Stream and Wetland Biological Survey

Proposed NorthMet Mining Project
Hoyt Lakes, Minnesota

Prepared for
PolyMet Mining Corporation, Inc.

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Table of Contents

Abstract –

A biological monitoring survey was conducted on four stream sites and two wetlands in the vicinity of a proposed mining operation in northern Minnesota. Fish and macroinvertebrate community composition, habitat characteristics, and water chemistry parameters were examined to establish biological condition at four stream reaches and two wetland complexes. Fish assemblages were sampled in streams by electrofishing, and in wetlands with 24-hour trap net sets. Macroinvertebrates were collected qualitatively with D-frame kick nets, and quantitatively with Hess, Ekman, or Petite Ponar dredge sampling gear. Total number of fish and total lengths per species were determined within each stream reach to estimate catch per unit effort (CPUE). Macroinvertebrates were identified, enumerated, and the relative abundance and taxa richness per site determined. Stream habitat characteristics and water quality parameters at each site were summarized by point estimates along randomly placed transects.

Invertebrate community composition between sites was predictable, with two wetland communities sharing similar characteristics (B5 and B7). The number of macroinvertebrate taxa was similar among stream sites (B1, B2, B3, and B6), but much higher than found in both wetland habitats. Three stream sites, including a designated reference reach located within the same drainage area (B1), provided similar community compositions. The remaining stream sampling location (B6) contained a macroinvertebrate and fish community that was unlike the previous three stream sites, and more similar to the wetland habitats based on the fish community composition. Fish communities among all sites were similar in respect to the functional proportions of taxa present. This survey suggests that the biological characteristics associated with stream and wetland sites sampled at the proposed NorthMet Mining Project site varied with respect to the distribution of fish and invertebrate functional categories between sites, but the overall community composition was typical of other systems in the region.

Introduction

This survey was conducted to establish baseline data for an environmental impact statement (EIS) on streams and wetlands within a proposed mining operation. The effort described below is limited to the physical, chemical, and biological parameters associated with four stream reaches and two wetlands complexes near the proposed activity. Our objective was to evaluate biological condition by sampling stream fauna, characterizing habitat conditions associated with each sample reach, and assess overall water quality. Quantitative estimates of fish and macroinvertebrate community abundances and total taxa richness at each site were used to compare locations. In addition, estimates of substrate type, riparian characteristics, and water quality were recorded to assess habitat conditions. Field sampling and laboratory procedures used to generate the information for this survey referred to Minnesota Pollution Control Agency (MPCA) Biological Monitoring guidelines or are part of established field sampling protocols at the University of Minnesota Duluth, Natural Resources Research Institute (NRRI). Standard operation procedure (SOP) documents are available as NRRI technical reports.

Materials and Methods

Study Site

An aquatic habitat survey was completed in the vicinity of the proposed NorthMet Mining project near Hoyt Lakes, Minnesota in August-September 2004 (Figure 1). Stream sample locations included an off-site reference stream on the South Branch Partridge River (B1), and sample reaches above and below a proposed mining operation on the Partridge River (B2 above, B3 below). An additional stream site (B4) was proposed, but following inspection the site was determined as non- representative of the Partridge River. Consequently, the site numbering scheme is not sequential. Trimble Creek originates from the wetlands and bogs to the north of a tailings basin, and the sample site (B6) was located several kilometers downstream. Two wetlands directly adjacent to the drainage outfall of the mine tailings basin (B5 and B7) were also included in the survey (Figure 1).

Fish Sampling

The fish sampling effort was conducted between late August and mid-September 2004. Stream fish assemblages were sampled using DC-pulsed gear outfitted with either a tote-barge or a portable backpack unit. The type of gear used depended on stream depth, width, and substrate type. The reach length included in this stream survey was generally based on 10x the stream width, but a minimum of 100 m was sampled. A single-pass method was determined adequate to establish an estimate of taxa richness within each sample reach. Due to constraints with the electrofishing equipment, wetland habitats were sampled with 24-hour Fyke net sets. Large-framed (LG-0.9x1.2m with a 0.9 m box and 12 mm mesh) and small-framed (SM- 0.45x0.75 m with a 0.45 m box and 4 mm mesh) nets were used for passive collection. Both designs included 3 m wings and 8 m leads. Both LG and SM nets were deployed in the larger wetland (B5), with only two small frame Fyke nets set in B7 due to the limited surface area.

All individual fish recovered were identified to species, divided into age classes when necessary (e.g., adult, juvenile, young of the year), enumerated, and a minimum of 25 individuals per group measured (total length in mm). With the exception of a few Cyprinidae species, all individuals were measured and released. Individuals retained for further identification were preserved in Kahle’s solution and returned to the laboratory. Following positive identification, specimens returned to the lab were either retained in a reference collection (Rm 486, NRRI) or disposed of via incineration. Catch per unit effort (CPUE) was calculated for each sample location. Streams CPUE was determined by standardizing abundance values by reach volume, and wetland sampling was standardized by net sampling hours.

Macroinvertebrate sampling

Benthic samples were collected in September 2004 during baseflow conditions. Quantitative samples were collected in run, riffle, and pool habitats using either a modified Hess (0.086 m^2) or Ekman grab (0.023 m^2) samplers. In the tailing basin wetlands, quantitative samples were collected with a petite Ponar dredge (0.023 m^2). Quantitative samples were collected at all sites, and either outfitted or washed in the field with a 254-µm mesh net or sieve. Where available, qualitative samples were collected in 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). The D-net effort lasted for 30 seconds per sample. Extensive herbaceous vegetation (primarily gramenoid grasses) and instream aquatic vegetation were swept, while wood dams and boulder piles were jabbed (*sensu* Barbour et al. 1999) to dislodge invertebrates. Qualitative samples in the wetlands targeted the transition zone by changes in vegetation or depth. Where vegetation was available, samples were collected in the zone between the terrestrial and emergent aquatic vegetations (EAV), and between the EAV and submergent aquatic vegetation (SAV). If vegetation was absent, sample effort was stratified by depth at both 0 to 0.5 m, and from 0.05 to 1 m. The distribution of the qualitative sampling effort was to improve our ability to collect all resident taxa from as many different habitats as available. All invertebrates from each sample were collected and preserved in the field using a Kahle's preservative.

Macroinvertebrates sample processing in the laboratory followed standard protocols (NRRI, 1999). In summary, samples are washed through a set of sieves (4 mm and 254-µm mesh) to further eliminate fine particulate organic matter (FPOM), and then invertebrates are separated by hand from the remaining debris. Particles retained in the 4 mm size fraction go directly to hand processing, and the 254-µm mesh portion is sub-sampled. Due to the large amount of debris retained in the 254-µm mesh, samples were sub-sampled into quarters prior to hand processing in order to increase efficiency. The effort required to completely process a quarter sample then determines the total amount of each sample processed. At a minimum, a quarter of each sample is processed. Macroinvertebrates from the resulting size fraction (i.e., ¼, ½, ¾, or whole), and the un-split 4 mm portion, are then separated from the remaining debris by hand under 6.4× magnification. Invertebrates extracted from each sample are placed in shelf vials and preserved with 70% ethanol. All macroinvertebrates are identified to lowest taxonomic level possible using appropriate keys (Hilsenhoff 1981, Brinkhurst 1986, Thorp and Covich 1991, Merritt and Cummins 1996). Chironomid larvae are sub-sampled and permanently slide-mounted for identification to genus (Wiederholm 1983, Merritt and Cummins 1996). The number of individuals per slide is then standardized to the total number of midge larvae mounted. Proportions of each genera mounted is then extrapolated to express the abundance of each genera per sample.

Sample Reach Characterization

Physical, chemical, and ecological parameters in each sampling reach were evaluated to summarize stream characteristics. Depending on average stream width, a series of 10 transects were placed along each reach to systematically sample instream cover-type. A set of observations across each transect provided point estimates for discharge rates, substrate type, percent embeddedness by secondary substrate or fine sediment, habitat cover, bank condition, and riparian cover. Sediment depth was estimated in streams with a meter stick or top-set wading rod, and in wetlands by recording the distance the dredge traveled from the sediment surface to the point of resistance. The distance was then ranked into six categories; 0, 1-25, 26-50, 51-100, and <100 cm of thickness. Water chemistry parameters at each location were also recorded with a YSI 556 multi-probe meter to establish baseline information on water temperature, dissolved oxygen, conductivity, pH, and ortho-phosphate during the sampling effort. A Qualitative Habitat Evaluation Index (Ohio EPA, 1987) to rank overall stream condition was also scored for each site following the sampling event.

Results

Physical and Chemical Habitat Conditions

Water quality parameters were measured at all stream sites (Table 1-1) and within the two wetland habitats sampled (Table 1-2). Although the wetland sample locations varied in overall surface area of accessible open water (B5 being smaller), depth and sediment characteristics were similar among sites (Appendix I). Both wetland sediments consisted of a black, organic mud, with a swampy, sulfur odor. The maximum depth recorded in B7 was 0.85 m and sediment depth was estimated at 10-25 cm. The B5 wetland was 1.5 m in maximum depth and the sediment layer estimated at 25-50 cm thick. Both wetlands were dominated by *Typha* sp. and *Ceratophylum* sp. and surrounded by alder brush.

Stream characteristics varied between sample locations with sites B1 and B2 containing similar habitat features. Although B2 was only 3.5 km upstream of B3, the two locations provided very different habitats (Appendix H). The upstream site (B2) included a stream reach with a substantial elevation relief compared to the downstream reach (B3). The B3 sample reach was located in an area of minimal relief, as the stream flows through an alder bog. Site B6 contained stream habitat features and channel conditions that were somewhat similar to B3. However, B6 was much smaller and only provided half of the estimated discharge as B3 (Table 1-3). Both B3 and B6 contained silt deposits that averaged 5 cm, but both habitats provided maximums sediment depths of approximately 20 cm. Bank conditions and instream habitat features for both B3 and B6 were dominated by silt, with undercut bank development and thick vegetative growth along the riparian zone. A qualitative habitat evaluation index (QHEI) provided identical scores for each site (Table 1-4). Sites B1 and B2 contained greater amounts of hard substrate, with boulders as the dominant feature. Minimal amounts of small substrate (e.g., pebbles, gravel, etc.) were observed, although both reaches contained pool/run habitats that included extensive silt deposits with SAV. Besides site B2 containing more alder brush that provided a dense canopy cover, sites B1 and B2 were similar in respect to channel and instream habitat features. Overall QHEI scores for B1 and B2 (79 and 70, respectively) were also similar, and site B1 appears to be an adequate off-site reference for B2 and B3 sample reaches.

Fish Community Characteristics

Based on information from a 2003 fish survey on Wyman Creek, no substantial differences were observed between fish populations sampled from streams near the proposed NorthMet mining project (Table 2-1). No species collected in this survey were endangered or considered rare to the region (Appendix A). More than 33% of the species collected were categorized as preferring streams as spawning habitat, with no species being recognized as river spawners (Appendix C). The majority of the species collected at all sites were designated as spawning generalists. Of those species collected, over 92% were described as spring spawners with a small percent (mean of 3.9%) associated with winter spawning. The fish community was primarily omnivorous (65%) with a substantial portion of the species collected utilizing benthic macroinvertebrates (18%) as forage. On average, only a small fraction of adult taxa were piscivores (6%).

The relative proportion of fish abundance as CPUE was highly variable among sites (Table 2-2). Community composition at the sample sites was made up of either species preferring benthic habitats or those described as generalist species. The abundance of fish at all sites was heavily dominated by these two categories (dominance ranged from 69 to 94%). The functional distribution of resource preference for each taxa was highly variable. The most commonly occurring feeding preference was omnivores, with 33 to 94% of individuals designated to that group (Appendix D). The fish community sampled at sites B1 and B2 had similar proportions of benthivorous taxa, and both sites were substantially greater than the remaining locations.

Macroinvertebrate Community Characteristics

From the six sample locations, 133 invertebrate genera were identified (Appendix E), with several other higher-level classifications being recorded (Appendix F). The proportion of total taxa comprised of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa per stream was similar among sites B1, B2, and B3 (Figure 2a), but lower in site B6. Stream communities included as many as 90 taxa per site, with the smaller stream (B6) providing only 64 macroinvertebrate taxa.

Midge larvae identified at the genus-level (Appendix G) comprised more than 30% of the taxa richness per site, and more than 50% of the total abundance at sites B1, B2, B3 (Table 1-5). Midge larvae at site B6 made up only 26% of the total macroinvertebrate abundance, although total numbers were much lower than compared to sites B1, 2, and 3. The proportional differences between sites B1, 2, 3, and site B6 resulted from higher Trichoptera abundance in B6 than in any other location. In addition, Ephemeroptera numbers in B6 were double those in B1, B2, or B3.

No differences were evident between stream sites when comparing functional characteristics, behavioral attributes, or mechanistic patterns. Even between trophic-level designations, all streams sites were equally distributed among herbivores, omnivores, and detritivores. The only noticeable difference between stream sites was lower carnivore taxa in sites B2 and B6 (with 8.4 and 7.6%, respectively) compared to 20.2 and 23.9% in sites B1 and B3, respectively (Table 1-5). The macroinvertebrate stream communities sampled from the four stream reaches in this survey were typical of populations sampled in the northeast region of Minnesota.

Similar to the EPT metric generated for streams, an Ephemeroptera, Trichoptera, Sphaeriidae, and Odonota (ETSO) metric was calculated, and is recommended for evaluating wetland communities (Figure 2b). Wetland sites contained the highest abundance values among all sites sampled, with a majority being midge larvae (Table 1-5). From the 54 and 37 different taxa observed in sites B5 and B7, respectively, over 30% of the macroinvertebrate taxa richness was exclusively Chironomidae (Diptera) genera. All other functional characteristics examined within the wetland communities were similar between sites.

Site Comparisons

In order to provide a comparison between community composition among all sites sampled, the relative abundance of all species per site was analyzed with a reciprocal averaging (RA) procedure in PCORD (McCune and Mefford, 1999). This procedure is analogous to a correspondence analysis that converts invertebrate community composition from multi-dimensional space into a two-dimensional bi-plot. Similarities in fish community composition can be seen with a separation between habitat types, and the association of specific species with those sites (Fig 3). The Trimble Creek fish community was more closely related to the two wetland sites than that sampled from the remaining stream sites. This may be caused by the headwaters of Trimble Creek originating near the tailings basin, or that sites B1, B2, and B3 are located in the same drainage basin. Species such as *Umbra limi, Catastomus commersoni, Culaea inconstans,* and *Semotilus atromachulatus* were associated with sites B5, 6, and 7. Species like *Esox lucius, Rhinichthys atratulatus,* and *Etheostoma nigrum* were more closely associated with sites B1, 2, and 3.

Macroinvertebrate community composition within wetland sites B5 and B7 were similar, and sites B1, 2, and 3 appear to be directed toward similar ordinational space (Fig 4). Although site B6 had sediment and bank characteristics similar to site B3, the community composition was not similar to that found in the other stream sites. As with the fish community, the difference in invertebrate community composition between stream locations may be due to confounding factors, including difference in actual stream size, flow, or simply three sites are contained in a similar watershed.

Discussion

Due to the low conductivity and channel conditions associated with some sample reaches included in this survey, sampling effort concentrated on riffle areas and shallow sections of each stream reach. However, some locations (e.g., B3) were relatively wide (e.g., 10 m), deep (2.5 m), and consisted of extremely soft sediments. These conditions provided marginal safety levels for effective wade-able electrofishing techniques. Because the effectiveness in sampling effort was not equal between streams, directly comparing total abundance between sites is not recommended. Similarly, differences in depth and surface area associated with the wetland sites eliminated the opportunity to use electrofishing gear or effectively apply equal net effort. CPUE estimates for both streams and wetlands provide some indication of fish abundance among habitat types, although effort and gear-type should both be considered prior to making any inferences between habitat types.

This survey describes the dominant habitat features and water quality parameters associated with seven study sites near the proposed NorthMet mining operation. Macroinvertebrate and fish assemblages provide baseline information, but due to an insufficient number of quantitative samples per site, direct community comparisons (e.g., by numbers per square meter, biomass, etc.) between locations are not appropriate. Counts of macroinvertebrate taxa per site and the relative abundance of individuals per sample type do provide some indication of the similarity in structure and function within the stream and wetland assemblages at each location. However, the correspondence analysis clearly indicates differences in both invertebrate and fish community composition between B6 and the remaining stream reaches. Consequently, B1 would not be considered an adequate reference comparison for the B6 sample location. However, B1 was determined an adequate reference site for sites B2 and B3. Wetland habitats contained similar assemblages, and although not surprising, were not associated with stream community composition. Considering the proximity to one another, flow origin, and habitat type, this exploratory analytical procedure including all sample locations is generally in agreement with the physical differences observed among sites, and how those differences in habitat characteristics may have influenced the resulting fish and macroinvertebrate assemblage collected.

Although the number of observations made during this survey were not sufficient enough to capture all the potential differences between sample locations, the types of data collected did provide an adequate view of community composition and habitat characteristics within a sample site. This survey suggests that the community composition associated with macroinvertebrate and fish assemblages sampled at the proposed NorthMet Mining Project site are typical of other aquatic habitats in the region.

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Tables

Table 1-1. Water chemistry characteristics measured at base flow conditions from streams near the PolyMet Co. Inc., NorthMet mine operation, Hoyt Lakes, MN. Values represent 1 minute averaging.

Sample Location		**Water Quality Characteristics**				
Name	**Site**	**Temp (^{o}C)**	**sCond (μmho)**	**DO (% sat.)**	**pH**	**ORP (mV)**
South Partridge	B1	15.50	55.00	62.80	6.19	492.60
Partridge	B2	15.84	112.00	61.90	6.86	481.20
Partridge	B3	14.88	98.00	65.10	6.25	390.20
Trimble	B6	15.36	506.00	66.60	7.58	302.80

Table 1-2. Water chemistry characteristics measured at wetlands near the PolyMet Co. Inc., NorthMet mine operation, Hoyt Lakes, MN. Values represent 1 minute averaging.

Sample Location		**Water Quality Characteristics**				
Name	**Site**	**Temp (^{o}C)**	**sCond (μmho)**	**DO (% sat.)**	**pH**	**ORP (mV)**
Tailings North	B5	14.30	857.00	57.50	7.43	436.10
Tailings Northwest	B7	14.32	760.00	51.20	7.51	278.10

Table 1-3. Water flow characteristics summarized per reach within Streams near the PolyMet Co. Inc., NorthMet mine operation, Hoyt Lakes, MN. Numbers represent mean values over the entire reach.

Sample Location		**Channel Characteristics**			
Name	**Site**	**Width (cm)**	**Depth (cm)**	**Velocity (cm/S)**	**Discharge (m3/s)**
S Partridge	B1	753	26.74	6.90	0.10
Partridge	B2	954	20.67	15.13	0.19
Partridge	B3	724	72.23	7.03	0.26
Trimble	B6	190	58.70	10.47	0.13

Table 1-4. Substrate and habitat characteristics associated with streams sample locations PolyMet Co. Inc., NorthMet mine operation, Hoyt Lakes, MN. Besides total reach length, habitat conditions represent mean values over the entire reach. EAV = emergent aquatic vegetation, SAV = Subemergent aquatic vegetation.

Site	Dominant Feature	Coverage (% m^2) [1]	Secondary Feature	Sample Reach (m)	Silt depth(cm)	Canopy Cover (%)	QHEI Score[2]
B1	Boulder	81.74	EAV	130	0.31	3.90	70
	Gravel	3.98	Islands				
	Silt	10.62	SAV				
	Woody debris	3.65					
B2	Boulder	84.12	EAV	135	1.36	45.50	79
	Pebbles	3.67	Islands				
	Silt	12.21	SAV				
B3	EAV	3.45	Cut bank	120	5.83	4.33	65
	Silt	96.55	SAV				
B6	Sand	43.16	Cut bank	105	5.83	8.23	65
	Silt	56.84	SAV				

[1] Substrate coverage estimate (Coverage (% m^2)) is expressed as percent of total reach surface area occupied by the dominant feature. This estimate is based on sample points from transects randomly placed along the stream reach.

[2] QHEI (qualitative habitat evaluation index) from Ohio EPA (1987).

Table 1-5. Macroinvertebrate community comparisons between sample locations near the PolyMet Co. Inc., NorthMet mine operation, Hoyt Lakes, MN. Category n represents the total number of samples collected per site. Total taxa represent the number of different taxa from all sample types. Other data represent mean total abundance per sample (Mean Abund.) and percent of total abundance as; EPT=Ephemeroptera,Trichoptera, and Plecoptera taxa, Chiro=Chironomidae, Detr=Detritivores, Omni=Omnivores, Herb=Herbivores, Carn=Carnivores).

Habitat	Site	n	Total Taxa	Mean Abund.	EPT	Chiro	Detr	Omni	Herb	Carn
stream	B1	7	90	626.57	6.24	57.80	46.10	21.46	7.42	20.24
stream	B2	6	89	1260.67	14.56	65.25	60.19	17.51	10.69	8.45
stream	B3	4	82	1278.09	15.78	52.15	45.56	18.31	7.36	23.93
stream	B6	4	64	653.54	0.47	26.96	72.12	10.30	4.73	7.74
wetland	B5	3	54	2529.48	16.94	46.78	57.08	7.92	17.71	14.27
wetland	B7	3	37	1549.19	1.98	64.64	57.80	10.75	4.00	24.56

Table 2-1. Trophic structure associated with the fish assemblage from sites sampled near the PolyMet Co. Inc., NorthMet mine operation, Hoyt Lakes, MN in 2004. Data are the relative number of total taxa (percent of total) designated as stream spawners (Strmsp) and multiple habitat spawners (Multsp); Percent benthivore (Bnth); Piscivore (Pisc); Herbivore (Herb); and Omnivore (Omni) taxa.

Habitat	**Site**	**Total Taxa**	**Strmsp**	**Multsp**	**Bnth**	**Pisc**	**Herb**	**Omni**
Stream	B1	8	25.00	37.50	25.00	25.00	0.00	50.00
Stream	B2	12	41.67	16.67	33.33	0.00	16.67	50.00
Stream	B3	5	20.00	40.00	20.00	0.00	0.00	80.00
Stream	B6	9	44.44	33.33	0.00	11.11	11.11	77.78
Stream	Wyman[1]	5	0.00	20.00	20.00	0.00	20.00	60.00
Wetland	B5	5	20.00	0.00	20.00	0.00	20.00	60.00
Wetland	B7	8	37.50	12.50	12.50	0.00	12.50	75.00

[1]Minnesota DNR survey conducted in 11 September 2003 using backpack electrofishing gear at a site 11 kilometers from the Wyman Creek confluence with Colby Lake.

Table 2-2. Fish community composition sampled at sites near the PolyMet Co. Inc., NorthMet mine operation, Hoyt Lakes, MN in 2004. Data are the relative abundance (percent of total CPUE) designated for those taxa that prefer benthic habitats (BenHab) or perform generalist strategies (GenHab). Feeding preferences of the fish community include percent Benthivores (Bnth), Piscivores (Pisc), Herbivores (Herb), and Omnivores (Omni).

Habitat	**Site**	**Mean CPUE**	**Ben Hab.**	**Gen Hab.**	**Bnth**	**Pisc**	**Herb**	**Omni**
Stream	B1	0.0974	76.47	23.53	35.29	15.69	0.00	49.02
Stream	B2	0.6029	14.95	85.05	46.11	0.00	20.25	33.64
Stream	B3	0.0127	87.50	12.50	12.50	0.00	0.00	87.50
Stream	B6	0.3074	73.61	26.39	0.00	2.78	2.78	94.44
Wetland	B5	2.3125	31.53	68.47	1.35	0.00	17.57	81.08
Wetland	B7	9.1875	6.12	93.88	2.04	0.00	46.49	51.47

Figures

Figure 1. Aerial photo of the proposed PolyMet Co. Inc., NorthMet mining operation, Hoyt Lakes, MN. Sample site locations include UTM 83 coordinates (x number y number) at the nearest road crossing or the furthest downstream point of the sample reach. B1= S. Branch Partridge River (x579577y526863), B2 (x580770y527456) and B3 (x577238y527184)= Upstream and Downstream reaches on Partridge River, B6= Trimble Creek (x564635y527597), and B5 (x565527y527597) and B7 (x563049y527553) are tailings basin wetlands.

Figure 2. Biological metrics generated for four stream reaches (B1, B2, B3, and B6) and two wetland sites (B5 and B7) sampled near Hoyt Lakes, MN. Bars represent the mean proportion of total taxa that occur as; a) Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in streams, and b) Ephemeroptera, Trichoptera, Sphaeriidae, and Odonata (ETSO) taxa per wetland sample location.

Figure 3. A bi-plot of fish community composition associated with four stream reaches and two wetland sites sampled near Hoyt Lakes, MN. The proximity of site locations to one another in ordinational space indicates a similarity in community abundance and species diversity. B1= S. Branch Partridge River, B2 and B3= Partridge, B6= Trimble Creek, and B5 and B7 are tailings pond wetlands. Fish species plotted with respect to sample sites include: Catosoni=White Sucker, Chroaeus=Finescale Dace, Chroeos=Northern Redbelly Dace, Culatans=Brook Stickleback, Esoxcius=Northern Pike, Ethegrum=Johnny Darter, Hybosoni=Brassy Minnow, Lotalota=Burbot, Notrutus=Common Shiner, Notuinus=Tadpole Madtom, Pimeelas=Fathead Minnow, Rhinctae=Longnose Dace, Rhinulus=Blacknose Dace, Semoatus=Creek Chub, Semorita=Pearl Dace, Umbrlimi=Central Mudminnow.

Figure 4. A bi-plot of macroinvertebrate community composition associated with four stream reaches and two wetland sites sampled near Hoyt Lakes, MN. The proximity of site locations to one another in ordinational space indicates a similarity in community abundance and species diversity. B1= S. Branch Partridge River, B2 and B3= Partridge, B6= Trimble Creek, and B5 and B7 are tailings pond wetlands.

Appendixes

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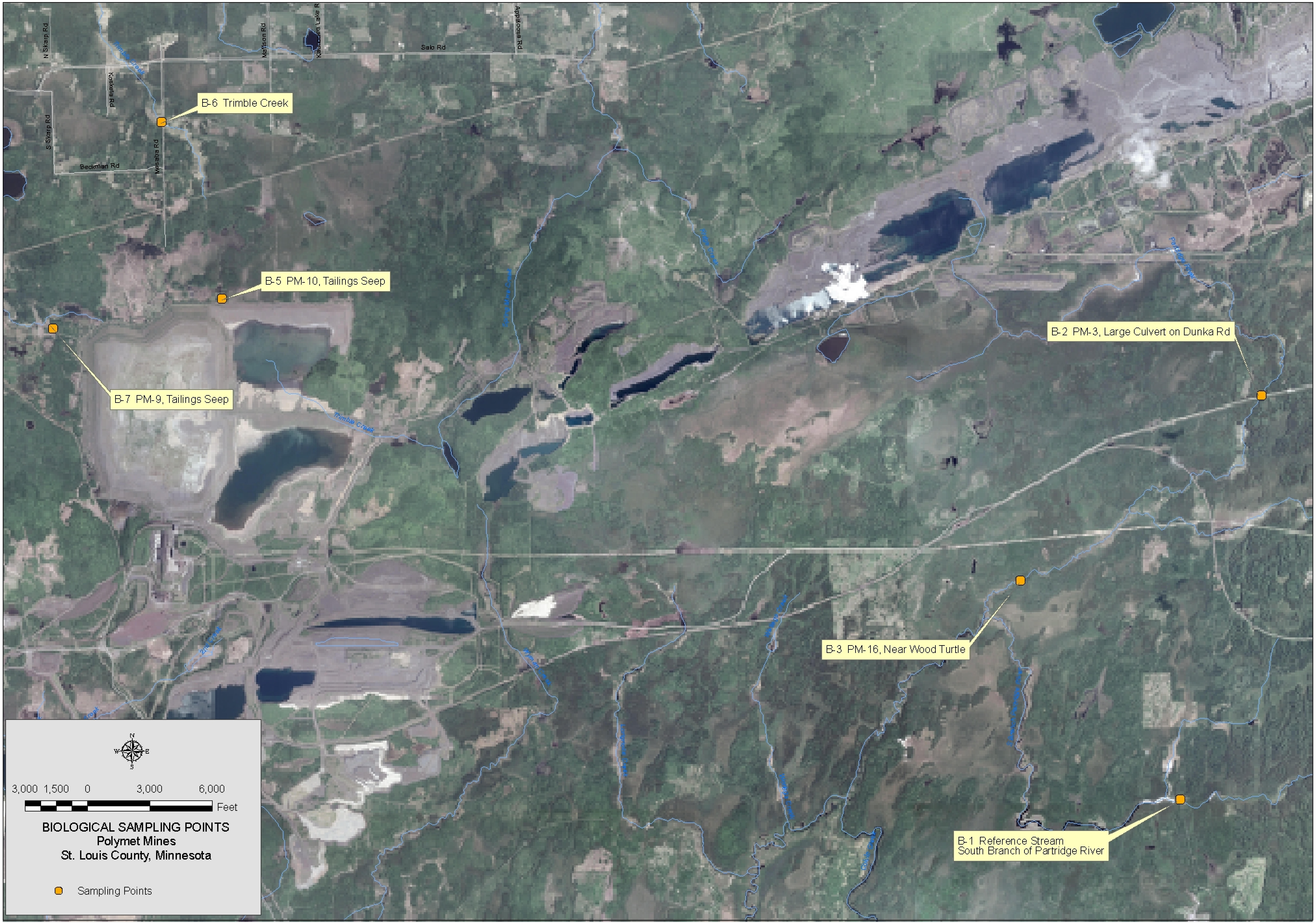
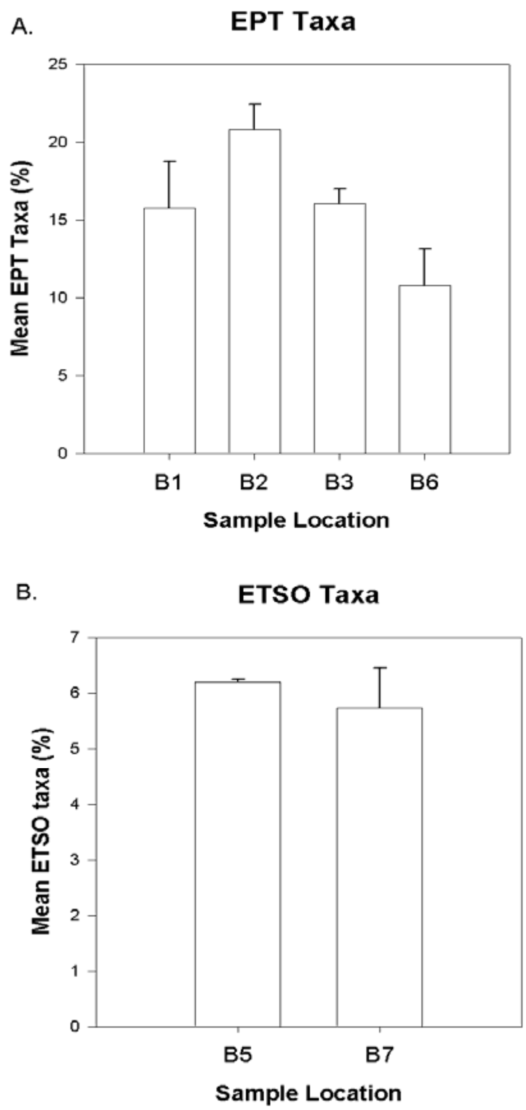


Figure 2a,b


A.
EPT Taxa
Mean EPT Taxa (%)
0
5
10
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20
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B1
B2
B3
B6
Sample Location
B.
ETSO Taxa
Mean ETSO taxa (%)
0
1
2
3
4
5
6
7
B5
B7
Sample Location

Figure 3.

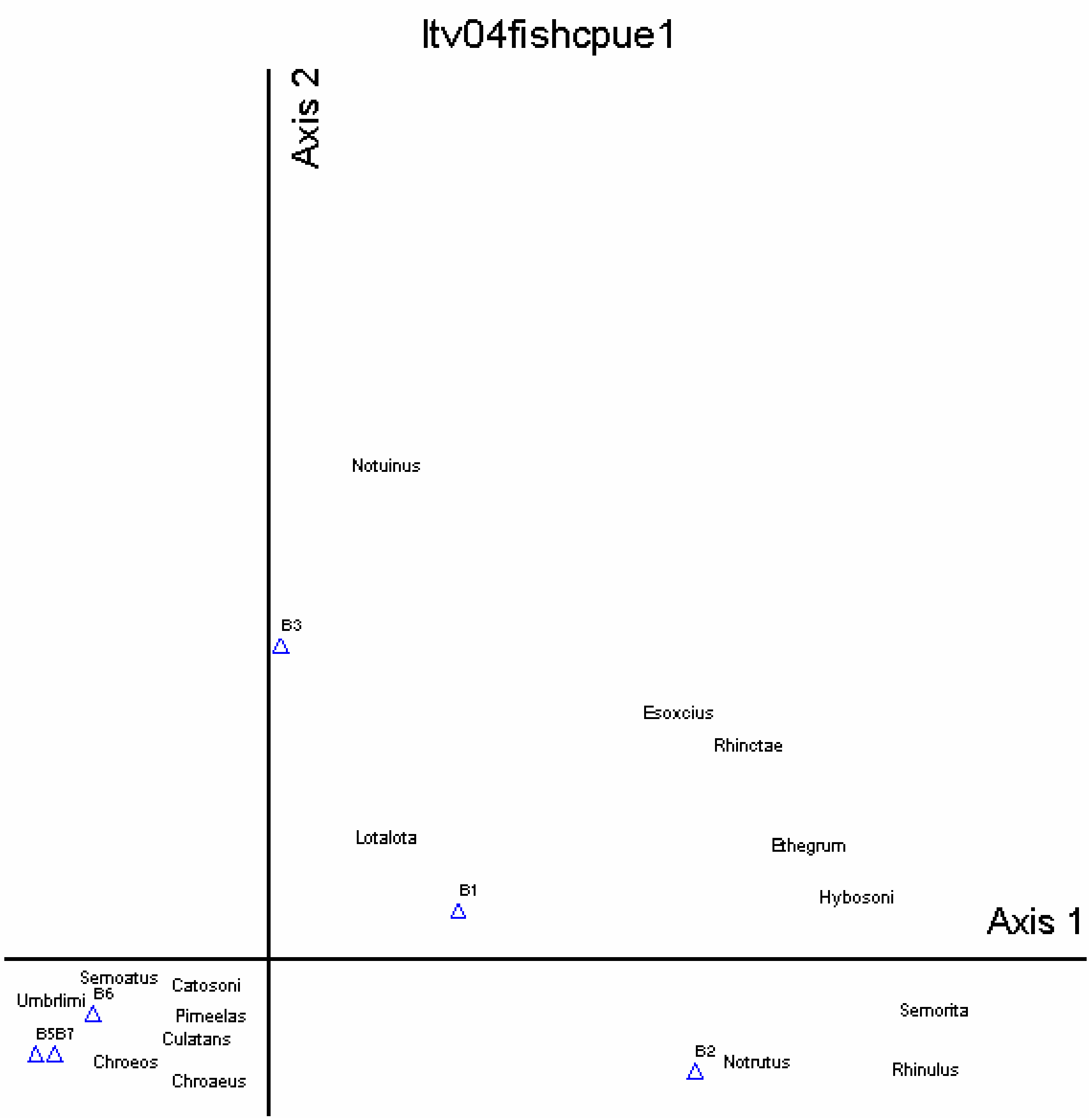
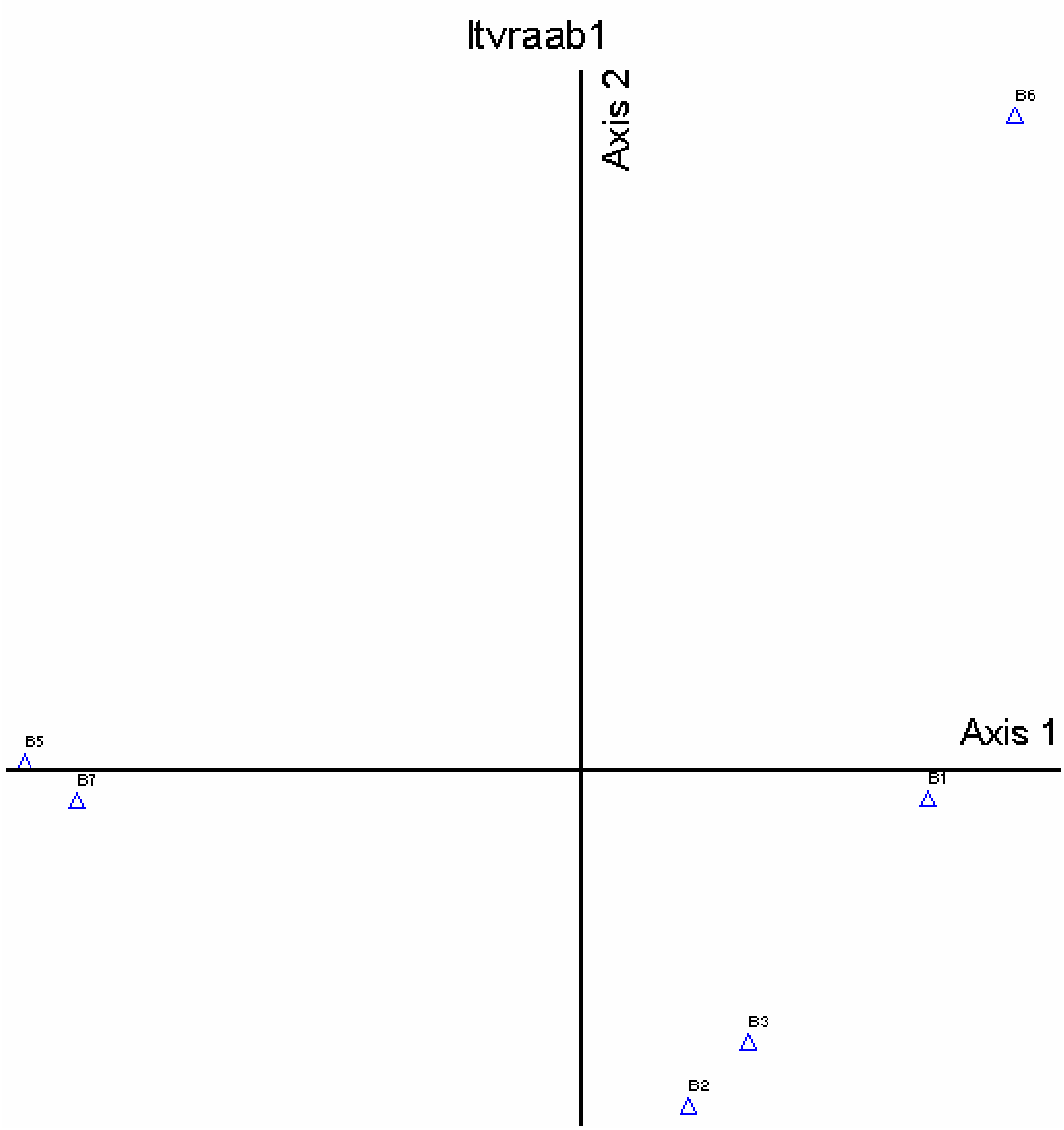

ltv04fishcpue1
Axis 2
Axis 1
Notuinus
B3
Esoxcius
Rhinctae
Lotalota
Ethegrum
B1
Hybosoni
Semoatus
Catosoni
Umbrlimi
B6
Pimeelas
B5
B7
Culatans
Chroeos
Chroaeus
Semorita
B2
Notrutus
Rhinulus

Figure 4



Appendix A.

Taxa	Phylum	Class	Order	Family	Trophic Status
Piscicolidae	Annelida	Clitellata	Rhynchobdellida	Piscicolidae	
Hirudinea	Annelida	Hirudinea	Hirudinea		crv
Erpobdellidae	Annelida	Hirudinea	Pharyngobdellida	Erpobdellidae	crv
Glossiphoniidae	Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	crv
Oligochaeta	Annelida	Oligochaeta	Oligochaeta		dtv
Hydrachnidae	Arthropoda	Arachnida	Acari	Hydrachnidae	crv
Gammarus	Arthropoda	Crustacea	Amphipoda	Gammaridae	dtv
Hyalella	Arthropoda	Crustacea	Amphipoda	Talitridae	dtv
Caecidotea	Arthropoda	Crustacea	Isopoda	Asellidae	dtv
Brachyvatus	Arthropoda	Insecta	Coleoptera	Dytiscidae	crv
Hydroporus	Arthropoda	Insecta	Coleoptera	Dytiscidae	crv
Dubiraphia	Arthropoda	Insecta	Coleoptera	Elmidae	dtv
Stenelmis	Arthropoda	Insecta	Coleoptera	Elmidae	dtv
Dineutus	Arthropoda	Insecta	Coleoptera	Gyrinidae	crv
Gyrinus	Arthropoda	Insecta	Coleoptera	Gyrinidae	crv
Haliplus	Arthropoda	Insecta	Coleoptera	Haliplidae	hbv
Peltodytes	Arthropoda	Insecta	Coleoptera	Haliplidae	omv
Ectopria	Arthropoda	Insecta	Coleoptera	Psephenidae	hbv
Bezzia	Arthropoda	Insecta	Diptera	Ceratopogonidae	crv
Ceratopogonidae	Arthropoda	Insecta	Diptera	Ceratopogonidae	omv
Probezzia	Arthropoda	Insecta	Diptera	Ceratopogonidae	crv
Serromyia	Arthropoda	Insecta	Diptera	Ceratopogonidae	crv
Stilobezzia	Arthropoda	Insecta	Diptera	Ceratopogonidae	crv
Chaoboridae	Arthropoda	Insecta	Diptera	Chaoboridae	crv
Chaoborus	Arthropoda	Insecta	Diptera	Chaoboridae	crv
Ablabesmyia	Arthropoda	Insecta	Diptera	Chironomidae	omv
Beckiella	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Brillia	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Chaetocladius	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Chironomus	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Cladopelma	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Cladotanytarsus	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Clinotanypus	Arthropoda	Insecta	Diptera	Chironomidae	crv
Coelotanypus	Arthropoda	Insecta	Diptera	Chironomidae	crv
Corynoneura	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Cricotopus	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Cryptochironomus	Arthropoda	Insecta	Diptera	Chironomidae	crv
Cryptotendipes	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Dicrotendipes	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Djalmabatista	Arthropoda	Insecta	Diptera	Chironomidae	crv
Endochironomus	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Eukiefferiella	Arthropoda	Insecta	Diptera	Chironomidae	omv
Glyptotendipes	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Kiefferulus	Arthropoda	Insecta	Diptera	Chironomidae	omv
Labrundinia	Arthropoda	Insecta	Diptera	Chironomidae	crv
Larsia	Arthropoda	Insecta	Diptera	Chironomidae	crv
Lauterborniella	Arthropoda	Insecta	Diptera	Chironomidae	omv

Appendix A.

Taxa	Phylum	Class	Order	Family	Trophic Status
Macropelopia	Arthropoda	Insecta	Diptera	Chironomidae	crv
Microchironomus	Arthropoda	Insecta	Diptera	Chironomidae	omv
Microtendipes	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Nanocladius	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Nilotanypus	Arthropoda	Insecta	Diptera	Chironomidae	crv
Orthocladius	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Pagastiella	Arthropoda	Insecta	Diptera	Chironomidae	omv
Parachironomus	Arthropoda	Insecta	Diptera	Chironomidae	omv
Parametriocnemus	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Paratanytarsus	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Phaenopsectra	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Polypedilum	Arthropoda	Insecta	Diptera	Chironomidae	omv
Procladius	Arthropoda	Insecta	Diptera	Chironomidae	omv
Psectrocladius	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Psectrotanypus	Arthropoda	Insecta	Diptera	Chironomidae	crv
Pseudochironomus	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Rheocricotopus	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Rheotanytarsus	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Robackia	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Saetheria	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Stempellinella	Arthropoda	Insecta	Diptera	Chironomidae	
Stenochironomus	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Stictochironomus	Arthropoda	Insecta	Diptera	Chironomidae	hbv
Tanypus	Arthropoda	Insecta	Diptera	Chironomidae	omv
Tanytarsus	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Thienemanniella	Arthropoda	Insecta	Diptera	Chironomidae	dtv
Thienemannimyia	Arthropoda	Insecta	Diptera	Chironomidae	crv
Zalutschia	Arthropoda	Insecta	Diptera	Chironomidae	
Zavrelimyia	Arthropoda	Insecta	Diptera	Chironomidae	crv
Empididae	Arthropoda	Insecta	Diptera	Empididae	omv
Tabanidae	Arthropoda	Insecta	Diptera	Tabanidae	crv
Ephemeroptera	Arthropoda	Insecta	Ephemeroptera		hbv
Baetidae	Arthropoda	Insecta	Ephemeroptera	Baetidae	dtv
Baetis	Arthropoda	Insecta	Ephemeroptera	Baetidae	dtv
Paracloeodes	Arthropoda	Insecta	Ephemeroptera	Baetidae	dtv
Caenidae	Arthropoda	Insecta	Ephemeroptera	Caenidae	dtv
Caenis	Arthropoda	Insecta	Ephemeroptera	Caenidae	dtv
Eurylophella	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	dtv
Hexagenia	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	dtv
Stenonema	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	dtv
Paraleptophlebia	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	dtv
Homoptera	Arthropoda	Insecta	Hemiptera		
Belostoma	Arthropoda	Insecta	Hemiptera	Belostomatidae	crv
Corixidae	Arthropoda	Insecta	Hemiptera	Corixidae	crv
Trepobates	Arthropoda	Insecta	Hemiptera	Gerridae	crv
Mesovelia	Arthropoda	Insecta	Hemiptera	Mesoveliidae	crv
Ranatra	Arthropoda	Insecta	Hemiptera	Nepidae	crv

Appendix A.

Taxa	Phylum	Class	Order	Family	Trophic Status
Neoplea	Arthropoda	Insecta	Hemiptera	Pleidae	crv
Veliidae	Arthropoda	Insecta	Hemiptera	Veliidae	crv
Lepidoptera	Arthropoda	Insecta	Lepidoptera		hbv
Parapoynx	Arthropoda	Insecta	Lepidoptera	Pyralidae	hbv
Chauliodes	Arthropoda	Insecta	Megaloptera	Corydalidae	crv
Anisoptera	Arthropoda	Insecta	Odonata		crv
Aeshnidae	Arthropoda	Insecta	Odonata	Aeshnidae	crv
Chromagrion	Arthropoda	Insecta	Odonata	Coenagrionidae	crv
Coenagrionidae	Arthropoda	Insecta	Odonata	Coenagrionidae	crv
Enallagma	Arthropoda	Insecta	Odonata	Coenagrionidae	crv
Cordulia	Arthropoda	Insecta	Odonata	Corduliidae	crv
Corduliidae	Arthropoda	Insecta	Odonata	Corduliidae	crv
Epitheca	Arthropoda	Insecta	Odonata	Corduliidae	crv
Tetragoneuria	Arthropoda	Insecta	Odonata	Corduliidae	crv
Gomphidae	Arthropoda	Insecta	Odonata	Gomphidae	crv
Gomphus	Arthropoda	Insecta	Odonata	Gomphidae	crv
Lestes	Arthropoda	Insecta	Odonata	Lestidae	crv
Celithemis	Arthropoda	Insecta	Odonata	Libellulidae	crv
Leucorrhinia	Arthropoda	Insecta	Odonata	Libellulidae	crv
Libellulidae	Arthropoda	Insecta	Odonata	Libellulidae	crv
Sympetrum	Arthropoda	Insecta	Odonata	Libellulidae	crv
Glossosomatidae	Arthropoda	Insecta	Trichoptera	Glossosomatidae	hbv
Hydroptilidae	Arthropoda	Insecta	Trichoptera	Hydroptilidae	hbv
Oxyethira	Arthropoda	Insecta	Trichoptera	Hydroptilidae	dtv
Leptoceridae	Arthropoda	Insecta	Trichoptera	Leptoceridae	omv
Leptocerus	Arthropoda	Insecta	Trichoptera	Leptoceridae	
Mystacides	Arthropoda	Insecta	Trichoptera	Leptoceridae	dtv
Nectopsyche	Arthropoda	Insecta	Trichoptera	Leptoceridae	omv
Oecetis	Arthropoda	Insecta	Trichoptera	Leptoceridae	omv
Ylodes	Arthropoda	Insecta	Trichoptera	Leptoceridae	omv
Limnephilidae	Arthropoda	Insecta	Trichoptera	Limnephilidae	dtv
Pycnopsyche	Arthropoda	Insecta	Trichoptera	Limnephilidae	dtv
Cernotina	Arthropoda	Insecta	Trichoptera	Polycentropodidae	omv
Polycentropodidae	Arthropoda	Insecta	Trichoptera	Polycentropodidae	omv
Crangonyx	Arthropoda	Malacostraca	Amphipoda	Crangonyctidae	
Hydra	Coelenterata	Hydrozoa	Hydroida	Hydridae	crv
Viviparus	Mollusca	Gastopoda	Architaeniglossa	Viviparidae	
Menetus	Mollusca	Gastopoda	Bassommatophora	Planorbidae	
Laevapex	Mollusca	Gastropoda	Basommatophora	Ancylidae	
Physella	Mollusca	Gastropoda	Basommatophora	Physidae	
Planorbella	Mollusca	Gastropoda	Basommatophora	Planorbidae	
Promenetus	Mollusca	Gastropoda	Basommatophora	Planorbidae	
Ferrissia	Mollusca	Gastropoda	Limnophila	Ancylidae	hbv
Fossaria	Mollusca	Gastropoda	Limnophila	Lymnaeidae	hbv
Lymnaeidae	Mollusca	Gastropoda	Limnophila	Lymnaeidae	hbv
Gyraulus	Mollusca	Gastropoda	Limnophila	Planorbidae	hbv
Helisoma	Mollusca	Gastropoda	Limnophila	Planorbidae	hbv

Appendix A.

Taxa	Phylum	Class	Order	Family	Trophic Status
Planorbidae	Mollusca	Gastropoda	Limnophila	Planorbidae	hbv
Hydrobiidae	Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae	hbv
Valvata	Mollusca	Gastropoda	Mesogastropoda	Valvatidae	hbv
Bithynia	Mollusca	Gastropoda	Neotaenioglossa	Bithyniidae	
Sphaeriidae	Mollusca	Pelecypoda	Veneroida	Sphaeriidae	dtv
Nematoda	Nematoda	Nematoda	Nematoda		omv
Mermithidae	Nematoda			Mermithidae	crv
Turbellaria	Platyhelminthes	Turbellaria			omv