Poplar River Macroinvertebrate and Habitat Survey

In support of the Poplar River TMDL study

prepared for

Cook County Soil and Water Conservation District

by
Valerie Brady and Dan Breneman
Center for Water and the Environment
Natural Resources Research Institute
University of Minnesota Duluth
5013 Miller Trunk Highway
Duluth, MN 55811-1442
218-720-4353

September 2008

NRRI Technical Report Number NRRI/TR-2008/27

Table of Contents

Executive Summary

We surveyed the biota and stream habitat of the lower mainstem of the Poplar River in August 2007 to obtain baseline information on stream assemblages as part of a TMDL (total maximum daily load) study for turbidity. Four sites were selected along the Poplar River within the last 3 km before it enters Lake Superior. Data collected included macroinvertebrate community composition, in-stream habitat structure and stream bottom substrate types, and sediment particle size distribution. Poplar River data generated from each sample site were compared to data from 24 other North Shore stream sites to better place the Poplar River's condition into a regional context.

The Poplar River sampling locations were all among the largest stream sites in our sample database, both in terms of width and in volume of water (discharge). However, the Poplar River is broad but shallow, so the water depths in riffles were quite comparable to many of the other sites. This shallow depth relative to the width gave the Poplar sites a width/depth ratio that made them among the greatest that we have sampled. The center of the stream channel was moderately shaded, and water temperatures were typical of North Shore streams in August. Current velocity was also among the greatest for all sites, leading to a stream substrate (stream bottom type) dominated by large rock (boulder (54 – 84%) and cobble). The higher current velocity, particularly during high water periods, has kept the substrate embeddedness (the amount that rocks were surrounded fine substrates [sand, silt, clay]) quite low. Poplar River sites contained a higher proportion of boulders than most other North Shore sites in our database, while the embeddedness was among the lowest. This indicates that there should be adequate amounts of interstitial space (crevices among the rocks) to provide habitat for stream invertebrates.

Poplar River habitat types were dominated by riffles and runs, with very few bank, pool, or depositional-type habitats. Landuse within 30 m of the stream on both sides at all sites was undeveloped mixed forest and the buffer width was large, greater than 50 m. (Note that this is a description of stream buffer at the sampled sites only). Qualitative habitat evaluation index (QHEI) scores were relatively high, but would have been higher had more fish cover habitat been available. The amount of organic matter in sediments was relatively low, and only one site contained much large woody debris. Because the banks of the stream are wooded, the low large woody debris amounts indicate that most of the wood entering the stream is probably smaller in size and/or gets washed downstream during high flows.

Use of the macroinvertebrate community to assess stream ecosystem condition relies on the varying sensitivities of the different taxa to the many different stressors to which they may be exposed (Rosenberg and Resh 1993). Benthic macroinvertebrates have been used extensively as a biological monitoring tool to assess water quality and habitat conditions (c.f., Rosenberg and Resh 1993) because of their widespread abundance, behavioral adaptations, and tolerance levels. Types of condition indicator metrics that we generated included taxonomic (based on what is known about the sensitivity or tolerance of various taxa), feeding group (how and on what the invertebrates feed), behavior group (how invertebrates function and move in their environment), and tolerance value (a number from 0 to 10 that indicates the tolerance of each invertebrate taxon to anthropogenic stress; 10 is the most tolerant).

A total of 107 unique macroinvertebrate taxa were collected from the lower mainstem of the Poplar River, with up to 79 unique taxa found at any one site. Taxa richness was similar among sites, but invertebrate densities (number per square meter of stream bottom) were lower at sites A and D than at sites B and C. Taxa richness at Poplar sites was lower than expected for the river's size and the level of taxonomic resolution that we applied to samples. Macroinvertebrate densities at sites A and D were also somewhat lower than expected and were more comparable to smaller stream systems in our database.

Macroinvertebrates that are considered among the most sensitive to stress are found in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). We found an average of 17-21 EPT genera in Poplar riffles, which compares relatively well with other North Shore stream sites. This indicates that mayflies, stoneflies, and caddisflies are relatively diverse taxonomically at Poplar sites. However, the proportion of the community comprised of individuals from these three orders (i.e., relative abundance) was lower than we expected. Only 30% or less of the macroinvertebrate community in Poplar River riffles were comprised of mayflies, stoneflies, and caddisflies, placing these sites in the lower 25% of North Shore stream sites. Instead, the invertebrate assemblage of the Poplar lower mainstem was made up largely of Diptera, the true flies, which ranged from 51 to 59% of the community. Only five other North Shore stream sites had such a large relative abundance of Diptera. Most of the Diptera were from the taxonomically-rich family Chironomidae (non-biting midges). While the Diptera family contain taxa covering a wide range of sensitivities, in general the Diptera and the Chironomidae are less sensitive to stress than the EPT taxa.

Functional feeding group categories describe how, and, to some extent, on what the invertebrates feed. Categories include collector-gatherers, which collect fine particles of detritus, collector filterers that filter fine detritus particles out of the water, scraper-grazers that scrape algae and detritus off of rock and plants, shredders that shred up leaves and sometimes wood, and predators that feed on other animals. Because the Diptera family Chironomidae contains such a variety of genera, there are some that feed in each of these ways, causing the Poplar sites to compare much more favorably with other North Shore streams in this analysis. In particular, Poplar sites contained a large proportion of predatory invertebrates and relative few collector-gatherers, the omnivorous scavengers of the stream invertebrate world. Grazer and shredder relative abundances were similar to those found in other North Shore streams, but filter-feeding invertebrates were relatively sparse.

Macroinvertebrate behavioral groups include clingers (invertebrates that cling to and hide beneath rocks), burrowers (which burrow into soft sediments), climbers (which typically climb on aquatic plants and sometimes rocks), swimmers, and sprawlers (which sprawl on top of fine sediments that might otherwise bury them). Poplar sites had fairly high proportions of clingers and among the lowest proportions of burrowers found in North Shore stream riffles. Swimmers were lower, and climbers higher, in relative abundance than was typical of most other North Shore sites.

Tolerance values are numeric values assigned to aquatic biota that indicate their tolerance of stress. We have defined sensitive taxa as those with a tolerance value less than or equal to three. Poplar River sites fall in the lower range of North Shore sites for the proportion of sensitive taxa, being only slightly higher than the Knife River TMDL sites which had much greater embeddedness, in general, than the Poplar River sites. Conversely, Poplar River sites have among the highest proportions of tolerant invertebrates of all North Shore streams in our database. Both of these indicators point to the low proportion and taxonomic composition of the macroinvertebrate community that is comprised of mayflies, stoneflies, and caddisflies, as well as other taxa that are considered delicate or sensitive. Instead, Poplar River sites have macroinvertebrate communities substantially made up of more tolerant and physically ‘hardy’ taxa. Finally, tolerance values were used to calculate an overall ‘tolerance score’ for each site. Non-urban North Shore streams in our database have tolerance scores ranging from 3.2 to 5.9. Poplar River site scores were all in the higher (more tolerant) end of this range, with Poplar Site B having the highest score calculated so far for non-urban streams.

A number of indicators point to the lower mainstem of the Poplar being a physically harsh environment due to flow velocity (particularly during high flows), lack of refugia such as pools and under-bank areas, and the potential for high flow events to carry large sediment loads. These indicators include 1) the relatively high current velocity even during summer low flow, 2) the large average substrate size (boulders, then cobble) and lack of fine substrates and large wood, 3) the relatively low abundance of invertebrates at some sites, and the overall low relative abundance of delicate and sensitive taxa (e.g., mayflies, stoneflies, and caddisflies) even though a variety of these taxa were collected, 4) the predominance of Chironomidae, which are physically hardier and can fill many of the feeding niches of other invertebrates, 5) the relatively high abundance of clingers and low abundance of burrowers and filterers, 6) the low abundance of swimming invertebrates relative to clingers and climbers, and 7) the high overall tolerance values for Poplar sites. The physical harshness of this system would be lessened for stream macroinvertebrates by the implementation of best management practices that slow and lessen the amount of stormwater runoff reaching the stream due to changes in land use within the watershed, reduce bank erosion and other sediment inputs, and stabilize eroding banks. It is important that the wide stream buffers along the mainstem be protected where they exist, and be restored where they have been infringed upon.

A more nuanced analysis of the Poplar River’s condition will require a longer sampling time frame (i.e., routine monitoring every few years) as well as comparison with other large rivers along the North Shore (which we currently do not have in our database). Based on samples from August 2007, our determination is that the Poplar River’s macroinvertebrate community places the stream at the poorer end of the condition spectrum relative to other non-urban North Shore streams that we have sampled over the last 12 years

Introduction

Stream systems are negatively impacted by excessive storm water runoff due to a number of events both natural and anthropogenically derived. Increased flow rates can amplify natural erosion of the stream channel, and storm events result in an introduction of fine particles, a multitude of other organic and inorganic wastes, and can contribute to large shifts in water chemistry parameters. One or all of these inputs can occur at intervals or levels that exceed limits established by Minnesota state water quality standards (MN Rule 7050), resulting in the stream being placed on the "impaired waters" or 303(d) list (http://www.pca.state.mn.us/water/tmdl/index.html). Streams on the impaired list (the 303(d) list) then enter into a process, called Total Maximum Daily Load (or TMDL), to determine viable options by determining causality, understanding system response, and coordinating future mitigation efforts to eventually restore an impaired waterbody.

Turbid water and a reduction in interstitial space availability (i.e., rock crevices) due to sedimentation can negatively impact fish assemblages by reducing foraging success (Sweka and Hartman 2001), altering diet (Stuart-Smith et al. 2004) and ultimately threatening survival (Magee 1996, Suttle et al. 2004). Excessive exposure to suspended particles is abrasive to delicate gill tissue used for aquatic respiration, and stream habitat quality is compromised as fine particles continually fill in refuge for both juvenile fish and invertebrates. Introductions of even inert particles into a stream system can result in direct and indirect impacts on natural processes (c.f., Wiederholm 1984) if conditions deteriorate to a point that stream habitats no longer provide adequate food and shelter for biota. Primary and secondary production in streams has proven to be an important indicator of system health. Benthic macroinvertebrates have been used extensively as a biological monitoring tool to assess water quality and habitat conditions (c.f., Rosenberg and Resh 1993) because their widespread abundance, behavioral adaptations, and tolerance levels make methods for incorporating them into a monitoring program adaptable and easily standardized.

A biological survey was conducted on the Poplar River in 2007 to obtain baseline information on stream assemblages as part of a TMDL (total maximum daily load) study for turbidity (http://www.pca.state.mn.us/water/tmdl/index.html). Field observations and data generated in the laboratory were used to characterize, among other parameters, primary production, invertebrate community composition, habitat structure, and sediment particle size distribution. Four sites were selected along the Poplar River within the last 3 km before it enters Lake Superior. Poplar River data generated from each sample site for this study were compared to data from other North Shore streams to better place the Poplar River's condition into a regional context. These comparisons were made to further understand the similarities among the streams and to isolate parameters potentially useful for future management decisions. Due to differences in sampling methodology between this survey and historic efforts, macroinvertebrate and habitat metrics were compared cautiously and only when similar protocols were verified.

Methods

Study Sites

Poplar River TMDL study sites were selected in order to distribute sample collection points longitudinally along the lower stream reach. Four sites were chosen to take advantage of established SWCD and Minnesota Pollution Control Agency (MPCA) long-term gauging stations, or were placed in proximity to tributaries in order to dissect the watershed into sub-basin units (Figure 1). Final site locations were approved in the Quality Assurance Project Plan (QAPP, NRRI/TR-2007/16) and sampled in late August 2007.

Historic datasets used for comparison include macroinvertebrate abundances, substrate composition, and habitat data collected by Valerie Brady and colleagues for a US EPA study during August 1997 and 1998 (Detenbeck et al. 2000). Urban streams were excluded from comparisons, leaving the Brady-EPA dataset with 19 North Shore stream sites (including two in the Poplar River watershed). A more recent dataset also included for comparison contains 5 sites from the Knife River watershed that were sampled in August 2006 for the Knife River TMDL (Figure 2).

Habitat Characteristics

Habitat data for the Poplar River TMDL sites were collected both from transects established across the channel perpendicular to flow and from whole-reach observations. Transect point selection followed standard protocols (NRRI/TR-1999/37) and were separated by a distance based on mean stream width (typically 35 x mean wetted width). When habitat features along a reach were homogenous, transects were placed at 10 m intervals (110 m minimum reach length). Evaluation of substrate characteristics, stream features, bank conditions, and available habitats occurred between each point. A schematic stream reach diagram noting habitat characteristics, cross-section measurements, unique structures, and sample locations was created.

Transect points - Seven points evenly spaced along each transect (first and last points were used to quantify size categories and proportion of each substrate (% coverage) within a grid. Points one and seven along the transect were on the bank and represent bank conditions, while points 2 through 5 were in the wetted stream channel and describe the in-stream habitat. Point estimates were used to evaluate stream features, discharge rates, substrate type, proportion of dominant to sub-dominant particles, substrate embeddedness by fine particles, in-stream habitat cover, bank and riparian condition, landuse, stream shading, and riparian corridor extent.

Substrate - Within each grid (25 cm^2), the extent (in percent surface area covered) and types of substrate particles were estimated for all particle size class categories. Classification schemes adhered to standardized particle size categories (e.g., Brusven and Prather 1974, Friedman and Sanders 1978, Gee and Bauder 1986). The extent large substrate particles (boulder, cobble, and pebble) were embedded by fine particles (sand, silt, and clay) was also estimated (as percent)

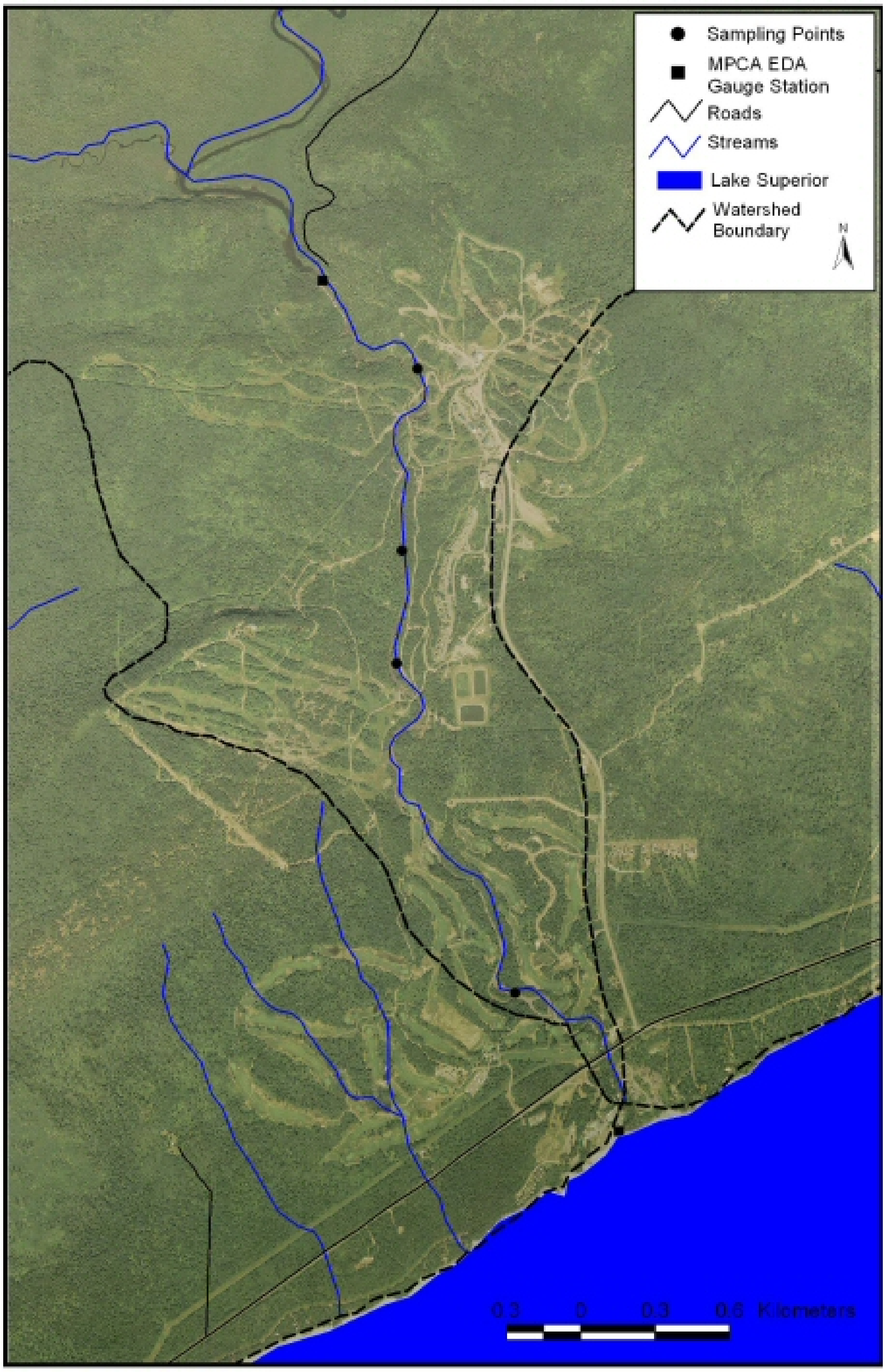

Figure 1 Macroinvertebrate and habitat sampling locations along the lower mainstem of the Poplar River.

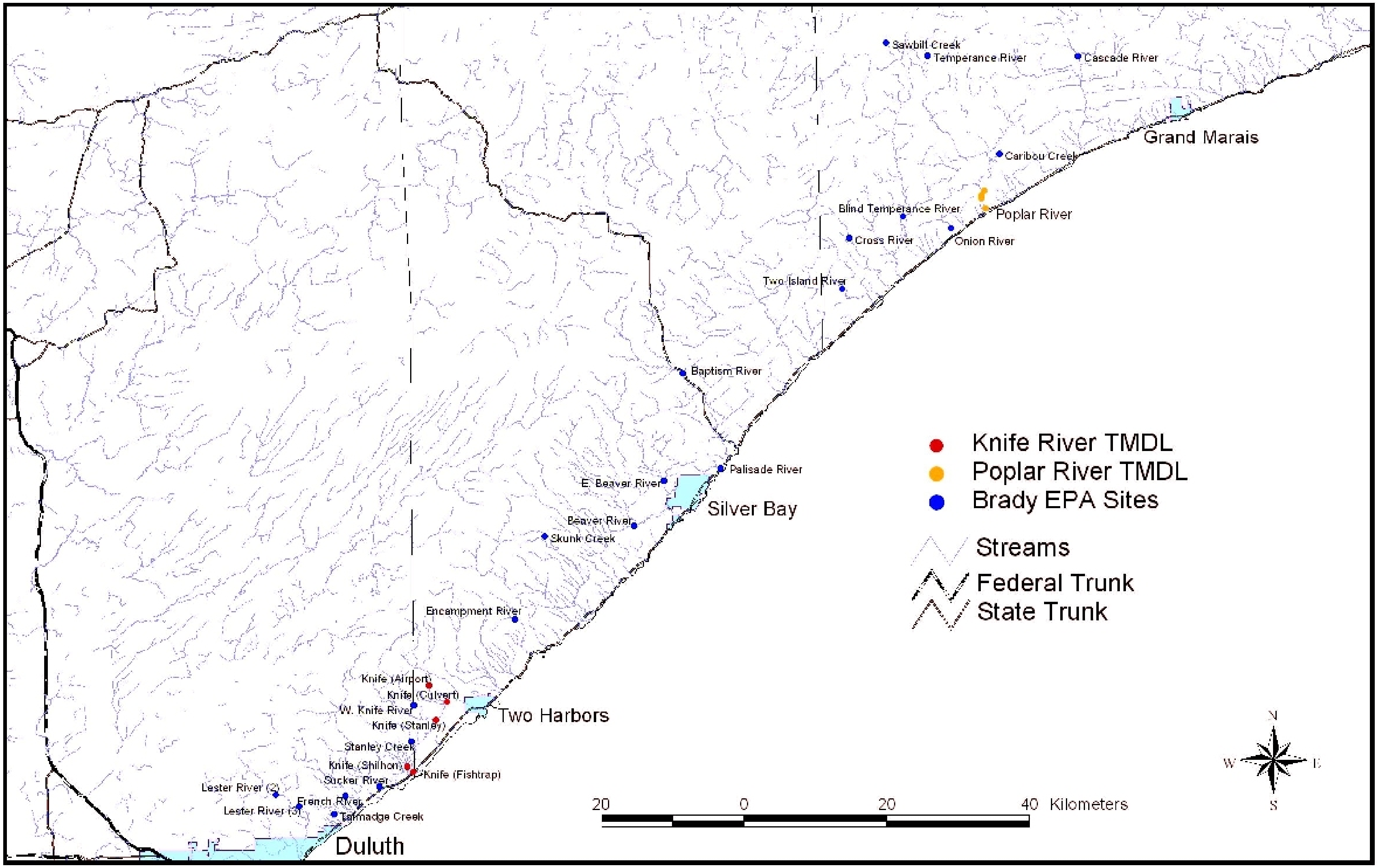

Figure 2. Location of all North Shore stream sites included in this report. The Knife River TMDL and Brady-EPA site data are used as a comparison for the data from the Poplar River TMDL macroinvertebrate and habitat data.

at one point within each grid. An additional sediment depth measurement along each transect was recorded to determine the maximum depth of fine particle deposition using a sediment rod. This point was not random; rather, a subjective choice was made based on the amount of fine particle accumulation. This measurement was repeated to obtain a maximum reading per transect. Finally, fine sediments were collected using a 7.62 cm diameter core from 3 locations along the stream reach and returned to the laboratory for particle size analysis.

Flow - Stream discharge was estimated from flow recordings at 5 points on each transect. Water depth was recorded at each transect point and flow rates were recorded from a point equivalent to 60% of the total water depth. Instructions for flow-weighted averaging (FWA) are provided in the Marsch-McBirney Flow-mate operators' manual.

In-stream cover - When transect lines intersected in-stream habitat cover, the type, size, and stability were described. Schematic diagrams of the size, shape, and dimensions of habitat cover such as large boulders, islands, etc., were also recorded. Large woody debris (greater than 1 m in length and 10 cm dia.), debris dams, roots wads, etc., that intersected each transect were recorded in detail, noting length or surface area, stability, and position along each transect. Total amount of woody debris per reach was also estimated by counting the number of intact units (≥ 100 cm in length by 10 cm dia.). A reach survey QHEI (Ohio EPA 1987) to rank overall stream condition was also completed for each site following the sampling event. QHEI categories include substrate, cover, channel type, riparian zone, width/depth ratio, and riffle/run quality; the gradient metric was not calculated or included in the final score.

Bank structure - Bank or shoreline structure and condition (stable or unstable) were evaluated on all transects by noting bank substrate type and the presence or absence of undercut banks. Bank-full width was recorded, as well as high water marks or indicators of flood extent.

Riparian corridor – Densiometer readings at a mid-stream point on each transect were used to estimate stream shading potential. Riparian width was estimated and vegetation type (ranked categories) noted. Adjacent riparian and landuse characteristics from 10-30 m and beyond were categorized.

Water Quality Parameters

Water chemistry parameters at each location were recorded with a YSI 556 multi-probe meter to establish baseline information on water temperature, dissolved oxygen, conductivity, pH, and oxidation-reduction potential (ORP) during the sampling effort. Water clarity observations were completed in triplicate using a transparency tube. Turbidity and total suspended solids were not sampled as part of this study.

Macroinvertebrate Sampling

Benthic samples were collected using a multi-habitat sampling approach (Lenat 1988) during baseflow conditions. Quantitative samples were collected in triplicate from riffle and run habitats using a modified Hess (0.086 m^2) in riffles (Appendix 1). All quantitative samples were washed on-site through a 254-µm mesh net or sieve. Where habitat was available, qualitative samples were collected from beneath bank or over-hanging vegetation, woody debris dams, boulder piles or rip-rap, or from sediments and aquatic vegetation in run and pool habitats using a D-frame kick net (mesh size: 500 µm; Appendix 2). The D-net effort was timed and measured (approx. 30 seconds per sample and a 10 m distance). Extensive herbaceous bank vegetation and instream aquatic vegetation were swept when present, while wood dams and boulder piles were jabbed (sensu Barbour et al. 1999) to dislodge invertebrates. All invertebrates from each sample type were preserved in the field using either Kahle's preservative, 10% Formalin, or 70% ethyl alcohol.

Sample Processing

Benthic macroinvertebrates - Samples were processed by washing materials through two sieve sizes (4 and 0.25 mm) to separate contents into large and small size fractions. The large size fraction (>4 mm) was completely picked ('whole picked') for invertebrates. The amount of 4-0.25 mm fraction processed was determined individually by the picking time and the volume of material. All samples were either quarter, half, or whole picked. Invertebrates were removed from organic and inorganic sample materials under a dissecting microscope or a 2x magnification lens. Each completed sample was subject to quality assurance/quality control (QA/QC) inspection (100% inspection). Rejected samples were re-processed until QA/QC guidelines were passed. A subsample of the Chironomidae (Diptera) consisting of 30-100 individuals per sample was permanently mounted on slides for identification to genus. Other macroinvertebrates were identified to the lowest practical taxonomic level using appropriate keys (Hilsenhoff 1981, Wiederholm 1983, Brinkhurst 1986, Thorp and Covich 1991, Merritt and Cummins 1996). A reference collection was also established from invertebrates at all sites, and specimens were subject to a rigorous QA/QC inspection (further details available from NRRI/TR 99/37).

Sediment processing - Approximately 300 cm3 of sediment from each depositional area was composited for each site (typically collected from 4 to 6 transects per site). Composite samples (approximately 1200-2000 cm3 per site) were labeled and stored on ice and/or frozen prior to analysis. In the lab, thawed sediment samples were transferred to a basin and homogenized for 1 minute. A small amount of water was added to each sample to facilitate thorough mixing. Homogenized sediment in the mixing container was tamped to settle material uniformly. Sediment was sub-sampled in triplicate by extracting 250 cm3 using a 5 cm (dia.) sediment core. Sub-samples were placed in labeled pans and dried (105o C) to a constant weight determined with a standard balance. Dried samples were ignited for 1 h at 500o C. After samples cooled, reagent-grade water was added to re-wet ash and compensate for water weight not driven off from clay particles during the drying period (APHA 1992). Samples were dried to a constant weight at 105^o C and re-weighed to determine the ash-free dry weight of each sub-sample.

Substrate particle size analysis - Dried sub-samples were run through a set of six sieves (4, 2, 0.5, 0.25, and 0.0625 mm) for 1 minute using a row-tapper to obtain six particle size fractions: 1)

> 4 mm, 2) 4-2 mm, 3) 2-0.5 mm, 4) 0.5-0.25 mm, 5) 0.25-0.0625 mm, and 6) < 0.0625 mm. Sediment retained in each size fraction was weighed using a standard balance.

Data Analyses

Comparison among Poplar TMDL sites - Trait characteristics for each invertebrate taxon were derived from an NRRI-maintained database compiled from a variety of sources (Merritt and Cummins 1996, Thorp and Covich 1991, Weiderholm 1983). These traits consist of functional feeding group classifications, trophic levels, methods of locomotion, preferred habitats, and other characteristics which help define aquatic invertebrate interactions within their environment. Invertebrate community metrics were generated based on known taxonomic sensitivities to environmental degradation (e.g., Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa) and on traits that may make select groups more or less sensitive (e.g., scraper-grazer feeders, burrowers, etc). Invertebrate metrics were compared among Poplar TMDL sites using a one-way ANOVA. Substrate, habitat, and water chemical/physical parameters were compared among sites in a similar fashion. Each invertebrate taxon was also assigned a tolerance value (0 to 10) indicating the taxon's overall level of tolerance of stressors. A value of 0 represents the least tolerant. Tolerance values came primarily from Hilsenhoff (1987), and were supplemented by values from EPA (Barbour et al. 1999). Sensitive taxa were defined as taxa with a tolerance value of 3 or less, and tolerant taxa were those with a tolerance value of 7 or higher. Tolerance scores for entire sites were calculated by multiplying the tolerance value of each taxon by the abundance of that taxon per sample, summing the resulting products, and dividing by the total number of invertebrates per sample. This was done for quantitative riffle samples only because the most sensitive insects typically reside in riffles and quantitative samples help ensure comparability. Riffle sample scores were then averaged to generate site tolerance scores.

All data collected for this study will be provided as electronic files to the Cook County Soil and Water Conservation District and to the Minnesota Pollution Control Agency.

Comparison with historic data - Invertebrates in the historic comparison datasets were collected in a manner similar to the current data (quantitative samples in riffles using similar mesh sizes). However, the Chironomidae in the Brady-EPA dataset were primarily identified to tribe, rather than genus, with the exception of a few highly recognizable genera. Thus, this dataset appears to have fewer taxa in comparison to datasets such as the Knife and Poplar TMDLs in which all Chironomidae were identified to genus.

Substrate composition data were collected differently between the Knife TMDL and the other studies, including the Poplar TMDL. In the Knife study, only dominant and subdominant substrate types were noted in each grid, whereas in the other studies, all substrate types within each grid were assigned a percent cover to sum to 100%. The resulting data bias makes the Knife sites appear to have higher amounts of dominant substrates and lower amounts of less dominant substrates (typically gravels, sands, silts, and clays) than actually occurred. This methodological difference precludes direct substrate composition comparisons among studies. However, percent embeddedness and depth of fine sediments were collected using similar methods during the all studies. Water quality data were collected similarly for the Poplar and Knife TMDL studies, but quite differently for the Brady-EPA study. Because of this, the water quality information from the Brady-EPA study is not included or used for comparison.

In summary, data comparisons across studies are fraught with difficulties, most stemming from sample collection and processing differences for which there are no easy corrections, or for which no corrections exist at all. Thus, assessments and decisions using such comparisons should be made with caution. In undertaking these analyses, we have attempted to correct for biases whenever possible, and to make clear when we feel that bias may still exist. Studies for which we have not yet been able to correct for these differences have not been included in the comparison even though we have these data.

Results and Discussion

Habitat Conditions

Poplar River sampling sites were located within an area close in proximity to Lake Superior, where the watershed becomes constricted and a substantial change in topography occurs. Stream conditions above the escarpment are predominantly slower flows, meandering through spruce bogs, with substrate dominated by soft organic sediments. Site D1 is located just downstream of an MPCA gauging station at the top of an escarpment above Lake Superior, with sites C then B moving upstream to downstream into the stretch of stream flowing through the recreational land use areas, and ending with site A just above another substantial drop in elevation about 0.5 km from the river's mouth (Figure 1, Table 1). Study sites included at least 100 m of stream reach, and efforts were made to be upstream of man-made stream crossing structures.

Table 1. Poplar River TMDL sampling site locations and macroinvertebrate sampling effort.

			UTM Coordinates			Gear Type (n)	
Site	Date	Reach (m)	X	Y	Habitat	D-Net	Hess
Poplar A	29-Aug	160	671845	5278925	Run		6
					Bank	3	
Poplar B	30-Aug	200	671272	5280299	Riffle		3
					Run		3
					Bank	3	
Poplar C	30-Aug	200	671328	5280740	Riffle		3
					Run		3
					Bank	3	
Poplar D	30-Aug	200	671682	5281409	Run		3
					Pool		3
					Bank	3	
Total						12	24

Stream habitat types were dominated by riffles and runs that contained large amounts of fairly large rock (Tables 1 and 2). There were very few bank, pool, or depositional-type habitats, making the stream at these sites relatively uniform. Boulders were the dominant substrate at all sites, ranging from 54% of the substrate at the most downstream site (A) to 83% of the substrate at the most upstream site (D). Landuse within 30 m of the stream on both sides at all sites was undeveloped mixed forest and the buffer width was large, greater than 50 m. Although other areas of the lower mainstem have altered vegetation within the buffer, this was not the case at our study sites. Stream buffer quality has been shown to be important to aquatic biota because the vegetation provides a food source (typically leaves in the fall); shading to cool the water; trapping, reduction, or removal of sediment and pollutants that might wash into the stream; and stabilization of the stream banks, among other benefits (Johnson et al. 2003).

QHEI (e.g., fish habitat) scores were relatively high, but would have been higher had more fish cover habitat been available. The amount of organic matter in sediments was relatively low, and only one site contained much large woody debris. Because the banks of the stream are wooded, the low large woody debris amounts indicate that most of the wood entering the stream is probably smaller size and gets washed downstream during high water events (e.g., "floods"). Even where a supply of potential large woody debris is present along the banks, stream power may be great enough to prevent buildup of large woody debris in the stream channel. In northern Wisconsin, Fitzpatrick and Knox (2000) found that stream power is greater now than it was prior to logging, giving streams extra power to move wood downstream. Stable wood material provides good habitat and cover for both stream fish and macroinvertebrates (Wallace et al. 1993, 1995; Johnson et al. 2003).

Table 2. Poplar River habitat characteristics measured at the TMDL sampling locations. Bank substrate and substrate percent are the percent of the dominant substrate as total bank surface area along transects. Adjacent landuse describes the dominant anthropogenic activity, and riparian zone refers to the riparian zone cover type. Undercut bank is the percent occurrence of undercut banks along sample transects. Amount of organic matter in sediments is expressed as grams dry weight after ashing (organic). Large woody debris (large woody debris) are expressed as meter length counts per reach of logs greater than 10 cm dia.

Site	Bank Substrate	Substrate (%)	Adj landuse	Rip'n zone	Rip'n width (m)	QHEI score*	Under bank (%)	Organic (g)	LWD (#)
Poplar A	Boulder	53.8	Undevel	Mixed Forest	>50m	62	20	2.0	170
Poplar B	Boulder	64.0	Undevel	Mixed Forest	>50m	67	10	3.4	0
Poplar C	Boulder	67.8	Undevel	Mixed Forest	>50m	71	20	2.6	9
Poplar D	Boulder	82.9	Undevel	Mixed Forest	>50m	66	5	2.0	32

* QHEI score was calculated without including the gradient component, worth 10 pts.

When comparing stream samples, it is important to take into consideration the basic physical differences and similarities among the sampling locations. Among the most important are stream size, current velocity, substrate type, and amount of shading. The Poplar River sampling locations were all among the largest sites in our sample database, with only the Knife, Cascade, and Baptism rivers of a similar channel width (Table 3). However, because the Poplar River is broad but shallow, water depths in riffles were quite comparable to many of the other sites. This shallow depth relative to the width gave the Poplar sites a width:depth ratio that located them within the group of largest sites in the database (Figure 3). Because of the topography, neither width nor width:depth ratio varies regularly from upstream to downstream along the lower Poplar mainstem. The center of the stream channel was moderately shaded at all Poplar sites, and water temperatures were typical of North Shore streams in August.

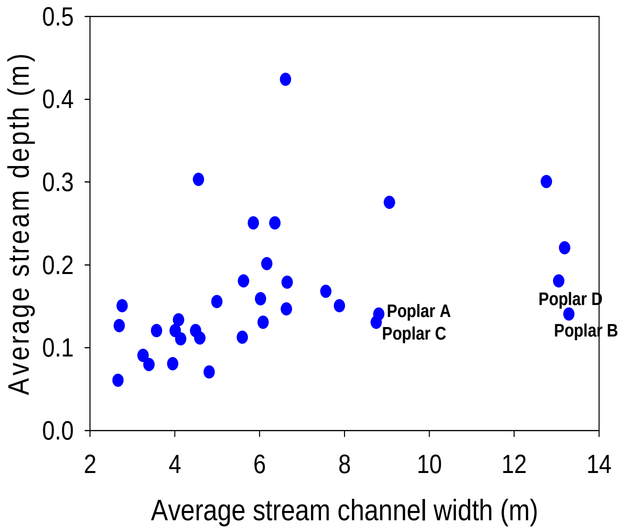

Figure 3. Relationship of stream channel width to depth for 28 North Shore stream sites. Sites on the Poplar River are labeled.

Current velocity (flow) was also among the greatest for all sites (Table 3, Figure 4). This has implications for the ability of the stream to flush out fine sediments and for the biota (fish, macroinvertebrates) to be able to hold their position during high water events to avoid being swept downstream. Figure 4 shows that the amount that large substrates were embedded in fine substrates was quite low at Poplar sites. This indicates that there should be quite a bit of interstitial space among the rocks to provide habitat for stream macroinvertebrates, small fish, fish fry, and fish eggs for those fish that spawn amongst larger rocks. Like width and depth, current and embeddedness do not show an upstream-downstream pattern along this stretch of the river.

Table 3. Physical characteristics of North Shore streams presented as means. Stream site code includes stream name, site name (if any), project abbreviation (see Methods), and year sampled (all sampling was done in August). Sites from the current study (Poplar TMDL) in blue. Depth and velocity (flow) were measured in riffles. 'Shade' represents mean percentage that the center of the stream channel was shaded.

Stream-site	Wet Width (m)	Bankfull width (m)	Depth (m)	Flow (m/s)	Temp [C]	Shade (%)
Knife-Culvert-TMDL2006	2.67	3.62	0.06	0.14	18.95	66.56
Stanley-EPA1997	2.77		0.15	0.004	19.94	16.15
West Knife-EPA1997	3.26		0.09	0.062	18.29	48.85
Blind Temperance-EPA1997	3.58		0.12	0.037	16.29	36.25
Talmadge-EPA1997	3.96		0.08	0.001	19.07	16.92
Onion-EPA1997	4.02		0.12	0.016	18.36	7.69
Palisade-EPA1997	4.15		0.11	0.028	18.28	15.00
Skunk-EPA1997	4.5		0.12	0.068	18.24	49.23
Two Island-EPA1998	4.57		0.30	0.02	17.93	28
Encampment-EPA1997	4.82		0.07	0.0161	18.82	13.85
Lester2-EPA1997	5.63		0.18	0.062	20.00	23.08
East Beaver-EPA1997	5.86		0.25	0.014	20.15	26.15
French-EPA1997	6.03		0.16	0.06	19.72	5
Knife-Airport-TMDL2006	6.09	7.58	0.13	0.29	20.47	75.71
Lester3-EPA1998	6.18		0.20	0.03	20.11	22
Caribou-EPA1997	6.37		0.25	0.099	21.81	45.00
Beaver-EPA1998	6.62		0.42	0.03	21.94	3
Temperence-EPA1998	6.64		0.15	0.09	21.57	11
Sucker-EPA1998	6.66		0.18	0.13	21.15	6
Baptism-EPA1998	7.57		0.17	0.10	20.21	3
Knife-Stanley-TMDL2006	7.89	8.33	0.15	0.2	20.99	42.43
Poplar C-TMDL2007	8.76	14.43	0.135	0.281	20.61	44.90
Poplar A-TMDL2007	8.82	12.78	0.144	0.225	21.46	22.2
Cascade-EPA1998	9.07		0.27	0.03	21.20	4
Knife-Shilhon-TMDL2006	12.77	22.86	0.3	0.26	20.53	10.82
Poplar D-TMDL2007	13.06	18.84	0.175	0.227	19.74	32.20
Knife-Fishtrap-TMDL2006	13.2	19.02	0.22	0.55	20.95	7.07
Poplar B-TMDL2007	13.30	18.30	0.142	0.227	16.16	37.8

Not only are Poplar River sites relatively free of embedding sediments, they contain very low amounts of sand, silt, and clay within the stream bottom (Table 4). The average amount of fine sediments along transects was less than 3% of the substrate composition for all 4 sites, and less than 1% for sites A and C. Instead, the stream substrate was primarily comprised of boulder, with cobbles making up most of the rest of the substrate. Even the amount of pebble (gravel) was quite low at sites. Cobble substrates are considered good stream bottom habitat for most of the more sensitive stream macroinvertebrate taxa, and these data and our personal observations indicate that habitat in the form of interstitial space is not a limiting resource in the lower mainstem of the Poplar River.

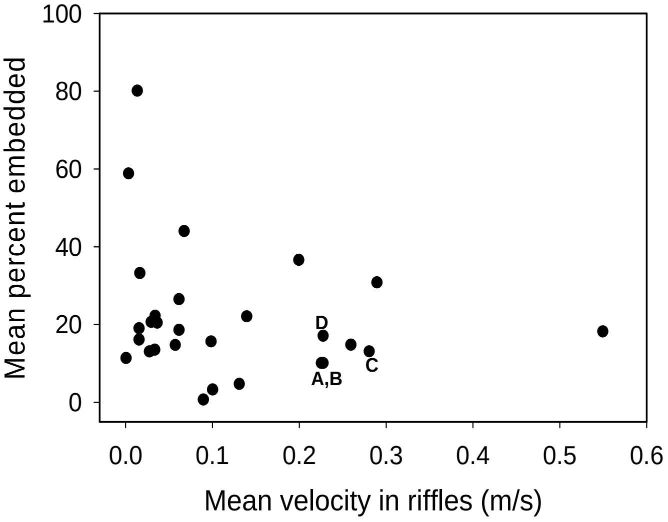

Figure 4. Relationship of current velocity in riffles to amount that large substrates are surrounded by fine substrates (e.g., sand, silt, and clay). Sites on the Poplar River are labeled.

In comparison with other North Shore sites, Poplar River sites contain a higher percentage of boulder than any yet sampled, with only Caribou Creek at its headwaters coming in a close second (Figure 5). As expected with the high amounts of boulder and cobble, the amount of fine sediments is among the lowest of the sampled sites, although the amount of embeddedness is perhaps a bit higher than one would expect given the low amount of total fines in the substrate. Taken together, these data indicate good habitat for stream macroinvertebrates.

Water chemistry parameters were reasonably similar among Poplar River sites, with site B having somewhat lower water temperature and site D having higher conductivity (Table 5). Site D’s conductivity was also higher than that seen at Knife River sites. Dissolved oxygen levels were reasonably high, and water clarity was very good, much higher than water clarity for most Knife River sites.

Table 4. Substrate characteristics of North Shore streams. Sites from the current study shown in blue. Substrates were characterized as bedrock (bed), boulder (bldr), cobble (cbl), pebble (pbl), sand, and silt and clay (st/cl) and are expressed as percents. Total fines (Tfines) are the sum of percents of sand, silt, and clay. Depth of fines is the depth of fine sediments in slow current areas. Embeddedness is the amount that large substrates (primarily cobbles and pebbles) are surrounded by fine substrates.

Stream-site	Bed (%)	Bldr (%)	Cbl (%)	Pbl (%)	Sand (%)	St/cl (%)	Tfines (%)	Depth Fines (m)	Embed (%)
Caribou-EPA1997	0.0	52.9	38.2	8.8	0.0	0.0	0.0	0.02	15.55
Knife-Fishtrap-TMDL2006	0.0	31.16	66.57	2.27	0.0	0.0	0.0	0.03	18.13
Sucker-EPA1998	0.0	23.0	50.2	26.4	0.4	0.0	0.5	0.00	4.61
Poplar A-TMDL2007	0.0	59.1	34.0	4.0	0.67	0	0.67	0.02	10.0
Lester2-EPA1997	0.0	3.8	49.5	45.7	0.9	0.0	0.9	0.02	26.4
Poplar C-TMDL2007	0.0	55.1	40.1	2.4	0.93	0	0.93	0.03	13.0
Baptism-EPA1998	0.0	24.8	50.2	24.1	1.0	0.0	1.0	0.00	3.17
Temperence-EPA1998	26.5	17.3	42.5	12.8	0.8	0.2	1.0	0.00	0.61
Poplar D-TMDL2007	0.0	77.8	18.5	2.3	1.33	0	1.33	0.02	17.0
Poplar B-TMDL2007	0.0	69.6	24.4	3.9	2.1	0	2.1	0.03	10.0
Skunk-EPA1997	0.0	13.6	47.7	36.4	2.3	0.0	2.3	0.1	43.93
Knife-Shilhon-TMDL2006	0.0	28.93	58.24	10.53	2.29	0.0	2.29	0.07	14.70
Lester3-EPA1998	0.0	0.0	72.5	25.0	2.2	0.3	2.5	0.02	22.14
Onion-EPA1997	0.0	26.0	48.7	22.7	2.4	0.1	2.5	0.03	18.92
Encampment-EPA1997	0.0	29.5	45.7	21.5	3.2	0.1	3.4	0.03	16.03
Palisade-EPA1997	43.9	7.3	21.9	21.9	4.9	0.1	5.0	0.01	12.96
Talmadge-EPA1997	12.8	15.4	41.1	25.7	4.8	0.2	5.0	0.26	11.28
French-EPA1997	0.0	0.0	58.8	35.4	5.5	0.3	5.8	0.01	14.64
Knife-Airport-TMDL2006	0.0	3.28	52.46	37.27	0.0	6.98	6.98	0.04	30.71
West Knife-EPA1997	0.0	4.7	46.5	41.9	6.8	0.2	7.0	0.02	18.51
Cascade-EPA1998	0.0	12.7	32.7	46.9	6.9	0.8	7.7	0.00	13.41
Stanley-EPA1997	0.0	0.0	45.4	45.4	9.0	0.3	9.3	0.1	58.75
Blind Temperance-EPA1997	0.0	38.3	30.6	17.9	13.1	0.2	13.3	0.04	20.37
Beaver-EPA1998	0.0	0.0	3.3	83.3	12.0	1.3	13.3	0.03	20.54
Knife-Stanley-TMDL2006	0.0	1.58	24.02	60.46	6.02	7.92	13.94	0.09	36.50
Two Island-EPA1998	0.0	0.0	37.8	42.8	15.8	1.4	17.2	0.02	33.13
Knife-Culvert-TMDL2006	0.0	0.0	16.48	64.79	4.87	13.86	18.73	0.06	22.00
East Beaver-EPA1997	0.0	0.0	0.0	50.0	48.1	1.9	50.0	0.17	80

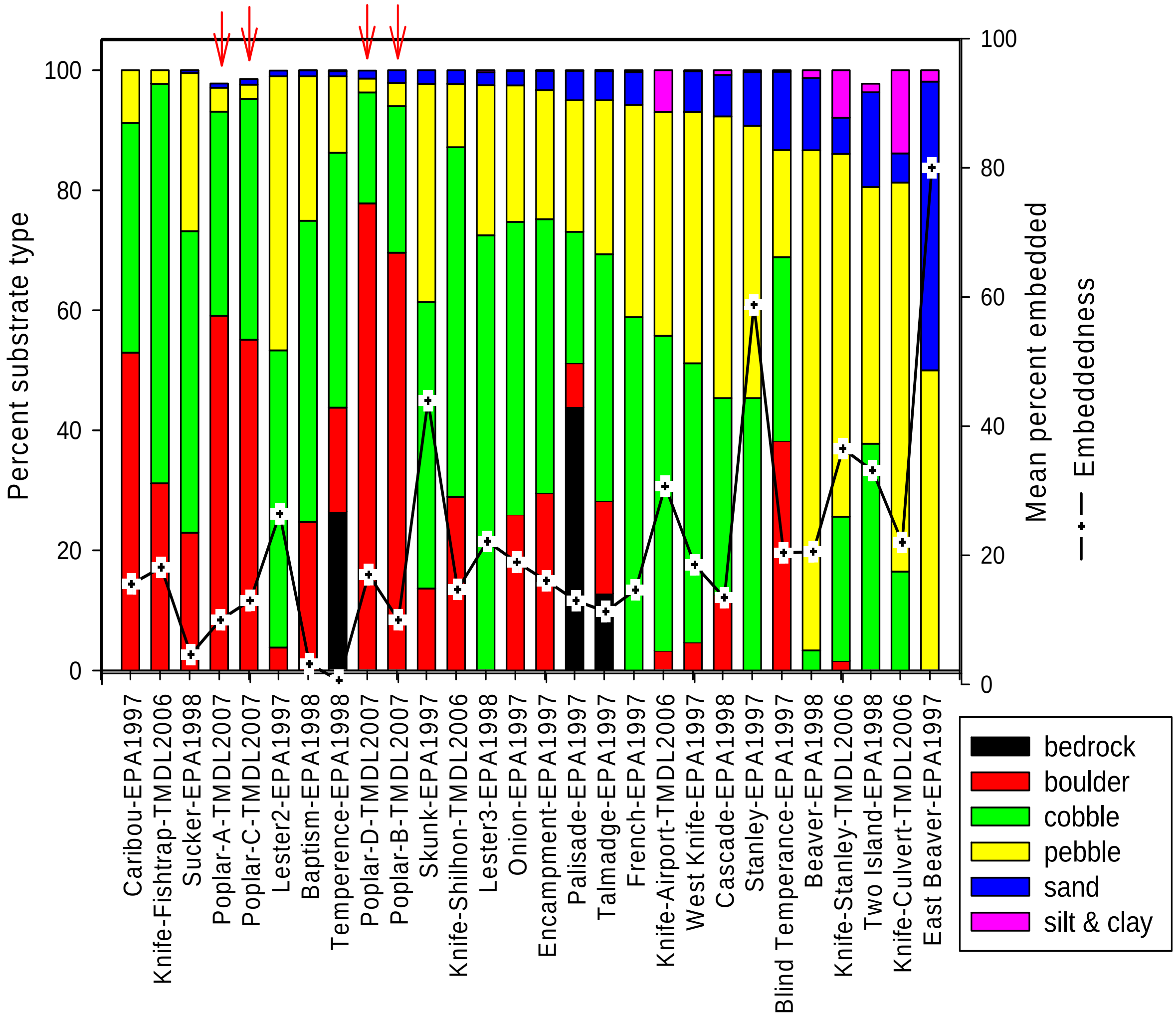

Figure 5. Average percent substrate types in riffles for North Shore streams, with average percent riffle embeddedness shown as + symbols connected by a black line. Sites from the current study are marked by arrows.

Table 5. Poplar and Knife River TMDL site water chemistry measurements collected only the day of macroinvertebrate sampling. These are single point-in-time samples during stream baseflow conditions.

Site	Temp (C)	Scond (us/s)	DO (%)	DO (mg/L)	pH	Clarity (cm)
Poplar A TMDL 2007	21.46	74	96	8.49	6.72	>120
Poplar B TMDL 2007	16.16	93	86.5	8.59	7.7	>120
Poplar C TMDL 2007	20.61	99	89.4	8.04	8.05	>120
Poplar D TMDL 2007	19.74	212	88	8.1	7.01	>120
Knife-AirportTMDL2006	20.47	136	105.4	9.49	7.63	>120
Knife-CulvertTMDL2006	18.95	138	81.8	7.56	6.46	52.1
Knife-StanleyTMDL2006	20.99	124	106.3	9.45	7.26	91.0
Knife-ShilhonTMDL2006	20.53	110	78.3	6.62	6.12	74.3
Knife-FishtrapTMDL2006	20.95	104	104	9.33	7.19	68.1

Macroinvertebrates

Use of the macroinvertebrate community to assess stream ecosystem condition relies on the varying sensitivities of the different taxa to the many different stressors to which they may be exposed (Rosenberg and Resh 1993). In the following comparisons, we have taken advantage of the full taxonomic resolution available in the TMDL and historic datasets. Thus, comparisons with other datasets that do not have the Diptera family Chironomidae identified to genus, or that contain little information about the non-insect invertebrates, should be done with considerable caution. The Chironomidae contain genera that are part of nearly every feeding group and behavioral type (Merritt and Cummins 1996), making them a rich source of information about stream conditions.

We evaluated the macroinvertebrates from Poplar River samples in several different ways to assess what they can tell us about the lower mainstem's condition. These included enumerating the number and types of invertebrate taxa present, the percent composition of the entire community, and evaluating the sensitivity of these taxa to various types of stress based on published data. A second set of evaluations included invertebrate feeding and behavioral traits. Finally, we used published numerical sensitivity values to quantify human-caused stress on invertebrate taxa. Most of the 'indicator metrics' generated from these analyses are commonly used in the evaluation of wadeable stream condition (c.f. Gerritsen 1995, Richards et. al. 1997, Breneman et. al. 2000).

A total of 107 unique macroinvertebrate taxa were collected from the lower mainstem of the Poplar River, with up to 79 unique taxa found at any one site (Table 6). Total numbers of taxa and taxa richness in samples was comparable among Poplar sites. Mean total abundance of macroinvertebrates per square meter of stream bottom (macroinvertebrate density) was lower at sites A and D than at sites B and C. The higher densities are within the range of those found by Brady in the EPA samples (Brady unpublished data), while the lower densities at sites A and D are more typical of smaller North Shore streams.

Table 6. Poplar River TMDL invertebrate summary. Taxa richness values are based on samples from all available habitats per site. Abundance values include only individuals collected with Hess samplers. Means without letters in common are significantly different ($p < 0.05$).

Site	Total taxa	Mean taxa/sample (± 1 se)	Total #/m^2 (± 1 se)
Poplar A-TMDL2007	75	34.7 (3.32)	9,868 (514)^{b,c}
Poplar B-TMDL2007	79	34.8 (3.73)	16,659 (1,430)^{a}
Poplar C-TMDL2007	70	36.2 (3.84)	13,843 (2,997)^{a,b}
Poplar D-TMDL2007	76	34.3 (3.77)	7,802 (1,628)^{c}

Macroinvertebrates that are particularly sensitive to stress often inhabit riffle habitats of streams because these areas typically contain substantial amounts of interstitial space, high dissolved oxygen levels, and good water flow which carries food particles to the invertebrates. Thus the following comparisons will focus primarily on macroinvertebrates collected quantitatively (i.e., using the Hess sampler) from riffle or run habitats.

Taxa richness is often considered a good indicator of stream condition (Table 7). Poplar and Knife TMDL sites should have higher overall taxa richness than the sites in the Brady-EPA study because the taxonomically-rich Diptera family, the Chironomidae, were not identified to genus in the Brady-EPA samples (with the exception of a few easily-recognized genera). Rather than making the TMDL sites appear especially taxonomically rich, however, the better taxonomic resolution simply puts these samples in the higher end of the spectrum among the Brady-EPA sites. This may indicate lower overall taxa richness, but this cannot be confirmed because taxonomic resolution could not be standardized between datasets.

Table 7. Macroinvertebrate trait variables from four sample locations on the Poplar River, MN. Values are represented as mean percent (%) of total macroinvertebrate abundances collected in the Hess sampling gear ±1 standard error. Sites were compared with a one-way ANOVA. Values with the same letter are not significantly different at the $p \leq 0.05$ level based on Duncan's procedure; rows with no letters indicate that no sites were significantly different from each other.

Invertebrate metrics	Poplar A	Poplar B	Poplar C	Poplar D
Percent EPT individuals	28.6±4.56	20.6±5.46	21.3±5.15	30.0±5.15
Percent Odonata	0.0±0.04^{b}	0.0±0.01^{b}	0.1±0.09^{b}	0.4±0.16^{a}
Count of Odonata genera	0.3±0.29^{b}	0.5±0.33^{b}	1.4±0.72^{b}	2.4±0.64^{a}
Percent Tanytarsini (of Chironomidae)	28.3±4.95	20.7±3.72	37.9±8.00	40.4±6.63
Percent Hydropsychidae (of Trichoptera)	14.9±3.58	10.7±1.22	10.4±2.51	16.1±2.67
Percent collector-filterers	13.5±1.57^{b}	18.4±3.13^{b}	24.1±4.85^{a}	14.8±2.75^{b}
Percent collector-gatherers	38.4±3.64	29.0±2.51	25.6±3.10	29.1±3.54
Percent predators	19.0±3.14^{b}	29.2±2.62^{a}	21.3±4.05^{b}	19.5±2.83^{ab}
Percent scraper-grazers	15.5±2.26	8.13±2.43	9.60±2.31	12.4±4.38
Count of grazer taxa	16.0±0.58^{a}	15.3±0.86^{a}	13.8±1.33^{ab}	14.5±1.19^{b}
Percent shredders	10.2±2.74	7.65±2.33	11.7±3.23	13.4±2.97
Percent detritivores	49.6±2.26^{a}	43.5±3.15^{b}	47.7±4.6^{a}	43.0±3.35^{ab}
Percent burrowers	14.6±3.10	12.7±1.99	12.8±3.18	8.0±1.35
Percent climbers	17.9±2.02^{a}	20.4±3.40^{a}	12.4±2.79^{b}	21.8±2.84^{a}
Percent clingers	45.3±4.25	33.3±4.64	47.7±7.00	37.8±4.18
Percent sprawlers	9.0±3.10^{b}	21.4±3.80^{a}	11.6±1.8^{ab}	18.9±3.39^{a}
Count of sensitive taxa	11.2±1.05	11.8±0.60	10.7±0.71	11.8±0.79
Percent tolerant individuals	23.5±2.43	20.8±4.12	24.3±3.38	16.8±2.67
Site tolerance score	5.48±0.35	5.90±0.23	5.64±0.20	5.23±0.20
Site MIBI score*	28.0±1.26	30.3±0.61	29.3±1.12	30.7±1.98

* Minnesota Index of Biotic Integrity for stream benthic macroinvertebrates, another measure of overall site condition using macroinvertebrates (http://www.pca.state.mn.us/water/biomonitoring/bio-streams-invert.html)..

Macroinvertebrates that are considered among the most sensitive to stress are found in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). We found an average of 17-21 EPT genera in Poplar riffles, which compares relatively well with sites on other North Shore streams (Table 8). This indicates that mayflies, stoneflies, and caddisflies are relatively diverse taxonomically at Poplar sites. However, when we calculated the proportion of individuals in these three orders from among all macroinvertebrates collected in quantitative riffle samples and compared them among Poplar sites (percent EPT, Table 7) and to the other datasets (Table 8, Figure 6), the relative abundances were lower than we expected. Only 30% or less of the macroinvertebrate community in Poplar River riffles was comprised of mayflies, stoneflies, and caddisflies, with no statistical difference among the sites. The sites in the other datasets covered a wider range, with percent EPT having a low of 17% at the Knife culvert TMDL site to a high of 65% at the Palisade Creek EPA site. This puts the Poplar sites on the lower end of North Shore sites in our database (Figure 6).

Thus, while these sensitive groups are well-represented taxonomically (number of genera found), they are not present in the abundances often seen in North Shore streams. This result may be due to a physically harsh environment. Because these groups are quite sensitive, they are also sensitive to harsh environments. In the case of the Poplar, the harshness may be due to high flow events and high current velocities along the lower mainstem. If flow is great enough to carry suspended sediment particles, or cause sand particles to bounce along the stream bottom (called 'saltation'), harsh conditions result, and detrimental effects on delicate invertebrates are more common. We do not have the data to assess whether or not this is the cause of low EPT abundances, but this is a likely explanation that could be further tested.

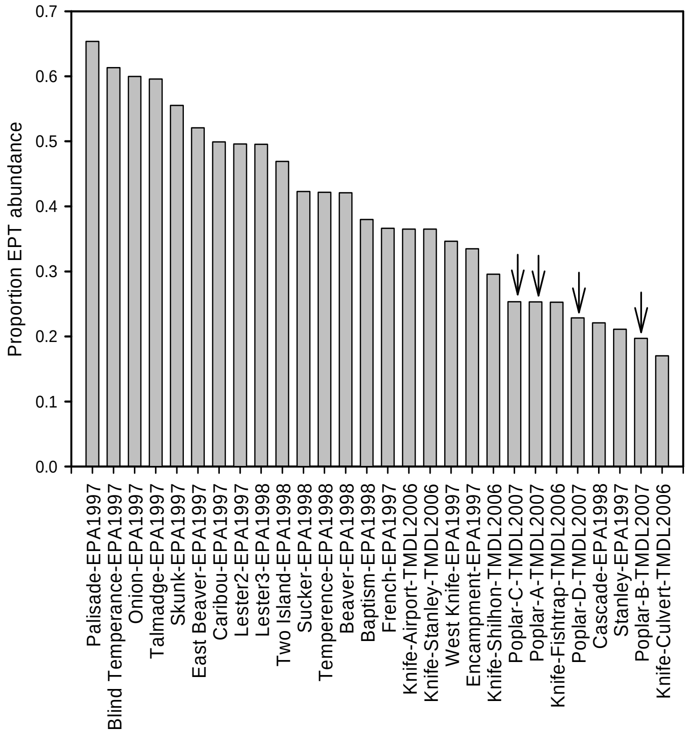

Figure 6. Proportion of macroinvertebrates in the indicator groups Ephemeroptera, Plecoptera, and Trichoptera (EPT). Poplar TMDL stream sites indicated by arrows.

Another good indicator group to look at in terms of stream condition, including physical harshness and long-term habitat stability, are the shredder stoneflies in the genus *Pteronarcys*. This genus has quite a long life cycle, taking 2-3 years to reach maturity in North Shore streams. Only a single small (probably first year) larva was found in the Poplar at site A (Table 8).We also found that odonates (dragonflies and damselflies) were quite uncommon in samples. They

Table 8. Metrics calculated using quantitative riffle samples from North Shore streams. Current study sites in blue. ‘Taxa’ indicates mean taxa richness per site. ‘Tol score’ is mean site tolerance score. ‘Sensit’ is mean number of sensitive taxa (tolerance values ≤3); ‘% Tol’ is mean percentage of tolerant insects in samples (tolerance values ≥7); ‘*Pteronarcys*’ is presence or absence of the stonefly *Pteronarcys* at sites. ‘Hydropsych’ is mean percent of Trichoptera from the family Hydropsychidae. Table is sorted by increasing tolerance score.

Stream-site	Taxa	EPT taxa	% EPT	Tol score	Sensit	% Tol	*Pteronarcys*	Hydropsych
Palisade-EPA1997	26.3	12.3	65.4	3.25	9.0	12.0	A	13
Onion-EPA1997	24.0	11.3	60.0	3.49	10.0	19.7	A	31
Blind Temperance-EPA1997	28.7	15.0	61.3	3.60	9.67	14.4	A	46
Lester2-EPA1997	38.3	16.3	49.6	3.71	14.0	15.6	A	20
Skunk-EPA1997	34.7	16.3	55.5	3.88	15.0	14.1	P	42
East Beaver-EPA1997	31.3	14.7	52.1	3.96	14.3	21.4	A	90
Talmadge-EPA1997	24.3	11.3	59.6	4.00	8.0	14.5	P	46
Two Island-EPA1998	43.0	22.0	46.9	4.36	19.0	27.8	P	46
Caribou-EPA1997	36.0	20.0	49.9	4.42	14.7	6.7	A	35
Knife-Shilhon-TMDL2006	48.3	20.0	29.6	4.52	11.3	20.4	A	71
Baptism-EPA1998	49.0	26.0	38.0	4.56	24.0	25.9	A	67
French-EPA1997	39.0	19.0	36.6	4.76	17.0	15.0	A	89
West Knife-EPA1997	25.7	15.0	34.6	4.76	11.0	7.7	A	34
Sucker-EPA1998	43.0	24.0	42.3	4.84	21.0	22.6	P	60
Beaver-EPA1998	46.0	27.0	42.1	4.86	20.0	27.7	A	41
Encampment-EPA1997	31.7	16.0	33.5	4.90	13.7	24.3	P	45
Lester3-EPA1998	48.0	24.0	49.5	4.91	20.0	21.9	A	86
Temperence-EPA1998	36.0	16.0	42.2	4.99	13.0	15.5	A	62
Knife-Stanley-TMDL2006	36.3	13.7	36.5	5.21	8.0	13.6	A	92
Poplar D-TMDL2007	40.0	20.8	22.9	5.23	10.8	28.2	A	16
Knife-Airport-TMDL2006	36.7	14.3	36.5	5.29	10.7	28.7	P	58
Stanley-EPA1997	30.3	16.7	21.1	5.48	13.0	31.6	P	40
Poplar A-TMDL2007	34.3	21.3	25.3	5.48	10.2	31.4	P	19
Knife-Fishtrap-TMDL2006	34.7	13.7	25.3	5.49	5.7	42.3	A	36
Knife-Culvert-TMDL2006	39.5	9.7	17.0	5.50	7.0	26.1	A	81
Poplar C-TMDL2007	37.8	18.5	25.3	5.64	9.3	28.9	A	35
Cascade-EPA1998	54.0	24.0	22.1	5.67	21.0	19.0	P	19
Poplar B-TMDL2007	39.0	17.0	19.7	5.90	11.2	34.3	A	16

were most abundant, with the most taxa present, at site D (Table 7), the most upstream site and just downstream of the area where the Poplar is significantly wider and slower than the areas we sampled. Although site D did not have slower current speeds than the other sites that we sampled (Table 3, Figure 4), we suspect that its invertebrate community is showing some influence of the slower stretch of river above it. Odonates, while often present in North Shore streams, typically do not make up a large component of the community (Figure 7).

One other interesting taxonomic note about the Poplar River macroinvertebrates involves the presence of the insect order Neuroptera. Spongillaflies are only found living on and eating freshwater sponges, making them relatively uncommon even in North Shore streams. We found a few spongillaflies in riffle samples at sites A and C (Appendix 1). Neuroptera are not

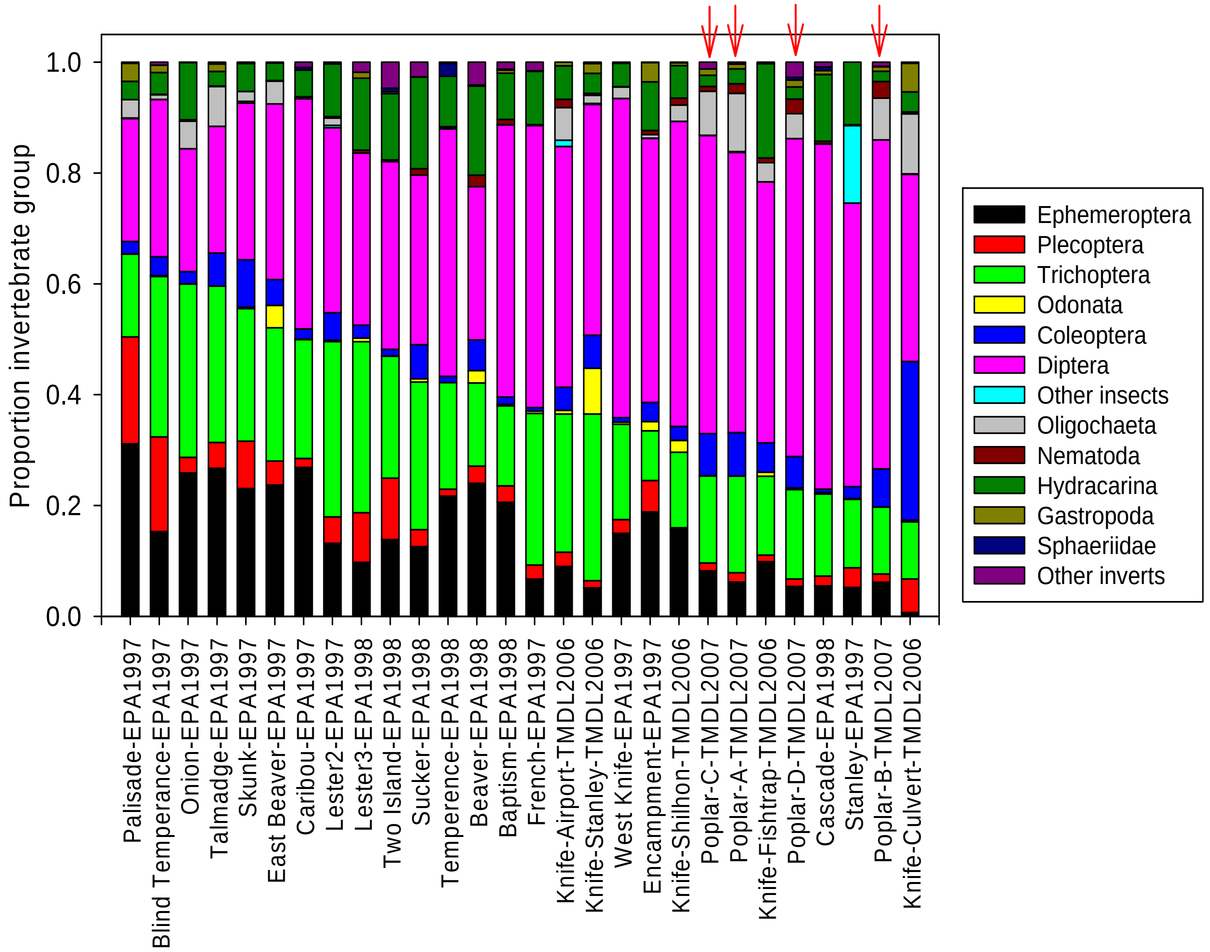

Figure 7. Proportion of macroinvertebrate taxonomic groups making up riffle samples in North Shore streams. Sites are ordered by descending cumulative proportions of Ephemeroptera, Plecoptera, and Trichoptera. Sites from the present study are marked with red arrows.

particularly sensitive to anthropogenic stressors, so their distribution is typically limited by the absence of sponges. Sensitive insect groups comprised a lower percentage of the overall community than would be expected based on data from other North Shore streams. Instead, the invertebrate assemblage of the Poplar lower mainstem was made up largely of Diptera, the true flies (Figure 7), which ranged from 51 to 59% of the community. Only five other North Shore stream sites had this high a proportion of the community made up of Diptera. Diptera in aquatic systems tend to be mostly from the taxonomically-rich family Chironomidae (non-biting midges), and this was especially true in Poplar samples, where very few other types of flies were found (Appendix 1). One other taxonomic group that is often used as an indicator of condition are the aquatic earthworms, Oligochaeta. High abundances of oligochaetes often indicate nutrient enrichment, lots of fine sediments, and low dissolved oxygen values. Oligochaetes made up a relatively small proportion of the riffle community of Poplar River sites (Figure 7), and the proportions reflect more the absence of the more sensitive taxa rather than high abundances of oligochaetes.

Exploring the make-up of the macroinvertebrate community by functional feeding group proportions can also be informative. Functional feeding group categories describe how, and, to some extent, on what the invertebrates feed. Categories include collector-gatherers, which collect fine particles to feed on, collector filterers that filter fine particles out of the water column, scraper-grazers that scrape algae and detritus off of rock and plants, shredders that shred up leaves and sometimes wood, and predators that feed on other animals. Because the Diptera family Chironomidae contains such a variety of genera, there are some that feed in each of these ways, causing the Poplar sites to compare much more favorably with other North Shore streams than was true of the taxonomic comparisons (Figure 8).

We typically assume that predators are more sensitive to stressors than are some other feeding groups because they feed higher up on the food chain. Figure 8 is sorted with streams having the highest proportion of predators on the left side of the graph and decreasing toward the right. Poplar River sites tend to have a relatively large proportion of the community represented by predatory invertebrates, including a number of chironomid genera. Site B had statistically higher relative abundances of predators than sites A and C (Table 7). On the other hand, collector-gatherers are considered the omnivorous scavengers of the aquatic invertebrate world, and as such should be much less sensitive to stress. Thus, streams with communities comprised largely of gatherers are often suspected of having nutrient enrichment problems. Gatherers make up a relatively small proportion of the community at Poplar River sites (Figure 8). Scraper-grazer invertebrates make their living scraping algae and detritus off of rocks, wood, and other structures; these include Gastropoda (snails) and several families of Trichoptera (caddisflies), among others. Grazers are affected by anything that influences the amount of algae on rocks and can become very abundant in nutrient-rich situations. Because algae grow on the tops of rocks where there is sunlight, grazers may also be affected by high flows and physical abrasion. Scrapers make up a relatively small proportion of most Poplar sites (Figure 8), with site D being significantly lower (Table 7) in grazer taxa diversity. Grazer proportions are not particularly low compared with other North Shore stream sites (Figure 8). Shredder proportions are also similar to those found at other North Shore streams, reflecting the availability of leaves for food (and thus trees alongside the stream).

Invertebrates that filter their food from the water column are often also abundant when there is nutrient enrichment, and typically make up a greater proportion of the community as one moves downstream from the headwaters to the mouth of a river. However, because these invertebrates must approach or even enter the current in order to capture food particles with their nets (most taxa), fans (Simuliidae), or gills (Sphaeriidae), they may be particularly vulnerable to sediment in the water. They may either be physically abraded by the larger particles such as sand, or may have their nets, fans, or gills clogged by silts and clays, making it difficult for them to feed. Filtering invertebrates comprise a relatively small percentage of the community at the Poplar sites, particularly considering that these sites are in the downstream section of the river (Figures 8 and 9). Poplar site C has a significantly greater proportion of filterers than all other Poplar sites

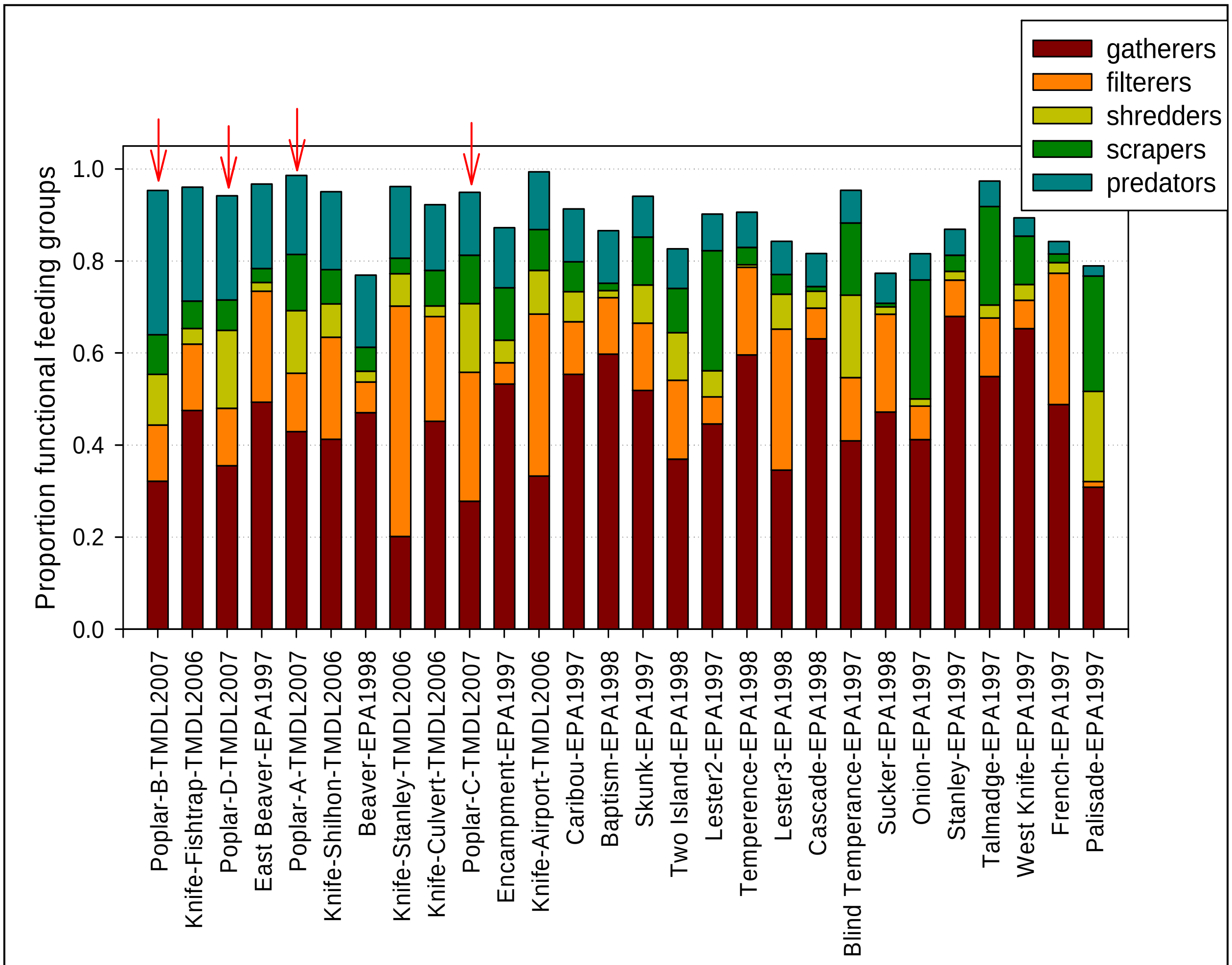

Figure 8. Functional feeding groups of insects in North Shore stream riffles. Proportions do not always add up to 1 because of a lack of information about some taxa or due to lumping of taxa. Poplar River sites are marked with red arrows.

(Table 7). Although both sites C and D have more filterers than sites A and B, the difference is not significant due to high variability. Thus, the upstream sites provide either more food or better habitat than do the downstream sites, or both. Unstable substrates also make life difficult for filterers, but unstable substrates are unlikely in this area of the Poplar because the substrate tends to be relatively large rocks.

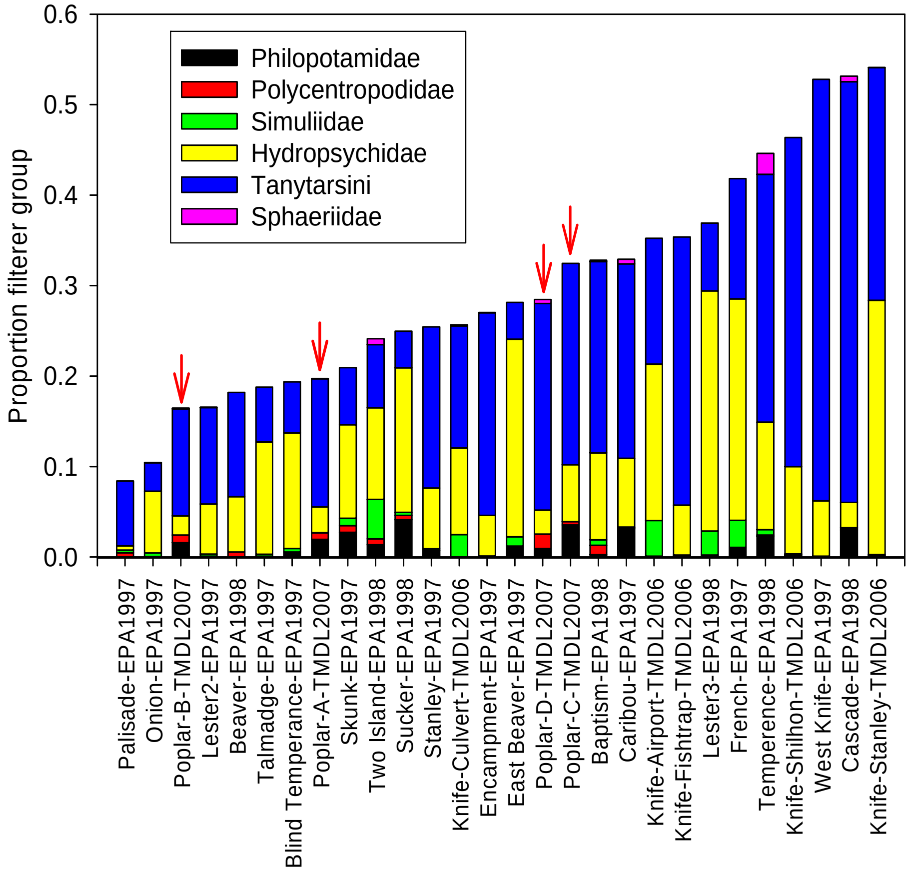

Figure 9. Taxonomic composition of macroinvertebrate filterers collected from North Shore stream riffles. Total bar height represents total proportion of all filterers in the community. Sites from the present study marked with red arrows.

Behavioral traits of stream invertebrates can also provide insight into stream condition and stream habitat. Chironomid genera do not cover as many behavioral trait categories as they do feeding group categories. Most chironomids fall into the behavior groups of burrowers, clingers, and climbers (to some extent). When assessing stream condition, we typically contrast the proportions of clingers and burrowers. Clingers cling to rocks in riffles in the current and use the interstitial spaces between and beneath rocks to escape from predators or find refuge from the flow, and to collect food particles. Thus, proportions of clingers tend to be reduced by anything that reduces interstitial space around larger substrates (boulder, cobble, pebble). This can be natural, as when a stream has large amounts of bedrock or is naturally sandy, or can be related to human-caused erosion and sedimentation issues. When there are abundant fine substrates, particularly silts, in streams, the proportion of burrowers usually increases. Poplar sites have fairly high proportions of clingers and among the lowest proportions of burrowers found in North Shore stream riffles (Figure 10). This is yet another indication that embeddedness and excess fine sediments are not problems facing the macroinvertebrate community in this stretch of the river. Another behavioral group important to a discussion of stream condition are the sprawlers. Sprawlers sprawl on top of substrates that would tend to bury them and are often found in areas with excess sediment. Sprawlers make up a greater proportion of the community at Poplar sites D and B (Figure 10), although the difference is only statistically significant versus site A (Table 7). Site D is also the most embedded of the Poplar sites we sampled (Figure 4).

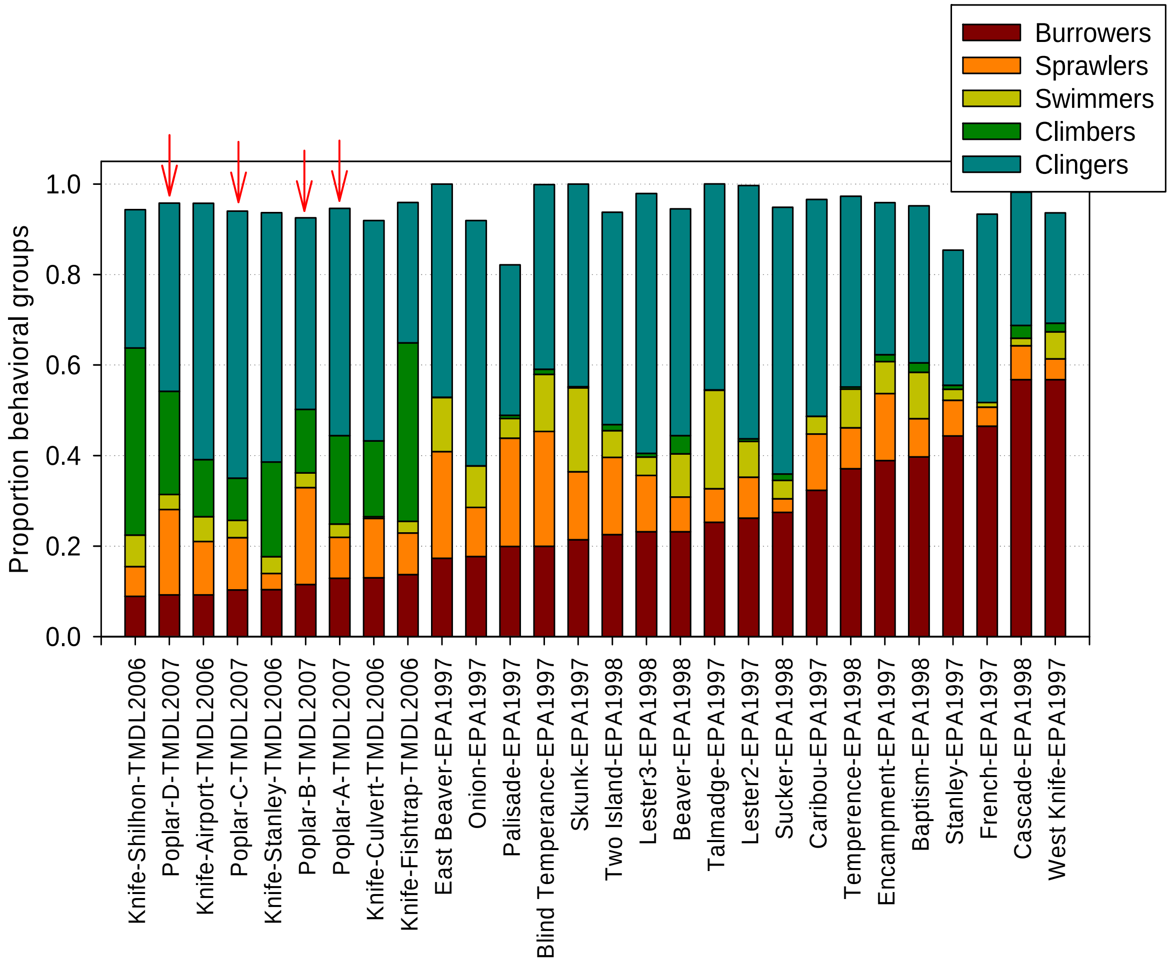

Figure 10. Behavioral groups of macroinvertebrates in North Shore stream riffles. Proportions do not always add up to 1 because of a lack of trait information on some groups, or due to lumping of taxa. Red arrows indicate Poplar River study sites.

Tolerance values are numeric values assigned to aquatic biota that indicate their tolerance of stress. These numbers are based on laboratory tests and large-scale biotic surveys across a variety of aquatic conditions. They are often used as a general measure of tolerance to anthropogenic stress, but tend to be more indicative of tolerance of nutrient enrichment and low dissolved oxygen (c.f., Barbour et al. 1999). We combined several sources to obtain the most appropriate tolerance values for the stream invertebrates found in northern Minnesota; these values range from 0 (least tolerant) to 10 (most tolerant) (see Methods). From these values, several indicators of stream condition can be created. One such indicator is the proportion of sensitive taxa (Figure 11); we have defined sensitive taxa as those with a tolerance value less than or equal to three. Poplar River sites fall in the lower range of the proportion of sensitive taxa, only slightly higher than the Knife River TMDL sites, which had much greater embeddedness, in general, than the Poplar River sites. The converse of the sensitive taxa metric is the proportion of macroinvertebrates that are considered 'tolerant' (tolerance value ≥ 7). Poplar River sites have among the highest proportions of tolerant invertebrates of all North Shore streams in our database. Both of these indicators point to the low proportion and taxonomic composition of the macoinvertebrate community that is comprised of mayflies, stoneflies, and caddisflies, as well as other taxa that are considered delicate, or sensitive. Instead, Poplar River sites have macroinvertebrate communities substantially made up of more tolerant and physically 'hardy' taxa.

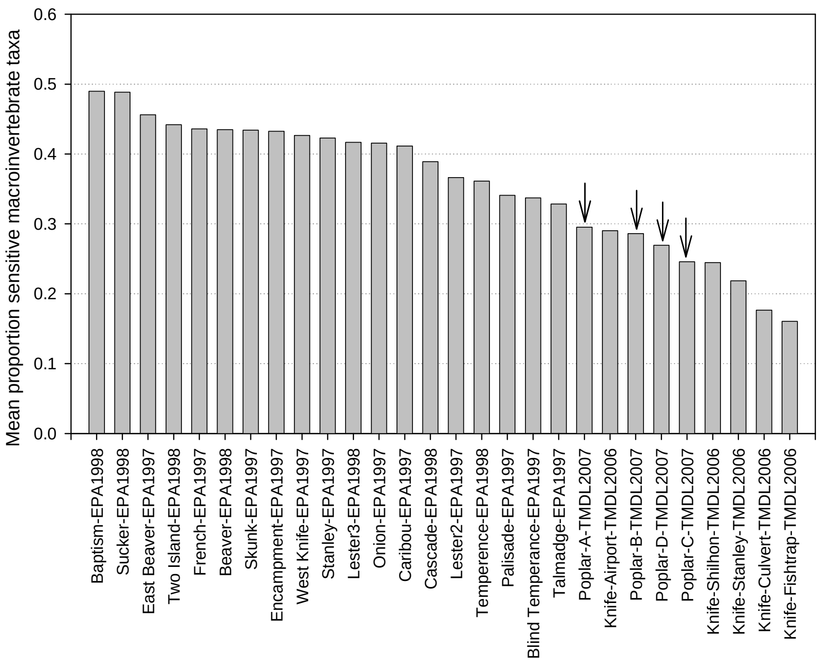

Figure 11. Mean number of macroinvertebrate taxa and sensitive taxa (tolerance value ≤3) in North Shore stream riffles. Poplar River sites are marked with arrows.

Finally, tolerance values are used to calculate an overall 'tolerance score' for each site. Tolerance scores cannot be lower than zero, but can be quite large for sites that have high abundances of very tolerant organisms. Non-urban North Shore streams in our database have tolerance scores ranging from 3.2 to 5.9 (Figure 13). Poplar River site scores are all in the higher (more tolerant) end of this range, with Poplar Site B having the highest score calculated so far for non-urban streams.

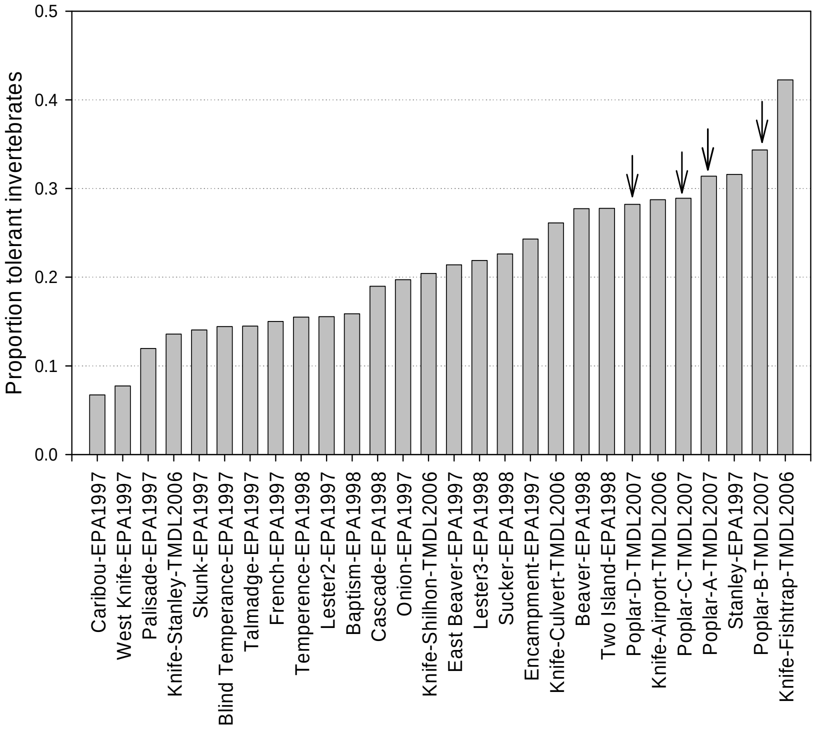

Figure 12. Proportion tolerant macroinvertebrates (tolerance value ≥7) in North Shore stream riffles. Poplar River sites marked by arrows.

Summary and Conclusions

In general, sites along the lower mainstem of the Poplar River had very rocky substrates with little embeddedness, the substrate was predominantly boulder, and the sites were wide and shallow with predominantly riffle and run habitat. Sites lacked pools and underbank habitat, and most sites had no large woody debris, thus limiting the variety of habitats available to biota.

Macroinvertebrate communities at Poplar sites were relatively similar to each other, especially in comparison to other North Shore stream sites. Macroinvertebrate assemblages were dominated by the Diptera family Chironomidae at a higher proportion than seen in most other North Shore streams in our database. The other dominant characteristic of Poplar River assemblages was the relative lack of sensitive and delicate taxa, particularly those in the indicator groups mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). The low abundance of these groups contributed to poor values for a number of other indicator metrics, including overall taxa richness, low relative abundance of filter-feeding invertebrates, a high proportion of tolerant

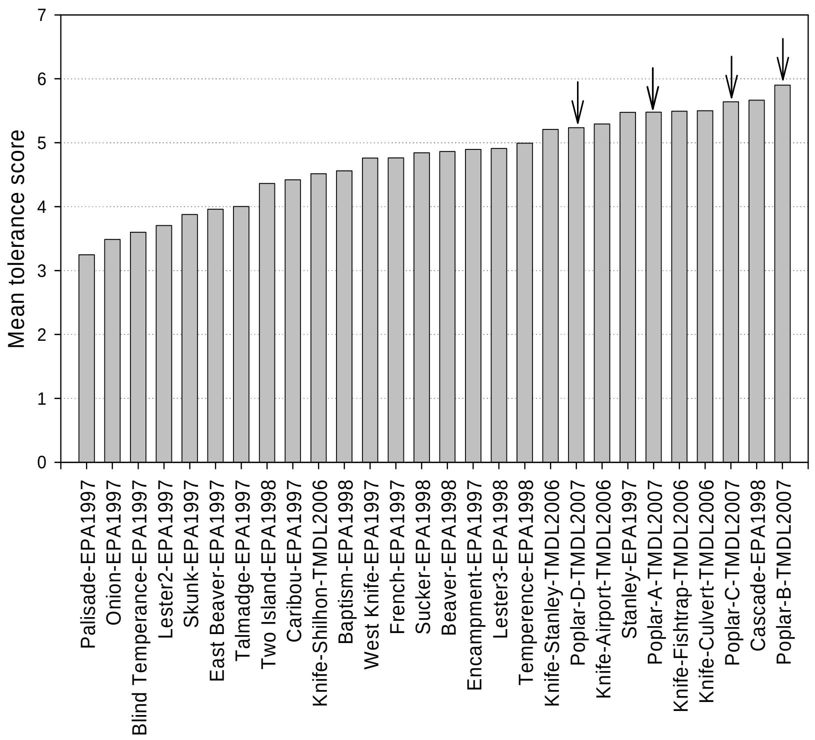

Figure 13. Mean tolerance score for North Shore stream riffles. Poplar River study sites marked with arrows.

invertebrates, and a high tolerance score. However, because the Chironomidae contain a high diversity of feeding and behavioral types, the indicator metrics relating to functional feeding groups and behavioral groups gave a more positive outlook of stream condition. This indicates that the chironomid genera in the Poplar River are filling many niches.

Relative to other North Shore streams, macroinvertebrate indicators for the lower mainstem of the Poplar River indicate a community under more stress than those of many other North Shore streams in our comparison database. Indicators based on taxonomy all rank the Poplar sites in the poorest quartile of North Shore streams we have sampled. Based on the data we have available, and conversations with the MCPA and others collecting water quality data, a likely explanation for our results is that the lower mainstem of the Poplar River is a physically harsh environment that limits the viability of delicate and sensitive stream biota. This physical harshness likely results from the steeper gradient, higher flow during storm events, lack of refugia for biota during high flows, and the probability that high flows contain a relatively large amount of suspended sediment particles that can dislodge or damage invertebrates that cannot find refuge. The physical harshness of this system would be lessened for stream macroinvertebrates by the implementation of best management practices that slow and lessen the amount of stormwater runoff reaching the stream due to changes in land use within the watershed, reduce bank erosion and other sediment inputs, and stabilize eroding banks. It is important that the wide stream buffers along the mainstem be protected where they exist, and be restored where they have been infringed upon. Continued efforts to sample streams of similar size, gradient, and channel type may provide further insight into the relative effects of land use and stream bank erosion on the Poplar River macroinvertebrate community.

Literature Cited

American Public Health Association (APHA), American Water Works Association, and Water Pollution Control Federation. 1985. Standard Methods for the Examination of Water and Waste Water. 16th ed. Washington, D.C. 1067 pp.

Barbour, M.T., Gerritsen. J., Snyder, B.D., and Stribling, J.B. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates, and fish (2nd edition). EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Breneman, D., Richards, C., and Lozano, S. 2000. Environmental influences on benthic community structure in a Great Lakes embayment. J. Great Lakes Res. 26(3):287-304.

Brinkhurst, R.O. 1986. Guide to the freshwater aquatic Microdrile Oligochaetes of North America. Can. Spec. Publ. Fish.Aquat. Sci. 84:259 pp.

Brusven, M.A. and Prather, K.V. 1974. Influence of stream sediments on distribution of macrobenthos. J. Entomol. Soc. Brit. Columbia. 71:25-32.

Detenbeck, N.E., Batterman, S.L., Brady, V.J., Brazner, J.C., Snarski, V.M., Taylor, D.L. Thompson, J.A., and Arthur, J.W. 2000. The Western Lake Superior comparative watershed framework: A test of geographically-dependent vs. geographically-independent, threshold-based watershed classification systems for ecological risk assessment. Env. Tox. Chem. 19:1174-1181.

Fitzpatrick, F. and Knox, J. 2000. Spatial and temporal sensitivity of hydrogeomorphic response and recovery to deforestation, agriculture, and floods. Phys Geogr. 21(2):98-108.

Friedman, G.M. and Sanders, J.E. 1978. Principles of Sedimentology. New York: John Wiley and Sons.

Gee, G.W. and Bauder, J.W. 1986. Particle-size analysis. In Methods of Soil Analysis, Part I. Physical and Mineralogical Methods, ed. A. Klute, pp. 383-411. Madison, WI: American Society of Agronomy-Soil Science Society of America.

Gerritson, J. 1995. Additive biological indices for resource management. J. N. Am. Benthol. Soc. 14:451-457.

Hilsenhoff, W.L. 1981. Aquatic Insects of Wisconsin. Keys to Wisconsin genera and notes on biology, distribution, and species. University of Wisconsin-Madison: Publication of the Natural History Council. 60 pp.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. Great Lakes Ent. 20(1):31-39.

Johnson, L.B., Breneman, D., and Richards, C. 2003. Macroinvertebrate community structure and function associated with large wood in low gradient streams. River Res. Applic. 19:199-218.

Lenat, D.R. 1988. Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. J. N. Am. Benthol. Soc. 7:222-233.

Magee, J.P., McMahon, T.E., and Thurow, R.F. 1996. Spatial variation in spawning habitat of cutthroat trout in a sediment-rich stream basin. Transactions of the American Fisheries Society. 125(5):768-779.

Merritt, R.W. and Cummins, K.W. (eds.). 1996. An Introduction to the Aquatic Insects of North America, 3rd edition. Dubuque, IA: Kendall/Hunt Publishing Co.

Natural Resources Research Institute. 1999. Standard Operating Procedures (SOP): Benthic sample collection and processing. University of Minnesota Duluth, Natural Resources Research Institute, Technical Report. NRRI/TR 99/37, 17 pp.

Ohio Environmental Protection Agency. 1987. Biological Criteria for the Protection of Aquatic Life, Volume 2. User’s manual for biological assessment of Ohio surface waters. Columbus, Ohio: Ohio Environmental Protection Agency.

Richards, C., Haro, R.J., Johnson, L.B., and Host, G.E. 1997. Catchment and reach-scale properties as indicators of macroinvertebrate species traits. Freshwater Biol. 37:219-23.

Rosenberg, D.M. and Resh, V.H. (eds). 1993. Freshwater biomonitoring and benthic macroinvertebrates. New York: Chapman and Hall, Inc.

Stuart-Smith, R.D., Richardson, A.M.M., and White, R.W.G. 2004. Increasing turbidity significantly alters the diet of brown trout: A multi-year longitudinal study. J Fish Biol. 65(2):376-388.

Suttle, K.B., Power, M.E., Levine, J.M., and McNeely, C. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecol. Appl. 14(4):969-974.

Sweka, J.A. and Hartman, KJ. 2001. Influence of turbidity on brook trout reactive distance and foraging success. Trans. Am. Fish. Soc. 130(1):138-146.

Thorp, J.H. and Covich, A.P. (eds.). 1991. Ecology and Classification of North American Freshwater Invertebrates. San Diego, CA: Academic Press, Inc., 911 pp.

Wallace, J.B., Grumbaugh, J.W., and Whiles, M.R. 1993. Influences of coarse woody debris on stream habitats, invertebrate diversity. In Biodiversity and Coarse Woody Debris in Southern Forests. Proceedings of the Workshop on Coarse Woody Debris in Southern Forests: Effects on Biodiversity. Athens, GA. October 18-20, 1993. USDA Forest Service. Southern Research Station General Technical Report SE-94:119-129.

Wallace, J.B., Webster, J.R., and Meyer, J.L. 1995. Influence of log additions on physical and biotic characteristics of a mountain stream. Can. J. of Fish. Aquat. Sci. 52:2120-2137.

Wiederholm, T. (ed.). 1983. Chironomidae of the Holarctic Region. Ent. Scand. Suppl.

Wiederholm, T. 1984. Responses of aquatic insects to environmental pollution. In The Ecology of Aquatic Insects, eds. Resh, V.H. and Rosenberg, D.M., pp. 508-557. New York: Praeger Pubs.

Appendix 1. Mean number of taxa per square meter occurring in habitats at each sampling location. SE = standard error; CV = coefficient of variation. If SE and CV are blank, the taxon was collected in only one sample at that site.

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	A	Riffle/run	Acari	217.61	56.49	68.69
Hess	A	Riffle/run	Acroneuria	53.16	17.18	85.52
Hess	A	Riffle/run	Baetis	127.91	43.43	89.84
Hess	A	Riffle/run	Caenis	11.63		
Hess	A	Riffle/run	Cardiocladius	160.17		
Hess	A	Riffle/run	Ceraclea	29.07	5.81	28.28
Hess	A	Riffle/run	Cheumatopsyche	147.29	47.15	78.42
Hess	A	Riffle/run	Chimarra	186.05	63.83	84.04
Hess	A	Riffle/run	Climacia	34.88		
Hess	A	Riffle/run	Corynoneura	59.04	7.09	16.98
Hess	A	Riffle/run	Cricotopus	1638.70	702.70	85.76
Hess	A	Riffle/run	Cryptochironomus	118.06	26.02	38.18
Hess	A	Riffle/run	Empididae	17.44	5.81	47.14
Hess	A	Riffle/run	Ephemera	11.63		
Hess	A	Riffle/run	Ephemerellidae	207.36	88.93	105.05
Hess	A	Riffle/run	Ephydridae	11.63		
Hess	A	Riffle/run	Eukiefferiella	108.51	28.34	52.24
Hess	A	Riffle/run	Ferrissia	66.86	15.29	45.74
Hess	A	Riffle/run	Glossosoma	169.77	110.78	145.91
Hess	A	Riffle/run	Helicopsyche	180.88	129.38	214.59
Hess	A	Riffle/run	Heterocloeon	15.50	3.88	43.30
Hess	A	Riffle/run	Hexatoma	34.88	10.40	73.03
Hess	A	Riffle/run	Hydropsyche	119.60	29.34	64.91
Hess	A	Riffle/run	Hydroptila	118.60	37.03	69.81
Hess	A	Riffle/run	Lepidostoma	298.45	156.72	128.62
Hess	A	Riffle/run	Leptophlebiidae	116.28	27.02	56.92
Hess	A	Riffle/run	Leuctridae	23.26		
Hess	A	Riffle/run	Lopescladius	808.06	386.83	82.91
Hess	A	Riffle/run	Microtendipes	1266.96	666.07	117.56
Hess	A	Riffle/run	Nematoda	162.79	57.91	87.13
Hess	A	Riffle/run	Nigronia	17.44	5.81	47.14
Hess	A	Riffle/run	Nyctiophylax	34.88		
Hess	A	Riffle/run	Oecetis	264.12	143.26	143.51
Hess	A	Riffle/run	Oligochaeta	648.58	253.36	117.19
Hess	A	Riffle/run	Optioservus	184.39	46.12	66.18
Hess	A	Riffle/run	Parachironomus	605.17	546.14	156.31
Hess	A	Riffle/run	Parametriocnemus	132.27		
Hess	A	Riffle/run	Paratanytarsus	51.95		
Hess	A	Riffle/run	Perlodidae	91.09	26.59	71.50
Hess	A	Riffle/run	Physella	44.19	13.46	68.12
Hess	A	Riffle/run	Planorbidae	11.63		

Appendix 1 (cont).

Gear	**Site**	**Habitat**	**Taxa**	**Abundance (#/m^2)**	**SE**	**CV**
Hess	A	Riffle/run	Polycentropus	76.74	33.82	98.54
Hess	A	Riffle/run	Polypedilum	380.51	93.52	42.57
Hess	A	Riffle/run	Psychomyia	11.63		
Hess	A	Riffle/run	Rheocricotopus	160.17		
Hess	A	Riffle/run	Rheotanytarsus	253.19	138.74	122.53
Hess	A	Riffle/run	Rhithrogena	11.63		
Hess	A	Riffle/run	Rhyacophila	11.63		
Hess	A	Riffle/run	Saldidae	11.63	0.00	0.00
Hess	A	Riffle/run	Simulium	11.63		
Hess	A	Riffle/run	Sphaeriidae	11.63		
Hess	A	Riffle/run	Stempellina	982.45	207.20	42.18
Hess	A	Riffle/run	Stempellinella	165.67	11.36	9.70
Hess	A	Riffle/run	Stenelmis	475.08	102.90	57.30
Hess	A	Riffle/run	Stenonema	84.30	29.13	97.74
Hess	A	Riffle/run	Synorthocladius	89.53	70.64	111.58
Hess	A	Riffle/run	Tabanus	11.63		
Hess	A	Riffle/run	Tanytarsus	533.34	115.36	52.98
Hess	A	Riffle/run	Thienemanniella	93.56	41.61	62.89
Hess	A	Riffle/run	Thienemannimyia	304.94	62.89	50.51
Hess	A	Riffle/run	Trichoptera	87.21	52.33	84.85
Hess	A	Riffle/run	Tricorythodes	11.63		
Hess	B	Riffle/run	Acari	300.39	30.38	24.78
Hess	B	Riffle/run	Acroneuria	75.58	27.31	88.51
Hess	B	Riffle/run	Atherix	11.63	0.00	0.00
Hess	B	Riffle/run	Baetis	179.07	41.05	51.25
Hess	B	Riffle/run	Brachycentridae	11.63		
Hess	B	Riffle/run	Ceraclea	69.77	46.51	94.28
Hess	B	Riffle/run	Cheumatopsyche	166.67	38.76	56.96
Hess	B	Riffle/run	Chimarra	288.37	144.97	112.41
Hess	B	Riffle/run	Cricotopus	1416.24	514.69	89.02
Hess	B	Riffle/run	Cryptochironomus	1109.99	285.09	62.91
Hess	B	Riffle/run	Empididae	11.63		
Hess	B	Riffle/run	Ephemera	11.63		
Hess	B	Riffle/run	Ephemerellidae	203.49	58.20	70.06
Hess	B	Riffle/run	Ferrissia	29.07	5.81	40.00
Hess	B	Riffle/run	Glossosoma	144.19	59.47	92.23
Hess	B	Riffle/run	Gomphidae	11.63		
Hess	B	Riffle/run	Gomphus	11.63		
Hess	B	Riffle/run	Helicopsyche	112.96	31.15	72.96
Hess	B	Riffle/run	Heterocloeon	85.27	44.70	90.80
Hess	B	Riffle/run	Hexatoma	34.88	11.63	57.74
Hess	B	Riffle/run	Hydropsyche	123.55	40.16	91.93
Hess	B	Riffle/run	Hydropsychidae	46.51		
Hess	B	Riffle/run	Hydroptila	282.39	62.19	58.27

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	B	Riffle/run	Ithytrichia	186.05		
Hess	B	Riffle/run	Lepidostoma	204.32	56.27	72.87
Hess	B	Riffle/run	Leptophlebia	11.63		
Hess	B	Riffle/run	Leptophlebiidae	323.64	84.78	64.17
Hess	B	Riffle/run	Leuctridae	23.26		
Hess	B	Riffle/run	Lopescladius	695.68	88.53	31.17
Hess	B	Riffle/run	Microtendipes	1312.75	378.51	64.47
Hess	B	Riffle/run	Nanocladius	255.81		
Hess	B	Riffle/run	Nematoda	329.46	84.76	77.18
Hess	B	Riffle/run	Nigronia	11.63		
Hess	B	Riffle/run	Nilothauma	11.63		
Hess	B	Riffle/run	Nyctiophylax	27.91	4.65	37.27
Hess	B	Riffle/run	Oecetis	242.73	76.61	89.27
Hess	B	Riffle/run	Oligochaeta	882.43	254.29	86.45
Hess	B	Riffle/run	Optioservus	577.52	256.95	108.98
Hess	B	Riffle/run	Parachironomus	1247.62	558.72	100.14
Hess	B	Riffle/run	Paracladopelma	212.92		
Hess	B	Riffle/run	Paratendipes	196.95		
Hess	B	Riffle/run	Perlodidae	155.04	54.59	86.26
Hess	B	Riffle/run	Phaenopsectra	506.25	172.53	48.20
Hess	B	Riffle/run	Philopotamidae	11.63		
Hess	B	Riffle/run	Physella	96.35	29.88	82.07
Hess	B	Riffle/run	Polycentropus	114.34	36.70	78.62
Hess	B	Riffle/run	Polypedilum	1194.31	335.63	56.21
Hess	B	Riffle/run	Probezzia	11.63		
Hess	B	Riffle/run	Prodiamesa	255.81		
Hess	B	Riffle/run	Psectrotanypus	212.92		
Hess	B	Riffle/run	Psychomyia	46.51		
Hess	B	Riffle/run	Rheotanytarsus	631.40	226.57	80.24
Hess	B	Riffle/run	Rhithrogena	34.88		
Hess	B	Riffle/run	Rhyacophila	15.50	3.88	43.30
Hess	B	Riffle/run	Saetheria	333.72		
Hess	B	Riffle/run	Sphaeriidae	31.01	7.75	43.30
Hess	B	Riffle/run	Stempellina	325.16	88.82	54.63
Hess	B	Riffle/run	Stempellinella	534.28	131.02	54.84
Hess	B	Riffle/run	Stenelmis	396.80	124.12	88.47
Hess	B	Riffle/run	Stenonema	200.58	72.04	101.59
Hess	B	Riffle/run	Synorthocladius	311.39	114.45	51.98
Hess	B	Riffle/run	Tabanus	11.63		
Hess	B	Riffle/run	Tanytarsus	719.32	191.10	65.07
Hess	B	Riffle/run	Thienemanniella	113.86		
Hess	B	Riffle/run	Thienemannimyia	1375.47	312.58	55.67
Hess	B	Riffle/run	Trichoptera	165.70	76.01	91.74
Hess	B	Riffle/run	Tricorythodes	23.26		

Appendix 1 (cont).

Gear	**Site**	**Habitat**	**Taxa**	**Abundance (#/m^2)**	**SE**	**CV**
Hess	B	Riffle/run	Turbellaria	11.63		
Hess	C	Riffle/run	Acari	228.68	85.64	91.73
Hess	C	Riffle/run	Acroneuria	61.05	15.81	73.24
Hess	C	Riffle/run	Atherix	17.44	5.81	47.14
Hess	C	Riffle/run	Baetis	162.79	48.33	89.07
Hess	C	Riffle/run	Caenis	23.26		
Hess	C	Riffle/run	Ceraclea	17.44	5.81	47.14
Hess	C	Riffle/run	Cheumatopsyche	195.74	39.19	49.05
Hess	C	Riffle/run	Chimarra	300.66	106.77	93.95
Hess	C	Riffle/run	Cricotopus	1902.37	699.83	90.11
Hess	C	Riffle/run	Cryptochironomus	157.24	87.77	111.63
Hess	C	Riffle/run	Echinogammarus	34.88		
Hess	C	Riffle/run	Ephemerellidae	320.93	70.12	48.85
Hess	C	Riffle/run	Eukiefferiella	265.69	96.44	72.60
Hess	C	Riffle/run	Eurylophella	11.63		
Hess	C	Riffle/run	Ferrissia	86.05	17.48	45.43
Hess	C	Riffle/run	Glossosoma	63.95	22.22	85.09
Hess	C	Riffle/run	Gomphidae	11.63		
Hess	C	Riffle/run	Gomphus	17.44	5.81	47.14
Hess	C	Riffle/run	Helicopsyche	206.98	85.79	92.69
Hess	C	Riffle/run	Heterocloeon	104.65		
Hess	C	Riffle/run	Hydropsyche	360.47	63.69	46.75
Hess	C	Riffle/run	Hydropsychidae	177.33	53.99	60.90
Hess	C	Riffle/run	Hydroptila	144.52	47.39	86.76
Hess	C	Riffle/run	Lepidostoma	94.68	23.86	66.67
Hess	C	Riffle/run	Leptophlebiidae	142.86	37.87	70.13
Hess	C	Riffle/run	Leucotrichia	11.63		
Hess	C	Riffle/run	Lopescladius	344.80	100.69	50.58
Hess	C	Riffle/run	Microtendipes	157.30	102.45	112.81
Hess	C	Riffle/run	Naididae	232.56		
Hess	C	Riffle/run	Nematoda	81.40	20.73	72.04
Hess	C	Riffle/run	Nigronia	11.63		
Hess	C	Riffle/run	Nilothauma	37.79		
Hess	C	Riffle/run	Nyctiophylax	34.88	11.63	47.14
Hess	C	Riffle/run	Oecetis	156.98	74.98	117.00
Hess	C	Riffle/run	Oligochaeta	572.35	239.87	125.73
Hess	C	Riffle/run	Optioservus	252.91	78.80	88.12
Hess	C	Riffle/run	Parachironomus	326.43	34.76	15.06
Hess	C	Riffle/run	Paraleptophlebia	81.40		
Hess	C	Riffle/run	Parametriocnemus	186.25	80.05	85.96
Hess	C	Riffle/run	Paratanytarsus	419.19		
Hess	C	Riffle/run	Paratendipes	323.34	253.57	156.84
Hess	C	Riffle/run	Perlodidae	76.41	29.25	101.27
Hess	C	Riffle/run	Phaenopsectra	37.79		

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	C	Riffle/run	Pharyngobdellida	81.40		
Hess	C	Riffle/run	Physella	62.79	7.89	28.08
Hess	C	Riffle/run	Polycentropus	48.84	18.16	83.16
Hess	C	Riffle/run	Polypedilum	423.63	113.43	59.87
Hess	C	Riffle/run	Psectrotanypus	46.75		
Hess	C	Riffle/run	Psychomyia	34.88		
Hess	C	Riffle/run	Rheotanytarsus	3200.35	1876.47	143.62
Hess	C	Riffle/run	Rhithrogena	11.63		
Hess	C	Riffle/run	Rhyacophila	11.63		
Hess	C	Riffle/run	Saetheria	90.12		
Hess	C	Riffle/run	Sisyridae	11.63		
Hess	C	Riffle/run	Stempellina	83.21	10.30	17.50
Hess	C	Riffle/run	Stempellinella	549.03	168.05	68.44
Hess	C	Riffle/run	Stenelmis	380.81	114.98	85.40
Hess	C	Riffle/run	Stenonema	123.26	43.13	110.66
Hess	C	Riffle/run	Synorthocladius	234.82	103.10	87.81
Hess	C	Riffle/run	Tanytarsus	325.11	44.91	33.84
Hess	C	Riffle/run	Thienemanniella	686.02	347.29	101.25
Hess	C	Riffle/run	Thienemannimyia	552.54	124.06	55.00
Hess	C	Riffle/run	Trichoptera	193.02	57.27	66.35
Hess	C	Riffle/run	Tricorythodes	23.26		
Hess	D	Riffle/run	Acari	162.79	43.61	65.62
Hess	D	Riffle/run	Acroneuria	39.53	5.93	33.53
Hess	D	Riffle/run	Attenella	17.44	5.81	47.14
Hess	D	Riffle/run	Baetis	151.16	57.04	92.44
Hess	D	Riffle/run	Brachycentridae	23.26	0.00	0.00
Hess	D	Riffle/run	Caenis	20.35	2.91	28.57
Hess	D	Riffle/run	Ceraclea	17.44	3.36	38.49
Hess	D	Riffle/run	Cheumatopsyche	14.53	2.91	40.00
Hess	D	Riffle/run	Chimarra	88.37	28.62	72.43
Hess	D	Riffle/run	Corynoneura	63.11	16.84	37.73
Hess	D	Riffle/run	Cricotopus	790.01	261.52	81.09
Hess	D	Riffle/run	Cryptochironomus	362.21	178.33	110.09
Hess	D	Riffle/run	Dicranota	23.26		
Hess	D	Riffle/run	Dicrotendipes	107.07		
Hess	D	Riffle/run	Dubiraphia	11.63		
Hess	D	Riffle/run	Ephemerellidae	106.98	44.94	93.94
Hess	D	Riffle/run	Eukiefferiella	118.38	24.34	35.62
Hess	D	Riffle/run	Ferrissia	89.70	44.94	132.56
Hess	D	Riffle/run	Glossosoma	38.76	27.13	121.24
Hess	D	Riffle/run	Gomphidae	14.53	2.91	40.00
Hess	D	Riffle/run	Gomphus	23.26	6.71	50.00
Hess	D	Riffle/run	Helicopsyche	62.02	20.94	82.73
Hess	D	Riffle/run	Hemerodromia	20.35	2.91	28.57

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	D	Riffle/run	Heptageniidae	81.40		
Hess	D	Riffle/run	Heterocloeon	69.77	58.14	117.85
Hess	D	Riffle/run	Hexatoma	17.44	5.81	47.14
Hess	D	Riffle/run	Hydra	46.51		
Hess	D	Riffle/run	Hydropsyche	111.63	31.33	62.76
Hess	D	Riffle/run	Hydropsychidae	651.16		
Hess	D	Riffle/run	Hydroptila	177.74	51.92	77.29
Hess	D	Riffle/run	Lepidostoma	228.68	101.53	108.75
Hess	D	Riffle/run	Leptophlebiidae	67.83	20.89	75.44
Hess	D	Riffle/run	Leucotrichia	40.70	7.51	36.89
Hess	D	Riffle/run	Lopescladius	248.55	116.07	80.89
Hess	D	Riffle/run	Microtendipes	174.58	75.65	75.05
Hess	D	Riffle/run	Mystacides	11.63		
Hess	D	Riffle/run	Nematoda	212.62	125.33	155.95
Hess	D	Riffle/run	Nilotanypus	79.94		
Hess	D	Riffle/run	Nilothauma	135.34	35.78	45.79
Hess	D	Riffle/run	Nyctiophylax	63.95	14.00	53.63
Hess	D	Riffle/run	Oecetis	220.93	57.79	58.49
Hess	D	Riffle/run	Oligochaeta	308.97	103.25	88.42
Hess	D	Riffle/run	Optioservus	170.54	21.99	31.59
Hess	D	Riffle/run	Parachironomus	65.16	27.37	59.41
Hess	D	Riffle/run	Paracladopelma	206.40		
Hess	D	Riffle/run	Parametriocnemus	220.12	10.10	7.95
Hess	D	Riffle/run	Paratanytarsus	46.27		
Hess	D	Riffle/run	Paratendipes	206.40		
Hess	D	Riffle/run	Perlodidae	69.77	18.26	64.12
Hess	D	Riffle/run	Phaenopsectra	107.07		
Hess	D	Riffle/run	Physella	29.07	17.44	84.85
Hess	D	Riffle/run	Polycentropus	52.33	7.51	28.69
Hess	D	Riffle/run	Polypedilum	142.81	49.49	69.31
Hess	D	Riffle/run	Psectrotanypus	37.79		
Hess	D	Riffle/run	Psychomyia	34.88	4.75	27.22
Hess	D	Riffle/run	Rheotanytarsus	640.42	577.40	156.16
Hess	D	Riffle/run	Sphaeriidae	77.52	33.79	75.50
Hess	D	Riffle/run	Stempellina	915.09	289.91	77.60
Hess	D	Riffle/run	Stempellinella	242.78	95.05	87.54
Hess	D	Riffle/run	Stenelmis	225.91	89.67	105.02
Hess	D	Riffle/run	Stenonema	43.60	20.90	95.84
Hess	D	Riffle/run	Tanytarsus	429.06	213.85	122.08
Hess	D	Riffle/run	Thienemanniella	153.50	38.09	60.78
Hess	D	Riffle/run	Thienemannimyia	689.56	269.79	95.84
Hess	D	Riffle/run	Trichoptera	156.15	49.32	83.57
Hess	D	Riffle/run	Zavrelimyia	206.40		

Appendix 2. Mean number of taxa occurring in stream habitats sampled qualitatively at each sampling location. SE = standard error; CV = coefficient of variation. If SE and CV are blank, the taxon was collected in only one sample at that site.

Gear	Site	Habitat	Taxa	Mean count	SE	CV
Dnet	A	Riffle/run	Acari	4.00		
Dnet	A	Riffle/run	Acroneuria	1.50	0.50	47.14
Dnet	A	Riffle/run	Baetis	4.67	1.45	53.93
Dnet	A	Riffle/run	Boyeria	1.00		
Dnet	A	Riffle/run	Brillia	1.25		
Dnet	A	Riffle/run	Chimarra	1.67	0.67	69.28
Dnet	A	Riffle/run	Collembola	1.00		
Dnet	A	Riffle/run	Cricotopus	1.13	0.08	10.61
Dnet	A	Riffle/run	Cryptochironomus	1.04		
Dnet	A	Riffle/run	Ephemerellidae	1.00		
Dnet	A	Riffle/run	Eukiefferiella	1.21		
Dnet	A	Riffle/run	Ferrissia	1.00		
Dnet	A	Riffle/run	Glossosoma	2.00		
Dnet	A	Riffle/run	Helicopsyche	5.75	2.84	98.76
Dnet	A	Riffle/run	Hemerodromia	1.00		
Dnet	A	Riffle/run	Heterocloeon	3.00	1.00	47.14
Dnet	A	Riffle/run	Hydra	1.00		
Dnet	A	Riffle/run	Hydropsyche	2.00		
Dnet	A	Riffle/run	Hydroptila	2.00	0.58	50.00
Dnet	A	Riffle/run	Lepidostoma	6.00	2.35	78.17
Dnet	A	Riffle/run	Leptophlebiidae	1.50	0.50	47.14
Dnet	A	Riffle/run	Lopescladius	1.96	0.46	40.42
Dnet	A	Riffle/run	Lumbriculida	1.21		
Dnet	A	Riffle/run	Macronychus	3.00		
Dnet	A	Riffle/run	Microcricotopus	1.04		
Dnet	A	Riffle/run	Microtendipes	8.97	1.99	38.44
Dnet	A	Riffle/run	Nematoda	2.00	0.00	0.00
Dnet	A	Riffle/run	Oecetis	3.00	2.00	115.47
Dnet	A	Riffle/run	Oligochaeta	8.00	4.60	115.02
Dnet	A	Riffle/run	Optioservus	8.33	5.90	122.57
Dnet	A	Riffle/run	Parachironomus	4.71	1.48	54.31
Dnet	A	Riffle/run	Parametriocnemus	1.21		
Dnet	A	Riffle/run	Perlodidae	1.00		
Dnet	A	Riffle/run	Phaenopsectra	2.39	1.26	91.36
Dnet	A	Riffle/run	Physella	3.40	1.36	89.69
Dnet	A	Riffle/run	Polypedilum	2.95	1.90	91.35
Dnet	A	Riffle/run	Pteronarcys	1.00		
Dnet	A	Riffle/run	Rhagovelia	8.00	5.04	140.87
Dnet	A	Riffle/run	Rheotanytarsus	6.06		
Dnet	A	Riffle/run	Saetheria	4.80		
Dnet	A	Riffle/run	Sphaeriidae	3.50	1.50	60.61

Appendix 2 (cont).

Gear	Site	Habitat	Taxa	Mean count	SE	CV
Dnet	A	Riffle/run	Stempellina	1.21		
Dnet	A	Riffle/run	Stempellinella	5.45	3.32	105.64
Dnet	A	Riffle/run	Stenelmis	11.33	5.33	81.51
Dnet	A	Riffle/run	Stenochironomus	10.85		
Dnet	A	Riffle/run	Stenonema	1.50	0.50	47.14
Dnet	A	Riffle/run	Tanytarsus	13.30	7.26	94.52
Dnet	A	Riffle/run	Thienemanniella	3.02	0.62	29.00
Dnet	A	Riffle/run	Thienemannimyia	16.79	3.66	30.84
Dnet	A	Riffle/run	Tricorythodes	1.00		
Dnet	B	Riffle/run	Acari	1.00	0.00	0.00
Dnet	B	Riffle/run	Baetis	4.50	1.50	47.14
Dnet	B	Riffle/run	Caenis	1.50	0.50	47.14
Dnet	B	Riffle/run	Cheumatopsyche	1.00	0.00	0.00
Dnet	B	Riffle/run	Cladotanytarsus	25.80		
Dnet	B	Riffle/run	Cricotopus	3.06		
Dnet	B	Riffle/run	Cryptochironomus	30.66	7.80	44.08
Dnet	B	Riffle/run	Ephemerellidae	1.00	0.00	0.00
Dnet	B	Riffle/run	Ephydridae	1.00		
Dnet	B	Riffle/run	Ferrissia	1.00		
Dnet	B	Riffle/run	Glossosoma	4.00		
Dnet	B	Riffle/run	Helicopsyche	1.50	0.50	47.14
Dnet	B	Riffle/run	Hemerodromia	1.00		
Dnet	B	Riffle/run	Heterocloeon	1.00		
Dnet	B	Riffle/run	Hydra	1.50	0.50	47.14
Dnet	B	Riffle/run	Hydroptila	4.33	0.67	26.65
Dnet	B	Riffle/run	Lepidostoma	1.00		
Dnet	B	Riffle/run	Leptoceridae	4.50	3.50	109.99
Dnet	B	Riffle/run	Leptophlebiidae	1.00		
Dnet	B	Riffle/run	Microtendipes	13.02	2.29	24.92
Dnet	B	Riffle/run	Nematoda	1.00		
Dnet	B	Riffle/run	Oecetis	1.00	0.00	0.00
Dnet	B	Riffle/run	Oligochaeta	19.00	9.54	86.96
Dnet	B	Riffle/run	Optioservus	2.00		
Dnet	B	Riffle/run	Pagastiella	4.91	1.84	53.15
Dnet	B	Riffle/run	Parachironomus	5.99	2.61	61.71
Dnet	B	Riffle/run	Paracladopelma	3.38		
Dnet	B	Riffle/run	Phaenopsectra	9.60	7.02	126.52
Dnet	B	Riffle/run	Physella	2.33	1.33	98.97
Dnet	B	Riffle/run	Polypedilum	18.89	15.51	116.15
Dnet	B	Riffle/run	Psectrocladius	3.38		
Dnet	B	Riffle/run	Rhagovelia	10.67	8.69	141.04
Dnet	B	Riffle/run	Rheotanytarsus	8.60		
Dnet	B	Riffle/run	Saetheria	25.08	21.86	150.98
Dnet	B	Riffle/run	Sphaeriidae	1.00	0.00	0.00

Appendix 2 (cont).

Gear	Site	Habitat	Taxa	Mean count	SE	CV
Dnet	B	Riffle/run	Stempellinella	24.04	9.57	68.97
Dnet	B	Riffle/run	Stenelmis	1.67	0.33	34.64
Dnet	B	Riffle/run	Tanytarsus	76.05	15.56	35.44
Dnet	B	Riffle/run	Thienemanniella	10.29	6.91	95.03
Dnet	B	Riffle/run	Thienemannimyia	7.76	2.24	49.94
Dnet	B	Riffle/run	Trichoptera	2.50	1.50	84.85
Dnet	B	Riffle/run	Tricorythodes	1.00		
Dnet	C	Riffle/run	Acari	1.00		
Dnet	C	Riffle/run	Baetis	1.50	0.50	47.14
Dnet	C	Riffle/run	Cheumatopsyche	2.00		
Dnet	C	Riffle/run	Cricotopus	8.03	0.45	7.84
Dnet	C	Riffle/run	Cryptochironomus	53.95	25.26	81.09
Dnet	C	Riffle/run	Dicrotendipes	15.17		
Dnet	C	Riffle/run	Ephemerellidae	1.00		
Dnet	C	Riffle/run	Eukiefferiella	7.58		
Dnet	C	Riffle/run	Gomphus	1.50	0.50	47.14
Dnet	C	Riffle/run	Helicopsyche	12.00		
Dnet	C	Riffle/run	Hemerodromia	2.00		
Dnet	C	Riffle/run	Hydropsyche	2.00		
Dnet	C	Riffle/run	Hydroptila	5.67	1.67	50.94
Dnet	C	Riffle/run	Lepidostoma	2.33	0.88	65.47
Dnet	C	Riffle/run	Leptoceridae	4.00		
Dnet	C	Riffle/run	Leptophlebiidae	2.00		
Dnet	C	Riffle/run	Lopescladius	7.58		
Dnet	C	Riffle/run	Microtendipes	7.90		
Dnet	C	Riffle/run	Nematoda	5.50	0.50	12.86
Dnet	C	Riffle/run	Oecetis	3.00		
Dnet	C	Riffle/run	Oligochaeta	15.00	2.65	30.55
Dnet	C	Riffle/run	Optioservus	1.67	0.67	69.28
Dnet	C	Riffle/run	Parachironomus	12.59	10.16	114.22
Dnet	C	Riffle/run	Paratendipes	7.58		
Dnet	C	Riffle/run	Perlodidae	3.00		
Dnet	C	Riffle/run	Phaenopsectra	36.20	28.62	111.80
Dnet	C	Riffle/run	Physella	4.00	1.15	50.00
Dnet	C	Riffle/run	Polypedilum	23.07	7.27	44.55
Dnet	C	Riffle/run	Psectrocladius	7.58		
Dnet	C	Riffle/run	Rhagovelia	11.67	4.98	73.90
Dnet	C	Riffle/run	Rheotanytarsus	15.80		
Dnet	C	Riffle/run	Rhyacophila	1.00		
Dnet	C	Riffle/run	Saetheria	43.31	2.19	7.14
Dnet	C	Riffle/run	Sphaeriidae	3.00	2.00	94.28
Dnet	C	Riffle/run	Stempellinella	13.36	6.55	84.98
Dnet	C	Riffle/run	Stenelmis	3.67	2.19	103.25
Dnet	C	Riffle/run	Tanytarsus	52.50	27.45	90.54

Appendix 2 (cont).

Gear	Site	Habitat	Taxa	Mean count	SE	CV
Dnet	C	Riffle/run	Thienemannimyia	13.66	5.97	75.66
Dnet	C	Riffle/run	Trichoptera	1.00		
Dnet	D	Riffle/run	Acari	2.00		
Dnet	D	Riffle/run	Acroneuria	1.00		
Dnet	D	Riffle/run	Baetis	3.00	0.58	33.33
Dnet	D	Riffle/run	Brachycentridae	1.00		
Dnet	D	Riffle/run	Caenis	1.75	0.48	54.71
Dnet	D	Riffle/run	Ceraclea	1.00		
Dnet	D	Riffle/run	Cricotopus	16.70	12.55	106.25
Dnet	D	Riffle/run	Cryptochironomus	9.93	2.26	32.20
Dnet	D	Riffle/run	Ephemera	1.00		
Dnet	D	Riffle/run	Eukiefferiella	3.83		
Dnet	D	Riffle/run	Eurylophella	2.00		
Dnet	D	Riffle/run	Ferrissia	2.00	1.00	70.71
Dnet	D	Riffle/run	Glossosoma	1.00		
Dnet	D	Riffle/run	Gomphidae	1.00		
Dnet	D	Riffle/run	Gomphus	2.00		
Dnet	D	Riffle/run	Helicopsyche	3.50	0.50	20.20
Dnet	D	Riffle/run	Heterocloeon	4.00	1.00	35.36
Dnet	D	Riffle/run	Hydropsyche	2.00		
Dnet	D	Riffle/run	Hydroptila	5.67	1.76	53.91
Dnet	D	Riffle/run	Lepidostoma	1.00	0.00	0.00
Dnet	D	Riffle/run	Leucotrichia	1.00		
Dnet	D	Riffle/run	Microtendipes	4.09	1.66	57.22
Dnet	D	Riffle/run	Mystacides	4.50	2.50	78.57
Dnet	D	Riffle/run	Nematoda	1.00		
Dnet	D	Riffle/run	Oecetis	4.00		
Dnet	D	Riffle/run	Oligochaeta	5.00	3.00	103.92
Dnet	D	Riffle/run	Optioservus	2.00		
Dnet	D	Riffle/run	Parachironomus	1.92		
Dnet	D	Riffle/run	Paracladopelma	1.74	0.70	56.92
Dnet	D	Riffle/run	Paratanytarsus	1.92		
Dnet	D	Riffle/run	Perlodidae	1.00		
Dnet	D	Riffle/run	Phaenopsectra	3.04	1.12	52.12
Dnet	D	Riffle/run	Phoridae	1.00		
Dnet	D	Riffle/run	Physella	1.67	0.33	34.64
Dnet	D	Riffle/run	Polypedilum	1.48	0.44	42.03
Dnet	D	Riffle/run	Probezzia	1.00		
Dnet	D	Riffle/run	Psectrocladius	1.92		
Dnet	D	Riffle/run	Psectrotanypus	1.04		
Dnet	D	Riffle/run	Rhagovelia	6.00		
Dnet	D	Riffle/run	Rheotanytarsus	2.08		
Dnet	D	Riffle/run	Saetheria	1.92		
Dnet	D	Riffle/run	Sphaeriidae	1.50	0.50	47.14

Appendix 2 (cont).

Gear	Site	Habitat	Taxa	Mean count	SE	CV
Dnet	D	Riffle/run	Stempellina	4.35	0.52	16.92
Dnet	D	Riffle/run	Stempellinella	20.08	8.17	70.45
Dnet	D	Riffle/run	Stenelmis	4.00	1.15	50.00
Dnet	D	Riffle/run	Stenonema	1.00		
Dnet	D	Riffle/run	Tanytarsus	24.66	11.17	78.43
Dnet	D	Riffle/run	Thienemanniella	1.04		
Dnet	D	Riffle/run	Thienemannimyia	1.74	0.70	56.92
Dnet	D	Riffle/run	Trichoptera	2.00	1.00	70.71
Dnet	D	Riffle/run	Tricorythodes	1.00		