madtom	4
7	Brindled madtom	34
8	Orangespotted sunfish	3
9	White crappie	2
10	Dusky darter	5
11	Greensided darter	2

Table 4.2.5. List of species found only in the Middlefork Basin.

1	Silver redhorse	5
2	Channel catfish	1
3	Stonecat	6
4	Smallmouth bass	3
5	Rock bass	1

4.2.2 Reach Specific Fisheries

Farm Creek

At Farm Creek 24 collections were made from five sites on eight dates between June 1, 1987 and September 14, 1988. A total of 28 species were identified (Appendix II, Table 1). Shannon-Weaver Diversity indices calculated for combined data for each collection site ranged from 0.80 to 0.95 with a composite of 1.01 for all sites. Total numbers of fish captured at each sampling site are presented in Appendix I, Table 1. The number of species collected at five sites ranged from 12 to 25 with the largest number of species captured at FC-03 which received the greatest collection effort.

The most common species in Farm Creek are listed in Table 4.2.6. Seven species occurred at all five sites, seven species at four of five sites, and five species at three of five sites. A total of nineteen species occurred at three or more sites while eleven species occurred at less than three sites (Table 4.2.6). In general, the most common species were also the most abundant. The fish community in Farm Creek is dominated by minnows and shiners throughout the year. Extended periods of no flow restrict use of this stream by larger species. Farm Creek's intermittent character further limit adults of large species. Young-of-the-year and juveniles of species attaining larger sizes do utilize the creek to some extent. Adults of larger species, such as the White sucker, Hognose sucker, and Quillback were collected during the spring, high flow periods.

Of the twenty-eight species collected the percent of game, commercial, and forage fish was 25%, 21%, and 54% (Table 4.2.2). Of the 2029 fish collected this percent by numbers was 5%, 3%, and 92%. Game and commercial species were well represented, but the community is dominated by forage species.

Middlefork River

The Middlefork River was sampled in August of 1987 and June of 1988 to provide an estimate of the potential colonization pool for a small tributary such as Farm Creek. A total of 32 species were present in the two collections. Twenty-nine species were collected in August of 1987 and 23 species were collected in June of 1988 (Appendix II, Table 1). Drought conditions may have contributed to the lower number of species in July 1988. Because samples were collected late in the summer, these results are biased to low flow conditions and should not be considered truly representative of Middlefork fisheries. The Shannon-Weaver diversity index was 1.15 in August, 1.12 in June, and 1.23 for the composite collections from both dates. Total numbers of fish and species collected in the Middlefork are presented in Appendix I, Table 1.

Common Middlefork fish species are listed in Table 4.2.7. Of the 32 species collected from the Middlefork the percent of game, commercial, and forage species were 25%, 25%, and 50% respectively (Table 4.2.2). Of the 646 fish collected this percent by numbers was 13%, 23%, and 64%. Game and commercial species comprise half the species collected and a good forage base exists.

Table 4.2.6. Fish species collected in Farm Creek (listed in order of % occurrence at five sites).

	Species	% Occurrence	No. collected
1	Grass pickerel	100%	14
2	Striped shiner	100%	169
3	Spotfin shiner	100%	23
4	Redfin shiner	100%	169
5	Silverjaw minnow	100%	134
6	Bluntnose minnow	100%	748
7	Longear sunfish	100%	68
8	Creek chub	80%	274
9	Red shiner	80%	15
10	Common stoneroller	80%	224
11	Quillback carpsucker	80%	9
12	White sucker	80%	34
13	Creek chubsucker	80%	8
14	Rainbow darter	80%	22
15	Sand shiner	60%	30
16	Northern hog sucker	60%	8
17	Yellow bullhead	60%	7
18	Johnny darter	60%	26
19	Carp	40%	2
20	Suckermouth minnow	40%	6
21	Black bullhead	40%	3
22	Green sunfish	40%	3
23	Golden shiner	20%	1
24	Highfin carpsucker	20%	3
25	Golden redhorse	20%	1
26	Blackstripe topminnow	20%	25
27	Largemouth bass	20%	1
28	Bluegill	20%	2
29	Gizzard shad	0%	0
30	Hornyhead chub	0%	0
31	Emerald shiner	0%	0
32	Bigmouth shiner	0%	0
33	River carpsucker	0%	0
34	Silver redhorse	0%	0
35	Shorthead redhorse	0%	0
36	Spotted sucker	0%	0
37	Channel catfish	0%	0
38	Slender madtom	0%	0
39	Stonecat	0%	0
40	Brindled madtom	0%	0
41	Smallmouth bass	0%	0
42	Orangespotted sunfish	0%	0
43	Rock bass	0%	0
44	White crappie	0%	0
45	Blackside darter	0%	0

Table 4.2.7. Fish species identified in two samples from Middlefork River (listed in order of abundance).

	Species	No. Collected
1	Bluntnose minnow	125
2	Common stoneroller	66
3	Longear sunfish	65
4	Sand shine	49
5	Golden redhorse	45
6	Spotfin shiner	40
7	Quillback carpsucker	40
8	Silverjaw minnow	28
9	Northern hog sucker	25
10	Suckermouth minnow	24
11	Shorthead redhorse	18
12	Red shiner	16
13	Johnny darter	14
14	Striped shiner	12
15	Redfin shiner	12
16	White sucker	10
17	Blackside darter	9
18	Creek chub	6
19	Stonecat	6
20	Grass pickerel	5
21	Silver redhorse	5
22	Green sunfish	5
23	Highfin carpsucker	3
24	Creek chubsucker	3
25	Smallmouth bass	3
26	Greensided darter	3
27	Gizzard shad	2
28	Yellow bullhead	2
29	Largemouth bass	2
30	Carp	1
31	Channel catfish	1
32	Rock bass	1
33	Golden shiner	0
34	Hornyhead chub	0
35	Emerald shiner	0
36	Bigmouth shiner	0
37	River carpsucker	0
38	Spotted sucker	0
39	Black bullhead	0
40	Slender madtom	0
41	Brindled madtom	0
42	Blackstripe topminnow	0
43	Orangespotted sunfish	0
44	Bluegill	0
45	White crappie	0

Farm Creek/Middlefork Comparisons

When comparing Farm Creek and Middlefork collections, 23 of 37 species are common to both sites (Table 4.2.8 and Appendix II, Table 1). The relative abundance differences between collections produces a difference in diversity indices (0.94 versus 1.23). The percentage of game, commercial, forage species is similar for both collections, however, the average size of game and commercial fish was greater in the Middlefork.

Five species have been found only in Farm Creek (Table 4.2.9). These species are expected to occur in the Middlefork but may not have been present in collections for a variety of reasons. For example, the blackstripe topminnow, although common throughout North and Central Illinois, was only collected in Farm Creek. Although similar habitat conditions may exist in Farm Creek and the Middlefork, the low numbers in the Middlefork may be due to the presence of large predators which are absent in Farm Creek. Of the nine species noted to occur only in the Middlefork (Table 4.2.10), all are species typically occurring in larger rivers. Collection of these species in Farm Creek is not expected.

East Branch Embarras

Thirty-one species were identified in ten samples from four sites on the East Branch of the Embarras (Appendix II, Table 2). The Shannon-Weaver diversity index ranged from 0.19 to 0.99 with a composite of 0.89. Common species are listed Table 4.2.11. The percent of game, commercial, forage species was 26%, 29%, 45%, respectively (Table 4.2.2). Of the 986 fish collected this percent by number was 15%, 16%, 68%.

West Branch Embarras

Thirty-nine species were identified in twenty-five samples from three sites on the West Branch of the Embarras River (Appendix II, Table 2). The Shannon-Weaver diversity index ranged from 0.52 to 0.86 with a composite of 0.81. Common species are identified in Table 4.2.12. The percent of game, commercial, forage species was 21%, 18%, 62%, respectively (Table 4.2.2). Of the 5352 fish collected this percent by numbers was 15%, 2%, 83%.

Table 4.2.8. Fish species found in both Farm Creek and Middlefork River.

	Species	FC-All Sites 24 Dates/Sites	Middlefork 2 Dates	Farm Creek & Middlefork 26 dates/sites
1	Grass pickerel	14	5	19
2	Carp	2	1	3
3	Creek chub	274	6	280
4	Suckermouth minnow	6	24	30
5	Striped shiner	169	12	181
6	Red shiner	15	16	31
7	Spotfin shiner	23	40	63
8	Sand shiner	30	49	79
9	Redfin shiner	169	12	181
10	Silverjaw minnow	134	28	162
11	Bluntnose minnow	748	125	873
12	Common stoneroller	224	66	290
13	Quillback carpsucker	9	40	49
14	Highfin carpsucker	3	3	6
15	Golden redhorse	1	45	46
16	Northern hog sucker	8	25	33
17	White sucker	34	10	44
18	Creek chubsucker	8	3	11
19	Yellow bullhead	7	2	9
20	Largemouth bass	1	2	3
21	Green sunfish	3	5	8
22	Longear sunfish	68	65	133
23	Johnny darter	26	14	40
	No. Species	1976	598	2574

Table 4.2.9. Fish species found only in Farm Creek (not in Middlefork)

1	Golden shiner	1
2	Black bullhead	3
3	Blackstripe topminnow	25
4	Bluegill	2
5	Rainbow darter	22

Table 4.2.10. Fish species found only in Middlefork River (not in Farm Creek)

1	Gizzard shad	2
2	Silver redhorse	5
3	Shorthead redhorse	18
4	Channel catfish	1
5	Stonecat	6
6	Smallmouth bass	6
7	Rock bass	1
8	Blackside darter	9
9	Greensided darter	3

Table 4.2.11. Fish species collected from East Branch of Embarras River (in order of percent occurrence at four collection sites).

		% Occurrence	No. collected
1	Redfin shiner	100%	478
2	Blackstripe topminnow	100%	15
3	Longear sunfish	100%	110
4	Striped shiner	75%	5
5	Spotfin shiner	75%	43
6	Sand shiner	75%	8
7	Bluntnose minnow	75%	49
8	Golden redhorse	75%	42
9	Creek chubsucker	75%	6
10	Gizzard shad	50%	57
11	Grass pickerel	50%	9
12	Carp	50%	27
13	Quillback carpsucker	50%	43
14	Yellow bullhead	50%	3
15	Brindled madtom	50%	2
16	Green sunfish	50%	4
17	Bluegill	50%	17
18	Blackside darter	50%	4
19	Creek chub	25%	3
20	Common stoneroller	25%	3
21	River carpsucker	25%	6
22	Highfin carpsucker	25%	4
23	Shorthead redhorse	25%	1
24	Northern hog sucker	25%	1
25	White sucker	25%	3
26	Spotted sucker	25%	33
27	Black bullhead	25%	2
28	Largemouth bass	25%	3
29	Orangespotted sunfish	25%	3
30	Dusky darter	25%	1
31	Johnny darter	25%	1
32	Golden shiner	0%	0
33	Hornyhead chub	0%	0
34	Suckermouth minnow	0%	0
35	Emerald shiner	0%	0
36	Bigmouth shiner	0%	0
37	Red shiner	0%	0
38	Silverjaw minnow	0%	0
39	Silver redhorse	0%	0
40	Channel catfish	0%	0
41	Slender madtom	0%	0
42	Stonecat	0%	0
43	Smallmouth bass	0%	0
44	Rock bass	0%	0
45	White crappie	0%	0

Table 4.2.12 Fish species collected from West Branch of Embarras River (in order of percent occurrence at three collection sites).

		% Occurrence	No. collected
1	Grass pickerel	100%	31
2	Striped shiner	100%	230
3	Spotfin shiner	100%	218
4	Redfin shiner	100%	3041
5	Bluntnose minnow	100%	339
6	Creek chubsucker	100%	132
7	Blackstripe topminnow	100%	3865
8	Bluegill	100%	246
9	Johnny darter	100%	59
10	Gizzard shad	67%	41
11	Creek chub	67%	85
12	Emerald shiner	67%	11
13	Sand shiner	67%	60
14	Common stoneroller	67%	48
15	Quillback carpsucker	67%	114
16	Spotted sucker	67%	29
17	Yellow bullhead	67%	40
18	Brindled madtom	67%	32
19	Green sunfish	67%	164
20	Longear sunfish	67%	1022
21	Dusky darter	67%	4
22	Carp	33%	45
23	Golden shiner	33%	2
24	Hornyhead chub	33%	2
25	Suckermouth minnow	33%	10
26	Bigmouth shiner	33%	10
27	Red shiner	33%	2
28	Silverjaw minnow	33%	2
29	Highfin carpsucker	33%	2
30	Golden redhorse	33%	18
31	Northern hog sucker	33%	28
32	White sucker	33%	14
33	Black bullhead	33%	4
34	Slender madtom	33%	4
35	Largemouth bass	33%	10
36	White crappie	33%	2
37	Blackside darter	33%	7
38	Greensided darter	33%	2
39	Rainbow darter	33%	2
40	River carpsucker	0%	0
41	Silver redhorse	0%	0
42	Shorthead redhorse	0%	0
43	Channel catfish	0%	0
44	Stonecat	0%	0
45	Smallmouth bass	0%	0
46	Orangespotted sunfish	0%	0
47	Rock bass	0%	0

East and West Branch Comparisons

Although detailed comparisons between fish communities in the East and West Branch of the Embarras are not possible because of sampling differences, general comparisons can be made. Fish communities in the East and West Branches are similar. Diversity, 0.81 versus 0.89, was comparable. Both branches have high species richness.

When comparing East and West Branch collections, 28 species are common to both collections (Table 4.2.13). Three species were found only in the East Branch (Table 4.2.14) and eleven species only in the West branch (Table 4.2.15). Since species not in common were present in low numbers, differences may be due to sampling intensity.

Table 4.2.13. Fish Species found in both East and West Branches of Embarras.

Species	East Branch All sites 10 samples	West Branch All sites 25 samples	Total for East and West Branches 35 samples
1 Gizzard shad	57	41	98
2 Grass pickerel	9	31	40
3 Carp	27	45	72
4 Creek chub	3	85	88
5 Striped shiner	5	230	235
6 Spotfin shiner	43	218	261
7 Sand shiner	8	60	68
8 Redfin shiner	478	3041	3519
9 Bluntnose minnow	49	339	388
10 Common stoneroller	3	48	51
11 Quillback carpsucker	43	114	157
12 Highfin carpsucker	4	2	6
13 Golden redhorse	42	18	60
14 Northern hog sucker	1	28	29
15 White sucker	3	14	17
16 Spotted sucker	33	29	62
17 Creek chubsucker	6	132	138
18 Black bullhead	2	4	6
19 Yellow bullhead	3	40	43
20 Brindled madtom	2	32	34
21 Blackstripe topminnow	15	3865	3880
22 Largemouth bass	3	10	13
23 Green sunfish	4	164	168
24 Bluegill	17	246	263
25 Longear sunfish	110	1022	1132
26 Blackside darter	4	7	11
27 Dusky darter	1	4	5
28 Johnny darter	1	59	60

Table 4.2.14. Fish species found only in East Branch of Embarras (not West Branch)

1	River carpsucker	6
2	Shorthead redhorse	10
3	Orangespotted sunfish	3

Table 4.2.15. Fish species found only in West Branch of Embarras (not East Branch)

1	Golden shiner	2
2	Hornyhead chub	2
3	Suckermouth minnow	10
4	Emerald shiner	11
5	Bigmouth shiner	10
6	Red shiner	2
7	Silverjaw minnow	2
8	Slender madtom	4
9	White crappie	2
10	Greensided darter	2
11	Rainbow darter	2

4.3 Seasonal Analysis of Fisheries

4.3.1 Introduction

The fisheries data was analyzed to assess the nature and extent of the movements made by fish in low order drainage systems. Fish movement in large stream systems has been well documented in the literature, however few studies have been directed to highly modified low order streams. In low order streams flow regime and associated changes in habitat have proven to be key components in determining fish community structure and movement patterns (Schlosser 1985; Paloumpis 1958). Funk (1957) provides an analysis of the movement patterns of fourteen species of warm-water stream fishes in Missouri using mark-recapture studies and angler returns. Gerking (1950, 1953) and Larimore (1952) identify movement patterns of several native species in Illinois.

Two types of movement have been identified. The first consists of directed travel through extensive lengths of stream. Such "runs" are often associated with spawning activity which occurs in early spring or summer. The second consists of random movements made within a limited area. The random movement patterns are associated with daily or short-term cycles, feeding patterns, or changes in local habitat conditions resulting from fluctuating flows. Mobile and sedentary individuals and groups of fish have also been identified.

4.3.2 Results and Discussion Farm Creek

The total number of species collected in Farm Creek in 1987 and 1988 in spring, summer, and fall was 22, 21, and 17, respectively (Table 4.3.1). Rarefaction analysis scaled to 300 individuals for each data set resulted in 20, 18, and 15 species in spring, summer, and fall. Shannon-Weaver diversity was 2.21, 2.03, and 1.86, respectively. These results indicated differences in species composition during each season with both species richness and diversity highest in the spring and lowest in the fall. Relative abundance of fish, scaled to equal sample effort, increased from spring through fall. A Jaccard index of 0.667 for summer/fall, 0.654 for spring/summer, and 0.50 for spring/fall indicates that the fisheries populations for the summer/fall periods are most similar, closely followed by spring/summer. Cluster analysis also grouped the summer/fall periods as most similar, followed by spring/summer, and spring/fall as least similar.

Decreases in species richness was accompanied by increases in abundance as the season progressed. Increases in abundance is largely attributed to the presence of young-of-the-year and juvenile fish in later collections. Decreases in species richness may be attributed to the presence of uncommon species in early samples or the presence of species which primarily occupy the stream for spring spawning. Higher diversity and lower similarity for spring samples may either be the result of greater evenness in the distribution of species or the presence of spawning adults.

Table 4.3.2 lists fish species collected by season. Most species were collected during all seasons (Spring, Summer, and Fall), however, some exhibited a seasonal presence. In particular carpsuckers were present only in the spring season during high flows, suggesting that this tributary is utilized by some species for spring runs.

Table 4.3.1 Farm Creek fisheries by season.

	Species	Spring 9 samples	Summer 10 samples	Fall 5 samples
1	Grass pickerel	4	10	
2	Carp		1	1
3	Golden shiner	1		
4	Creek chub	54	89	131
5	Suckermouth minnow	6		
6	Striped shiner	101	32	36
7	Red shiner		11	4
8	Spotfin shiner	8	9	6
9	Sand shiner	14	16	
10	Redfin shiner	47	54	68
11	Silverjaw minnow	4	109	21
12	Bluntnose minnow	117	391	240
13	Common stoneroller	29	149	46
14	Quillback carpsucker	3	2	4
15	Highfin carpsucker	3		
16	Golden redhorse	1		
17	Northern hog sucker	6	1	1
18	White sucker	20	7	7
19	Creek chubsucker	5	3	
20	Black bullhead	3		
21	Yellow bullhead		7	
22	Blackstripe topminnow			25
23	Largemouth bass			1
24	Green sunfish		3	
25	Bluegill	1	1	
26	Longear sunfish	11	48	9
27	Rainbow darter	1	16	5
28	Johnny darter	2	23	1
No. Species		22	21	17
No. Fish		441	982	606
Shannon-Weaver Diversity		2.21	2.03	1.86
Rarefraction to 300 individuals				
No. species		20	18	15

Table 4.3.2. Species collected in Farm Creek during represented season.

Spring	Summer
Golden shiner (1)	Yellow bullhead (7)
Suckermouth minnow (6)	Green sunfish (3)
Highfin carpsucker (3)	
Golden redhorse (1)	
Black bullhead (3)	Spring/Summer
	Grass pickerel (4-10)
Fall	Sand shiner (14-16)
Blackstripe topminnow (25)	Creek chubsucker (5-3)
Largemouth bass (1)	Bluegill (1-1)
	Summer/Fall
Spring/Summer/Fall	Carp (1-1)
Creek chub (54-89-131)	Red shiner (11-4)
Striped shiner (101-32-36)	
Spotfin shiner (8-9-6)	
Redfin shiner (47-54-68)	
Silverjaw minnow (4-109-21)	
Bluntnose minnow (117-391-240)	
Common stoneroller (29-149-46)	
Northern hog sucker (6-1-1)	
White sucker (20-7-7)	
Longear sunfish (11-48-9)	
Rainbow darter (1-16-5)	
Johnny darter (2-23-1)	

4.3.3 Results and Discussion Embarras River

The total number of species collected in the Embarras River in 1987 and 1988 in spring, summer, and fall was 19, 31, and 34 respectively (Table 4.3.3). Rarefaction analysis scaled to 157 individuals for each data set resulted in 19, 17, and 16 species in spring, summer, and fall. Thus, while a direct count indicates an increase in species richness as the seasons progressed, the transformed data suggests an opposite effect. Relative abundance of fish, scaled to equal sample effort, increased from spring through fall. No distinct trend in Shannon-Weaver diversity was noted with index values 1.68, 2.23, and 1.61 for spring, summer, and fall. Sample size differences and sampling intensity is the likely cause for the lack of a consistent trend in diversity. The Jaccard index for presence absence data indicated a high similarity between summer/fall (0.667) distantly followed by spring/summer (0.429) and spring/fall (0.395). Cluster analysis grouped the summer/fall periods as most similar and spring/fall as least similar.

Table 4.3.4 lists fish species collected by season. Most species were collected during all seasons (Spring, Summer, and Fall). Some species exhibited a seasonal presence, however, unlike Farm Creek, no distinct spring run of any species was evident.

Table 4.3.3. Embarras River fisheries by season.

	Species	Spring 7 Samples	Summer 19 Samples	Fall 9 Samples
1	Gizzard shad		41	49
2	Grass pickerel		13	10
3	Carp	2	14	32
4	Golden shiner			1
5	Creek chub	2	21	17
6	Hornyhead chub	1		
7	Suckermouth minnow	1	4	
8	Emerald shiner		1	5
9	Striped shiner	3	54	65
10	Bigmouth shiner	5		
11	Red shiner	1		
12	Spotfin shiner	2	114	23
13	Sand shiner	1	17	20
14	Redfin shiner	92	544	1353
15	Silverjaw minnow		1	
16	Bluntnose minnow	10	160	47
17	Common stoneroller	1	15	14
18	River carpsucker			6
19	Quillback carpsucker		76	24
20	Highfin carpsucker	1		4
21	Golden redhorse		10	41
22	Shorthead redhorse		1	
23	Northern hog sucker		11	4
24	White sucker		3	7
25	Spotted sucker		29	19
26	Creek chubsucker	2	47	23
27	Black bullhead			4
28	Yellow bullhead	1	15	7
29	Slender madtom			2
30	Brindled madtom		9	6
31	Blackstripe topminnow	5	824	1463
32	Largemouth bass		5	3
33	Green sunfish	4	57	34
34	Orangespotted sunfish		3	
35	Bluegill	5	129	22
36	Longear sunfish	18	385	234
37	White crappie			1
38	Blackside darter		6	1
39	Dusky darter		2	
40	Greensided darter			1
41	Rainbow darter			1
42	Johnny darter		19	8
	No. Species	19	31	34
	No. Fish	157	2630	3551
	Shannon-Weaver Diversity	1.68	2.23	1.61
	Rarification to 157 individuals	19	17	16

Table 4.3.4 Species collected in Embarras River during represented season.

Spring

Hornyhead chub (1)
Bigmouth shiner (5)
Red shiner (1)

Spring /Summer

Suckermouth minnow (1-4)

Spring/Summer/Fall

Carp (2-14-32)
Creek chub (2-21-17)
Striped shiner (3-54-65)
Spotfin shiner (2-114-23)
Sand shiner (1-17-20)
Redfin shiner (92-544-1353)
Bluntnose minnow (10-160-47)
Common stoneroller (1-15-14)
Creek chubsucker (2-47-23)
Yellow bullhead (1-15-7)
Blackstripe topminnow (5-824-1463)
Green sunfish (4-57-34)
Bluegill (5-129-22)
Longear sunfish (18-385-234)

Summer

Silverjaw minnow (1)
Shorthead redhorse (1)
Orangespotted sunfish (3)
Dusky darter (2)

Fall

Golden shiner (1)
River carpsucker (1)
Black bullhead (4)
Slender madtom (2)
White crappie (1)
Greensided darter (1)

Summer/Fall

Gizzard shad (41-49)
Grass pickerel (13-10)
Emerald shiner (1-5)
Quillback carpsucker (76-24)
Golden redhorse (10-41)
Northern hog sucker (11-4)
White sucker (3-7)
Spotted sucker (29-19)
Brindled madtom (9-6)
Largemouth bass (5-3)
Blackside darter (6-1)
Johnny darter (19-8)

4.4 Random Skewers Analysis

4.4.1 Description

Perry and Schaeffer (1987) describe the use of a random skewers analysis (RSA) to assess benthic invertebrate distribution along a gradient. Schaeffer and Perry (1986) suggested that RSA using species proportions was the most sensitive in demonstrating a gradient. In this study, RSA was used to determine if the distribution of fish species was associated with habitat gradients (headwaters to downstream areas) or colonization gradients (both upstream to downstream associated with drift, and downstream to upstream associated with migration).

For both Farm Creek and the Embarras River the null hypothesis stated that a trend in species composition is expected, associated with an upstream to downstream gradient in habitat conditions. Acceptance of the null hypothesis would lead to the conclusion that fish communities in these areas are responding to specific habitat cues which control their distribution. Rejection of the null hypothesis would indicate that no gradient exists.

In this study three types of data were used. First, RSA was applied to species abundance data. This analysis tests gradient as influenced by relative numbers of the species present. Second, RSA was applied to the species present at each station. This analysis tests the sensitivity to species distributions and provides insight into weak gradients in taxonomic composition. The third RSA used transformed data, taxon-proportional data was generated for each station by dividing the cumulative organism count by the total organism count at that station. Analysis of this transformed data was intended to identify a gradient in the taxonomic composition of the sample.

Initially, 500 random skewers were passed through each data set and the results presented as a frequency distribution of Kendall's tau. The occurrence of a bimodal distribution indicates that a gradient exists in the distribution of organisms between sampling sites. Multi-modal distributions suggests no gradient exists. A unimodal distribution indicates the organisms are randomly distributed. Where greater sensitivity was required to discern the shape of the distribution curve, either 1500 or 2000 skewers were used.

4.4.2 Results

The first test was to determine if RSA would identify a known distributional gradient. RSA was applied to a data set with a known longitudinal distribution of fish (Matthews 1986). The list of species and collection stations is provided in Table 4.4.1. Random skewers analysis of this data set produced a bimodal distribution, indicating a gradient in number of individuals per taxon (Figure 4.4.1a). Bimodality for taxon-proportional analysis suggests there is also a gradient in abundance of taxa per station (Figure 4.4.1b). These results agree with the conclusions drawn from this data set by Matthews (1986) thus, RSA appears to be effective for fisheries as well as invertebrate data.

Table 4.4.1. Data taken from Matthews (1986). Numbers of individuals collected per species at seven stations in the Kiamichi River, Oklahoma, 11-12 July 1981.

Species	Collecting stations						
	Upstream station			Downstream station			
	8	7	6	4	3	2	1
<i>Campostoma anomalum</i>	1	7	5	2		17	
<i>Notropis boops</i>	32	87	80	14		22	
<i>Notropis umbratilis</i>	17	117	29		39	2	8
<i>Lepomis megalotis</i>	1		2	3	3		11
<i>Etheostoma radiosum</i>	1	9		2		9	
<i>Labidesthes sicculus</i>	11	12	1	3	8	7	6
<i>Notropis orthenburgeri</i>		1	2		9		2
<i>Notropis whipplei</i>		2	15	96	3	134	36
<i>Fundulus notatus</i>		3			5		
<i>Fundulus olivaceus</i>		1	1				3
<i>Notropis rubellus</i>			6	43	14	82	1
<i>Ictalurus natalis</i>			2				
<i>Micropterus punctulatus</i>			4	2		1	3
<i>Percina sciera</i>			5	5		2	1
<i>Gambusia affinis</i>				3	35		1
<i>Lepisosteus osseus</i>				3			
<i>Notropis volucellus</i>				2			
<i>Lepomis machrochirus</i>					1		8
<i>Micropterus salmoides</i>					4		
<i>Notropis perpallidus</i>					14		
<i>Notropis emiliae</i>				9			
<i>Etheostoma gracile</i>				7			
<i>Etheostoma nigrum</i>					3		4
<i>Lepomis cyanellus</i>					1	1	1
<i>Pimphales notatus</i>						1	4
<i>Dorosoma cepedianum</i>						6	1
<i>Pylodictus olivarius</i>						1	
<i>Percina copelandi</i>						1	1
<i>Notropis venustus</i>							17
<i>Pomoxis nigromaculatus</i>							1
<i>Pimphales vigilax</i>							2

Figure 1a. Raw data.

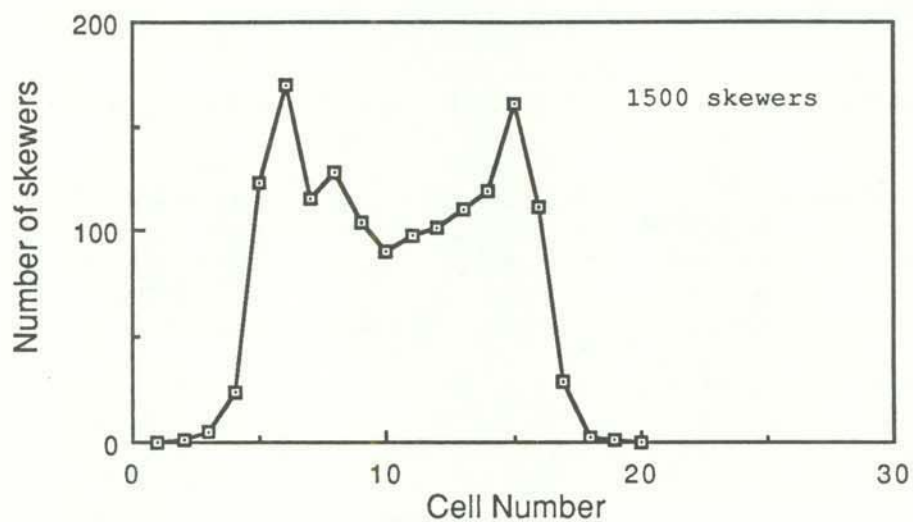
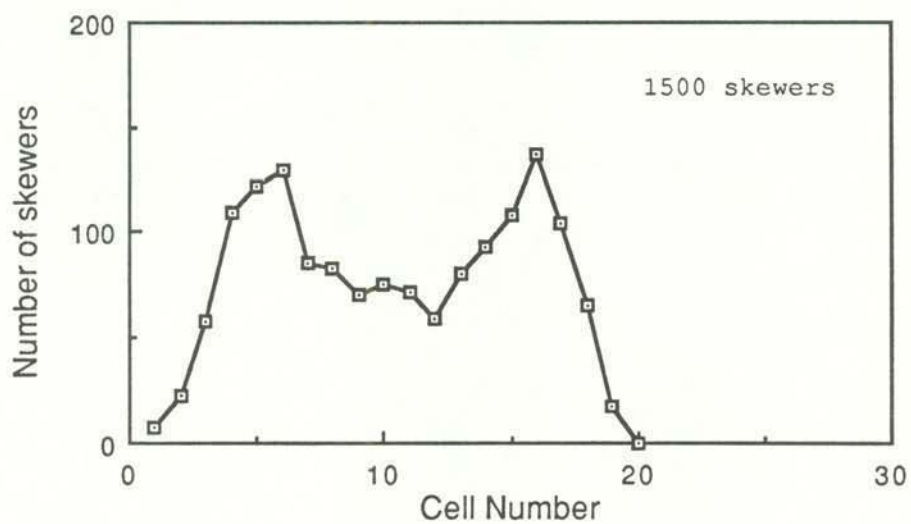


Figure 1b. Taxon-proportional data.



Figures 4.4.1a-b. Frequency distribution of 1500 random skewers for fisheries data (Matthews 1986) with a known longitudinal gradient.

Farm Creek

Farm Creek collections were tested for an upstream to downstream gradient. The total numbers of each species collected between June of 1987 and September of 1988 (Table 4.4.2). Because unequal sampling effort was expended at each station, two data sets were analyzed. The first included pooled data, the second analyzed only the same sampling dates or same number of sampling dates for each site (Table 4.4.2).

For Farm Creek, RSA analysis produced a multi-modal distribution with 500 random skewers (Figure 4.4.2) for both species abundance and taxon-proportional data. These results lead us to accept the null hypothesis that no gradient in either total numbers of organisms (Figure 4.4.2a) or taxonomic composition (Figure 4.4.2b) is present. Increasing the number of skewers to 2500 and 5000 yielded similar results.

Embarras River

The East Branch of the Embarras was tested for an upstream to downstream gradient. Species abundance and the transformed taxon-proportional data from collections made June 1987 and October 1988 were pooled by location for the East Branch (Table 4.4.3). RSA produced multi-modal distributions with 500 skewers (Figure 4.4.3) indicating no gradient in either total numbers (Figure 4.4.3a) or species composition (Figure 3b) for the East Branch of the Embarras River. Because of limited sampling on the West Branch, no RSA analysis was performed on this data set.

Seasonal Analysis of Farm Creek and Embarras River

From the previous information it is obvious that a longitudinal gradient does not exist for pooled data for either of our study sites. Fishery gradients may be evident, however, during certain seasons which correspond to migratory periods. For example, a gradient may exist during spring when species such as the White sucker or Hognose sucker migrate upstream to spawn. To evaluate the possible seasonal effects on fisheries distribution, seasonal collection data was used for an RSA.

Data for the East Branch of the Embarras was suitable for an RSA for summer. The total numbers of each species collected in June 1987 were pooled by location (Table 4.4.4) to create a data set representative of the summer sampling season. Nineteen species were collected from three sites. No gradient in species numbers or composition was identified during the summer as both frequency distributions of 500 skewers were multi-modal (Figures 4.4.4a and 4.4.4b).

A seasonal analysis of distribution in Farm Creek was performed. The total numbers of each species collected in 1987 and 1988 were pooled by location to create three data sets representative of spring, summer, and fall sampling seasons. In spring, twenty-two species were collected from three sites (Table 4.4.5). In summer, twenty-two species were collected from four sites (Table 4.4.6). In fall, twenty-one species were collected from four sites (Table 4.4.7). For each of these seasonal periods the frequency distribution of 400 skewers was multi-modal. No gradient in species number or composition was identified for spring, summer, or fall periods.

Table 4.4.2 Fisheries data from six sites on Farm Creek used for random skewers analysis.

Species	Collection Stations					
	Upstream sites					Downstream sites
	FC-03 8 Dates	FC-2.75 3 Dates	FC-2.5 3 Dates	FC-02 7 Dates	FC-01 Middlefork 3 Dates	2 Dates
Gizzard shad						2
Grass pickerel	2	1	2	4	5	5
Carp	1	1				1
Golden shiner	1					
Creek chub	61	14		168	31	6
Suckermouth minnow	2		4			24
Striped shiner	114	15	19	16	5	12
Red shiner	2	4		5	4	16
Spotfin shiner	12	3	1	6	1	40
Sand shiner	15			10	5	49
Redfin shiner	53	34	10	53	19	12
Silverjaw minnow	16	12	1	24	81	28
Bluntnose minnow	206	112	13	228	189	125
Common stoneroller	48	38		12	126	66
Quillback carpsucker	3	4		1	1	40
Highfin carpsucker	3					3
Silver redhorse						5
Golden redhorse	1					45
Shorthead redhorse						18
Northern hog sucker	6	1			1	25
White sucker	17	4	3	10		10
Creek chubsucker	1	1	5		1	3
Black bullhead	2		1			
Yellow bullhead	3			1	3	2
Channel catfish						1
Stonecat						6
Blackstripe topminnow		25				
Smallmouth bass						3
Largemouth bass				1		2
Green sunfish	1				2	5
Bluegill				2		
Longear sunfish	31	10	2	3	22	65
Rock bass						1
Blackside darter						9
Greensided darter						3
Rainbow darter	1		1	10	10	
Johnny darter	8			11	7	14
No. Species	25	16	12	18	18	32
No. Fish	610	279	62	565	513	646

Figure 2a. Raw data.

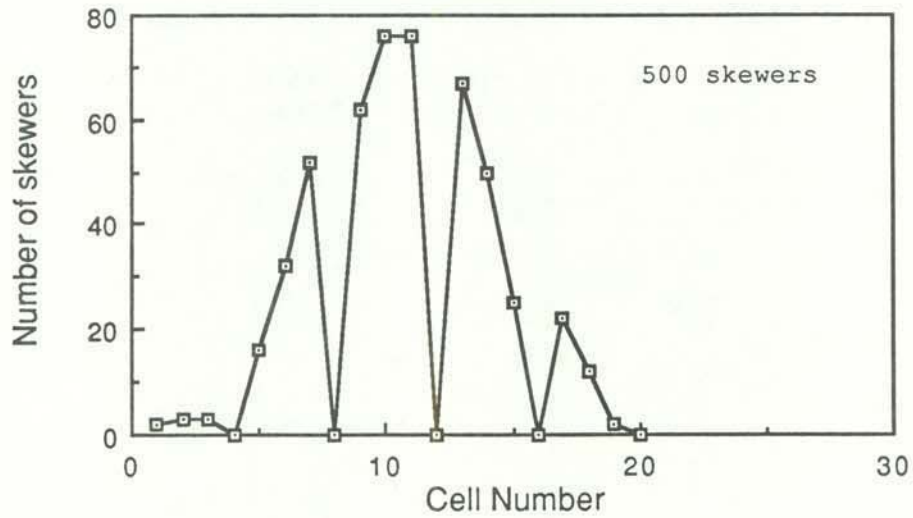


Figure 2b. Taxon-proportional data.

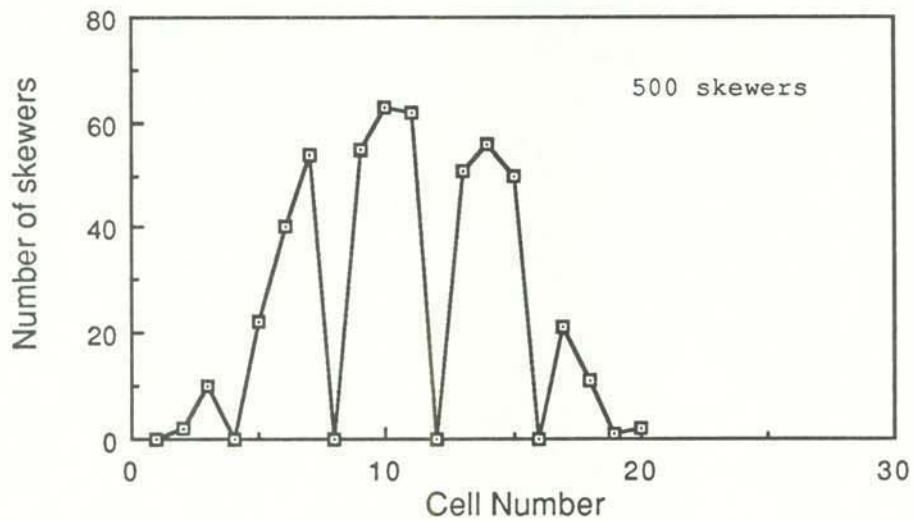


Figure 4.4.2a-b. Frequency distribution of 500 random skewers for Farm Creek fishery data.

Table 4.4.3. Fisheries data from four sites on East Branch of Embarras River used for random skewers analysis.

Species	Collection stations			
	Upstream			Downstream
	EC-01 1 Date	EC-02 1 Date	EC-03 6 Dates	EC-04 2 Dates
Gizzard shad		2	55	
Grass pickerel			4	5
Carp			24	3
Creek chub				3
Striped shiner	1		1	3
Spotfin shiner	15		11	17
Sand shiner	5		1	2
Redfin shiner	25	167	248	38
Bluntnose minnow	17		8	24
Common stoneroller				3
River carpsucker			6	
Quillback carpsucker			42	1
Highfin carpsucker			4	
Golden redhorse	2	1	39	
Shorthead redhorse			1	
Northern hog sucker	1			
White sucker			3	
Spotted sucker			33	
Creek chubsucker	2		3	1
Black bullhead			2	
Yellow bullhead			2	1
Brindled madtom	1			1
Blackstripe topminnow	2	1	6	6
Largemouth bass			3	
Green sunfish			2	2
Orangespotted sunfish			3	
Bluegill			12	5
Longear sunfish	14	17	61	18
Blackside darter	3			1
Dusky darter				1
Johnny darter				1
No. Species	12	5	24	20
No. Fish	88	188	574	136

Figure 3a. Raw data.

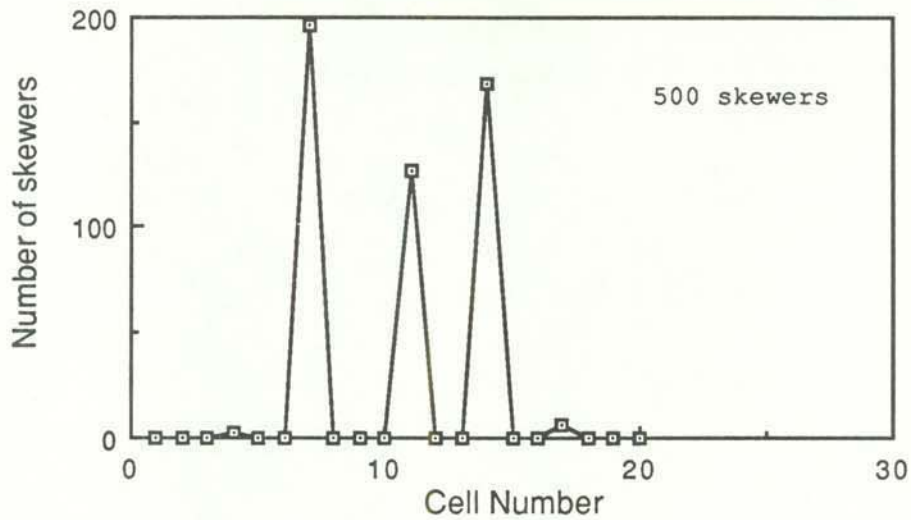


Figure 3b. Taxon-proportional data

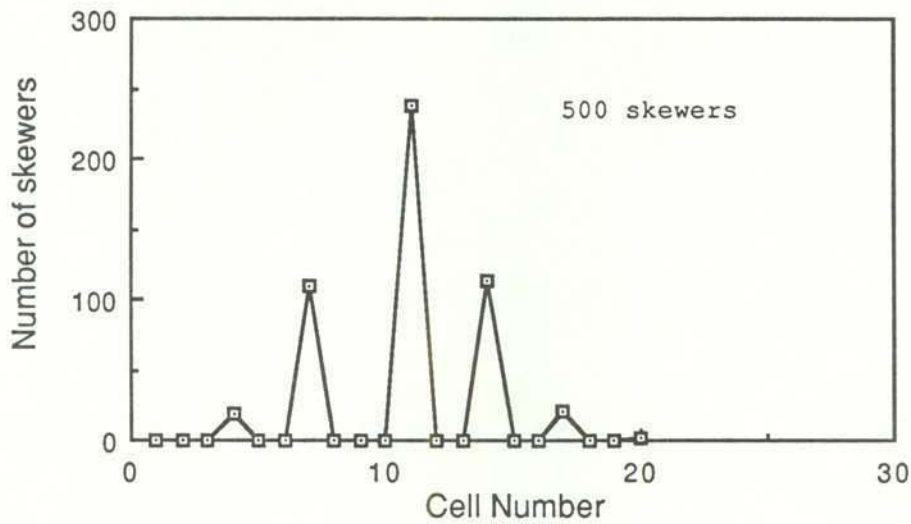


Figure 4.4.3a-b. Frequency distribution of 500 random skewers for East Branch of Embarras fishery data.

Table 4.4.4 Fish collected at three sites on the East Branch of the Embarras during summer, 1987.

Species	Collection Stations		
	Upstream		Downstream
	EC-01 6/24/87 SH	EC-03 6/24/87 SH	EC-04 6/25/87 SH
Creek chub			2
Striped shiner	1		2
Spotfin shiner	15	8	9
Sand shiner	5	1	2
Redfin shiner	25	70	21
Bluntnose minnow	17	6	4
Common stoneroller			1
Golden redhorse	2	1	
Shorthead redhorse		1	
Northern hog sucker	1		
Spotted sucker		1	
Creek chubsucker	2	3	
Brindled madtom	1		
Blackstripe topminnow	2	3	1
Green sunfish			1
Orangespotted sunfish		3	
Longear sunfish	14	23	3
Blackside darter	3		
Dusky darter			1
No. Species	12	11	11
No. Fish	88	120	47

Figure 4a. Raw data

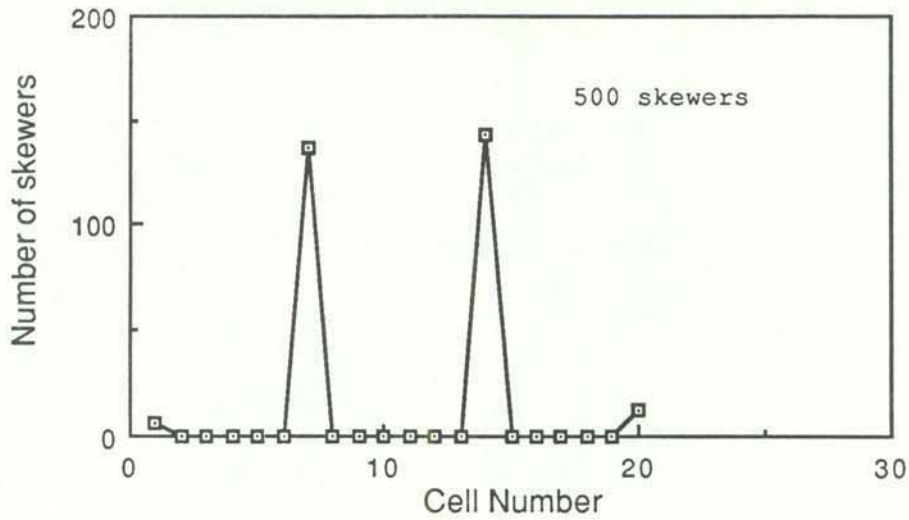


Figure 4b. Taxon proportional data

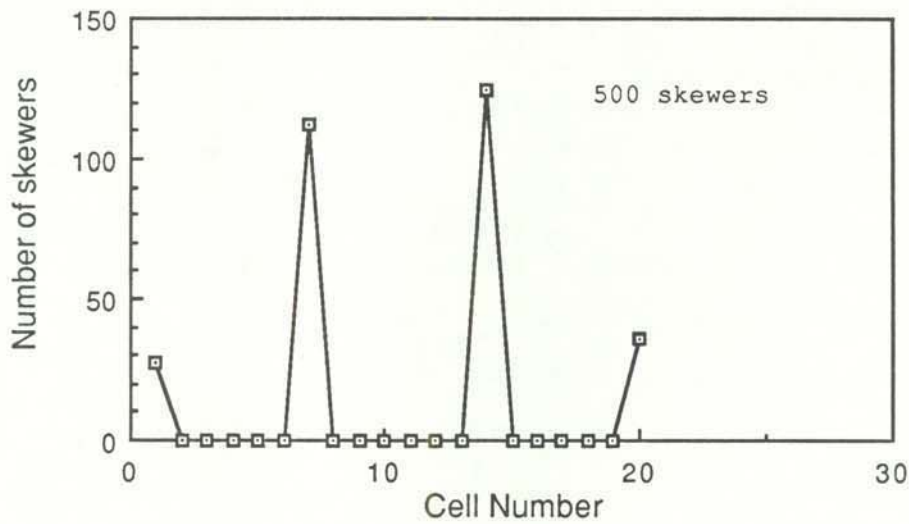


Figure 4.4.4a-b. Frequency distribution of 500 skewers for three sites on East Branch of Embarras River during the summer, 1987.

Table 4.4.5 Fish collected at three sites on Farm Creek during the spring, 1988.

Species	Collection Stations		
	Upstream	Downstream	
	FC-03 spring 88 4 dates	FC-02.5 spring 88 2 dates	FC-02 spring 88 3 dates
Grass pickerel	1	2	1
Golden shiner	1	0	0
Creek chub	31	0	23
Suckermouth minnow	2	4	0
Striped shiner	100	0	1
Spotfin shiner	7	0	1
Sand shiner	14	0	0
Redfin shiner	42	2	3
Silverjaw minnow	4	0	0
Bluntnose minnow	91	0	26
Common stoneroller	17	0	12
Quillback carpsucker	3	0	0
Highfin carpsucker	3	0	0
Golden redhorse	1	0	0
Northern hog sucker	6	0	0
White sucker	16	3	1
Creek chubsucker	0	5	0
Black bullhead	2	1	0
Bluegill	0	0	1
Longear sunfish	8	2	1
Rainbow darter	1	0	0
Johnny darter	1	0	1
No. Species	20	7	11
No. Fish	351	19	71

Table 4.4.6 Fish collected at four sites on Farm Creek during the summer, 1987.

Species	Collection Stations			
	Upstream			Downstream
	FC-03 summer 87 3 dates	FC-02.75 summer 87 2 dates	FC-02 summer 87 3 dates	FC-01 summer 87 3 dates
Grass pickerel	1	1	3	5
Carp	1	1	0	0
Creek chub	26	12	31	31
Striped shiner	14	9	11	5
Red shiner	2	3	5	4
Spotfin shiner	5	1	3	1
Sand shiner	1	0	10	5
Redfin shiner	11	3	24	19
Silverjaw minnow	12	10	16	81
Bluntnose minnow	80	112	122	189
Common stoneroller	23	29	0	126
Quillback carpsucker	0	1	0	1
Northern hog sucker	0	0	0	1
White sucker	1	4	4	0
Creek chubsucker	1	1	0	1
Yellow bullhead	3	0	1	3
Blackstripe topminnow	0	1	0	0
Green sunfish	1	0	0	2
Bluegill	0	0	1	0
Longear sunfish	23	10	2	22
Rainbow darter	0	0	6	10
Johnny darter	7	0	9	7
No. Species	17	15	15	18
No. Fish	212	198	248	513

Table 4.4.7 Fish collected at four sites on Farm Creek during the Fall, 1988.

Species	Collection Stations			
	Upstream			Downstream
	FC-03 10/03/87 1 date	FC-02.75 Fall 87/88 2 dates	FC-02.5 9/14/88 1 date	FC-02 9/14/88 1 date
Gizzard shad		1		
Creek chub	4	13		114
Striped shiner		13	19	4
Red shiner		4		
Spotfin shiner		3	1	2
Redfin shiner		34	8	26
Silverjaw minnow		12	1	8
Bluntnose minnow	35	112	13	80
Common stoneroller	8	38		
Quillback carpsucker		3		1
Northern hog sucker		1		
White sucker		2		5
Blackstripe topminnow		25		
Largemouth bass				5
Longear sunfish		9		
Rainbow darter			1	4
Johnny darter				1
No. Species	3	14	6	11
No. Fish	47	270	43	250

Presence-Absence Information and Random Skewers

The previous discussions dealt with abundance data analyses. A third RSA analysis was performed on species distribution data. In a review of the literature, no reports of RSA on presence-absence data was found. Although qualitative data does not carry the same amount of information as quantitative data, there are often practical constraints in acquiring consistent quantitative information. It would be desirable to examine the effect of utilizing binary information on test results. Therefore, the feasibility of identifying a gradient in species composition by applying random skewers analysis to binary data was examined.

Quantitative data from Farm Creek (Table 4.4.2) and the Embarras River (Table 4.4.3) was converted to presence-absence matrices. Random skewers analysis was performed using 500 skewers. It should be noted that binary data precludes identifying trends in total numbers of organisms, thus this comparative piece of information is lost. Only trends in species composition can be identified.

Multi-modal distributions for binary data for both Farm Creek and the Embarras River implies that there is no detectable gradient in species composition. These results are similar to those acquired through quantitative analysis. The present results are consistent, however, additional testing would be required to examine the application of this technique to binary data more thoroughly.

4.4.3 Conclusions

Within the reaches sampled no species or numbers gradient could be identified for any study site. The results, however, do not support a random distribution of organisms, as would be indicated by unimodal distributions. If habitat conditions were uniform throughout, a more random distribution would be expected.

4.5 Index of Biotic Integrity Analysis

4.5.1 Index Description

The Index of Biotic Integrity (IBI) was developed by Karr (1981) to determine the relative health or condition (integrity) of flowing water ecosystems. The index is based on the identification of fish species, placing species in functional groups then calculating the index based on relative numbers of species in each group. Karr argues that the IBI provides a direct measure of ecosystem condition and is more effective than surrogate measures such as physical or chemical properties. When used in conjunction with conventional measures of physical and chemical monitoring, the IBI provides a comprehensive evaluation of biological condition.

The IBI is calculated using twelve attributes, termed metrics, of the fish community (Karr et. al. 1986). When compared with metrics from an undisturbed fish community in a stream of similar size in the same region, the IBI can provide an assessment of relative integrity. The metrics include the species richness and composition, local indicator species, trophic composition, fish abundance, and fish condition. Each metric is scored one, three, or five. Scoring for some metrics is based on subjective evaluation. Metric totals are tallied resulting in an assignment to one of five integrity classes, very poor through excellent. Although the IBI produces numbers which can be compared between sites and streams, the accuracy of any IBI value is highly dependent on the knowledge and experience of the individual assigning metric values.

The IBI has been widely used and has received considerable review in the fisheries and management literature (Angermeier and Karr 1986, Fausch et. al. 1984, Steedman 1988, Miller 1988). The IBI is felt to have advantages over other biological assessment techniques such as indicator species, diversity indices, relative abundance estimates, or measurement of physical habitat. The IBI is used in Illinois by the Illinois Department of Conservation (DOC) as part of their stream monitoring program.

4.5.2 Results

Embarras River Drainage

Twenty-five of the thirty-five samples from the Embarras were used for IBI analysis (Appendix IV, Table 1). Sample IBI's for ten samples collected with fixed electrodes were not included in the analysis because this sampling method is designed for specific habitats and does not produce a representative community sample required for IBI calculation. The sample IBI ranged from 34 to 56 with an average of 46 (Table 4.5.1). Eleven samples were rated fair, thirteen good, and one sample poor. The average IBI of 46 classifies the Embarras stations as fair to good.

Table 4.5.1. Index of Biotic Integrity for the Embarras River.

Data Set Used	IBI Range	Avg. IBI (Basin IBI)	Integrity Class
East and West Branches (25 samples)	34-56 -	46 -	Fair/Good 1 sample Poor, 11 Fair, 13 Good
East Branch (10 samples)	40-50 -	45 -	Fair/Good 6 samples Fair, 4 Good
West Branch (15 samples)	34-56 -	47 -	Fair/Good 1 sample Poor, 5 Fair, 9 Good
East Branch Pooled Data (4 stations)	42-54 -	49.5 -	Good 1 site Fair, 3 Good
Site EC-01 (1 sample)	-	50	Good
Site EC-02 (1 sample)	-	42	Fair
Site EC-03 (6 samples)	-	52	Good
Site EC-04 (2 samples)	-	54	Good
West Branch Pooled Data (3 stations)	48-56 -	50.3 -	Good 3 sites Good
Site EC-05 (1 sample)	-	48	Good
Site EC-07 (23 samples)	-	56	Good
Site EC-07.5 (1 sample)	-	50	Good
East and West Branches (All 25 samples pooled)	- -	56 -	Good/Excellent -
Embarras River (12 sites) Fausch et. al. (1984)	- -	- -	Good 1 site Fair, 9 Good, 1 Excellent
Embarras River, Fixed Electrode Samples (10 samples)	32-44 - -	37.2 - -	Poor/Fair - -

IBI scores were calculated for both the East and West Branches of the Embarras River using single samples. For the East Branch, the sample IBI for ten collections ranged from 40 to 50 with an average of 45 (Table 4.5.1 and Appendix IV, Table 1). Six samples were rated fair and 4 samples rated good. A basin IBI of 45 classifies the East Branch as fair to good. For the West Branch the sample IBI for fifteen samples ranged from 34 to 56 with an average of 47. One sample was rated poor, five samples were rated fair, and nine samples were rated good. A basin IBI of 47 classifies the West Branch as fair to good. The basin IBI for the East and West Branches are comparable, no major differences in the relative quality of the two branches is indicated.

Multiple data sets from the East and West branches of the Embarras were pooled for the four stations on the East Branch and the three stations on the West Branch (Table 4.5.1 and Appendix IV, Table 2). The station IBI for the East Branch ranged from 42 to 54 with an average of 49.5. The West Branch IBI ranged from 48 to 56 with an average of 51.3. This pooled data classifies the basins as good, slightly higher than the fair/good rating noted for the single sample analysis. This result is anticipated because pooled data sets have a greater species richness.

Site pooled data was also used to examine differences between fisheries at all Embarras stations. The differences or similarity of IBI for individual sites can be due to both differences in quality (water quality or habitat quality) and differences in sampling efficiency. Three comparable samples from the East Branch, EC01, EC03, and EC04 were rated good. All three sites on the West Branch rated good, again indicating no difference in quality rating between sampling locations. Pooled data from all sites on the Embarras yielded a basin IBI of 56 (Table 4.5.1) which rates this basin as good/excellent. Assuming that all species are represented in this pooled sample, an IBI of 56 may be considered the upper limit for the Embarras basin.

Fausch et. al. (1984) calculated the IBI for twelve sites on the Embarras River. Eighty-three percent of sites ranked in the good to excellent range. One site rated fair, nine sites good, and one site excellent. In this study, a similar score was attained using site-pooled data sets. Individual data sets resulted in a lower score, but not considerably less than that noted by Fausch. In general, both studies support the presence of a high quality fisheries in the upper reaches of the Embarras River.

By noting the metrics with the lowest ratings we can identify the groups of species which are the greatest limiting factors for the condition of the fishery. We can assume that by improving conditions for these critical species an improvement in quality of the fisheries, as indicated by the IBI, can be achieved. Table 4.5.2 (also Appendix IV, Table 2) presents the average index value for each metric. The proportion of piscivores has the lowest index value of 2.71. For this metric no site has a score greater than three, an intermediate score. Two sites rate one, the lowest score. All other metrics score five for at least one or more sites, reflecting an inherently high potential.

Only four piscivore species have been collected in the Embarras; the Grass pickerel, Largemouth bass, Green sunfish, and White crappie. Only the Green sunfish was collected in large numbers. Management activity can be directed to habitat improvement for these species or efforts can be made to enhance conditions for other species known to exist in the watershed, such as the Channel catfish or Smallmouth bass.

Table 4.5.2. Metric and average metric scores for collection sites on the Embarras River.

Metric	Metric Scores								Average metric score
	East Br EC-01 1Date	East Br EC-02 1 Date	East Br EC-03 6 Dates	East Br EC-04 2 Dates	West Br EC-05 1 Date	West Br EC-07 23 Dates	West Br EC-07.5 1 Date	East & West EC-All 25 dates	
No. Species									
Total	5	3	5	5	5	5	5	5	4.71
Darters	3	1	1	5	3	5	3	5	3.00
Sunfish	3	3	5	5	3	5	5	5	4.14
Suckers	5	3	5	5	3	5	5	5	4.43
Intolerants	5	3	5	3	3	5	3	5	3.86
Proportion of Individuals									
Green sunfish	5	5	5	5	5	5	5	5	5.00
Omnivores	5	5	3	3	5	5	5	5	4.43
Insectivorous cyprinids	5	5	5	5	5	3	1	3	4.14
Piscivores	1	1	3	3	3	3	3	3	2.71
Hybrids	5	5	5	5	5	5	5	5	5.00
Diseased	5	5	5	5	5	5	5	5	5.00
Total No. Individuals	3	3	5	3	3	5	5	5	3.86
IBI total score	50	42	52	54	48	56	50	56	50.29
Integrity Class	G	F	G	G	G	G	G	G	G

Middlefork River Drainage

The IBI for the two samples from the Middlefork River was 52 and 54 (Table 4.5.3 and Appendix IV, Table 3). A basin IBI of 53 places the Middlefork in the good/excellent integrity class. Pooling data from both sites gave an IBI of 54 (Table 4.5.3 and Appendix IV, Table 4), a score with a similar integrity class rating as one-sample data.

Seventeen of the twenty-four samples from Farm Creek were used to calculate an IBI (Appendix IV, Table 3). Ten samples collected with fixed-electrodes were not included in this analysis. IBI values ranged from 26 to 50 with an average of 41. Six samples were rated good, seven samples were rated fair, and four samples were rated poor. A basin IBI of 41 categorizes Farm Creek as fair.

Data from Farm Creek was pooled (Appendix IV, Table 4) to examine differences between the fishery at each site. The station IBI ranged from 44 to 50 with an average of 48.4. Four sites were rated good and one site fair. The fair rating at site FC2.75 was produced from a sample collected by conventional seine rather than by electroseine and should not be directly compared with other samples. A basin IBI of 48.4 for pooled data places Farm Creek in the fair/good integrity class. This is a higher rating than the single-site data presented, as would be expected of a data set with greater species richness.

Pooling all data for Farm Creek gives an IBI of 50 which rates this basin as good. Assuming that all species are represented in this pooled sample, an IBI of 50 may be considered the upper limit for Farm Creek. A rating of 50 approaches that found in the Middlefork. This result suggests that drainage ditches may have a fishery potential similar to their higher-order source waterways.

An IBI rating was not identified in the literature for Farm Creek or the Middlefork River. The high quality of the Middlefork fish population, however, has been well documented (Larimore and Smith 1963). The Middlefork River is one of the highest quality stream systems in Illinois with diverse habitats of clear pools, wide sand and gravel bars, rubble-gravel riffles, boulders, and exposures of bedrock (Smith 1971). Species such as the Bluebreast darter, River redhorse, Dusky darter, Eastern sand darter, Mimic shiner, and Rosyface shiner are found in the Middlefork. Of all sites sampled in this study, the Middlefork IBI was highest. Two of the unusual species listed by Smith, the River redhorse and Dusky darter, were collected as a part of this study.

By noting the metrics with the lowest ratings we can identify the groups of species which tend to lower IBI values. Improving conditions for these species could increase IBI scores. Table 4.5.4 (and Appendix IV, Table 4) presents an average index value for each metric. The proportion of individuals as piscivores has the lowest index value of 1.8 while the proportion of individuals as omnivores follows with a score of three. No site has a score greater than three, an intermediate score, for either the omnivore or piscivore metric. For piscivores, half the sites rate the lowest score of one. The ten remaining metrics score five for at least one or more sites, reflecting the potential for the reach to attain a more optimal condition.

Only three piscivore species have been collected in Farm Creek; the Grass pickerel, Smallmouth bass, and Green sunfish. None were collected in large numbers. Management activity can be directed to habitat improvement for these species or efforts can be made to enhance conditions for other species known to exist in the watershed, such as the Channel catfish or Largemouth bass.

Table 4.5.3. Index of Biotic Integrity for Farm Creek.

Data Set Used	IBI Range	Avg. IBI (Basin IBI)	Integrity Class
Middlefork River (2 samples)	52-54 -	53 -	Good/Excellent
Middlefork Pooled Data (2 samples)	- -	54 -	Good/Excellent
Farm Creek (17 samples)	26-50 -	41 -	Fair 4 samples Poor, 7 Fair, 6 Good
Farm Creek Pooled Data (5 stations)	44-50 -	48.4 -	Fair/Good 1 site Fair, 4 Good
Site FC-01 (3 samples)	-	50	Good
Site FC-02 (7 samples)	-	50	Good
Site FC-2.5 (3 samples)	-	48	Good
Site FC-2.75 (3 samples)	-	44	Fair
Site FC-03 (8 samples)	-	50	Good
Farm Creek (All 27 samples pooled)	- -	50 -	Good -
Farm Creek, Fixed Electrode (7 samples)	28-44 -	37.7 -	Poor/Fair -

Table 4.5.4. Metric and average metric scores for collection sites on the Middlefork River.

Metric	FC-01 3 Dates	FC-02 7 Dates	FC-2.5 3 Dates	FC-2.75 3 Dates	FC-03 8 Dates	Middlefork 2 Dates	FC-All Sites 27 Dates/Sites	Average metric score
No. Species								
Total	5	5	5	5	5	5	5	5
Darters	3	3	3	1	3	5	3	2.6
Sunfish	5	5	3	3	5	5	5	4.2
Suckers	5	5	5	5	5	5	5	5
Intolerants	3	3	3	3	5	5	5	3.4
Proportion of Individuals								
Green sunfish	5	5	5	5	5	5	5	5
Omnivores	3	3	3	3	3	3	3	3
Insectivorous cyprinids	3	5	5	3	3	3	3	3.8
Piscivores	3	1	3	1	1	3	1	1.8
Hybrids	5	5	5	5	5	5	5	5
Diseased	5	5	5	5	5	5	5	5
Total No. Individuals	5	5	3	5	5	5	5	4.6
IBI total score	50	50	48	44	50	54	50	48.4
Integrity Class	G	G	G	F	G	G	G	G

4.5.3 Conclusions

Farm Creek has a biotic integrity index somewhat lower than that of the Middlefork. Since Farm Creek is a tributary, this result is expected. The results do suggest that as a tributary, even though the channel has been modified and the stream is subject to agricultural drainage, fisheries conditions are good and should be considered in developing management strategies.

Individual metric values for Farm Creek and the Middlefork River were compared to identify factors contributing to a lower IBI for Farm Creek. Ten of twelve metrics had identical ratings (Table 4.5.4). Two metrics rated higher for the Middlefork River, the number of darters and the proportion of piscivores. These results agree with collection records in which darter and piscivore species were not highly represented in the low order tributary as compared to the high order source system.

IBI values for both the East and West Branches of the Embarras were comparable. The general biotic integrity rating was good for both streams. The Embarras drainage is severely impacted by agricultural practices. Regular channelization occurs throughout the drainage net. Habitat conditions, particularly riparian vegetation, are limited, but fisheries quality is still good. This suggests that the Embarras has a strong fisheries potential and that proper management of the watershed can reap large benefits in fisheries quality.

4.6 Hydraulic Design Requirements and Management/Maintenance History

The history of three representative drainage districts in Champaign County was reviewed to determine the availability of information on engineering modifications to stream channels produced by drainage district activity (Garbaciak 1986). This review suggested that the size of the drainage system, largely determined by topography and multiple drainage districts, may be present on a single large watershed. Detailed records of drainage maintenance projects (modification, design, or maintenance standards) are not readily available in the historical records. The information available includes the general location of the project, the length of the improvement, and the approximate amount of bed material removed. In some cases more detailed records may be retained by the design engineer. In Champaign County the span between "major" repairs has been about ten years. Major repairs include dredging and removal of stream bed material. "Routine" maintenance is often performed annually on a site by site basis as required. Routine maintenance includes removal of small trees and shrubs, spraying herbicides, removal of obstructions, and other minor repairs.

In a review of maintenance activities on the East Branch of the Embarras, records revealed brush had been cut along the entire length of the ditch (thirteen miles) in 1952. Brush clearing and straightening of sharp bends had been performed on two different four mile stretches in 1979 and 1980. On the West Branch of the Embarras bends were straightened and brush removed in 1930 and 1933. Routine maintenance has been performed in the 1980's.

4.6.1 Engineering Design Criteria

No engineering records for these three drainage districts were identified. Representative design standards are available in Section 16, Chapter 5 of the Soil Conservation Service National Engineering Handbook, Drainage of Agricultural Land (U. S. Dept. of Agriculture 1971). These standards state that open channel drainage ditches must be designed to meet five major criteria:

1. The primary design criteria for the channel is the provision for sufficient capacity to carry design flow.
2. The channel must meet project needs without aggradation or degradation of the bed or erosion of the banks.
3. The project must be designed for easy maintenance.
4. The expected benefits of the project must be greater than construction and maintenance costs.
5. The construction, operation, and maintenance should not significantly contribute to downstream sediment loads or on-site deterioration of environmental quality.

Suggestions for erosion control on ditch banks are: construction of grade control structures, bank protection by vegetation or riprap, use of longer channels on non-erosive grades, avoiding cutoffs and straightening of natural channels, and use of wider and shallower channels to decrease hydraulic radius and velocity.

Established drainage coefficients are utilized to determine the flow capacity needed. The general formula used where natural land slopes are 1% or less is:

$$Q=CM^{5/6}$$

where:

Q = required capacity of ditch (c.f.s.)

C = a coefficient related to characteristics of watershed and magnitude of storm against which the watershed is to be protected

M = drainage area (sq. mi.)

Values for C have been established for different areas of the County based on years of professional experience. For a given area, a range of values for C are available depending on the level of protection desired.

After the flow capacity is determined, the structure of the channel may be designed. The primary equation used for design is the Manning Equation:

$$V=(1.486/n) r^{2/3} s^{1/2}$$

where:

V = mean velocity of water (ft/s)

n = Manning's n, coefficient of roughness

r = mean hydraulic radius (ft)

s = energy loss per foot of length. For uniform flow or very small slopes, s is the drop in chan

The value of Manning's n is dependent on the roughness of the channel bed. A cleaner or newer channel has a lower value for n, while a channel that is overgrown will have a much higher value.

The cross-sectional area of the channel (A) is determined from the equation $A = Q/V$ where Q and V are determined from the equations above. The channel section should be a) large enough to permit the required discharge, b) deep enough to provide an outlet for both surface and subsurface drainage, and c) of a width-depth ratio and side slopes which result in a stable channel which can be maintained in a satisfactory condition at reasonable cost.

Although the criteria specify consideration of environmental issues, the design guidance provides no detailed specifications to meet environmental quality objectives. For example, no element of diversity is incorporated into design criteria. It is the diversity of current patterns, substrate types, and depth which lead to high quality habitat. The present design has been adopted primarily for its reliability in meeting design flows as well as for reduced maintenance requirements and level of accessibility for maintenance.

4.7 Determination of Habitat Requirements

4.7.1 Introduction

Habitat quality and critical habitat requirements for several fish species were evaluated using Habitat Suitability Index (HSI) models available from the U. S. Fish and Wildlife Service (U. S. Fish and Wildlife Service 1980a,b). HSI models are designed to quantify habitat condition and assist in identifying the effects of changes in habitat to the life stages of selected species. HSI models also provide a means of estimating the impact that alternative management practices will have on fish habitat (Armour et. al. 1984). HSI models are based on estimates of parameter suitability. Suitability is described as a unitless number from zero, indicating unsuitable condition, to one, indicating highly suitable condition. Single parameter suitability values are aggregated in HSI models to provide a habitat quality rating. HSI models are available for riverine or lacustrine species. Individual (species specific) HSI models may handle life stages and seasonal factors differently.

HSI models have been most commonly used in impact assessment and mitigation planning as a part of the U. S. Fish and Wildlife Service Habitat Evaluation Procedures (HEP), however the models are flexible and may be adapted to a variety of modeling needs and management requirements. Because HSI models are species specific, model quality varies with the amount of supporting documentation available for each species. In general, HSI models for salmonid species are empirical and of high quality. HSI models for warmwater fish species are less empirical and more subjective, typically based on expert panel findings. Although HSI models are criticized for a lack of uniformity and an inability to make exact predictions of the effect of habitat modification, these models do represent the state-of-the-art in tools generally available for assessment, planning, and management. HSI models were selected for use in this study because they provide a flexible analytical tool which, when supplemented by field sampling and a careful review of the literature, provide a basis for assessment of relative impact and guidance for management approaches.

The U.S. Fish and Wildlife Service, Biological Services Program supports microcomputer software (Micro-HSI Version 2), an HSI analysis package often used in conjunction with HEP. In this study the Micro-HSI software was replaced with a more flexible spreadsheet approach. Published HSI models were adapted to spreadsheet calculation and validated against Micro-HSI results. The spreadsheet models allowed more comprehensive sensitivity analysis for single parameters and allowed rapid determination of the expected effects of management alternatives. They perform calculations more quickly and easily and facilitate ease of model modification for custom model development. Spreadsheet based models provide immediate feedback to the user. Habitat variables can be quickly manipulated to determine the effective change of a habitat variable on the quality of habitat or habitat components. The user interactive and iterative nature of the spreadsheet models assist the watershed manager in visualizing the effect of different management options.

HSI models transferred from Micro-HSI to spreadsheet models were selected from the HSI model library and included species present at the study sites or known to occur in the Middlefork and Embarras River drainage basins. The FWS currently provides models for over 50 fresh and saltwater species. HSI spreadsheet models were developed for seven fish species: Carp, Green sunfish, Largemouth bass, Smallmouth buffalo, Channel catfish, Warmouth, and Black bullhead. The species selected are relatively common, are representative of diverse habitat requirements, and include both tolerant and intolerant taxa.

4.7.2 General Descriptions of Models and Sensitivity Analysis

Each model is a straightforward application of the species specific HSI models published by the Fish and Wildlife Service. For reference, the appropriate FWS publication number is found on the top row of each model. These publications (McMahon and Terrell 1982, McMahon et. al. 1984, Stuber 1982a, Stuber et. al. 1982b-c, and Edwards and Twomey 1982a-b) may be referred to for detailed model descriptions.

The model for each species consists of a spreadsheet template, a model without data, which lists relevant habitat variables and provides data input columns. Habitat variables used for a species may vary, but considerable overlap does occur. HSI models group several parameters (habitat variables) into categories termed life requisite variables (food, cover, water quality, reproduction/spawning, etc.). Intermediate calculations produce a life requisite index. The life requisite indices are used for calculation of a final HSI. An example of the spreadsheet implementation of an HSI model is provided for Carp. Calculations for habitat conditions in the Embarras River are provided in Table 4.7.1.

An analysis of suitability values for each parameter provides insight into possible limiting habitat conditions. Figure 4.7.1 provides several parameter specific suitability curves with the corresponding suitability and parameter value indicated. These curves help visualize the change in suitability as parameter values change.

A change in a single suitability value may or may not affect the final HSI, depending on the algorithm used to calculate the HSI. A sensitivity analysis is required to determine how a change in a single habitat variable will affect the HSI. This sensitivity analysis was performed by selecting a single habitat variable, then calculating the HSI for a range values. This procedure was repeated for all variables. HSI vs. habitat variable values were then plotted as in Figure 4.7.2. From these graphs the minimum habitat value producing an optimal HSI could be identified. Iterations were continued for the next limiting variable until little change in the HSI was noted. The sensitivity analysis was expanded by considering the response of a range of species. This allowed identification of critical habitat variables for the expected or desired fisheries community under current habitat conditions.

4.7.3 HSI Modelling Objectives

HSI models were used to evaluate the habitat conditions and identify habitat parameters which, when improved, would improve stream fisheries in the Embarras River. Objectives of this analysis were to: 1) assess the quality of existing habitat in a representative reach of the Embarras River for seven fish species, 2) identify critical habitat parameters for each species, and 3) evaluate management options and activities which would improve expected environmental quality of the Embarras.

4.7.4 Data Requirements and Sources (Application of Models to the Embarras River)

Values for habitat variables for the Embarras River study site were determined using physical and chemical data collected from this site in 1987 and 1988 (Appendix V, Table 1) and water chemistry data compiled from U.S. Geological Survey Water Data Reports, Water Resources Data, Illinois (Appendix V, Table 2). Rather than selecting a target year or target conditions for habitat variables, the entire record was reviewed to provide conditions considered typical during average flows. The general habitat conditions selected were:

The percent vegetative cover in shallows and percent cover in pools is low. Pools (areas of no or comparatively low flow) occur throughout the reach, but most are shallow with no cover (overhanging vegetation or instream structure such as fallen trees). No pools exceeded a depth of four feet and most were less than two feet deep during average flows. There are long stretches of uniform depth and flow (expected due to drainage system maintenance). Discharge and associated water levels fluctuate rapidly and widely. Turbidity fluctuates with season and flow, both clear and extremely turbid conditions were observed. Summer temperatures vary widely with recorded diurnal ranges between 68 and 96 degrees F. Dissolved oxygen was generally sufficient throughout critical periods with observed oxygen concentrations not falling below 5.0 mg/l. Supersaturation was observed during summer months. The pH ranged from 7.5 to 9.0.

4.7.5 HSI and Sensitivity Analysis Results

The HSI analysis results are described in detail for the Common Carp. Results for the remaining six species are summarized in Table 4.7.4.

Common Carp

Carp have been collected in low numbers in Farm Creek (2) and the Middlefork (1), and in high numbers in the Embarras River (72). In the Embarras adults and juveniles occurred sporadically, often in large numbers. Carp were collected most frequently in deeper pools.

Carp are known to tolerate highly disturbed or polluted conditions. They prefer areas of slow currents and deep pools with abundant instream cover, including logs, brush and other objects (Pflieger 1975). Adults are most often associated with abundant vegetation and substrates of mud or silt.

The HSI model for Carp consists of twelve habitat variables (Table 4.7.1). Conditions in the Embarras for nine of the twelve variables are sub-optimal (Figure 4.7.1). An HSI of 0.16 suggests this reach of the Embarras provides poor habitat conditions. Although the reach HSI was low, fisheries collections suggested habitat quality might be underestimated by the present model formulation. This underestimate may be due to better habitat conditions in the basin which contribute to greater numbers of fish observed (e.g. normal movement patterns may bring fish into our study reach) or a poor estimate of parameter values. It is possible to address the second point by a sensitivity analysis.

An examination of life requisite indices used for calculation of the HSI reveals that food, cover, and reproduction have moderate values (Table 4.7.1). The water quality life requisite, with a value of 0.16, is the principle cause of a low HSI. The water quality life requisite consists of five parameters which incorporate turbidity, temperature, dissolved oxygen, and pH. Four of these five variables have an optimal SI. Only variable V7, maximum summer temperature for adults, is sub-optimal.

Results for the first iteration of the sensitivity analysis are presented in Figure 4.7.2. One binding variable is identified, V7, maximum summer temperature. All other variables are non-binding for this solution set. By visually interpreting the graph for V7 it is noted that decreasing V7 from 31 to 26 degrees F increases the HSI to about 0.60. A recalculation of the HSI (Table 4.7.2) shows an increase from 0.16 to 0.63 with the water quality life requisite index increasing from 0.16 to 0.91. At this point a new variable becomes binding and must be identified. An HSI of 0.60 for Carp is more reasonable when compared to collection records for this species.

The second iteration of the sensitivity analysis is presented in Figure 4.7.3. For this solution set three variables are binding, V1, V2, and V3. But, the greatest improvement in HSI is achieved by increasing V1, the percent vegetative cover in shallows. A new model was formulated with the percent vegetative cover in shallows (V1) incremented from 10% to 35% (Table 4.7.3). The HSI increased from 0.63 to 0.80 and the cover component was raised from 0.48 to 0.65. Increasing the percent cover in pools (V2) from 10% to 50% or increasing the percent pools during summer (V3) from 25% to 35% would have only increased the HSI to slightly less than 0.70. Once again, a new variable becomes binding and must be identified.

A third iteration of the sensitivity analysis indicated a change in percent cover in pools (V2) would result in an HSI of 0.87. In a fourth and final iteration an increase in percent pools in summer (V3) yielded an HSI of 0.93. At this point it is obvious that significant improvements in HSI could be realized with changes in only a few habitat variables specifically, decreasing temperature and increasing cover elements.

Green Sunfish

Green sunfish were collected in both Farm Creek and the Middlefork, however the species was not collected often in Farm Creek. Only three green sunfish were identified in 27 samples. One sample produced five green sunfish from the Middlefork. Green sunfish were routinely collected in the Embarras. The species is common throughout the State (Smith 1979) with small, sluggish creeks considered prime habitat. It is seldom found in larger rivers. Green sunfish typically inhabit pools and the optimum riverine habitat consists of at least 50% pool area. Species abundance is positively correlated with vegetative cover. Green sunfish tolerate high water temperatures, high turbidity, and low dissolved oxygen. Because it is tolerant, the Green sunfish is considered a pioneer species in newly created and intermittent waterways. The presence of this species has been used as an indicator for disturbed aquatic systems.

The HSI model for the Green sunfish consists of fourteen variables. For the baseline model only four of these twelve values result in a sub-optimal SI, while eight SI's are optimal. An HSI of 0.76 suggests this reach of the Embarras provides a suitable habitat. The predicted HSI supports field observations, Green sunfish were routinely collected from the Embarras. In fact, Green sunfish were one of the most common species collected at all sample sites.

Table 4.7.1 Baseline HSI Model for Common Carp in the Embarras River.

Habitat Suitability Index (HSI) Model Common Carp (Riverine)
FWS/OBS-82/10.12 July 1982

		HSI		0.16		
Variable Description		Variable	SI			
V1*	% veg cover shallows (0-100%)	10	0.40	food	0.55	
V2*	% cover in pools (0-100%)	10	0.36	cover	0.48	
V3	% pools, bckwtr summer (0-100%)	25	0.77	wq	0.16	
V6	Max avg turbidity summer (0-300 JTU)	75	1.00	repro	0.65	
V7*	Max summer temp (adult) (0-40 C)	31	0.16	HSI	0.16	
V8	Max spring temp (spawning) (0-40 C)	25	0.60			
V9	Max summer temp pools (j & f) (0-40 C)	31	0.88			
V10	Max depth pools spawning (0-2 m)	1.5	0.70			
V12	Min D.O. (midsummer) (0-8 mg/l)	6	1.00			
V13	Min D.O. (march-june) (0-10 mg/l)	8	0.88			
V14	min pH (1-11)	7	1.00			
V14	max pH (1-11)	8.5	0.60			

HSI 0.16

Variable descriptions

- V1 Percent vegetative cover in shallow areas during the spring and summer.
- V2 Percent cover in pools such as logs, brush, submerged objects, and depth.
- V3 Percent pools, backwaters, and marsh areas during average summer flow.
- V6 Maximum monthly average turbidity during average summer flow.
- V7 Maximum midsummer water temperature.
- V8 Average water temperatures during spawning within specified areas (embryo, in spring).
- V9 Maximum midsummer water temperature in pools, backwaters, or littoral areas (juv or fry, in summer).
- V10 Maximum depth of pools, marshes, and backwaters during spawning.
- V12 Minimum dissolved oxygen during midsummer.
- V13 Minimum dissolved oxygen levels within specified areas during spawning (March-June).
- V14 Minimum and maximum pH during the year.

* Critical or binding habitat variables

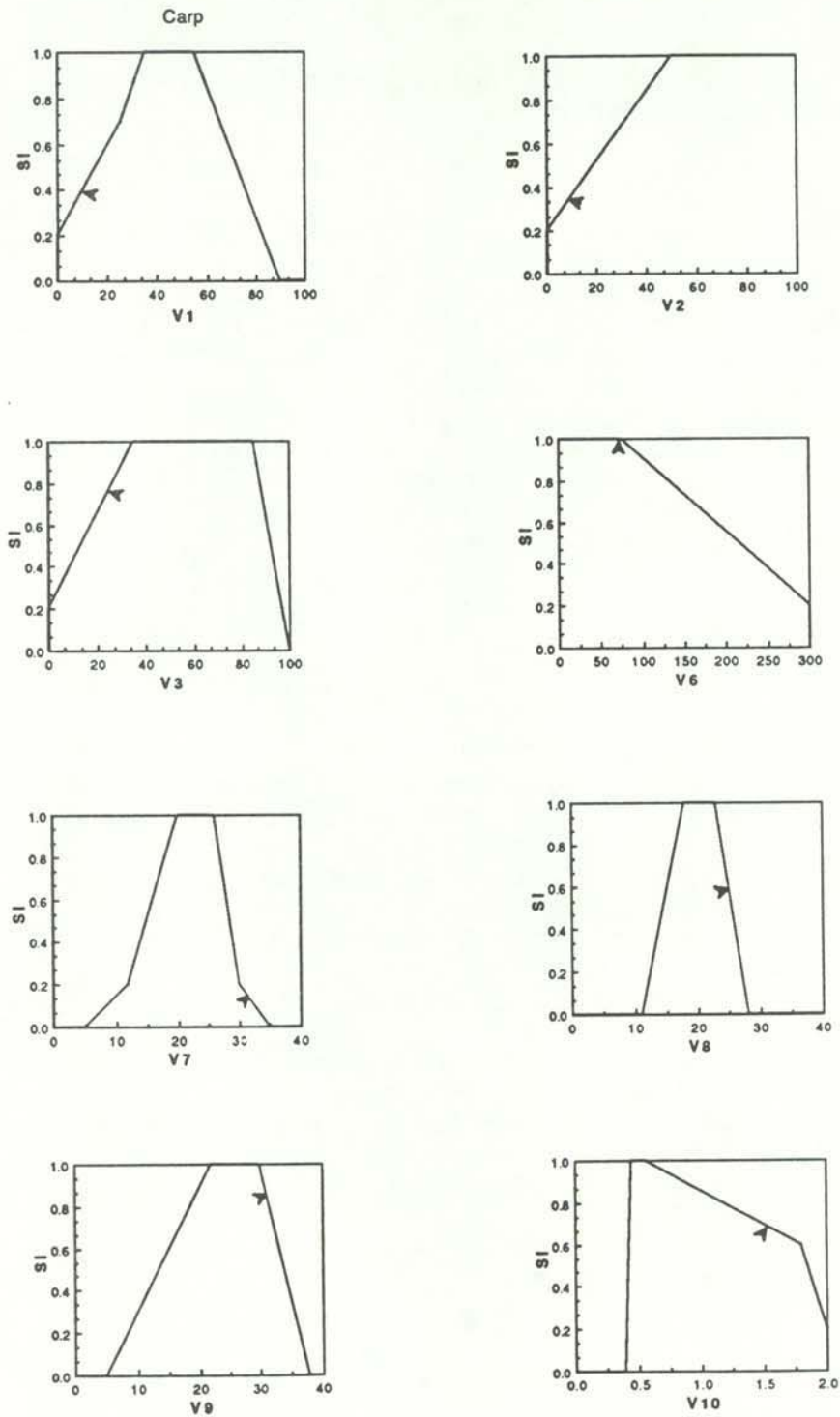


Figure 4.7.1 Suitability curves for Common Carp HSI Models. Arrow depicts level of habitat variables for the Embarras River.

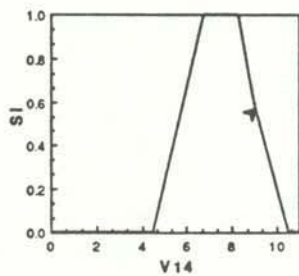
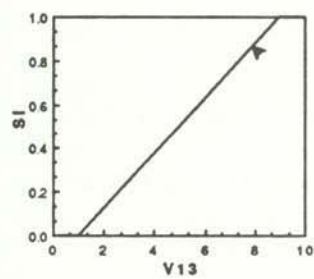
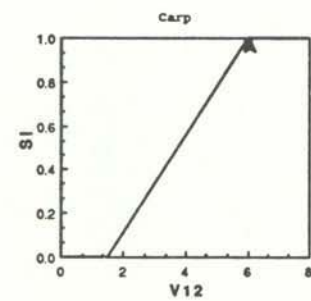


Figure 4.7.1 continued.

Table 4.7.2 First iteration HSI Model for Common Carp in the Embarras River depicting an improvement in maximum summer temperature.

Habitat Suitability Index (HSI) Model Common Carp (Riverine)
FWS/OBS-82/10.12 July 1982

		HSI 0.63			
Variable Description		Variable	SI		
V1*	% veg cover shallows (0-100%)	10	0.40	food	0.55
V2*	% cover in pools (0-100%)	10	0.36	cover	0.48
V3	% pools, bckwtr summer (0-100%)	25	0.77	wq	0.91
V6	Max avg turbidity summer (0-300 JTU)	75	1.00	repro	0.65
V7*	Max summer temp (adult) (0-40 C)	26	1.00		
V8	Max spring temp (spawning) (0-40 C)	25	0.60	HSI	0.63
V9	Max summer temp pools (j & f) (0-40 C)	31	0.88		
V10	Max depth pools spawning (0-2 m)	1.5	0.70		
V12	Min D.O. (midsummer) (0-8 mg/l)	6	1.00		
V13	Min D.O. (march-june) (0-10 mg/l)	8	0.88		
V14	min pH (1-11)	7	1.00		
V14	max pH (1-11)	8.5	0.60		

HSI 0.63

Variable descriptions

- V1 Percent vegetative cover in shallow areas during the spring and summer.
- V2 Percent cover in pools such as logs, brush, submerged objects, and depth.
- V3 Percent pools, backwaters, and marsh areas during average summer flow.
- V6 Maximum monthly average turbidity during average summer flow.
- V7 Maximum midsummer water temperature.
- V8 Average water temperatures during spawning within specified areas (embryo, in spring).
- V9 Maximum midsummer water temperature in pools, backwaters, or littoral areas (juv or fry, in summer).
- V10 Maximum depth of pools, marshes, and backwaters during spawning.
- V12 Minimum dissolved oxygen during midsummer.
- V13 Minimum dissolved oxygen levels within specified areas during spawning (March-June).
- V14 Minimum and maximum pH during the year.

* Critical or binding habitat variables

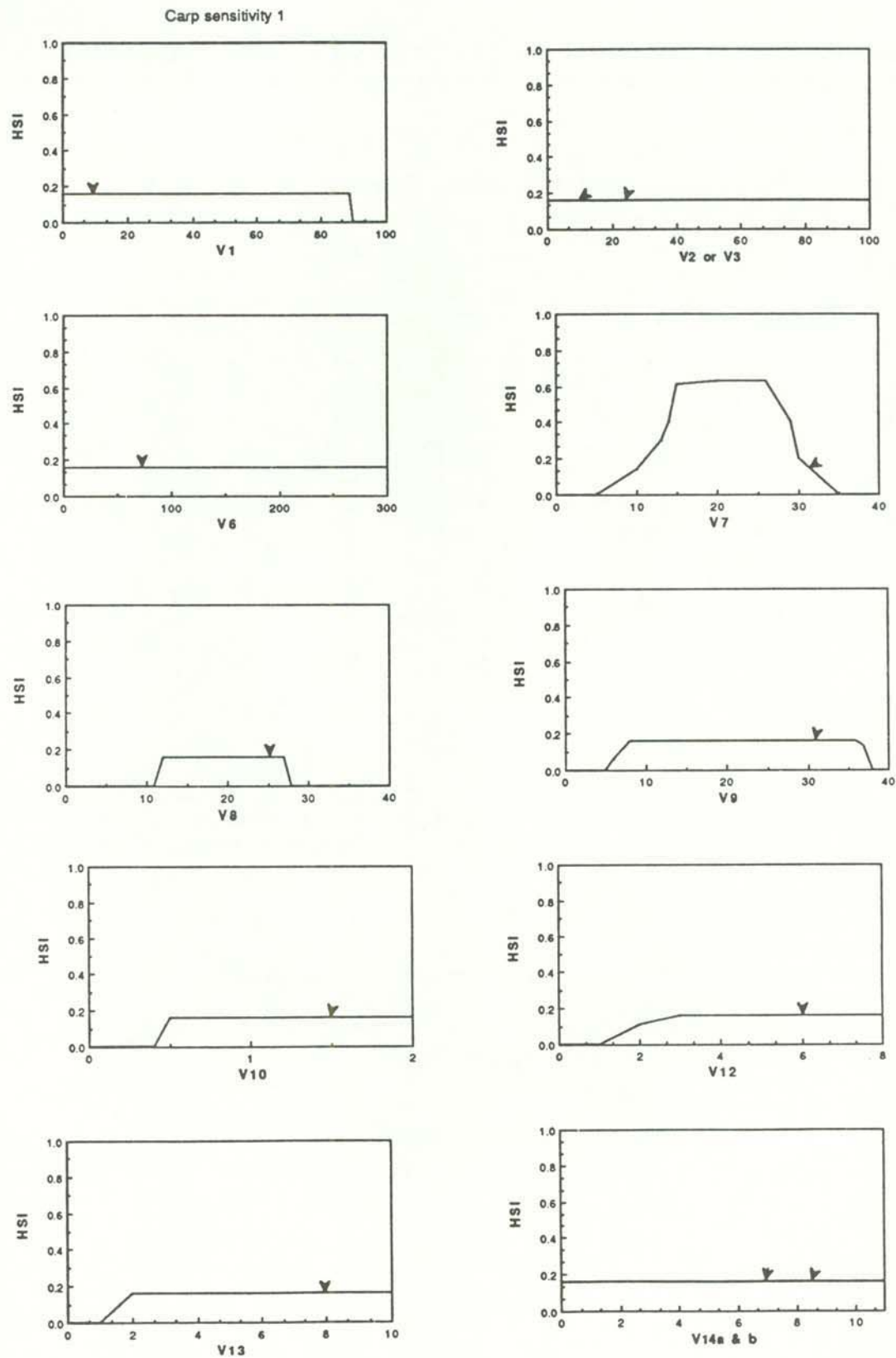


Figure 4.7.2 Sensitivity analysis for Common Carp in Embarras River. This presents the first iteration of sensitivity. Arrows depict the current level for each habitat variable.

Table 4.7.3 Second iteration HSI Model for Common Carp in the Embarras River depicting an improvement in maximum summer temperature and % vegetative cover in shallows.

Habitat Suitability Index (HSI) Model Common Carp (Riverine)
FWS/OBS-82/10.12 July 1982.

		HSI	0.80		
Variable Description	Variable	SI			
V1*	% veg cover shallows (0-100%)	35	1.00	food	0.88
V2*	% cover in pools (0-100%)	10	0.36	cover	0.65
V3	% pools, bckwtr summer (0-100%)	25	0.77	wq	0.91
V6	Max avg turbidity summer (0-300 JTU)	75	1.00	repro	0.78
V7*	Max summer temp (adult) (0-40 C)	26	1.00		
V8	Max spring temp (spawning) (0-40 C)	25	0.60	HSI	0.80
V9	Max summer temp pools (j & f) (0-40 C)	31	0.88		
V10	Max depth pools spawning (0-2 m)	1.5	0.70		
V12	Min D.O. (midsummer) (0-8 mg/l)	6	1.00		
V13	Min D.O. (march-june) (0-10 mg/l)	8	0.88		
V14	min pH (1-11)	7	1.00		
V14	max pH (1-11)	8.5	0.60		

HSI 0.80

Variable descriptions

- V1 Percent vegetative cover in shallow areas during the spring and summer.
- V2 Percent cover in pools such as logs, brush, submerged objects, and depth.
- V3 Percent pools, backwaters, and marsh areas during average summer flow.
- V6 Maximum monthly average turbidity during average summer flow.
- V7 Maximum midsummer water temperature.
- V8 Average water temperatures during spawning within specified areas (embryo, in spring).
- V9 Maximum midsummer water temperature in pools, backwaters, or littoral areas (juv or fry, in summer).
- V10 Maximum depth of pools, marshes, and backwaters during spawning.
- V12 Minimum dissolved oxygen during midsummer.
- V13 Minimum dissolved oxygen levels within specified areas during spawning (March-June).
- V14 Minimum and maximum pH during the year.

* Critical or binding habitat variables

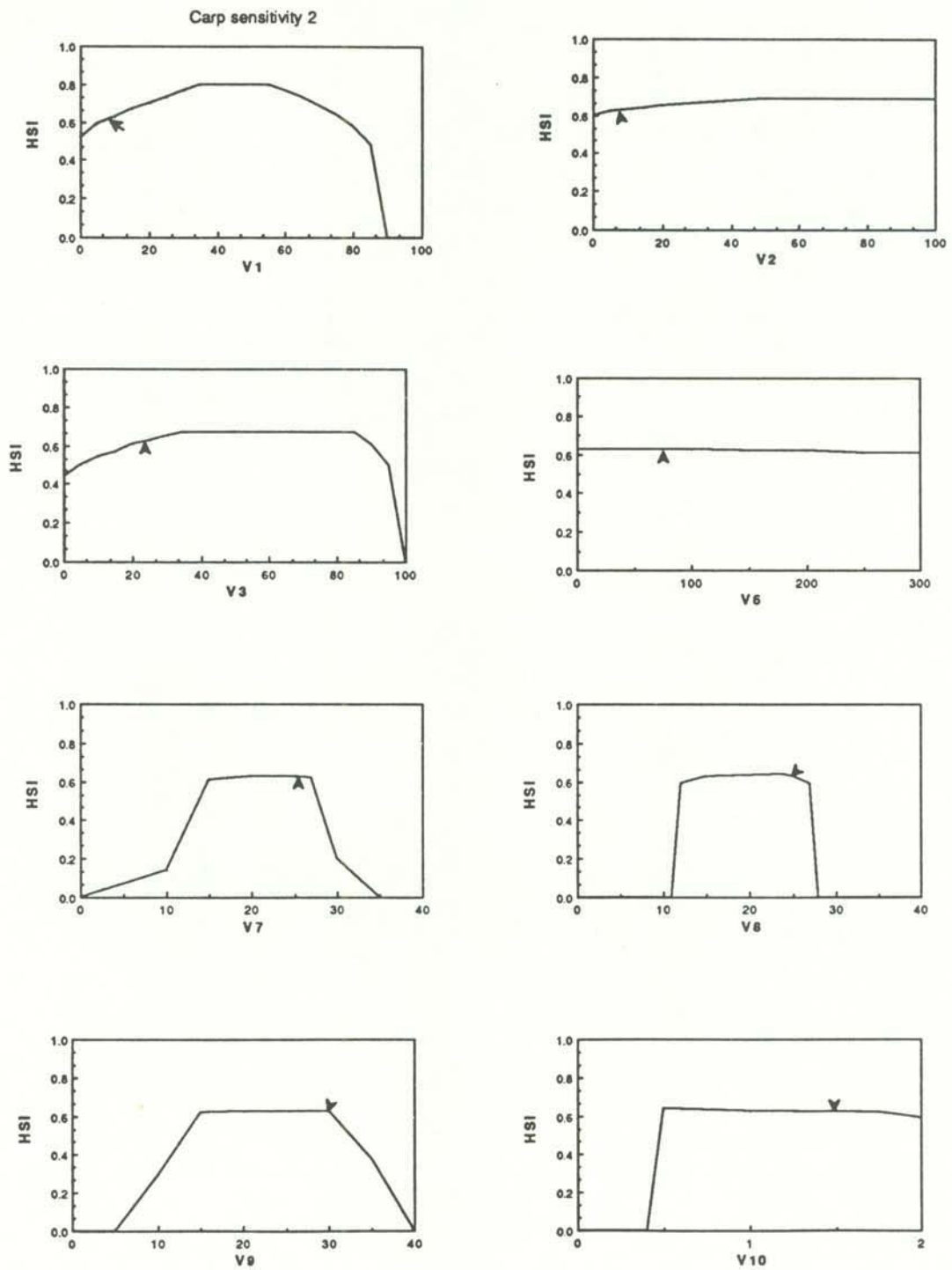


Figure 4.7.3 Sensitivity analysis for Common Carp in Embarras River. This presents the second iteration of sensitivity. Arrows depict the current level for each habitat variable.

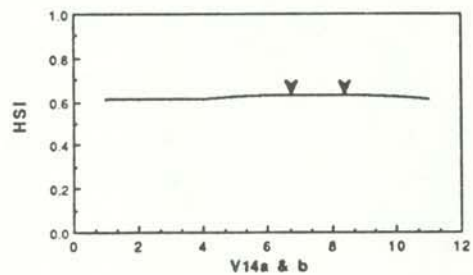
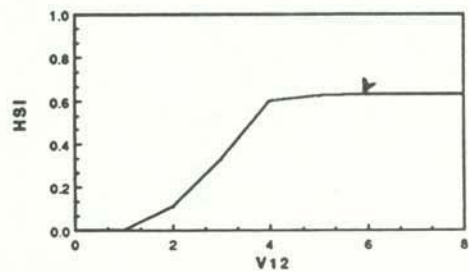
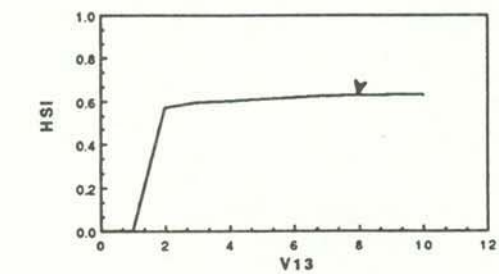


Figure 4.7.3 continued.

Table 4.7.4. Effect of habitat improvements on baseline HSI for Embarras River.

Species	1st Iteration		2nd Iteration	
	Initial HSI	Improved Variable	Improved Variable	New HSI
Carp	0.16	V7 max summer temp from 31 to 25%	V1 % veg cover in shallows from 10 to 35%	0.80
Green sunfish	0.76	V2 % pools from 25 to 50% or V1 % bottom cover from 10 to 35%	both V1 and V2 improved	0.96
Largemouth bass	0.5	V1 % pools from 25 to 60%	V3 % cover pools from 10 to 40%	0.76
Smallmouth buffalo	0.24	V10 Avg current vel summer from 15 to 25 cm/s	V15 % veg cover pools spring from 10 to 40%	0.83
Channel catfish	0.64	V2 % cover pools summer from 10 to 40%	V4 Substrate type from fines to rubble dominant	0.91
Warmouth	0.08	V1 % pools summer from 25 to 90%	V2 % bottom cover pools from 10 to 50%	0.95
Black bullhead	0.63	V1 % pools from 25 to 50% or V2 % cover pools from 10 to 30%	both V1 and V2 improved	0.92

The first iteration of the sensitivity analysis indicates that three variables (V1, V2, and V10) are binding, but only two will provide an increase in HSI. The remaining variable, while not optimal, is non-binding for this solution set. The HSI increased from 0.76 to 0.87 as V2 (% pool area during average summer flow) is increased from 25 to 50%. Increasing V1 (% bottom cover in pools or littoral areas) from 10% to 35% produces similar results. A second iteration indicates an increase in HSI from 0.87 to 0.96 as V1 or V2 are changed. Additional iterations produce no major change. Modification of only two habitat variables, percent pools and percent cover in pools, resulted in the improvement in habitat for Green sunfish.

Largemouth Bass

Largemouth bass were represented in moderate numbers in the Middlefork, but only one specimen, a juvenile, was collected from Farm Creek. Thirteen specimens, all fry and juveniles, were collected in the Embarras. Largemouth bass are known to be present in low order systems, but not in abundance. Historical records indicate that Largemouth bass have regularly been collected in the Embarras.

Largemouth bass are most often found in lacustrine habitats, but it is not unusual for them to occur in riverine habitats. Optimal riverine habitat is characterized by large, slow moving rivers, large deep pools, soft bottoms, some aquatic vegetation, and relatively clear water (Larimore and Smith 1963). Low order streams are generally poor habitat. Largemouth bass have a low tolerance for low dissolved oxygen, but are quite adaptable to high temperatures.

The HSI model for the Largemouth bass consists of twenty parameters. Eleven of the twenty parameters produce sub-optimal suitability values using Embarras conditions, while nine suitabilities are near optimal. An HSI of 0.50 suggests this reach of the Embarras provides only moderately suitable habitat conditions.

The first iteration of the sensitivity analysis indicates that five variables (V1, V3, V4, V9, and V21) are binding, but only three will provide a major increase in the HSI. The remaining six variables, while not optimal, are non-binding for this solution set. The HSI increases from 0.50 to 0.68 as V1 (% pools and backwater areas during average summer flow) is increased from 25% to 60%. A second iteration produced an increase in HSI from 0.68 to 0.76 as V3 (% bottom cover such as aquatic vegetation, brush, logs, and debris, during summer in pools, backwaters or littoral areas) is increased from 10% to 40%. A third iteration increases the HSI to 0.87 as V21 (average current velocity during the summer) is reduced from 3 to 0.5 cm/s. Additional iterations produce no major change. Modification of only two or three habitat variables, percent pools and percent cover in pools, resulted in an improvement in habitat for the largemouth bass.

Smallmouth Buffalo

No Smallmouth buffalo were collected in this study and historical data does not indicate their occurrence in Champaign County. The species does occur in downstream areas of the Embarras and has the potential of occurring in upstream areas. The HSI model for the Smallmouth buffalo was selected for analysis because it provides an example of a "management driven" HSI model application. Using the same analysis techniques on management species allows identification of critical habitat parameters and assessment of habitat management potential.

Smallmouth buffalo typically inhabit large rivers, preferring deep riffles and runs with a current. The species is sometimes found in upstream headwaters of large reservoirs. They prefer firm bottom substrates, tolerate turbid waters and high temperatures.

The HSI model for the Smallmouth buffalo uses twelve parameters. Six of these twelve parameters show sub-optimal suitability using Embarras conditions, while six parameters indicate near optimal conditions. An HSI of 0.24 suggests this reach does not provide suitable habitat. This result is supported by field observations.

The first iteration of the sensitivity analysis indicates that only one sub-optimal variable (V1) is binding. The remaining five sub-optimal variables are non-binding for this solution set. HSI increases from 0.24 to 0.40 as V10 (average current velocity in summer) is increased from 15 to 25 cm/s. A second iteration identifies V15 (percent vegetative cover in pools during spring) as the only binding variable. Raising V15 from 10% to 40% increases the HSI from 0.40 to 0.83. Additional iterations produced no major change. Modification of only two habitat variables, average current velocity and percent cover in pools, resulted in an improvement in habitat for the smallmouth buffalo.

Channel Catfish

Channel catfish were not collected from the Embarras or Farm Creek during this study. One specimen was collected from the Middlefork River. This species has been identified in both basins in historical records, although not in large numbers. Channel catfish may be more abundant than is evident from fisheries collections, as sampling techniques are generally inefficient in collecting this species.

Channel catfish prefer clear, fast flowing streams with sand, gravel, or rubble substrates. During the day adults frequent large pools near cover. At night they frequent deep riffles for feeding. Spawning is dependent on suitable nesting cover, usually submerged structures or undercut banks. Deep pools and littoral areas with greater than 40% cover provide optimal habitat. The species is tolerant of warm temperatures and silt.

The HSI model for Channel catfish uses thirteen habitat parameters. Seven of these parameters indicate Embarras conditions produce sub-optimal habitat. An HSI of 0.64 suggests this reach of the Embarras provides moderately suitable habitat.

The first iteration of the sensitivity analysis indicate that four variables (V1, V2, V4, and V8) are binding, but only two will produce a major increase in HSI. The remaining three variables, while not optimal, are non-binding for this solution set. HSI increases from 0.64 to 0.84 as V2 (% cover such as logs, boulders, cavities, brush, debris, or standing timber during summer in pools, backwaters or littoral areas) is increased from 10% to 40%. Results from the second iteration indicate an increase in HSI from 0.84 to 0.91 as V4 (substrate type during average summer flow) is changed from fines and silt dominant to cobble and rock dominant. Additional iterations produce no major change. Modification of only two habitat variables, percent pools and dominant substrate type, resulted in an improvement in habitat for Channel catfish.

Warmouth

No Warmouth were collected in this study. This species was once abundant throughout Illinois, however depletion of dense cover has contributed to its sparse appearance in recent collections. The Warmouth model was included in this study to demonstrate the potential for improving habitat conditions for a diminished species. Also, both the Smallmouth buffalo and the Warmouth model were chosen to provide an example of "management driven" HSI application in which critical habitat parameters are identified and management potentials assessed.

Larimore (1957) provides a detailed ecological life history of the Warmouth in Illinois. Warmouth occur in waters having little or no gradient and current, soft substrates, and abundant vegetation. The species tends to congregate in weedy and stump-filled waters where brush and roots abound. It has a greater tolerance of turbid waters and low dissolved oxygen than most sunfish.

The HSI model for the Warmouth is a descriptive model in which the most limiting habitat parameter is used to determine the final suitability index. All sub-optimal habitat parameters will be binding in this model. The model uses twelve habitat parameters. For the Embarras site, only two parameters are sub-optimal while ten are optimal. An HSI of 0.08 suggests that this reach of the Embarras provides a highly unsuitable habitat for the Warmouth. This conclusion is further supported by field observations.

A sensitivity analysis was not required for this model. The first binding variable was V1 (% pool area during average summer flows). Increasing this from 25 to 90% increased the HSI from 0.08 to 0.30. Increasing V2, percent cover in pools from 10 to 40%, raised the HSI from 0.30 to 0.95. Additional iterations produce no major change. Modification of only two habitat variables, percent pools and percent cover in pools, resulted in an improvement in habitat for the Warmouth.

Black Bullhead

Both Black bullhead and Yellow bullhead were commonly collected from Farm Creek, Middlefork, and the Embarras. In all cases the Yellow bullhead predominated in both abundance and occurrence. Adults were collected in all seasons. Spawning success was evident as schools of fry were often observed in deep pools during the summer. Adult bullheads were concentrated in isolated pools as waters receded during summer drought. Condition factors during this period were relatively high, as this piscivore voraciously consumed entrapped schools of minnows. Nearly all fish captured were engorged with such forage. Historical records note that these fish have always been common.

Bullheads are noted for their tolerance to high temperatures, turbidity, pollution, and low dissolved oxygen. They are most often found in shallow, silty water of low gradient and sluggish creeks and rivers. The Black bullhead does not require vegetation nor prefer rocky or sandy bottoms. The Yellow bullhead, however, prefers heavily vegetated areas and permanently flowing waters with a rocky substrate.

The HSI model for the Black bullhead uses twelve habitat parameters. Only five of the twelve parameters produce sub-optimal suitability using Embarras conditions, while seven are optimal. An HSI of 0.63 suggests this reach of the Embarras provides a moderately suitable habitat. This conclusion is further supported by field observations as Yellow bullhead were routinely collected throughout the sampling season.

The first iteration of the sensitivity analysis indicates that three variables (V1,V2, and V12) are binding, but only two produce a major increase in HSI. The remaining two variables, while not optimal, are non-binding for this solution set. HSI increases from 0.63 to 0.76 as V2 (% cover such as vegetation, brush, debris, during summer in pools, backwaters or littoral areas) is increased from 10% to 30%. Increasing V1 (percent pools and backwater areas during average summer flows) from 25% to 50% produces the same results. A second iteration indicates an increase in HSI from 0.76 to 0.92 as V1 or V2 is improved. Additional iterations produce no major change. Modification of only two habitat variables, percent pools and percent cover in pools, resulted in an improvement in habitat for Black bullhead.

4.8 Evaluation of Management Alternatives

4.8.1 Introduction

In this section we address how different management options will affect each habitat parameter, the life requisites, and the HSI for each species. With this information different management alternatives are evaluated for their net impact on habitat quality and the fishery.

Three general management options are evaluated; an increase or improvement of riparian vegetation (I), instream cover (II), and number or depth of pools (III). These general management categories have been selected because they include available techniques for habitat restoration (Item II) and procedures which can be modified by a change in drainage district maintenance practices (Items I and III). Each option has been related to HSI model parameters and would mitigate one or more of the critical limiting factors identified in the sensitivity analysis.

The following procedure was used to evaluate options. The results from the sensitivity analysis described in Section 4.7 were used to identify the individual habitat parameters affected by Management Option I, II, or III and the direction of the effect. The selected habitat parameters were then adjusted to reflect a feasible level of implementation of the management option. The new HSI was then calculated. These results are summarized in Tables 4.8.1, 4.8.2, and 4.8.3 which identifies the effect of each management option on individual habitat parameters and on the HSI for each of seven fish species in the Embarras River. The +, -, and O symbols indicate a positive, negative, or no effect for the change in parameters resulting from implementing each option.

4.8.2 Management Option I (Riparian Vegetation)

Many direct and indirect impacts on stream habitat have been linked to the establishment of riparian vegetation. Nearstream and bankside vegetation affect both channel morphology and water quality. Shoreline vegetation provides for bank stabilization by providing a physical barrier to the effects of high velocities and turbulence (Beschta and Platts 1986). Woody debris, overhanging tree limbs, and exposed root systems not only are important determinants of channel morphometry, but also provide physical cover for fish (Schlosser and Karr 1981). Vegetation also contributes to fish productivity through input of organic materials and nutrients, which are utilized by stream biota. Riparian vegetation provides shade cover which often affects fish distribution, as some species are more sensitive to light stimuli than others. Many species identified in this study tend to seek out areas of low intensity light, and therefore prefer dense cover or shade. The intensity of illumination also has a considerable effect on algal growth and on water temperature; both notably reduced in a shaded stream. Significant reductions in water temperature (19 C vs 28 C) have been noted in low order streams in highly vegetated areas as compared to unshaded reaches (Karr and Schlosser 1978). Hughes (1966) reported differences of 3 C between shaded and unshaded reaches of a small stream. During the peak of summer drought in 1988, shaded reaches on the Embarras were lower (88 F) than nearby unshaded areas (94 F).

Table 4.8.1. Comparison of Management Option I (Riparian Vegetation) for seven fish species.*										
Habitat Variables	Current		New **		Species					
	Value		Value		CC	Carp	Bull	LMB	SB	GS
% pools & backwater (0-100%)					0	0	0	0	0	0
% bottom cover pools adults (0-100%)					0	0	0	0	0	0
Min DO pools summer (menu 1-4)					0	0	0	0	0	0
pH (menu 1-3)					0	0	0	0	0	0
Mean/Max temp pools summer (0-40 C)	30 C	26 C			+	+	+	0	+	+
Mean/Max temp pools spring (0-30 C)	25 C	21 C			-	+	-	+	+	0
Max monthly avg turbidity (menu 1-3)					0	0	0	0	0	0
Max salinity summer (0-24 ppt)					0		0	0		
Max salinity spring (0-12 ppt)					0		0	0		
Dominant substrate pools (menu 1-4)					0		0	0		0
Avg water level fluc summer adult (-5 to 5 m)								0		
Max water level fluc spring embryo (-10 to 10 m)								0		
Avg vel 0.6 depth summer (0-20 cm/s)					0		0	0	0	0
Max vel pools 0.8 depth spring (0-10 cm/s)					0			0	0	0
Gradient (0-4 m/km)								0		0
% veg cover shallows (0-100%)						0				
% veg cover pools (0-100%)										
Max depth pools (0-2 meters)						0				
Stream width (0-60 m)									0	0
Current HSI					0.64	0.16	0.63	0.5	0.24	0.76
New HSI					0.61	0.65	0.65	0.51	0.4	0.78
* blanks indicate that variables do not appear in model for that species										
** new values for habitat variables are only noted for variables producing a change in HSI										

Table 4.8.2. Comparison of Management Option II (Instream Cover) for seven fish species. *												
Habitat Variables	Current	New**	Species					LMB	SB	GB	War	
	Value	Value	CC	Carp	Bull							
% pools & backwater (0-100%)			0	0	0			0	0	0	0	
% bottom cover pools adults (0-100%)	10%	25%	+	+	+			+		+	+	
Min DO pools summer (menu 1-4)			0	0	0			0	0	0	0	
pH (menu 1-3)				0	0			0	0	0	0	
Mean/Max temp pools summer (0-40 C)			0	0	0			0	0	0	0	
Mean/Max temp pools spring (0-30 C)			0	0	0			0	0	0	0	
Max monthly avg turbidity (menu 1-3)			0	0	0			0	0	0	0	
Max salinity summer (0-24 ppt)			0		0			0				
Max salinity spring (0-12 ppt)			0		0			0				
Dominant substrate pools (menu 1-4)			0		0			0		0		
Avg water level fluc summer adult (-5 to 5 m)								0				
Max water level fluc spring embryo (-10 to 10 m)								0				
Avg vel 0.6 depth summer (0-20 cm/s)	20	10			+			+	-		0	
Max vel pools 0.8 depth spring (0-10 cm/s)			0					0	0	0		
Gradient (0-4 m/km)								0		0	0	
% veg cover shallows (0-100%)	10%	25%		0							+	
% veg cover pools (0-100%)	10%	25%							+		+	
Max depth pools (0-2 meters)				0								
Stream width (0-60 m)									0	0		
Current HSI			0.64	0.16	0.63	0.5	0.24	0.76	0.08			
New HSI			0.76	0.16	0.66	0.56	0.15	0.82	0.08			
* blanks indicate that variables do not appear in model for that species												
** new values for habitat variables are only noted for variables producing a change in HSI												

Table 4.8.3. Comparison of Management Option III (Increase No/Depth of Pools) for seven fish species. *											
Habitat Variables	Current Value	New ** Value	Species				Bull	LMB	SB	G6	War
			CC	Carp							
% pools & backwater (0-100%)	25%	40%	+	+			+	+	0	+	+
% bottom cover pools adults (0-100%)			0	0			0	0		0	0
Min DO pools summer (menu 1-4)			0	0			0	0	0	0	0
pH (menu 1-3)				0			0	0	0	0	0
Mean/Max temp pools summer (0-40 C)	30 C	26 C	+	+			+	0	+	+	0
Mean/Max temp pools spring (0-30 C)	25 C	21 C	-	+			-	+	+	0	0
Max monthly avg turbidity (menu 1-3)			0	0			0	0	0	0	0
Max salinity summer (0-24 ppt)			0				0	0			
Max salinity spring (0-12 ppt)			0				0	0			
Dominant substrate pools (menu 1-4)			0				0	0		0	
Avg water level fluc summer adult (-5 to 5 m)								0			
Max water level fluc spring embryo (-10 to 10 m)								0			
Avg vel 0.6 depth summer (0-20 cm/s)	20	10					+	+	-		0
Max vel pools 0.8 depth spring (0-10 cm/s)			0				0	0	0	0	
Gradient (0-4 m/km)								0		0	0
% veg cover shallows (0-100%)				0							0
% veg cover pools (0-100%)									0		0
Max depth pools (0-2 meters)	1.0 m	2.0 m		-							
Stream width (0-60 m)									0	0	
Current HSI			0.64	0.16			0.63	0.5	0.24	0.76	0.08
New HSI			0.63	0.65			0.74	0.62	0.15	0.85	0.23
* blanks indicate that variables do not appear in model for that species											
** new values for habitat variables are only noted for variables producing a change in HSI											

For the purposes of this analysis the principle benefit derived from enhancing riparian vegetation is shade cover and overhead cover which reduces instream water temperature. While the establishment of riparian vegetation often accompanies changes in stream structure and water quality, we assume no other changes in physical habitat in the evaluation of this option.

The sensitivity analysis indicated that implementing Option I affects only two sub-optimal habitat components for six of seven species; (1) maximum summer temperature, and (2) maximum spring temperature (Table 4.8.1). The Warmouth is not affected, since temperature is not a limiting habitat component for this species. Positive effects (+) were generally noted, however, carp and bullhead were negatively affected (-) by the decrease in maximum spring temperature associated with this option.

For Option I, it was estimated that strategic placement of vegetative shade would reduce maximum summer temperatures in pools from 30 C to 26 C, and reduce early spring temperatures from 25 C to 21 C. Increasing riparian vegetation improved habitat conditions for only two of seven species, the Carp and Smallmouth buffalo. The HSI for Carp increased from 0.16 to 0.65 and for Smallmouth buffalo from 0.24 to 0.40. With an HSI of 0.40, Smallmouth buffalo habitat remained highly unsuitable. Thus, implementation of this management option would only improve conditions for one species, the Carp.

The HSI models indicate that the fishery response to reducing stream temperature is minimal. The species selected, which are adapted to the warm water temperatures prevalent in these drainage systems, derive little benefit from slightly reduced temperatures. It should be noted, however, the temperatures observed in the Embarras River and Farm Creek do approach the tolerance limit for many species. For example, an increase of 1-2 C (31-32 C maximum temperature), greatly reduce the HSI for five of seven species. By reducing stream temperature, greater improvements in habitat suitability may be achieved than is indicated by the model results. The advantages of reduced stream temperatures, particularly in conjunction with the implementation of other management options, should be further explored.

Literature linking the effectiveness of riparian vegetation and riparian buffer strips in controlling stream temperature is available (Hewlett and Fortson 1982, Brown and Krygier 1970, Lee and Samuel 1976, and Barton and Taylor 1985), however, most studies concentrate on the effect on coldwater streams; trout streams in particular. The literature for midwestern warmwater streams is sparse. Barton and Taylor (1985) provides an excellent example of the importance of riparian buffer strips in the maintenance of cold water fisheries. He presents three regression models which relate maximum summer temperatures to riparian buffer strip length, width, and percent forested cover. This information provides a basis for evaluating the effectiveness of riparian patches or buffer zones in modifying stream temperatures.

4.8.3 Management Option II (Instream Cover)

Wesche (1985) defines in-stream cover for fish as areas which provide protection from the effects of high current velocities and predation. Cover may be divided into two categories; overhead cover and submerged cover. Overhead cover is provided by overhanging vegetation (trees or grasses), suspended logs, and undercut banks. Submerged or instream cover can be provided by aquatic vegetation, submerged objects or structures, floating debris, and water turbulence. Fish production in streams and the structure and function of the fishery community is closely associated with appropriate instream cover (Gorman and Karr 1978). Gore (1985) provides a review of the importance of cover elements to the enhancement of cold water fish populations. Similar relationships are identified for woody instream cover in a small warmwater Illinois stream (Angermeier and Karr 1984). Both Angermeier and Karr (1984) and Fraser and Cerri (1982) have linked the presence of predator and prey species in headwater streams to the structural complexity of habitat and cover components. Instream structure is important because it modifies the interaction of predator/prey communities. Prey species were less apt to avoid areas that contained predators if instream structural complexity was high.

For the purposes of this analysis, Option II includes only the enhancement of instream submerged cover and not overhead vegetative cover or structures. Submerged cover elements are exemplified by permanent, or non-permanent, woody or rock structures which modify velocity in the channel. It may also include submerged or emergent aquatic vegetation in shallows or pools. Our analysis assumes, from an engineering context, that these structural elements will have some effect on overall channel flow capacity and that they represent more or less permanent additions to the stream channel.

The sensitivity analysis indicated that implementing Option II affects four sub-optimal habitat components; (1) the percent bottom cover in pools, (2) average summer velocity, (3) percent vegetative cover in shallows, and (4) percent vegetative cover in pools (Table 4.8.2). Option II improved these habitat components (+) for all species except the Smallmouth buffalo. The Smallmouth buffalo was negatively affected (-) by the decrease in the average current velocity associated with this management option.

For Option II, it was estimated that the percent bottom cover and percent vegetative cover in pools and shallows could be increased from 10% to 25%. The average current velocity was reduced from 20 to 10 cm/s. As a result, the HSI improved for three species, the Channel catfish, Largemouth bass, and Green sunfish and decreased for one species, the Smallmouth buffalo. The HSI did not change for Carp, Bullhead, or Warmouth. Habitat for Carp would not improve unless summer temperature could be reduced; and for Warmouth there would be no improvement unless pool habitat was increased.

This management option is one that has been extensively explored in the literature (Wesche 1985 and Jackson 1986). Wesche (1985) describes a variety of engineered structures which have been implemented to enhance fish habitat. Additional considerations in planning, design, installation, and monitoring of projects utilizing instream structures are provided by Orsborn and Anderson (1986), and Shields (1983). The attractiveness of the demonstrated successes of this approach in agricultural drainage areas is diminished by the possible effect channel structures have on retarding flow and reducing the effectiveness of field drainage. Structural additions to a stream channel which do not have a significant effect on flow can be considered, but the literature dealing with this area is limited.

4.8.4 Management Option III (Increase Number/Depth of Pools)

Pools are a notable morphological feature of most stream channels, varying in shape, size, and causative factors. These deepened portions of the channel are generally distinguished by relative depth, average current velocity, and substrate type. They are an integral component in maintaining balanced fluvial dynamics in stream systems. The detailed morphology of pools and the fluvial processes which create and maintain pool structure are covered in detail in Jackson (1986), and Wesche (1985).

Pools are of major importance to fish during low flows when much of the stream's total water volume may reside in pools (Beschta and Platts 1986). Paloumpis (1958) considered deep pools to serve as stream havens during drought. The structure of fish populations during adverse conditions is often possible because certain rather limited habitats remain, even during the most serious catastrophes. This phenomenon was observed by Larimore et. al. (1959) and during this study in both Farm Creek and the Embarras River. Remnant fish populations were sustained in deep pools even during extended periods of no flow in 1988. Pools of adequate depth, however, are not characteristic of our study reaches. Only a few deep pools were identified in the Embarras during low flow periods, however, shallow pools periodically occurred throughout each site (Tables 2.3a-b). Extensive sections of highly vegetated areas had no defined pools during the survey.

High quality pools alone, however, do not make the fishery. A variation in pool shapes, sizes, and quality are required to support a diverse fish community, support fish at different stages of maturity, and provide a range of habitats during different flows. In Illinois, Schlosser (1982a,b) identified that shallow and slow habitat was used by small, young fish of several species, while deep areas were primarily inhabited by larger, older fish. This observation was further supported in this study; most larger fish were captured in the deepest pools. Additional studies have found water depth and current velocity to be the most important habitat variable affecting fish distribution (Sheldon 1968, Gorman and Karr 1978). Fish production in streams has also been closely associated with riffle-pool periodicity (Wesche 1985).

For the purpose of this analysis, Option III assumes an increase in the percent of high quality pools. Further improvement in habitat conditions are assumed if pools are deep enough to provide areas of reduced summer temperatures. When considering this option the objective would be to deepen existing pools to produce preferred habitat for fisheries. It would not involve the addition of above grade structural elements but would involve creation of deeper pools during maintenance activities.

The sensitivity analysis indicated that implementing Option III affects five sub-optimal habitat components; (1) percent pools, (2) the maximum temperature in pools in spring, (3) maximum summer temperature, (4) average summer velocity, and (5) maximum depth of pools (Table 4.8.3). The percent pools and maximum depth would increase, spring and summer temperatures decrease, and average current velocity would decrease. Improvements (+) in the individual habitat components were noted for most species, but negative effects (-) did occur. For example the Smallmouth buffalo is negatively affected by a decrease in the average current velocity, as it prefers swift currents. Bullhead and Channel catfish are negatively affected because they require warmer waters in early spring for spawning.

For Option III, it was estimated that the percent pools could reasonably be increased from 25% to 40%, maximum depth of pools increased from one to two meters, the average velocity reduced from 20 to 10 cm/s, maximum summer temperatures of pools reduced from 30 C to 26 C, and maximum spring temperatures reduced from 25 C to 21 C. As a result, the HSI improved for five of seven species. The HSI for Smallmouth buffalo decreased and Channel catfish remained the same. Habitat conditions remained highly unsuitable for Smallmouth buffalo and Warmouth which only attained an HSI of 0.15 and 0.23, respectively.

This management option is attractive because it does not impede flow and can be implemented by minor changes in present drainage district maintenance activities. This option requires some sensitivity to the geomorphic process of these channels. The geomorphic design element is important in order to promote development of a normal pool riffle sequence. The critical design parameter will be location and sequencing of pools to minimize sedimentation or filling. One method of design for pools would be a simple channel survey, similar to that conducted as a part of this research (Tables 2.3a,b), which identifies existing pools at low flow. The assumption in this process is that natural stream flow conditions maintain pools at these locations and depth conditions could be enhanced during maintenance with an expectation of permanence.

Literature on riffle-pool spacing, average depths, widths, and current velocities are available for headwater streams in Illinois. Singh et. al. (1986) collected field measurements to determine depths and velocities occurring through typical riffle-pool sequences in the Sangamon River Basin, Illinois. Relationships defining expected depth and velocity distributions through riffle-pool sequences over a range of flows were then developed from the field data. Singh's results present a basis for some of the practices which could be used to select pool-riffle sequencing designs in agricultural drainage systems.

4.8.5 Management Conclusions

For the existent habitat conditions on the Embarras River the HSI has been calculated and a sensitivity analysis performed for Channel catfish, Carp, Black Bullhead, Largemouth bass, Smallmouth buffalo, Warmouth, and Green sunfish. In all cases the HSI value appears reasonable for the Embarras river. For each species the most sensitive habitat components have been determined. In most cases an improvement in only two to three habitat components will provide an optimal HSI. A noted improvement in HSI can be acquired by a nominal increase in only one or two habitat components.

The limiting habitat components differ for each species, however a critical habitat component for many species is the percent cover represented by deep pools during the summer. Specifically, catfish are limited by percent pools and substrate type, Carp by summer temperatures and vegetative cover in shallows, Black bullhead by percent pools and physical cover in pools, Largemouth bass by percent pools and summer current velocities, Smallmouth buffalo by summer current velocity and vegetative cover in deep pools in spring, and Green sunfish and Warmouth by percent pools and physical bottom cover in pools in summer. These critical habitat components must be addressed in management plans.

Three general management options have been evaluated for their relative effect on habitat quality for seven fish species. The management categories selected for analysis using HSI models include 1) an increase in riparian vegetation 2) an increase in instream cover structures, and 3) an increase in number or depth of pools. The effect on individual habitat components and overall HSI has been determined. Increasing riparian vegetation improved habitat conditions for only two of seven species, the Carp and Smallmouth buffalo (Table 4.8.4). Smallmouth buffalo habitat, however, remained highly unsuitable. Increasing stream cover improved habitat conditions for three species, the Channel catfish, Largemouth bass, and Green sunfish and decreased habitat for one species, the Smallmouth buffalo. Increasing the number or depth of pools proved to be the most effective management option as it improved habitat conditions for five of seven species. Smallmouth buffalo habitat was reduced and Channel Catfish habitat did not change.

Of the three options evaluated, the most critical need is an increase in high quality pool habitats. For any single management option, the greatest benefit to the fishery is achieved by providing improved pool depth, followed by improved instream cover, and finally improved riparian vegetation. The most effective management option is also highly desirable because it can be implemented by minor changes in present drainage district maintenance activities.

Table 4.8.4. Improvement in HSI for three management options.

Management Options	Species					
	Channel catfish	Carp	Black bullhead	Largemouth bass	Green sunfish	Smallmouth buffalo Warmouth
I Riparian Vegetation	0	+	0	0	0	0
II Instream Cover	+	0	0	+	+	0
III Increase No/Depth pools	0	+	+	+	+	+

5. GENERAL CONCLUSIONS

This study was undertaken to explore options for the improvement of environmental quality in agricultural drainage systems. The focus of this analysis was stream fisheries. Our goal was to improve the management of agricultural drainage systems through an improved understanding of the type and quantity of habitat required for maintenance of high quality fisheries and aquatic resources.

We found that fisheries quality, under existing conditions is good. Both the Middlefork study site and study sites on the Embarras River have well developed fisheries communities with good quality. Through use of Habitat Suitability Index models the research was able to identify critical habitat parameters which, if changed, would be expected to improve conditions for individual species and correspondingly, overall environmental quality. This information was used in conjunction with field observations and a review of existing engineering practices of drainage system maintenance to identify management options for agricultural drainage system improvement.

An evaluation of management options suggests the most critical need is for improved pool depth. The greatest improvement in habitat conditions were identified when pool habitats were improved. It is possible to envision a change in existing drainage district maintenance activities to meet the requirements of this management option. When existing ditches are maintained, it would be possible to create pools in the channel bottom. Spacing and location of pools can be established from simple field surveys of existing pool riffle conditions at low flow.

A second management option, adding structure to the stream channel also improved general habitat conditions. This option is less attractive in agricultural drainage systems due to the potential for interference with flow and the effects backwater stage elevations may have on tile drainage. Nonetheless, this option should be explored when habitat enhancement procedures are being selected.

A third option, riparian vegetation, had a minimal effect on general habitat conditions. Habitat enhancement associated with the reduced water temperatures reflected by this option should be further explored; particularly when used in conjunction with another management procedure which mitigates other critical habitat components.

APPENDICES I, II, III, IV, V

APPENDIX I

Historical Fisheries Data Tables for Middlefork and Embarras Rivers

Appendix I, Table 1. Historical Fisheries Middlefork River, Champaign County						
Species	Middlefork Cumtiv to 1959	Middlefork Cumtiv to 1988	Middlefork Larimore 1959	Middlefork this study 1987/88	Middlefork Lapinot (DOC) 1962	
1 Longnose gar	x	x	x			
2 Gizzard shad		x		x		
3 Grass pickerel		x		x		x
4 Carp	x	x	x	x		
5 Golden shiner	x	x	x	x		
6 Creek chub	x	x	x	x		
7 Hornyhead chub	x	x	x			
8 Bigeye chub	x	x				
9 Silver chub	x	x				
10 Suckermouth minnow	x	x	x	x		
11 Emerald shiner						
12 Bigeye shiner	x	x				
13 Striped shiner	x	x	x	x		
14 Bigmouth shiner	x	x	x			
15 Red shiner		x		x		
16 Rosyface shiner	x	x	x			
17 Spottin shiner	x	x	x	x		x
18 Sand shiner	x	x	x	x		
19 Mimic shiner	x	x	x			
20 Steelcolor shiner	x	x	x			x
21 Redfin shiner	x	x	x			
22 Silverjaw minnow	x	x	x	x		
23 Silvery minnow	x	x				
24 Bluntnose minnow	x	x	x	x		x
25 Common stoneroller	x	x	x	x		
26 River carpsucker		x		x		
27 Ouilback carpsucker	x	x	x	x		
28 Highfin carpsucker	x	x	x	x		
29 Silver redbhorse		x		x		
30 Golden redbhorse	x	x	x	x		x
31 Shorthead redbhorse		x		x		
32 Northern hog sucker	x	x	x	x		x
33 White sucker	x	x	x	x		x
34 Spotted sucker	x	x				
35 Creek chubsucker	x	x	x	x		x
36 Black bullhead	x	x	x	x		x
37 Yellow bullhead	x	x	x	x		
38 Channel catfish	x	x	x	x		
39 Flathead catfish	x	x	x			
40 Slender madtom	x	x				
41 Stonecat	x	x	x	x		
42 Brindled madtom	x	x	x			
43 Pirate perch						
44 Blackstripe topminnow	x	x	x	x		x
45 Smallmouth bass	x	x	x	x		x
46 Spotted bass	x	x	x			x
47 Largemouth bass	x	x	x	x		
48 Green sunfish	x	x	x	x		x
49 Orangespotted sunfish	x	x	x			x
50 Bluegill		x		x		
51 Longear sunfish	x	x	x	x		x
52 Rock bass	x	x	x	x		x
53 White crappie	x	x	x			x
54 Logperch	x	x	x			
55 Blackside darter	x	x	x	x		
56 Slenderhead darter	x	x	x			
57 Dusky darter	x	x	x	x		
58 Eastern sand darter	x	x	x			
59 Greensided darter	x	x	x	x		
60 Rainbow darter	x	x	x			
61 Fantail darter	x	x	x			
62 Johnny darter	x	x	x	x		
63 Orangefthroat darter	x	x	x			
Number species	54	61	48	39	17	plus

Appendix I, Table 2. Historical Fisheries Embarras River, Champaign County.					
Species	Embarras	Embarras	Embarras	Embarras	
	Cumtiv to	Cumtiv to	Lerimore	this study	
	1959	1988	1959	1987/88	
	Champaign Co	Champaign Co	Champaign Co	Champaign Co	
1 Longnose gar					
2 Gizzard shad	x	x	x	x	
3 Grass pickerel	x	x	x	x	
4 Carp	x	x	x	x	
5 Golden shiner	x	x	x	x	
6 Creek chub	x	x	x	x	
7 Hornyhead chub		x		x	
8 Bigeye chub	x	x			
9 Silver chub					
10 Suckermouth minnow	x	x	x	x	
11 Emerald shiner	x	x	x	x	
12 Bigeye shiner					
13 Striped shiner	x	x	x	x	
14 Bignmouth shiner		x		x	
15 Red shiner		x		x	
16 Rosyface shiner					
17 Spottin shiner	x	x	x	x	
18 Sand shiner	x	x	x	x	
19 Mimic shiner					
20 Steelcolor shiner	x	x	x		
21 Redfin shiner	x	x	x	x	
22 Silverjaw minnow	x	x	x	x	
23 Silvery minnow					
24 Bluntnose minnow	x	x	x	x	
25 Common stoneroller	x	x	x	x	
26 River carpsucker		x		x	
27 Quillback carpsucker		x		x	
28 Highfin carpsucker		x		x	
29 Silver redborse					
30 Golden redborse	x	x	x	x	
31 Shorthead redborse		x		x	
32 Northern hog sucker	x	x	x	x	
33 White sucker	x	x	x	x	
34 Spotted sucker		x		x	
35 Creek chubsucker	x	x	x	x	
36 Black bullhead	x	x	x	x	
37 Yellow bullhead	x	x	x	x	
38 Channel catfish					
39 Flathead catfish					
40 Slender madtom		x		x	
41 Stonecat					
42 Brindled madtom	x	x	x	x	
43 Pirate perch	x	x	x		
44 Blackstripe topminnow	x	x	x	x	
45 Smallmouth bass					
46 Spotted bass					
47 Largemouth bass		x		x	
48 Green sunfish	x	x	x	x	
49 Orangespotted sunfish		x		x	
50 Bluegill		x		x	
51 Longear sunfish	x	x	x	x	
52 Rock bass					
53 White crappie	x	x		x	
54 Logperch	x	x	x		
55 Blackside darter	x	x	x	x	
56 Slenderhead darter					
57 Dusky darter		x		x	
58 Eastern sand darter					
59 Greensided darter	x	x	x	x	
60 Rainbow darter	x	x	x	x	
61 Fantail darter	x	x			
62 Johnny darter	x	x	x	x	
63 Orangethroat darter	x	x	x		
Number species	35	48	32	42	

Appendix I, Table 3. Historical Fisheries Vermilion River Watershed								
	Species	WOMIS	WOMIS	WOMIS	WOMIS	WOMIS	WOMIS	Vermil. Watershed
	Post 1965 data	Headwater	Creeks	Small stream	Large stream	Small river	total basin of Vermilion	DOC
		0-10 sq. mi	10-50 sq. mi	50-200 sq. mi	200-500	500-2000		1962
								18 stations
								Champaign Co.
1	Brook lamprey							
2	Longnose gar							
3	Shortnose gar							
4	Bowfin							
5	American eel							
6	Skipjack herring					X	X	
7	Gizzard shad	X	X		X	X	X	X
8	Goldfish							
9	Grass pickerel		X		X		X	X
10	Northern pike							
11	Carp	X	X		X		X	X
12	Golden shiner				X		X	X
13	Creek chub	X	X	X	X		X	X
14	Hornyhead chub		X				X	
15	Bigeye chub							
16	Silver chub							
17	Gravel chub							
18	Blacknose dace							X
19	Suckermouth minnow				X		X	X
20	Emerald shiner					X	X	
21	River shiner					X	X	
22	Bigeye shiner	X	X			X	X	
23	Striped shiner	X	X	X	X	X	X	X
24	Bigmouth shiner							
25	Ribbon shiner							
26	Red shiner	X			X		X	X
27	Rosyface shiner				X	X	X	
28	Spotfin shiner	X	X	X	X	X	X	X
29	Sand shiner	X	X	X	X	X	X	X
30	Mimic shiner							
31	Steelcolor shiner				X	X	X	
32	Redfin shiner	X	X	X	X		X	X
33	Silverjaw minnow	X	X	X	X	X	X	X
34	Silvery minnow							
35	Bluntnose minnow	X	X	X	X	X	X	X
36	Fathead minnow							
37	Bullhead minnow							
38	Common stoneroller	X	X	X	X	X	X	X
39	Bigmouth buffalo							
40	Black buffalo							
41	River carpsucker				X		X	
42	Ouillback carpsucker		X	X	X	X	X	X
43	Highfin carpsucker		X	X			X	
44	Silver redbhorse		X		X		X	
45	Golden redbhorse	X	X	X	X		X	X
46	Shorthead redbhorse		X				X	X
47	Northern hog sucker	X	X	X	X		X	X
48	White sucker	X	X	X	X		X	X
49	Spotted sucker	X	X		X		X	
50	Creek chubsucker	X	X		X		X	X
51	Black bullhead		X				X	X
52	Yellow bullhead	X	X		X		X	X
53	Channel catfish		X				X	X
54	Flathead catfish							
55	Slender madtom							
56	Stoneroller		X	X	X		X	X
57	Brindled madtom				X		X	
58	Freckled madtom							
59	Pirate perch							
60	Blackstripe topminnow	X	X	X	X		X	X
61	Mosquito fish							
62	Brook silverside		X		X		X	
63	Yellow bass							
64	Smallmouth bass	X	X		X	X	X	X
65	Spotted bass		X	X	X		X	X
66	Largemouth bass				X		X	X
67	Green sunfish	X	X		X	X	X	X
68	Warmouth				X		X	
69	Orangespotted sunfish		X		X		X	
70	Bluegill				X	X	X	X
71	Longear sunfish	X	X	X	X	X	X	X
72	Redear sunfish							
73	Rock bass		X		X	X	X	X
74	White crappie							
75	Black crappie							
76	Sauger							
77	Logperch		X		X		X	
78	Blackside darter	X	X	X	X		X	X
79	Slenderhead darter			X	X		X	
80	Dusky darter				X		X	X
81	Eastern sand darter							
82	Mud darter							
83	Greenside darter		X	X	X		X	X
84	Rainbow darter				X		X	X
85	Bluntnose darter							
86	Fantail darter				X		X	
87	Slough darter							
88	Harlequin darter							
89	Johnny darter	X	X	X	X		X	X
90	Orangethroat darter	X					X	
91	Freshwater drum							
	Number species	25	38	21	46	18	56	52
								39

Appendix I Table 3 continued Historical Fisheries Vermilion River Watershed				
Species	Commonly occurring	Cumulative to 1959	All studies	
Post 1965 data	species all dates	Middlefork Champaign Co	Total	
1 Brook lamprey				
2 Longnose gar	x	x	x	
3 Shortnose gar				
4 Bowfin				
5 American eel				
6 Skipjack herring			x	
7 Gizzard shad	x		x	
8 Goldeye				
9 Grass pickerel	x		x	
10 Northern pike				
11 Carp	x	x	x	
12 Golden shiner	x	x	x	
13 Creek chub	x	x	x	
14 Hornyhead chub	x	x	x	
15 Bigeye chub	x	x	x	
16 Silver chub		x	x	
17 Gravel chub				
18 Blacknose dace			x	
19 Suckermouth minnow	x	x	x	
20 Emerald shiner	x		x	
21 River shiner			x	
22 Bigeye shiner	x	x	x	
23 Striped shiner	x	x	x	
24 Bigmouth shiner		x	x	
25 Ribbon shiner				
26 Red shiner	x		x	
27 Rosyface shiner	x	x	x	
28 Spottfin shiner	x	x	x	
29 Sand shiner	x	x	x	
30 Mimic shiner		x	x	
31 Steelcolor shiner	x	x	x	
32 Redfin shiner	x	x	x	
33 Silverjaw minnow	x	x	x	
34 Silvery minnow	x	x	x	
35 Bluntnose minnow	x	x	x	
36 Fathead minnow				
37 Bullhead minnow				
38 Common stoneroller	x	x	x	
39 Bigmouth buffalo				
40 Black buffalo				
41 River carpsucker	x		x	
42 Quillback carpsucker	x	x	x	
43 Highfin carpsucker	x	x	x	
44 Silver redhorse	x		x	
45 Golden redhorse	x	x	x	
46 Shorthead redhorse	x		x	
47 Northern hog sucker	x	x	x	
48 White sucker	x	x	x	
49 Spotted sucker	x	x	x	
50 Creek chubsucker	x	x	x	
51 Black bullhead	x	x	x	
52 Yellow bullhead	x	x	x	
53 Channel catfish	x	x	x	
54 Flathead catfish	x	x	x	
55 Slender madtom		x	x	
56 Stonecat	x	x	x	
57 Brindled madtom	x	x	x	
58 Freckled madtom				
59 Pirate perch			x	
60 Blackstripe topminno	x	x	x	
61 Mosquito fish				
62 Brook silverside	x		x	
63 Yellow bass		x	x	
64 Smallmouth bass	x	x	x	
65 Spotted bass	x	x	x	
66 Largemouth bass	x	x	x	
67 Green sunfish	x	x	x	
68 Warmouth			x	
69 Orangespotted sunfish	x		x	
70 Bluegill	x	x	x	
71 Longear sunfish	x	x	x	
72 Redear sunfish			x	
73 Rock bass	x	x	x	
74 White crappie	x	x	x	
75 Black crappie				
76 Sauger				
77 Logperch	x	x	x	
78 Blackside darter	x	x	x	
79 Slenderhead darter	x	x	x	
80 Dusky darter	x	x	x	
81 Eastern sand darter		x	x	
82 Mud darter				
83 Greensided darter	x	x	x	
84 Rainbow darter	x	x	x	
85 Bluntnose darter				
86 Fantail darter	x	x	x	
87 Slough darter				
88 Harlequin darter				
89 Johnny darter	x	x	x	
90 Orangethroat darter	x		x	
91 Freshwater drum				
Number species	58	54	70	

Appendix I, Table 4. Historical Fisheries Embarras River Watershed.

	Species	WOMIS Headwater 0-10 sq mi	WOMIS Creek 10-50 sq mi	WOMIS Small stream 50-200 sq mi	WOMIS Large stream 200-500 sq	WOMIS Small river 500-2000	WOMIS total basin of embarras	Embar Watshd DOC 1962 20 stations	Embar Watshd DOC 1967 27 stations	Embar Watshd DOC 1974 35 stations
1	Brook lamprey					x	x			
2	Longnose gar					x	x			1
3	Shortnose gar					x	x			1
4	Bowfin			x		x	x			1
5	American eel					x	x			
6	Skipjack herring					x	x			1
7	Gizzard shad	x	x	x	x	x	x	3	5	7
8	Goldeye					x	x			1
9	Grass pickerel		x	x	x	x	x	9	12	10
10	Northern pike		x							
11	Carp	x	x	x	x	x	x	4	6	8
12	Golden shiner	x	x	x			x	4	9	8
13	Creek chub	x	x	x	x	x	x	12	10	14
14	Hornhead chub									
15	Bigeye chub									
16	Silver chub									
17	Gravel chub					x	x			
18	Blacknose dace									
19	Suckermouth minnow	x	x	x	x	x	x	6	7	7
20	Emerald shiner		x	x	x	x	x		2	3
21	River shiner			x	x	x	x	1	2	
22	Bigeye shiner							1		
23	Striped shiner		x	x	x	x	x	4	5	6
24	Bigmouth shiner									
25	Ribbon shiner		x	x		x	x	2	3	5
26	Red shiner		x				x	1	2	3
27	Rosyface shiner									
28	Spotfin shiner	x	x	x	x	x	x	7	11	13
29	Sand shiner		x	x	x	x	x	6	6	9
30	Mimic shiner									
31	Steelcolor shiner	x	x	x	x	x	x	6	9	9
32	Redfin shiner	x	x	x	x	x	x	11	13	12
33	Silverjaw minnow	x	x	x	x	x	x	10	12	9
34	Silvery minnow		x	x	x	x	x	3	4	3
35	Bluntnose minnow	x	x	x	x	x	x	14	14	17
36	Fathead minnow			x			x		1	
37	Bullhead minnow	x	x	x	x	x	x	1	3	2
38	Common stoneroller	x	x	x	x	x	x	5	6	9
39	Bigmouth buffalo		x		x	x	x			1
40	Black buffalo			x		x	x		1	
41	River carpsucker	x	x			x	x		6	1
42	Oullback carpsucker		x		x	x	x	3	3	4
43	Highfin carpsucker			x		x	x			1
44	Silver redbhorse					x	x			1
45	Golden redbhorse	x	x	x	x	x	x	8	3	5
46	Shorthead redbhorse	x				x	x		1	1
47	Northern hog sucker	x	x	x	x	x	x	4	4	2
48	White sucker		x	x	x	x	x	8	10	8
49	Spotted sucker	x	x	x	x	x	x	3	8	4
50	Creek chubsucker	x	x	x		x	x	4	10	4
51	Black bullhead		x	x		x	x	5	5	4
52	Yellow bullhead		x	x	x	x	x	9	11	3
53	Channel catfish	x		x		x	x	3	4	3
54	Flathead catfish	x					x	1	1	1
55	Slender madtom									
56	Stoneroller									
57	Brindled madtom	x	x	x	x	x	x	5		3
58	Freckled madtom	x				x	x	1		1
59	Pirate perch		x	x		x	x	6	4	4
60	Blackstripe topminnow	x	x	x	x	x	x	12	14	12
61	Mosquito fish							1	1	2
62	Brook silverside					x	x		1	
63	Yellow bass					x	x	1		
64	Smallmouth bass					x	x			
65	Spotted bass	x	x	x	x	x	x	6	8	7
66	Largemouth bass		x	x	x	x	x	5	6	7
67	Green sunfish	x	x	x	x	x	x	14	15	10
68	Warmouth		x	x		x	x	1	4	1
69	Orangespotted sunfish	x	x	x	x	x	x	2	5	2
70	Bluegill	x	x	x	x	x	x	8	7	14
71	Longear sunfish	x	x	x	x	x	x	12	13	8
72	Redear sunfish		x	x		x	x		1	5
73	Rock bass		x			x	x	2	1	2
74	White crappie		x		x	x	x	2	1	1
75	Black crappie					x	x	4	1	2
76	Sauger					x	x			1
77	Logperch	x		x	x	x	x	3	3	
78	Blackside darter	x		x	x	x	x	5	8	5
79	Slenderhead darter	x				x	x	1	2	2
80	Dusky darter	x		x	x	x	x		3	4
81	Eastern sand darter	x				x	x			
82	Mud darter			x	x	x	x		2	
83	Greensided darter	x	x			x	x	1	1	1
84	Rainbow darter		x	x		x	x	2	3	6
85	Bluntnose darter		x			x	x		1	2
86	Fantail darter					x	x	1	1	0
87	Slough darter		x	x	x		x		4	1
88	Harlequin darter	x				x	x		1	
89	Johnny darter	x	x	x	x	x	x	10	12	9
90	Orangethroat darter		x	x	x	x	x	1	3	1
91	Freshwater drum				x	x	x	1	1	1
	Number species	36	49	50	43	75	80	55	63	67

Appendix I, Table 4 continued Historical Fisheries Embarras River Watershed					
	Species	Embar Watshd	Embar Watshd	Commonly	Cumtvt to
	Post-1965 data	DOC	1987/88	occurring	1959
		All dates	this study	species	Embar
		1962-74	Champaign Co.	all data	Champaign Co.
1	Brook lamprey				x
2	Longnose gar	x			x
3	Shortnose gar	x			x
4	Bowfin	x			x
5	American eel				x
6	Skipjack herring	x			x
7	Gizzard shad	x	x	x	x
8	Goldeye	x			x
9	Grass pickerel	x	x	x	x
10	Northern pike				x
11	Carp	x	x	x	x
12	Golden shiner	x	x	x	x
13	Creek chub	x	x	x	x
14	Hornhead chub		x		x
15	Bigeye chub				x
16	Silver chub				x
17	Gravel chub				x
18	Blacknose dace				x
19	Suckermouth minnow	x	x	x	x
20	Emerald shiner	x	x	x	x
21	River shiner	x			x
22	Bigeye shiner	x			x
23	Striped shiner	x	x	x	x
24	Bigmouth shiner		x		x
25	Ribbon shiner	x		x	x
26	Red shiner	x	x	x	x
27	Rosyface shiner				
28	Spottin shiner	x	x	x	x
29	Sand shiner	x	x	x	x
30	Mimic shiner				
31	Steelcolor shiner	x		x	x
32	Redfin shiner	x	x	x	x
33	Silverjaw minnow	x	x	x	x
34	Silvery minnow	x		x	x
35	Bluntnose minnow	x	x	x	x
36	Fathead minnow	x			
37	Bullhead minnow	x		x	x
38	Common stoneroller	x	x	x	x
39	Bigmouth buffalo	x			x
40	Black buffalo	x			x
41	River carpsucker	x	x		x
42	Oullback carpsucker	x	x	x	x
43	Highfin carpsucker	x	x		x
44	Silver redborse	x			x
45	Golden redborse	x	x	x	x
46	Shorthead redborse	x	x		x
47	Northern hog sucker	x	x	x	x
48	White sucker	x	x	x	x
49	Spotted sucker	x	x	x	x
50	Creek chubsucker	x	x	x	x
51	Black bullhead	x	x	x	x
52	Yellow bullhead	x	x	x	x
53	Channel catfish	x		x	x
54	Flathead catfish	x			x
55	Slender madtom		x		x
56	Stoneroll				
57	Brindled madtom	x	x	x	x
58	Freckled madtom	x			x
59	Pirate perch	x		x	x
60	Blackstripe topminnow	x	x	x	x
61	Mosquito fish	x		x	x
62	Brook silverside	x			x
63	Yellow bass	x			x
64	Smallmouth bass				x
65	Spotted bass	x		x	x
66	Largemouth bass	x	x	x	x
67	Green sunfish	x	x	x	x
68	Warmouth	x			x
69	Orangespotted sunfish	x	x	x	x
70	Bluegill	x	x	x	x
71	Longear sunfish	x	x	x	x
72	Redear sunfish	x		x	x
73	Rock bass	x		x	x
74	White crappie	x	x	x	x
75	Black crappie	x		x	x
76	Sauger	x			x
77	Logperch	x			x
78	Blackside darter	x	x	x	x
79	Slenderhead darter	x		x	x
80	Dusky darter	x	x	x	x
81	Eastern sand darter				x
82	Mud darter	x			x
83	Greensided darter	x	x	x	x
84	Rainbow darter	x	x	x	x
85	Bluntnose darter	x		x	x
86	Fantail darter	x			x
87	Slough darter	x			x
88	Harlequin darter	x			x
89	Johnny darter	x	x	x	x
90	Orangethroat darter	x			x
91	Freshwater drum	x			x
	Number species	76	42	49	86

APPENDIX II

Fisheries Data

for Middlefork River, Farm Creek and Embarras River

Collected During this Study, 1987 and 1988.

APPENDIX II, TABLE 1. List of species collected in Middlefork River and Farm Creek in 1987 and 1988.

Species	FC-03 8 Dates	FC-2.75 3 Dates	FC-2.5 3 Dates	FC-02 7 Dates	FC-01 3 Dates	FC-All Sites 24 Dates/Sites	Middlefork 6/21/88	Middlefork 8/11/87	Middlefork All dates 2 Dates	Farm Creek & Midk 6 dates/sites
1 Gizzard shad								2	2	2
2 Grass pickerel	2	1	2	4	5	14	1	4	5	19
3 Carp	1	1				2		1	1	3
4 Golden shiner	1					1				1
5 Creek chub	61	14		168	31	274	5	1	6	280
6 Hornyhead chub										
7 Suckermouth minnow	2		4			6	1	23	24	30
8 Emerald shiner										
9 Striped shiner	114	15	19	16	5	169	7	5	12	181
10 Bigmouth shiner										
11 Red shiner	2	4		5	4	15	7	9	16	31
12 Spottfin shiner	12	3	1	6	1	23	31	9	40	63
13 Sand shiner	15			10	5	30	25	24	49	79
14 Redfin shiner	53	34	10	53	19	169		12	12	181
15 Silverjaw minnow	16	12	1	24	61	134	5	23	28	162
16 Bluntnose minnow	206	112	13	228	169	748	24	101	125	873
17 Common stoneroller	48	38		12	126	224	11	55	66	290
18 River carpsucker										
19 Quillback carpsucker	3	4		1	1	9	10	30	40	49
20 Highfin carpsucker	3					3		3	3	6
21 Silver redbhorse								5	5	5
22 Golden redbhorse	1					1	2	43	45	46
23 Shorthead redbhorse							17	1	18	18
24 Northern hog sucker	6	1			1	8	1	24	25	33
25 White sucker	17	4	3	10		34		10	10	44
26 Spotted sucker										
27 Creek chubsucker	1	1	5		1	8	3		3	11
28 Black bullhead	2		1			3				3
29 Yellow bullhead	3			1	3	7	1	1	2	9
30 Channel catfish								1	1	1
31 Slender madtom										
32 Stonecat								6	6	6
33 Brindled madtom										
34 Blackstripe topminnow		25				25				25
35 Smallmouth bass							1	2	3	3
36 Largemouth bass				1		1		2	2	3
37 Green sunfish	1				2	3	2	3	5	8
38 Orangespotted sunfish										
39 Bluegill				2		2				2
40 Longear sunfish	31	10	2	3	22	68	43	22	65	133
41 Rock bass							1		1	1
42 White crappie										
43 Blackside darter							7	2	9	9
44 Dusky darter										
45 Greensided darter							3		3	3
46 Rainbow darter	1		1	10	10	22				22
47 Johnny darter	8			11	7	26	11	3	14	40
No. Species	25	16	12	18	18	28	23	29	32	37
No. Fish	610	279	62	565	513	2029	219	427	646	2675
Shannon-Weaver Divers	0.94	0.86	0.87	0.77	0.80	0.94	1.12	1.15	1.23	1.07
% of Farm and Middlefork ratio	68% 25/37	43% 16/37	32% 12 / 37	49% 18/37	49% 18/37	76% 28/37	62% 23/37	76% 29/37	86% 32/37	100% 37/37
% of Farm Creek ratio	89% 25/28	57% 16/28	43% 12 / 28	64% 18/28	64% 18/28	100% 28/28				
% of Middlefork ratio							72% 23/32	91% 29/32	100% 32/32	
Middlefork River and Farm Creek have 23 species in common										
% of Middlefork species collected in FC				72%	(23/32) 9 Middlefork species were not collected in Farm Creek					
% of FC species collected in Middlefork				82%	(23/28) 5 Farm Creek species were not collected in Middlefork					

APPENDIX II. Table 2. List of species collected in Embarras River, 1987 and 1988.

	Species	East Br EC-01 1 sample	East Br EC-02 1 sample	East Br EC-03 6 samples	East Br EC-04 2 samples	East Br All sites 10 samples	West Br EC-05 1 sample	West Br EC-07 23 samples	West Br EC-07.5 1 sample	West Br All sites 25 samples	Total East/West Branches 35 samples	Percent Occurrence 7 sites
1	Gizzard shad		2	55		57		8	25	33	90	57%
2	Grass pickerel			4	5	9	2	8	4	14	23	71%
3	Carp			24	3	27		21		21	48	43%
4	Golden shiner							1		1	1	14%
5	Creek chub				3	3	8	29		37	40	43%
6	Hornyhead chub							1		1	1	14%
7	Suckermouth minnow							5		5	5	14%
8	Emerald shiner							5	1	6	6	29%
9	Striped shiner	1		1	3	5	7	96	14	117	122	86%
10	Bigmouth shiner							5		5	5	14%
11	Red shiner							1		1	1	14%
12	Spotfin shiner	15		11	17	43	22	61	13	96	139	86%
13	Sand shiner	5		1	2	8		28	2	30	38	71%
14	Redfin shiner	25	167	248	38	478	33	1426	52	1511	1989	100%
15	Silverjaw minnow							1		1	1	14%
16	Bluntnose minnow	17		8	24	49	6	135	27	168	217	86%
17	Common stoneroller				3	3		18	9	27	30	43%
18	River carpsucker			6		6		0		6	6	29%
19	Ouliback carpsucker			42	1	43		56	1	57	100	57%
20	Highfin carpsucker			4		4		1		1	5	29%
21	Silver redborse							0				14%
22	Golden redborse	2	1	39		42		9		9	51	57%
23	Shorthead redborse			1		1		0			1	29%
24	Northern hog sucker	1				1		14		14	15	29%
25	White sucker			3		3		7		7	10	29%
26	Spotted sucker			33		33		14	1	15	48	43%
27	Creek chubsucker	2		3	1	6	1	63	2	66	72	86%
28	Black bullhead			2		2		2		2	4	29%
29	Yellow bullhead			2	1	3		19	1	20	23	57%
30	Channel catfish							0				14%
31	Slender madtom							2		2	2	14%
32	Stonecat							0				14%
33	Brindled madtom	1			1	2	5	8		13	15	57%
34	Blackstripe topminnow	2	1	6	6	15	5	1572	700	2277	2292	100%
35	Smallmouth bass							0				14%
36	Largemouth bass			3		3		5		5	8	29%
37	Green sunfish			2	2	4		71	20	91	95	57%
38	Orangespotted sunfish			3		3		0			3	29%
39	Bluegill			12	5	17	3	96	40	139	156	71%
40	Longear sunfish	14	17	61	18	110		477	50	527	637	86%
41	Rock bass							0				14%
42	White crappie							1		1	1	14%
43	Blackside darter	3			1	4		3		3	7	43%
44	Dusky darter				1	1	1	0		1	2	43%
45	Greensided darter							1		1	1	14%
46	Rainbow darter							1		1	1	14%
47	Johnny darter				1	1	8	16	2	26	27	57%
	No Species	12	5	24	20	31	12	47	18	39	42	
	No Fish	88	188	574	136	986	101	4287	964	5352	6338	
	Shannon-Weaver Diversity	0.85	0.19	0.90	0.99	0.89	0.88	0.79	0.52	0.78	0.84	
	% of East & West Branches ratio	29% 12 / 42	12% 5 / 42	57% 24 / 42	48% 20 / 42	74% 31 / 42	29% 12 / 42	112% 39 / 42	43% 18 / 42	93% 39 / 42	100% 42 / 42	
	% of East Branch ratio	39% 12 / 31	16% 5 / 31	77% 24 / 31	65% 20 / 31	100% 31 / 31						
	% of West Branch ratio						31% 12 / 39	100% 39 / 39	46% 18 / 39	100% 39 / 39		
	East and West Branch have 28 species in common											
	% of East Branch species also collected in West Branch					(28/39)	72%	11 West Branch species were not collected in East Branch				
	% of West Branch species also collected in East Branch					(28/31)	90%	3 East Branch species were not collected in West Branch				

	Species	Game/ Commercial/ Forage	FC-All Sites 24 samples	Middlefork All dates 2 Dates	Farm Creek and Middlefork 26 samples	East Branch Embaras 10 samples	West Branch Embaras 25 samples	Total for East and West Branches Embaras 35 samples
1	Gizzard shad	F		2	2	57	33	90
2	Grass pickerel	G	14	5	19	9	14	23
3	Carp	C	2	1	3	27	21	48
4	Golden shiner	F	1		1		1	1
5	Creek chub	F	274	6	280	3	37	40
6	Hornyhead chub	F					1	1
7	Suckermouth minnow	F	6	24	30		5	5
8	Emerald shiner	F					6	6
9	Striped shiner	F	169	12	181	5	117	122
10	Bigmouth shiner	F					5	5
11	Red shiner	F	15	16	31		1	1
12	Spotfin shiner	F	23	40	63	43	96	139
13	Sand shiner	F	30	49	79	6	30	38
14	Redfin shiner	F	169	12	181	478	1511	1989
15	Silverjaw minnow	F	134	28	162		1	1
16	Bluntnose minnow	F	748	125	873	49	168	217
17	Common stoneroller	F	224	66	290	3	27	30
18	River carpsucker	C				6		6
19	Oullback carpsucker	C	9	40	49	43	57	100
20	Highfin carpsucker	C	3	3	6	4	1	5
21	Silver redhorse	C		5	5			
22	Golden redhorse	C	1	45	46	42	9	51
23	Shorthead redhorse	C		18	18	1		1
24	Northern hog sucker	C	8	25	33	1	14	15
25	White sucker	C	34	10	44	3	7	10
26	Spotted sucker	C				33	15	48
27	Creek chubsucker	F	8	3	11	6	66	72
28	Black bullhead	G	3		3	2	2	4
29	Yellow bullhead	G	7	2	9	3	20	23
30	Channel catfish	G		1	1			
31	Slender madtom	F					2	2
32	Stoneroll	F		6	6			
33	Brindled madtom	F				2	13	15
34	Blackstripe topminnow	F	25		25	15	2277	2292
35	Smallmouth bass	G		3	3			
36	Largemouth bass	G	1	2	3	3	5	8
37	Green sunfish	G	3	5	8	4	91	95
38	Orangespotted sunfish	G				3		3
39	Bluegill	G	2		2	17	139	156
40	Longear sunfish	G	68	65	133	110	527	637
41	Rock bass	G		1	1			
42	White crappie	G					1	1
43	Blackside darter	F		9	9	4	3	7
44	Dusky darter	F				1	1	2
45	Greensided darter	F		3	3		1	1
46	Rainbow darter	F	22		22		1	1
47	Johnny darter	F	26	14	40	1	26	27
No. Species			28	32	37	31	39	42
% of all species collected			76%	86%	100%	74%	93%	100%
No. Fish			2029	646	2675	986	5352	6338
% of all numbers collected			76%	24%	100%	16%	84%	100%
Number Forage Species			15	16	19	14	24	24
% forage species collected			54%	50%	51%	45%	62%	57%
Number Forage Fish			1874	415	2289	675	4429	5104
% numbers forage collected			92%	64%	86%	68%	83%	81%
Number Commercial Species			6	8	8	9	7	9
% commercial species collected			21%	25%	22%	29%	18%	21%
Number Commercial Fish			57	147	204	160	124	284
% numbers commercial collected			3%	23%	8%	16%	2%	4%
Number Game Species			7	8	10	8	8	9
% game species collected			25%	25%	27%	26%	21%	21%
Number Game Fish			98	84	182	151	799	950
% numbers game collected			5%	13%	7%	15%	15%	15%

APPENDIX III

Fisheries Data

for Farm Creek and Embarras River

Listed by Site and Date.

Appendix III, Table 1. Farm Creek By Date										
Species	FC-01 6/01/87	FC-02 6/03/87	FC-03 6/03/87	FC-01 7/11/87	FC-02 7/11/87	FC-03 7/11/87	FC-01 8/06/87	FC-02 8/06/87	FC-02.75 8/06/87	FC-03 8/06/87
	BE	BE	BE	BE	BE	BE	BE	BE		
1 Gizzard shad										
2 Grass pickerel	3			1	2	1	1	1	1	
3 Carp						1				
4 Golden shiner										
5 Creek chub	16	8	11	7	10	3	8	13	1	12
6 Hornhead chub										
7 Suckermouth minnow										
8 Emerald shiner										
9 Striped shiner		8		5	1	13		2	2	1
10 Bigmouth shiner										
11 Red shiner	3	3	2		2		1			
12 Spottfin shiner				1	3	5				
13 Sand shiner	4	10				1	1			
14 Redfin shiner	15	8	2	1	12	4	3	4		5
15 Silverjaw minnow	11	8	3	5	7	8	65	1		1
16 Bluntnose minnow	18	46	21	15	3	15	156	73		44
17 Common stoneroller	32			4		3	90			20
18 River carpsucker										
19 Quillback carpsucker							1		1	
20 Highfin carpsucker										
21 Silver redbhorse										
22 Golden redbhorse										
23 Shorthead redbhorse										
24 Northern hog sucker				1						
25 White sucker					2	1		2	2	
26 Spotted sucker										
27 Creek chubsucker				1		1			1	
28 Black bullhead										
29 Yellow bullhead				2			1	1		3
30 Channel catfish										
31 Slender madtom										
32 Stonecat										
33 Brindled madtom										
34 Blackstripe topminnow										
35 Smallmouth bass										
36 Largemouth bass										
37 Green sunfish				2		1				
38 Orangespotted sunfish										
39 Bluegill		1								
40 Longear sunfish	6		8	8	1	4	8	1	1	11
41 Rock bass										
42 White creppie										
43 Blackside darter										
44 Dusky darter										
45 Greensided darter										
46 Rainbow darter	8	2		2	1			3		
47 Johnny darter	4	1		1	1	1	2	7		6
No. Species	11	10	8	15	12	15	12	11	7	9
No. Fish	120	95	47	56	45	62	337	108	9	103
Shannon-Weaver Diversity	2.12	1.71	1.44	2.30	2.09	2.25	1.38	1.24	1.89	1.67
Shannon-Weaver Diversity Range	.74-2.39									
Average	2.62									

Appendix III, Table 1. Farm Creek By Date contd.										
Species	FC-02.75 10/03/87	FC-03 10/03/87	FC-03 4/07/88	FC-02 4/18/88	FC-03 4/18/88	FC-02 5/05/88	FC-02.5 5/05/88	FC-03 5/05/88	FC-02 5/31/88	FC-02.5 5/31/88
	ES			FE	FE	FE	FE	FE	FE	FE
1 Gizzard shad										
2 Grass pickerel				1						2
3 Carp	1									
4 Golden shiner			1							
5 Creek chub	11	4	15	8	8	5		5	10	
6 Hornyhead chub										
7 Suckermouth minnow					1					4
8 Emerald shiner										
9 Striped shiner	7		6	1	78			5		
10 Bluntnose shiner										
11 Red shiner	3									
12 Spottin shiner	1				5	1				
13 Sand shiner			13		1					
14 Redfin shiner	3		15	1	12	2				2
15 Silverjaw minnow	10		3							
16 Bluntnose minnow	112	35	20	3	68	6		1	17	
17 Common stoneroller	29	8		6	4	2			4	
18 River carpsucker										
19 Quillback carpsucker										
20 Highfin carpsucker										
21 Silver redborse										
22 Golden redborse										
23 Shorthead redborse										
24 Northern hog sucker					2					
25 White sucker	2		1		1	1	2	7		1
26 Spotted sucker										
27 Creek chubsucker										5
28 Black bullhead										1
29 Yellow bullhead										
30 Channel catfish										
31 Slender madtom										
32 Stonecat										
33 Brindled madtom										
34 Blackstripe topminnow	1									
35 Smallmouth bass										
36 Largemouth bass										
37 Green sunfish										
38 Orangespotted sunfish										
39 Bluegill						1				
40 Longear sunfish	9				1	1				2
41 Rock bass										
42 White crappie										
43 Blackside darter										
44 Dusky darter										
45 Greensided darter										
46 Rainbow darter			1							
47 Johnny darter			1	1						
No. Species	12	3	10	7	11	8	1	4	3	7
No. Fish	189	47	76	21	181	19	2	18	31	17
Shannon-Weaver	1.45	0.73	1.85	1.58	1.39	1.81	0.00	1.24	0.96	1.79

Appendix III, Table 1. Farm Creek By Date contd											
	Species	FC-03 5/31/88	FC-02 9/14/88	FC-02.5 9/14/88	FC-02.75 9/14/88	Middlefork 6/21/88	Middlefork 8/11/87	No. Samples 24	No. samples 24	No. samples 2	No. samples 26
			SH	SH	SH	BS	BS	% Occurrence Farm Creek	Total No. Farm Creek	Total No. Middlefork	Total No. FC & Midfk
1	Gizzard shad						2	0%		2	2
2	Grass pickerel	1				1	4	42%	14	5	19
3	Carp						1	8%	2	1	3
4	Golden shiner							4%	1		1
5	Creek chub	3	114		2	5	1	88%	274	6	280
6	Hornyhead chub										
7	Suckermouth minnow	1				1	23	13%	6	24	30
8	Emerald shiner										
9	Striped shiner	11	4	19	6	7	5	67%	169	12	181
10	Bigmouth shiner										
11	Red shiner				1	7	9	29%	15	16	31
12	Spottin shiner	2	2	1	2	31	9	42%	23	40	63
13	Sand shiner					25	24	25%	30	49	79
14	Redfin shiner	15	26	8	31		12	79%	169	12	181
15	Silverjaw minnow	1	8	1	2	5	23	63%	134	28	162
16	Bluntnose minnow	2	80	13		24	101	83%	748	125	873
17	Common stoneroller	13			9	11	55	54%	224	66	290
18	River carpsucker							0%			0
19	Ouillback carpsucker	3	1		3	10	30	21%	9	40	49
20	Highfin carpsucker	3					3	4%	3	3	6
21	Silver redhorse						5	0%		5	5
22	Golden redhorse	1				2	43	4%	1	45	46
23	Shorthead redhorse					17	1	0%		18	18
24	Northern hog sucker	4			1	1	24	17%	8	25	33
25	White sucker	7	5				10	54%	34	10	44
26	Spotted sucker										
27	Creek chubsucker					3		17%	8	3	11
28	Black bullhead	2						8%	3		3
29	Yellow bullhead					1	1	17%	7	2	9
30	Channel catfish						1	0%		1	1
31	Slender madtom										
32	Stonecat						6	0%		6	6
33	Brindled madtom										
34	Blackstripe topminnow				24			8%	25		25
35	Smallmouth bass					1	2	0%		3	3
36	Largemouth bass		1				2	4%	1	2	3
37	Green sunfish					2	3	8%	3	5	8
38	Orangespotted sunfish										
39	Bluegill							8%	2		2
40	Longear sunfish	7				43	22	58%	68	65	133
41	Rock bass					1		0%		1	1
42	White crappie										
43	Blackside darter					7	2	0%		9	9
44	Dusky darter							0%			
45	Greensided darter					3		0%		3	3
46	Rainbow darter		4	1				33%	22		22
47	Johnny darter		1			11	3	46%	26	14	40
	No Species	16	11	6	10	23	29	No species	28	32	37
	No Fish	76	246	43	81	219	427	Total No fish	2029	646	2675
	Shannon-Weaver	2.39	1.53	1.30	1.67	2.58	2.65		2.16	2.82	2.48

Appendix III, Table 1. Farm Creek By Date contd.				
	Species	No. samples	No. samples	No. samples
		9	10	5
		Total No.	Total No.	Total No.
		Spring	Summer	Fall
1	Gizzard shad			
2	Grass pickerel	4	10	
3	Carp		1	1
4	Golden shiner	1		
5	Creek chub	54	89	131
6	Hornyhead chub			
7	Suckermouth minnow	6		
8	Emerald shiner			
9	Striped shiner	101	32	36
10	Bigmouth shiner			
11	Red shiner		11	4
12	Spotfin shiner	8	9	6
13	Sand shiner	14	16	
14	Redfin shiner	47	54	68
15	Silverjaw minnow	4	109	21
16	Bluntnose minnow	117	391	240
17	Common stoneroller	29	149	46
18	River carpsucker			
19	Ouilback carpsucker	3	2	4
20	Highfin carpsucker	3		
21	Silver redborse			
22	Golden redborse	1		
23	Shorthead redborse			
24	Northern hog sucker	6	1	1
25	White sucker	20	7	7
26	Spotted sucker			
27	Creek chubsucker	5	3	
28	Black bullhead	3		
29	Yellow bullhead		7	
30	Channel catfish			
31	Slender madtom			
32	Stoneroller			
33	Brindled madtom			
34	Blackstripe topminnow			25
35	Smallmouth bass			
36	Largemouth bass			1
37	Green sunfish		3	
38	Orangespotted sunfish			
39	Bluegill	1	1	
40	Longear sunfish	11	48	9
41	Rock bass			
42	White crappie			
43	Blackside darter			
44	Dusky darter			
45	Greensided darter			
46	Rainbow darter	1	16	5
47	Johnny darter	2	23	1
	No. Species	22	21	17
	No. Fish	441	982	606
	Shannon-Weaver	2.21	2.03	1.88
	Restriction to 300 individuals			
	No. species	20	18	15

Appendix III, Table 2. Embarras River By Date											
Species	EC-01 6/24/87	EC-03 6/24/87	EC-04 6/25/87	EC-05 6/25/87	EC-07 6/25/87	EC-03 9/26/87	EC-07 9/26/87	EC-03 10/17/87	EC-07 10/17/87	EC-07-1 4/14/88	
	SH	SH	SH	SH	SH	ES	ES	ES	ES	FE	
1 Gizzard shad						24		8			
2 Grass pickerel				2		0	3	2	2		
3 Carp						12	13	5	1	1	
4 Golden shiner											
5 Creek chub			2	8			4		7	1	
6 Hornyhead chub										1	
7 Suckermouth minnow											
8 Emerald shiner											
9 Striped shiner	1		2	7			5		28		
10 Bigmouth shiner										4	
11 Red shiner										1	
12 Spottin shiner	15	8	9	22					8		
13 Sand shiner	5	1	2						14		
14 Redfin shiner	25	70	21	33		70	198		403	57	
15 Silverjaw minnow											
16 Bluntnose minnow	17	6	4	6	6		14		14	5	
17 Common stoneroller			1				2				
18 River carpsucker						6					
19 Quillback carpsucker						9		4			
20 Highfin carpsucker						1		3			
21 Golden redborse	2	1				7	2	10			
22 Shorthead redborse		1									
23 Northern hog sucker	1						1		3		
24 White sucker						2	1		4		
25 Spotted sucker		1				6	2	6	2		
26 Creek chubsucker	2	3		1	20		8		3	2	
27 Black bullhead							2	2			
28 Yellow bullhead						1					
29 Slender madtom							2				
30 Brindled madtom	1			5			5		1		
31 Blackstripe topminnow	2	3	1	5	10	2	40		15	1	
32 Largemouth bass						2		1			
33 Green sunfish			1			2	5		17	3	
34 Orangespotted sunfish		3									
35 Bluegill				3	2	5			1	1	
36 Longear sunfish	14	23	3			19	39	4	65		
37 White crappie											
38 Blackside darter	3								1		
39 Dusky darter			1	1							
40 Greensided darter									1		
41 Rainbow darter							1				
42 Johnny darter				8			3		1		
No. Species	12	11	11	12	4	16	20	10	20	11	
No. Fish	88	120	47	101	38	168	350	45	591	77	
Shannon-Weaver Diversity	1.96	1.40	1.79	2.02	1.14	1.98	1.67	2.13	1.32	1.11	
Shannon-Weaver	Average	Range									
East Branch	1.59	0.27-2.31									
West Branch	1.59	0.87-2.27									
East & West Branches	1.59	0.27-2.31									

Appendix III. Table 2. Embarras River By Date contd.											
	Species	EC-07-I 4/23/88	EC-07-III 4/23/88	EC-07-I 5/02/88	EC-07-III 5/02/88	EC-07-I 5/26/88	EC-07-III 5/26/88	EC-07 6/02/88	EC-07-I 6/02/88	EC-07-III 6/02/88	EC-04 6/09/88
		FE	FE	FE	FE	FE	FE	BS	FE	FE	BS
1	Gizzard shad							1			
2	Grass pickerel										5
3	Carp	1						3			3
4	Golden shiner										
5	Creek chub		1								1
6	Hornyhead chub										
7	Suckermouth minnow			1							
8	Emerald shiner										
9	Striped shiner		2		1			1			1
10	Bigmouth shiner	1									
11	Red shiner										
12	Spotfin shiner		2					15			8
13	Sand shiner			1							
14	Redfin shiner	2	8		18	1	6	148	3	1	17
15	Silverjaw minnow										
16	Bluntnose minnow	2	2				1	37			20
17	Common stoneroller		1					2			2
18	River carpsucker										
19	Outback carpsucker							2			1
20	Highfin carpsucker	1									
21	Golden redhorse							4			
22	Shorthead redhorse										
23	Northern hog sucker										
24	White sucker							1			
25	Spotted sucker							8			
26	Creek chubsucker							11			1
27	Black bullhead										
28	Yellow bullhead			1				1			1
29	Slender madtom										
30	Brindled madtom							1			1
31	Blackstripe topminnow	1		1		1	1	12			5
32	Largemouth bass							1			
33	Green sunfish	1						11			1
34	Orangespotted sunfish										
35	Bluegill	1	1			2		7			5
36	Longear sunfish	4	2	1	7	2	2	70	3	7	15
37	White crappie										
38	Blackside darter							1			1
39	Dusky darter										
40	Greensided darter										
41	Rainbow darter										
42	Johnny darter										1
	No. Species	9	8	5	3	4	4	20	2	2	18
	No. Fish	14	19	5	26	6	10	337	6	8	89
	Shannon-Weaver	2.05	1.78	1.61	0.73	1.33	1.09	1.86	0.69	0.38	2.31

	Species	EC-07-IV 6/14/88 ES	EC-07-V 6/14/88 ES	EC-03 6/16/88 ES	EC-07-I 6/16/88 FE	EC-07-IV 6/30/88 ES-AS	EC-07-V 6/30/88 ES-ASC	EC-07-IV 8/02/88 ES-AS	EC-07-V 8/02/88 ES-ASC	EC-07-IV 8/22/88 ES-AS	EC-07-V 8/30/88 SH
1	Gizzard shad			8	1	3			1	2	25
2	Grass pickerel		1								4
3	Carp			6	2						
4	Golden shiner										
5	Creek chub	4	2					3	1		
6	Hornyhead chub										
7	Suckermouth minnow							4			
8	Emerald shiner										1
9	Striped shiner	6	1			5		11	1	4	14
10	Bogmouth shiner										
11	Red shiner										
12	Spotfin shiner	13		2	3			2	1	3	13
13	Sand shiner	7									2
14	Redfin shiner	58		8	2	11		45	36	14	52
15	Silverjaw minnow	1									
16	Bluntnose minnow	8		1	1			17	3	7	27
17	Common stoneroller	1									9
18	River carpsucker										
19	Oullback carpsucker	10	19	19	1	20		2	1		1
20	Highfin carpsucker										
21	Golden redborse	2				1					
22	Shorthead redborse										
23	Northern hog sucker	5	2			3					
24	White sucker			1						1	
25	Spotted sucker	1		17		1					1
26	Creek chubsucker					3			3	1	2
27	Black bullhead										
28	Yellow bullhead	6	1	1		1		1	2		1
29	Slender madtom										
30	Brindled madtom	1									
31	Blackstripe topminnow	6	1			16		23	20	20	700
32	Largemouth bass	2	1			1					
33	Green sunfish	4	3			7		6	3	1	20
34	Orangespotted sunfish										
35	Bluegill	19	5	7	1	13	6	12	9		40
36	Longear sunfish	51	28	11	2	30	27	13	16	22	50
37	White crappie										
38	Blackside darter	1									
39	Dusky darter										
40	Greensided darter										
41	Rainbow darter										
42	Johnny darter	2					4	2			2
	No Species	21	11	12	8	14	3	13	13	10	18
	No Fish	208	64	82	13	115	37	141	97	75	964
	Shannon-Weaver	2.29	1.61	2.10	1.99	2.16	0.77	2.08	1.85	1.60	1.19

Appendix III, Table 2. Embarras River By Date contd.

Species	EC-07-IV 9/10/88 SH-AS	EC-02 9/16/88 SH	EC-03 9/16/88 SH	EC-07-IV 10/06/88 SH-AS	EC-03 10/22/88 ES	No. Samples 10	No. Samples 25	No. Samples 35
						% Occurrence East Branch	% Occurrence West Branch	% Occurrence East & West
1 Gizzard shad		2			15	50%	24%	31%
2 Grass pickerel				2	1	50%	24%	31%
3 Carp					1	50%	24%	31%
4 Golden shiner	1					0%	4%	3%
5 Creek chub	6					20%	40%	34%
6 Hornyhead chub						0%	4%	3%
7 Suckermouth minnow						0%	8%	6%
8 Emerald shiner	5					0%	8%	6%
9 Striped shiner	23		1	8		40%	60%	54%
10 Bigmouth shiner						0%	8%	6%
11 Red shiner						0%	4%	3%
12 Spottin shiner	14		1			60%	44%	49%
13 Sand shiner	2			4		30%	24%	26%
14 Redfin shiner	306	167	100	109		80%	84%	83%
15 Silverjaw minnow						0%	4%	3%
16 Bluntnose minnow	12		1	6		60%	68%	66%
17 Common stoneroller	12					20%	24%	23%
18 River carpsucker						10%	0%	3%
19 Ouilback carpsucker	1				10	50%	36%	40%
20 Hightin carpsucker						20%	4%	9%
21 Golden redbone		1	1		20	70%	16%	31%
22 Shorthead redbone						10%	0%	3%
23 Northern hog sucker						10%	20%	17%
24 White sucker						20%	16%	17%
25 Spotted sucker					3	50%	24%	31%
26 Creek chubsucker	8			4		30%	48%	43%
27 Black bullhead						10%	4%	6%
28 Yellow bullhead				6		30%	36%	34%
29 Slender madtom						0%	4%	3%
30 Brindled madtom						20%	20%	20%
31 Blackstripe topminnow	1200	1	1	204		70%	76%	74%
32 Largemouth bass						20%	16%	17%
33 Green sunfish				10		30%	52%	46%
34 Orangespotted sunfish						10%	0%	3%
35 Bluegill				16		30%	68%	57%
36 Longear sunfish	28	17		58	4	90%	88%	89%
37 White crappie				1		0%	4%	3%
38 Blackside darter						20%	12%	14%
39 Dusky darter						10%	4%	6%
40 Greensided darter						0%	4%	3%
41 Rainbow darter						0%	4%	3%
42 Johnny darter	1			3		10%	36%	29%
No. Species	14	5	6	13	7			
No. Fish	1619	188	105	431	54			
Shannon-Weaver	0.87	0.43	0.27	1.54	1.54			

Appendix III. Table 2. Embarras River By Date contd.						
Species	No. Samples	No. Samples	No. Samples	No. Samples	No. Samples	No. Samples
	10	25	35	7	19	9
	Total No	Total No	Total No	Total No	Total No	Total No
	East Branch	West Branch	East & West	Spring	Summer	Fall
1 Gizzard shad	57	33	90		41	49
2 Grass pickerel	9	14	23		13	10
3 Carp	27	21	48	2	14	32
4 Golden shiner		1	1			1
5 Creek chub	3	37	40	2	21	17
6 Hornyhead chub		1	1	1		
7 Suckermouth minnow		5	5	1	4	
8 Emerald shiner		6	6		1	5
9 Striped shiner	5	117	122	3	54	65
10 Bigmouth shiner		5	5	5		
11 Red shiner		1	1	1		
12 Spottfin shiner	43	96	139	2	114	23
13 Sand shiner	8	30	38	1	17	20
14 Redfin shiner	478	1511	1989	92	544	1353
15 Silverjaw minnow		1	1		1	
16 Bluntnose minnow	49	168	217	10	160	47
17 Common stoneroller	3	27	30	1	15	14
18 River carpsucker	6		6			6
19 Oulback carpsucker	43	57	100		76	24
20 Highfin carpsucker	4	1	5	1		4
21 Golden redborse	42	9	51		10	41
22 Shorthead redborse	1		1		1	
23 Northern hog sucker	1	14	15		11	4
24 White sucker	3	7	10		3	7
25 Spotted sucker	33	15	48		29	19
26 Creek chubsucker	6	66	72	2	47	23
27 Black bullhead	2	2	4			4
28 Yellow bullhead	3	20	23	1	15	7
29 Slender madtom		2	2			2
30 Brindled madtom	2	13	15		9	6
31 Blackstripe topminnow	15	2277	2292	5	824	1463
32 Largemouth bass	3	5	8		5	3
33 Green sunfish	4	91	95	4	57	34
34 Orangespotted sunfish	3		3		3	
35 Bluegill	17	139	156	5	129	22
36 Longear sunfish	110	527	637	18	385	234
37 White crappie		1	1			1
38 Blackside darter	4	3	7		6	1
39 Dusky darter	1	1	2		2	
40 Greensided darter		1	1			1
41 Rainbow darter		1	1			1
42 Johnny darter	1	26	27		19	8
No Species	31	39	42	19	31	34
No Fish	986	5352	6338	157	2630	3551
Shannon-Weaver	2.07	1.80	1.94	1.68	2.23	1.61
Rarification						
to 157 individuals				19	17	16

APPENDIX IV

Data Tables for Index of Biotic Integrity (IBI)

	A	B	C	D	E	F	G	H	I	J	K
1		East Br	East Br	East Br	East Br	East Br	East Br	East Br	East Br	East Br	East Br
2	Species	EC-01	EC-02	EC-03	EC-03	EC-03	EC-03	EC-03	EC-03	EC-04	EC-04
3		6/24/87	9/16/88	6/24/87	9/26/87	10/17/87	6/16/88	9/16/88	10/22/88	6/09/88	6/25/87
4		SH	SH	SH	ES	ES	ES	SH	ES	ES	SH
5											
6	Gizzard shad		2		24	8	8		15		
7	Grass pickerel				0	2	1		1	5	
8	Carp				12	5	6		1	3	
9	Golden shiner										
10	Creek chub										2
11	Hornyhead chub									1	
12	Suckermouth minnow										
13	Emerald shiner										
14	Striped shiner	1						1		1	2
15	Bigmouth shiner										
16	Red shiner										
17	Spotfin shiner	15		8			2	1		8	9
18	Sand shiner	5		1							2
19	Redfin shiner	25	167	70	70		8	100		17	21
20	Silverjaw minnow										
21	Bluntnose minnow	17		6			1	1		20	4
22	Common stoneroller									2	1
23	River carpsucker				6						
24	Ouilback carpsucker				9	4	19		10	1	
25	Highfin carpsucker				1	3					
26	Silver redhorse										
27	Golden redhorse	2	1	1	7	10		1	20		
28	Shorthead redhorse			1							
29	Northern hog sucker	1									
30	White sucker				2		1				
31	Spotted sucker			1	6	6	17		3		
32	Creek chubsucker	2		3						1	
33	Black bullhead					2					
34	Yellow bullhead				1		1			1	
35	Channel catfish										
36	Slender madtom										
37	Stoneroller										
38	Brindled madtom	1									
39	Blackstripe topminnow	2	1	3	2			1		5	1
40	Smallmouth bass										
41	Largemouth bass				2	1					
42	Green sunfish				2					1	1
43	Orangespotted sunfish			3							
44	Bluegill				5		7			5	
45	Longear sunfish	14	17	23	19	4	11		4	15	3
46	Rock bass										
47	White crappie										
48	Blackside darter	3									
49	Dusky darter									1	
50	Greensided darter										1
51	Rainbow darter										
52	Johnny darter									1	
53											
54											
55	* Intolerant species										
56											
57											
58	No. Species	12	5	11	16	10	12	6	7	18	11
59	No. Fish	88	188	120	168	45	82	105	54	89	47
60											
61											
62	Shannon-Weaver Diversity	0.85	0.19	0.81	0.86	0.92	0.91	0.12	0.67	1.00	0.78
63											
64	No. Species										
65	Total	12	5	11	16	10	12	6	7	18	11
66	Darters	1	0	0	0	0	0	0	0	2	1
67	Sunfish	1	1	2	3	1	2	0	1	3	2
68	Suckers	3	1	4	6	4	3	1	3	2	0
69	Intolerants	3	1	2	3	3	2	0	2	2	1
70	Proportion of Individuals										
71	Green sunfish	0.00%	0.00%	0.00%	1.19%	0.00%	0.00%	0.00%	0.00%	1.12%	2.13%
72	Omnivores	19.32%	1.06%	5.00%	30.95%	44.44%	41.46%	0.95%	48.15%	26.97%	8.51%
73	Insectivorous cyprinids	52.27%	88.83%	65.83%	41.67%	0.00%	12.20%	97.14%	0.00%	30.34%	76.60%
74	Piscivores	0.00%	0.00%	0.00%	1.19%	6.67%	1.22%	0.00%	1.85%	5.62%	0.00%
75	Hybrids										
76	Diseased										
77	Total No. Individuals	88	188	120	168	45	82	105	54	89	47
78											
79	Metric Ratings										
80											
81	No. Species										
82	Total	5	3	5	5	5	5	3	3	5	5
83	Darters	3	1	1	1	1	1	1	1	3	3
84	Sunfish	3	3	5	5	3	5	3	3	5	5
85	Suckers	5	3	5	5	5	5	3	5	5	1
86	Intolerants	5	3	3	5	5	3	1	3	3	3
87	Proportion of Individuals										
88	Green sunfish	5	5	5	5	5	5	5	5	5	5
89	Omnivores	5	5	5	3	3	3	5	1	3	5
90	Insectivorous cyprinids	5	5	5	3	1	1	5	1	3	5
91	Piscivores	1	1	1	3	5	3	1	3	5	1
92	Hybrids	5	5	5	5	5	5	5	5	5	5
93	Diseased	5	5	5	5	5	5	5	5	5	5
94	Total No. Individuals	3	3	3	3	1	3	3	3	3	1
95											
96	IBI total score	50	42	48	48	44	44	40	38	50	44
97	Integrity Class	G	F	G	G	F	F	F	F	G	F

APPENDIX IV, TABLE 1

	L	M	N	O	P	Q	R	S	T	U	V	W
1	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.
2	EC-05	EC-07	EC-07	EC-07	EC-07	EC-07-I	EC-07-I	EC-07-I	EC-07-I	EC-07-I	EC-07-I	EC-07-III
3	6/25/87	6/25/87	9/25/87	10/17/87	6/02/88	4/14/88	4/23/88	5/02/88	5/26/88	6/02/88	6/16/88	4/23/88
4	SH	SH	ES	ES	ES	FE	FE	FE	FE	FE	FE	FE
5												
6					1						1	
7	2		3	2								
8			13	1	3	1	1				2	
9												
10	8		4	7		1						1
11						1						
12								1				
13												
14	7		5	28	1							2
15						4	1					
16						1						
17	22			8	15						3	2
18				14				1				
19	33		198	403	148	57	2		1	3	2	8
20												
21	6	6	14	14	37	5	2				1	2
22			2		2							1
23												
24					2						1	
25							1					
26												
27			2		4							
28												
29			1	3								
30			1	4	1							
31			2	2	8							
32	1	20	8	3	11	2						
33			2									
34					1			1				
35												
36			2									
37												
38	5		5	1	1							
39	5	10	40	15	12	1	1	1	1			
40												
41					1							
42			5	17	11	3	1					
43												
44	3	2		1	7	1	1		2		1	1
45			39	65	70		4	1	2	3	2	2
46												
47												
48				1	1							
49	1											
50				1								
51			1									
52	8		3	1								
53												
54												
55												
56												
57												
58	12	4	20	20	20	11	9	5	4	2	8	8
59												
60	101	38	350	591	337	77	14	5	6	6	13	19
61												
62	0.88	0.49	0.72	0.57	0.81	0.48	0.89	0.70	0.58	0.30	0.86	0.77
63												
64												
65	12	4	20	20	20	11	9	5	4	2	8	8
66	2	0	2	3	1	0	0	0	0	0	0	0
67	1	1	2	3	3	2	3	1	2	1	2	2
68	1	1	5	4	5	1	1	0	0	0	1	0
69	1	0	5	5	3	0	2	1	1	1	1	1
70												
71	0.00%	0.00%	1.43%	2.88%	3.26%	3.90%	7.14%	0.00%	0.00%	0.00%	0.00%	0.00%
72	5.94%	15.79%	7.71%	2.54%	12.76%	9.09%	28.57%	0.00%	0.00%	0.00%	38.46%	10.53%
73	69.31%	0.00%	59.14%	77.83%	48.66%	81.82%	21.43%	40.00%	16.67%	50.00%	38.46%	68.42%
74	1.98%	0.00%	0.86%	0.34%	0.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
75												
76												
77	101	38	350	591	337	77	14	5	6	6	13	19
78												
79												
80												
81												
82	5	3	5	5	5	5	3	3	3	1	3	3
83	3	1	3	5	3	1	1	1	1	1	1	1
84	3	3	5	5	5	5	5	3	5	3	5	5
85	3	3	5	5	5	3	3	1	1	1	3	1
86	3	1	5	5	5	1	3	3	3	3	3	3
87												
88	5	5	5	5	5	5	3	5	5	5	5	5
89	5	5	5	5	5	5	3	5	5	5	3	5
90	5	1	5	5	5	5	3	3	1	5	3	5
91	3	1	1	1	1	1	1	1	1	1	1	1
92	5	5	5	5	5	5	5	5	5	5	5	5
93	5	5	5	5	5	5	5	5	5	5	5	5
94	3	1	5	5	5	3	1	1	1	1	1	1
95												
96	48	34	54	56	54	44	36	36	36	36	38	40
97	G	P	G	G	G	F	P/F	P/F	P/F	P/F	P/F	F

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.	West Br.
2	EC-07-III	EC-07-III	EC-07-III	EC-07-IV	EC-07-IV	EC-07-IV	EC-07-IV	EC-07-IV	EC-07-IV	EC-07-V	EC-07-V	EC-07-V
3	5/02/88	5/26/88	6/02/88	6/14/88	6/30/88	8/02/88	8/22/88	9/10/88	10/06/88	6/14/88	6/30/88	8/02/88
4	FE	FE	FE	ES	ES-AS	ES-AS	ES-AS	SH-AS	SH-AS	ES	ES-ASC	ES-ASC
5												
6					3		2					1
7									2	1		
8												
9								1				
10				4		3		6		2		1
11						4						
12								5				
13												
14	1			6	5	11	4	23	8	1		1
15												
16												
17				13		2	3	14				1
18				7				2	4			
19	18	6	1	58	11	45	14	306	109			36
20				1								
21		1		8		17	7	12	6			3
22				1				12				
23												
24				10	20	2		1		19		1
25												
26												
27				2	1							
28												
29				5	3					2		
30												
31				1	1		1					
32					3		1	8	4			3
33												
34				6	1	1			6	1		2
35												
36												
37												
38				1								
39		1		6	16	23	20	1200	204	1		20
40												
41				2	1					1		
42				4	7	6	1		10	3		3
43												
44				19	13	12			16	5	6	9
45	7	2	7	51	30	13	22	28	58	28	27	16
46												
47									1			
48				1								
49												
50												
51												
52				2		2		1	3		4	
53												
54												
55												
56												
57												
58	3	4	2	21	14	13	10	14	13	11	3	13
59												
60	26	10	8	208	115	141	75	1619	431	64	37	97
61												
62	0.32	0.47	#NUM!	#NUM!	0.94	#NUM!	0.78	0.38	0.67	0.70	0.33	num
63												
64												
65	3	4	2	21	14	13	10	14	13	11	3	13
66	0	0	0	2	0	1	0	1	1	0	1	0
67	1	1	1	3	3	3	2	1	4	3	2	3
68	0	0	0	4	5	1	2	2	1	2	0	2
69	1	1	1	4	3	1	1	1	1	2	1	1
70												
71	0.00%	0.00%	0.00%	1.92%	6.09%	4.26%	1.33%	0.00%	2.32%	4.69%	0.00%	3.09%
72	0.00%	10.00%	0.00%	8.65%	20.00%	13.48%	12.00%	0.86%	1.39%	29.69%	0.00%	5.15%
73	73.08%	60.00%	12.50%	42.79%	13.91%	46.10%	28.00%	21.99%	28.07%	4.69%	0.00%	40.21%
74	0.00%	0.00%	0.00%	0.96%	0.87%	0.00%	0.00%	0.00%	0.70%	3.13%	0.00%	0.00%
75												
76												
77	26	10	8	208	115	141	75	1619	431	64	37	97
78												
79												
80												
81												
82	1	3	1	5	5	5	5	5	5	5	1	5
83	1	1	1	3	1	3	1	3	3	1	3	1
84	3	3	3	5	5	5	5	3	5	5	5	5
85	1	1	1	5	5	3	5	5	3	5	1	5
86	3	3	3	5	5	3	3	3	3	3	3	3
87												
88	5	5	5	5	3	5	5	5	5	5	5	5
89	5	5	5	5	3	5	5	5	5	3	5	5
90	5	5	1	3	1	5	3	3	3	1	1	3
91	1	1	1	1	1	1	1	1	1	3	1	1
92	5	5	5	5	5	5	5	5	5	5	5	5
93	5	5	5	5	5	5	5	5	5	5	5	5
94	1	1	1	5	3	3	3	5	5	3	1	3
95												
96	36	38	32	52	42	48	46	48	48	44	36	46
97	P/F	P/F	P	G	F	G	F/G	G	G	F	F	F

APPENDIX IV, TABLE 1

	AJ	AK	AL	AM	AN	AO
1	West Br.		No. Sites	Species		
2	EC-07.5		35			
3	8/30/88		Percent			
4	SH		Occurrence	Trophic Guild	Total No	
5						
6	25		31% Gizzard shad	O	90	
7	4		31% Grass pickerel	P	23	
8			31% Carp	O	48	
9			3% Golden shiner	O	1	
10			34% Creek chub	I	40	
11			3% Hornyhead chub	I	1	
12			6% Suckermouth minnow	I	5	
13	1		6% Emerald shiner	I	6	
14	14		54% Striped shiner	I	122	
15			6% Bigmouth shiner	I	5	
16			3% Red shiner	O	1	
17	13		49% Spottfin shiner	I	139	
18	2		26% Sand shiner	I	38	
19	52		83% Redfin shiner	I	1989	
20			3% Silverjaw minnow	I	1	
21	27		66% Bluntnose minnow	O	217	
22	9		23% Common stoneroller	H	30	
23			3% River carpsucker	O	6	
24	1		40% Quillback carpsucker	O	100	
25			9% Highfin carpsucker *	O	5	
26			0% Silver redbhorse	I	0	
27			31% Golden redbhorse	I	51	
28			3% Shorthead redbhorse	I	1	
29			17% Northern hog sucker*	I	15	
30			17% White sucker	I	10	
31	1		31% Spotted sucker *	I	48	
32	2		43% Creek chubsucker	I	72	
33			6% Black bullhead	I	4	
34	1		34% Yellow bullhead	I	23	
35			0% Channel catfish	P	0	
36			3% Slender madtom *	I	2	
37			0% Stonecat	I	0	
38			20% Brindled madtom *	I	15	
39	700		74% Blackstripe topminnow	I	2292	
40			0% Smallmouth bass	P	0	
41			17% Largemouth bass	P	8	
42	20		46% Green sunfish	P	95	
43			3% Orangespotted sunfish	I	3	
44	40		57% Bluegill	I	156	
45	50		89% Longear sunfish *	I	637	
46			0% Rock bass *	I	0	
47			3% White crappie	P	1	
48			14% Blackside darter	I	7	
49			6% Dusky darter	I	2	
50			3% Greensided darter *	I	1	
51			3% Rainbow darter	I	1	
52	2		29% Johnny darter	I	27	
53						
54						
55						
56						
57						Total No. Fish
58	18		Integrity Class Scoring Criteria			6338
59						
60	964		12-22 Very Poor			
61			28-34 Poor			
62	0.52		40-44 Fair			
63			48-52 Good			
64			58-60 Excellent			
65	18					
66	1					
67	3					
68	3					
69	2					
70						
71	2.07%					
72	5.50%					
73	8.51%					
74	0.41%					
75						
76						
77	964					
78						
79						
80			Avg index value			
81						
82	5		3.97			
83	3		1.80			
84	5		4.26			
85	5		3.46			
86	3		3.29			
87						
88	5		4.89			
89	5		4.43			
90	1		3.29			
91	1		1.51			
92	5		5.00			
93	5		5.00			
94	5		2.66			
95						
96	48		46.08			
97	G		F/G			

APPENDIX IV, TABLE 2

	A	B	C	D	E	F	G	H	I	J	K	L
	Species	East Br. EC-01 1 Date	East Br. EC-02 1 Date	East Br. EC-03 6 Dates	East Br. EC-04 2 Dates	West Br. EC-05 1 Date	West Br. EC-07 23 Dates	West Br. EC-07.5 1 Date	East & West EC-All 25 dates	No. sites 7	Species	
1												
2												
3												
4												
5												
6	Gizzard shad		2	55			16	25	98	57%	Gizzard shad	
7	Grass pickerel			4	5	2	25	4	40	71%	Grass pickerel	
8	Carp			24	3		45		72	43%	Carp	
9	Golden shiner				3	8	2		2	14%	Golden shiner	
10	Creek chub						77		88	43%	Creek chub	
11	Hornyhead chub						2		2	14%	Hornyhead chub	
12	Suckermouth minnow						10		10	14%	Suckermouth minnow	
13	Emerald shiner						10	1	11	29%	Emerald shiner	
14	Striped shiner	1		1	3	7	209	14	235	86%	Striped shiner	
15	Bigmouth shiner						10		10	14%	Bigmouth shiner	
16	Red shiner						2		2	14%	Red shiner	
17	Spotfin shiner	15		11	17	22	183	13	261	86%	Spotfin shiner	
18	Sand shiner	5		1	2		58	2	68	71%	Sand shiner	
19	Redfin shiner	25	167	248	38	33	2958	52	3519	100%	Redfin shiner	
20	Silverjaw minnow						2		2	14%	Silverjaw minnow	
21	Bluntnose minnow	17		8	24	6	306	27	388	86%	Bluntnose minnow	
22	Common stoneroller				3		39	9	51	43%	Common stoneroller	
23	River carpsucker			6					6	14%	River carpsucker	
24	Quillback carpsucker			42	1		113	1	157	57%	Quillback carpsucker	
25	Highfin carpsucker			4			2		6	29%	Highfin carpsucker *	
26	Silver redhorse									0%	Silver redhorse	
27	Golden redhorse	2	1	39			18		60	57%	Golden redhorse	
28	Shorthead redhorse			1					1	14%	Shorthead redhorse	
29	Northern hog sucker	1					28		29	29%	Northern hog sucker *	
30	White sucker			3			14		17	29%	White sucker	
31	Spotted sucker			33			28	1	62	43%	Spotted sucker *	
32	Creek chubsucker	2		3	1	1	129	2	138	86%	Creek chubsucker	
33	Black bullhead			2			4		6	29%	Black bullhead	
34	Yellow bullhead			2	1		39	1	43	57%	Yellow bullhead	
35	Channel catfish									0%	Channel catfish	
36	Slender madtom						4		4	14%	Slender madtom *	
37	Stoneroller									0%	Stoneroller	
38	Brindled madtom	1			1	5	27		34	57%	Brindled madtom *	
39	Blackstripe topminnow	2	1	6	6	5	3160	700	3880	100%	Blackstripe topminnow	
40	Smallmouth bass									0%	Smallmouth bass	
41	Largemouth bass			3			10		13	29%	Largemouth bass	
42	Green sunfish			2	2		144	20	168	57%	Green sunfish	
43	Orangespotted sunfish			3					3	14%	Orangespotted sunfish	
44	Bluegill			12	5	3	203	40	263	71%	Bluegill	
45	Longear sunfish	14	17	61	18		972	50	1132	86%	Longear sunfish *	
46	Rock bass									0%	Rock bass *	
47	White crappie						2		2	14%	White crappie	
48	Blackside darter	3			1		7		11	43%	Blackside darter	
49	Dusky darter				1	1	3		5	43%	Dusky darter	
50	Greensided darter						2		2	14%	Greensided darter *	
51	Rainbow darter						2		2	14%	Rainbow darter	
52	Johnny darter				1	8	49	2	60	57%	Johnny darter	
53												
54												
55	* Intolerant species											
56												
57												
58	No. Species	12	5	24	20	12	39	18	42			
59												
60	No. Fish	88	188	574	136	101	8912	964	10963			
61												
62												
63	Shannon-Weaver Diversity	0.85	0.19	0.90	0.99	0.88	0.81	0.52				
64												
65	No. Species											
66	Total	12	5	24	20	12	39	18	42			
67	Darters	1	0	0	3	2	5	1	5			
68	Sunfish	1	1	4	3	1	4	3	5			
69	Suckers	3	1	8	2	1	7	3	9			
70	Intolerants	3	1	3	2	1	7	2	7			
71	Proportion of Individuals											
72	Green sunfish	0.00%	0.00%	0.35%	1.47%	0.00%	1.62%	2.07%	1.53%			
73	Omnivores	19.32%	1.06%	24.22%	20.59%	5.94%	5.45%	5.50%	6.87%			
74	Insectivorous cyprinids	52.27%	88.83%	45.47%	46.32%	69.31%	39.46%	8.51%	38.37%			
75	Piscivores	0.00%	0.00%	1.57%	5.15%	1.98%	2.03%	2.49%	2.03%			
76	Hybrids											
77	Diseased											
78	Total No. Individuals	88	188	574	136	101	8912	964	10963			
79												
80	Metric Ratings											
81												
82	No. Species											
83	Total	5	3	5	5	5	5	5	5			4.71
84	Darters	3	1	1	5	3	5	3	5			3.00
85	Sunfish	3	3	5	5	3	5	5	5			4.14
86	Suckers	5	3	5	5	3	5	5	5			4.43
87	Intolerants	5	3	5	3	3	5	3	5			3.86
88	Proportion of Individuals											
89	Green sunfish	5	5	5	5	5	5	5	5			5.00
90	Omnivores	5	5	3	3	5	5	5	5			4.43
91	Insectivorous cyprinids	5	5	5	5	5	3	1	3			4.14
92	Piscivores	1	1	3	5	3	3	3	3			2.71
93	Hybrids	5	5	5	5	5	5	5	5			5.00
94	Diseased	5	5	5	5	5	5	5	5			5.00
95	Total No. Individuals	3	3	5	3	3	5	5	5			3.86
96												
97	IBI total score	50	42	52	54	48	56	50	56			50.29
98	Integrity Class	G	F	G	G	G	G	G	G			G

Integrity Class Scoring

12-22 Very Poor
28-34 Poor
40-44 Fair
48-52 Good
58-60 Excellent

Average metric value

APPENDIX IV, TABLE 3

	A	B	C	D	E	F	G	H	I	J	K
1	Species	FC-01	FC-01	FC-01	FC-02	FC-02	FC-02	FC-02	FC-02	FC-02	FC-02
2		6/01/87	7/11/87	8/06/87	8/03/87	7/11/87	8/06/87	4/18/88	5/05/88	5/31/88	9/14/88
3		BE	BE	BE	BE	BE	BE	FE	FE	FE	SH
4											
5	Gizzard shad										
6	Grass pickerel	3	1	1		2	1	1			
7	Carp										
8	Golden shiner										
9	Creek chub	16	7	8	8	10	13	8	5	10	114
10	Honeyhead chub										
11	Suckermouth minnow										
12	Emerald shiner										
13	Striped shiner		5		8	1	2	1			4
14	Bigmouth shiner										
15	Red shiner	3		1	3	2					
16	Spotfin shiner		1			3			1		2
17	Sand shiner	4		1	10						
18	Redfin shiner	15	1	3	8	12	4	1	2		26
19	Silverjaw minnow	11	5	65	8	7	1				8
20	Bluntnose minnow	18	15	156	48	3	73	3	6	17	80
21	Common stoneroller	32	4	90				6	2	4	
22	River carpsucker										
23	Ouilback carpsucker			1							1
24	Highfin carpsucker										
25	Silver redborse										
26	Golden redborse										
27	Shorthead redborse										
28	Northern hog sucker		1								
29	White sucker					2	2		1		5
30	Spotted sucker										
31	Creek chubsucker		1								
32	Black bullhead										
33	Yellow bullhead		2	1			1				
34	Channel catfish										
35	Slender madtom										
36	Stoneycat										
37	Brindled madtom										
38	Blackstripe topminnow										
39	Smallmouth bass										
40	Largemouth bass										1
41	Green sunfish		2								
42	Orangespotted sunfish										
43	Bluegill				1				1		
44	Longear sunfish	6	8	8		1	1		1		
45	Rock bass										
46	White crappie										
47	Blackside darter										
48	Dusky darter										
49	Greensided darter										
50	Rainbow darter	8	2		2	1	3				4
51	Johnny darter	4	1	2	1	1	7	1			1
52											
53	* Intolerant species										
54											
55	No. Species	11	15	12	10	12	11	7	8	3	11
56											
57	No. Fish	120	56	337	95	45	108	21	19	31	246
58											
59	Shannon-Weaver Diversity	0.92	1.00	0.59	0.74	0.91	0.54	0.69	0.79	0.42	0.60
60											
61	No. Species										
62	Total	11	15	12	10	12	11	7	8	3	11
63	Darters	2	2	1	2	2	2	1	0	0	2
64	Sunfish	1	2	1	1	1	1	0	2	0	0
65	Suckers	0	2	1	0	1	1	0	1	0	2
66	Intolerants	1	2	1	0	1	1	0	1	0	0
67	Proportion of Individuals										
68	Green sunfish	0.00%	3.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
69	Omnivores	17.50%	26.79%	46.88%	51.58%	11.11%	67.59%	14.29%	31.58%	54.84%	32.93%
70	Insectivorous cyprinids	38.33%	33.93%	22.85%	44.21%	73.33%	18.52%	47.62%	42.11%	32.26%	62.60%
71	Piscivores	2.50%	1.79%	0.30%	0.00%	4.44%	0.93%	4.76%	0.00%	0.00%	0.41%
72	Hybrids										
73	Diseased										
74	Total No. Individuals	120	56	337	95	45	108	21	19	31	246
75											
76	Metric Ratings										
77											
78	No. Species										
79	Total	5	5	5	5	5	5	3	3	1	5
80	Darters	3	3	3	3	3	3	3	1	1	3
81	Sunfish	3	5	3	3	3	3	3	5	3	3
82	Suckers	1	5	3	1	3	3	1	3	1	5
83	Intolerants	3	3	3	1	3	3	1	3	1	1
84	Proportion of Individuals										
85	Green sunfish	5	5	5	5	5	5	5	5	5	5
86	Omnivores	5	3	1	1	5	1	5	3	1	3
87	Insectivorous cyprinids	3	3	3	3	5	1	5	3	3	5
88	Piscivores	3	3	1	1	3	1	3	1	1	1
89	Hybrids	5	5	5	5	5	5	5	5	5	5
90	Diseased	5	5	5	5	5	5	5	5	5	5
91	Total No. Individuals	3	3	5	3	1	3	1	1	1	5
92											
93	IBI total score	44	48	42	36	46	38	40	38	28	46
94	Integrity Class	F	G	F	F	G	F	F	F	P	G

	L	M	N	O	P	Q	R	S	T	U	V	W
1	FC-02.5	FC-02.5	FC-02.5	FC-02.5	FC-02.75	FC-02.75	FC-03	FC-03	FC-03	FC-03	FC-03	FC-03
2	5/05/88	5/31/88	9/14/88	8/06/87	10/03/87	9/14/88	6/03/87	7/11/87	8/06/87	10/03/87	4/07/88	4/18/88
3	FE	FE	SH		ES	SH	BE	BE				FE
4												
5												
6		2			1			1				
7						1		1				
8											1	
9					1	11	2	11	3	12	4	15
10												8
11												1
12		4										
13				19	2	7	6		13	1		6
14												78
15						3	1	2				
16				1		1	2		5			5
17									1			1
18						3	31	2	4		13	12
19		2	8			10	2	3	8	5	15	3
20			1			112	29	9	15	44	35	20
21			13						3	20	8	68
22												4
23					1		3					
24												
25												
26												
27												
28												
29							1					2
30	2	1			2	2			1		1	1
31												
32		5			1				1			
33		1										
34										3		
35												
36												
37												
38						1	24					
39												
40												
41									1			
42												
43												
44		2			1	9		8	4	11		1
45												
46												
47												
48												
49												
50				1								
51									1	6		1
52												
53												
54												
55	1	7	6	7	12	10	6	15	9	3	10	11
56												
57	2	17	43	9	189	81	47	62	103	47	76	181
58												
59	0.00	0.78	0.56	0.82	0.63	0.73	0.63	0.98	0.73	0.32	0.80	0.61
60												
61												
62	1	7	6	7	12	10	6	15	9	3	10	11
63	0	0	1	0	0	0	0	1	1	0	2	0
64	0	1	0	1	1	0	1	2	1	0	0	1
65	1	2	0	3	1	2	0	2	0	0	1	2
66	0	1	0	1	1	1	1	1	1	0	0	2
67												
68	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.61%	0.00%	0.00%	0.00%	0.00%
69	0.00%	0.00%	30.23%	11.11%	61.38%	4.94%	48.94%	25.81%	42.72%	74.47%	27.63%	37.57%
70	0.00%	35.29%	67.44%	33.33%	16.93%	53.09%	34.04%	54.84%	18.45%	8.51%	68.42%	58.01%
71	0.00%	11.76%	0.00%	11.11%	0.00%	0.00%	0.00%	1.61%	0.00%	0.00%	0.00%	0.00%
72												
73												
74	2	17	43	9	189	81	47	62	103	47	76	181
75												
76												
77												
78												
79	1	3	3	3	5	5	3	5	3	1	5	5
80	1	1	3	1	1	1	1	3	3	1	3	1
81	3	3	3	3	3	3	3	5	3	3	3	3
82	3	5	1	5	3	5	1	5	1	1	3	5
83	1	3	1	3	3	3	3	3	3	1	1	3
84												
85	5	5	5	5	5	5	5	5	5	5	5	5
86	5	5	3	5	1	5	1	3	3	1	3	3
87	1	3	5	3	1	5	3	5	1	1	5	5
88	1	5	1	5	1	1	1	3	1	1	1	1
89	5	5	5	5	5	5	5	5	5	5	5	5
90	5	5	5	5	5	5	5	5	5	5	5	5
91	1	1	1	1	3	3	1	3	3	1	3	3
92												
93	32	44	36	44	36	46	32	50	36	26	42	44
94	P	F	P	F	F	G	P	G	P	VP	F	F

	X	Y	Z	AA	AB	AC	AD	AE	AF
1	FC-03	FC-03	Middlefork	Middlefork		No. Sites	Species		
2	5/05/88	5/31/88	6/21/88	8/11/87		26			
3	FE		ES	ES					
4						% Occurrence		Total No	Trophic Guild
5				2		4%	Gizzard shad	2	O
6		1	1	4		46%	Grass pickerel	19	P
7				1		12%	Carp	3	O
8						4%	Golden shiner	1	O
9	5	3	5	1		88%	Creek chub	280	I
10						0%	Honeyhead chub	0	I
11		1	1	23		19%	Suckermouth minnow	30	I
12						0%	Emerald shiner	0	I
13	5	11	7	5		69%	Striped shiner	181	I
14						0%	Bigmouth shiner	0	I
15			7	9		35%	Red shiner	31	O
16		2	31	9		46%	Spotfin shiner	63	I
17			25	24		31%	Sand shiner	79	I
18		15		12		77%	Redfin shiner	181	I
19		1	5	23		65%	Silverjaw minnow	162	I
20	1	2	24	101		85%	Bluntnose minnow	873	O
21		13	11	55		58%	Common stoneroller	290	H
22						0%	River carpsucker	0	O
23		3	10	30		27%	Quillback carpsucker	49	O
24		3		3		8%	Highfin carpsucker *	6	O
25				5		4%	Silver redhorse	5	I
26		1	2	43		12%	Golden redhorse	46	I
27			17	1		8%	Shorthead redhorse	18	I
28		4	1	24		23%	Northern hog sucker*	33	I
29	7	7		10		54%	White sucker	44	I
30						0%	Spotted sucker *	0	I
31			3			19%	Creek chubsucker	11	I
32		2				8%	Black bullhead	3	I
33			1	1		23%	Yellow bullhead	9	I
34				1		4%	Channel catfish	1	P
35						0%	Slender madtom *	0	I
36				6		4%	Stoneroller	6	I
37						0%	Brindled madtom *	0	I
38						8%	Blackstripe topminnow	25	I
39			1	2		8%	Smallmouth bass	3	P
40				2		8%	Largemouth bass	3	P
41			2	3		15%	Green sunfish	8	I
42						0%	Orangespotted sunfish	0	I
43						8%	Bluegill	2	I
44		7	43	22		62%	Longear sunfish *	133	I
45			1			4%	Rock bass *	1	I
46						0%	White crappie	0	P
47			7	2		8%	Blackside darter	9	I
48						0%	Dusky darter	0	I
49			3			4%	Greensided darter *	3	I
50						31%	Rainbow darter	22	I
51			11	3		50%	Johnny darter	40	I
52									
53									
54									
55	4	16	23	29				Total No. Fish	
56								2675	
57	18	76	219	427					
58									
59	0.54	1.04	1.12	1.15					
60									
61									
62	4	16	23	29					
63	0	0	3	2					
64	0	1	3	2					
65	1	5	5	7					
66	0	3	4	3					
67									
68	0.00%	0.00%	0.91%	0.70%					
69	5.56%	10.53%	18.72%	34.19%					
70	55.56%	43.42%	33.79%	22.72%					
71	0.00%	1.32%	0.91%	2.11%					
72									
73									
74	18	76	219	427					
75									
76									
77									
78									
79	3	5	5	5				3.83	
80	1	1	5	3				2.00	
81	3	3	5	5				3.25	
82	3	5	5	5				3.00	
83	1	5	5	5				2.33	
84									
85	5	5	5	5				5.00	
86	5	5	5	3				3.17	
87	5	3	3	3				3.33	
88	1	3	1	3				1.83	
89	5	5	5	5				5.00	
90	5	5	5	5				5.00	
91	1	3	5	5				2.25	
92									
93	38	48	54	52				41	
94	P/F	G	G/E	G				F	

	A	B	C	D	E	F	G	H	I
1	Species	FC-01	FC-02	FC-2.5	FC-2.75	FC-03	Middlefork	FC-All	Sites
2		3 Dates	7 Dates	3 Dates	3 Dates	8 Dates	2 Dates		27
3								Dates/Sites	
4									
5	Gizzard shad						2		
6	Grass pickerel	5	4	2	1	2	5		14
7	Carp				1	1	1		2
8	Golden shiner					1			1
9	Creek chub	31	168		14	61	6		274
10	Hornyhead chub								
11	Suckermouth minnow			4		2	24		6
12	Emerald shiner								
13	Striped shiner	5	16	19	15	114	12		169
14	Bigmouth shiner								
15	Red shiner	4	5		4	2	16		15
16	Spotfin shiner	1	6	1	3	12	40		23
17	Sand shiner	5	10			15	49		30
18	Redfin shiner	19	53	10	34	53	12		169
19	Silverjaw minnow	81	24	1	12	16	28		134
20	Bluntnose minnow	189	228	13	112	206	125		748
21	Common stoneroller	126	12		38	48	66		224
22	River carpsucker								
23	Quillback carpsucker	1	1		4	3	40		9
24	Highfin carpsucker					3	3		3
25	Silver redhorse						5		
26	Golden redhorse					1	45		1
27	Shorthead redhorse						18		
28	Northern hog sucker	1			1	6	25		8
29	White sucker		10	3	4	17	10		34
30	Spotted sucker								
31	Creek chubsucker	1		5	1	1	3		8
32	Black bullhead			1		2			3
33	Yellow bullhead	3	1			3	2		7
34	Channel catfish						1		
35	Slender madtom								
36	Stoneroller						6		
37	Brindled madtom								
38	Blackstripe topminnow				25				25
39	Smallmouth bass						3		
40	Largemouth bass		1				2		1
41	Green sunfish	2				1	5		3
42	Orangespotted sunfish								
43	Bluegill		2						2
44	Longear sunfish	22	3	2	10	31	65		68
45	Rock bass						1		
46	White crappie								
47	Blackside darter						9		
48	Dusky darter								
49	Greensided darter						3		
50	Rainbow darter	10	10	1		1			22
51	Johnny darter	7	11			8	14		26
52									
53									
54	* Intolerant species								
55									
56									
57	No. Species	18	18	12	16	25	32		28
58									
59	No. Fish	513	565	62	279	610	646		2029
60									
61									
62	Shannon-Weaver Diversity	0.80	0.77	0.87	0.86	0.94	1.23		0.94
63									
64	No. Species								
65	Total	18	18	12	16	25	32		28
66	Darters	2	2	1	0	2	3		2
67	Sunfish	2	2	1	1	2	3		3
68	Suckers	3	2	2	4	6	8		6
69	Intolerants	2	1	1	2	3	5		3
70	Proportion of Individuals								
71	Green sunfish	0.39%	0.00%	0.00%	0.00%	0.16%	0.77%		0.15%
72	Omnivores	37.82%	41.42%	20.97%	43.37%	35.41%	28.95%		38.34%
73	Insectivorous cyprinids	27.68%	49.03%	56.45%	27.96%	44.75%	26.47%		39.67%
74	Piscivores	1.36%	0.88%	3.23%	0.36%	0.49%	2.48%		0.89%
75	Hybrids								
76	Diseased								
77	Total No. Individuals	513	565	62	279	610	646		2029
78									
79	Metric Ratings								
80									
81	No. Species								
82	Total	5	5	5	5	5	5		5
83	Darters	3	3	3	1	3	5		3
84	Sunfish	5	5	3	3	5	5		5
85	Suckers	5	5	5	5	5	5		5
86	Intolerants	3	3	3	3	5	5		5
87	Proportion of Individuals								
88	Green sunfish	5	5	5	5	5	5		5
89	Omnivores	3	3	3	3	3	3		3
90	Insectivorous cyprinids	3	5	5	3	3	3		3
91	Piscivores	3	1	3	1	1	3		1
92	Hybrids	5	5	5	5	5	5		5
93	Diseased	5	5	5	5	5	5		5
94	Total No. Individuals	5	5	3	5	5	5		5
95									
96	IBI total score	50	50	48	44	50	54		50
97	Integrity Class	G	G	G	F	G	G		G
98									

APPENDIX IV, TABLE 4

	J	K	L	M
1	No. Sites	Species		
2	6			
3			Trophic	
4	% Occurrence		Guild	
5	17%	Gizzard shad	O	
6	100%	Grass pickerel	P	
7	50%	Carp	O	
8	17%	Golden shiner	O	
9	83%	Creek chub	I	
10	0%	Honeyhead chub	I	
11	50%	Suckermouth minnow	I	
12	0%	Emerald shiner	I	
13	100%	Striped shiner	I	
14	0%	Bigmouth shiner	I	
15	83%	Red shiner	O	
16	100%	Spotfin shiner	I	
17	67%	Sand shiner	I	
18	100%	Redfin shiner	I	
19	100%	Silverjaw minnow	I	
20	100%	Bluntnose minnow	O	
21	83%	Common stoneroller	H	
22	0%	River carpsucker	O	
23	83%	Quillback carpsucker	O	
24	33%	Highfin carpsucker *	O	
25	17%	Silver redbreast	I	
26	33%	Golden redbreast	I	
27	17%	Shorthead redbreast	I	
28	67%	Northern hog sucker*	I	
29	83%	White sucker	I	
30	0%	Spotted sucker *	I	
31	83%	Creek chubsucker	I	
32	33%	Black bullhead	I	
33	67%	Yellow bullhead	I	
34	17%	Channel catfish	P	
35	0%	Slender madtom *	I	
36	17%	Stoneroller	I	
37	0%	Brindled madtom *	I	
38	17%	Blackstripe topminnow	I	
39	17%	Smallmouth bass	P	
40	33%	Largemouth bass	P	
41	50%	Green sunfish	P	
42	0%	Orangespotted sunfish	I	
43	17%	Bluegill	I	
44	100%	Longear sunfish *	I	
45	17%	Rock bass *	I	
46	0%	White crappie	P	
47	17%	Blackside darter	I	
48	0%	Dusky darter	I	
49	17%	Greensided darter *	I	
50	67%	Rainbow darter	I	
51	67%	Johnny darter	I	
52				
53				
54				
55				
56				
57	FC Metric			
58				
59	12-22	Very Poor		
60	28-34	Poor		
61	40-44	Fair		
62	48-52	Good		
63	58-60	Excellent		
64				
65				
66				
67				
68				
69				
70				
71				
72				
73				
74				
75				
76				
77				
78				
79				
80	Avg index value FC			
81				
82	5			
83	2.6			
84	4.2			
85	5			
86	3.4			
87				
88	5			
89	3			
90	3.8			
91	1.8			
92	5			
93	5			
94	4.6			
95				
96	48.4			
97	G			
98				

APPENDIX V

Water Chemistry Data for Embarras River

Appendix V, Table 2. Sample of water chemistry data provided by Geological Survey Water Data Reports, Embarras River near Carmage (03 343395).

DATE	pH	TEMP (C)	TURBIDITY (NTU)	DO (MG/L)	ALKALINITY (MG/L) (AS CaCO3)	HARDNESS N (NO3/NO2) (MG/L AS N)	N (NH3) (MG/L AS N)	SS AT 105 C (MG/L)	VOLATILES (MG/L)	TOTALS (MG/L)	FLOW (CFS)
10/27/78	7.8	18		7.5		7.2	0.2	67	9	76	22
10/10/79	8.2	12			202	3.4	0	25	2	27	9.7
11/20/79	7.9	11			345	2.2	0	25	1	26	12
12/17/79	8.2	1			241	6.4	0	26	1	27	18
1/21/80		2									
2/25/80	8.2	1.5			211	7.5	0	24	0	24	28
4/1/80	7.9	6.5			183	9.2	0.1	24	1	25	133
5/1/80		13.5		10.7	137	13	0	21	6	27	698
5/21/80	8.1	16.5		11.1	193	12	0	28	2	30	95
6/23/80	8.2	23.5			185	14	0	25	4	29	168
7/22/80	8	23.5			188	11	0	24	6	30	48
8/19/80	8.2	24.5		5.3	113	1.1	0.1	24	14	38	56
9/18/80	7.6	20			59	2.7	0	6	17	23	194
					134	3.5	0.1	18	9	25	45
10/23/85	7.1	15	3.9		249	<0.1	<0.1	1	1	2	3.1
12/9/85	7.5	6		10.6	185	10	<0.1	20	4	24	211
2/3/86	7.5	0	2.6	13.6	192	8.2	<0.1	6	2	8	62
3/4/86	7.7	4	5.2	12.1	186	11	<0.1	9	1	10	169
3/27/86	7.8	9	3.1	10.6	191	11	<0.1	22	6	28	130
4/29/86	7.7	14	9.5	8.6	205	9.2	<0.1	25	2	27	44
6/11/86	7.6	21	4.5	7.1	178	13	<0.1	112	12	124	291
7/10/86	7.9	25	29	5.6	225	5.5	<0.1	79	15	94	17
10/3/86	7.8	20		7.7	266	0.19	<0.1				0
10/2/87	6.8	21	2.7	4.7	137	3.7	<0.1	105	10	125	113
11/19/87	7.2	5	1.1	10.1	227	6.2	<0.1	4	2	6	30
1/12/87	8.3	0	2	14.8	194	8.5	<0.1	5	1	6	54
2/11/87	7.7	5	3.7	11.1	165	12	<0.1	13	2	15	297
3/26/87	6.8	9	2.5	10.6	183	9.9	<0.1	15	2	17	62
5/4/87	7.1	16	2.2	7.8	175	11	0.11	43	8	51	93
6/16/87	7.2	26	12	5.5	219	8.3	<0.1	47	8	55	33
8/4/87	7.2	27	6	5.2	228	3.5	<0.1	1	1	2	23
9/3/87	7.4	18	30	6	240	2.6	0.18	63	9	72	5.5

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