Knife River Macroinvertebrate and Sediment Survey

In support of the Knife River TMDL Study

Prepared for

South Saint Louis Soil and Water Conservation District

By

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Introduction

This effort was conducted as part of the Knife River TMDL (total maximum daily load) study for turbidity, and includes data to compare invertebrate community composition, habitat structure, and sediment deposition among Knife River sites. Macroinvertebrate, stream substrate, water quality, and fish and invertebrate habitat data were collected from five sites along the Knife River and its tributaries in August 2006. The study's objectives were two-fold: first, to collect baseline data from several locations within the Knife River watershed, which is currently listed as impaired for turbidity; and second, to compare these data to historical data from the Knife River watershed and other North Shore streams.

Turbidity and embeddedness affect stream invertebrates and fish by raising water temperature, reducing search distances for visual predators, clogging or abrading delicate gill tissue, filling in interstitial spaces among stream cobbles, and other detrimental effects. To put current data into perspective, Knife River TMDL sample locations were compared to historical samples within the Knife River watershed and other North Shore streams using macroinvertebrate assemblage metrics and, for one set of samples, substrate and water physical parameters. Due to differences in sampling methodology, macroinvertebrate metrics had to be calculated differently for comparison with historical data.

Methods

Study Sites

Knife River TMDL study sites were selected as a collaborative effort between South Saint Louis Soil and Water Conservation District (hereafter SWCD). Sites were sampled in August 2006 and included stream sections near five different stream-road crossings (Fig. 1). Sample locations included established SWCD and Minnesota Pollution Control Agency (MPCA) gauging stations, or were chosen to dissect the watershed into sub-basin units.

Historic datasets used for comparison include macroinvertebrate abundances, substrate composition, and habitat data collected by Valerie Brady and colleagues for a U.S. EPA study during August 1997 and 1998 (Detenbeck et al. 2000). Comparisons were also made with macroinvertebrates collected by Andy Wold and Anne Hershey during August 1998 (Wold and Hershey 1999). Urban streams were excluded from comparisons, leaving the Brady-EPA dataset with 19 North Shore stream sites (including two in the Knife River watershed), and the Hershey (AH) dataset with six North Shore sites (four in the Knife River watershed; Fig. 1).

Habitat characteristics

Habitat data for the Knife River TMDL sites were collected from transects established across the channel perpendicular to flow and from whole-reach observations. A minimum of ten transects were placed at 10 m intervals (100 m minimum reach length) to evaluate substrate characteristics, stream features, bank conditions, and available habitats. A schematic stream reach diagram noting habitat characteristics, and a cross-section diagram at each transect, were completed.

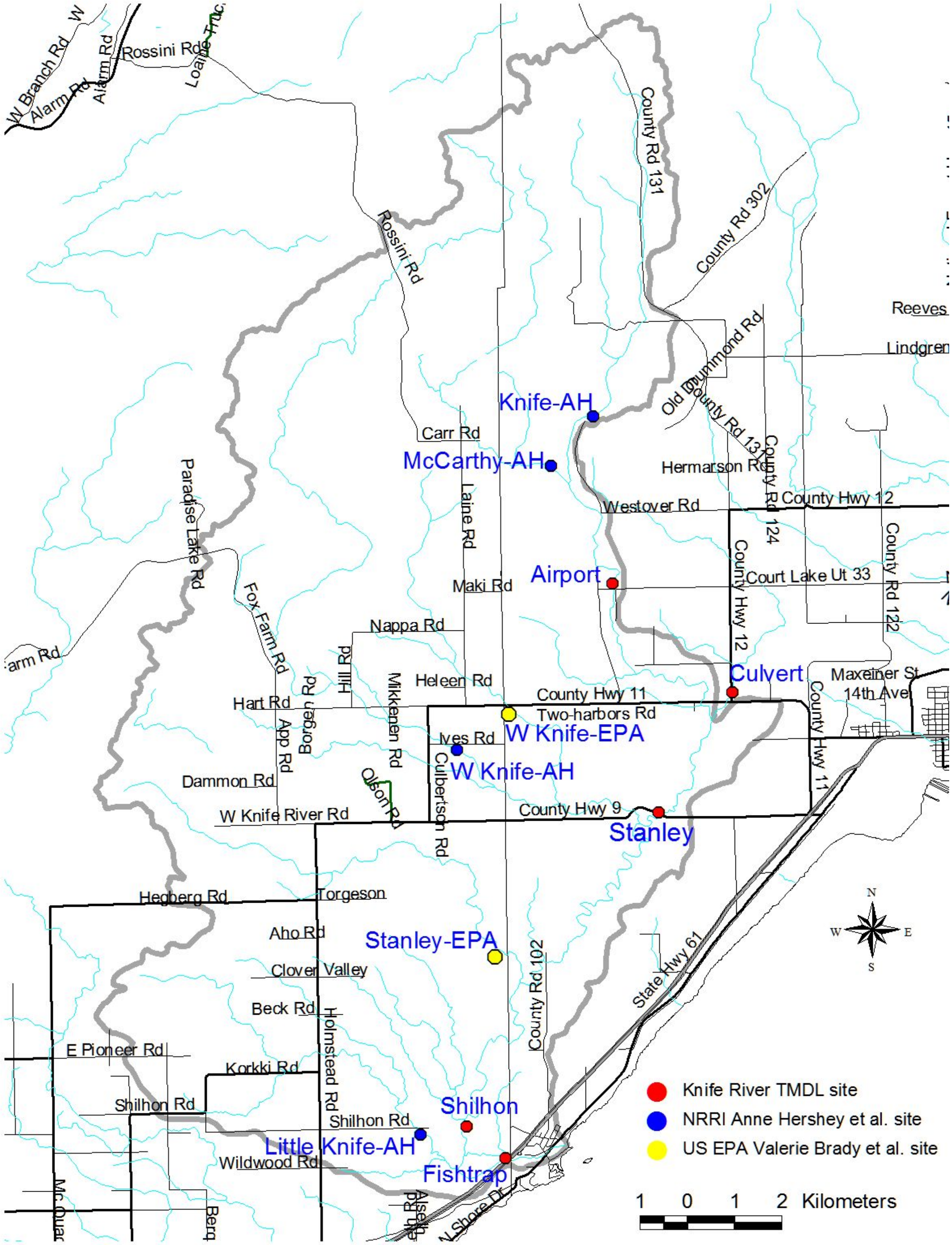

Figure 1. Location of macroinvertebrate sampling locations within the Knife River watershed, color-coded by study. Samples were collected in August 2006 for the TMDL study, 1996 for the Hershey study, and 1997 for the Brady-EPA study.

Transect points

Point estimates were used to evaluate stream features, discharge rates, substrate type and proportional coverage (dominant and sub-dominant particles), substrate embeddedness by fine particles, in-stream habitat cover, bank and riparian condition, and riparian corridor extent. Five points evenly spaced along each transect were used to quantify substrate size categories and composition (percent coverage).

Substrate

Within each grid (25 cm^2), the extent (in percent surface area covered) and types of substrate particles were estimated for dominant and subdominant particles. 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 were embedded by fine particles (sand, silt, and clay) was also estimated (as percent embedded) at 1 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 three 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 total water depth. Instructions for flow-weighted averaging (FWA) are provided in the Marsch-McBirney Flow-mate operator's manual.

In-stream cover

When transect lines intersected in-stream habitat cover, the type, size, and stability were described. Schematic diagrams of 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 qualitative habitat evaluation index (Ohio EPA 1987) to rank overall stream condition was 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 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.

Macroinvertebrate sampling

Benthic samples were collected using a multi-habitat sampling approach (Lenat 1988) during baseflow conditions. Quantitative samples were collected in triplicate from run, riffle, and pool habitats using a modified Hess (0.086 m^2) in riffles or sediment core tube (0.0045 m^2) in shallow depositional areas (App. 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 sediments and aquatic vegetation in run and pool habitats using a D-frame kick net (mesh size: 500 µm; App. 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, 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 a 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 time and volume of material. All samples were ¼, ½, 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

Approximately 300 cm^3 of sediment from each depositional area was composited for each site (typically collected from four to six transects per site). Composite samples (approximately 1200-2000 cm^3 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 cm^3 using a 5 cm (dia.) sediment core. Sub-samples were placed in labeled pans and dried (105° C) to a constant weight determined with a standard balance. Dried samples were ignited for 1 h at 500° 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° C and re-weighed to determine the ash-free dry weight of each sub-sample.

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 (Gordon et al. 1992). Sediment retained in each size fraction was weighed using a standard balance.

Data analyses

Comparison among Knife TMDL sites

Trait characteristics for each invertebrate taxon were derived from a 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 Knife 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 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 abundance of that taxon per sample, summing the resulting products, and dividing by the total number of invertebrates per sample. This was done for riffle samples only because the most sensitive insects typically reside in riffles. Riffle sample scores were then averaged to generate site tolerance scores.

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, there were some differences in sample processing. The Hershey-data include few non-insect taxa, and those included have coarse taxonomic resolution. Thus, invertebrate assemblage metrics had to be re-calculated and based solely on insect taxa. Metrics relying solely or primarily on non-insect taxa were not included in historic comparisons. In addition, fewer insect taxa than expected are included in the Hershey dataset, so comparisons using taxa richness were made with caution. Both the Hershey- and Brady-EPA studies sampled the same location on Skunk Creek, but in different years (1996 and 1997, respectively). Comparison of these two sampling events is encouraged to help illuminate differences due to methods and/or data processing.

Finally, substrate composition data were collected differently between the Knife TMDL and

Hershey- and Brady-EPA study. In the former studies, only dominant and subdominant substrate types were noted in each grid, whereas in the EPA study, all substrate types within each grid were assigned a percent cover to sum to 100%. The resulting data bias makes the Knife TMDL and Hershey 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 between studies. However, percent embeddedness and depth of fine sediments were collected using similar methods during the Knife TMDL and Brady-EPA studies (the Hershey dataset does not include these two variables). 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. Thus, assessments and decisions using such comparisons should be made with caution. In undertaking these analyses, we attempted to correct for biases whenever possible, and to make clear when we felt that bias may still exist.

RESULTS AND DISCUSSION

Habitat Conditions

Knife River sampling sites for the current study included (upstream to downstream) Airport, Culvert, Stanley, Shilhon, and Fishtrap locations (Fig. 1). Study sites included a minimum of 100 m of stream reach, and began at least 50 m from a road crossing or other man-made structures (Table 1). Although the Airport and Stanley sites were in close proximity and similar in size to the Culvert site, habitat conditions were quite different. The Culvert site included an extremely altered riparian habitat (Table 2). Although the stream had incorporated a slight meander and one bank was regenerated with scrub and alder, the opposite bank was a road abutment and maintained ditch. Airport, Stanley, and Shilhon sites exhibited typical meanders. Historic flows, based on total bank width and flood sign (e.g., scours, large wood deposits, debris lodged in standing trees) were also consistent from an upstream to downstream perspective. Total stream widths at the Airport and Culvert sites were only slightly greater than the wetted width measured at baseflow (Table 3). Wetted width to total width comparisons doubled going downstream at Stanley, then tripled at Shilhon and Fishtrap sampling locations. These greater total widths indicate greater flow rates, and the flows impact habitat structure as stream power dramatically increases. This progression was also noted in velocity and discharge measurements, with the Culvert site having the lowest readings which increased at each downstream sampling location (Table 3).

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

			UTM coordinates			Gear Type (n)		
Site	Date	Reach (m)	X	Y	Habitat	Core	D-net	Hess
Airport	8/7/06	100	593901	5212082	Bank		1	
					Riffle			3
					Debris		1	
Culvert	8/7/06	100	596436	5209787	Bank		1	
					Riffle			3
					Debris		1	
Stanley	8/4/06	102.5	594881	5207268	Bank		1	
					Pool	3		
					Run		1	
					Riffle			3
Shilhon	8/4/06	136	590840	5200657	Riffle		1	3
					Run		1	
Fishtrap	8/3/06	100	591646	5199993	Bank		1	
					Riffle			3
					Wood		1	
Grand Total						3	10	15

Table 2. Knife River habitat and riparian zone characteristics for the TMDL sampling locations. Entries divided by a "/" indicate conditions separately for each bank; otherwise the banks are similar. Bank substrate and substrate percent are the percent of the dominant substrate as total bank surface area along transects. Adjacent landuse is that adjacent to the riparian zone. QHEI score was calculated without including the gradient component, worth 10 pts. Undercut bank is the percent occurrence of undercut banks on transects. Amount of organic matter in sediments is expressed as grams dry weight after ashing (Organic). Large woody debris (LWD) are expressed as counts per reach.

Site	Bank Substr	Subs %	Adj landuse	Ripn zone	Ripn width (m)	QHEI score	Under bank (%)	Organic (g)	LWD
Airport	Gravel	54	Forest	Con/Asp	>50	70	35	5.13	100
Culvert	Silt-clay	94	Rd/fldpln	Grass/Ald	0/30	36	10	2.53	0
Stanley	Silt-clay	49	Forest	Con/Asp	>50	64	10	2.60	0
Shilhon	Cobble	73	Forest	Con/Asp	>50	53	0	2.97	0
Fishtrap	Boulder	54	Forest	Con/Asp	>50	61	40	2.73	0

Rd = road; fldpln = floodplain; Ripn = riparian; Con = conifer; Asp = aspen; Ald = alder.

An important consideration when comparing data from various streams and sites are physical differences, such as stream size, velocity, substrate type, and amount of shading. Stream sites in the present study tended to be wider, have shallower depths for their width, and have faster baseflow in riffles than sites from historic datasets (Table 3, Fig. 2). The notable exception was the Culvert site, which had one of the smallest widths and shallowest depths, in part due to its channel alteration into essentially a road drainage ditch (Table 2). We noted a marked difference in average riffle velocities between the Hershey and Knife TMDL sites versus the Brady-EPA sites. While this may indicate real differences among sites, it is also possible there was some inherent difference in the way velocity was measured, may be due to instrumentation differences (the Hershey and Knife TMDL studies used the same velocity meter and setup, which was different from the meter used in the Brady-EPA study), or there may have been a difference in the way the data were summarized.

Stream substrate has a pivotal influence on macroinvertebrate community taxonomic composition and structure. The type of substrate and amount of interstitial space beneath and around large substrate chiefly determines which macroinvertebrate taxa inhabit stream riffles. Flow, temperature, and dissolved oxygen are also important, but are more highly variable and, thus, snapshot measurements of these variables often do not correlate well with macroinvertebrate assemblages. Therefore, we have chosen to concentrate on some substrate comparisons among sites.

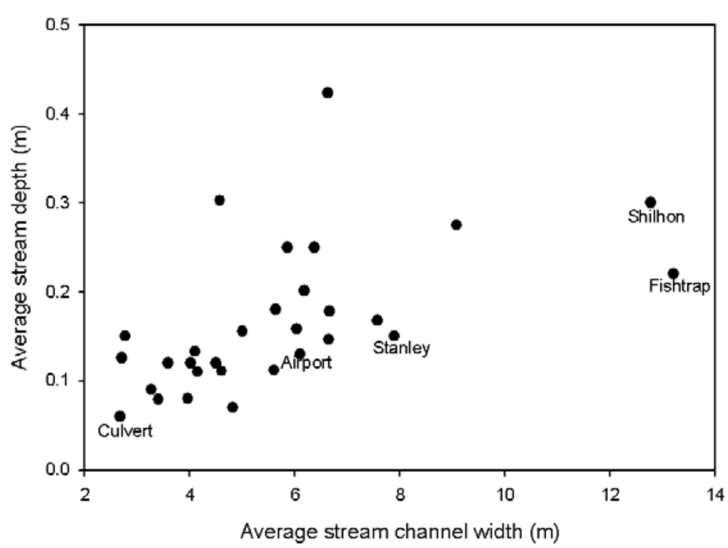

Figure 2. Relationship of stream channel width to depth for 30 North Shore stream sites. Current sites on the Knife River are

Embeddedness, an inverse estimate of the amount of interstitial space available to aquatic invertebrates, fish fry, and fish eggs, is measured as the percent that larger substrates (e.g., boulders, cobbles, and pebbles) are surrounded by fine substrates of sand, silt, and clay. This measurement is notoriously prone to personnel bias, so values are typically estimated only to the nearest 25%. Higher stream velocities keep larger sediment particles in suspension and move them downstream, typically resulting in lower embeddedness. There is a trend toward lower

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 (Knife 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
McCarthy-AH1996	2.7		0.126	0.395	-	43.3
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
Skunk-AH1996	3.4		0.079	0.127	-	81.7
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
Knife-AH1996	4.1		0.133	0.167	-	56.7
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
West Br Knife-AH1996	4.6		0.111	0.242	-	33.3
Encampment-EPA1997	4.82		0.07	0.0161	18.82	13.85
East Split Rock-AH1996	5		0.155	0.143	-	20
Little Knife-AH1996	5.6		0.112	0.085	-	36.7
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
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
Knife-Fishtrap-TMDL2006	13.2	19.02	0.22	0.55	20.95	7.07

embeddedness at sites with higher velocity (Fig. 3), but the relationship is not clear-cut because of differences in erodible material among sites The Culvert and Stanley sites have more erodible banks than other sites (Table 2). Mean embeddedness in riffles at the Knife TMDL sites is within the range of the two other sites within the watershed where such data were collected, and are in the middle to high range overall for the historic data (Table 4, Fig. 3).

Another measurement of the amount of excessive sedimentation in streams is the depth of fine sediments deposited in areas of slower current velocity (such as behind boulders, along bank edges, behind sand bars, etc.). Fine sediment depth measured in depositional areas (e.g., eddies behind in-stream habitats such as boulders) increased from Airport to Culvert to Stanley, then decreased at Shilhon and Fishtrap sites (Table 4). This may be explained by normal processes as the stream picks up and deposits sediment load. Sand and silt deposits were highest at the middle site; such buildup would be expected to continue downstream to the point at which flow becomes adequate to entrain the particles and move them further downstream. Shilhon and Fishtrap sites most likely experience flow regimes strong enough to flush fine sediments, even gravels, farther downstream or out into Lake Superior during high flow events. Fine sediment depth at the Knife TMDL sites was in the middle to high range compared to other sites, and the Airport site is the highest of any site in the dataset.

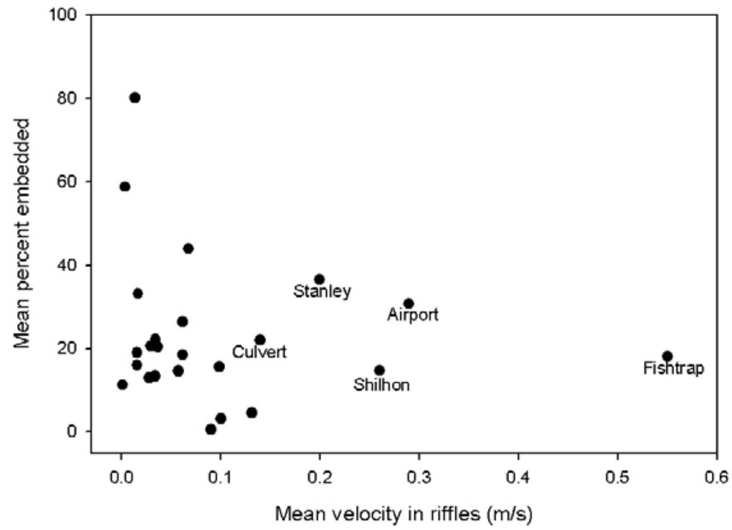

Figure 3. Average riffle velocity versus average amount of riffle embeddedness for North Shore streams. Sites from the current study are labeled.

Size class fractionation of fine sediment deposits at Knife TMDL sites again indicated that Stanley has the highest percentages of all fine sediments (Fig. 4). This indicates that the stream at this point has the least power among sampled TMDL sites to move sediments through the system and has a supply of erodible material (i.e., banks of silt and clay, Table 2). The Shilhon site, consistently had one of the lowest percentages of fine sediments and therefore the highest power to entrain and move these particles resulting in fewer erodible banks Table 2). It is important to note that absence of silt and clay at the Airport site may indicate a lack of clay and other fine-grained materials to be eroded. Instead, embeddedness at this site is primarily from fine sand. Together, these measurements indicate the Knife TMDL sites are experiencing relatively high levels of sedimentation, likely on a par with other streams currently experiencing high turbidity and sedimentation (e.g., Amity Creek, Poplar River).

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 (boulders to pebbles) are surrounded by fine substrates.

Stream-site	Bed (%)	Bldr (%)	Cbl (%)	Pbl (%)	Sand (%)	St/cl (%)	Tfines (%)	Depth Fines (m)	Embed (%)
McCarthy-AH1996	0.0	20	80.0	0.0	0.0	0.0	0.0	-	-
Skunk-AH1996	0.00	33.3	66.70	0.00	0.00	0.00	0.00	-	-
Knife-AH1996	0.0	60	40.0	0.0	0.0	0.0	0.0	-	-
West Br Knife-AH1996	0.0	21.7	65.0	10	0.0	0.0	0.0	-	-
East Split Rock-AH1996	0.00	20	80.00	0.00	0.00	0.00	0.00	-	-
Little Knife-AH1996	0.00	26.7	60.00	13.1	0.00	0.00	0.00	-	-
Caribou-EPA1997	0.0	52.9	38.2	8.8	0.0	0.0	0.0	0.02	15.55
Knife-Fishtrap-TMDL2006	0.00	31.16	66.57	2.27	0.00	0.00	0.00	0.03	18.13
Sucker-EPA1998	0.0	23.0	50.2	26.4	0.4	0.0	0.5	0.00	4.61
Lester2-EPA1997	0.0	3.8	49.5	45.7	0.9	0.0	0.9	0.02	26.4
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
Skunk-EPA1997	0.0	13.6	47.7	36.4	2.3	0.0	2.3	0.1	43.93
Knife-Shilhon-TMDL2006	0.00	28.93	58.24	10.53	2.29	0.00	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	0.00	3.28	52.46	37.27	0.00	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	0.00	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	0.00	0.00	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

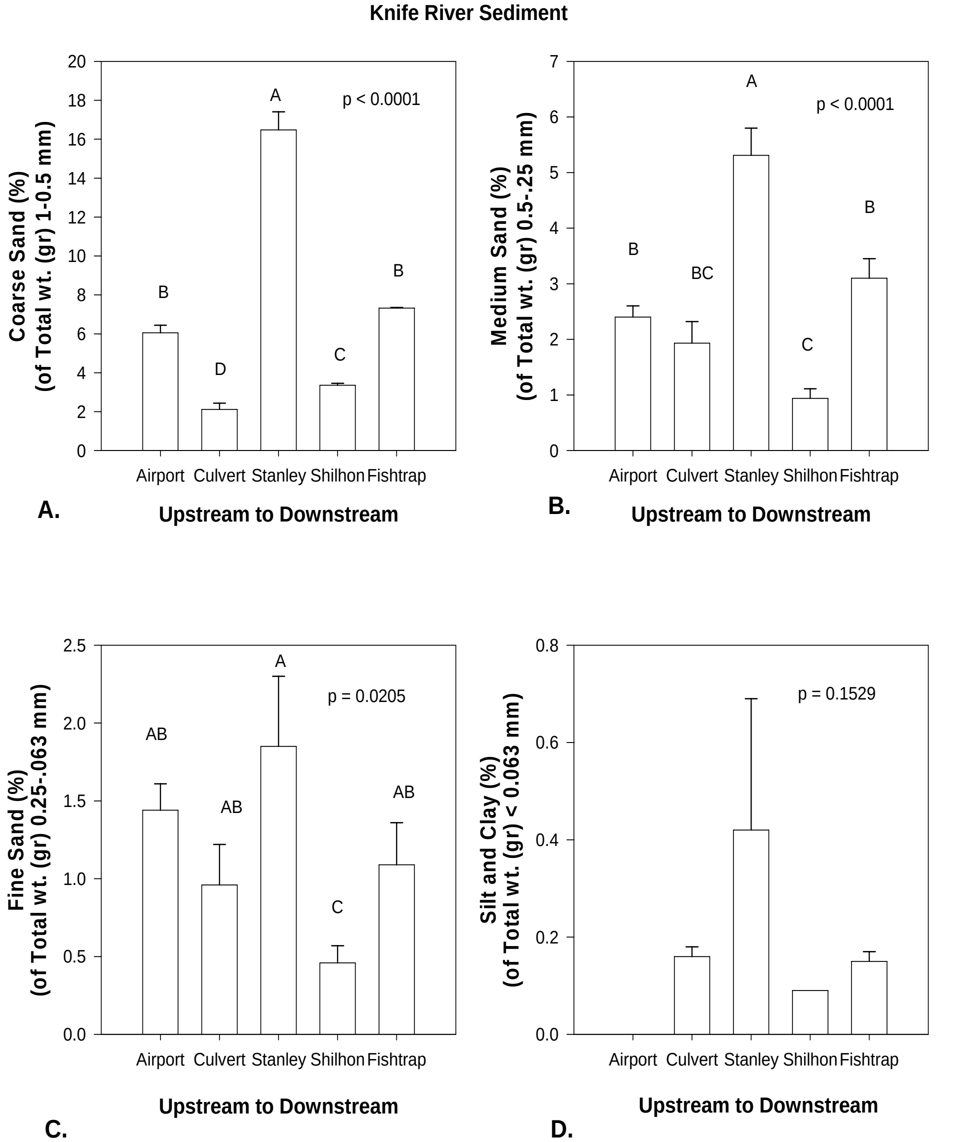

Figure 4. Mean proportion of sediment size particles from the total volume (weight in grams) of fine sediments sampled at locations along the Knife River, MN. Data represent mean proportions ± 1 standard error of A) coarse, B) medium, and C) fine sand, plus D) silt and clay particles. The value of p is from the overall ANOVA. Bars with the same letter are not significantly different based on Tukey's procedure.

Differences in substrate characterization among the studies make matching sites with similar substrate almost impossible across studies (see Methods). Thus, the percentage of fine sediments in Knife TMDL riffle sites is quite likely higher than shown in the present data. Even given these caveats, the Stanley and Culvert TMDL sites have among the highest percentages of fine sediments in their riffles of any measured site (Fig. 5). On the other end of the spectrum, the Fishtrap and Shilhon sites have high amounts of boulders (Fig. 5), in some cases with bedrock beneath them (data not shown). Bedrock stream beds provide less habitat for macroinvertebrates, fish fry, and fish eggs due to the lower amount of interstitial space. Consequently, streams with high amounts of bedrock can share similarities in invertebrate assemblages with streams in which the substrate is embedded. Because bedrock was a subdominant rather than dominant feature of the downstream Knife sites, it is unclear how much of an effect its presence had on the macroinvertebrates.

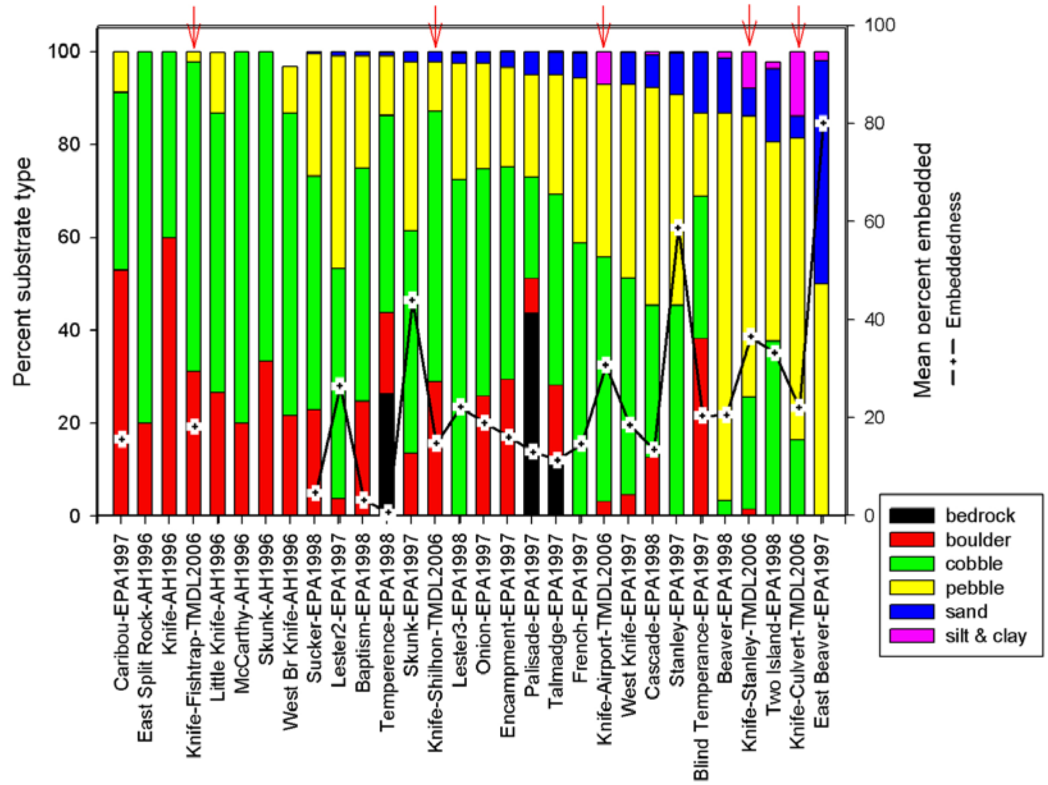

Figure 5. Average percent substrate types in riffles for North Shore streams, with average percent riffle embeddedness shown as dashed lines with + symbols. Sites from the current study marked with red arrows. See Methods for description of substrate sampling differences among studies.

Notable habitat differences among the Knife TMDL study sites included substantial amounts of large woody debris (LWD) at the upstream Airport site, with an apparent lack of debris at the remaining locations. The riparian vegetation at the Airport site was primarily a contiguous, mature conifer/aspen stand. A difference in woody debris deposits can be attributed to two potential factors: 1) stream flow (indicated above), and 2) riparian vegetation. Large riparian woody vegetation was lacking at the Culvert site, which consisted of a maintained ditch on one bank, and a heavily vegetated bank on the other (Table 2). Riparian vegetation was primarily composed of alder clumps (less than 10 cm dia.). Allochthanous inputs at the Culvert site could easily be transported downstream by high flows due to the channelized design. Although the stream channels at the remaining sites appeared natural, and abundant forest existed on both banks at each site, LWD was only noted as deposits on the bank or gravel bar (e.g., Shilhon and Fishtrap), and not intersecting stream flow. Therefore, these materials were present, with ample supply available, but were not incorporated into stream processes during base flow conditions. Thus, this LWD was not included in the total count. It is likely the stream power at these sites was great enough to keep LWD from accumulating in the active channel, resulting in a loss of this habitat type for macroinvertebrates and as fish cover. It is probable that such power represents an increase over pre-logging conditions, as has been shown for other area streams (Fitzpatrick and

Knox 2000). Canopy cover, measured as proportion of the stream channel that was shaded, steadily declined from upstream to downstream, with the Airport site being 75% shaded and the Fishtrap site only 7% shaded (Table 3). The Airport site sediments also contained significantly more organic matter than other sites (ANOVA $p < 0.01$; Table 2), in keeping with greater canopy cover and more LWD in the channel. Finally, fish habitat assessment (QHEI) scores were highest (best) at the Airport site and lowest (worst) at the Culvert site, indicating poor habitat quality at this site (Table 2). Differences among the sites included amount of cover, LWD, and sinuosity, channel shape, and condition of riffles/runs (extremely low for the Culvert site). Organic particles embedding larger substrates should have less effect on macroinvertebrates because they can be more easily moved about or burrowed through. However, these particles do still decrease habitat space.

Table 5. Knife River TMDL site water chemistry measurements. Water clarity values were all significantly different from each other (ANOVA $p < 0.05$).

Site	Temp (°C)	Scond (us/s)	DO (%)	DO (mg/L)	pH	ORP	Clarity (cm)
Airport	20.47	136	105.4	9.49	7.63	202.3	>120[a]
Culvert	18.95	138	81.8	7.56	6.46	259.9	52.1[e]
Stanley	20.99	124	106.3	9.45	7.26	235.6	91.0[b]
Shilhon	20.53	110	78.3	6.62	6.12	273	74.3[c]
Fishtrap	20.95	104	104.0	9.33	7.19	n/a	68.1[d]

Water chemistry parameters were similar among sites, although water clarity among sites was significantly different (Table 5). Transparency tube readings were highest at the Airport site, substantially lower at the Culvert site, came back up for the Stanley site, but declined again at the two downstream sites. A large storm system came through the area on July 29 and 30, 2006, dropping over 2 inches of rain on areas of the North Shore (www.lakesuperiorstreams.org). The low clarity values may be due to this high water event, but it is important to note that even eight days postrainfall, the Culvert site still had quite low water clarity. This indicates substantial erosion problems at the Culvert site and presumably at some upstream reaches or tributaries above the Shilhon and Fishtrap sites.

Macroinvertebrates

Use of macroinvertebrate community information to assess stream ecosystem condition relies on the varying sensitivities of the different taxa to the variety of different stressors to which they may be subjected. Because of the differences in methods and identification among studies, we calculated some of the metrics separately for the Knife TMDL sites so as to take advantage of greater taxonomic resolution and inclusion of non-insect taxa (Table 6). Metrics for comparison with the historic data were calculated using only insect taxa (Table 7).

Some of the most sensitive taxa are found in the Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) orders of insects. We calculated the proportion of EPT individuals from all macroinvertebrates (Table 6) or insects (Table 7) collected from riffles in the various stream studies. Proportions at the Knife TMDL sites were all at the lower end of the range for

Table 6. Knife River TMDL site macroinvertebrate metrics generated from quantitative riffle samples. Numbers represent mean values (± 1 standard error). Metric values with letters indicate a significant test result ($p \leq 0.05$). Means with the same letter were not different based on Tukey's comparison.

Invertebrate metrics	Airport	Culvert	Stanley	Shilhon	Fishtrap
Proportion EPT indiv.	36.5 (8.47)	15.3 (6.10)	22.6 (7.34)	27.2 (5.93)	25.2 (3.63)
Count of sensitive taxa	10.6 (2.18)[ab]	7 (0.57)[ab]	8 (1.00)[ab]	11.3 (1.20)[a]	5.6 (1.20)[b]
Percent tolerant indiv.	28.7 (6.98)[ab]	23.5 (3.07)[ab]	13.5 (3.64)[b]	20.3 (1.47)[b]	42.2 (3.4)[a]
Percent Tanytarsini (of Chironomidae)	37.5 (5.87)	43.9 (7.66)	51.9 (5.61)	66.6 (7.27)	48.6 (11.3)
Percent burrowers	9.2 (2.21)	11.3 (1.71)	24.2 (6.46)	9.6 (2.21)	13.6 (4.70)
Percent climbers	12.6 (1.29)[b]	17.7 (2.68)[b]	15.5 (3.11)[b]	42.5 (2.10)[a]	39.4 (3.74)[a]
Percent clingers	56.6 (2.84)	47.7 (3.52)	28.9 (12.0)	28.2 (2.70)	31.0 (2.45)
Percent collector-filterers	35.2 (7.29)	21.8 (2.67)	27.2 (10.8)	19.3 (1.85)	14.4 (0.50)
Percent collector-gatherers	33.2 (1.42)	43.0 (7.50)	36.6 (7.71)	44.2 (2.59)	47.5 (2.27)
Percent predators	12.5 (1.88)	14.5 (2.03)	26.9 (5.46)	15.3 (1.30)	24.7 (1.07)
Percent scraper-grazers	8.8 (1.45)[a]	10.8 (3.14)[a]	2.0 (0.83)[b]	7.4 (0.68)[a]	5.9 (0.47)[a]
Percent shredders	9.5 (5.91)	2.4 (0.21)	3.8 (2.03)	8.0 (0.64)	3.4 (1.34)
Site Tolerance Score	5.2 (0.21)[ab]	5.5 (0.03)[a]	5.2 (0.01)[ab]	4.5 (0.31)[b]	5.4 (0.23)[a]

North Shore streams, with the Culvert site having the lowest at only 19% (Fig. 6). In contrast, Hershey reported 80% or more EPT individuals for sites on the Little Knife and McCarthy Creek. The number of EPT taxa is another commonly used indicator of invertebrate community condition. However, due to the differences in taxonomy among studies, this indicator is not a good one for comparison. For example, the Brady-EPA study found 24 EPT taxa at exactly the same site where, in the same month the previous year, the Hershey study reported only 13 EPT taxa (Table 7). It is unlikely that environmental conditions improved greatly in just a year, especially since percent EPT was not appreciably different between the two sampling events. For similar reasons, we were unable to use the number of sensitive taxa in historic comparisons. Among the Knife TMDL sites, EPT taxa richness and sensitive taxa richness were highest at the Shilhon site and lowest at the Airport site (Table 6).

One genus of stream stonefly, Pteronarcys, is occasionally used to indicate stream condition and habitat and food resource stability. Pteronarcids are large, shredder stoneflies that take several years to reach maturity in northern streams, and do best in cool, well-oxygenated water (Merritt and Cummins 1996). They feed by shredding deciduous tree leaves that fall into streams, and thus are not found in stream areas that lack deciduous trees nearby or upstream. Approximately ⅓ of North Shore streams contained Pteronarcys stoneflies, including the Airport site, the Brady-EPA Stanley Creek site, and the Hershey West Branch of the Knife site (Table 7).

Table 7. Metrics calculated using riffle insect taxa collected from North Shore streams. Current study sites in blue. See Methods for description of other studies. “Taxa” indicate richness counts. “Tol score” is site tolerance score. “Sensit” is number of sensitive taxa; “% Tol” is percentage of tolerant insects in samples (tolerance values ≥7); “Pteronarcys” is presence or absence of the stonefly Pteronarcys at sites. “Hydropsych” is proportion of Trichoptera from the family Hydropsychidae.

Stream-site	Taxa	Insect taxa	EPT taxa	% EPT	Tol score	Sensit	% Tol	Ptero-narcys	Hydro-psych
Knife-Culvert-TMDL2006	27.3	22	9.7	19.1	4.70	6.30	4.30	A	0.81
Cascade-EPA1998	49	39	24	25.9	5.30	19.00	1.00	P	0.19
Stanley-EPA1997	40	33	23	26.3	5.30	12.70	16.00	P	0.40
Knife-Shilhon-TMDL2006	28.7	24	16.3	30.5	5.20	9.00	3.60	A	0.71
Encampment-EPA1997	43	33	23	31.2	4.40	12.70	0.40	P	0.45
Knife-Fishtrap-TMDL2006	24	20	13.7	32.9	5.20	4.70	12.00	A	0.36
West Knife-EPA1997	32	26	19	32.9	3.30	11.00	0.00	A	0.34
Knife-Stanley-TMDL2006	27.7	21	13.7	38.3	5.00	7.00	0.30	A	0.92
Knife-AH1996	22	21	15	40.0	3.10	7.70	0.00	A	0.31
French-EPA1997	36	27	18	41.0	4.70	16.00	3.00	A	0.89
Knife-Airport-TMDL2006	28	24	14.3	42.4	4.70	10.00	5.20	P	0.58
Baptism-EPA1998	45	38	26	42.9	4.30	22.00	0.90	A	0.67
Temperence-EPA1998	32	26	16	47.8	4.70	13.00	0.80	A	0.62
Caribou-EPA1997	41	33	23	51.6	4.10	14.70	0.70	A	0.35
Sucker-EPA1998	38	33	24	53.1	4.30	20.00	2.20	P	0.60
Lester2-EPA1997	41	33	20	53.4	3.10	14.00	0.50	A	0.20
Beaver-EPA1998	42	36	27	54.3	4.20	19.00	7.00	A	0.41
Two Island-EPA1998	38	30	21	56.2	3.60	19.00	6.20	P	0.46
West Br Knife-AH1996	17	17	11	56.7	3.30	5.70	0.00	P	0.17
East Beaver-EPA1997	34	29	17	57.0	3.50	13.70	1.10	A	0.90
Skunk-EPA1997	46	40	24	58.0	3.60	14.70	1.40	P	0.42
Lester3-EPA1998	43	37	23	59.3	4.40	20.00	3.00	A	0.86
Skunk-AH1996	20	19	13	59.9	3.70	5.70	1.70	A	0.42
Blind Temperance-EPA1997	36	29	21	63.8	3.30	9.70	0.90	A	0.46
Talmadge-EPA1997	29	20	15	66.9	3.50	7.30	0.70	P	0.46
Onion-EPA1997	29	23	16	71.0	2.70	9.70	0.50	A	0.31
Palisade-EPA1997	33	25	15	72.3	2.80	8.00	1.20	A	0.13
McCarthy-AH1996	21	20	12	79.9	1.70	8.00	0.00	A	0.12
Little Knife-AH1996	12	12	8	82.2	3.50	3.70	0.00	A	0.79
East Split Rock-AH1996	18	17	13	82.5	1.90	6.00	2.10	A	0.22

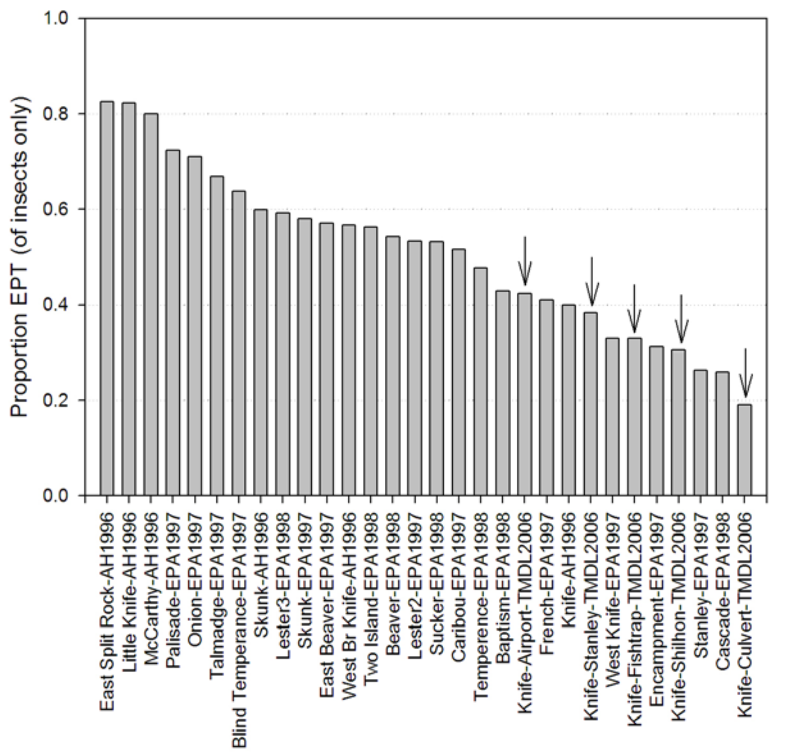

Figure 6. Proportion of insects in the orders Ephemeroptera, Plecoptera, and Trichoptera in North Shore stream riffles. Sites from current study marked with arrows.

Of course, not all species within the EPT orders are highly sensitive to environmental stress. A family of net-spinning caddisflies (the Hydropsychidae) is among the more tolerant of the Trichopera. Calculating the percentage of Trichoptera that are Hydropsychidae is a metric recommended by the U.S. EPA for stream assessment (Barbour et al. 1999). At three of the Knife TMDL sites, most of the caddisflies were in the family Hydropsychidae (Table 7; Fig. 7). However, the Fishtrap and Airport sites were exceptions with lower proportions of hydropsychids. Several sites had high proportions of Hydropsychidae, including; Lester River 3 (a third-order Lester River site), East Beaver River, French River, and Little Knife. Hydropsychidae construct spun-silk retreats that include nets; these retreats are attached to rocks in the current in riffles, and the insects use the nets to capture particles carried by the current, which they eat. High numbers of hydropsychid caddisflies are considered indicative of nutrient enrichment. Large amounts of sedimentation would potentially clog or bury their nets, but we did not find a correlation between proportion Hydropsychidae and percent embeddedness.

Other insects, such as the Diptera family Chironomidae (non-biting midges), are considered even more tolerant of stressors. In particular, some members of this group have hemoglobin to help them remove oxygen from the water under low oxygen conditions. Proportions of Chironomidae at Knife TMDL sites were among the highest of the three studies for non-urban North Shore streams (Fig. 8), indicating stressful conditions. Other Chironomidae, in particular the family Tanytarsini, spin nets to filter food from the current and have the potential to be adversely affected by both turbidity and sedimentation. The proportion of Tanytarsini comprising the Chironomidae was highest at the Shilhon site and lowest at the Airport site (Table 6). This likely reflects increasing amounts of nutrients and food particles in the water at downstream sites, rather than any impact of sediments or turbidity. The low percent of Tanytarsini at the Fishtrap site may indicate poor habitat.

Comparing major taxonomic groups of insects among sites causes one of the Knife TMDL sites to stand out from the others. The Culvert site contained a much higher proportion of Coleoptera than was reported for any other site (Fig. 8). The channel alteration of this site, lack of a true pool-riffle and meander structure, and its slow flow probably account for this marked difference.

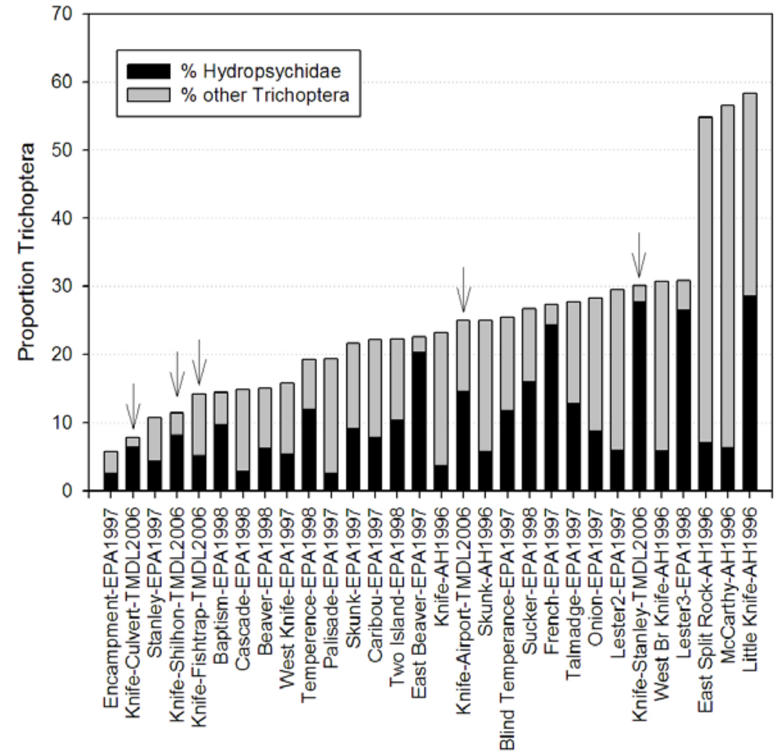

Figure 7. Percent of riffle insect community comprised of Trichopera, and percent of Trichoptera in the family Hydropsychidae, in North Shore streams. Current study sites marked by arrows.

Potential tolerance scores range from 0 to 10, with higher scores indicating that the insects are more tolerant of various types of stress, including nutrient enrichment, low dissolved oxygen, some chemical pollutants, and sedimentation and turbidity. Comparing the percent of tolerant insects in riffles (those with tolerance values of 7 and higher) among sites shows a now-familiar pattern, with most of the Knife TMDL sites having a higher percentage of tolerant individuals than was found in other North Shore streams (Fig. 9, Tables 6 and 7). Although some of the variation may be due to differences in taxonomy among studies, the two Skunk Creek sampling events cluster close together in this analysis, suggesting that taxonomic variability had little influence.

When tolerance scores were calculated for entire sites using insects collected from riffles, the Knife TMDL sites clustered tightly together within the overall comparison among stream samples (Fig. 9). Again, the close proximity of the two Skunk Creek samples suggests taxonomic differences among studies did not have a large effect, and that the differences among sites are due to true differences in the insect communities. Tolerance scores for Knife TMDL sites ranged from 4.7 to 5.2 (4.5 – 5.5 based on all macroinvertebrates, Table 6), while non-urban North Shore streams had a range of 1.7 to 5.3 (Table 7, Fig. 9). Sites within the Knife River watershed covered that entire range, with the Hershey-McCarthy site having the lowest (best) score at 1.7 and the Brady-EPA Stanley site having the highest (worst) at 5.3.

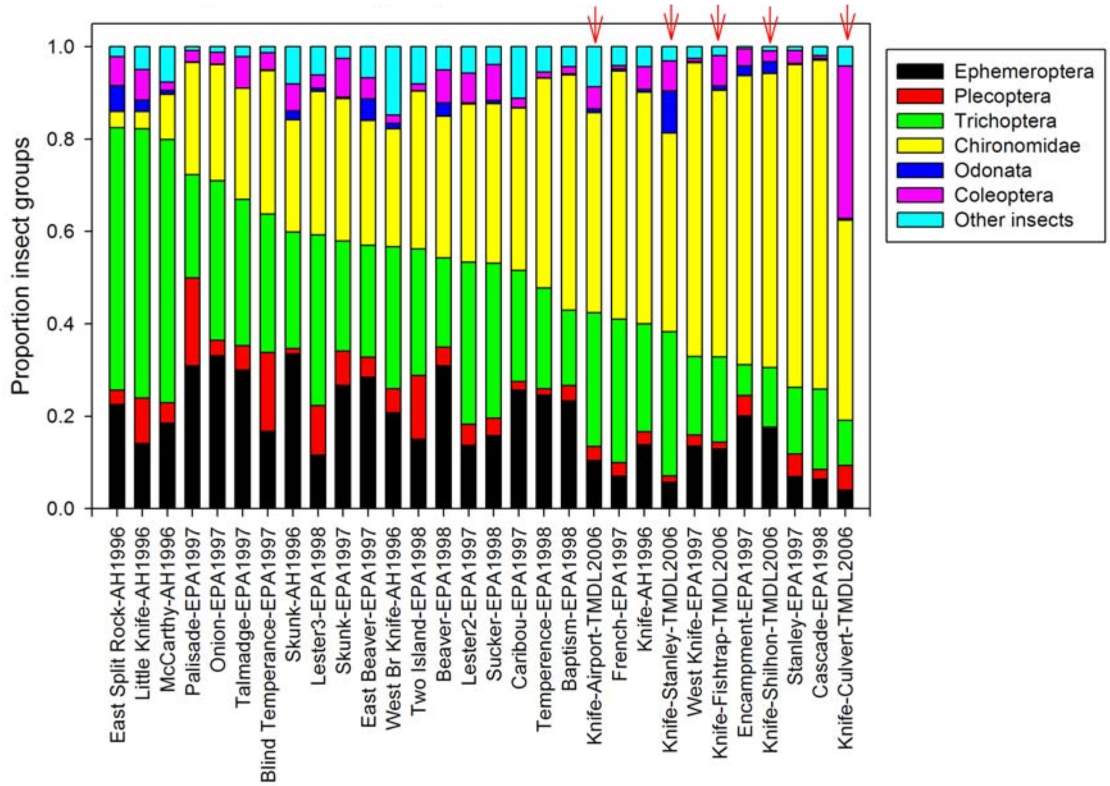

Figure 8. Proportion of taxonomic groups making up riffle insect communities in North Shore streams. Current study sites marked with arrows.

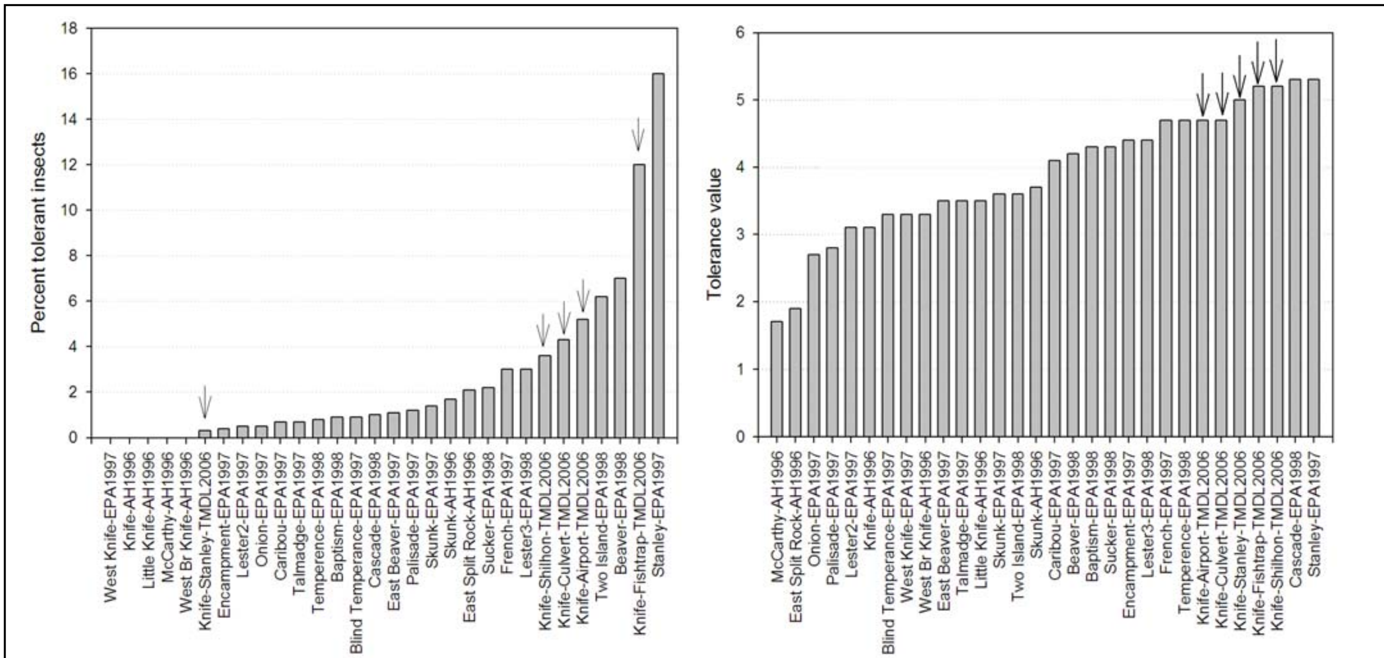

Figure 9. (left) Percent of "tolerant" insects in North Shore stream riffles. (Right) Tolerance score for North Shore stream sites based on riffle insects. Current study sites marked with arrows.

Another set of metrics used with macroinvertebrates assesses various traits that the invertebrates exhibit. These include; how and on what the taxa feed, how they move about, and how long they live, etc. Insects considered “clingers” cling to rocks in riffles in the current; many of these insects need interstitial space among the riffle rocks to find food particles, escape from predators, and find refuge from the current. As space around rocks becomes filled with sediment, clingers lose habitat and become less abundant. Most mayflies, stoneflies, and caddisflies are considered clingers, so this metric is also sensitive to nutrient pollution and low dissolved oxygen conditions. The proportion of clinger insects at Knife TMDL sites is in the lower half of the range reported from North Shore stream sites (Fig. 10). The Airport and Culvert sites have the highest proportion of clingers among the Knife TMDL sites. The beetles (Coleoptera) at the culvert site are considered clingers, which explains why this site looks less degraded than would be expected based on other metric values.

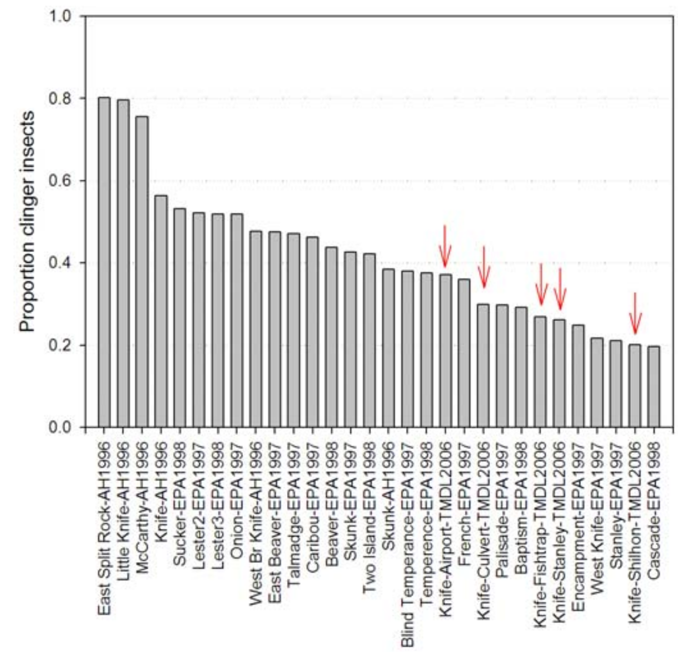

Figure 10. Proportion of insect community considered “clingers” in North Shore stream riffles.

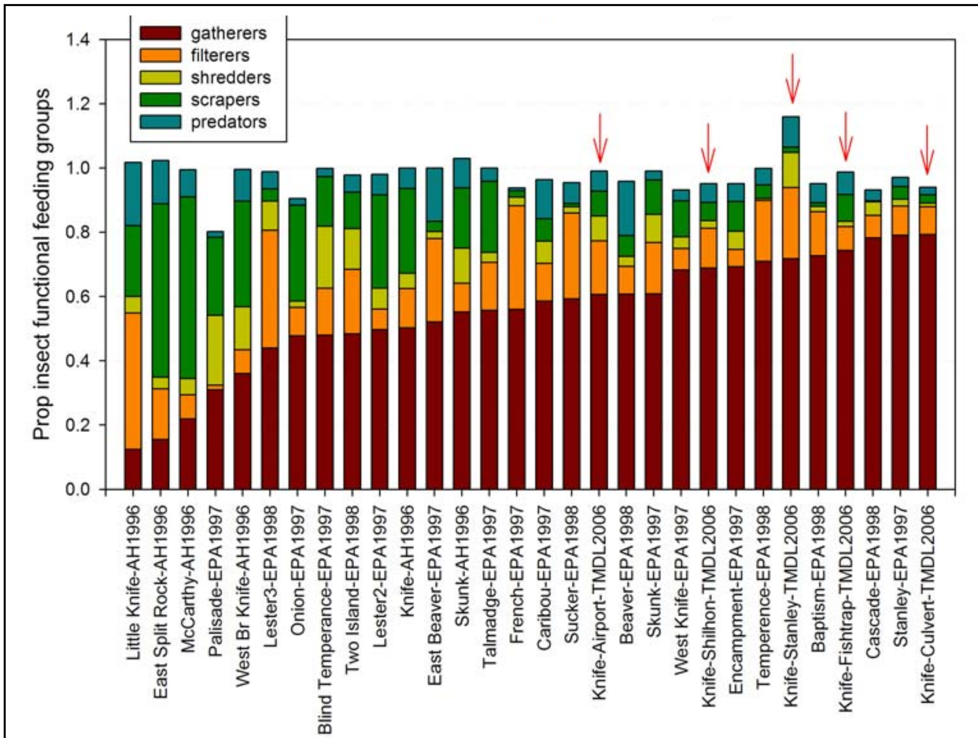

Figure 11. Functional feeding groups if insects in North Shore stream riffles. Proportions do not always add up to 1 because of lack of information on some groups, or due to lumping of taxa.

Comparing sites based on insect trophic groups shows that Knife TMDL sites tend to have more gatherers than average for North Shore streams (Fig. 11). Insects that eat many types of food would be expected to be more tolerant of stressful conditions than their more resource-specific counterparts such as carnivores. Herbivorous insects, particularly those that scrape algae off of rocks, would not be expected to thrive in high-sedimentation conditions, and the proportion of grazers reported for Knife TMDL sites was lower than for many other North Shore streams (Fig. 11). Grazers proportions were highest at the more open Culvert site, and they may be getting nutrients from the sediment eroding into the stream. The low proportion of grazers at the Stanley site may reflect its high embeddedness, forested banks, and land cover. There was a trend toward lower proportion grazers with increased riffle embeddedness (Fig. 12), but there were too few highly embedded sites to show this strongly. Grazer amounts can also be affected by amount of stream shading (which would limit algal growth), but we found no correlation or trend when plotting proportion grazers vs. stream canopy cover measurements (data not shown).

SUMMARY AND CONCLUSIONS

The Airport and Shilhon sites are in the best condition of the Knife TMDL sites, with Airport representing the smaller tributaries and Shilhon representing the better of the large stream sites. Overall, embeddedness levels are high enough at most Knife TMDL sites that we would predict effects on macroinvertebrates. Plots of percent riffle embeddedness versus various insect community measures that would be expected to show such effects, in fact show very little correlation. However, these same metrics indicate that sites within the Knife River watershed, and in particular those sampled for this study, have insect communities indicative of sites that are of a poorer condition than those at other North Shore stream sites. Although it is likely that the true differences among sites are not as extreme as they appear because of the spread in time of the sampling events and the differences in methodology, these data do suggest that the invertebrates at the Knife TMDL sites are experiencing enough stress to alter their community structure. Thus, the invertebrates at these sites are likely responding to a variety of stresses, only one of which is embeddedness. The Fishtrap site in particular is likely experiencing the cumulative effects of a variety of upstream stressors. On the other hand, turbidity and embeddedness may be having more of an effect on macroinvertebrate communities than we can currently demonstrate. We recommend that the Hershey sites on the Little Knife, McCarthy, and West Knife be re-sampled and evaluated as potential reference sites for the Knife system, in comparison with the Airport site from this study. Continued efforts should be made to add historic invertebrate, substrate, and turbidity data from the Knife River watershed and similar streams to better calibrate current Knife River biotic conditions evaluated in this study.

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Appendix 1. Mean number of taxa per square meter occurring in habitats at each sampling location. SE = standard error; CV = coefficient of variation.

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Airport	Riffle	Acari	2739.13	630.560	0.399
Hess	Airport	Riffle	Acroneuria	565.22	319.499	0.979
Hess	Airport	Riffle	Antocha	507.25	251.440	0.859
Hess	Airport	Riffle	Atherix	43.48	na	na
Hess	Airport	Riffle	Baetidae	456.52	53.250	0.202
Hess	Airport	Riffle	Bezzia	652.17	na	na
Hess	Airport	Riffle	Brachycentrus	434.78	212.999	0.849
Hess	Airport	Riffle	Cardiocladius	1720.11	na	na
Hess	Airport	Riffle	Ceratopogonidae	173.91	na	na
Hess	Airport	Riffle	Cheumatopsyche	594.20	233.239	0.680
Hess	Airport	Riffle	Collembola	217.39	35.500	0.283
Hess	Airport	Riffle	Cricotopus	1751.23	1042.352	1.031
Hess	Airport	Riffle	Dolophilodes	173.91	na	na
Hess	Airport	Riffle	Empididae	173.91	na	na
Hess	Airport	Riffle	Epeorus	43.48	na	na
Hess	Airport	Riffle	Eukiefferiella	2585.74	720.695	0.483
Hess	Airport	Riffle	Eurylophella	304.35	35.500	0.202
Hess	Airport	Riffle	Ferrissia	333.33	181.594	0.944
Hess	Airport	Riffle	Glossosoma	3028.99	2246.938	1.285
Hess	Airport	Riffle	Glossosomatidae	43.48	na	na
Hess	Airport	Riffle	Gomphidae	449.28	268.410	1.035
Hess	Airport	Riffle	Hemerodromia	173.91	na	na
Hess	Airport	Riffle	Hydropsyche	7173.91	3824.440	0.923
Hess	Airport	Riffle	Hydropsychidae	6347.83	71.000	0.019
Hess	Airport	Riffle	Leptophlebiidae	2782.61	1239.194	0.771
Hess	Airport	Riffle	Leuctra	1913.04	na	na
Hess	Airport	Riffle	Limnephilidae	217.39	na	na
Hess	Airport	Riffle	Lopescladius	1320.01	537.793	0.706
Hess	Airport	Riffle	Microtendipes	1146.74	na	na
Hess	Airport	Riffle	Nematoda	898.55	358.824	0.692
Hess	Airport	Riffle	Nigronia	260.87	175.715	1.167
Hess	Airport	Riffle	Oligochaeta	3536.23	1423.171	0.697
Hess	Airport	Riffle	Ophiogomphus	43.48	na	na
Hess	Airport	Riffle	Optioservus	2304.35	821.881	0.618
Hess	Airport	Riffle	Paragnetina	130.43	71.000	0.943
Hess	Airport	Riffle	Paraleptophlebia	347.83	na	na
Hess	Airport	Riffle	Parametriocnemus	428.44	118.333	0.478
Hess	Airport	Riffle	Paratanytarsus	573.37	na	na
Hess	Airport	Riffle	Physella	173.91	na	na
Hess	Airport	Riffle	Plecoptera	413.04	230.749	0.968
Hess	Airport	Riffle	Polypedilum	1416.63	605.313	0.740
Hess	Airport	Riffle	Protoptila	869.57	na	na
Hess	Airport	Riffle	Pseudocloeon	347.83	na	na

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Airport	Riffle	Psychomyia	86.96	na	na
Hess	Airport	Riffle	Pteronarcys	130.43	71.000	0.943
Hess	Airport	Riffle	Pycnopsyche	43.48	na	na
Hess	Airport	Riffle	Rheotanytarsus	3550.11	499.665	0.244
Hess	Airport	Riffle	Sialis	130.43	71.000	0.943
Hess	Airport	Riffle	Simulium	2463.77	2021.362	1.421
Hess	Airport	Riffle	Stempellinella	283.51	na	na
Hess	Airport	Riffle	Stenonema	1333.33	463.768	0.602
Hess	Airport	Riffle	Synorthocladius	397.08	92.723	0.404
Hess	Airport	Riffle	Tanytarsus	4567.93	951.840	0.361
Hess	Airport	Riffle	Thienemanniella	1676.17	891.716	0.921
Hess	Airport	Riffle	Thienemannimyia	1720.11	na	na
Hess	Airport	Riffle	Trichoptera	869.57	177.499	0.354
Hess	Culvert	Riffle	Acari	2000.00	1134.885	0.983
Hess	Culvert	Riffle	Acroneuria	43.48	0.000	0.000
Hess	Culvert	Riffle	Antocha	86.96	na	na
Hess	Culvert	Riffle	Bezzia	782.61	354.999	0.786
Hess	Culvert	Riffle	Boyeria	86.96	35.500	0.707
Hess	Culvert	Riffle	Caenis	869.57	695.652	1.386
Hess	Culvert	Riffle	Cheumatopsyche	2811.59	787.558	0.485
Hess	Culvert	Riffle	Chrysops	86.96	0.000	0.000
Hess	Culvert	Riffle	Cricotopus	1523.85	652.438	0.742
Hess	Culvert	Riffle	Dicranota	391.30	248.499	1.100
Hess	Culvert	Riffle	Dicrotendipes	1373.19	na	na
Hess	Culvert	Riffle	Dubiraphia	347.83	71.000	0.354
Hess	Culvert	Riffle	Elmidae	7304.35	1561.993	0.370
Hess	Culvert	Riffle	Endochironomus	225.54	na	na
Hess	Culvert	Riffle	Ephemera	43.48	na	na
Hess	Culvert	Riffle	Erpobdellidae	43.48	na	na
Hess	Culvert	Riffle	Eukiefferiella	1022.64	98.364	0.167
Hess	Culvert	Riffle	Ferrissia	5884.06	2750.418	0.810
Hess	Culvert	Riffle	Gomphidae	86.96	0.000	0.000
Hess	Culvert	Riffle	Helicopsyche	239.13	124.249	0.900
Hess	Culvert	Riffle	Hemerodromia	130.43	35.500	0.471
Hess	Culvert	Riffle	Hexatoma	86.96	na	na
Hess	Culvert	Riffle	Hydrophilidae	86.96	na	na
Hess	Culvert	Riffle	Hydropsyche	637.68	466.478	1.267
Hess	Culvert	Riffle	Hydropsychidae	260.87	na	na
Hess	Culvert	Riffle	Larsia	798.61	289.386	0.628
Hess	Culvert	Riffle	Limnephilidae	217.39	na	na
Hess	Culvert	Riffle	Lopescladius	225.54	na	na
Hess	Culvert	Riffle	Micropsectra	1143.12	na	na
Hess	Culvert	Riffle	Microtendipes	1373.19	na	na
Hess	Culvert	Riffle	Nematoda	391.30	175.715	0.778
Hess	Culvert	Riffle	Oligochaeta	6188.41	3059.619	0.856

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Culvert	Riffle	Ophiogomphus	43.48	na	na
Hess	Culvert	Riffle	Optioservus	15188.41	9002.567	1.027
Hess	Culvert	Riffle	Paragnetina	130.43	na	na
Hess	Culvert	Riffle	Paraleptophlebia	1695.65	1100.495	1.124
Hess	Culvert	Riffle	Parametriocnemus	1413.50	687.440	0.842
Hess	Culvert	Riffle	Paratanytarsus	686.59	na	na
Hess	Culvert	Riffle	Paratendipes	686.59	na	na
Hess	Culvert	Riffle	Perlidae	173.91	na	na
Hess	Culvert	Riffle	Physella	173.91	0.000	0.000
Hess	Culvert	Riffle	Plecoptera	1797.10	853.966	0.823
Hess	Culvert	Riffle	Polypedilum	1064.31	204.903	0.333
Hess	Culvert	Riffle	Procladius	225.54	na	na
Hess	Culvert	Riffle	Pseudolimnophila	173.91	na	na
Hess	Culvert	Riffle	Psychomyia	434.78	283.999	1.131
Hess	Culvert	Riffle	Rheotanytarsus	686.59	na	na
Hess	Culvert	Riffle	Sialis	152.17	88.750	1.010
Hess	Culvert	Riffle	Simulium	695.65	437.672	1.090
Hess	Culvert	Riffle	Sphaeriidae	260.87	na	na
Hess	Culvert	Riffle	Stempellina	571.56	na	na
Hess	Culvert	Riffle	Stempellinella	2476.15	1076.053	0.753
Hess	Culvert	Riffle	Stenelmis	884.06	142.737	0.280
Hess	Culvert	Riffle	Stenonema	478.26	106.500	0.386
Hess	Culvert	Riffle	Tanypus	624.09	42.896	0.119
Hess	Culvert	Riffle	Tanytarsus	9709.54	3656.982	0.652
Hess	Culvert	Riffle	Thienemannimyia	2054.95	1034.647	0.872
Hess	Culvert	Riffle	Trichoptera	86.96	0.000	0.000
Hess	Culvert	Riffle	Zavrelimyia	1672.40	537.005	0.556
Hess	Fishtrap	Riffle	Ablabesmyia	345.11	na	na
Hess	Fishtrap	Riffle	Acari	3782.61	739.557	0.339
Hess	Fishtrap	Riffle	Acroneuria	152.17	17.750	0.202
Hess	Fishtrap	Riffle	Antocha	202.90	101.449	0.866
Hess	Fishtrap	Riffle	Baetis	152.17	17.750	0.202
Hess	Fishtrap	Riffle	Bezzia	86.96	na	na
Hess	Fishtrap	Riffle	Caenis	1260.87	230.065	0.316
Hess	Fishtrap	Riffle	Cardiocladius	157.61	na	na
Hess	Fishtrap	Riffle	Cheumatopsyche	565.22	239.460	0.734
Hess	Fishtrap	Riffle	Chimarra	43.48	0.000	0.000
Hess	Fishtrap	Riffle	Cladotanytarsus	423.91	217.437	0.888
Hess	Fishtrap	Riffle	Corynoneura	345.11	na	na
Hess	Fishtrap	Riffle	Cricotopus	461.05	216.565	0.814
Hess	Fishtrap	Riffle	Cryptochironomus	345.11	na	na
Hess	Fishtrap	Riffle	Dicrotendipes	1217.39	656.155	0.934
Hess	Fishtrap	Riffle	Elmidae	782.61	na	na
Hess	Fishtrap	Riffle	Ephemeroptera	673.91	53.250	0.137
Hess	Fishtrap	Riffle	Eukiefferiella	146.74	na	na

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Fishtrap	Riffle	Eurylophella	43.48	na	na
Hess	Fishtrap	Riffle	Ferrissia	86.96	na	na
Hess	Fishtrap	Riffle	Glossosoma	43.48	na	na
Hess	Fishtrap	Riffle	Gomphidae	144.93	14.493	0.173
Hess	Fishtrap	Riffle	Helicopsyche	666.67	188.406	0.489
Hess	Fishtrap	Riffle	Hemerodromia	130.43	na	na
Hess	Fishtrap	Riffle	Hexatoma	43.48	na	na
Hess	Fishtrap	Riffle	Hydropsyche	637.68	233.239	0.634
Hess	Fishtrap	Riffle	Hydroptila	65.22	17.750	0.471
Hess	Fishtrap	Riffle	Isonychia	43.48	0.000	0.000
Hess	Fishtrap	Riffle	Leptoceridae	43.48	na	na
Hess	Fishtrap	Riffle	Limnephilidae	43.48	na	na
Hess	Fishtrap	Riffle	Lopescladius	345.11	na	na
Hess	Fishtrap	Riffle	Microtendipes	534.42	78.465	0.254
Hess	Fishtrap	Riffle	Nematoda	173.91	0.000	0.000
Hess	Fishtrap	Riffle	Oecetis	898.55	247.652	0.477
Hess	Fishtrap	Riffle	Oligochaeta	710.14	623.694	1.521
Hess	Fishtrap	Riffle	Optioservus	652.17	156.763	0.416
Hess	Fishtrap	Riffle	Parametriocnemus	423.91	217.437	0.888
Hess	Fishtrap	Riffle	Physella	65.22	17.750	0.471
Hess	Fishtrap	Riffle	Plecoptera	282.61	124.249	0.761
Hess	Fishtrap	Riffle	Polycentropus	43.48	na	na
Hess	Fishtrap	Riffle	Polypedilum	146.74	na	na
Hess	Fishtrap	Riffle	Pseudocloeon	43.48	0.000	0.000
Hess	Fishtrap	Riffle	Rheotanytarsus	692.03	145.909	0.365
Hess	Fishtrap	Riffle	Stempellina	4122.28	1609.460	0.676
Hess	Fishtrap	Riffle	Stempellinella	694.75	208.788	0.521
Hess	Fishtrap	Riffle	Stenelmis	231.88	88.156	0.658
Hess	Fishtrap	Riffle	Stenonema	318.84	167.139	0.908
Hess	Fishtrap	Riffle	Tanypus	345.11	na	na
Hess	Fishtrap	Riffle	Tanytarsus	1214.67	608.880	0.868
Hess	Fishtrap	Riffle	Thienemannimyia	245.92	80.984	0.570
Hess	Fishtrap	Riffle	Trichoptera	478.26	106.500	0.386
Hess	Shilhon	Riffle	Acari	3362.32	751.949	0.387
Hess	Shilhon	Riffle	Acroneuria	173.91	106.500	1.061
Hess	Shilhon	Riffle	Antocha	65.22	17.750	0.471
Hess	Shilhon	Riffle	Baetidae	666.67	76.688	0.199
Hess	Shilhon	Riffle	Baetis	115.94	28.986	0.433
Hess	Shilhon	Riffle	Bezzia	347.83	na	na
Hess	Shilhon	Riffle	Boyeria	43.48	na	na
Hess	Shilhon	Riffle	Caenis	826.09	109.418	0.229
Hess	Shilhon	Riffle	Cheumatopsyche	2782.61	1094.179	0.681
Hess	Shilhon	Riffle	Chimarra	43.48	na	na
Hess	Shilhon	Riffle	Cladotanytarsus	412.14	na	na
Hess	Shilhon	Riffle	Cricotopus	2817.33	214.523	0.132

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Shilhon	Riffle	Cryptochironomus	412.14	na	na
Hess	Shilhon	Riffle	Curculionidae	43.48	na	na
Hess	Shilhon	Riffle	Dicranota	86.96	na	na
Hess	Shilhon	Riffle	Dicrotendipes	1648.55	na	na
Hess	Shilhon	Riffle	Ephemerellidae	86.96	na	na
Hess	Shilhon	Riffle	Ephemeroptera	782.61	na	na
Hess	Shilhon	Riffle	Erpobdellidae	86.96	na	na
Hess	Shilhon	Riffle	Ferrissia	202.90	115.942	0.990
Hess	Shilhon	Riffle	Gomphidae	1101.45	331.438	0.521
Hess	Shilhon	Riffle	Helicopsyche	130.43	na	na
Hess	Shilhon	Riffle	Hemerodromia	43.48	na	na
Hess	Shilhon	Riffle	Heptageniidae	2971.01	1278.570	0.745
Hess	Shilhon	Riffle	Hexatoma	86.96	0.000	0.000
Hess	Shilhon	Riffle	Hydropsyche	782.61	301.226	0.667
Hess	Shilhon	Riffle	Hydropsychidae	753.62	370.062	0.851
Hess	Shilhon	Riffle	Hydroptila	43.48	na	na
Hess	Shilhon	Riffle	Isonychia	3239.13	1721.743	0.921
Hess	Shilhon	Riffle	Laevapex	43.48	na	na
Hess	Shilhon	Riffle	Larsia	642.21	na	na
Hess	Shilhon	Riffle	Lepidostoma	1695.65	na	na
Hess	Shilhon	Riffle	Leucrocuta	1289.86	471.182	0.633
Hess	Shilhon	Riffle	Lopescladius	692.03	na	na
Hess	Shilhon	Riffle	Microtendipes	667.12	20.338	0.053
Hess	Shilhon	Riffle	Nanocladius	642.21	na	na
Hess	Shilhon	Riffle	Nematoda	681.16	355.294	0.903
Hess	Shilhon	Riffle	Nyctiophylax	86.96	na	na
Hess	Shilhon	Riffle	Oecetis	884.06	365.781	0.717
Hess	Shilhon	Riffle	Oligochaeta	1420.29	642.112	0.783
Hess	Shilhon	Riffle	Ophiogomphus	152.17	17.750	0.202
Hess	Shilhon	Riffle	Optioservus	717.39	337.249	0.814
Hess	Shilhon	Riffle	Parametriocnemus	812.80	293.248	0.625
Hess	Shilhon	Riffle	Paratendipes	642.21	na	na
Hess	Shilhon	Riffle	Phaenopsectra	692.03	na	na
Hess	Shilhon	Riffle	Polycentropus	86.96	na	na
Hess	Shilhon	Riffle	Polypedilum	1705.16	867.897	0.882
Hess	Shilhon	Riffle	Procladius	692.03	na	na
Hess	Shilhon	Riffle	Pseudocloeon	202.90	63.172	0.539
Hess	Shilhon	Riffle	Psychomyia	101.45	38.344	0.655
Hess	Shilhon	Riffle	Rheotanytarsus	1455.01	623.596	0.742
Hess	Shilhon	Riffle	Stempellina	14057.97	2946.283	0.363
Hess	Shilhon	Riffle	Stempellinella	1548.91	633.275	0.708
Hess	Shilhon	Riffle	Stenelmis	434.78	260.870	1.039
Hess	Shilhon	Riffle	Synorthocladius	692.03	na	na
Hess	Shilhon	Riffle	Tanytarsus	3518.57	517.336	0.255
Hess	Shilhon	Riffle	Thienemanniella	1284.42	na	na

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Shilhon	Riffle	Thienemannimyia	758.15	53.989	0.123
Hess	Shilhon	Riffle	Tipulidae	695.65	na	na
Hess	Shilhon	Riffle	Trichoptera	420.29	185.031	0.763
Hess	Shilhon	Riffle	Tricorythodes	173.91	na	na
Core	Stanley	Pool	Acari	518.52	74.074	0.247
Core	Stanley	Pool	Baetidae	222.22	na	na
Core	Stanley	Pool	Caenis	2370.37	296.296	0.217
Core	Stanley	Pool	Calopterygidae	222.22	na	na
Core	Stanley	Pool	Cladotanytarsus	7828.46	955.055	0.211
Core	Stanley	Pool	Corixidae	222.22	na	na
Core	Stanley	Pool	Cricotopus	611.11	na	na
Core	Stanley	Pool	Cryptochironomus	1135.96	428.541	0.653
Core	Stanley	Pool	Cryptotendipes	859.16	202.533	0.408
Core	Stanley	Pool	Dubiraphia	666.67	181.444	0.471
Core	Stanley	Pool	Ephemeroptera	888.89	na	na
Core	Stanley	Pool	Eurylophella	222.22	na	na
Core	Stanley	Pool	Ferrissia	444.44	na	na
Core	Stanley	Pool	Larsia	553.61	na	na
Core	Stanley	Pool	Leptoceridae	888.89	na	na
Core	Stanley	Pool	Lopescladius	796.30	na	na
Core	Stanley	Pool	Microcricotopus	1222.22	na	na
Core	Stanley	Pool	Mystacides	444.44	na	na
Core	Stanley	Pool	Nematoda	740.74	74.074	0.173
Core	Stanley	Pool	Oligochaeta	555.56	272.166	0.849
Core	Stanley	Pool	Optioservus	444.44	na	na
Core	Stanley	Pool	Pagastiella	11493.50	3249.657	0.490
Core	Stanley	Pool	Paracladopelma	674.95	99.078	0.254
Core	Stanley	Pool	Paratendipes	553.61	na	na
Core	Stanley	Pool	Probezzia	777.78	272.166	0.606
Core	Stanley	Pool	Procladius	611.11	na	na
Core	Stanley	Pool	Pseudochironomus	4982.46	na	na
Core	Stanley	Pool	Saetheria	1307.34	146.438	0.194
Core	Stanley	Pool	Stempellina	1388.24	536.264	0.669
Core	Stanley	Pool	Stempellinella	1022.74	323.486	0.548
Core	Stanley	Pool	Stenonema	444.44	na	na
Core	Stanley	Pool	Stictochironomus	3518.52	378.008	0.186
Core	Stanley	Pool	Tanytarsus	1838.21	674.307	0.635
Core	Stanley	Pool	Zavrelimyia	2768.03	na	na
Hess	Stanley	Riffle	Acari	5246.38	1807.415	0.597
Hess	Stanley	Riffle	Acroneuria	652.17	106.500	0.283
Hess	Stanley	Riffle	Antocha	4043.48	1281.933	0.549
Hess	Stanley	Riffle	Baetidae	1608.70	816.497	0.879
Hess	Stanley	Riffle	Baetis	43.48	na	na
Hess	Stanley	Riffle	Boyeria	43.48	na	na

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Stanley	Riffle	Caecidotea	173.91	na	na
Hess	Stanley	Riffle	Caenis	347.83	na	na
Hess	Stanley	Riffle	Calopterygidae	173.91	na	na
Hess	Stanley	Riffle	Cheumatopsyche	35797.10	14774.344	0.715
Hess	Stanley	Riffle	Cladotanytarsus	2285.33	na	na
Hess	Stanley	Riffle	Cricotopus	7284.76	1724.022	0.410
Hess	Stanley	Riffle	Empididae	173.91	na	na
Hess	Stanley	Riffle	Ephemeroptera	2608.70	851.996	0.566
Hess	Stanley	Riffle	Eukiefferiella	5687.50	911.902	0.278
Hess	Stanley	Riffle	Ferrissia	3594.20	1480.249	0.713
Hess	Stanley	Riffle	Glossosoma	43.48	na	na
Hess	Stanley	Riffle	Gomphidae	13768.12	5725.518	0.720
Hess	Stanley	Riffle	Helicopsyche	173.91	na	na
Hess	Stanley	Riffle	Helisoma	43.48	na	na
Hess	Stanley	Riffle	Hemerodromia	717.39	550.248	1.329
Hess	Stanley	Riffle	Heptageniidae	521.74	na	na
Hess	Stanley	Riffle	Hydropsyche	9989.13	7381.818	1.280
Hess	Stanley	Riffle	Hydropsychidae	6608.70	2981.988	0.782
Hess	Stanley	Riffle	Hydroptilidae	173.91	0.000	0.000
Hess	Stanley	Riffle	Isonychia	478.26	212.999	0.771
Hess	Stanley	Riffle	Larsia	969.42	134.430	0.240
Hess	Stanley	Riffle	Lepidostoma	1217.39	na	na
Hess	Stanley	Riffle	Leptophlebiidae	3884.06	1030.515	0.460
Hess	Stanley	Riffle	Lopescladius	3889.14	813.925	0.362
Hess	Stanley	Riffle	Nematoda	695.65	265.657	0.661
Hess	Stanley	Riffle	Nigronia	369.57	17.750	0.083
Hess	Stanley	Riffle	Oecetis	173.91	na	na
Hess	Stanley	Riffle	Oligochaeta	2753.62	942.029	0.593
Hess	Stanley	Riffle	Ophiogomphus	985.51	276.504	0.486
Hess	Stanley	Riffle	Optioservus	8681.16	1581.703	0.316
Hess	Stanley	Riffle	Parametriocnemus	1134.06	na	na
Hess	Stanley	Riffle	Physella	173.91	na	na
Hess	Stanley	Riffle	Plecoptera	1565.22	100.409	0.111
Hess	Stanley	Riffle	Polycentropodidae	347.83	na	na
Hess	Stanley	Riffle	Polycentropus	173.91	na	na
Hess	Stanley	Riffle	Polypedilum	3194.12	861.103	0.467
Hess	Stanley	Riffle	Psychomyia	695.65	425.998	1.061
Hess	Stanley	Riffle	Rheotanytarsus	15769.13	6209.969	0.682
Hess	Stanley	Riffle	Simulium	695.65	na	na
Hess	Stanley	Riffle	Sphaeriidae	43.48	na	na
Hess	Stanley	Riffle	Stempellina	1944.57	406.963	0.362
Hess	Stanley	Riffle	Stempellinella	3620.88	694.555	0.332
Hess	Stanley	Riffle	Stenonema	4695.65	1987.992	0.733
Hess	Stanley	Riffle	Stratiomyidae	43.48	na	na
Hess	Stanley	Riffle	Tanypus	1609.55	na	na

Appendix 1 (cont).

Gear	Site	Habitat	Taxa	Abundance (#/m^2)	SE	CV
Hess	Stanley	Riffle	Tanytarsus	26196.43	14329.938	0.947
Hess	Stanley	Riffle	Thienemannimyia	1134.06	na	na
Hess	Stanley	Riffle	Trichoptera	2333.33	1368.549	1.016
Hess	Stanley	Riffle	Turbellaria	521.74	141.999	0.471

Appendix 2. Mean number of taxa occurring in stream habitats sampled qualitatively at each sampling location.

Type	Site	Habitat	Taxa	Mean Count
Dnet	Airport	Bank	Brachycentrus	1.00
Dnet	Airport	Bank	Calopteryx	2.00
Dnet	Airport	Bank	Cladotanytarsus	2.33
Dnet	Airport	Bank	Corynoneura	2.33
Dnet	Airport	Bank	Cricotopus	2.33
Dnet	Airport	Bank	Curculionidae	2.00
Dnet	Airport	Bank	Ferrissia	2.00
Dnet	Airport	Bank	Leptophlebiidae	2.00
Dnet	Airport	Bank	Nematoda	2.00
Dnet	Airport	Bank	Oecetis	2.00
Dnet	Airport	Bank	Oligochaeta	10.00
Dnet	Airport	Bank	Ophiogomphus	1.00
Dnet	Airport	Bank	Optioservus	2.00
Dnet	Airport	Bank	Paratendipes	2.33
Dnet	Airport	Bank	Polypedilum	14.00
Dnet	Airport	Bank	Pycnopsyche	2.00
Dnet	Airport	Bank	Rheotanytarsus	7.00
Dnet	Airport	Bank	Sphaeriidae	12.00
Dnet	Airport	Bank	Stempellinella	11.67
Dnet	Airport	Bank	Tanytarsus	4.67
Dnet	Airport	Bank	Thienemanniella	2.33
Dnet	Airport	Bank	Trichoptera	6.00
Dnet	Airport	Wood	Acari	4.00
Dnet	Airport	Wood	Antocha	4.00
Dnet	Airport	Wood	Baetidae	4.00
Dnet	Airport	Wood	Bezzia	12.00
Dnet	Airport	Wood	Eukiefferiella	11.79
Dnet	Airport	Wood	Ferrissia	4.00
Dnet	Airport	Wood	Gomphidae	4.00
Dnet	Airport	Wood	Hydropsyche	12.00
Dnet	Airport	Wood	Leptophlebiidae	4.00
Dnet	Airport	Wood	Leuctra	8.00
Dnet	Airport	Wood	Microtendipes	3.93
Dnet	Airport	Wood	Nanocladius	3.93
Dnet	Airport	Wood	Nigronia	12.00
Dnet	Airport	Wood	Oligochaeta	42.00
Dnet	Airport	Wood	Ophiogomphus	1.00
Dnet	Airport	Wood	Optioservus	4.00
Dnet	Airport	Wood	Orthocladius	7.86
Dnet	Airport	Wood	Parametriocnemus	11.79
Dnet	Airport	Wood	Polypedilum	39.29
Dnet	Airport	Wood	Rheotanytarsus	11.79
Dnet	Airport	Wood	Stempellinella	3.93
Dnet	Airport	Wood	Stenochironomus	7.86

Appendix 2 (cont).

Type	Site	Habitat	Taxa	Mean Count
Dnet	Airport	Wood	Stenonema	4.00
Dnet	Airport	Wood	Tanytarsus	3.93
Dnet	Airport	Wood	Thienemannimyia	3.93
Dnet	Airport	Wood	Trichoptera	20.00
Dnet	Culvert	Bank	Acroneuria	1.00
Dnet	Culvert	Bank	Aeshnidae	1.00
Dnet	Culvert	Bank	Calopterygidae	2.00
Dnet	Culvert	Bank	Collembola	12.00
Dnet	Culvert	Bank	Cricotopus	6.58
Dnet	Culvert	Bank	Dicrotendipes	9.88
Dnet	Culvert	Bank	Dixella	2.00
Dnet	Culvert	Bank	Dubiraphia	15.00
Dnet	Culvert	Bank	Ephemerellidae	2.00
Dnet	Culvert	Bank	Hydropsyche	2.00
Dnet	Culvert	Bank	Hygrotus	2.00
Dnet	Culvert	Bank	Larsia	9.88
Dnet	Culvert	Bank	Leptophlebia	8.00
Dnet	Culvert	Bank	Limnephilidae	2.00
Dnet	Culvert	Bank	Microtendipes	3.29
Dnet	Culvert	Bank	Oligochaeta	2.00
Dnet	Culvert	Bank	Paracymus	6.00
Dnet	Culvert	Bank	Paraleptophlebia	1.00
Dnet	Culvert	Bank	Parametriocnemus	3.29
Dnet	Culvert	Bank	Paratanytarsus	13.17
Dnet	Culvert	Bank	Phaenopsectra	6.58
Dnet	Culvert	Bank	Physella	2.00
Dnet	Culvert	Bank	Polypedilum	55.96
Dnet	Culvert	Bank	Pycnopsyche	1.00
Dnet	Culvert	Bank	Rheotanytarsus	6.58
Dnet	Culvert	Bank	Simulium	2.00
Dnet	Culvert	Bank	Stenochironomus	3.29
Dnet	Culvert	Bank	Tanypus	3.29
Dnet	Culvert	Bank	Tanytarsus	36.21
Dnet	Culvert	Bank	Triaenodes	2.00
Dnet	Culvert	Wood/Pool	Ablabesmyia	1.12
Dnet	Culvert	Wood/Pool	Caenis	5.00
Dnet	Culvert	Wood/Pool	Chironomus	1.12
Dnet	Culvert	Wood/Pool	Cladotanytarsus	1.12
Dnet	Culvert	Wood/Pool	Collembola	1.00
Dnet	Culvert	Wood/Pool	Cryptotendipes	1.12
Dnet	Culvert	Wood/Pool	Dicrotendipes	4.49
Dnet	Culvert	Wood/Pool	Dubiraphia	1.00
Dnet	Culvert	Wood/Pool	Eukiefferiella	1.12
Dnet	Culvert	Wood/Pool	Ferrissia	9.00
Dnet	Culvert	Wood/Pool	Glyptotendipes	1.12
Dnet	Culvert	Wood/Pool	Larsia	4.49

Appendix 2 (cont).

Type	Site	Habitat	Taxa	Mean Count
Dnet	Culvert	Wood/Pool	Leptophlebiidae	1.00
Dnet	Culvert	Wood/Pool	Mystacides	3.00
Dnet	Culvert	Wood/Pool	Oligochaeta	1.00
Dnet	Culvert	Wood/Pool	Ophiogomphus	1.00
Dnet	Culvert	Wood/Pool	Paratanytarsus	2.24
Dnet	Culvert	Wood/Pool	Polypedilum	4.49
Dnet	Culvert	Wood/Pool	Sphaeriidae	1.00
Dnet	Culvert	Wood/Pool	Stempellinella	4.49
Dnet	Culvert	Wood/Pool	Stenelmis	1.00
Dnet	Culvert	Wood/Pool	Stenochironomus	3.37
Dnet	Culvert	Wood/Pool	Tanypus	1.12
Dnet	Culvert	Wood/Pool	Tanytarsus	7.85
Dnet	Culvert	Wood/Pool	Thienemannimyia	6.73
Dnet	Fishtrap	Bank	Baetis	4.00
Dnet	Fishtrap	Bank	Caenis	1.00
Dnet	Fishtrap	Bank	Dubiraphia	1.00
Dnet	Fishtrap	Bank	Oligochaeta	1.00
Dnet	Fishtrap	Bank	Parachironomus	1.12
Dnet	Fishtrap	Bank	Polypedilum	13.41
Dnet	Fishtrap	Bank	Pseudocloeon	4.00
Dnet	Fishtrap	Bank	Rheotanytarsus	1.12
Dnet	Fishtrap	Bank	Simulium	2.00
Dnet	Fishtrap	Bank	Stenelmis	2.00
Dnet	Fishtrap	Bank	Tanytarsus	1.12
Dnet	Fishtrap	Bank	Thienemanniella	2.24
Dnet	Fishtrap	Wood	Cricotopus	3.00
Dnet	Fishtrap	Wood	Dicrotendipes	1.00
Dnet	Fishtrap	Wood	Dubiraphia	4.00
Dnet	Fishtrap	Wood	Eukiefferiella	1.00
Dnet	Fishtrap	Wood	Helicopsyche	1.00
Dnet	Fishtrap	Wood	Heptageniidae	1.00
Dnet	Fishtrap	Wood	Physella	2.00
Dnet	Fishtrap	Wood	Polypedilum	2.00
Dnet	Fishtrap	Wood	Pseudocloeon	1.00
Dnet	Fishtrap	Wood	Rheotanytarsus	4.00
Dnet	Fishtrap	Wood	Stenelmis	1.00
Dnet	Fishtrap	Wood	Stenochironomus	1.00
Dnet	Fishtrap	Wood	Tanytarsus	1.00
Dnet	Fishtrap	Wood	Thienemanniella	1.00
Dnet	Shilhon	Riffle	Acari	2.00
Dnet	Shilhon	Riffle	Acroneuria	1.00
Dnet	Shilhon	Riffle	Baetidae	10.00
Dnet	Shilhon	Riffle	Baetis	2.00
Dnet	Shilhon	Riffle	Caenis	4.00
Dnet	Shilhon	Riffle	Cheumatopsyche	43.00
Dnet	Shilhon	Riffle	Chimarra	4.00

Appendix 2 (cont).

Type	Site	Habitat	Taxa	Mean Count
Dnet	Shilhon	Riffle	Cricotopus	3.27
Dnet	Shilhon	Riffle	Empididae	2.00
Dnet	Shilhon	Riffle	Erpobdellidae	2.00
Dnet	Shilhon	Riffle	Eukiefferiella	6.54
Dnet	Shilhon	Riffle	Gomphidae	3.00
Dnet	Shilhon	Riffle	Helicopsyche	6.00
Dnet	Shilhon	Riffle	Heptageniidae	2.00
Dnet	Shilhon	Riffle	Hexatoma	2.00
Dnet	Shilhon	Riffle	Hydropsyche	32.00
Dnet	Shilhon	Riffle	Isonychia	15.00
Dnet	Shilhon	Riffle	Nematoda	2.00
Dnet	Shilhon	Riffle	Oecetis	2.00
Dnet	Shilhon	Riffle	Oligochaeta	15.00
Dnet	Shilhon	Riffle	Optioservus	12.00
Dnet	Shilhon	Riffle	Physella	2.00
Dnet	Shilhon	Riffle	Polypedilum	81.77
Dnet	Shilhon	Riffle	Pseudocloeon	10.00
Dnet	Shilhon	Riffle	Rheotanytarsus	26.17
Dnet	Shilhon	Riffle	Simulium	2.00
Dnet	Shilhon	Riffle	Stempellina	16.35
Dnet	Shilhon	Riffle	Stenelmis	13.00
Dnet	Shilhon	Riffle	Tanytarsus	19.63
Dnet	Shilhon	Riffle	Thienemannimyia	3.27
Dnet	Shilhon	Riffle	Trichoptera	2.00
Dnet	Shilhon	Run	Acari	4.00
Dnet	Shilhon	Run	Caenis	14.00
Dnet	Shilhon	Run	Cheumatopsyche	3.00
Dnet	Shilhon	Run	Cladotanytarsus	6.13
Dnet	Shilhon	Run	Cryptochironomus	3.06
Dnet	Shilhon	Run	Didymops	2.00
Dnet	Shilhon	Run	Eukiefferiella	3.06
Dnet	Shilhon	Run	Ferrissia	2.00
Dnet	Shilhon	Run	Gomphidae	5.00
Dnet	Shilhon	Run	Hexatoma	2.00
Dnet	Shilhon	Run	Hydrophilidae	4.00
Dnet	Shilhon	Run	Hydropsyche	1.00
Dnet	Shilhon	Run	Isonychia	2.00
Dnet	Shilhon	Run	Larsia	3.06
Dnet	Shilhon	Run	Leucrocuta	14.00
Dnet	Shilhon	Run	Macronychus	2.00
Dnet	Shilhon	Run	Microtendipes	3.06
Dnet	Shilhon	Run	Mystacides	1.00
Dnet	Shilhon	Run	Oecetis	8.00
Dnet	Shilhon	Run	Ophiogomphus	2.00
Dnet	Shilhon	Run	Optioservus	8.00
Dnet	Shilhon	Run	Physella	2.00

Appendix 2 (cont).

Type	Site	Habitat	Taxa	Mean Count
Dnet	Shilhon	Run	Polypedilum	9.19
Dnet	Shilhon	Run	Rheotanytarsus	36.77
Dnet	Shilhon	Run	Stempellina	6.13
Dnet	Shilhon	Run	Stempellinella	6.13
Dnet	Shilhon	Run	Stenelmis	2.00
Dnet	Shilhon	Run	Tanytarsus	64.34
Dnet	Shilhon	Run	Thienemannimyia	3.06
Dnet	Shilhon	Run	Tricorythodes	3.00
Dnet	Stanley	Bank	Acari	4.00
Dnet	Stanley	Bank	Acroneuria	2.00
Dnet	Stanley	Bank	Baetidae	8.00
Dnet	Stanley	Bank	Brillia	2.03
Dnet	Stanley	Bank	Caenis	12.00
Dnet	Stanley	Bank	Calopteryx	11.00
Dnet	Stanley	Bank	Cheumatopsyche	12.00
Dnet	Stanley	Bank	Cladotanytarsus	2.03
Dnet	Stanley	Bank	Collembola	4.00
Dnet	Stanley	Bank	Corynoneura	2.03
Dnet	Stanley	Bank	Cricotopus	8.11
Dnet	Stanley	Bank	Decapoda	2.00
Dnet	Stanley	Bank	Dubiraphia	4.00
Dnet	Stanley	Bank	Eukiefferiella	2.03
Dnet	Stanley	Bank	Glossiphoniidae	59.00
Dnet	Stanley	Bank	Gomphidae	4.00
Dnet	Stanley	Bank	Helisoma	2.00
Dnet	Stanley	Bank	Hydropsyche	4.00
Dnet	Stanley	Bank	Lepidoptera	2.00
Dnet	Stanley	Bank	Leptophlebiidae	2.00
Dnet	Stanley	Bank	Oecetis	2.00
Dnet	Stanley	Bank	Oligochaeta	8.00
Dnet	Stanley	Bank	Ophiogomphus	2.00
Dnet	Stanley	Bank	Optioservus	8.00
Dnet	Stanley	Bank	Oxyethira	2.00
Dnet	Stanley	Bank	Pagastiella	2.03
Dnet	Stanley	Bank	Physella	7.00
Dnet	Stanley	Bank	Plecoptera	2.00
Dnet	Stanley	Bank	Polypedilum	16.22
Dnet	Stanley	Bank	Pycnopsyche	12.00
Dnet	Stanley	Bank	Rhagovelia	4.00
Dnet	Stanley	Bank	Rheotanytarsus	12.17
Dnet	Stanley	Bank	Simulium	6.00
Dnet	Stanley	Bank	Sphaeriidae	5.00
Dnet	Stanley	Bank	Stempellina	6.08
Dnet	Stanley	Bank	Stenonema	4.00
Dnet	Stanley	Bank	Tanytarsus	20.28
Dnet	Stanley	Bank	Tricorythodes	2.00

Appendix 2 (cont).

Type	Site	Habitat	Taxa	Mean Count
Dnet	Stanley	Riff/Run	Acari	30.00
Dnet	Stanley	Riff/Run	Acroneuria	2.00
Dnet	Stanley	Riff/Run	Antocha	4.00
Dnet	Stanley	Riff/Run	Atherix	2.00
Dnet	Stanley	Riff/Run	Baetis	24.00
Dnet	Stanley	Riff/Run	Boyeria	2.00
Dnet	Stanley	Riff/Run	Caenis	4.00
Dnet	Stanley	Riff/Run	Ceraclea	2.00
Dnet	Stanley	Riff/Run	Cheumatopsyche	32.00
Dnet	Stanley	Riff/Run	Cladotanytarsus	9.15
Dnet	Stanley	Riff/Run	Corynoneura	9.15
Dnet	Stanley	Riff/Run	Cricotopus	18.29
Dnet	Stanley	Riff/Run	Cryptochironomus	9.15
Dnet	Stanley	Riff/Run	Ferrissia	16.00
Dnet	Stanley	Riff/Run	Gomphidae	108.00
Dnet	Stanley	Riff/Run	Helichus	2.00
Dnet	Stanley	Riff/Run	Hexatoma	6.00
Dnet	Stanley	Riff/Run	Hydropsyche	20.00
Dnet	Stanley	Riff/Run	Hydroptilidae	4.00
Dnet	Stanley	Riff/Run	Leptophlebia	14.00
Dnet	Stanley	Riff/Run	Lopescladius	18.29
Dnet	Stanley	Riff/Run	Microtendipes	9.15
Dnet	Stanley	Riff/Run	Monodiamesa	9.15
Dnet	Stanley	Riff/Run	Oecetis	10.00
Dnet	Stanley	Riff/Run	Oligochaeta	52.00
Dnet	Stanley	Riff/Run	Ophiogomphus	27.00
Dnet	Stanley	Riff/Run	Optioservus	104.00
Dnet	Stanley	Riff/Run	Pagastiella	9.15
Dnet	Stanley	Riff/Run	Parametriocnemus	27.44
Dnet	Stanley	Riff/Run	Physella	12.00
Dnet	Stanley	Riff/Run	Plecoptera	22.00
Dnet	Stanley	Riff/Run	Polypedilum	73.17
Dnet	Stanley	Riff/Run	Pseudocloeon	20.00
Dnet	Stanley	Riff/Run	Rhagovelia	2.00
Dnet	Stanley	Riff/Run	Rheotanytarsus	18.29
Dnet	Stanley	Riff/Run	Simulium	2.00
Dnet	Stanley	Riff/Run	Stempellinella	36.58
Dnet	Stanley	Riff/Run	Stenonema	12.00
Dnet	Stanley	Riff/Run	Tanytarsus	173.77
Dnet	Stanley	Riff/Run	Thienemannimyia	18.29
Dnet	Stanley	Riff/Run	Trichoptera	32.00
Dnet	Stanley	Riff/Run	Turbellaria	12.00