ANALYSIS OF BENTHIC MACROINVERTEBRATE COMMUNITIES IN THE MINNESOTA RIVER WATERSHED

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INTRODUCTION

Biological communities have features that make them valuable in assessing the overall health of a stream and to define environmental impacts. The animal species that inhabit a particular section of stream are indicators of present and past physical, chemical and biological conditions. They reflect interactions of factors such as chemical and habitat quality, stream flow and pollutant loadings. Macroinvertebrate communities are especially useful in stream quality assessment and restoration programs because they are an important functional component of the ecosystem and are effective monitors of environmental conditions (Furse et al., 1984; Wright et al., 1984; Rosenberg et al., 1986; Richards and Minshall, 1992; Richards and Host, 1993).

The objective of this study was to assess the status of benthic macroinvertebrate communities in streams of the Minnesota River basin. Major measures of community condition were taxonomic richness and diversity and the abundance of species relative to their pollution sensitivity. Most of the area studied is heavily agricultural; corn and soybeans are the major crops and nonpoint source pollution is the primary water quality concern.

Channels sampled for macroinvertebrates ranged widely in size and riparian and instream characteristics. The mainstem of the Minnesota River was sampled at locations from the confluence with the Mississippi at Fort Snelling to just below the Lac Qui Parle Reservoir. Data was also collected from large tributaries such as the Watonwan and Yellow Medicine Rivers and smaller inflowing streams such as High Island and Camp Pope Creeks. The Blue Earth River drainage has a major impact on conditions in the Minnesota River. For this reason stream sites in the Blue Earth watershed ranging from small streams, such as St. James Creek, to agricultural ditches were sampled. During the latter phase of the study some streams were sampled because it was suspected that they were subject to specific pollution impacts, such as feedlot runoff.

Benthic macroinvertebrates have been widely used in stream water quality assessment studies. There are a number of factors that make them especially useful in water pollution surveys including:

1. stream macroinvertebrate communities are permanent and relatively immobile
2. sampling effort and cost are both relatively low
3. communities react quickly to environmental change
4. they are found in all stream habitats and display a wide variety of functional feeding characteristics (i.e., shredders, collectors, scrapers, predators)
5. they are a major food source for fish and other aquatic and terrestrial vertebrates
6. taxonomic, environmental requirements and pollution tolerance information is available for most macroinvertebrate taxa
7. pollution tolerance ratings, from very sensitive to very tolerant, have been determined for most taxa

The structure of a benthic macroinvertebrate community in a stream is determined by a variety of environmental factors that exist throughout the life of the species comprising the community. Environmental disturbances, long-term or short-term, can alter community structure. Streams with high water quality and suitable habitat usually have well-balanced, stable macroinvertebrate communities. The dominant insects are pollution-sensitive groups such as stoneflies, mayflies and caddisflies. Pollution-tolerant groups, such as oligochaete annelids, pulmonate snails and dipteran insect larvae, are usually represented by a few species with few individuals. In a stream where environmental quality has been adversely impacted, pollution-sensitive groups decline in abundance or are eliminated and a few tolerant groups increase greatly in number; under extremely toxic conditions, all forms may be absent.

Previous studies which contain macroinvertebrate data for the Minnesota River were conducted from 1964 to 1985. Area surveys include a Federal Water Pollution Control Administration study (1966), a bridge location study in the Mankato area by the U.S. Corps of Engineers (1981) and a survey of the lower Minnesota River by the Minnesota Department of Health (1964). The Minnesota Pollution Control Agency (1979, 1981) conducted general surveys in which only a few sites on the Minnesota River were sampled from 1976 to 1979. Additional macroinvertebrate surveys of the river were conducted by Kirsch et al., (1985) and King (1985). Cordie (1991) studied macroinvertebrate communities at nine locations in the Blue Earth River watershed.

In this study the status of the stream benthic macroinvertebrate communities at 41 locations in the Minnesota River basin were assessed (Table 1). Site descriptions are given in the Appendix. The main sampling periods were during the four summers from 1989 to 1992. In 1989 and 1990, samples were collected at the following locations on the mainstem of the river: Lac Qui Parle, Upper Sioux Agency, Delhi, Morton, Fort Ridgely, Courtland, Judson, St. Peter and Henderson, Jordan and Fort Snelling; the following ten tributaries were also sampled: Chippewa River, Yellow Medicine River, Hawk Creek, Redwood River, Cottonwood River, Watonwan River, Le Sueur River, Blue Earth River, Rush River and High Island Creek (Fig. 1). During the winter of 1990 samples were collected at Fort Ridgely, Morton, St. Peter and Henderson on the mainstem. Sampling and sample processing in 1989 and 1990 were conducted by personnel at St. Olaf and Gustavus Adolphus Colleges and Mankato State University. At streams near the following communities one set of samples was collected in 1991 and two sets were taken in 1992: Mountain Lake, St. James, Fairmont, Blue Earth (2), Frost, Wells, Pemberton, Beauford and north of Lake Washington (Fig. 2). Two sets of samples were collected from small streams near the following new sites in the summer of 1992: Lake Shaokotan, Mountain Lake, Minnesota, Redwood Falls (Camp Pope Creek), Fairfax, Roseland, Arlington, Gaylord, Nicollet, Frost (East Branch of Blue Earth River) and two sites near Winnebago (Fig. 3, 4). All of the sampling and sample processing during 1991 and 1992 was conducted by personnel at St. Olaf College. In 1989 and 1990 samples were collected on the mainstem of the Minnesota River at Jordan and Fort Snelling by personnel of the Metropolitan Waste Control Commission.

METHODS

Habitat Assessment

Evaluating habitat quality is an important part of any assessment of stream macroinvertebrate communities. A systematic assessment of habitat quality was conducted at each macroinvertebrate sampling location. Each location was assessed in terms of its physical characteristics, water quality, local watershed, stream bank and instream characteristics.

The habitat assessment technique described by the Ohio Environmental Protection Agency (1987, 1989) was employed in this study. This procedure includes the calculation of a Qualitative Habitat Evaluation Index (QHEI) from information collected at each sampling site.

The following geographical information was provided with each habitat assessment:

River mile or watershed number
County, specific location (proximity to local landmark, e.g., bridge, road, discharge outfall, railroad crossing, park, tributary, dam, etc.)
Map reference (name, number and date of U.S. Geological Survey quadrangle)
Township, section
Latitude, longitude

The Qualitative Habitat Evaluation Index is a physical habitat index designed to provide an empirical, quantified evaluation of the lotic habitat quality. The index consists of seven metrics, each of which is given an individual score, with a maximum possible site score of 100.

The standardized definitions of stream habitats, as provided by Platts et al., (1983), given below was used in the survey.

Riffle - areas of the stream with fast current velocity and shallow depth; the water surface is visibly broken.
Run - areas of the stream that have a rapid, non-turbulent flow; runs are deeper than riffles with faster current velocity than pools and are generally located downstream from riffles where the stream narrows; the stream bed is often flat beneath a run and the water surface is not visibly broken.
Pool - an area of the stream with slow current velocity and a depth greater than riffle and run areas; the stream bed is often concave and stream width frequently is the greatest; the water surface slope is nearly zero.
Glide - this is an area common to most modified stream channels that do not have distinguishable pool, run, and riffle habitat; the current and flow is similar to that of a canal; the water surface gradient is nearly zero.

The following seven metrics were used to compute the QHEI for each macroinvertebrate sampling site in the Minnesota River basin. The information was entered on a site description sheet (Appendix).

1. Substrate type and quality (see Appendix for substrate definitions).
2. Instream cover type and amount.
3. Channel morphology - relates to the creation and stability of habitat and includes channel sinuosity (degree to which the channel meanders), channel development (development of riffle/pool complexes), channelization (man-made channel modifications) and channel stability.
4. Riparian zone and bank erosion - emphasizes the quality of the riparian buffer zone and quality of the floodplain vegetation and includes riparian zone width, floodplain quality (forest, rowcrop, urban, etc.) and bank erosion (ratings from Platts et al., 1983).
5. Pool and riffle-run quality - emphasizes quality of the pool, glide and/or riffle-run habitats and includes pool depth, pool cover, pool current, pool morphology (width of pools compared to width of riffles), riffle-run depth, riffle-run substrate, and riffle-run substrate quality.
6. Map gradient - calculated from a U.S. Geological Survey 7.5 minute topographic map by measuring the elevation drop through the sampling area and converting the gradient to a metric score from the scale of the Ohio EPA (1987).
7. Drainage area - refers to the watershed area in square miles upstream from the sampling site, a chart provided by the Ohio EPA (1987) was used to score the metric.

The total QHEI score was computed by adding the components of each metric to obtain the metric scores and then summing the seven metric scores (total maximum score 100).

Habitat assessments at the 1989 and 1990 mainstem and tributary sampling sites were made by Robert Bellig, Biology Department, Gustavus College. All other assessments were by James Zischke, Biology Department, St. Olaf College.

Field Procedures

Three different techniques were employed to sample benthic macroinvertebrates. Quantitative samples were taken with Hester-Dendy artificial substrate samplers. In 1989 and 1990 qualitative samples were also taken with a kick-net and by hand-picking from solid substrates.

Multiplate Hester-Dendy samplers were used to provide a consistent substrate for colonization at each sampling location. This sampling device has several advantages including: reduction of the effects of substrate differences, relatively low sampling and processing effort, use of data to make statistical inferences and calculate diversity indices, comparison of data with other investigators and use of data to detect subtle differences in certain macroinvertebrate groups. The sampler consists of eight 3 x 3 inch plates of one-eighth inch tempered hardboard attached together with a one-fourth inch eye-bolt. The plates are separated by one-inch

square spacers in such a way that there are three single spaces, three double spaces and one triple space between the plates (Appendix, Fig. 1).

Three samplers were attached to a concrete patio block equipped with J-shaped metal bars. The samplers were placed in approximately 1.0 m of water and allowed to colonize for six weeks. To retrieve the Hester-Dendy samplers, a net (0.153 mm mesh) drawstring bag was placed over the sampler while still submerged to reduce loss of organisms. The bagged sampler was then placed in a one quart plastic jar containing 70% ethanol and returned to the laboratory for processing.

In 1989 and 1990 samples from riffle areas, primarily in major tributaries, were taken with a kick-net and by hand picking. Samples were collected with an indestructible A-frame dip net. Riffles were sampled at areas of both fast and slower current velocities from an area of approximately 1.0 m^2. The net rim was placed against the stream bottom with the handle held at arm's length downstream from the collector. The substrate was agitated by kicking, allowing the current to carry organisms into the net. Where a riffle community with a rock substrate was not present, samples were collected by hand-picking from other solid substrates. Two workers each collected for 30 minutes from available substrates, such as boulders, logs, bridge abutments and other submerged structures. The kick-net and hand-picked samples were placed in sample jars and preserved in 70% ethanol.

Laboratory Procedures

All samples were coded for easy reference purposes. Each sample was assigned a number and recorded in a log book.

Samples were sorted and tabulated in a glass tray over a glow box. Initial sample examination was made with a light-equipped magnifying lens; final examination was done with the aid of a stereomicroscope. To reduce analysis time for samples containing large numbers of individuals of one taxonomic group, such as oligochaetes and midges, all other organisms were removed first and then the remaining specimens were thoroughly mixed in a tray, the bottom of which had been delineated into quarters with a glass-marking pen. For Hester-Dendy samples two opposite quarters of the tray were then sorted. Kick-net and hand-picked qualitative samples with large numbers of an individual taxa were sorted as a subsample as described by Plafkin et al. (1987). Subsampling procedures are described in the Appendix. Midges were identified by mounting the head capsules of the larvae on glass slides and examining under the microscope. The midge head capsule mounting procedure and the relationship between the number of specimens in the sample and the number of microscope slide preparations and identifications is given in the Appendix.

All macroinvertebrates were identified to the lowest taxonomic level practicable, usually genus. A list of the major taxonomic references used is given in the Appendix. A reference collection of voucher specimens has been assembled. Lists of the taxa collected are given in the Appendix.

Data Analysis

Data from both the qualitative and quantitative samples were used to calculate different metrics to compare sampling stations and assess the health of the macroinvertebrate community at a sampling station. The following metrics apply either to the whole community or to different taxonomic groups, some of which are pollution-sensitive and others pollution-tolerant.

Richness

Richness is simply the total number of taxa in a community. Healthy communities have larger numbers of taxa than impacted communities. Streams with more than 25 taxa are generally regarded as non-impacted while communities with less than 10 taxa are considered severely impacted.

Diversity Index

The Shannon-Weaver species diversity index (d) can be calculated with the following expression:

$$d = \frac{C}{N} (N \log_{10} N - \Sigma n_i \log_{10} n_i)$$

where

C = 3.321923 (converts base 10 log to base 2 bits)
N = total number of individuals
n_i = total number of individuals in the ith species

The species diversity index indicates the relative importance of each species collected, not merely the relationship between the total numbers of species and individuals. Wilhm (1970) calculated the diversity indices from data on several streams studied by other investigators. He concluded that the d values for unpolluted streams were generally between 3 and 4, and for polluted streams were generally less than 1. However, the diversity index can be affected by other factors, such as current velocity, flows and substrate, that must be considered when water quality comparisons are made.

Equitability Index

Equitability (e) values can be determined by using the following formula:

$$e = \frac{S^1}{S}$$

where

S = number of taxa
S^1 = tabulated value provided in the U.S. EPA methods manual (Weber, 1973)

The equitability value is a comparison of d to MacArthur's broken stick model, which is based on a community structure theoretically found in nature. Computation of e theoretically increases the sensitivity of d.

Equitability values will range between 0 and 1 for most samples. EPA data (Weber, 1973) indicates that streams in the southeastern United States unaffected by oxygen-demanding wastes generally have e values of 0.6 to 0.8 and never below 0.5, and even slightly impacted streams have e values below 0.5 and generally range from 0.0 to 0.3.

Ratio of Insect Scraper and Filtering Collector Functional Feeding Groups

The abundances of scraper and filtering collector insects will be compared to assess the community foodbase and gain insight into the nature of disturbance factors. An unbalanced community dominated by one feeding type may indicate a response to an overabundant food source. The ratio of scrapers and filtering collectors indicates the periphyton community composition and availability of Fine Particulate Organic Material (FPOM) resulting from organic enrichment. Scraper abundance increases as benthic diatoms increase and decreases as filamentous algae and mosses increase. Filamentous algae increase in abundance as a result of organic enrichment and provide good attachment sites for filtering collectors that also obtain FPOM as a result of organic enrichment.

The insects collected were assigned to a functional feeding group according to Merritt and Cummins (1984).

Macroinvertebrate Biotic Index (MBI)

The Macroinvertebrate Biotic Index (MBI) is a modification by Plafkin et al., (1987) of an index developed by Hilsenhoff.

Most freshwater macroinvertebrate taxa known to occur in Minnesota have been assigned a pollution tolerance rating ranging from 0 (low tolerance) to 11 (high tolerance). A zero is assigned to taxa found only in unaltered streams and an 11 is assigned to taxa known to occur in severely polluted streams. Taxa with intermediate ratings occur in streams with intermediate degrees of pollution. Those taxa in the Minnesota River basin not assigned a rating were rated with available references (see Appendix). The MBI is an average of tolerance ratings weighted by organism abundance and is calculated from the formula:

$$MBI = \Sigma \frac{(ni\ ti)}{N}$$

where

ni = number of individuals in each taxon
ti = tolerance rating assigned to a taxon
N = total number of individuals in the sample

If no tolerance rating could be assigned to a taxon, that taxon was recorded as present in the sample with no tolerance rating. However, if the unassigned taxon made up a significant percentage of the total sample, that taxon was assigned the tolerance rating of the family to which it belonged. Communities with MBI values less than 2.5 are regarded as non-impacted while those with MBIs greater than 3.5 are considered severely impacted.

Invertebrate Community Index

A full or partial Invertebrate Community Index (ICI) was calculated for each sampling site and date. The ICI was developed by the Ohio Environmental Protection Agency (Ohio EPA 1987a, 1989a) as a modification of the Index of Biotic Integrity (IBI) for fish developed by Karr (1981). It consists of ten structural and functional community metrics with four scoring categories to reflect the following levels of biological community conditions: 6 exceptional, 4 good, 2 fair and 0 poor. In 1989 and 1990 both quantitative artificial substrate samples and qualitative dip net and hand picked samples were collected from the mainstem of the Minnesota River and major tributaries. Most of the sites sampled in 1991 and 1992 did not lend themselves to qualitative sampling, primarily because of water depths and types of substrate. Therefore, metric 10, total qualitative Ephemeroptera, Plecoptera and Trichoptera taxa, was not calculated and the ICI scores were based on nine metrics.

The Invertebrate Community Index (ICI) was calculated for each sampling site from the macroinvertebrate data (Ohio EPA 1987, 1989). The following metrics were employed:

1. total number of taxa (richness)
2. total number of mayfly taxa
3. total number of caddisfly taxa
4. total number of dipteran taxa
5. percent mayflies
6. percent caddisflies
7. percent Tribe Tanytarsini (Order Diptera) midges
8. percent other dipterans and non-insects
9. percent tolerant organisms
10. total number of qualitative Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa

Each metric was scored 0, 2, 4 or 6, primarily on the basis of the drainage area of the watershed at the sampling site, according to graphs prepared by Ohio EPA (1989).

The ICI scoring system was developed by the Ohio Environmental Protection Agency from macroinvertebrate sampling data from the state. The following is a brief summary of the nature and importance of each metric used to calculate the ICI's.

Metric 1. Total Number of Taxa

The total number of different macroinvertebrate taxa, or richness, at a sampling site is a measure of the relative health of the bottom community. High species richness and diversity indicates a healthy, stable community. Richness tends to decrease in larger rivers.

Metric 2. Number of Mayfly Taxa

Mayflies are pollution sensitive; large numbers of species in a sample is an indication of higher water quality. The number of mayfly taxa varies with the drainage area of the stream's watershed. Slightly higher diversity of species is found in intermediate-sized streams than in those with smaller and larger drainages.

Metric 3. Number of Caddisfly Taxa

Caddisflies as a group are somewhat more pollution-tolerant than mayflies, although their species vary widely in tolerance. Few can tolerate heavy pollution and therefore they can be good indicators of stress. The number of mayfly taxa increases with stream size and drainage area.

Metric 4. Number of Dipteran Taxa

Dipterans occur in great numbers and diversity in streams. The species vary widely in their sensitivity to pollution, but as a group they are considered to be tolerant. In streams with drainage areas greater than 100 square miles, the number of dipteran taxa present decreases inversely and in larger rivers there is a tendency toward increased populations of fewer taxa.

Metric 5. Percent Mayflies

The abundance of mayflies is a good indication of water quality. Numbers of individuals in a sample are reduced sharply under even slight pollution impact. Under severe conditions no mayflies may be present. Percent abundance of mayflies in a stream does not vary with drainage area. Good water quality is indicated by samples containing 25% or more.

Metric 6. Percent Caddisflies

Caddisflies are generally considered to be intermediate in pollution tolerance between mayflies and dipterans. Their percent abundance is strongly related to stream size and drainage area because the types of food material different species consume is different in smaller versus larger streams.

Metric 7. Percent Tanytarsini Midges

The Tribe Tanytarsini is a taxonomic subgroup of the Family Chironomidae (midges) in the insect Order Diptera. This group of midges, unlike the rest, is judged to be relatively pollution sensitive. Their percent abundance is not related to the size of the drainage area of the stream site they are found in.

Metric 8. Percent Other Dipterans and Non-Insects

Dipterans other than the Tanytarsini midges are considered to be relatively pollution tolerant and tend to become predominant under adverse water quality conditions. The percent abundance of this group tends to be inversely related to stream size when the drainage area exceeds 100 square miles.

Metric 9. Percent Tolerant Organisms

Most macroinvertebrates have now been rated on the basis of their pollution sensitivity. However, the tolerance ratings have often been based on the effects of different types of pollution. The metric in this report includes as tolerant organisms (see Appendix) those listed by the Ohio EPA (1987). On the mainstem of the river and half of its tributaries where drainage areas exceeded 1000 square miles, this metric was of limited value.

Metric 10. Qualitative EPT

Qualitative sampling was done with a dip net and picking macroinvertebrates by hand from solid substrates. This method is substrate dependent; it is affected by the kinds of substrates available and measures habitat quality as well as habitat types. Total numbers of taxa of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) were determined. This metric varies with the drainage area of the stream being sampled. Richness of these taxa tends to be higher in streams of intermediate size.

For Tables of ICI metric scores see Appendix (Tables 1-9).

RESULTS AND CONCLUSIONS

Macroinvertebrate Communities on the Mainstem of the Minnesota River - 1989 and 1990

The major invertebrate taxa at sampling locations on the mainstem of the Minnesota River in 1989 and 1990 are shown in Figures 5 and 6. The most common insects were mayflies and midges that dominated the communities at eight of the nine locations. At Lac Qui Parle amphipods were the most abundant invertebrate in both years. Mayflies were most common at Morton and Delhi. The most common caddisfly genera on the mainstem were *Hydropsche*, *Cheumatopsyche* and *Cyrnellus*.

Glyptotendipes was the most common midge; it was collected at all locations. Other common chironomids were *Polypedilum* and *Tanytarsus*. *Stenonema* and *Stenacron* were the dominant mayflies followed by *Potamanthus* and *Tricorythodes*. Some changes in dominance of the two major insect groups were seen between 1989 and 1990.

Average richness, diversity and equitability were all higher on the mainstem sites in 1990 than in 1989 (Tables 5 and 6). In 1989 richness ranged from 8 to 21 with an average of 15, diversity from 1.19 to 2.67, average 2.0, and equitability from 0.15 to 0.64, average 0.35. In 1990 richness ranged from 14 to 22, average 18.5, diversity from 0.96 to 2.89, average 2.2, and equitability from 0.12 to 0.53, average 0.37. By these three measures the section of the Minnesota River between Henderson and Lac Qui Parle would be rated as moderately pollution impacted.

Using Macroinvertebrate Biotic Index scores this section of the river would be rated as severely pollution impacted (Tables 5 and 6). MBIs in 1989 ranged from 4.47 to 8.85, average 6.2, and in 1990 the range was 3.41 to 7.71, average 5.2.

Invertebrate Community Index scores rate this river section below the Ohio Eastern Cornbelt Ecoregion warm water biocriteria level of 36 (Tables 5 and 6). In 1989 ICIs ranged from 6 to 46, average 27, and in 1990 the range was 14 to 42, average 27 (Figs. 7 and 8). In both years values were lowest at the most upstream (Lac Qui Parle) and downstream (Henderson) sampling locations.

A brief assessment of each sampling location on the mainstem of the Minnesota River is given below. The pollution impact ratings are based on community measures, Richness, Diversity, Equitability, and pollution tolerances of the animals collected, Macroinvertebrate Biotic Index MBI and Invertebrate Community Index ICI.

Henderson (RM 73) - Habitat Quality: below mainstem average (QHEI 60); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 42% of Ohio Cornbelt biocriteria.

St. Peter (RM 98) - Habitat Quality: mainstem average (QHEI 64); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 83% of Ohio Cornbelt biocriteria.

Judson (RM 127) - Habitat Quality: below mainstem average (QHEI 61); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI equal to Ohio Cornbelt biocriteria.

Courtland (RM 140) - Habitat Quality: below mainstem average (QHEI 59.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI equal to Ohio Cornbelt biocriteria.

Fort Ridgely (RM 178) - Habitat Quality: slightly above mainstem average (QHEI 65); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 92% of Ohio Cornbelt biocriteria.

Morton (RM 203) - Habitat Quality: slightly above mainstem average (QHEI 64.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 1.08 times Ohio Cornbelt biocriteria.

Delhi (RM 219) - Habitat Quality: above mainstem average (QHEI 69.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 1.06 times Ohio Cornbelt biocriteria.

Upper Sioux (RM 238) - Habitat Quality: above mainstem average (QHEI 66.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 69% of Ohio Cornbelt biocriteria.

Lac Qui Parle (RM 282) - Habitat Quality: above mainstem average (QHEI 70); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 28% of Ohio Cornbelt biocriteria.

Macroinvertebrate Communities at Jordan and Fort Snelling

In September of 1989 and August and October of 1990 the Metropolitan Waste Control Commission in St. Paul collected macroinvertebrates with Hester-Dendy samplers on the mainstem of the Minnesota River at Jordan. They also collected samples at Fort Snelling in September of 1989 and March and October of 1990. The samplers were set for four rather than six weeks.

The major taxonomic groups of invertebrates collected at Jordan and Fort Snelling were similar to those found further upstream. At Jordan in 1989 the samples consisted of 80% caddisflies and 19% midges. In 1990 at the same site the August samples were 74% caddisflies, 23% mayflies and 4% midges, while the October samples were 91% caddisflies, 3% mayflies and 6% midges. At Fort Snelling the September 1989 samples were 98% midges and 2% caddisflies. However, in October of 1990 samples from the same site consisted of 80% caddisflies, 11% mayflies and 8% midges. The Jordan community was clearly dominated by caddisflies while a shift in dominance between midges and caddisflies was seen at Fort Snelling. Insect genera in the Jordan and Fort Snelling samples were similar to those found at upstream stations on the mainstem of the river.

Macroinvertebrate Communities on Tributaries of the Minnesota River - 1989 and 1990

The major taxa at sampling locations on tributaries of the Minnesota River in 1989 and 1990 are shown in Figures 9 and 10. Samplers were not recovered from the Blue Earth and Le Sueur Rivers in 1990. As on the mainstem, caddisflies and midges were the dominant taxa but mayflies were more common at the tributary sites. Shifts in dominance of specific taxa between the two years occurred at most stations.

Average richness, diversity and equitability at tributary sites were similar in 1989 and 1990 (Tables 5 and 6) In 1989 richness ranged from 14 to 25 with an average of 18, diversity from 1.68 to 3.23, average 2.73, and equitability from 0.36 to 0.87, average 0.55. In 1990 richness ranged from 13 to 29, average 18, diversity from 1.54 to 3.90, average 2.86, and equitability from 0.27 to 0.79, average 0.61.

All tributary locations were rated severely polluted with the Macroinvertebrate Biotic Index (Tables 5 and 6). MBIs in 1989 ranged from 4.68 to 8.87, average 6.5, and in 1990 the range was 4.78 to 8.96, average 5.95.

Invertebrate Community Index (ICI) scores for tributary sites are shown in Figures 11 and 12. The only stations with ICI values equal to or greater than the Ohio Cornbelt biocriteria of 33 were the Le Sueur, Watonwan, Cottonwood and Yellow Medicine Rivers, each in one year only. Lowest ICI scores were for the Chippewa River.

Brief assessments of the sampling locations on Minnesota River tributaries in 1989 and 1990 are given below. The pollution impact ratings are based on community measures, Richness, Diversity and Equitability, and pollution tolerances of the animals collected, Macroinvertebrate Biotic Index (MBI) and Invertebrate Community Index (ICI).

High Island Creek (RM 61) - Habitat Quality: below tributary average (QHEI 70.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 58% of Ohio Cornbelt biocriteria.

Rush River (RM 68) - Habitat Quality: slightly below tributary average (QHEI 69.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 55% of Ohio Cornbelt biocriteria.

Blue Earth River (RM 112) - Habitat Quality: below tributary average (QHEI 60); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 73% of Ohio Cornbelt biocriteria.

Le Sueur River (RM 113) - Habitat Quality: above tributary average (QHEI 72.5); Richness, Diversity, Equitability pollution rating: slight; MBI pollution rating: severe; ICI above Ohio Cornbelt biocriteria.

Watonwan River (RM 114) - Habitat Quality: above tributary average (QHEI 75.5); Richness, Diversity, Equitability pollution rating: slight to non-impacted; MBI pollution rating: severe; ICI 79% of Ohio Cornbelt biocriteria.

Cottonwood River (RM 144) - Habitat Quality: above tributary average (QHEI 72); Richness, Diversity, Equitability pollution rating: slight; MBI pollution rating: severe; ICI 79% of Ohio Cornbelt biocriteria.

Redwood River (RM 217) - Habitat Quality: well above tributary average (QHEI 82); Richness, Diversity, Equitability pollution rating: slight; MBI pollution rating: severe; ICI 83% of Ohio Cornbelt biocriteria.

Hawk Creek (RM 237) - Habitat Quality: above tributary average (QHEI 73.5); Richness, Diversity, Equitability pollution rating: slight; MBI pollution rating: severe; ICI 76% of Ohio Cornbelt biocriteria.

Yellow Medicine River (RM 244) - Habitat Quality: below tributary average (QHEI 76.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 88% of Ohio Cornbelt biocriteria.

Chippewa River (RM 275) - Habitat Quality: well below tributary average (QHEI 55); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 33% of Ohio Cornbelt biocriteria.

Macroinvertebrate Communities in the Blue Earth River Watershed - 1991 and 1992

The major taxa at sampling locations on streams in the Blue Earth River watershed in 1989 and 1990 are shown in Figures 13 and 14. Samplers were not recovered from the Mountain Lake site in 1991. The most common insects were caddisflies, mayflies and midges. These insects dominated the communities at most of the sampling sites. Taxa other than caddisflies, mayflies and midges dominated several locations, at least at one of the three sampling times. Following is a list of these sites and the dominant taxa.

Beauford 1991 Amphipods

Frost	1991 mosquitoes July 1992 oligochaete annelids September 1992 oligochaete annelids
Lake Washington	1991 Isopods July 1992 Isopods September 1992 Isopods and leeches
Mountain Lake	July 1992 *Physella* (snail) September 1992 *Physella* (snail)
Wells	July 1992 leeches September 1992 *Physella* (snail)

Average richness, diversity and equitability at Blue Earth watershed sites were all somewhat higher in 1992 than in 1991 (Tables 7 and 8). In 1989 richness ranged from 6 to 26 with an average of 11, diversity from 0.64 to 2.7, average 1.94, and equitability from 0.15 to 1.14, average 0.59. In 1992 richness ranged from 8 to

24, average 17, diversity from 1.29 to 3.49, average 2.5, and equitability from 0.22 to 1.0, average 0.54.

All Blue Earth River watershed locations, except County Road 13 in 1992, were rated as severely polluted with the Macroinvertebrate Biotic Index (Tables 7 and 8). MBIs in 1991 ranged from 4.36 to 7.74, average 5.80, and in 1992 the range was 3.25 to 7.54, average 6.02.

Invertebrate Community Index (ICI) scores for the Blue Earth watershed sampling sites are shown in Figures 15 and 16. The stations at Beauford, Blue Earth, County Road 13, Fairmont, Pemberton and St. James approached or exceeded the Ohio Cornbelt biocriteria of 33. Low ICI values were recorded at Wells, Mountain Lake, Frost and Lake Washington.

Brief assessments of the sampling locations in the Blue Earth River watershed in 1991 and 1992 are given below. The pollution impact ratings are based on community measures, Richness, Diversity, Equitability, and pollution tolerances of the animals collected, Macroinvertebrate Biotic Index (MBI) and Invertebrate Community Index (ICI).

Beauford (WS #32073) - Habitat Quality: good (QHEI 67.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 87% of Ohio Cornbelt biocriteria.

Blue Earth (WS #30030) - Habitat Quality: good (QHEI 63.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 83% of Ohio Cornbelt biocriteria.

County Road 13 (WS #30047) - Habitat Quality: good (QHEI 63); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 91% of Ohio Cornbelt biocriteria.

St. James (WS #31015) - Habitat Quality: good (QHEI 68); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 89% of Ohio Cornbelt biocriteria.

Wells (WS #32042) - Habitat Quality: poor (QHEI 49); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 44% of Ohio Cornbelt biocriteria.

Lake Washington (WS #28033) - Habitat Quality: poor (QHEI 47); Richness, Diversity, Equitability pollution rating: moderate to severe; MBI pollution rating: severe; ICI 18% of Ohio Cornbelt biocriteria.

Mountain Lake (WS #31058) - Habitat Quality: poor (QHEI 50); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 42% of Ohio Cornbelt biocriteria.

Pemberton (WS #32067) - Habitat Quality: poor (QHEI 45.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 1.05 times Ohio Cornbelt biocriteria.

Fairmont (WS #30056) - Habitat Quality: fair (QHEI 55); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 81% of Ohio Cornbelt biocriteria.

Frost (WS #30050) - Habitat Quality: fair (QHEI 57); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 30% of Ohio Cornbelt biocriteria.

Macroinvertebrate Communities in Small Streams in the Minnesota River Watershed - 1992

The major taxa at locations on the small streams in the Minnesota River watershed sampled in 1992 are shown in Figures 17 and 18. Samplers were not recovered from Camp Pope Creek and Lake Shaokotan in July, and the east branch of the Blue Earth River and Gaylord in September. The most common insects were caddisflies, mayflies and midges. These insects dominated the communities at all but 2 of the 12 sampling sites. Amphipods dominated the communities at Minneota and Lake Shaokotan.

Richness, diversity and equitability at the small watershed sites varied considerably (Tables 9 and 10). Richness ranged from 4 to 26, diversity from 1.40 to 3.42 and equitability from 0.19 to 1.25.

All of the smaller watersheds sampled in 1992 were rated severely polluted by the Macroinvertebrate Biotic Index (Tables 9 and 10). MBIs ranged from 3.78 to 6.84.

Invertebrate Community Index (ICI) scores for the small streams in the Minnesota River watershed are shown in Figures 19 and 20. The stations at Camp Pope Creek, Fairfax, Nicollett, Old Mountain Lake and Winnebago 1 all approached or exceeded the Ohio Cornbelt biocriteria of 33. The stations at Gaylord, Lake Shaokotan and Minneota had ICI scores far below the Ohio biocriteria level.

Brief assessments of the sampling locations at the small watershed sampling sites in 1992 are given below. The pollution impact ratings are based on community measures, Richness, Diversity, Equitability, and pollution tolerances of the animals collected, Macroinvertebrates Biotic Index (MBI) and Invertebrate Community Index (ICI).

Arlington (WS #33075) - Habitat Quality: fair (QHEI 54); Richness, Diversity, Equitability pollution rating: fair; MBI pollution rating: severe; ICI 50% of Ohio Cornbelt biocriteria.

Camp Pope Creek (WS #25161) - Habitat Quality: good (QHEI 61); Richness, Diversity, Equitability pollution rating: slight; MBI pollution rating: severe; ICI 1.27 times Ohio Cornbelt biocriteria.

East Branch Blue Earth River (WS #30049) - Habitat Quality: good (QHEI 72.5); Richness, Diversity, Equitability pollution rating: slight; MBI pollution rating: severe; ICI 91% of Ohio Cornbelt biocriteria.

Fairfax (WS #28004-5) - Habitat Quality: poor (QHEI 45); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 91% of Ohio Cornbelt biocriteria.

Gaylord (WS #33070) - Habitat Quality: poor (QHEI 44.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 48% of Ohio Cornbelt biocriteria.

Lake Shaokotan (WS #25147) - Habitat Quality: fair (QHEI 56); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 42% of Ohio Cornbelt biocriteria.

Minnesota (WS #27051) - Habitat Quality: poor (QHEI 49.5); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 33% of Ohio Cornbelt biocriteria.

Nicollett (WS #28066) - Habitat Quality: fair (QHEI 53); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 94% of Ohio Cornbelt biocriteria.

Old Mountain Lake (WS #31047) - Habitat Quality: good (QHEI 65); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 97% of Ohio Cornbelt biocriteria.

Roseland (WS #25022) - Habitat Quality: poor (QHEI 45); Richness, Diversity, Equitability pollution rating: moderate; MBI pollution rating: severe; ICI 94% of Ohio Cornbelt biocriteria.

Winnebago 1 (WS #30024) - Habitat Quality: good (QHEI 69); Richness, Diversity, Equitability pollution rating: slight; MBI pollution rating: severe; ICI 1.06 times Ohio Cornbelt biocriteria.

Winnebago 2 (WS #30023) - Habitat Quality: good (QHEI 66.5); Richness, Diversity, Equitability pollution rating: slight to moderate; MBI pollution rating: severe; ICI 88% of Ohio Cornbelt biocriteria.

Community Foodbases

The ratio of scraper and filtering collector insects was determined for each sampling location. Abundance of scrapers increases as benthic diatoms increase and decreases as filamentous algae and mosses increase. Increase in these two plant groups is the result of organic enrichment. Filamentous algae and moss also provide attachment sites for filtering insects that feed on fine particulate organic material (FPOM).

Filter feeding insects dominated all sampling stations on the mainstem of the Minnesota River. They were from 3 to 100 times more abundant than scrapers. This indicates a good supply of FPOM, which would be expected on the mainstem of the river, as well as substantial organic enrichment.

Filterers also dominated most tributary sampling sites. Scrapers exceeded filters at sites on High Island Creek and the Rush and Redwood Rivers, which indicates an abundance of benthic diatoms at these locations.

In the Blue Earth River watershed filterers dominated all but three stations indicating organic enrichment. Scrapers were more abundant at the Beauford, Blue Earth, and County Road 13 sites suggesting somewhat less enrichment.

Scrapers to filterers ratios at sites on small streams in the Minnesota River watershed sampled in 1992 indicated that there were balanced food bases at most locations. Scrapers were much more abundant at the Fairfax and Roseland sites.

Overall Conditions of Benthic Macroinvertebrate Communities in the Minnesota River Watershed

On the mainstem of the Minnesota River the status of the benthic invertebrate communities was fairly similar. From the most upstream sampling site at Lac Qui Parle to Fort Snelling the river has stream characteristics of a run or glide. Midges and caddisflies were the most abundant insects. On the basis of community measures and pollution tolerance ratings the communities at all sampling sites would be judged as moderately to severely impacted; communities with the lowest ratings were at Henderson and Lac Qui Parle. Not enough data was available to make firm judgements about the stations at Jordan and Fort Snelling.

The Minnesota River tributary sites sampled varied greatly in stream characteristics. High Island Creek has features of a smaller natural stream, whereas the Yellow Medicine and Watonwan are large rivers. Composition of the benthic macroinvertebrate communities on the tributaries was more variable than on the mainstem; mayflies, a more pollution-sensitive group, were more common. Most of the large tributaries would be judged as moderately pollution impacted on the basis of invertebrate community measures and tolerance ratings. The lowest ratings were for the Chippewa River site.

Characteristics of the streams sampled in 1991 and 1992 also varied greatly. The sites at Beauford and on Camp Pope Creek were like small natural streams. Other locations, such as Blue Earth, Frost, County Road 13, St. James, Old Mountain Lake and the two Winnebago sites are modified streams. The sampling sites such as those at Fairfax, Pemberton, Minneota and Roseland were on agricultural ditches. The composition of the benthic communities on these streams naturally varied widely. Mayflies were abundant at many of these sites while much more pollution tolerant forms such as snails and amphipod and isopod crustaceans were abundant at several locations. Based on community measures and pollution tolerance ratings most of these sites would be judged as moderately impacted and some, such as Frost and Minneota, as severely affected. Within this group of small streams those with ICI scores near or above the Ohio Cornbelt biocriteria level of 33 were Beauford and Camp Pope Creek, which are natural streams, and County Road 13, East Branch of Blue Earth River, Nicollett, Old Mountain Lake and Winnebago 1, which are modified streams.

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Table 1. Minnesota River Assessment Project macroinvertebrate sampling locations.

MAINSTEM 1989, 1990

	RIVER MILE
HENDERSON HEN	73
ST. PETER STP	98
JUDSON JUD	127
COURTLAND CTD	140
FORT RIDGELY FTR	178
MORTON MOR	203
DELHI DEL	219
UPPER SIOUX UPS	238
LAC QUI PARLE LQP	282

TRIBUTARIES 1989, 1990

	RIVER MILE
HIGH ISLAND CREEK HIS	61
RUSH RIVER RSH	68
BLUE EARTH RIVER BER	112
LE SUEUR RIVER LSR	113
WATONWAN RIVER WTW	114
COTTONWOOD RIVER COT	144
REDWOOD RIVER RWD	217
HAWK CREEK HWK	237
YELLOW MEDICINE RIVER YMR	244
CHIPPEWA RIVER CHP	275

BLUE EARTH RIVER WATERSHED
1991, 1992

	WATERSHED NO.
BEAUFORD BFD	32073
BLUE EARTH BLE	30030
COUNTY ROAD 13 CR13	30047
FAIRMONT	30056
FROST FRO	30050
LAKE WASHINGTON LWA	28033
MOUNTAIN LAKE MTL	31058
PEMBERTON PEM	32067
ST. JAMES STJ	31015
WELLS WEL	32042

SMALLER WATERSHEDS
1992

	WATERSHED NO.
ARLINGTON ARL	33075
CAMP POPE CREEK CPC	25161
E BRANCH BLUE EARTH RIVER EBE	30049
FAIRFAX FFX	28004-5
GAYLORD GAY	33070
LAKE SHAOKOTAN LSH	25147
MINNEOTA MIN	27051
NICOLLETT NIC	28066
OLD MOUNTAIN LAKE OML	31047
ROSELAND ROS	25022
WINNEBAGO 1 (SOUTH) WIN1	30024
WINNEBAGO 2 (NORTH) WIN2	30023

Table 2. Quality Habitat Assessment Index (QHEI) metric scores and total value for macroinvertebrate monitoring locations on the mainstem of the Minnesota River and tributaries sampled during 1989 and 1990.

LOCATION	RIVER MILE	SUBSTRATE TYPE	INSTREAM COVER	CHANNEL MORPHOLOGY	RIPARIAN ZONE-BANK EROSION	POOL/GLIDE RIFFLE/RUN QUALITY	GRADIENT	DRAINAGE AREA	TOTAL QHEI
MAINSTEM									
HENDERSON	73	5	6	9	11	10	4	15	60
ST. PETER	98	6	8	9	13	9	4	15	64
JUDSON	127	7	6	9	11	9	4	15	61
COURTLAND	140	8	6	8	9.5	9	4	15	59.5
FORT RIDGELY	178	10	6	10	9	11	4	15	65
MORTON	203	10	5	10	7.5	13	4	15	64.5
DELHI	219	9	9	12	6.5	14	4	15	69.5
UPPER SIOUX	238	9	6	10	10.5	12	4	15	66.5
LAC QUI PARLE	282	11	8	11	8	13	4	15	70
TRIBUTARIES									
HIGH ISLAND CREEK	61	7	10	10	10	10	8	13	68
RUSH RIVER	68	9	9	10	13.5	6	8	14	69.5
BLUE EARTH RIVER	112	8	5	10	11	7	4	15	60
LESUEUR RIVER	113	9	7	11	12.5	12	6	15	72.5
WATONWAN RIVER	114	12	8	12	9.5	11	8	15	75.5
COTTONWOOD RIVER	144	11	8	12	10	10	6	15	72
REDWOOD RIVER	217	13	8	12	14	14	6	15	82
HAWK CREEK	237	9	9	12	10.5	11	8	14	73.5
YELLOW MEDICINE RIVER	244	10	9	11	10.5	13	8	15	76.5
CHIPPEWA RIVER	275	7	6	9	7	7	4	15	55