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Evaluation of Low Order Stream Quality in Central Iowa

by

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Preface

The Federal Clean Water Act has requested that procedures be developed to protect fish, wildlife, and water quality and provide definitions for biological integrity. The purpose of this research is to perform laboratory and field procedures to define the biotic quality of low order streams in Central Iowa where the land use is primarily agricultural. Past studies have largely relied on individual approaches such as chemical-specific, toxicological, or biosurvey methods. An integrated approach is needed to achieve a more holistic appraisal of watershed quality and represent an application of integrated physical, chemical, and biological procedures.

Abstract

Identifying descriptors to characterize watershed quality involves identifying, quantifying, and associating multiple physical and chemical stressors with biological responses. This research describes procedures and results obtained to evaluate the baseline (existing) watershed quality in the low order streams in a tri-county area in central Iowa. The five streams evaluated were located in the Upper Skunk River Basin. Field work was conducted over a three-year period from 1992 to 1994, and sampling conducted at 12 locations. The field procedures used physical (habitat), chemical (surface and sediment pore water quality), toxicological (daphnid and algal bioassays), and biological (macroinvertebrates and fish) techniques. Habitat quality was the highest in the larger drainages. Non-farmed streamside vegetative buffers were greater at the larger drainage sites. Significant associations were found among the macroinvertebrate community indices, surface and sediment pore water quality and drainage area. Correlations were also found between habitat quality and the biological community indices. Few associations were found when comparing the fish community results with the physical/chemical watershed components. Based on our measurements, lowest watershed quality was present in the upper drainage reaches. This study found that elevated concentrations of sediments and nutrients were associated with degraded biological communities found in low order agricultural streams.

Content

Tables

Figures

No. Page

List of Selected Abbreviations and Symbols

Abbreviations

C	Celsius
cms	cubic meters/second
DMW	deionized mineral water solution
EDTA	ethylenediamine tetraacetic acid
EPT	Ephemeroptera/Plecoptera/Trichoptera
IBI	Index of Biotic Integrity
ICI	Index of Invertebrate Community Integrity
in	inch
µg	microgram
MED-D	Mid-Continent Ecology Division-Duluth
µg/l	microgram per liter
mg/l	milligram per liter
m	meter
mi^2	square mile
mm	millimeter
NH_3-N	total ammonia nitrogen
NO_2+NO_3-N	total nitrite plus nitrate nitrogen
O-PO_4	ortho-phosphorus
$P<0.05$	probability less than 5% by chance alone
PCB	polychlorinated biphenyl compounds
QHEI	Qualitative Habitat Evaluation Index
RPM	revolutions per minute
TDS	total dissolved solids
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
U.S.EPA	United States Environmental Protection Agency
WCB	Western Corn Belt Plains ecoregion
YCT	yeast-cerophyl-trout chow
X G	times gravity

Symbols

$<$	less than
$>$	greater than
$\leq$	less than equal to
$\geq$	greater than equal to
%	percent

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Tom Grau, Agricultural Stabilization and Conservation Service (ASCS) Director, Des Moines, and ASCS staff located in the Story, Boone, and Hamilton County field offices, Nevada, Boone, and Webster City, Iowa, respectively, made the streamside non-farmed buffer determinations from aerial photos.

Jerry Hatfield, USDA/ARS National Soil Tilth Laboratory, Ames and Anthony (Ron) Carlson provided encouragement and logistical field support throughout the project.

1. Introduction

1.1 Background Information

Agricultural activities are the leading cause of water quality impairment according to recent state biannual water quality reports (U.S. EPA, 1994). Primary river stressors identified in these reports were siltation, nutrients, pathogens, pesticides, and organic enrichment. Sediment was found to be the dominant pollutant associated with stream impairment in Iowa (Iowa DNR, 1994) and was linked to major impacts along 84% of the state's stream miles. Identifying descriptors to define impairment can be complex and involves the consideration of multiple physical and chemical stressors and biological responses. To better integrate this information, a watershed protection approach was recommended by the EPA (U.S. EPA, 1991) as the definable unit to address water quality and has become the focal unit for diagnostic research.

Demonstration studies continue to be needed to define and apply diagnostic procedures in assessing watershed impairment. Watershed studies at MED-Duluth have been underway since 1987 with the objective to assess, consolidate, and classify stressors and responses in midwestern streams. Habitat quality was influenced by the amount of row crop farming and instream substrate composition, embeddedness and total suspended solids (Richards et al., 1993). Important chemical stressors identified were total ammonia and nitrite-nitrate nitrogen, with the amounts of ammonia being a major factor contributing to toxic inplace sediments. Factors uncovered that described fish and macroinvertebrate quality were total taxa, percent ephemeroptera/plecoptera/trichoptera (EPT) taxa, and calculated indices of community integrity (ICI) and biotic integrity (IBI). Structural, rather than functional measures, have been found to supply more meaningful information in defining the biological community quality (Arthur et al., 1996).

1.2 Scope and Purpose

This study is part of a more comprehensive study determining the transport, fate and ecological effects of agrichemicals into a small watershed called Walnut Creek near Ames, IA. This larger project, called MASTER or (Midwest Agrichemical Surface Subsurface Transport and Effects Research) has involved participants from three federal agencies (U.S. EPA, USDA, and U.S. Geological Survey). The National Soil Tilth Laboratory, Ames, IA, was responsible for the general logistics of the study and performed the agricultural crop measurements. Groups from the other two agencies concentrated on transport and fate measurements from the field agrichemical applications and other ecological studies.

MED-Duluth's assignment was to investigate the ecological and toxicological effects from intensive row crop farming. In addition to Walnut Creek and the goals of the MASTER study, four nearby creeks in Story, Boone, and Hamilton counties were chosen for comparative biological community analyses. All five streams empty into the Skunk River Drainage. Biosurveys were done to characterize the macroinvertebrate and fish communities. The same physical, chemical, and biological procedures used in our previous MED-Duluth watershed studies (Arthur and Zischke, 1994; Arthur et al., 1996), were also applied to the Iowa streams. Our general study hypothesis continues to be that an integrated physical, chemical, biological approach can supply meaningful definitions of watershed quality.

2. Methods

2.1 Description of Study Area

The Skunk River Drainage Basin is part of the Western Corn Belt (WCB) Ecoregion, and in the Des Moines Lobe region of Iowa (Omernick and Gallant, 1988). Watersheds found in the WCB ecoregion have been described as irregular in topography and receive average annual precipitations between 25-35 inches. Major land uses are for crop (corn, soybeans, feed grains) and livestock (swine) production. Dominant native vegetation is tall-grass prairie growing in deep fertile soil. Agricultural practices that alter water quality are stream channelization and artificial ditching, and applications of fertilizer and herbicides. Streams in the Skunk River basin flow through into the Mississippi River. The drainage area for the entire Skunk River Basin is 4,355 mi² (Larimer, 1974).

Five low order streams were sampled in the Upper Skunk River Basin — Crooked, Squaw, Walnut, Montgomery, and Bear Creeks. Four of the streams (Bear, Crooked, Montgomery, and Walnut) were small with total drainage areas covering 18-34 mi². Total drainage area for Squaw Creek is larger at 227 mi² (Larimer, 1974). The streams are located within a tri-county area in central Iowa (Boone, Hamilton, and Story counties), Figure 2-1. Three of the sampled streams cross county boundaries.

Cropland accounts for 82% of the landuse in the tri-county area (Appendix A.1). Other identified landuses were urban (5%), forest (4%), and pasture/rural (6%). Most farm fields adjoining the stream locations were tiled to help control soil moisture levels. Non-row crop farming in Iowa has progressively declined from an 82% intensity level in 1940 to 48% in 1964 and further down to 36% in 1987. Amounts of woodland found on Iowa farms since 1940 have remained at a 5% to 7% level. Iowa records dating back to 1964 have shown large increases in fertilizers and insecticides in recent years (Hatfield, 1996). Major urban centers in this tri-county area and populations are Ames (46,000), Boone (13,000), Webster City (9,000), and Nevada (6,000).

The Iowa streams were sampled a total of 11 times during 1992 to 1994. There were five sampling periods in 1992 (May, June, August, September, and November); four in 1993 (April, June, August, and October); and two sampling periods in 1994 (April and July). Twelve locations were sampled: three stations in Bear Creek, one station in Crooked and Montgomery Creeks, three stations in Squaw, and four stations in Walnut Creek. Sample locations in Crooked and Montgomery Creeks were positioned near their mouth, while the other streams were longitudinally sampled. Further descriptions of the sampling locations and their corresponding upstream drainage areas are given in Table 2-1. Five of the sites (WC 1, WC 2, WC 3, BC 1, and MC 1) can be classified as headwater sites (< 20 mi², using Ohio EPA, 1987 nomenclature). The remaining seven sites can be classified as wading sites (representing drainage areas between 20-500 mi²). Sampling efforts during 1992 were confined to four locations in Walnut Creek, one location in Montgomery and Squaw Creeks, and two locations in Bear Creek. Additional locations were added in 1993 to supply a more longitudinal and interstream comparability. The sampling sites were positioned either 50 to 200 m upstream or downstream from the road bridge crossings with a sampling area coverage represented by four to eight times the width of each stream segment.

2.2 Habitat

Habitat quality was evaluated using the habitat assessment technique of the Ohio Environmental Protection (1987). This qualitative and empirical procedure involves a calculation of a Qualitative Habitat Evaluation Index (QHEI) score. Seven metrics were used to calculate the index: substrate type/quality, instream cover, channel morphology, riparian zone/bank erosion, pool/riffle-run, gradient, and drainage area. The individual metric ratings were added together for a composite score; best attainable score being 100. This streamside scoring protocol represents best professional judgement.

A determination of the amount of fine particles (proportion of particles ≤ 2.4 mm) were determined at each location, and represents substrate embeddedness. Representative surficial samples at the sites were collected with a scoop (approx. upper 6 inches of substrate). Proportion of fine particles from the larger fraction was measured with a large graduated volumetric cylinder (Richards et al., 1993). Additional stream substrate sizing was determined by oven drying the sample, wet-sieving to separate the silt/clay and sand/gravel fractions using procedures of

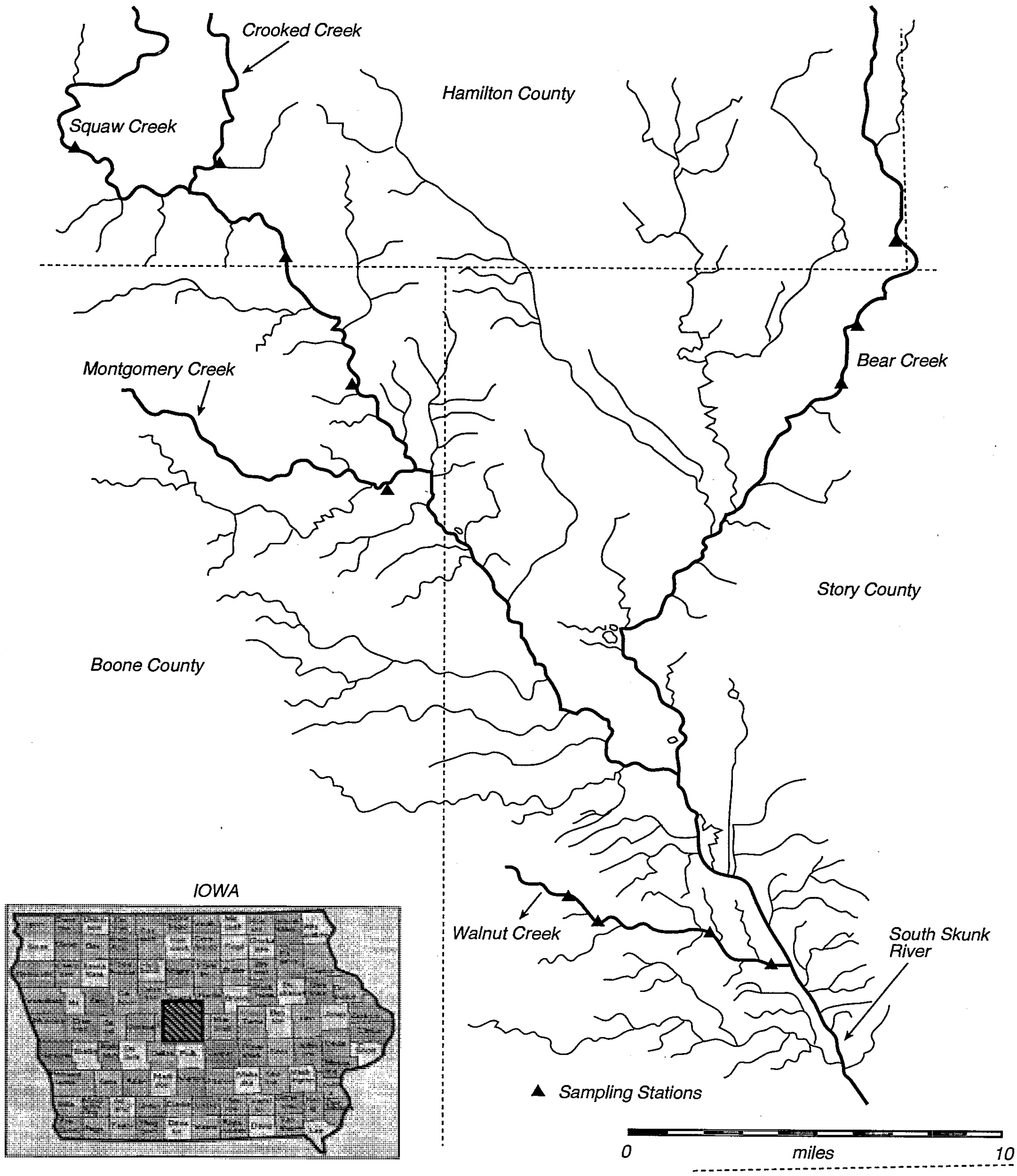


Figure 2-1. Stream sampling locations.

Table 2-1. Description of Sample Locations

Stream	Station #	Description	County	Drng Area[a]	Active Site 1992	1993	1994
Walnut Cr.	WC 1	Pothole site	Story	< 7	√	√	√
	WC 2	Hilton site	Story	7	√	√	√
	WC 3	Blacks site	Story	12	√	√	√
	WC 4	Camp Ridge site	Story	20	√	√	√
Bear Cr.	BC 1	400th St./Zublin	Hamilton	12		√	√
	BC 2	1-1/4 mi N Roland R-77	Story	20	√	√	√
	BC 3	2 mi S Roland,1 mi E. R-77	Story	32	√	√	√
Squaw Cr.	SC 1	370th St., (near Fenton Rd)	Hamilton	20		√	√
	SC 2	390th St & Hwy 17	Hamilton	62		√	√
	SC 3	2 mi N Zenorsville	Boone	130	√	√	√
Crooked Cr.	CC 1	Inkapudata Ave	Hamilton	32		√	√
Montgomery Cr.	MC 1	1 mi N Zenorsville	Boone	18	√	√	√

1992 Sampling Periods - during months of May, June, August, September, November.
1993 Sampling Periods - during months of April, June, August, October.
1994 Sampling Periods - during months of April, July.

	Longitude	*Latitude*		*Longitude*	*Latitude*
WC 1	-93.650	41.963	SC 1	-93.891	42.254
WC 2	-93.634	41.956	SC 2	-93.786	42.211
WC 3	-93.582	41.948	SC 3	-93.752	42.165
WC 4	-93.555	41.938			
			CC 1	-93.820	42.250
BC 1	-93.505	42.160			
BC 2	-93.499	42.183	MC 1	-93.741	42.123
BC 3	-93.476	42.216			

[a]Drng Area = Drainage area in square miles, source - Larimer (1974).

Lewis (1984). Particle size classifications were as follows: gravel > 2,000 μ, sand 50-2,000 μ, silt 2-50 μ and clay < 2 μ.

The extent of the non-farmed buffer strips on each side of the stream banks were estimated at location. These streamside areas were obtained by tracing the land areas from aerial 1990 ASCS flight-line photos using a digitized planimeter. The longitudinal stream length containing these buffer strips was also measured with the planimeter.

2.3 Water and Sediment Analytical Procedures

Water and sediment samples were collected in mid-stream areas, generally during baseline flows, and away from shoreline influences. All surface water samples were grab samples. Sediment samples were collected with a Ponar grab at three or more representative points at each sampling location and composited together. The surface water and sediment samples were kept cold (unfrozen, < 4°C) in ice chests for transportation to the laboratory.

At the laboratory, sediment pore water was prepared in a refrigerated centrifuge. The sediment samples were spun at 2500 X G, at 5°C, for 20 minutes, and the supernatant was collected. Portions of the supernatant were stored at 4°C for toxicity testing, and the reminder stored frozen for nutrient analyses.

The surface and sediment pore water samples were analyzed for six anions (fluoride, chloride, nitrite, bromide, nitrate, sulfate), five cations (Ca, Mg, Na, K, Mn), and five nutrients (NH_3-N, NO_2+NO_3-N, TN, O-PO_4, and TP). Inductive coupled plasma/atomic emission spectrometry (ICP/AES) techniques were used to measure the cations. Ion chromatography procedures, Dionex Series, EPA method 300.0 (U.S. EPA, 1989a) were used to analyze the anions. The detection limits for calcium, magnesium, sodium, and potassium were 0.1 mg/l; limit for manganese was 0.001 mg/l. Detection limits for anions were ≤ 0.03 mg/l. A Lachat automated ion analyzer (Lachat, 1988) measured the main nutrients - total ammonia nitrogen (NH_3-N), total nitrite-nitrate nitrogen (NO_2+NO_3-N), ortho-phosphorus (O-PO_4 as P), total phosphorus (TP), and total nitrogen (TN). The detection limits for NH_3-N, O-PO_4, and TP were 0.02 mg/l, and for NO_2+NO_3-N and TN were 0.1 mg/l. A Dohrmann instrument (using U.S. EPA, 1989a procedures) measured total organic carbon (nonpurgeable, as C). Surface water samples were also analyzed for total alkalinity (as $CaCO_3$), temperature, conductivity, total suspended solids, and total dissolved solids (TDS) using American Public Health Association (1980) methods.

Known quality control standards and spikes were used when analyzing each batch of samples. Individual analyses were conducted in duplicate or triplicate for 1-2 stations in each analytical batch. Agreement attained was generally within 10%.

2.4 Toxicity Testing

Toxicity tests were conducted with two standardized procedures, using a green alga, *Selenastrum capricornutum*, and a microcrustacean or daphnid, *Ceriodaphnia dubia*. Source of the laboratory cultures for both test organisms were from MED-Duluth laboratory cultures. Chronic toxicity tests were conducted only with the sediment pore water samples and no dilutions.

The *C. dubia* tests were initiated with animals of known parentage and ≤ 24 hours old when the chronic tests were initiated using U.S. EPA (1989b) procedures. The daphnid tests were 7-days in duration. To begin a test, one animal was placed into each of ten, 30 ml cups containing 10 ml of sediment pore water. The animals were fed a mixture of yeast-trout chow (YCT) and green algae daily. Test solutions were changed during day 2 and day 4 of the test. Determination of the differences between young production in the samples and control responses was done with the Kruskall Wallis test. Significance level was set at $P < 0.05$.

The *S. capricornutum* algal tests were conducted according to the U.S. EPA (1989b). All sediment pore water samples were filtered through a 0.45 μ millipore filter and nutrients and EDTA added to a concentrations of the control. The control consisted of a stock culture medium containing 100 μg/l EDTA ($Na_2EDTA \cdot 2H_20$). Tests were conducted under continuous illumination of 400 ± 50 foot candles, 24 ± 2 °C, and continuously shaken. Algal growth (increase in cell numbers) was determined at 2- and 4-day intervals with an electronic particle counter. Toxicity was indicated when the mean algal cell densities were less than (inhibition) the control response. The test responses were summarized using the Kruskall-Wallis test, significance level at $P < 0.05$.

2.5 Macroinvertebrate Community

Macroinvertebrate community characteristics were determined from samples collected using two separate procedures: artificial substrates and qualitative sampling. The two procedures followed U.S. EPA (Klemm et al., 1990) protocols. All biological samples were preserved onsite with 10% formalin. A fixed time interval, 30-45 minutes, was allowed to complete all the biological sampling activities, including qualitative sampling at each location.

Hester-Dendy masonite artificial samplers were attached to concrete blocks and placed near the midstream at each station in 0.75 to 1.5 m depths. The samplers were allowed to colonize for 7-8 weeks prior to removal. Removal of the sampling unit was accomplished by placing a dip net under the unit while submerged to prevent loss of organisms.

Qualitative sampling was done with the kick method and shoreline handpicking. The stream substrate was agitated by kick upstream from a dip net allowing the current to carry the organisms into the net. A representative collection of attached animals were also collected by handpicking representative submerged logs, rock, and vegetation.

Preserved samples were sorted and tabulated in glass trays over a fluorescent glow box. Initial examinations were done visually; the final sorting completed with a lighted magnifying (2X) lens. Subsampling procedures were used to enumerate taxa representing over 100 individuals in a sample. The subsampler was a glass tray with the bottom marked-off into quadrants for subdividing the sample contents.

The macroinvertebrates were identified to the lowest possible taxonomic level, usually to genus. Midge larvae were identified from head capsule mounts. Community metrics were calculated for richness (total taxa), numbers of EPT taxa, and the ICI as developed by the Ohio EPA (1987). Functional feeding habit classifications were identified according to Merritt and Cummins (1984).

2.6 Fish Community

Fish community characteristics were determined with two procedures: seining and electroshocking. Seining was the principal collection technique. The two procedures followed guidelines after Klemm et al. (1993). All collected fish were preserved in 10% formalin.

The primary collection technique was with the use of a bag seine, 30'L X 4'H (0.125 inch mesh) with a 20' wing span. A backpack, battery-operated Coffelt BT-4 model electroshocker, was deployed when necessary due to uneven stream bottoms such as too rocky or cobbly for efficient seining operations. A minimum of two collection runs were made during each sampling operation, with longitudinal reach sampled at least > 300 ft. Preserved samples were sorted in the laboratory and tabulated to the species level. A range in total lengths and weight for each species/sampling period was obtained.

Pollution-tolerance, feeding, and habitat classifications were according to the Ohio EPA (1987) and Lyons (1992). Classifications according to flowing habitat preference were from tabulations of Harlan and Speaker (1987). Metric procedures for calculating an Index of Biotic Integrity (IBI) were those of Bailey et al. (1994). The IBI metrics developed by Bailey et al. (1994) were for low order streams in southern Minnesota having landscapes similar to the Upper Skunk drainage.

2.7 Data Management and Statistical Analyses

Each of the 11 surveys were sequentially numbered, and separate identification codes given for each analysis, taxa, and sampling location. The separate year codes and composite summary identification numbers permitted additional temporal and spacial comparisons. All data were compiled into computerized spreadsheets for management and analysis.

Multivariate procedures were used to determine relationships among the physical/chemical and macroinvertebrate information. The data were analyzed by correlation, principal component, regression, and canonical correspondence analyses. The eight chemical/physical variables selected for analysis were TSS, O-PO_4, TP, TN, NO_2+NO_3-N, TN, NH_3-N, and drainage area. For the regressions, models were selected using the MAXR procedure in SAS. The Canonical correspondence analyses were limited to comparing the artificial substrate data with the environmental information. Spring months were designated as April and May, summer as June to August, and fall months when surveys were conducted in September to November. All variables were analyzed for normality and transformed where appropriate. Zero values were replaced by one-half of the detection limit. Comparative analyses were done on the environmental data with and without transformation. The levels of strong and medium significance were set at $P < 0.01$, and $P < 0.05$ and > 0.01, respectively. Pearson correlations were also calculated to normalize the effect of unequal sampling among locations. The weights were the inverse of the number of samples taken, and only used for the Pearson correlation analyses. The sum of weights applied to each site equalled one to approximate equivalent contributions for the analyses. Additional descriptions on the techniques used for these multivariant analyses are on file at the Natural Resources Research Institution, University of Minnesota-Duluth, as NRRI Report TR-95/40, CWE 165.

Correlations were also performed using minitab statistical software for comparing the fish community metrics with the water quality information, and the macroinvertebrate community indices with the QHEI habitat index and drainage area. Since the QHEI index and drainage area each represented a one time measurement, mean macroinvertebrate community indices were used for this comparison.

3. Evaluation of Watershed Quality

3.1 Habitat Assessment

Agricultural activity was the dominant land use. Small discontinuous grass and wooded shelterbelts (approximately 1-10 acres) were found scattered across the landscape, and appeared more prevalent at the larger drainage locations. Sampling was conducted in shallow water, generally in < 2 ft of depth. Bankful widths were not appreciably larger than normal flow stream widths and varied from 12-76 and 5-53 feet, respectively. Stream bottom substrate was composed of gravel and sand, sand being the dominant substrate. Some of the upstream locations also included mixtures of silt and clay material. Stream substrate bottoms were more embedded at the upstream locations (Table 3-1). Non-farmed streamside buffers varied from 1.6 to 24.3 acres/1,000 lineal feet of stream measured. Upstream locations were appreciably less in streamside non-farmed buffers than the downstream locations. The Montgomery Creek site had the greatest amounts of nonfarm streamside buffer (Appendix A.2).

Habitat quality was highest at the larger drainage areas such as in the lower portions of Squaw Creek (SC 2, SC 3). Figure 3-1 shows physical conditions at SC 3. Greater stream gradients and larger wooded riparian areas were found at Squaw Creek (SC 2, SC 3) and were reflected by the higher QHEI scores of 52 and 67. Streams with lower habitat quality were Bear, Crooked and portions of Walnut Creek, and with reduced QHEI scores ranging from 40-51. A mixture of open grassland, cultivated fields, absence of instream woody debris and straightened channels characterized the upstream sites (Figure 3-2). However, greater amounts of wooded riparian areas and a higher stream gradient were present at WC 3, WC 4, and MC 1, and reflected in higher QHEI scores (58, 49 and 56, respectively). There was a noticeable absence of aquatic macrophytes at all the sampling locations.

Rankin et al. (1995) have attributed channelization and sedimentation as habitat factors associated with degraded biological communities. Poorer habitat quality in Ohio has been defined as QHEI scores < 45, intermediate as 46 to 60, and good habitat scores > 61. Ohio's scores in the good range usually reflected intact habitat with little disturbance. Based on Ohio's classifications, most of our sites would have habitats in the intermediate range, with two locations (WC 1 and WC 2) in the poor range, and one location (SC 3) reflecting the good quality.

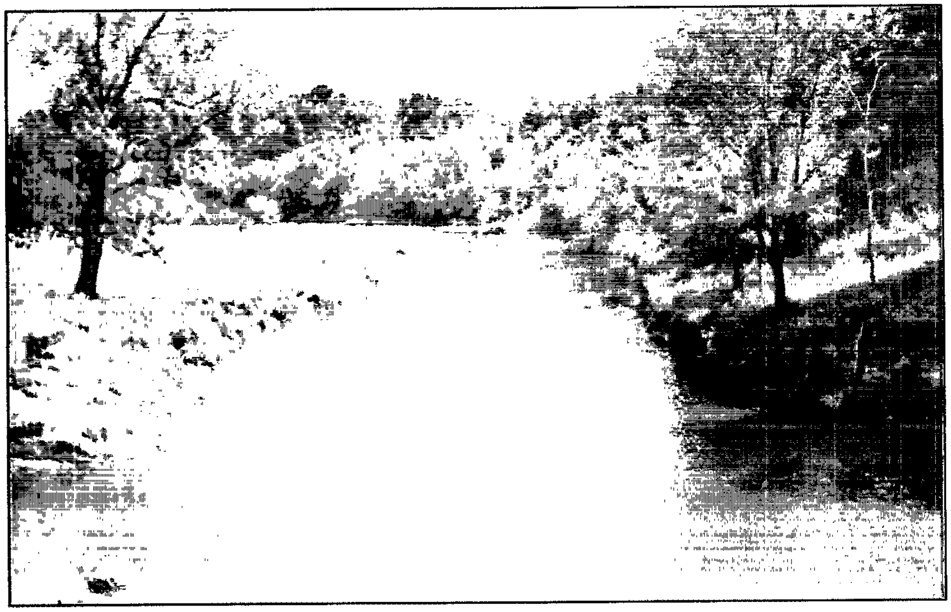
Habitat descriptions by Menzel et al. (1984) for a low order stream study in central Iowa approximated habitat quality found in our study. Sand and gravel were the dominant stream substrates, and overhanging riparian and submerged macrophytes rarely found in their streams. As in our study, they listed only a few sites where clay was part of the stream substrate. Riffle/Pool development was low and many of the streams were channelized. Menzel (1983), in another description of Iowa streams, depicted the stream channelization process as reducing cross sectional stream area and reconstructing the bottom into one composed of more uniform particles. Richards et al. (1993) found that substrate composition and fine embedded particles negatively influenced the quality of macroinvertebrate communities in a study in central Michigan. In our study, 6 of the 12 sites sampled had stream bottoms containing > 50% fine particles in the upper layers. Walnut Creek had the greatest amounts of embedded substrates.

3.2 Toxicity Findings

Few toxic responses were found in the chronic toxicity tests. For *C. dubia*, toxicity was observed during only one of the seven test periods. The toxic response was confined to the upper station in Walnut Creek (WC 1). For *S. capricornutum*, toxicity was observed during one of two sampling periods, and recorded in samples collected at the Walnut Creek (WC 1) and Crooked Creek (CC 1, Table 3-2).

The significant test response with *C. dubia* was reduced survival at WC 1. Reproductive yield during this test was lower at this site, but was not significant (Appendix A.3). During this particular test, control reproduction was suboptimal and lower room temperatures may have been a contributing factor. Except for this test response, similar daphnid responses were obtained across location and time.

More varied responses were obtained with the *S. capricornutum* tests (Appendix A.4). Both inhibitory and



Squaw Creek (SC 3)

Figure 3-1. Largest sampling site.

Crooked Creek (Station CC 1)

Bear Creek (Station BC 2)

Figure 3-2. Smaller sampling sites.

Table 3-1. Habitat Characteristics

Strm Loc.	Stream Wdth[a]	Bnkfl Wdth[b]	QHEI Score	Degr Embd.[c]	Drng Area[d]	Dominant Substrate Type (in %) Gravel	Sand	Silt	Clay
Walnut Creek									
WC 1	5	16	40	I	-	3	70	15	12
WC 2	10	12	41	I	-	46	52	1	< 1
WC 3	14	30	58	II	8	22	78	1	< 1
WC 4	15	29	49	I	13	43	55	2	< 1
Av. Score			47	I		29	64	5	4
Bear Creek									
BC 1	19	32	48	II	12	51	46	4	1
BC 2	18	38	49	II	20	56	43	2	< 1
BC 3	29	41	51	II	-	29	70	< 1	< 1
Av. Score			49	II		45	53	2	< 1
Squaw Creek									
SC 1	11	20	46	I	10	43	36	11	11
SC 2	23	44	52	-	63	18	82	NM	NM
SC 3	53	76	67	II	130	50	50	NM	NM
Av. Score			55	II		37	56	4	4
Crooked Creek									
CC 1	12	18	47	II	18	50	46	6	2
Montgomery Creek									
MC 1	-	-	56	II	32	33	65	1	< 1

- Not measured
[a]Stream width in ft.
[b]Stream bankfull width in ft.
[c]Percent embeddedness = I - > 50% by volume, II - 11% to 50%.
[d]Drainage area in mi^2.
NM = Not measurable.

stimulatory growth responses relative to control responses were recorded during the first test in April, while test responses were inhibitory in July. The two significant toxic responses were limited to the upper end of Walnut Creek (WC 1) and the one sampled location in Crooked Creek (CC 1) Table 3-2.

In previous studies conducted at midwestern agricultural locations (Wisconsin - Ankley et al., 1990, Minnesota - Arthur et al., 1994, and Michigan - Arthur et al., 1996), ambient toxicity was limited with sediment pore water samples. None of the surface water samples exhibited toxicity. In all of these previous studies, toxic responses (survival and growth - *Ceriodaphnia dubia*, generally occurred when NH_3-N concentrations exceeded 9.4 mg/l. In this study, the highest sediment pore water NH_3-N value obtained was 6.4 mg/l, and apparently insufficient in concentration to demonstrate toxicity.

3.3 Stream Chemistry Profiles

Water quality was generally similar at all locations (Table 3.3). The primary nutrient differences found were with sediment pore water concentrations of NH_3-N. Two drainages, Crooked and Walnut creeks, showed the greatest mean differences between the surface water and sediment pore water chemistries and had the widest minimum/maximum values. Montgomery Creek had lower nutrient, conductivity, and organic carbon levels. Crooked and Walnut Creeks, had lower surface water temperatures and lower amounts of total suspended solids (TSS). Soluble (filtered) phosphorus (O-PO_4) comprised 50% to 80% of the total phosphorus (TP) measured, and exhibited a uniform concentrations profile (0.04 to 0.06 mg/l) in all the drainages. Lowest concentrations of O-PO_4 were at the two downstream Walnut Creek locations (WC 3 and WC 4). The highest ratio of TP to O-PO_4 was 2:1 at Montgomery Creek, otherwise the ratio at the other locations was about 1.5:1. All of the other routine monitored surface water constituents given in Table 3-3 were similar among the drainages. The Kansas Biological Survey and Iowa State University (1996) reported on seasonal water quality characteristics in Walnut Creek during 1992 to 1994. Their reported water quality characteristics were similar to those obtained in our study.

Nutrient comparisons between surface and sediment pore waters have been reported at other midwestern agricultural sites (Ankley et al.; 1990, Arthur and Zischke, 1994; and Arthur et al., 1996). These investigations found that the main difference was the disparity in NH_3-N concentrations between the surface and sediment pore waters. In these studies, elevated sediment pore water NH_3-N concentrations > 1.0 mg/l were commonly associated with degraded biological communities. Frazier et al. (1996) re-

Table 3-2. Chronic Toxicity Test Results

	Ceriodaphnia dubia						
	05/92	06/92	09/92	04/93	06/93	04/94	07/94
Walnut Creek							
WC 1	NT	NT	NT	NT	NT	NT	T[a]
WC 2	NT	NT	NT	NT	NT	NT	NT[b]
WC 3	NT	NT	NT	NT	NT	-[c]	NT
WC 4	NT	NT	NT	NT	-	NT	NT
Bear Creek							
BC 1	-	-	-	NT	-	NT	NT
BC 2	NT	NT	NT	NT	NT	NT	NT
BC 3	NT	NT	NT	NT	-	-	-
Squaw Creek							
SC 1	-	-	-	-	-	NT	NT
SC 2	-	-	-	NT	-	NT	NT
SC 3	NT	NT	NT	NT	-	NT	NT
Montgomery Creek							
MC 1	NT	-	NT	NT	-	-	-
Crooked Creek							
CC 1	-	-	-	-	NT	NT	NT

	Selenastrum capricornutum	
	04/94	07/94
Walnut Creek		
WC 1	NT	T[a]
WC 2	NT	NT
WC 3	-	-
WC 4	NT	NT
Bear Creek		
BC 1	NT	NT
BC 2	NT	NT
BC 3	-	-
Squaw Creek		
SC 1	NT	NT
SC 2	NT	-
SC 3	NT	NT
Montgomery Creek		
MC 1	-	-
Crooked Creek		
CC 1	NT	T[a]

[a]Toxic ($P < 0.05$ level).
[b]Not toxic.
[c]No measurements taken.

cently reported on finding appreciably higher concentrations of NH_3-N in Mississippi River sediment pore water, particularly in the summer months, and linked to silt and volatile solid constituents in the river bottom substrates. In addition, Frazier's surface and sediment NH_3-N profiles approximated those found in our study.

Intrastream water quality longitudinal differences occurred in some of the drainages (Appendix A.5). Upstream to downstream decreases were observed for total conductivity and alkalinity in Squaw and Walnut Creeks, but not in Bear Creek. A progressive longitudinal increase was also found with turbidity and TSS only in Walnut Creek.

Similar anion and cation characteristics were found (Appendix A.6). Sulfate and chloride were the principal anions, and calcium and magnesium the main cations measured. Concentrations of bromide and manganese were at the limit of detectability. Longitudinal downstream increases were also found for chloride.

McCollor and Heiskary (1993) summarized summertime Minnesota surface water TP and TSS values in the Western Corn Belt Plains during the years of 1970-1992. They concluded that the minimal levels for these two respective constituents would be approximately 0.29 and 58 mg/l. Using these values as a bench mark, our mean surface water TP values were 2-3 times less while the TSS mean values were 1.5 to 2 times higher. Gosselink (1990) has concluded that TP values > 0.1 mg/l can be associated with disturbed stream communities. The only drainage with mean TP values > 0.1 mg/l was at Crooked Creek.

Atrazine concentrations were monitored during the same time periods in Walnut Creek by the Kansas Biological Survey and Iowa State University (1996). Mean sur-

Table 3-3. Water Quality Characteristics

	Bear Creek	Crooked Creek	Montgomery Creek	Squaw Creek	Walnut Creek
Surface Water					
NH_3-N mg/l	0.03 (<.01-0.08)	0.05 (.02-.12)	0.03 (.01-.04)[a]	0.04 (.01-.14)	0.03 (<.01-.19)
TP mg/l	0.07 (<.01-.29)	0.12 (.02-.30	0.08 (.02-.18)	0.08 (.01-.22)	0.06 (<.01-.49)
NO_2+NO_3-N mg/l	9.4 (5.1-13.8)	9.5 (6.2-11.7)	8.3 (.3-12.9)	9.0 (1.9-13.0)	9.2 (<.1-16.9)
O-PO_4 (as P), mg/l	0.05 (.01-.10)	0.09 (.02-.23)	0.04 (.01-.07)	0.05 (.01-.18)	0.04 (<.01-.19)
TN (as N), mg/l	9.9 (6.5-13.1)	10.3 (8.0-12.6)	8.5 (.8-13.0)	9.5 (2.3-13.0)	9.9 (4.6-19.0)
TSS mg/l	130 (8-397)	89 (12-150)	125 (50-263)	131 (3-369)	84 (9-130)
T. Alkalinity mg/l	335 (212-616)	357 (260-530)	358 (261-560)	343 (238-578)	367 (202-740)
Turbidity NTU	55 (2-99)	67 (2-128)	58 (37-88)	49 (2-95)	39 (1-90)
T. Conductivity µmhos/cm^2	532 (402-716)	575 (430-699)	490 (423-573)	546 (457-655)	532 (440-716)
T. Organic Carbon mg/l	4.4 (2.0-18.0)	3.8 (0.4-7.6)	2.5 (2.1-2.8)	3.6 (2.9-5.9)	3.1 (1.9-10.0)
pH units	7.9 (7.3-8.5)	- (7.7-8.3)[b]	-[c]	8.0 (7.6-8.3)	7.9 (7.4-8.4)
Temperature °C	17.8 (8.0-23.8)	16.8 (9.8-23.1)	19.3 (12.2-25.3)	17.3 (8.7-25.0)	15.3 (4.3-25.1)
Sediment Pore Water					
NH_3-N mg/l	0.24 (.02-2.53)	1.12 (.05-2.74)	0.11 (.02-.22)	0.28 (.03-1.31)	1.11 (.01-9.05)
TP mg/l	0.06 (.02-.14)	0.08 (.03-.15)	0.07 (.03-.12)	0.07 (<.01-.16)	0.08 (<.01-.45)
NO_2+NO_3-N mg/l	8.4 (1.2-12.0)	6.7 (0.7-11.3)	7.3 (.2-11.3)	7.8 (1.0-11.8)	6.7 (<.1-13.3)
O-PO_4 (as P), mg/l	0.05 (.01-.14)	0.05 (.01-.08)	0.05 (.01-.10)	0.06 (.01-.15)	0.04 (<.01-.23)
TN (as N), mg/l	9.1 (3.8-12.3)	9.0 (5.6-11.9)	7.6 (.8-11.3)	8.0 (2.9-11.3)	8.3(1.7-14.8)

[a]Average and (minimum - maximum) values.
[b]Less than three measurements taken.
[c]No measurements taken.

face water values were < 0.5 µg/l. Atrazine was not detectable during baseline flows. Solomon et al. (1996) have concluded that atrazine levels need to be at or above 50 µg/l in surface waters to be ecologically relevant. It then appears that herbicides in the surface waters may have been an insignificant variable during this study.

3.4 Macroinvertebrate Community Characteristics

A total of 77 individual macroinvertebrate taxa were identified (Appendix B.1). Three orders, represented by 47 taxa, comprised the bulk of the community: Ephemeroptera (mayflies), Trichoptera (caddisflies), and Diptera Chironomidae (midges). The most diverse group were the midges. Only a few individual Hemiptera and no Lepidoptera representatives were collected. More plecopterans, oligochaetes, and mollusks were encountered in Walnut Creek, while mayflies and caddisflies were more common in the other four drainages. A larger taxa list was found in the qualitative samples. The Montgomery Creek site was troublesome as on only one occasion were artificial substrate samplers recovered despite numerous attempts at deployment.

Similar taxa were gathered with both the artificial substrate and qualitative sampling techniques (Appendix B.2). Mayfly and caddisfly taxa were more diverse and numerous at the Bear and Squaw Creek locations. Common mayfly genera (>5% in abundance) found were *Heptagenia*, *Isonychia*, *Stenacron*, and *Tricorythodes*. Common caddisfly and midge taxa were *Cheumatopsyche Hydropsyche*, and *Crictopus*, *Polypedilum*, *Tanytarsini*, respectively. Other taxa frequently encountered with both sampling techniques were *Physa* snails and oligochaetes. Community structure was more evenly distributed among the drainages in the qualitative samples, especially with the mayfly and midge taxa. The Kansas Biological Survey and Iowa State University (1996) recently sampled the macroinvertebrate community in Walnut Creek using qualitative techniques (D frame sweep net and substrate kicking). Their community was composed of three groups: Ephemeroptera (48%), Diptera (30%) and Gastropoda (9%), and represented by baetid and heptageniid mayflies, orthoclad midges, and physid snails. Dominant taxa within these three groups were *Stenacron*, *Leptophlebia*, *Isonychia*, *Crictopus*, *Stictochironomus* and *Physa*. The benthic community found in our qualitative Walnut Creek samples was generally similar except for the numerical dominance of Tanytarsini over the *Crictopus* midges and no occurrence of *Stictochironomus*.

Gammon et al. (1983) has characterized agricultural streams as having increased numbers of chironomids, oligochaetes, and nematodes relative to other groups. They found that chironomids continue to increase with further agricultural intensity, the benthic taxa apparently having a preference for soft bottomed substrates. In our study, oligochaetes and chironomids comprised greater proportions of the abundance, especially at the upstream Walnut Creek (WC 1 and WC 2) and Crooked Creek (CC 1) locations

(Tables 3-4 and 3-5). Menzel et al. (1984) described their Iowa community as lacking predacious insects such as Megaloptera (absent), Coleoptera (rare), Hemiptera (absent) and Odonata (rare). The macroinvertebrate community in our study was represented by 10% predators. The Kansas Biological Survey and Iowa State University (1996) found greater percentages of Odonata and Coleoptera than in our study, but each group accounting for < 5% of the total macroinvertebrate abundance.

Additional community comparisons are given in Table 3-6 and Appendix B.3 and B.4. Highest average abundances, richness (total taxa), EPT and ICI scores were found in Squaw Creek, while lowest values were present in Walnut Creek. Too few samples were collected in Montgomery and Crooked Creeks. Higher ratios of EPT to total taxa were present at the Bear and Squaw Creek locations. Drainages with higher abundances also showed higher numbers of taxa. The Kansas Biological Station and Iowa State University (1996) also noted higher taxa richness with increased watershed benthic abundance. Collectors and grazers were the principal functional groups, shredders and predators were less commonly found, and predators were uniformly ≤ 10% of the total. Lower proportions of shredders (≤ 10% of total) occurred with both types of sampling in Bear and Walnut Creeks. The majority of taxa were classified as erosional or as erosional/depositional forms. Lenat (1984) and Richards et al. (1993) have found few EPT taxa at agricultural dominated sites. Based on this information, it appears that all of our sites had moderately impacted macroinvertebrate communities. Walnut Creek was the most impacted drainage based on community composition, EPT taxa and ICI scores.

3.5 Fish Community Characteristics

Twenty-one individual fish taxa were identified (Appendix B.5). The most abundant family was the Cyprinidae, and represented by 12 taxa. The bigmouth shiner, bluntnose minnow, common shiner, creek chub, sand shiner, and central stoneroller were the most numerically dominant (each taxa ≥ 5.0% of total abundance, Appendix B.6). Few catostomids and centrarchids were collected. The only centrachids collected were green sunfish and smallmouth bass; and the only darter found was the johnny darter. Carp, brassy minnow, suckermouth minnow, quillback, high fin carpsucker, and black bullhead were found in very low numbers and at only one or two locations. A further breakdown of the fish community composition is given in Table 3-7. Menzel et al. (1984) collected 29 fish species in their Iowa study, represented by six families. As in our study, Cyprinidae was the most common family, and dominant fish were the bigmouth shiner, stoneroller, common shiner, bluntnose minnow, and creek chub. Twenty fish species were collected in the Kansas Biological Survey and Iowa State University (1996) study in Walnut Creek, with the creek chub being the most numerous followed in order of abundance by bluntnose minnows, bigmouth shiners, central stonerollers, johnny darters, and the common shiner. In addition, studies by the Iowa DNR (Paragamian, 1990) found cyprinids to be the dominant group in the Des Moines lobe and within the Skunk drainage.

Our sampled fish community was mainly comprised of equivalent populations of omnivores and insectivores, less numbers of herbivores, and almost no piscivores Table 3-8. Most insectivores found in our study were represented by the family Cyprinidae. Karr (1981) has indicated that fish samples containing < 20% omnivores reflect good stream sites, > 45% omnivores as degraded locations. Percentages of omnivores at our sites ranged between 36% to 47%. Karr (1991) also found that as stream degradation increases, proportions of omnivores will increase while cyprinid insectivores and piscivores will decrease. These functional analyses reflect an Iowa fish community in an intermediate stage of degradation.

An index of biotic integrity (IBI) has been widely used to quantify stream conditions and assist in defining water resource quality (Karr, 1991). IBI scores ≥ 48 were generally thought to reflect good to excellent conditions. Values ≤ 34 were indicative of poor quality, with intermediate values representative of fair conditions. The mean site IBI scores in our study ranged from 28 to 44 (Table 3-8), and overall represented a fair to poor fish community according to Karr.

Most of the fish collected were tolerant and preferred flowing water conditions (Table 3-7). Karr's (1991) attributes for describing a fair to poor fish community are having low total taxa numbers, increasing proportions of omnivores, high percentages of tolerant taxa, and few top carnivores. Based on these attributes, the fish community found in this study would match these conditions.

3.6 Integrated Watershed Analyses

Significant associations were found among the physical and chemical measurements. Strong relationships ($P \leq 0.01$) were found with the surface water and sediment pore water phosphorus (TP, O-PO_4) and the nitrogen analyses (TN, NO_2+NO_3-N, NH_3-N, Table 3-9). Drainage area was strongly associated with NH_3-N, but had weaker relationships with TSS and TN values. Nitrogen was higher in the smaller drainages, and TSS concentrations were higher at the larger drainage sites. However, additional surveys would be needed to more fully determine seasonal and annual relationships. A strong relationship was found between surface water TP and TSS values. Gosselink et al. (1990) also found the same relationship and thought it may be due to the binding of phosphorus to the stream sediment particles.

Strong correlations were found among the macroinvertebrate community indices, water quality values and drainage area (Table 3-10). Size of drainage area was strongly and positively correlated with all community indices and total taxa. Highest correlations were with quantitative EPT taxa (from the artificial substrate samplers), and remained a dominant descriptor when drainage area

Table 3-4. Macroinvertebrate Artificial Substrate Results

	Walnut Creek				Bear Creek			Squaw Creek			Mntry	Crked	Percent
	WC 1	WC 2	WC 3	WC 4	BC 1	BC 2	BC 3	SC 1	SC 2	SC 3	MC 1[a]	CC 1[a]	Comp.
Ephemeroptera													
Tricorythodes	0	0	0	0	0	25	6	0	11	124	2	6	4.4
Caenis	0	1	3	1	15	29	35	11	7	12	1	18	1.7
Stenacron	0	31	104	2	24	34	3	700	37	5	0	55	9.5
Stenonema	0	0	0	0	0	1	0	0	36	49	2	8	1.7
Heptagenia	0	42	21	48	790	295	126	979	311	42	22	561	24.1
Isonychia	0	0	0	2	29	6	1	8	15	71	0	6	2.6
Baetis	0	7	18	21	3	32	1	0	3	76	1	4	3.7
Leptophlebia	0	2	0	0	3	4	13	10	9	1	10	5	0.4
Baetisca	0	0	0	0	0	3	0	0	0	9	0	0	0.3
Plecoptera													
Perlesta	0	20	4	6	0	0	1	0	0	11	0	0	1.1
Pternarcys	0	0	0	0	0	0	0	0	0	3	0	0	0.1
Trichoptera													
Cheumatopsyche	0	11	5	2	271	48	2	226	185	121	2	435	9.2
Hydropsyche	0	0	2	0	123	9	1	3	31	65	1	98	3.2
Neureclipsis	0	0	0	0	0	125	0	0	0	0	0	0	2.3
Nectopsyche	0	0	0	1	0	0	1	0	0	1	0	0	0.1
Hydroptilidae	0	1	1	0	0	5	1	0	0	54	0	0	1.8
Coleoptera													
Elmidae	0	1	4	0	0	1	1	2	2	8	0	8	0.4
Agabus	3	4	2	1	0	0	0	0	0	0	0	0	0.1
Chironomidae													
Psectrocladius	0	2	1	0	0	0	1	0	0	3	0	0	0.2
Crictopus	45	23	30	1	0	43	2	0	0	33	0	0	4.0
Corynoneuria	1	1	2	0	0	0	0	0	0	0	0	0	0.1
Thienemanniella	0	0	0	1	0	0	0	0	0	2	0	0	0.1
Brillia	0	6	9	4	33	2	23	1	5	5	30	206	1.3
Microtendipes	0	0	0	0	0	0	0	0	0	6	0	0	0.2
Dicrotendipes	20	1	1	0	0	0	9	0	0	7	0	0	0.6
Polypedilum	0	10	2	2	2	3	0	0	0	24	8	0	1.2
Tribelos	1	1	0	0	0	0	0	0	0	0	0	0	0.1
Chironomus	0	2	7	0	0	0	17	2	12	30	21	0	1.5
Cryptochironomus	0	2	0	0	0	0	1	1	0	0	0	1	0.1
Tanytarsini	3	334	27	7	4	2	19	2	6	93	5	28	14.3
Ablabesmyia	1	8	9	3	14	9	5	10	10	39	1	33	2.2
Other Diptera													
Ceratopogonidae	0	0	0	1	0	0	0	1	0	1	0	1	0.1
Hemerodromia	0	0	1	2	0	0	2	0	0	0	0	0	0.1
Simuliidae	0	2	1	4	3	0	0	1	0	0	0	78	0.2
Ephydridae	0	1	5	2	4	4	0	0	3	2	0	4	0.4
Mollusca													
Physa	99	10	28	0	0	0	4	0	0	1	0	0	2.4
Other													
Hyalella	0	0	1	0	5	0	9	0	1	0	0	32	0.2
Asellus	0	2	1	0	0	0	0	0	0	0	0	4	0.1
Hydra	0	0	11	0	0	0	1	0	0	3	0	0	0.3
Oligochaeta	91	40	5	1	0	12	2	2	0	6	1	87	2.9
Planaria	0	0	1	0	0	0	0	0	0	14	0	1	0.4
Hirudinea	0	1	0	0	0	0	3	1	0	0	0	0	0.1
Copepoda	0	1	2	0	0	0	0	0	0	0	0	0	0.1
Totals	262	567	305	111	1323	692	285	1960	684	921	107	1679	100.0

[a]Less than three measurements taken, Mntry = Montgomery Creek, Crked = Crooked Creek.
Note: All values are averages.

Table 3-5. Macroinvertebrate Qualitative Results

	Walnut Creek				Bear Creek			Squaw Creek			Mntry	Crked	Percent
	WC 1	WC 2	WC 3	WC 4	BC 1	BC 2	BC 3	SC 1	SC 2	SC 3	MC 1[a]	CC 1[a]	Comp.
Ephemeroptera													
Tricorythodes	0	0	0	1	12	16	9	0	2	82	65	4	4.6
Caenis	0	2	11	9	8	56	42	10	2	16	18	4	4.3
Stenacron	0	154	61	7	11	14	5	12	3	11	0	34	9.0
Stenonema	0	0	0	0	1	4	1	0	5	38	10	1	1.4
Heptagenia	0	34	24	20	126	40	71	303	6	25	48	149	12.2
Isonychia	0	0	0	0	16	2	6	2	1	4	41	5	1.6
Baetis	2	39	94	21	12	43	64	118	3	7	107	25	11.8
Paraleptophlebia	0	0	0	0	0	1	0	2	0	0	0	0	0.1
Hexagenia	0	5	0	0	1	3	0	0	0	0	0	0	0.3
Pseudocloeon	0	0	0	0	2	0	1	10	1	2	4	3	0.3
Potomanthus	0	0	0	0	0	0	0	0	0	2	0	0	0.1
Leptophlebia	0	0	0	0	0	5	0	0	1	3	0	1	0.2
Plecoptera													
Acroneuria	0	0	0	0	0	0	0	0	0	3	0	0	0.1
Perlesta	0	20	16	6	0	0	0	0	0	4	2	0	1.6
Trichoptera													
Cheumatopsyche	0	7	5	0	26	10	33	159	4	11	30	100	4.7
Hydropsyche	0	2	7	0	15	2	24	28	3	16	9	46	2.4
Hydroptilidae	1	1	7	5	2	0	19	0	0	31	11	0	2.0
Orchrotrichia	0	0	0	0	0	0	0	0	0	0	10	0	0.3
Coleoptera													
Elmidae	0	0	7	0	0	1	1	4	1	22	7	4	1.1
Chironomidae													
Psectrocladius	0	1	0	7	0	0	1	0	0	13	0	0	0.7
Cricotopus	5	26	30	11	35	8	34	557	12	67	33	105	10.3
Thienemanniella	0	0	1	0	0	0	0	0	0	0	0	1	0.1
Brillia	0	1	1	1	17	2	1	12	3	1	5	39	1.0
Microtendipes	0	0	1	0	0	0	0	0	0	2	0	0	0.1
Dicrotendipes	6	0	3	0	0	0	1	1	0	32	0	0	1.0
Polypedilum	0	1	3	1	1	4	55	0	0	5	3	3	1.9
Tribelos	0	3	1	0	0	0	0	0	0	0	0	0	0.2
Chironomus	1	0	4	7	1	1	1	0	1	23	4	1	1.2
Glyptotendipes	4	0	0	0	1	0	0	0	0	2	0	0	0.1
Cryptochironomus	1	2	2	0	0	0	2	1	0	3	0	0	0.3
Tanytarsini	3	107	18	21	3	3	24	1	3	72	3	14	7.9
Robakia	0	0	0	0	0	0	0	0	2	2	0	0	0.1
Ablabesmyia	6	7	4	4	8	3	20	3	1	12	9	7	1.8
Procladius	1	0	2	0	0	0	0	0	0	2	0	0	0.1
Heterotrissocladius	0	0	3	2	1	0	0	0	0	0	0	1	0.2
Other Diptera													
Ceratopogonidae	0	1	2	1	0	0	0	1	0	4	0	0	0.2
Hemerodromia	0	0	1	0	0	0	2	0	0	0	4	0	0.2
Tipulidae	0	0	2	0	0	0	0	9	0	0	0	0	0.1
Simuliidae	4	8	6	2	7	1	7	17	0	0	10	174	2.9
Ephydridae	0	0	3	1	1	0	1	0	0	0	2	2	0.2
Mollusca													
Physa	97	5	29	1	0	0	0	0	0	2	0	1	2.1
Pelecypoda	15	1	2	0	0	1	2	29	1	1	0	1	0.5
Other													
Hyalella	0	0	2	0	2	0	2	28	2	1	0	27	0.6
Asellus	0	1	1	0	1	0	0	0	0	0	0	1	0.1
Hydra	0	0	0	0	0	0	0	0	0	3	0	0	0.1
Oligochaeta	70	9	13	2	8	3	35	9	1	8	2	107	4.0
Planaria 0	0	8	0	0	0	94	9	1	26	0	0	3.4	
Decapoda	1	3	1	0	0	1	0	0	0	0	0	0	0.2
Totals	214	445	372	135	312	229	562	1325	53	565	441	853	100.0

[a]Less than three measurements taken, Mntry = Montgomery Creek, Crked = Crooked Creek.
Note: All values are averages.

Table 3-6. Macroinvertebrate Community Composition

	Walnut Creek	Bear Creek	Squaw Creek	Mntry Cr.[a]	Crked Cr.[a]
Artificial Substrates					
Total Abundance	351(52-2014)	670 (156-1462)	1114 (620-1971)[b]	110 (*)[c]	1704 (*)[c]
Total Taxa	16 (9-24)	19 (15-27)	27 (30-36)	17 (*)	26 (*)
Community Structure					
% Mayflies	26 (0-94)	63 (49-83)	55 (14-87)	36 (*)	39 (*)
% Caddisflies	2 (0-17)	24 (0-31)	23 (12-33)	3 (*)	31 (*)
% Midges	51 (2-88)	10 (2-41)	18 (1-59)	61 (*)	17 (*)
% Other	20 (1-79)	3 (1-9)	3 (0-8)	1 (*)	13 (*)
Functional Groups					
% Collectors	43 (3-82)	38 (25-47)	51 (14-81)	40 (*)	36 (*)
% Grazers	37 (9-94)	53 (42-73)	36 (7-85)	23 (*)	44 (*)
% Predators	7 (0-32)	2 (0-8)	6 (0-20)	8 (*)	2 (*)
% Shredders	8 (0-53)	6 (1-16)	3 (0-21)	28 (*)	12 (*)
% Macrophyte Par.[d]	0	0	4 (0-14)	0	0
Other Groups					
% Erosional	25 (0-95)	80 (49-94)	69 (22-98)	36 (*)	74 (*)
% Depositional	6 (0-25)	7 (0-25)	9 (1-34)	28 (*)	5 (*)
% Both	65 (4-97)	13 (4-28)	23 (1-58)	35 (*)	21 (*)
EPT Taxa	5 (0-10)	9 (5-12)	12 (9-15)	9 (*)	12 (*)
Total ICI Score	24 (4-42)	36 (26-42)	38 (24-42)	30 (*)	42 (*)
Qualitative Sampling					
Total Taxa	19 (1-20)	20 (11-36)	25 (10-41)	19 (*)	21 (*)
Community Structure					
% Mayflies	50 (0-87)	49 (17-97)	33 (12-69)	65 (*)	47 (*)
% Caddisflies	4 (0-15)	11 (1-23)	11 (4-17)	14 (*)	15 (*)
% Midges	31 (0-69)	22 (0-54)	44 (19-54)	15 (*)	14 (*)
% Other	16 (0-100)	17 (1-61)	11 (4-22)	6 (*)	25 (*)
Functional Groups					
% Collectors	41 (0-68)	52 (26-87)	47 (27-71)	65 (*)	49 (*)
% Grazers	38 (14-100)	25 (7-52)	18 (10-58)	13 (*)	34 (*)
% Predators	9 (0-46)	10 (0-21)	5 (0-13)	4 (*)	7 (*)
% Shredders	7 (0-26)	7 (0-42)	22 (0-41)	9 (*)	21 (*)
% Macrophyte Par.[d]	1 (0-14)	2 (0-9)	3 (0-9)	3 (*)	5 (*)
Other Groups					
% Erosional	36 (0-91)	36 (17-89)	38 (20-73)	50 (*)	61 (*)
% Depositional	7 (0-31)	21 (3-55)	9 (2-19)	8 (*)	7 (*)
% Both	53 (6-100)	42 (3-75)	44 (4-58)	39 (*)	29 (*)
EPT Taxa	6 (0-9)	11 (8-15)	13 (10-16)	11 (*)	9 (*)

[a]Mntry = Montgomery Creek, Crked = Crooked Creek.
[b]Average and (minimum-maximum) values.
[c]Less than three measurements taken.
[d]% Macrophyte Par. = % Macrophyte Parasite.

Table 3-7. Fish Sampling Results

	Walnut Creek			Bear Creek			Squaw Creek		Crked	Percent
	WC 2	WC 3	WC 4	BC 1	BC 2	BC 3	SC 1	SC 3	CC 1	Comp.
Central stoneroller	14	149	29	3	22	29	12	26	34	5.2
Common carp	0	0	1	0	0	0	2	0	0	0.1
Brassy minnow	0	0	0	0	0	0	0	0	3	0.1
Common shiner	35	22	70	20	66	29	13	134	8	12.7
Bigmouth shiner	6	22	105	141	110	34	11	407	32	25.8
Red shiner	1	0	12	0	10	1	1	4	0	1.0
Sand shiner	0	0	24	36	30	25	0	197	7	9.2
Suckermouth minnow	0	0	0	0	0	0	0	3	1	0.1
Bluntnose minnow	149	58	57	38	72	31	58	315	48	24.6
Fathead minnow	7	2	18	1	0	0	12	0	7	1.6
Blacknose dace	2	0	1	0	0	0	0	1	0	0.1
Creek chub	35	29	97	43	19	14	29	35	75	10.9
Quillback	0	0	0	0	0	0	0	6	0	0.2
Highfin carpsucker	0	0	0	0	0	0	0	2	0	0.1
White sucker	1	4	2	1	2	3	0	6	3	0.6
Northern hog sucker	0	0	0	3	0	2	0	2	0	0.2
Black bullhead	0	1	0	0	0	0	0	0	0	0.1
Green sunfish	0	0	3	0	1	0	0	0	4	0.3
Smallmouth bass	0	0	0	0	1	4	0	0	0	0.1
Johnny darter	73	47	3	12	3	9	60	16	27	7.0
Totals	322	195	422	297	333	181	195	1155	248	100.0
Total Taxa	8	8	10	9	9	9	8	11	12	

Note: All values are averages.

was removed. Best and highest associations in this study occurred with surface water TN, NO_2+NO_3-N, NH_3-N ,and the EPT quantitative index. Arthur and Zischke (1994) and Arthur et al. (1996) have also found similar significant relationships with the same community indices to increasing concentrations of TP, NH_3-N and NO_2+NO_3-N.

Ordination analyses yielded additional interactive information. The first three factors explained 67% of the variability (Table 3-11). Most of the variability was explained by the TN and NO_2+NO_3-N concentrations. Other associated chemical factors were surface water TP, surface water/sediment pore water O-PO_4, and sediment pore water NH_3-N.

Less ($P < 0.05$ and > 0.01) significant correlations occurred when comparing habitat quality (as QHEI scores), drainage area values, and mean biological community indices. Good associations were found with the EPT Quantitative and Qualitative indices, drainage area, and QHEI (Table 3-12). The EPT-Quantitative index also correlated with the QHEI index. No similar correlations were found using the ICI index.

Fewer associations were found with the fish community metrics (Table 3-13). No correlations were found with fish IBI index and fish abundance, water quality values, and drainage area. Mixed results were found with the total taxa comparisons. Fish total taxa correlated with increasing NH_3-N and also with decreasing concentrations of NO_2+NO_3-N.

Table 3-8. Fish Community Composition

	Walnut Creek	Bear Creek	Squaw Creek	Crooked Creek[a]
Total Abundance	323 (45-1006)	274 (20-541)[a]	771 (47-1736)	248 (*)[b]
Total Taxa	9 (5-13)	9 (7-11)	9 (7-14)	12 (*)
Community Structure				
% Minnows	31 (2-67)	19 (0-27)	28 (0-51)	24 (*)
% Shiners	32 (4-67)	61 (35-77)	59 (0-65)	19 (*)
% Suckers	1 (0-2)	1 (0-45)	1 (0-35)	1 (*)
% Bass/Sunfish	< 1 (0-1)	1 (0-8)	< 1 (0-1)	1 (*)
% Darters	12 (0-58)	3 (0-6)	4 (0-32)	11 (*)
% Chubs	17 (4-30)	7 (2-37)	4 (0-17)	30 (*)
Functional Groups				
% Herbivores	0	< 1 (0-1)	0	1 (*)
% Insectivores	4 (0-24)	13 (7-20)	16 (0-19)	3 (*)
% Omnivores	50 (35-82)	27 (11-33)	34 (27-51)	54 (*)
% Piscivores	0	< 1 (0-1)	0	0 (*)
Sensitivity				
% Intolerants	0	1 (0-10)	< 1 (0-9)	0 (*)
% Tolerants	52 (25-67)	26 (18-47)	33 (3-49)	53 (*)
Habitat				
% Generalists	32 (6-82)	20 (2-67)	17 (12-94)	20 (*)
% Flowing	70 (18-94)	81 (33-98)	81 (16-88)	80 (*)
Total IBI Score	37 (32-42)	44 (38-54)	28 (23-34)	30 (*)

[a]Average and (minimum-maximum) values.
[b]Two measurements taken.

Table 3-9. Water Quality and Drainage Correlations

	DRNG	Surface Water: TSS	Surface Water: O-PO_4	Surface Water: TP	Surface Water: TN	Surface Water: NO_2+NO_3-N	Surface Water: NH_3-N	Sediment Pore Water: O-PO_4	Sediment Pore Water: TP	Sediment Pore Water: TN	Sediment Pore Water: NO_2+NO_3-N	Sediment Pore Water: NH_3-N
Surface Water												
TSS	★	-										
O-PO_4	NS	NS	-									
TP	NS	■	■	-								
TN	★[a]	NS	NS	NS	-							
NO_2+NO_3-NNS	NS	NS	NS	NS	■	-						
NH_3-N	NS	NS		NS	NS	NS	-					
Sediment Pore Water												
O-PO_4	NS	NS	■	■	NS	NS	★	-				
TP	NS	NS	■	★	NS	NS	■	■	-			
TN	NS	★	NS	NS	■	■	NS	NS	NS	-		
NO_2+NO_3-N	NS	■	NS	NS	■	■	NS	NS	NS	■	-	
NH_3-N	■[a]	★[a]	NS	NS	★	■[a]	■	■[a]	NS	NS	■	-

★ - Positive correlation, significant at $P \leq 0.05$ and > 0.01.
★[a] - Negative correlation, significant at $P \leq 0.05$ and > 0.01.
■ - Positive correlation, significant at $P \leq 0.01$.
■[a] - Negative correlation, significant at $P \leq 0.01$.
NS - Not significant.

Table 3-10. Macroinvertebrate, Water Quality, and Drainage Correlations

	ICI	EPT-Qual.	EPT-Quant.	Total Taxa
Drainage Area	■	■	■	■
Surface Water				
TSS	NS	NS	NS	NS
$O\text{-}PO_4$	NS	NS	NS	NS
TP	NS	NS	NS	NS
TN	★[a]	★[a]	■[a]	NS
NO_2+NO_3	★[a]	★[a]	■[a]	NS
$NH_3\text{-}N$	NS	NS	■[a]	NS
Sediment Pore Water				
$O\text{-}PO_4$	NS	NS	NS	NS
TP	NS	NS	NS	NS
TN	NS	★[a]	■[a]	NS
NO_2+NO_3	NS	NS	NS	NS
$NH_3\text{-}N$	■[a]	NS	★[a]	NS

★[a] - Negative correlation, significant at $P \le 0.05$ and > 0.01.
■ - Positive correlation, significant at $P \le 0.01$.
■[a] - Negative correlation, significant at $P \le 0.01$.
NS - Not significant.

Table 3-11. Principal Component Analyses

	Factor		
	1	2	3
Eigenvalue	3.414	2.602	2.049
% Variance Explained	28.5	21.7	17.1
Cumulative %	28.5	50.2	67.2
	Coordinates		
Drainage	-0.182	0.312	- 0.545
Surface Water			
TSS	0.318	0.476	- 0.389
$O\text{-}PO_4$	0.074	0.761[a]	0.285
TP	0.107	0.714	0.018
TN	0.895	- 0.197	0.250
NO_2+NO_3	0.924	- 0.185	0.165
$NH_3\text{-}N$	0.162	0.175	0.511
Sediment Pore Water			
$O\text{-}PO_4$	- 0.027	0.858	0.157
TP	0.124	0.486	0.556
TN	0.933	- 0.052	- 0.108
NO_2+NO_3	0.832	0.103	- 0.453
$NH_3\text{-}N$	- 0.055	- 0.317	0.786

[a]Underlined correlations significant $P \le 0.05$.

Table 3-12. Macroinvertebrate, Habitat, and Drainage Correlations

	DRNG[a]	QHEI[b]
Macroinvertebrate Community Index		
ICI[c]	NS	NS
EPT-Qual.[d]	★	★
EPT-Quant.[e]	NS	★[f]

[a]DRNG = Drainage area.
[b]QHEI = Qualitative habitat evaluation index.
[c]ICI = Index community integrity.
[d]EPT-Qual. = Ephemeroptera-Plecoptera-Trichoptera index, qualitative samples.
[e]EPT-Quant. = Ephemeroptera-Plecoptera-Trichoptera index, artificial substrate samples.
[f]Positive correlation, significant at $P \leq 0.05$ and > 0.01.

Table 3-13. Fish, Water Quality, and Drainage Correlations

	IBI[a]	Total Taxa	Abundance
Drainage Area	NS	NS	NS
Surface Water			
TSS	NS	NS	NS
O-PO_4	NS	NS	NS
TP	NS	NS	NS
TN	NS	NS	NS
NO_2+NO_3-N	NS	★[b]	NS
NH_3-N	NS	NS	NS
Sediment Pore Water			
O-PO_4	NS	NS	NS
TP	NS	NS	NS
TN	NS	NS	NS
NO_2+NO_3-N	NS	NS	NS
NH_3-N	NS	★	NS

[a]IBI - Index of biotic integrity.
★[b] - Negative correlation, significant at $P \leq 0.05$ and > 0.01.
★ - Positive correlation, significant at $P \leq 0.05$ and > 0.01.
NS - Not significant.

4. Summary and Conclusions

This study is consistent with the conclusion by the U.S. EPA (1994) that sediments and nutrients are the primary pollutants found in agricultural streams. Agricultural activity can promote physical changes in streams such as increases in bottom substrate embeddedness (fine particles), elevated TSS concentrations, and decreases in habitat quality. Dominant chemical components adversely affecting the biological community in this study were NO_2+NO_3-N and NH_3-N. The principal macroinvertebrate response linked to these chemical components were lowered numbers of EPT taxa. Fewer associations were found with the macroinvertebrate ICI index and fish community structure and the chemical constituents. Ammonia nitrogen concentrations did not reach the toxicity threshold levels identified in previous studies (Arthur et al., 1996). Using U.S. EPA (1984) waterbody quality definitions, these surveyed central Iowa streams would receive a "fair" rating based on the macroinvertebrate and fish community structure, elevated nutrients and sediments, and degraded habitat conditions.

Menzel et al. (1984) have depicted central Iowa headwater streams as composed of "mud-loving" fauna preferring soft-bottomed substrates and living in turbid stream conditions. Streamside changes such as channelization and the general disappearance of streamside riparian vegetation belts account for decreasing allochthonous leaf and natural organic debris inputs into streams resulting in a benthic community dominated by scrapers and collectors. Our study also observed the same type of macroinvertebrate community. These investigators concluded that the fish community may have changed little over the past 50 years except for the large declines in sensitive forms species as the southern redbelly dace, hornyhead chub, rosyface shiner and smallmouth bass. Of these four sensitive fish species mentioned by Menzel, we collected only a few smallmouth bass.

Few historical and/or unaltered site descriptions of prairie streams are available. Lack of reference descriptions will increase the difficulty in devising meaningful strategies to improve watershed integrity. Because of the general absence of historical information, Menzel et al. (1984) recommended an adoption of a holistic land to water management approach with an emphasis on controlling hydrology, instream erosion, and preserving natural undisturbed stream areas as buffer zones. Of the 12 locations sampled in our study, the least physically disturbed location, and most "natural," was at Montgomery Creek. The more disturbed locations were found in the upper reaches of Squaw, Bear, and Crooked Creeks.

Studies at other midwestern locations (Minnesota and Michigan) using similar sampling protocols (Arthur and Zischke, 1994 and Arthur et al., 1996) found associations among many of the same stressors and biological responses. The dominant stressors were habitat disruption (as measured by the QHEI index), TSS, NO_2+NO_3-N, TP, and NH_3-N. Sensitive biological responses were the macroinvertebrate community indices and richness (total taxa). Despite these associations, more data are needed to further quantify and identify sensitive stressor/responses linkages in agricultural streams. The EPA Science Advisory Board (1994), in a review of the Iowa MASTER study, recommended that procedures be developed to separate specific causes rather than relying on composite indices, and concentrating on devising multiple metrics to define stream impairments. This group also called for more emphasis on defining reference (undisturbed) conditions and for devising how this information can be applied into the impact description process. Both suggestions provide future directions in pursuing the definition of watershed integrity.

References

American Public Health Association. 1980. *Standard Methods for the Examination of Water and Wastewater*, 15th edition, American Public Health Association, Washington, D.C.

Ankley, G.T., A. Katko, and J.W. Arthur. 1990. Identification of ammonia as an important sediment-associated toxicant in the lower Fox river, Green Bay, Wisconsin. Environmental *Toxicological and Chemistry.* 9:313-322.

Arthur, J.W. and J.A. Zischke. 1994. Evaluation of watershed quality in the Minnesota River Basin. EPA/600/R-94/143, August, Environmental Research Laboratory-Duluth, Duluth, MN 55804.

Arthur, J.W., T. Roush, J.A. Thompson, F.A. Puglisi, C. Richards, G.E. Host, and L.B. Johnson. 1996. Evaluation of watershed quality in the Saginaw River Basin. EPA/600/R-95/153, September, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division, Duluth, MN 55804.

Bailey, P.A., J.W. Enblom, S.R. Hanson, P.A. Renard ,and K. Schmidt. 1994. A fish community analysis of the Minnesota River Basin. IN: Minnesota River Assessment Project Report, Volume III, Biological and Toxicological Assessment, January, Report to the Legislative Commission of Minnesota Resources, 212 p.

EPA Science Advisory Board. 1994. An SAB Report: Evaluation of draft technical guidance on biological criteria for streams and small rivers. Prepared by the Biological Criteria Subcommittee of the Ecological Processes and Effects Committee.

Frazier, B.E. , T.J. Naimo, and M.B. Sandheinrich. 1996. Temporal and vertical distribution of total ammonia nitrogen and un-ionized ammonia nitrogen in sediment pore water from the Upper Mississippi River. *Environmental Toxicology Chemistry.* 15:92-99.

Gammon, J.R., M.D. Johnson, C.E. Mays, D.A. Schiappa, W.L. Fisher, and B.L. Pearman. 1983. Effects of agriculture on stream fauna in Central Indiana. EPA-600/3-83-020, April, Environmental Research Laboratory, Corvallis, OR 97333.

Gosselink, J.G., G.P. Shaffer, L.C. Lee, D.M. Burdick, D.L. Childers, N.C. Leibowitz, S.C. Hamilton, R. Boumans, D. Cushman, S. Fields, M. Koch ,and J.M. Visser. 1990. Landscape conservation in a forested wetland watershed. *Bioscience.* 40:588-600.

Harlan, J.R., E.B. Speaker, and J. Mayhew. 1987. Iowa Fish and Fishing. Iowa Department of Natural Resources.

Hatfield, J.L. 1996. Description of alternative farming systems for master assessment. IN: Preliminary master assessment of the impacts of alternative agricultural management practices on ecological and water resource attributes of Walnut Creek Watershed, Iowa, J.B. Waide, editor, FTN Associates, Ltd, Little Rock, AR, Chapter 4, pp. 4-1 to 4-21. IN PRESS.

Iowa Department of Natural Resources. 1994. Water quality in Iowa during 1992 and 1993. Iowa Department of Natural Resources, Des Moines, IA 50319.

Kansas Biological Survey and Iowa State University. 1996. Assessment of the effects of nonpoint source pollution on the biotic integrity of Walnut Creek. January. Internal Progress Report.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. *Bioscience.* 6(6):21-27.

Karr, J.R. 1991. Biological integrity: a long-neglected aspect of water resource management. *Ecological Applications.* 1:66-84.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA-600/4-90-030, November, Environmental Monitoring Systems Laboratory, Cincinnati, OH.

Klemm, D.J., Q.J. Stober, and J.M. Lazorchak. 1993. Fish field and laboratory methods for evaluating the biological integrity of surface waters. EPA-600/R-92/111, March, Environmental Monitoring Systems Laboratory, Cincinnati, OH.

Lachat, 1988. Methods manual for the Quickchem automated ion analyzer. Lachat Instruments, Milwaukee, WI.

Larimer, O.J. 1974. Drainage areas of Iowa streams. Bulletin No. 7, Iowa State Highway Commission, Iowa Natural Resources Council.

Lenat, D.R. 1984. Agriculture and stream water quality: A biological evaluation of erosion control practices. *Environ. Management.* 8:333-344.

Lewis, D.W. 1984. Practical Sedimentology. New York, Van Nostrand Reinhold Company, Inc., p. 85-108.

Lyons, J. 1992. Using the index of biotic integrity (IBI) to measure environmental quality in warmwater streams of Wisconsin. Gen. Tech. Rep. NC-149. U.S. Dept. Agriculture, Forest Service, North Central Forest Experimental Station, 51 p.

McCollor, S and S. Heiskary. 1993. Selected water quality characteristics of minimally impacted streams from Minnesota's seven ecoregions. Addendum, February.

Menzel, B.W. 1983. Agricultural management practices and the integrity of instream biological habitat. IN: Agricultural Management and Water Quality, F.W. Schaller and G.W. Bailey, eds., Iowa State University Press, Ames, p. 305-328.

Menzel, B.W., J.B. Barnum, and L.M. Antosch. 1984. Ecological alterations of Iowa prairie-agricultural streams. *Iowa State Journal Research* 59:5-30.

Merritt, R.W. and K.W. Cummins. 1984. An Introduction to the Aquatic Insects of North America. Second edition. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Volumes II and III. Users manual for biological field assessments of Ohio surface waters. Surface Water Section, Division of Water Quality, Columbus, OH .

Omernick, J.M. and A.L. Gallant. 1988. Ecoregions of the upper midwest states. EPA/600/3-88/037, September, Environmental Research Laboratory, Corvallis, OR.

Paragamian, V.L. 1990. Fish populations in Iowa Rivers and Streams. Technical Bulletin No. 3, Iowa Department of Natural Resources, Des Moines, IA 50319, May.

Rankin, E.T. 1995. Habitat indices in water resource quality assessments. IN: Biological Assessment and Criteria, Lewis Publishers, Boca Raton, p. 183-208.

Richards, C., G.E. Host, and J.W. Arthur. 1993. Identification of predominant environmental factors structuring stream macroinvertebrate communities within a large agricultural catchment. *Freshwater Biology.* 29:285-294.

Solomon, K.R., D.B. Baker, R.P. Richards, K.R. Dixon, S.J. Klaine, T.W. La Point, R.J. Kendall, C.P. Weisskopf, J.M. Giddings, J.P. Giesy, L.W. Hall Jr., and W.M. Williams. 1996. Ecological risk assessment of atrazine in North American surface waters. *Environmental Toxicology and Chemistry.* 15:31-76.

U.S. EPA. 1984. Technical support manual: Waterbody surveys and assessments for conducting use attainability analyses. November. Office of Water. Washington DC.

U.S. EPA. 1989a. Methods for the chemical analysis of water and wastes. EPA-600/4-79/020, March. Environmental Monitoring Systems Laboratory, Cincinnati, OH.

U.S. EPA. 1989b. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. EPA/600/4-89/001 and Supplement EPA/600/4-89/001A, Second Edition, Environmental Monitoring and Support Laboratory, Cincinnati, OH.

U.S. EPA. 1991. The watershed protection approach. An overview. EPA-503/9-92-002, December, Office of Water, Washington DC.

U.S. EPA. 1994. The quality of our nation's water: 1992. EPA-841-S-94-002, March, Office of Water, Washington, DC.

Appendix A

Physical, Toxicological, and Chemical Information

Table A-1. Land Use by County

	Story	Boone	Hamilton	Overall Summary
Use Designation				
% Cropland	82	77	87	82
% Forest	3	7	3	4
% Urban	6	7	3	5
% Pasture/Rural	5	8	4	6
% Water	< 1	< 1	< 1	< 1
% Other	3	2	3	3
Total Acres	363,490	366,560	369,920	1,100,420

Source: Agricultural Stabilization Conservation Service Offices in Story, Boone, and Hamilton Counties, 1994.

Table A-2. Non-Farmed Streamside Buffer Measurements

	Stream Reach Measured (lineal ft)	Total Non-Farmed (acres)	Streamside Buffer (acres/1000 ft)
Location			
Between WC 1-2	1,584	3	1.9
Between WC 2-3	13,134	147	11.2
Between WC 3-4	30,162	544	18.0
Between BC 1-2	21,120	51	2.4
Between BC 2-3	29,120	358	12.1
Between SC 1-2	36,261	47	1.3
Between SC 2-3	22,308	254	11.4
Upstream MC 1	15,144	367	24.3
Upstream CC 1	12,719	20	1.6

Source: Agricultural Stabilization Conservation Service Offices in Story, Boone, and Hamilton Counties, 1994.

Table A-3. *Ceriodaphnia dubia* and Sediment Pore Water Test Results

Station	Percent Conc.	Sampling Periods 05/92 Surv.	Yld	06/92 Surv.	Yld	09/92 Surv.	Yld	04/93 Surv.[a]	Yld[b]
WC 1	100	100	27	100	28	100	20	100	17
	50	100	24	100	29	100	23	-	-[c]
WC 2	100	90	23	100	28	100	22	100	23
	50	100	24	100	28	90	20	-	-
WC 3	100	100	25	100	26	80	17	90	21
	50	100	26	100	35	-	-		
WC 4	100	100	19	100	32	100	22	100	21
	50	100	24	100	34	-	-	-	-
BC 1	100	-	-	-	-	-	-	100	18
	50	-	-	-	-	-	-	-	-
BC 2	100	100	24	100	31	100	22	100	28
	50	100	25	-	-	-	-	-	-
BC 3	100	100	22	100	32	100	21	100	23
	50	100	25	-	-	-	-	-	-
SC 1	100	-	-	-	-	-	-	-	-
	50	-	-	-	-	-	-	-	-
SC 2	100	-	-	-	-	-	-	100	26
	50	-	-	-	-	-	-	-	-
SC 3	100	100	25	100	29	100	22	100	24
	50	-	-	-	-	-	-	-	-
MC 1	100	100	27	-	-	100	19	100	22
	50	100	27	-	-	-	-	-	-
CC 1	100	-	-	-	-	-	-	-	-
	50	-	-	-	-	-	-	-	-

Station	Percent Conc.	Sampling Periods 06/93 Surv.	Yld	04/94 Surv.	Yld	07/94 Surv.	Yld
WC 1	100	100	20	90	21	100	12
	50	-	-	-	-	-	-
WC 2	100	100	26	100	26	100	17
	50	-	-	-	-	-	-
WC 3	100	90	19	-	-	100	17
	50	-	-	-	-	-	-
WC 4	100	-	-	100	24	100	17
	50	-	-	-	-	-	-
BC 1	100	-	-	100	30	100	17
	50	-	-	-	-	-	-
BC 2	100	100	22	100	25	100	17
	50	-	-	-	-	-	-
BC 3	100	-	-	-	-	-	-
	50	-	-	-	-	-	-
SC 1	100	-	-	100	26	100	16
	50	-	-	-	-	-	-
SC 2	100	-	-	100	28	100	17
	50	-	-	-	-	-	-
SC 3	100	-	-	100	25	90	13
	50	-	-	-	-	-	-
MC 1	100	-	-	-	-	-	-
	50	-	-	-	-	-	-
CC 1	100	100	20	100	30	90	15
	50	-	-	-	-	-	-

[a]Surv. = Percent Survival.
[b]Yld = Yield, average number of young produced at end of test.
[c]No test conducted.

Table A-4. *Selenastrum capricornutum* and Sediment Pore Water Test Results

Station	Percent Conc.	04/94 Final Biomass	04/94 Prop. % Response	07/94 Final Biomass[a]	07/94 Prop. % Response
WC 1	100	3.5	-15	1.8	-79[b]
WC 2	100	4.1	-2	3.5	-58
WC 3	100	-	-	-	-[c]
WC 4	100	10.0	145	6.5	-23
BC 1	100	5.0	21	5.8	-31
BC 2	100	3.3	-20	11.4	35
BC 3	100	-	-	-	-
SC 1	100	5.4	30	3.2	-62
SC 2	100	7.7	87	-	-
SC 3	100	6.9	68	4.9	-42
MC 1	100	-	-		
CC 1	100	4.2	1	1.8	-79

[a]Final biomass in mg/l.
[b]Proportional percent response from control response.
[c]No test conducted.

Table A-5. Water Quality Measurements - Average Values

	Bear Creek BC 1	Bear Creek BC 2	Bear Creek BC 3	Crked Cr.[a] CC 1	Mntry Cr.[a] MC 1
Surface Water					
NH_3-N mg/l	0.03	0.06	0.03	0.05	0.05
TP mg/l	0.07	0.05	0.09	0.12	0.08
NO_2+NO_3-N mg/l	9.3	9.6	9.4	9.5	8.3
O-PO_4 (as P), mg/l	0.05	0.04	0.06	0.09	0.04
TN (as N), mg/l	9.8	10.0	9.8	10.3	8.5
TSS mg/l	123	117	150	89	125
T. Alkalinity mg/l	317	339	343	357	358
Turbidity NTU	52	54	59	67	58
T. Conductivity µmhos/cm²	486	498	520	575	490
T. Organic Carbon mg/l	6.0	3.9	3.2	3.8	2.5
pH units	7.8	8.1	7.9	-	-[b]
Temperature °C	17.4	18.1	17.7	16.8	17.3
Sediment Pore Water					
NH_3-N mg/l	0.15	0.17	0.39	1.12	0.11
TP mg/l	0.03	0.05	0.07	0.08	0.07
NO_2+NO_3-N mg/l	8.1	9.0	8.0	6.7	7.3
O-PO_4 (as P), mg/l	0.05	0.04	0.07	0.05	0.05
TN (as N), mg/l	8.8	9.6	8.7	9.0	7.6

	Squaw Creek SC 1	Squaw Creek SC 2	Squaw Creek SC 3	Walnut Creek WC 1	Walnut Creek WC 2	Walnut Creek WC 3	Walnut Creek WC 4
Surface Water							
NH_3-N mg/l	0.05	0.04	0.04	0.04	0.03	0.03	0.05
TP mg/l	0.08	0.08	0.08	0.06	0.07	0.08	0.03
NO_2+NO_3-N mg/l	9.3	8.5	9.1	11.5	9.8	8.3	8.1
O-PO_4 (as P), mg/l	0.06	0.05	0.05	0.04	0.05	0.03	0.02
TN (as N), mg/l	10.2	8.9	9.3	12.2	10.4	9.4	8.4
TSS mg/l	120	195	113	66	82	88	108
T. Alkalinity mg/l	358	351	338	378	383	370	340
Turbidity NTU	39	52	52	20	39	47	56
T. Conductivity µmhos/cm²	578	567	528	605	554	531	497
T. Organic Carbon mg/l	3.6	3.8	3.8	2.9	2.6	2.8	4.1
pH units	7.9	8.0	8.0	7.6	7.9	8.0	8.1
Temperature °C	16.0	16.7	18.4	13.9	14.8	16.4	16.9
Sediment Pore Water							
NH_3-N mg/l	0.35	0.22	0.32	3.25	0.56	0.40	0.19
TP mg/l	0.08	0.08	0.06	0.16	0.07	0.05	0.06
NO_2+NO_3-N mg/l	7.2	7.4	8.1	5.6	6.5	8.5	7.3
O-PO_4 (as P), mg/l	0.06	0.08	0.06	0.04	0.05	0.03	0.03
TN (as N), mg/l	7.8	8.2	7.5	9.7	7.7	9.1	7.9

[a]Crked = Crooked Creek, Mntry = Montgomery Creek.
[b]No measurements taken.

Table A-6. Anion/Cation Analyses

	Bear Creek	Crooked Creek	Montgomery Creek	Squawk Creek	Walnut Creek
Anions					
Fluoride mg/l	0.2 (0.1-0.2)	0.3 (-)	0.2 (-)	0.2 (0.2-0.3)	0.3 (0.2-0.3)
Chloride mg/l	16.8 (9.7-27.0)	12.4 (9.4-15.5)	13.5 (15.2-19.8)[a]	16.8 (9.2-29.1)	18.4 (10.1-27.3)
Bromide mg/l	0.03 (0.02-0.03)	0.02 (0.01-0.02)	0.03 (-)	0.02 (0.02-0.03)	0.03 (0.02-0.03)
Sulfate mg/l	19.3 (11.1-35.8)	14.2 (13.2-15.2)	28.3 (17.5-36.6)	25.4 (13.6-54.2)	20.6 (12.2-34.4)
Cations					
Calcium mg/l	25.7 (20.0-28.7)	28.6 (25.0-32.1)	38.9 (24.3-56.0)	32.9 (24.3-56.0)	39.5 (26.3-69.8)
Magnesium mg/l	34.5 (14.6-53.4)	30.1 (2.0-50.4)	36.9 (31.4-46.8)	34.6 (10.8-59.0)	34.9 (11.8-78.0)
Manganese mg/l	0.01 (-)	0.02 (< 0.01-0.04)	0.01 (-)	0.01 (-)	0.01 (-)
Sodium mg/l	1.3 (0.8-2.0)	0.9 (< 0.1-1.7)	5.9 (1.0-9.5)	2.4 (1.2-8.9)	3.7 (0.6-13.3)
Potassium mg/l	4.7 (3.6-6.0)	3.2 (0.1-5.6)	3.2 (1.6-4.8)	5.2 (1.5-7.9)	4.1 (0.8-7.8)

[a]Average and (minimum - maximum) values.

Appendix B

Macroinvertebrate and Fish Community

Table B-1. Macroinvertebrate Checklist/Classifications

	Classification	
	Feeding	Habitat
Ephemeroptera - 12 Taxa		
Baetis	c	both
Baetisca	c	
Caenis	c	dep
Heptagenia	gz	ero
Hexagenia	c	
Isonychia	c	ero
Leptophlebia	c	ero
Paraleptophlebia	c	ero
Potomanthus	gz	
Stenacron	gz	ero
Stenonema	gz	ero
Tricorythodes	c	ero
Plecoptera - 3 Taxa		
Acroneuria	pd	ero
Perlesta	pd	both
Pteronarcys	sh	both
Trichoptera - 12 Taxa		
Agrypnia	sh	
Cheumatopsyche	c	ero
Hydropsyche	c	ero
Hydroptilidae	mp	both
Mystacides	c	
Nectopsyche	sh	both
Nemotalius	sh	
Neureclipsis	c	ero
Nyctiophylax	pd	both
Orchrotrichia		
Psychomyia	c	ero
Trianodes	sh	
Coleoptera - 4 Taxa		
Agabus	pd	both
Elmidae	c	ero
Hydaticus	pd	
Peltodytes	mp	
Hemiptera - 1 Taxon		
Corixidae	pd	dep
Odonata - 3 Taxa		
Argia	pd	both
Gomphidae	pd	both
Ischnura	pd	dep

	Classification	
	Feeding	Habitat
Chironomidae - 23 Taxa		
Ablabesymia	pd	both
Brillia	sh	both
Chironomus	c	dep
Corynoneuria	c	dep
Cricotopus	sh	both
Cryptochironomus	pd	dep
Dicrotendipes	c	dep
Endochironomus	sh	
Glyptotendipes	sh	dep
Heterotrissocladius	c	both
Microtendipes	c	dep
Nilothauma	c	dep
Nylotanypus	pd	ero
Polypedilum	pd	dep
Procladius	pd	dep
Pseudocladius	c	dep
Robakia	c	
Stenochironomus	c	both
Stictiochironomus	c	dep
Tanypus	pd	
Tanytarsini	c	both
Thienemanniella	c	both
Tribelos	c	dep
Other Diptera - 10 Taxa		
Atherix	pd	both
Anthomyiidae		
Ceratopogonidae	pd	dep
Empididae	pd	both
Ephydridae	c	dep
Hemerodromia	pd	
Psychodidae	c	
Simuliidae	c	ero
Tabanidae	pd	dep
Tipulidae	sh	both
Amphipoda - 1 Taxon		
Hyalella	gz	dep
Isopoda - 1 Taxon		
Asellus	c	dep
Mollusca - 2 Taxa		
Physa	gz	both
Pelecypoda	c	
Others - 5 Taxa		
Copepoda	pd	dep
Decapoda	pd	both
Hirudinea	pd	both
Hydra	pd	dep
Oligochaeta	gz	both

Total Taxa = 77 Taxa

Classification Definitions

c = collector
gz = grazer
mp = macrophyte parasite
pd = predator
sh = shredder

ero = erosional
dep = depositional

Table B-2. Macroinvertebrate Community Composition

	Walnut Creek	Bear Creek	Squaw Creek	Montgomery Creek	Crooked Creek
Artificial Substrates - - - - - - - - - - -					
Tricorythodes		+	■	+	+[a]
Caenis	+	+	+	+	+
Stenacron	■	+	■		+
Stenonema		+	+		+
Heptagenia	■	■	■	■	■[b]
Isonychia	+	+	■		+
Baetis	+	+	+	+	+
Paraleptophlebia	+	+			
Hexagenia			+	+	
Leptophlebia	+	+	+	■	+
Baetisca		+	+		
Acroneuria			+		
Perlesta	+		+		
Pternarcys			+		
Cheumatopsyche	+	■	■	+	■
Hydropsyche	+	+	+	+	■
Neureclipsis		■			
Nectopsyche	+				
Hydroptilidae	+	+	+		
Elmidae	+	+	+		+
Agabus	+				
Psectrocladius	+		+		
Cricotopus	+	+	+		
Corynoneuria	+				
Thienemanniella	+		+		
Brillia	+	+	+	■	■
Microtendipes			+		
Dicrotendipes	+	+	+		
Polypedilum	+	+	+	■	
Tribelos	+				
Chironomus		+	+	■	
Glyptotendipes		+			
Cryptochironomus	+				+
Tanytarsini	■	+	■	+	+
Robakia		+			
Ablabesmyia	+	+	+	+	+
Procladius		+			
Nylotanypus			+		
Ceratopogonidae	+		+		+
Hemerodromia	+	+			
Tipulidae	+				
Simuliidae	+	+			+
Ephydridae	+	+	+		+
Physa	■	+			
Hyalella		+			+
Asellus	+				+
Hydra	+	+	+		
Oligochaeta	■	+	+		■
Planaria	+		+		+
Hirudinea	+	+			
Decapoda	+				
Copepoda	+				

continued

Table B-2. Continued

	Walnut Creek	Bear Creek	Squaw Creek	Mongtomery Creek	Crooked Creek
Qualitative ---------------					
Tricorythodes	+	+	■	■	+
Caenis	+	■	+	+	+
Stenacron	■	+	+		+
Stenonema		+	+	+	+
Heptagenia	■	■	■	■	■
Isonychia	+	+	+	■	+
Baetis	■	■	+	■	+
Paraleptophlebia		+	+	+	
Hexagenia	+	+			
Ephron		+			
Pseudocloeon		+	+	+	+
Potomanthus			+		
Leptophlebia		+			+
Acroneuria			+	+	
Perlesta	+	+	+	+	
Pternarcys			+		
Cheumatopsyche	+	■	■	■	■
Hydropsyche	+	+	+	+	■
Nectopsyche	+	+	+	+	
Hydroptilidae	+	+	+	+	
Orchrotrichia				+	
Elmidae	+	+	+	+	+
Agabus	+				
Gomphidae		+	+		
Ischnura			+		
Agrion	+				
Agria			+		
Psectrocladius	+	+	+		
Crictopus	■	■	■	■	■
Thienemanniella	+	+			+
Brillia	+	+	+	+	+
Microtendipes	+		+	+	
Dicrotendipes	+	+	+		
Polypedilum	+	■	+	+	+
Tribelos	+				
Chironomus	+	+	+	+	+
Glyptotendipes	+		+		
Cryptochironomus	+	+	+		
Tanytarsini	■	+	■	+	+
Robakia	+		+		
Ablabesmyia	+	+	+	+	+
Procladius	+		+		
Heterotrissocladius	+				+
Ceratopogonidae	+		+		
Hemerodromia	+	+		+	
Tipulidae	+				
Simuliidae	+	+	+	+	■
Ephydridae	+	+		+	+
Physa	■	+	+		+
Pelecypoda	+	+	+		+

continued

Table B-2. Continued

	Walnut Creek	Bear Creek	Squaw Creek	Mongtomery Creek	Crooked Creek
Hyalella	+	+	+		+
Asellus	+				+
Hydra		+	+		
Oligochaeta	+	+	+	+	■
Planaria	+	■	+		
Hirudinea	+				+
Decapoda	+	+			

[a]+ = ≥ 0.05% in abundance.
[b]■ = ≥ 5.0% in abundance.

Table B-3. Macroinvertebrate Community Composition - By Major Group (in percent)

	Walnut Creek	Bear Creek	Squaw Creek	Montgomery Creek	Crooked Creek
Artificial Substrates					
Ephemeroptera	28	63	56	36	39
Megaloptera	0	0	0	0	0
Plecoptera	2	< 1	1	0	0
Trichoptera	2	24	23	3	32
Coleoptera	< 1	< 1	< 1	0	< 1
Hemiptera	0	0	0	0	0
Lepidoptera	0	0	0	0	0
Odonata	< 1	0	0	0	0
Diptera - Chironomidae	49	10	18	60	16
Diptera - Other	2	< 1	< 1	0	5
Amphipoda	0	< 1	0	0	2
Isopoda	< 1	0	0	0	< 1
Oligochaeta	8	1	< 1	< 1	5
Mollusca	7	< 1	0	0	0
Platyhelminthes	0	0	< 1	0	< 1
Others	1	< 1	< 1	0	0
Qualitative					
Ephemeroptera	49	50	34	67	26
Megaloptera	0	0	0	0	0
Plecoptera	4	< 1	1	< 1	0
Trichoptera	3	12	12	14	17
Coleoptera	< 1	< 1	3	1	< 1
Hemiptera	0	0	0	0	0
Lepidoptera	0	0	0	0	0
Odonata	< 1	< 1	< 1	0	0
Diptera - Chironomidae	28	20	42	13	20
Diptera - Other	3	2	1	3	21
Amphipoda	< 1	< 1	< 1	0	3
Isopoda	< 1	0	0	0	< 1
Oligochaeta	4	5	1	< 1	13
Mollusca	7	< 1	1	0	< 1
Platyhelminthes	< 1	10	3	0	0
Others	< 1	< 1	0	0	0

Table B-4. Macroinvertebrate Community Metrics - By Station (Averages)

	WC 1	WC 2	WC 3	WC 4
Abundance - AS[a]	264	580	317	114
Richness - AS[b]	9	18	20	13
EPT - AS[c]	0	5	7	7
ICI[d]	4	24	27	35
# AS Measurements[e]	2	5	5	4
Richness - Qual.[f]	10	20	19	16
EPT - Qual.[g]	1	6	7	6
# Qual. Measurements[h]	2	7	6	6

	BC 1	BC 2	BC 3
Abundance - AS	1327	700	295
Richness - AS	18	18	21
EPT - AS	9	10	8
ICI	42	37	31
# AS Measurements	1	3	2
Richness - Qual.	19	19	20
EPT - Qual.	9	9	11
# Qual. Measurements	2	5	5

	SC 1	SC 2	SC 3
Abundance - AS	1972	705	925
Richness - AS	23	20	28
EPT - AS	9	11	13
ICI	42	40	36
# AS Measurements	1	1	5
Richness - Qual.	20	16	31
EPT - Qual.	10	9	14
# Qual. Measurements	2	2	5

	MC 1	CC 1
Abundance - AS	110	1704
Richness - AS	17	26
EPT - AS	9	12
ICI	30	42
# AS Measurements	1	1
Richness - Qual.	20	21
EPT - Qual.	11	10
# Qual. Measurements	5	2

[a]Artificial substrates.
[b]Richness or mean number of taxa recovered from artificial substrates.
[c]Mean number of Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa on artificial substrates.
[d]Mean ICI index value. ICI = Index of Community Integrity.
[e]Number (#) of artificial substrate measurements taken.
[f]Richness or mean number of qualitative taxa.
[g]Mean number of Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa in qualitative samples.
[h]Number (#) of qualitative measurements taken.

Table B-5. Fish Checklist/classifications

		Classification		
Cyprinidae - 12 Taxa		Toler.	Feeding	Habitat
Campostoma anomalum	Central stoneroller	I		F
Cyprinus carpio	Common carp	T	O	HG
Hybognathus hankinsoni	Brassy minnow		H	F
Notropis cornutus	Common shiner			HG
Notropis dorsalis	Bigmouth shiner			F
Notropis lutrensis	Red shiner	T	I	F
Notropis stramineus	Sand shiner		I	F
Phenacobius mirabilis	Suckermouth minnow		I	F
Pimephales notatus	Bluntnose minnow	T	O	F
Pimephales promelas	Fathead minnow	T	O	HG
Rhinichthys atratulus	Blacknose dace		O	F
Semotilus atromaculatus	Creek chub	T	O	F
Catostomidae - 5 Taxa				
Carpiodes cyprinus	Quillback		O	HG
Carpiodes velifer	Highfin carpsucker	I	O	HG
Catostomus commersoni	White sucker	T	O	HG
Hypentelium nigricans	Northern hog sucker	I	I	F
Moxostoma macrolepidotum	Shorthead redhorse	I	I	HG
Ictaluridae - 1 Taxon				
Ictalurus melas	Black bullhead			HG
Centrachidae - 2 Taxa				
Lepomis cyanellus	Green sunfish		I	HG
Micropterus dolomieui	Smallmouth bass	I	P	F
Percidae - 1 Taxon				
Etheostoma nigrum	Johnny darter	T	I	HG
Total Taxa = 21				

Classification Definitions
I = Intolerant; T = Tolerant
H = Herbivore; I = Insectivore; O = Omnivore; P = Piscivore
F = Flowing water; HG = No obvious flowing preference

Table B-6. Fish Community - Dominant Taxa

	Walnut Creek	Bear Creek	Squaw Creek	Crooked Creek
Central stoneroller	■	■	+[a]	■[b]
Common carp	+			
Brassy minnow				+
Common shiner	■	■	■	+
Bigmouth shiner	■	■	■	■
Red shiner	+	+	+	
Sand shiner	+	■	■	+
Suckermouth minnow	+	+	+	
Bluntnose minnow	■	■	■	■
Fathead minnow	+		+	+
Blacknose dace	+			
Creek chub	■	■	+	■
Quillback			+	
Highfin carpsucker			+	
White sucker	+	+	+	+
Northern hog sucker		+	+	
Black bullhead	+			
Green sunfish	+	+		+
Smallmouth bass		+		
Johnny darter	■	+	+	■

[a]≥ 0.05% in abundance.
[b]≥ 5.0% in abundance.

Table B.7 Fish Community Metrics - By Station (Averages)

	WC 2	WC 3	WC 4
Abundance[a]	1875	1303	2390
Richness[b]	8	8	10
IBI[c]	34	38	39
# Measurements[d]	4	3	4
	BC 1	BC 2	BC 3
Abundance	1944	3968	2967
Richness	9	9	9
IBI	41	44	46
# Measurements	2	4	3
	SC 1	SC 3	
Abundance	1370	3599	
Richness	8	11	
IBI	28	26	
# Measurements	2	3	
	CC 1		
Abundance	1872		
Richness	12		
IBI	30		
# Measurements	2		

[a]Abundance (#/300 meters) of stream length.
[b]Richness or mean number of taxa.
[c]Mean IBI - Index of Biotic Integrity.
[d] Mean number (#) of measurements taken.

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