Evaluating Fish Habitat Compensation in the Canadian Arctic: Stream Habitat Attributes and Macroinvertebrate Assemblages

by

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Abstract

Resource development is expanding in Canada, particularly in the Arctic. In Canada, damage to stream ecosystems as a result of development requires habitat restoration or compensation measures. A compensation project, focused on improving ecosystem connectivity and aquatic habitat for fish within three small fish-bearing Barrenland lakes and their outlet streams, was conducted in the Lac de Gras, NWT watershed as a result of diamond mine development at Diavik Diamond Mine Inc. Habitat manipulations to the three outlet streams used two general fishway designs: gabion-style pool-weir and nature-like choke-pool structures. I used a Before-After-Control-Impact (BACI) design to assess stream habitat attributes, their ecosystem functions, and the macroinvertebrate assemblages before and after the compensation project. Many impacts resulted from the manipulations, but few were relevant to the long term ecological function of the system. The removal of riparian vegetation during manipulation construction best explains the reduction in stream organic matter, specifically course particulate organic matter (CPOM), observed at the gabion-weir treatment streams after manipulations. However, given the reasonable organic matter retention rates observed, CPOM can be expected to increase as vegetation reestablishes. For future compensation projects, it is recommended to take added measures to preserve and actively re-establish the riparian vegetation as much as possible during and after construction activities. There were many shifts in abundance of the macroinvertebrate assemblages for both treatments (fishway designs) in riffle and pool habitat, but no easily distinguished overall patterns emerged from ordinations, in part because shifts in at reference streams in riffle habitat also occurred. The observed decrease in Simuliidae at the gabion-weir treatment may be of concern as it is a potential food source for fish; however the affected stream was fishless. Although a reduction in some organic matter was observed at the gabion-weir treatment, and there were shifts in the macroinvertebrate

assemblages, my research suggested that the compensation manipulations were largely successful in maintaining ecosystem structure and function, with some room for improvement.

This thesis is dedicated to my father, Keith Edgar Erwin. He would be proud.

Acknowledgements

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Chapter I: General Introduction and Project Overview

INTRODUCTION

Resource development is expanding in Canada, particularly in the Arctic. As a result, formerly pristine aquatic habitats are being compromised. In Canada, damage to stream ecosystems as a result of development requires habitat restoration or compensation measures (DFO, 1986). Habitat compensation is based on the assumption that we understand the habitat needs and supporting ecosystems of the focal species. Because that is rarely the case completely, especially in the Arctic where research has been limited, compensation projects need to be assessed as ecological experiments, with the inclusion of reference sites, from which we can address our knowledge gaps (Quigley and Harper, 2006; Roni *et al*., 2008; Underwood, 1991, 1993). Compensation is often focused on fish and their freshwater stream habitats. Stream ecosystem productivity and functioning is often measured through proxies such as nutrients, epilithon growth, couse particulate organic matter (CPOM), woody debris, and leaf litter decomposition (Chapter 2) that are critical to consumers such as macroinvertebrates (Chapter 3) and fish (Vincent and Hobbie, 2000; Wang *et al.*, 2007).

Available organic matter is an essential component of system productivity but can be limited in Arctic systems due to low decomposition rates (Jones *et al*., 2003), and slow growth rates and short growing seasons potentially delaying re-establishment of riparian vegetation removed during compensation activities (Adams and Lamoureux, 2005; Scrimgeour et al., 2014). Allocthonous organic inputs are important to secondary producers such as macroinvertebrates, providing food and habitat (Cummins *et al.*, 1989).

As a critical component in arctic stream ecosystem food webs, macroinvertebrates can provide a valuable measure of ecosystem productivity and health. For example, Jones *et al*. (2003) found that macroinvertebrates composed greater than 79% of stomach contents in young-of-the-year Arctic Grayling in Barrenland streams. Golden and Deegan (1998) concluded community dynamics of Arctic tundra streams are determined by nutrient status, hydrological regime, and predation on benthic macroinvertibrates by young grayling. Shredders, an important macroinvertebrate feeding guild, feed on CPOM, including allochthonous leaf litter inputs and convert a significant amount of CPOM into fine particulate organic matter (FPOM) used by collector, or filterer, guilds (Cummins *et al.*, 1989). Scraper invertebrates, which feed on algae such as epilithon, can also provide an indication of system productivity.

A compensation project, focused on a set of small Barrenland lakes and their outlet streams, was recently conducted in the Lac de Gras, NWT watershed as a result of diamond mine development at Diavik Diamond Mine Inc (DDMI). As a result of mine construction three small fish-bearing lakes were permanently removed from the landscape, and habitat in 24 ephemeral streams was altered by mine infrastructure (DDMI, 1998). To compensate, an essentially pristine three-lake system and its outlet streams east of the mine site was selected for habitat manipulation, with the primary goal of improving existing aquatic habitat for fish.

The project focuses on improving ecosystem connectivity within the small three-lake system. Prior to manipulations, fish passage among the three lakes and with Lac de Gras was largely impossible due to a combination of dense willow growth, narrow and undefined sections of stream channel, and in some cases, a steep stream gradient with limited seasonal flow. By increasing connectivity, available foraging, spawning, and rearing habitat for resident fish was expected to increase by providing access into existing lakes and streams previously unavailable, and creating new stream habitat (Golder, 2001). The primary goals of the compensation project were to improve ecosystem connectivity, increase duration of continuous flow, and allow fish passage through the streams.

In addition to the manipulation site, two similar reference sites were established within 10 km of the manipulation streams. The first was a small two-lake system connected to Lac de Gras by a single stream with second small stream connecting the two lakes, neither stream having complete fish passage. The second site was a single small lake connected to Lac de Gras by a single unpassable ephemeral stream.

To assess the compensation project, a Before-After-Control-Impact (BACI) study was initiated in 2009. During 2009-2011, physical, chemical, and biological properties of the pristine aquatic ecosystems (references and to-be-modified) were measured to document the structure of the ecological communities and component populations, quantify their relations with stream habitat, and establish the baseline functioning of the ecosystem prior to the initiation of compensation activities during late 2011. In 2012 and 2013 the same ecosystem measures were taken at the reference and modified sites for two years of post manipulation monitoring. Additionally, during late 2012 modifications were made to the initial compensation activities in 2011.

This project created opportunities to integrate investigations of the ecological communities of small Barrenland lakes and streams and the functioning of these ecosystems while incorporating the BACI design to assess the effectiveness of the compensation project. The comparative data on undisturbed reference ecosystems should also improve our understanding of Arctic stream ecosystems and thus improve our attempts to design future compensation projects in the Arctic (Jones *et al*., 2003).

HABITAT RESTORATION, COMPENSATION AND THE BACI DESIGN

Restoration ecology is a relatively new science (Young and Petersen, 2005) and fish habitat compensation in the Canadian Arctic it is very new. There are just two published articles to date evaluating compensation in the Arctic, both by Jones *et al*. (2003, and 2008). However, several publications have evaluated riverine and stream rehabilitation and restoration practices used in North America (Palmer *et al.*, 2005, and 2009; Roni *et al*., 2008; Roni and Beechie, 2013).

As part of a global review of stream habitat rehabilitation techniques, Roni *et al*. (2008) evaluated the effectiveness of instream habitat improvements involving the placement of artificial and natural structures into stream channels. They concluded many western North American streams experienced large (>50%) significant increases in positive physical habitat features such as pool frequency and depth, woody debris, spawning gravel, and organic matter retention as a result of such modifications. Biological effectiveness in terms of fish and macroinvertebrate resonses to rehabilitation techniques was variable, however, and dependent on factors such as sampling technique, species and life stages examined, and duration of monitoring. Roni *et al*. (2008) suggested that macroinvertebrates may be limited by primary productivity, not habitat complexity, therefore habitat modification alone may be insufficient and habitat complexity may not be a good sole indication of success. Palmer *et al.* (2009) reviewed 78 stream or river restoration projects and found only two projects in which increased habitat heterogeneity correlated with significant increases in macroinvertebrate biodiversity. This concurs with Quigley and Harper (2005), who suggested that an array of indicators, including invertebrates and periphyton, is preferred to single metrics (particularly fish biomass) to dectect responses. Roni and Beechie (2013) compiled a comprehensive book to guide riverine restoration with a strong emphasis on the need for rigorous monitoring and evaluation, ideally incorporating multiple sites with a broad-scale design, such as multiple BACI (MBACI) (Underwood, 1991).

The BACI design has been highly regarded in environmental assessment study design (e.g. Downes *et al*., 2002), but despite this has been incorporated into habitat compensation studies infrequently (Quigley and Harper, 2006; Roni *et al*., 2008). The design theoretically allows researchers to monitor for potential environmental impacts resulting from compensation activies and evaluate their magnitute while accounting for temporal, spatial and environmental variability (Underwood, 1992). The MBACI design uses spatial replication of treatments and reference sites allowing for the broadest application of results (Roni and Beechie, 2013). In contrast, thebeyond-BACI design has only a single treatment site but incorporates multiple control sites, and therefore has improved response detection abilities, but does not have the broad applicability of the MBACI.

Determining success of habitat compensation projects in Canada has proven very challenging. Using an array of indicators, Quigley and Harper (2006) determined that 63% of the 16 projects they evaluated resulted in overall net losses in habitat productivity. Quigley and Harper (2006; also Harper and Quigley, 2005) conclude the shortfall lies in three main areas: lack of compliance by industry regarding monitoring and reporting on compensation projects, the need to change institutional aproaches to compensation including improved compliance monitoring and enforcement activities, and the need for improvements to compensation science. It is my hope that by incorporating the BACI design, this project can help bridge some of these gaps.

STUDY AREA

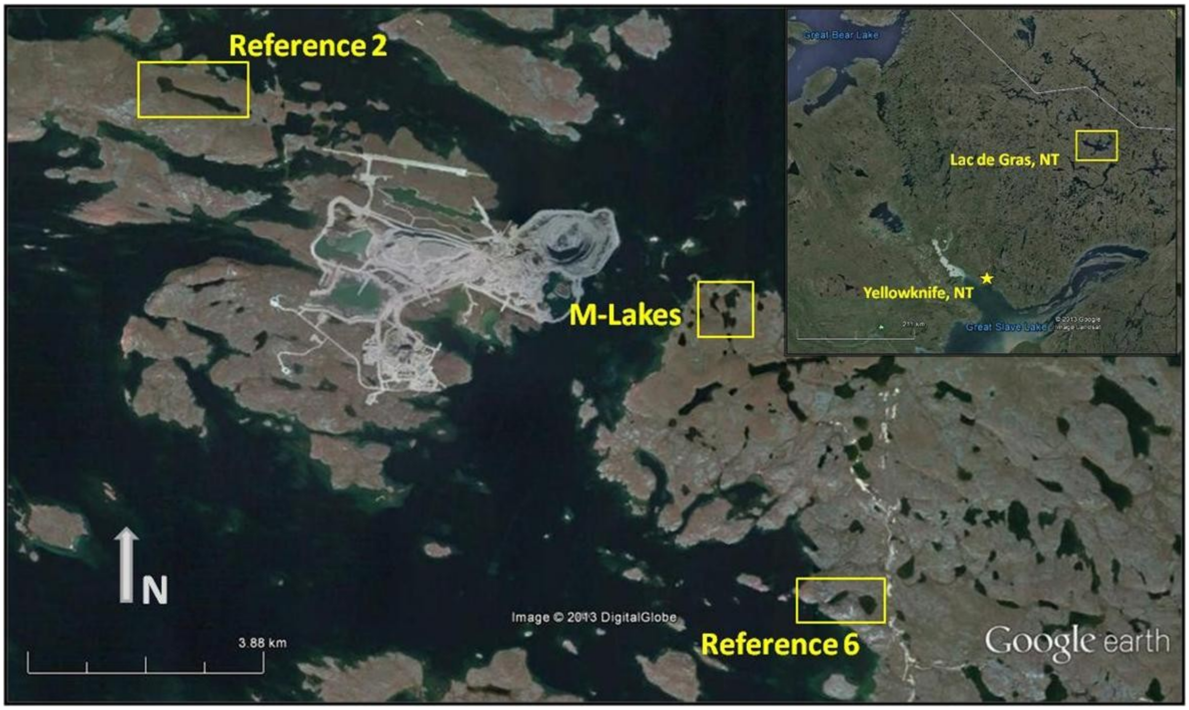

Figure 1-1. Photo (Google Earth) showing locations of study sites and the Diavik Diamond Mines Inc. mine site in the Lac de Gras watershed, Northwest Territories. Insert: Regional photo showing the location of the study area aproximately 300 km NE of Yellowknife, NT.

The study area is located in the Barrenlands region of the Southern Arctic ecozone, approximately 300km NE of Yellowknife, NWT in the Lac de Gras watershed (Figure 1-1). This region is semiarid, recieving only 200-300mm of percipitation annually. Average annual temperature is -12 ^{o}C, but extremes can drop as low as -51.2^{o}C in long, cold winters and reach up to 32.5^{o}C during short cool summers (Environment Canada, 2012). The sun is above the horizon for 20 hours/day in June, and only 5 hours/day in December. At an elevation of 416m, Diavik is located 100km north of the treeline and the surrounding landscape is classified as arctic tundra and is within the continuous permafrost zone (DDMI, 2009). The vegetation is dominated by shrubs, grasses, mosses, and lichen.

Stream banks and low lying wet areas are often lined with dense willow (*Salix* spp.) and moss (*Shpagnum* spp.) (DDMI, 2009). Other species common to the area include dwarf birch (*Betula nana*), northern Labrador tea (*Rhododendron subarcticum*), and *Vaccinium* species.

The habitat compensation site is located approximately 3km east of the site of the Diavik mine (Figure 1-1). It is a system of three small weakly connected lakes referred to as Mainland Lakes, or M-Lakes (M1, M2 and M3). Lakes M2 and M3 drain into M1, which drains into Lac de Gras. Compensation work focused on the stream channels connecting the three lakes, referred to as M2S and M3S, as well as the outlet from M1 to Lac de Gras, M1S. The two control sites are also located within the Lac de Gras watershed. Reference 6 is a chain of two lakes draining into Lac de Gras approximately 7km SE of the mine, and Reference 2 is a single lake that drains into Lac de Gras approximately 6km NW of the mine.

These small lake-outlet streams (Table 1-1) are ephemeral with peak flows occuring in early June and the channels often becomming stagnant or dry by mid-July to mid-August as evaporation reduces lake water levels (Jones *et al*. 2003; Baki et al. 2012a, b). Prior to compensation activities, fish species inhabiting portions of the streams while wetted included Arctic Grayling (*Thymallus arcticus*), Ninespine Stickleback (*Pungitius pungitius*), Burbot (*Lota lota*) and Slimy Sculpin (*Cottus cognatus*)(Courtice *et al.*, *in press*). However, no fish were ever observed in M3S prior to compensation (2009-2011). Fish observed in reference streams include Arctic Grayling, Ninespine Stickleback, Burbot, Slimy Sculpin, Lake Trout (*Salvelinus namaycush*) and Round Whitefish (*Prosopium cylindraceum*) (Cahill, *in prep*).

Prior to compensation, the small headwater lakes drained by these streams (Table 1-1) each contained up to 7 of the 8 recorded species including Arctic Grayling, Ninespine Stickleback, Burbot, Slimy Sculpin, Lake Trout, Round Whitefish, Lake Whitefish (*Coregonus clupeaformis*), and Longnose

Sucker (*Catostomus catostomus*). These species, along with Cisco (*Coregonus artedi*) can also be found in Lac de Gras. The DDMI compensation activities focus on Lake Trout, Arctic Grayling, Lake Whitefish, Round Whitefish, and Cisco (Golder, 2001). The habitat of these species was to be the most affected by mine infrastructure construction, which eliminated three small lakes and altered 24 streams, and Lake Trout, Arctic Grayling, and Cisco were identified as having fishery potential (DDMI, 1998). Habitat manipulations were designed to meet specific compensation goals and mitigate impacts to these species and their habitat.

Table 1-1. The six Barrenlands study lakes and streams In the Northwest Territories, Canada, lake size (ha), stream length (m), and channel widths (m).

Site	Lake Name	Size (ha)	Stream Name	Length (m)	Pre construction mean channel width (m)	Post construction mean channel width (m)
M-Lakes	M1L	5.68	M1S	50	2.62	2.23
	M2L	4.65	M2S	27.5	1.49	1.41
	M3L	3	M3S	40	5.49	1.64
R2	R2L	18.87	R2S	103	0.95	-
R6	R6L1	3.91	R6S1	108	1.52	-
	R6L2	6.82	R6S2	177	1.09	-

Figure 1-2. M1S, M2S, and M3S compensation study streams post construction (white arrows indicate direction of flow); photo taken July 2, 2012, facing SE.

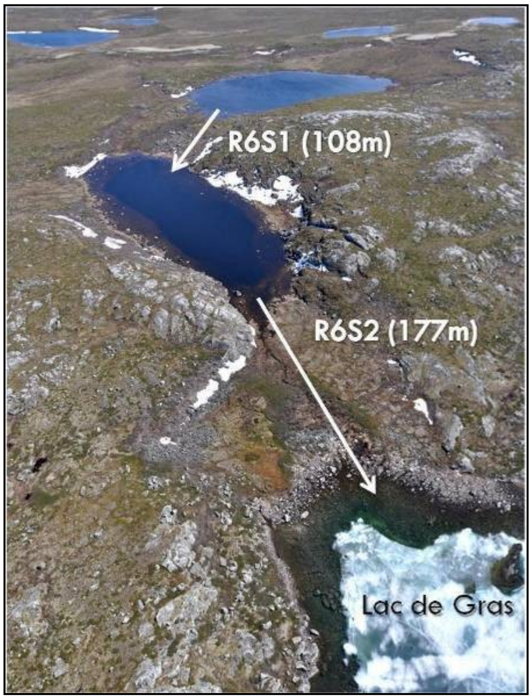

Figure 1-3. R6S1 and R6S2 reference study streams (white arrows indicate direction of flow); photo taken June 9, 2012, facing E.

Figure 1-4. R2 reference study stream (white arrow indicates direction of flow); photo taken June 5, 2012, facing SE.

HABITAT MANIPULATIONS

Habitat manipulations within the M-Lakes stream channels used two general fishway designs: gabion-style pool-weir and nature-like choke-pool structures (from here on referred to as gabion-weir and nature-like, respectively) (Courtice *et al.*, *in press*) (Table 1-1). In fall 2011, M1S and M3S each had 6 gabion weirs (wire baskets filled with crushed rock) installed to create step-pool structures throughout the two channels. M2S had a single choke point, constructed of boulders found on site, and a single pool downstream of the choke point, constructed mid channel. Channel definition was improved at all 3 streams. A gabion berm was installed on M1 Lake adjacent to the M1S outlet along the NE shoreline to increase lake water levels and increase M1S flow. In fall 2012, the gabion weirs of M1S and M3S were retrofitted in the field by notching the centre of the weirs and adding boulders to their design to improve channel flow and fish passage, objectives for which the original design was unsuccessful (Courtice *et al,. in press*). M2S was not additionally modified in 2012.

Figure 1-5. M1S aerial view, pre construction. Lac de Gras (downstream) is at the top. Arrows indicate direction of flow. Photo taken June 3, 2010.

Figure 1-6. Gabion-weir treatment at M1S. M1L (upstream) is to the left. Red bars indicate gabion weir locations, white arrows indicate direction of flow, and red box indicates location of photo insert (looking upstream to M1L) depicting more detail of step-pool structures after retrofitting in fall, 2012. Photo taken June 2, 2013, insert photo taken June 27, 2013.

Figure 1-7. M3S looking uptream pre construction. White arrow indicates direction of flow if it were present. Photo taken August 4, 2010.

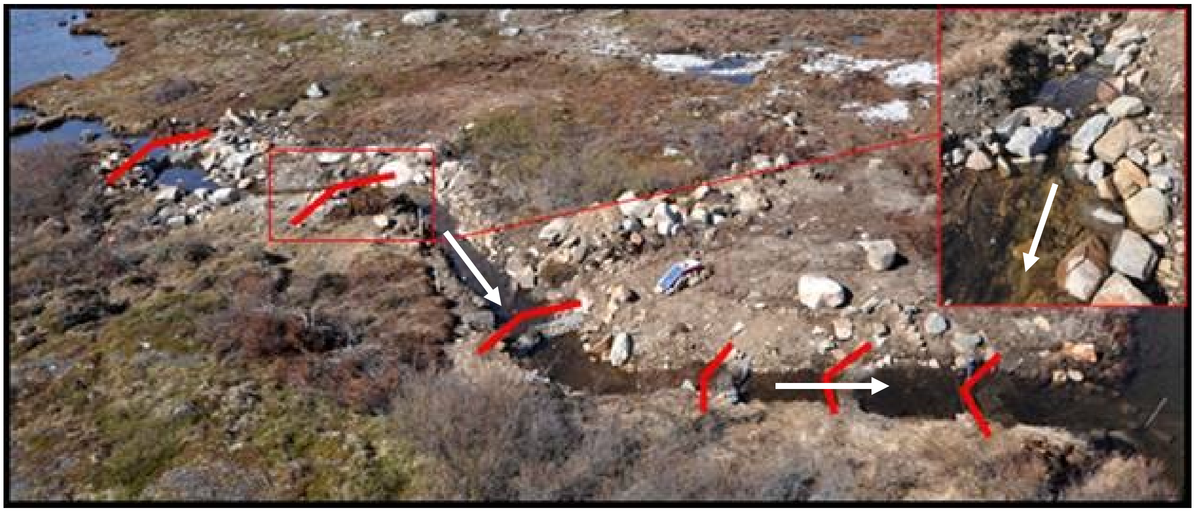

Figure 1-8. Gabion-weir treatment at M3S. M3L (upstream) is at the upper left; M1L (downstream) is at the lower bottom. Red bars indicate gabion weir locations, white arrows indicate direction of flow, and red box indicates location of photo insert depicting more detail of step-pool structures after retrofitting in fall, 2012. Photo taken June 12, 2012, insert photo taken June 9, 2013.

Figure 1-9. M2S looking downstream pre construction. M1L (downstream) is at the top left. White arrow indicates direction of flow. Photo taken June 9, 2010.

Figure 1-10. Nature-like treatment at M2S. M1L (downstream) is at the bottom; M2L (upstream) is at the top. Red box indicates location of photo insert depicting more detail of the choke-and-pool structure; white arrows indicate direction of flow. Photo taken June 7, 2012; insert photo taken June 27, 2013.

RESEARCH OBJECTIVES

There are many ways to evaluate compensation efforts; my thesis research assessed ecosystem functioning before and after compensation efforts by Diavik thereby assessing, in part, the effectiveness of the fish habitat compensation. My research goal was to use baseline abiotic and biotic habitat data collected over three field seasons (2009-2011), and post-compensation data collected over two (2012-2013) seasons, to characterize and compare stream habitat structure and ecosystem functioning (Chapter2), and macroinvertebrate assemblages (Chapter 3) using a Before-After-Control-Impact (BACI) design. More specifically, I addressed the following research questions: 1) How will stream habitat attributes and their functions change after habitat manipulations compared to reference sites? 2) Will macroinvertebrate assemblages in these Arctic streams re-establish their natural (pre-manipulation) state within the first two post-manipulation years? If not, how will macroinvertebrate abundance, diversity, and taxonomic composition change after habitat manipulation activities relative to reference sites? Use of a BACI design to address these questions should allow interpretation of any changes in the stream habitat and macroinvertebrates as a result of compensation activities.

LITERATURE CITED

Adams, P.W., S. Lamoureux. 2005. A literature review of the use of native northern plants for the re-vegetation of arctic mine tailings and mine waste. Government of Northwest Territories Environment and Natural Resources. Available at http://www.enr.gov.nt.ca/_live/documents/content/WKSS_Northern_Plants_Re-vegetation-2005.pdf (accessed March 27, 2012).

Baki, A.B.M., D.Z. Zhu, G. Courtice. 2012a. Hydraulic geometry and resistance to flow in headwater streams in the Northwest Territories, Canada. Canadian Journal of Civil Engineering 39: 1252-1263.

Baki, A.B.M., M.F. Hulsman, B.D. Lunn, W.M. Tonn, and D.Z. Zhu. 2012b. The hydrological characteristics of a stream within an integrated framework of lake-stream connectivity in the Lac de Gras Watershed, Northwest Territories, Canada. Canadian Journal of Civil Engineering 39: 279-292.

Cahill, C.L., A.C. Erwin, K.L. Howland, M.F. Hulsman, B.D. Lunn, W.M. Tonn, A.B. Baki, G. Courtice, D.Z. Zhu. In prep. Assessing the Responses of Fish to Habitat Enhancement in Barrenlands Streams, NWT, Canada.

Courtice, G., A.B.M. Baki, D.Z. Zhu, C. Cahill, and W.M. Tonn. *in press*. Stream modifications for headwater lake system connectivity for fish habitat enhancement: a case study in the Barrenlands region of Canada. Canadian Journal of Civil Engineering.

Cummins, K.W., M.A. Wilzbach, D.M. Gates, J.B. Perry, and W.B. Taliaferro. 1989. Shredders and riparian vegetation. BioScience 39: 24-30.

Diavik Diamond Mine Inc. 2009. Diavik Diamond Mine Fact Book. Available at: http://www.diavik.ca/documents/diavikfactbook.pdf (last accessed March 6, 2014).

Diavik Diamond Mine Inc. 1998. Diavik Diamonds Project No Net Loss Plan.

Downes, B.J., L.A. Barmuta, P.G. Fairweather, D.P. Faith, M.J. Keough, P.S. Lake, B.D. Mapstone, and G.P. Quinn. 2002. Monitoring ecological impacts: concepts and practice in flowing waters. Cambridge University Press. 434p.

Environment Canada. 2012. Canadian climate normals 1971-2000. Ottawa. http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=1706&lang=e&dCode=1&province=NWT&provBut=Search&month1=0&month2=12

Fisheries and Oceans Canada. 1986. Policy for the management of fish habitat. Department of Fisheries and Oceans Communications Directorate. 28p. Available at: http://www.dfo-mpo.gc.ca/Library/23654.pdf (last accessed March 24, 2014).

Golden, H.E., L.A. Deegan. 1998. The trophic interactions of young Arctic grayling (*Thymallus arcticus*) in an Arctic tundra stream. Freshwater Biology 39: 637-648.

Golder and Associates. 2001. Conceptual design and compensation workplan for the fish habitat compensation program, Diavik Diamond Mines Inc. Lac de Gras.

Harper, D.J., J.T. Quigley. 2005. No net loss of fish habitat: A review and analysis of habitat compensation in Canada. Environmental Management 36: 343-355.

Jones, N.E., W.M. Tonn, G.J. Scrimgeour, C. Katopodis. 2003. Productive capacity of an artificial stream in the Canadian Arctic: assessing the effectiveness of fish habitat compensation. Canadian Journal of Fisheries and Aquatic Sciences 60: 849-863.

Palmer, M.A., E.S. Bernhardt, J.D. Allan, P.S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C.N. Dahm, J. Follstad Shah, D.L. Galat, S.G. Loss, P. Goodwin, D.D. Hart, B. Hassett, R. Jenkinson, G.M. Kondolf, R. Lave, J.L. Meyer, T.K. O'Donnell, L. Pagano, and E. Sudduth. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42: 208-217.

Palmer, M.A., H.L. Menninger, and E. Bernhardt. 2009. River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice? Freshwater Biology 55: 1-18.

Quigley, J.T., D.J. Harper. 2006. Effectiveness of fish habitat compensation in Canada in achieving No Net Loss. Environmental Management 37: 351-366.

Roni, P., K. Hanson, T. Beechie. 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management 28: 856-890.

Roni, P., and T. Beechie. 2013. A guide to restoring riverine processes and habitats. Chichester, West Sussex, UK: Wiley-Blackwell.

Underwood, A.J. 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42: 569-587.

Underwood, A.J. 1992. Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. Journal of Experimental Marine Biology and Ecology 161: 145-178.

Young, T.P., and D.A. Petersen. 2005. The ecology of restoration: historical links, emerging issues and unexplored realms. Ecology Letters 8: 662-673.

Chapter II: Stream Habitat Attributes and Their Function

INTRODUCTION

Often, when humans develop areas for their own purposes, disruption or destruction of aquatic habitat is unavoidable. In many jurisdictions, damage to aquatic ecosystems as a result of development requires habitat restoration or compensation measures (DFO, 1986). Compensation measures are based on our understanding of the habitat needs of the target species and their supporting ecosystems, and often result in large alterations of ecosystem components, particularly in streams and rivers. Common practices include monitoring and evaluating proxies of aquatic ecosystem productivity and functioning, such as stream nutrients, epilithon growth, couse particulate organic matter (CPOM), woody debris, and leaf litter decomposition, that are critical to consumers such as macroinvertebrates (Chapter 3) and fish (Vincent and Hobbie, 2000; Wang *et al.*, 2007).

Stream nutrients are often limited in arctic systems and arctic streams tend to be oligotrophic with primary productivity often limited by phosphorus and/or nitrogen availability (Hullar and Vestal, 1989; Benson *et al.*, 2013). For small lake-outlet streams, which are abundant in some arctic regions, such as the Barrenlands of the Northwest Territories, water chemistry is highly influenced by the lakes they drain (Kling *et al.*, 2000), yet changes may still occur following habitat manipulations. Water chemistry in streams may be altered by decreased inputs of organic material, decreased nutrient uptake due to the removal of riparian vegetation, or temporary increases in organic and inorganic materials resulting from other riparian or instream disturbances during construction activities (Jones *et al.*, 2003a; Dosskey *et al.*, 2010). Even where large changes in stream nutrients are unlikely to occur, small changes (in an absolute sense) could still be relatively important because of this limited nutrient availability.

Temperature can also limit primary productivity and influence a diversity of instream processes and functions (Cummins, 1974; Bothwell, 1988, Kalff, 2001). Topographic shading is one of the key drivers of water temperature (Poole and Berman, 2001) and vegetation removal can cause increased stream temperatures (Brown and Krygier, 1970).

Sestonic algae, whose abundance can be estimated by chlorophyll-a (Swanson and Bachmann, 1976), are an indicator of primary productivity. Flow rate can be a major driving factor of phytoplankton density in streams, together with water temperature, with lower flows and higher temperatures showing higher densities (Kilkus *et al.*, 1975). However, because most sestonic algae in small streams may originate from benthic populations (periphyton) (Swanson and Bachmann, 1976; Blum, 1956), factors affecting periphyton production may be as or more important than those affecting sestonic algae per se.

Periphyton growing on rocks (epilithon) is a matrix of algae, fungi, bacteria, and detritus and is an important food source for grazing invertebrates (Hill *et al*., 1996). In many streams, the algal component of epilithon is the photosynthetic base of the food chain, replacing the role that phytoplankton serves in lakes or slow-moving systems (Smith and Smith, 2001), and can be a good indicator of water quality. As with sestonic algae, temperature is an important driving factor affecting epilithic growth; light can also be an important factor but may be closely tied to nutrient availability (Bothwell, 1988; Frost and Elser, 2002). However, Schiller *et al.* (2007) found that algal biomass was mainly affected by light, and nutrient availability did not increase growth. In a nutrient rich system Munn *et al.* (1987) found water temperature and turbidity explained variation in chlorophyll-a accrual, and concluded that primary productivity was limited by temperature and light. Stream channelization during compensation manipulations and riparian vegetation removal may promote epilithon growth by increasing water temperatures and light levels, in turn boosting primary productivity of the stream.

Woody debris and CPOM are primarily composed of allochthonous inputs from riparian vegetation and are also critical components to the base of stream food webs (Cummins, 1974). Low inputs could fundamentally limit productive capacity (Cowan and Oswood, 1983), making it important to monitor them (and riparian vegetation) following habitat manipulation.

To compensate for habitat loss due to mining activities, Diavik Diamond Mine Inc (DDMI) developed several habitat manipulation projects designed to increase productivity of existing habitat. One such project, the subject of this study, focused on increasing connectivity among a series of small Barrenland lakes, referred to as M-Lakes, in the Lac de Gras, NWT watershed, through manipulation of their outlet streams. The M-Lakes project goal was to improve existing aquatic habitat for fish. Stream manipulations were used to increase flow, connectivity, and fish passage between adjacent lakes. To assess the effectiveness of this project, I evaluated changes to important habitat components with reference to undisturbed systems in the area.

Construction methods used during manipulations resulted in the removal of much of the adjacent stream riparian vegetation. As a consequence, in the initial years following habit manipulations I predicted that critical components of system productivity and ecosystem functioning, including vegetation cover, CPOM, woody debris, CPOM retention, leaf litter processing, nutrients (total phosphorus and total nitrogen), and chlorophyll-a would be reduced and epilithon and temperature would increase. To address this, I compared abiotic and biotic stream habitat attributes in manipulated and reference arctic headwater stream ecosystems to: 1) evaluate if, and how, they changed in the first two years after manipulations, and 2) determine if stream functions and habitat attributes were maintained within the range of natural variation following manipulation. Comparisons were made relative to baseline conditions at manipulation and reference streams, collected for 3 years prior to manipulations, and to regional baseline data collected by Jones *et al.* (2003a).

STUDY AREA AND HABITAT MANIPULATIONS

Refer to Chapter One for detailed study area and habitat manipulation descriptions.

METHODS

Unless otherwise noted, sampling protocols were identical during the pre (2009-2011) and post (2012-2013) manipulation monitoring. Fixed habitat stations were established along stream banks at riffle and pool habitats. Depending on stream length, four to six stations were spaced along each channel, each representing either a single pool or riffle habitat. CPOM, epilithon, and riparian vegetation cover measurements described below were strictly associated with habitat stations, while other measurements were taken at selected point locations or transects within the stream as described below. These locations usually focused on deeper sections of a channel with prolonged flow/water to allow for measurements throughout the season. The number of sample replicates and transect lengths were chosen within the constraints of the small size of the streams.

Each field season started in late May or early June when the stream channels became mostly ice free, and went until mid August, prior to fall when the weather becomes much less predictable and flows decline or cease. Within each season, samples were taken at approximatey the same time each year to minimize seasonal variablility.

Pysiochemical Attributes

Stream water was collected 2-4 times per season from a single location in each stream (usually a deeper section of the channel with prolonged flow). Samples were collected prior to any other stream work occuring that day and latex gloves were worn to minimize contamination from surveyors hands. Two liters of water were collected from each stream by submerging acid washed 1L amber sample bottles into the water column without distubing the bottom sediments and avoiding surface water film. Bottles were triple rinsed with stream water prior to the final sample collection. Samples were kept cool throughout the day and refridgerated until they could be processed.

For analysis of chlorophyll-a, a portion of each 2L sample (usually 300 ml or enough water to create a visual yellow stain) was filtered through an acid washed glass microfiber GF/F filter, which was then folded in quarters, placed in a petri dish, wrapped in tinfoil, and frozen until shipped to University of Alberta Biogeochemical Analytical Service Laboratory for processing using a Shimadzu RF-1501 spectrofluorophotometer. The remaining portion of each water sample was frozen and sent to the Biogeochemical Lab for TN (µg/L) and TP (µg/L) analysis using a TOC analyzer and Flow Injection Analysis, respectively.

Temperature (^{o}C) measurements were obtained in the field using a Hach Hydromet Hydrolab water quality sonde. A HOBO pendant temperature logger, installed in each stream, also recorded water temperature at hourly intervals for the duration of each field season, from which I calculated average monthly temperature for July.

Channel width (m) was measured and defined as the width of the scoured portion of the channel. Substrate surveys were conducted on representative 30 m transects within each stream bed. Surveyors walked the length of the transect and measured the width (mm) of one piece of substrate at the toe of each footstep, for a total of 100 steps or survey points. Substrate particles that were greater than 256 mm or too embedded to measure were recorded as boulders, while those less than ~2 mm were recorded as fines. Substrate was classified as percentages of coarse (>64mm), gravel (2-64mm), and fines (<2mm).

Biological Attributes

Measurements of biological attributes and photo documentation at habitat stations were conducted once each field season in mid-late July, once vegetation was fully flushed. Composition and cover of the near-channel riparian zone was based on a visual estimate of % rock, soil, grasses/forbs, shrubs, and moss within a 2 square meter section extending 1 m upstream, and 1 m downstream of each habitat station on each stream bank. Stream exposure was recorded as high, medium, or low based on a visual estimation of the overhead shading of the stream surface by riparian vegetation 1 m on either side of each habitat station (very little or no cover vs. moderate cover vs. dense vegetation shading, respectively). An estimate of overall stream exposure was determined for each stream by using the average exposure class across all stations within each stream.

I collected CPOM samples at each habitat station using plastic 500 ml sample jars (jar depth and diameter = 10 cm x 8 cm). Jars were pressed firmly into the substrate as deep as possible then quickly flipped up and pulled out of the stream. Organic matter was separated from non organics in the lab by using a large deep dished pan to float off organics into a 1-mm collection sieve. The sample was elutriated until all organic matter greater than 1 mm had been recovered. Organic matter was placed into a pre-weighed tin boat, dried at 40^0C until a stable mass was reached, and weighed to determine the final dry mass (g/m^2) of the CPOM.

Epilithon was scraped with a knife from a known area (for convenience, the area of the sample vial lids was used, 2.14-7.8 cm^2, depending on vial used) of the upper surface of a submerged rock and collected in a vial. One sample per habitat station was taken unless there were no suitable rocks to sample from within 1 m on either side of the station; in that case no sample was collected. Samples were frozen for later processing. In the lab, de-ionized water was added to the vial to cover the sample and it was agitated to break up epilithon chunks. The sample was then filtered onto glass microfiber GF/F filters. Filters were dried, weighed, burned at 550^{0}C for one hour, rewetted, dried, and reweighed to determine ash-free dry mass AFDM (mg) (Nusch, 1980; Sartory and Grobbelaar, 1984).

Ceramic tiles (10x10cm) were used to quantify seasonal epilithon growth in 2012 and 2013. One tile was placed in each of five riffles and five pools distributed throughout each stream. Prior to placement, tiles were sterilized in a bath of citric acid wash and tied to rocks 5-10 cm in diameter taken from a rock crush pile at DDMI. The rock mounted tiles were placed as flat as possible into the stream bed in early June and left for 6-7 weeks. Epilithon was obtained by scraping a 3.63 cm^2 area of the tile into a vial using a knife. AFDM was measured as outlined above. In 2013, HOBO pennant temperature and light loggers were tied to rocks and placed adjacent to each tile in the stream channel.

All wood pieces longer than 100 mm were collected from 30-m transects within each stream channel. Total length (mm), and diameter (mm) at each end of the wood pieces was measured and recorded to calculate instream woody debris volume (cm^3/m^2). Woody debris was then returned to the stream.

Stream Functioning

To assess leaf litter processing rates, I collected willow leaves from the local tundra. Air-dried leaves (6-8 g) were weighed and placed into a 30.5 cm x 30.5 cm, 0.5 cm mesh bag, which was subsequently folded and stapled shut to create a 15.25 cm x 15.25 cm square. Four leaf packs were placed into each stream in mid-late July, generally in deeper pools to prevent drying, and removed prior to streams drying up. In drier years, leaf packs were removed earlier resulting in variable incubation times (2-3 weeks) among years.

To quantify a stream's ability to retain woody debris, in 2013 during high flows in early June, I floated artificial debris pieces down 19 m reaches of each stream for 10 minutes. Debris pieces were made from 6.35 mm diameter plastic tubing cut into 30 small (10 cm), 10 medium (20 cm), and 5 large (30 cm) pieces. During the 10-min period, observers recorded distance travelled (m), size class of debris, and the channel feature that retained the debris (woody debris, stream margin/rock, or riparian vegetation/macrophytes). One observer was stationed at the bottom of the reach to record any pieces flushing through the reach. This procedure was replicated three times at each stream.

Ability to retain leaves was quantified using the same general protocol as with woody debris. I cut artificial leaves (n=15) from waterproof paper into 3 x 3 x 3 cm triangles and floated them down the same stretches of each stream. Three replicates of the 10-min trials were conducted per stream.

Statistical Analysis

A before-after-control-impact (BACI) design (Underwood, 1991) was used to assess responses of stream characteristics following habitat compensation manipulation (2012-2013), relative to their behaviour prior to the manipulation (2009-2011) and to the dynamics of the reference streams across both before and after periods. For each stream variable measured, data from individual samples within each stream were averaged to arrive at one value for each stream for each year. I used these values in linear mixed models to test the interaction between treatment (Control vs. Impact) and time (Before vs. After), with stream as the subject and year as repeated factor.

One-way nested ANOVA was used to compare seasonal epilithon growth on ceramic tiles and temperature and light measurements recorded at each tile. Replicates were nested within each stream, with streams nested within treatment. The relationship between epilithon tile AFDM and temperature and light was tested using Pearson's correlation coefficient (Microsoft Excel 2007).

Linear mixed models were used to test the effect of treatment on retention (%) of woody debris and leaves, and the distance they travelled. Average retention or distance for each replicate within each stream was used in the analysis with stream as the subject and replicate as the repeated factor. Treatment was included as a fixed factor. Pieces not retained were excluded from the distance travelled analysis.

Data were tested for normality using a Kolomogrov-Smirnov test, and homogeneity of variances using Levene's test. Most data were $\log_{10}(x + 1)$ transformed prior to analysis to correct for issues with normality and heterogeneity of variance among samples, streams, treatments, and years. Because of low sample size and high variation alpha 0.10 was used for all analyses (Underwood, 1994), which were performed (unless noted otherwise) in SPSS Version 21 (SPSS Inc., Chicago, IL, U.S.A.).

RESULTS

Pysiochemical Attributes

Habitat manipulations removed much of the shrubs and moss cover from the riparian zone and also led to an increase in exposed soil, especially at the gabion-weir streams, where the grasses and forbs also decreased considerably (Fig. 2-1). The decrease in riparian vegetation, and corresponding increase in rock and soil at both treatments showed a treatment*time interaction with reference streams ($p < 0.1$; Fig. 2-2). Exposure of each stream in the reference and manipulation treatments prior to construction was classified as moderate. Post construction, the manipulation streams were both classified as having high exposure, while reference streams remained at moderate. There was a decrease in coarse and an increase in gravel substrate at gabion-weir streams post construction (treatment*time interaction, $p < 0.1$; Fig. 2-2), but only non-significant increases in coarse and gravel material at the nature-like streams ($p > 0.1$; Fig. 2-2). The treatment*time interaction for fine substrate was not significant ($p > 0.1$) at either treatment (Fig. 2-1).

Mean total phosphorus, total nitrogen, and temperature (^{o}C) at all streams and chlorophyll-a at the step-pool streams showed little change before and after construction (treatment*time interactions, $p > 0.10$; Fig. 2-3). Relative to the reference streams, chlorophyll-a decreased at the nature-like stream after construction (treatment*time interaction; Fig. 2-3).

Biological Attributes

CPOM decreased at gabion-weir streams in pool habitats after construction relative to reference streams, but not in riffles (treatment*time interaction, Fig. 2-4). CPOM in the nature-like stream did not show significant treatment*time interactions ($p > 0.10$; Fig. 2-4).

Regarding woody debris, neither manipulation type showed a treatment*time interaction with reference streams, where, surprisingly, woody debris volume nearly doubled ($p > 0.10$; Fig. 2-5). There were similarly no treatment*time interactions with reference streams for epilithon ($p > 0.10$; Fig. 2-5).

There was no effect of treatment on seasonal growth of epilithon on tiles in pool habitats in 2012 ($F_{2,18} = 0.867$, $p = 0.437$) but there was in 2013 ($F_{2,20} = 9.76$, $p = 0.001$; Fig. 2-6). Epilithon growth at the nature-like stream was greater than reference and gabion-weir streams, but gabion-weir streams had lower growth than at reference. Both treatments had higher growth in riffle habitats than reference streams in both 2012 and 2013 ($p < 0.1$; Fig. 2-6).

Temperatures at nature-like pool and riffle tiles were significantly higher than those at gabion-weir and reference streams (Fig. 2-7). Temperature had a significant positive correlation with epilithon AFDM at pool ($r = 0.59$) and riffle ($r = 0.55$) tiles. In contrast, light intensity at pool tiles did not show a treatment effect ($F_{2,19} = 0.343$, $p = 0.714$; Fig. 2-7) but was higher in both treatments compared to references at riffle sites ($F_{2,20} = 9.538$, $p = 0.001$; Fig. 2-7). Light had a significant negative correlation to AFDM at pool sites ($r = -0.52$) but was not correlated to AFDM at riffle sites ($r = 0.27$).

Stream Functioning

Retention of artificial woody debris was highest at the reference streams at nearly 100% retention ($F_{2,3} = 25.45$, $p = 0.013$; Fig. 2-8). The gabion-weir streams retained more woody debris than the nature-like stream. Retention of artificial leaves did not differ among treatments ($F_{2,3} = 1.14$, $p = 0.56$; Fig. 2-8). Riparian vegetation retained the majority of the debris pieces and leaves in the reference streams, significantly more than in either treatment stream type (Fig. 2-8). A combination of riparian vegetation, macrophytes, woody debris, and the stream margin retained a majority of the material at the nature-like stream (Fig. 2-9), whereas material at the gabion-weir streams was retained primarily on instream rocks or woody debris (Fig. 2-9). Debris (all sizes) and leaves travelled similar distances at all three treatment types ($p > 0.1$; Fig. 2-10).

Leaf litter processing rates (percent loss/day) decreased at all streams after construction. Consequently, processing rates at manipulation streams did not show a significant treatment*time interaction with reference streams ($p > 0.10$; Fig. 2-11).

DISCUSSION

The post-manipulation findings for stream habitat attributes and stream function were generally encouraging. Both treatments saw significantly decreased riparian vegetation cover with corresponding increases in rock and exposed soil; however no changes were observed in stream nutrients or temperature. Course substrate decreased at the gabion-weir treatment, but gravel substrate increased. Chlorophyll-a decreased at the nature-like stream, and as predicted, the gabion-style pool-weir streams saw a decrease in CPOM. Annual epilithon growth at the treatment streams was generally higher than at the references. Finally, wood retention was highest at the reference streams post manipulations, where artificial wood and leaves were retained heavily by riparian vegetation and to a much greater extent than at the treatment streams. However, given the channelizing effects of the treatments and expected decline in retention of debris, retention level at the treatment streams was encouraging. In addition, natural woody debris was well maintained after manipulations.

Habitat manipulations had no observed effect on stream nutrient levels, which are likely strongly driven by the lakes (Kling *et al.*, 2000). Dissolved organic matter was not measured but because the lack of change in nutrients and the influence of water quality by lakes, I would also not expect to see a change. Despite the lack of change in stream nutrients, water-column chlorophyll-a concentrations decreased at the nature-like stream post construction. Kilkus *et al.* (1975) found flow rate to be a more important driving factor of sestonic algae density and consistent with this, discharge in this stream increased, decreasing the water residence time, and duration of flow was prolonged following construction (Courtice *et al.*, in press). As a result, a smaller proportion of the post-construction samples were collected before flows had become negligible, likely preventing build-up of phytoplankton populations. In contrast, the gabion-weir streams did not see a reduction in chlorophyll-a, as the six pools created by this treatment likely increased water residence relative to the nature-like stream.

I predicted stream temperature would increase with the removal of riparian vegetation but this was not observed. Although shading is an important driver of stream temperature, other drivers such as stream structure (such as short stream length and influence from source lakes) are more likely driving the temperature in these streams (Poole and Berman, 2001).

It was no surprise to see a decrease in CPOM at gabion-weir systems post construction, given the allochthonous nature of CPOM input to these streams and their higher level of riparian vegetation removal of during construction (A. Erwin, pers. obs.). Additionally, the increased discharge associated with the manipulations (Courtice *et al.*, in press), combined with the paucity of streamside vegetation, reduced retention of woody debris, and likely other CPOM. Although the nature-like stream saw a greater reduction in CPOM volume than gabion-weir streams in riffle habitats, the lack of a treatment*time interaction likely resulted from higher variation and smaller sample sizes.

Contrary to my prediction of a decrease, woody debris showed no treatment*time interaction. Nevertheless, there was somewhat more post-construction woody debris in the nature-like stream than the gabion-weir streams, which may have reflected the fact that the former retained more vegetation after the habitat manipulation. Zah and Uehlinger (2001) found a positive relationship between distance from allochthonous input source to stream channel, and organic stream inputs. Input variation may also be attributed to variation in the amount of debris entering the channel as a result of construction activities, or from wildlife such as the Barrenland caribou (*Rangifer tarandus*) crossing streams and trampling vegetation into them (Jones *et al.*, 2003a).

As predicted, epilithon increased at both the gabion-weir and nature-like treatments but given that it also increased at the reference streams post construction there was no detectable impact of construction activities. Epilithon tiles placed in pool and riffle habitats in 2013 had higher growth in treatment streams than reference streams for both treatments, which generally corresponded to higher levels of light and/or temperature. Light levels in riffle habitat were higher at both treatments than reference streams, but were not correlated to epilithon AFDM. Based on work by Bothwell (1988) this is not surprising given the oligotrophic nature of this system. He did not find a relationship between light and growth rate when nutrient availability was limited. At the nature-like stream, it seems higher temperature was a more important determining factor, and was positively correlated with AFDM at both riffle and pool tiles. Bothwell found a positive correlation between temperature and growth rate under limited nutrient availability. However, higher temperatures were not observed at the gabion-weir riffle habitat there . Given there was no change in nutrient levels post manipulations, and no strong patterns for light and temperature, it is unclear from my results the mechanism(s) driving epilithon growth in this system.

There was no BACI effect of the treatments on leaf litter processing rates. This contrasts with Jones *et al.* (2003b) who found substantial differences between the newly constructed channel and reference streams in their study. Because our manipulation streams were modified channels, rather than an entirely new channel blasted out of bedrock, we expected a higher degree of functionality to be maintained post construction compared to Jones *et al*.

However, to process CPOM, it must first be available. Thus, the ability of a stream to retain allochthonous organic matter is critical; retained organic matter can function as both a food source and as habitat (Quinn *et al*., 2007). But to retain organic matter, streams often need to already have some matter, creating a positive feedback system (Scrimgeour et al. 2014). Short term retention of woody debris was higher at reference streams, where this material was primarily retained by riparian vegetation. With the paucity of riparian vegetation at the treatment streams, retention of CPOM was more dependent on instream woody debris and large rocks, which were less effective. The retention of riparian vegetation along stream banks in manipulation streams not only provides a source for CPOM, but helps to retain inputs for critical instream processes.

Summary

Although the habitat manipulations had a number of impacts on the manipulated stream systems relative to reference streams, their implications did not appear to be particularly severe. As riparian vegetation reestablishes on the stream banks, CPOM should be increasingly produced and retained, returning to pre- construction levels without excessive delay (Quinn *et al.*, 2007). The manipulated stream already showed reasonable organic matter retention rates, especially given that streams were essentially channelized as part of the process to improve connectivity. Epilithon growth can be influenced by a wide variety of factors and results of this study were inconclusive as to the driving factor(s) in these systems. In 2013, epilithon growth was found to be higher at sites with higher light and temperatures, but correlation results were mixed, and showed considerably higher than reference growth on tiles during the post manipulation monitoring.

For future projects, I recommend that riparian vegetation be retained as much as possible to help maintain ecosystem function. The critical role it plays was evident from my study and the research by Jones *et al.* (2003a, 2003b) and Scrimgeour *et al.* (2014). The removal of some vegetation is likely inevitable during construction activities, however rapid suckering was observed at all manipulation streams where willow stumps were left in place. Retaining stumps and revegetating the riparian zone where possible will also aid in maintaining stream bank stability. Simple additional measures can include wedging willow branches freshly cut down during construction into the substrate between and under large boulders, preventing them from being dislodged during freshet. In turn, this should improve debris retention (Scrimgeour *et al*.2014). This approach was very cost efficient at another nearby manipulation stream (A. Erwin, pers. obs.) and is recommended for the M-Lakes streams to improve stream attributes and ecosystem function.

LITERATURE CITED

Álvaraz, M., and I. Pardo. 2007. Factors controlling epilithon biomass in a temporary, karstic stream: the interaction between substratum and grazing. Journal of the North American Benthological Society 26: 207-220.

Baki, A.B.M., D.Z. Zhu, G. Courtice. 2012a. Hydraulic geometry and resistance to flow in headwater streams in the Northwest Territories, Canada. Canadian Journal of Civil Engineering 39: 1252-1263.

Baki, A.B.M., M.F. Hulsman, B.D. Lunn, W.M. Tonn, and D.Z. Zhu. 2012b. The hydrological characteristics of a stream within an integrated framework of lake-stream connectivity in the Lac de Gras Watershed, Northwest Territories, Canada. Canadian Journal of Civil Engineering 39: 279-292.

Benson, E.R., M.S. Wipfli, J.E. Clapcott, N.F. Hughes. 2013. Relationships between ecosystem metaboloism, benthic macroinvertebrate densities, and environmental variables in a sub-arctic Alaskan river. Hydrobiologia 701: 189-207.

Blum, J.L. 1956. The ecology of river algae. Botanical Review 22: 291-341.

Bothwell, M.L. 1988. Growth rate responses of lotic periphytic diatoms to experimental phosphorus enrichment: the influence of temperature and light. Canadian Journal of Fish and Aquatic Science 45: 261-270.

Brown, G.W., and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resources Research 6: 1133-1139.

Chilibeck, B., G. Chislett, and G. Norris. 1992. Land development guidelines for the protection of aquatic habitat. Prepared for Department of Fisheries and Oceans and Ministry of Environment, Lands, and Parks. Available at: http://www.dfo-mpo.gc.ca/Library/165353.pdf (accessed March 24, 2014).

Craig, P.C., and P.J. McCart. 1975. Classification of stream types in Beaufort Sea drainages between Prudhoe Bay, Alaska, and the Mackenzie Delta, N.W.T., Canada. Arctic and Alpine Research 7: 183-198.

Courtice, G., A.B.M. Baki, D.Z. Zhu, C. Cahill, and W.M. Tonn. *in press*. Stream modifications for headwater lake system connectivity for fish habitat enhancement: a case study in the Barrenlands region of Canada. Canadian Journal of Civil Engineering.

Cowan, C.A., and M.W. Oswood. 1983. Input and storage of benthic detritus in an Alaskan subarctic stream. Polar Biology 2: 35-40.

Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience 24: 631-641.

Diavik Diamond Mine Inc. 2009. Diavik Diamond Mine Fact Book. Available at: http://www.diavik.ca/documents/diavikfactbook.pdf (accessed March 6, 2014).

Dosskey, M.G., P. Vidon, N.P. Gurwick, C.J. Allan, T.P. Duval, and R. Lowrance. 2010. The role of riparian vegetation in protecting and improving chemical water quality in stream. Journal of the American Water Resources Association: 1-18.

Environment Canada. 2012. Canadian climate normals 1971-2000. Ottawa. Available at: http://www.climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=1706&lang=e&dCode=1&province=NWT&provBut=Search&month1=0&month2=12 (accessed March 6, 2014).

Fisheries and Oceans Canada. 1986. Policy for the management of fish habitat. Department of Fisheries and Oceans Communications Directorate. 28p. Available at: http://www.dfo-mpo.gc.ca/Library/23654.pdf (accessed March 24, 2014).

Hershey, A.E., W.B. Bowden, L.A. Deegan, J.E. Hobbie, B.J. Peterson, G.W. Kipphut, G.W. Kling, M.A. Lock, R.W. Merritt, M.C. Miller, J.R. Vestal, and J.A. Schuldt. 1997. The Kuparuk River: A long-term study of biological and chemical processes in an Arctic river. In: Milner, A.M., M.W. Oswood, eds. Freshwaters of Alaska: Ecological synthesis. Ecological Studies Series, Vol. 119. Berlin: Springer. 107-130.

Hill, K. E., J.R. Marchesi, and J.C. Fry. 1996. Conjugation and mobilization in the epilithon. *Molecular Microbial Ecology Manual*, *5*: 1-28.

Hullar, M.A., and J.R. Vestal. 1989. The effects of nutrient limitation and stream discharge on the epilithic microbial community in an oligotrophic Arctic stream. Hydrobiologia 172: 19-26.

Jones, N.E., W.M. Tonn, G.J. Scrimgeour, C. Katopodis. 2003a. Ecological characteristics of streams in the Barrenlands near Lac de Gras, N.W.T., Canada. Arctic 56: 249-261.

Jones, N.E., W.M. Tonn, G.J. Scrimgeour, C. Katopodis. 2003b. Productive capacity of an artificial stream in the Canadian Arctic: assessing the effectiveness of fish habitat compensation. Canadian Journal of Fisheries and Aquatic Sciences 60: 849-863.

Kalff, J. 2001. Limnology: inland water ecosystems. Upper Saddle River, NJ: Prentice-Hall , Inc.

Kilkus, S.P., J.D. LaPerriere, and R.W. Bachmann. 1975. Nutrients and algae in some central Iowa streams. Journal (Water Pollution Control Federation) 47: 1870-1879.

Kling, G.W., G.W. Kipphut, M.M. Miller, and W.J. O'Brien. 2000. Integration of lakes and streams in a landscape perspective; the importance of material processing on spatial patterns and temporal coherence. Freshwater Biology 43: 477-497.

Lock, M.A. 1981. River epilithon - a light and organic energy transducer. In Lock, M.A., and D.D. Williams (eds), Perspectives in Running Water Ecology, pp. 3-40. Plenum Press, New York and London.

Lund, J.W.G. 1965. The ecology of the freshwater phytoplankton. Biological Reviews 40: 231-293.

Mathooko, J.M. 1995. The retention of plant coarse particulate organic matter (CPOM) at the surface of the wet-store and dry-store zones of the Njoro River, Kenya. African Journal of Ecology 33: 151-159.

Morgan, A.M., T.V. Royer, M.B. David, and L.E. Gentry. 2006. Relationships among nutrients, chlorophyll.-a, and dissolved oxygen in agricultural streams in Illinois. Journal of Environmental Quality 35: 1110-1117.

Munn, M.D., L.L. Osborne, and M.J. Wiley. 1989. Factors influencing periphyton growth in agricultural streams of central Illinois. Hydrobiologia 174: 89-97.

Nusch, E.A. 1980. Comparison of different methods for chlorophyll and phaeopigment determination. Archiv fur Hydrobiologie 14: 14-36.

Oswood, W.M. 1989. Community structure of benthic invertebrates in interior Alaskan (USA) streams and rivers. Hydrobiologia 172: 97-110.

Peterson, B.J., L. Deegan, J. Helfrich, J.E. Hobbie, M. Hullar, B. Moller, T.E. Ford, A. Hershey, A. Hiltner, G. Kipphut, M.A. Lock, D.M. Fiebig, V. McKinley, M.C. Miller, J.R. Vestal, R. Ventullo, and G. Volk. 1993. Biological responses of a tundra river to fertilization. Ecology 74: 653-672.

Poole, G.C., and C.H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management 27: 787-802.

Quinn, J.M., N.R. Phillips, and S.M. Parkyn. 2007. Factors influencing retention of coarse particulate organic matter in streams. Earth Surface Processes and Landforms 32: 1186-1203.

Sartory, D.P., and J.E. Grobbelaar. 1984. Extraction of chlorophyll a from freshwater phytoplankton for spectrophotometric analysis. Hydrobiologia 114: 177-187.

Schiller, D.V., E. Martí, J.L. Riera, and F. Sabater. 2007. Effects of nutrients and light on periphyton biomass and nitrogen uptake in Mediterranean streams with contrasting land uses. Freshwater Biology 52: 891-906.

Scrimgeour, G., W. Tonn, and N. Jones. 2014. Quantifying effective restoration: reassessing the productive capacity of a constructed stream 14 years after construction. Canadian Journal of Fisheries and Aquatic Sciences 71: 589-601.

Smith, R.L., and T.M. Smith. 2001. Ecology and field biology (6th Edition). Benjamin Cummings.

Swanson, C.D., and R.W. Bachmann. 1976. A model of algal exports in some Iowa streams. Ecology 57: 1076-1080.

Underwood, A.J. 1991. Beyond-BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42: 569-587.

Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4: 3-15.

Vincent, W.F., and J.E. Hobbie. 2000. Ecology of arctic lakes and rivers In M. Nuttal and T.V. Callaghan, The Arctic: Environment, People, Policy (pp. 647). Amsterdam: Harwood Academic Publishers

Wang, L., D.M. Robertson, and P.J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. Environmental Management 39: 194-212.

Watson, D.G., W.C. Hanson, J.J. Davis, and C.E. Cushing. 1966. Limnology of tundra ponds and Ogotoruk Creek. In: Wilimovsky, N.J., and J.N. Wolfe, eds. Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Commission. PNE-481:415-435.

Yentsch, C.S., and J.H. Ryther. 1957. Short-term variations in phytoplankton chlorophyll and their significance. Limnology and Oceanography 2: 140-142.

Zah, R., and U. Uehlinger. 2001. Particulate organic matter inputs to a glacial stream ecosystem in the Swiss Alps. Freshwater Biology 46: 1597-1608.

FIGURES

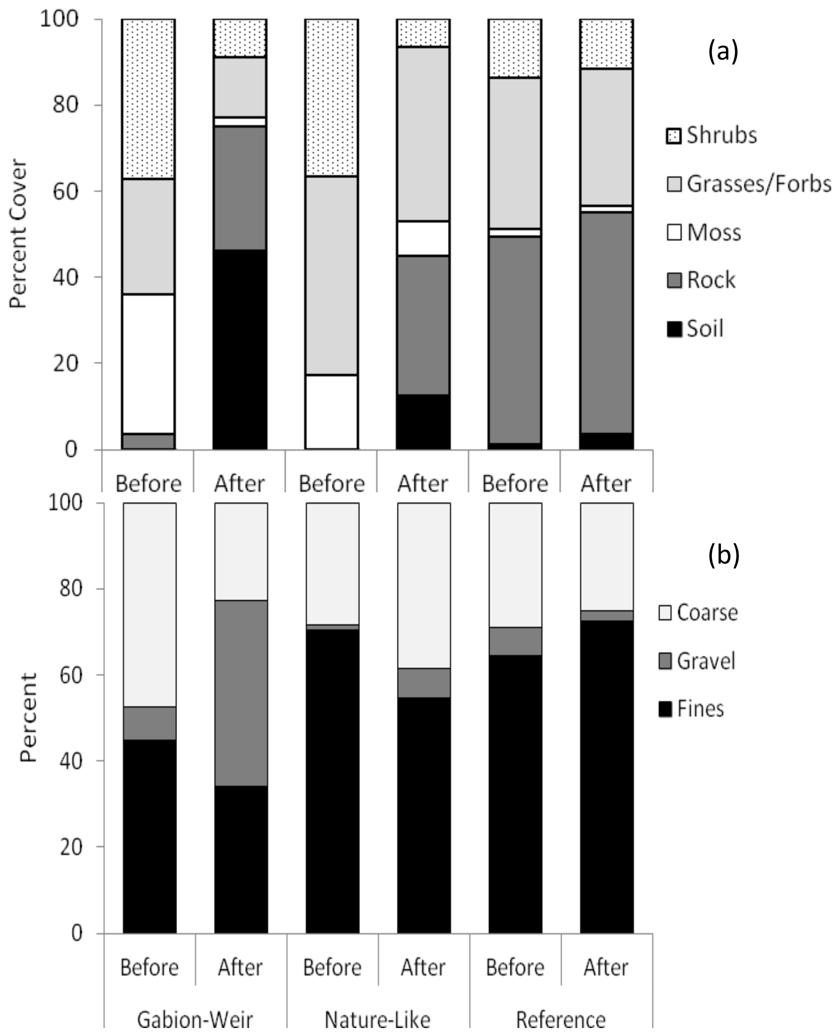

Figure 2-1. Composition of the riparian zones (a) and substrate size distributions (b) before and after manipulations at gabion-weir, nature-like, and reference streams.

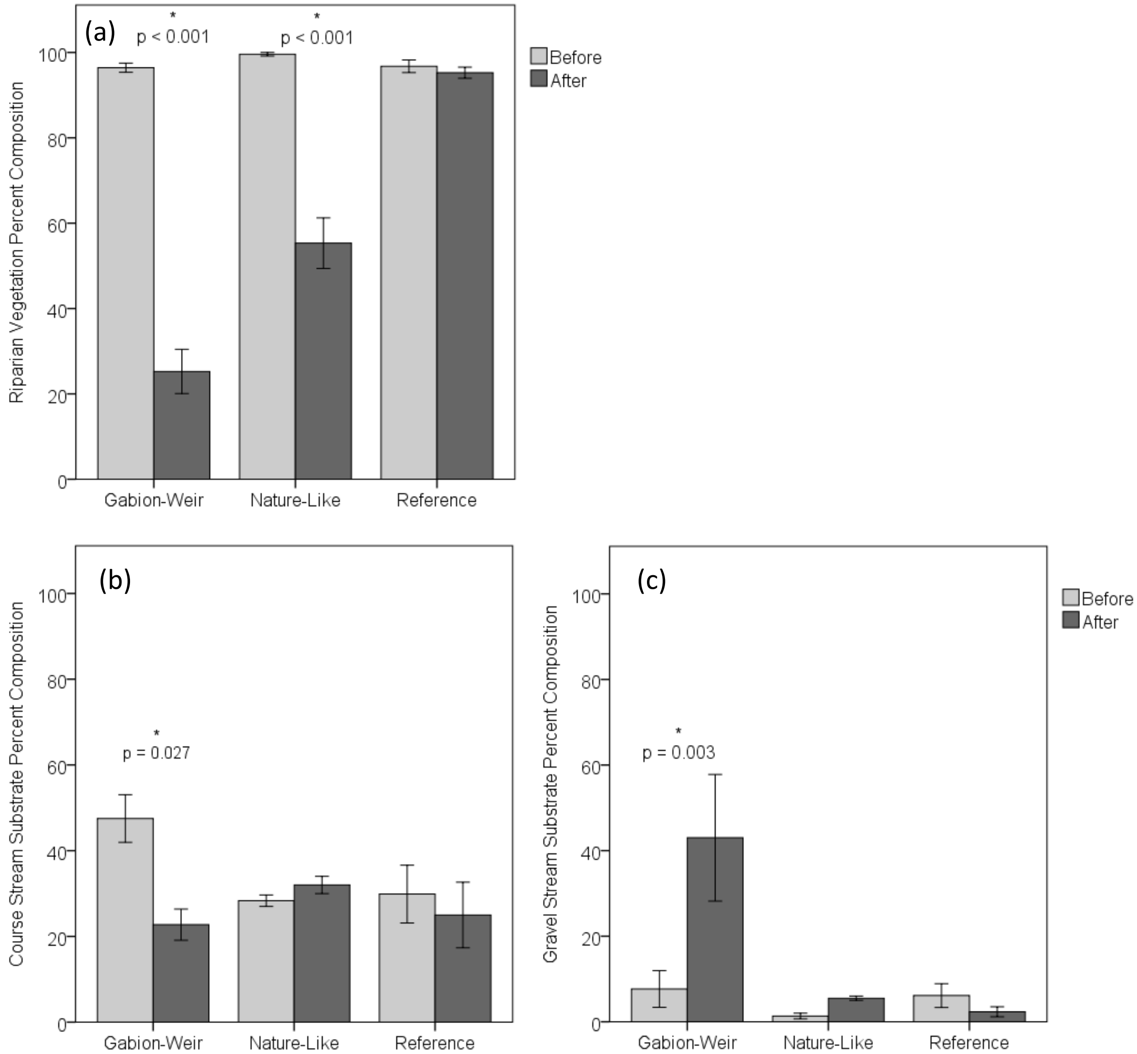

Figure 2-2. Riparian vegetation (a) percent cover, and course (b) and gravel (c) stream substrate percent composition at gabion-weir (n = 2), nature-like (n = 1), and reference streams (n = 3) before (2009-2011) and after (2012-2013) manipulations. Standard error bars depict variation around treatment-year means.

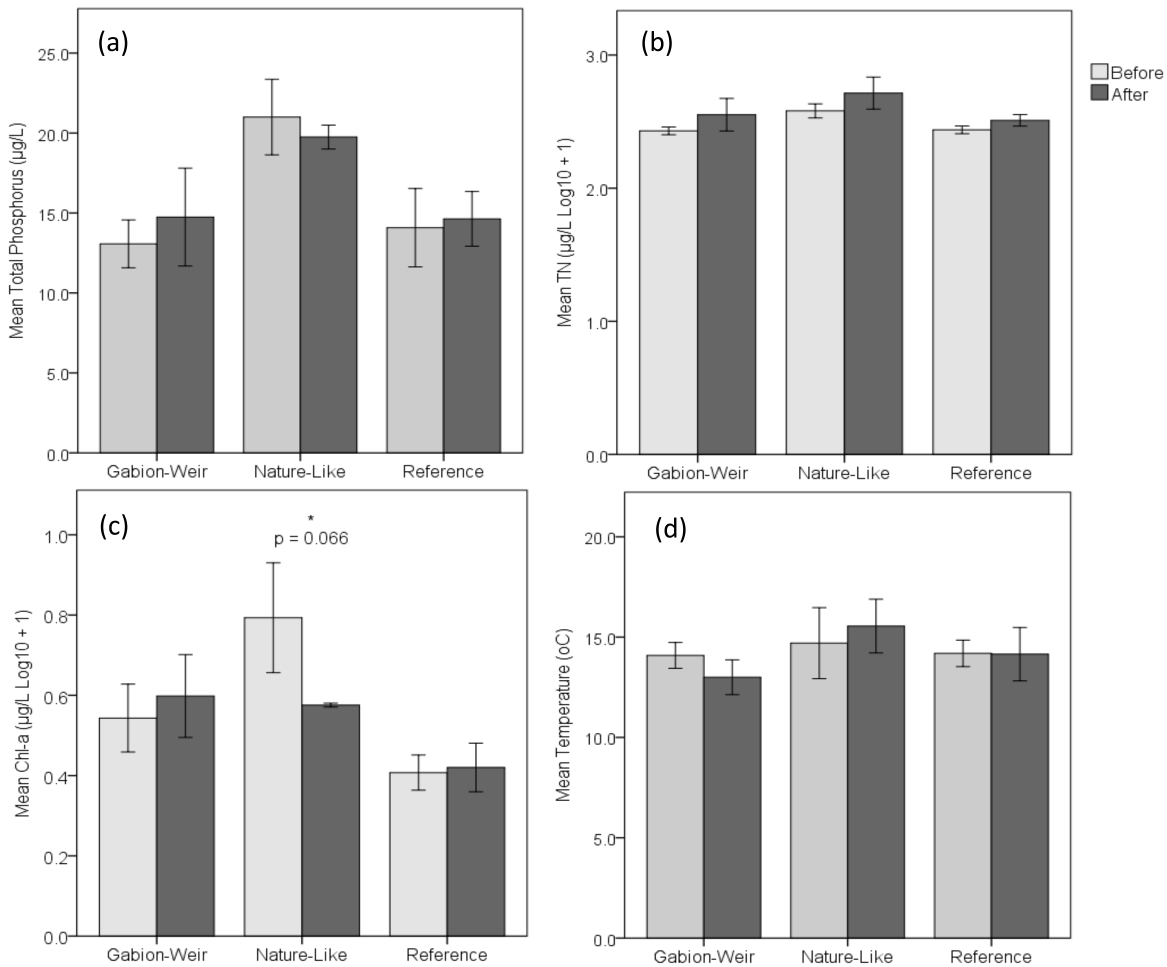

Figure 2-3. Mean total phosphorus (a), total nitrogen (b), chlorophyll-a (c), and temperature (d) (±1 SE) at gabion-weir (n = 2), nature-like (n = 1), and reference streams (n = 3) before (2009-2011) and after (2012-2013) manipulations. Standard error bars depict variation around treatment-year means and significant treatment*time interactions ($p < 0.10$) are indicated by an asterisk and the associated p-value.

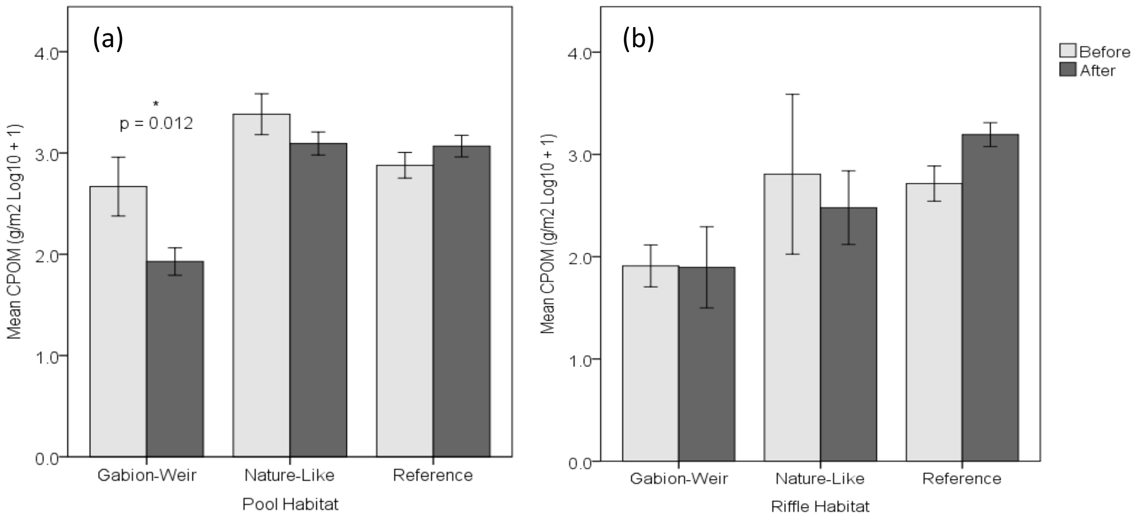

Figure 2-4. Mean CPOM ($\log_{10}$ (x + 1), ±1 SE) at gabion-weir (n = 2), nature-like (n = 1), and reference streams (n = 3) before (2009-2011) and after (2012-2013) manipulations at pool (a) and riffle (b) habitats. Standard error bars depict variation around treatment-year means. Significant treatment*time interactions ($p < 0.10$) are indicated by an asterisk and the associated p-value.

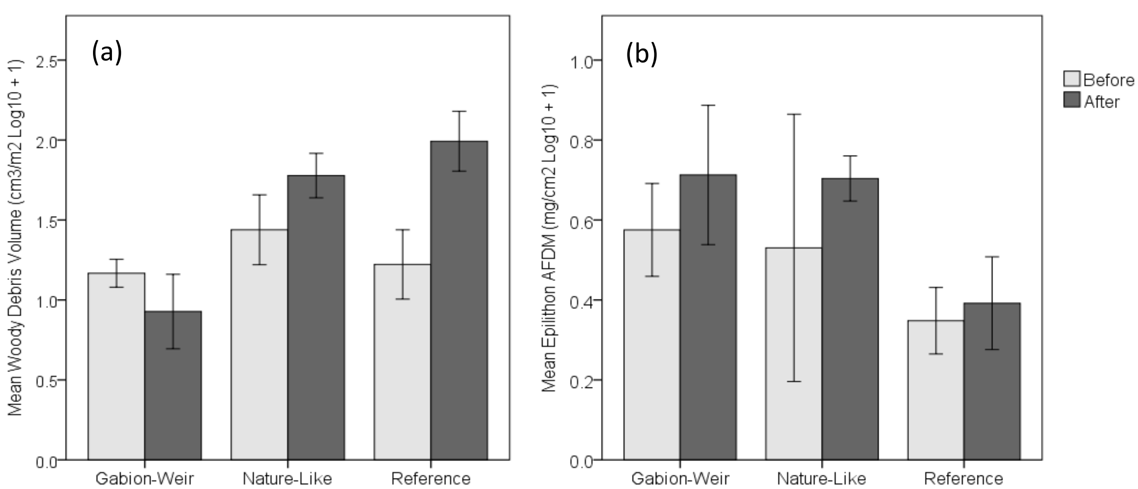

Figure 2-5. Mean woody debris (a) and epilithon (b) ($\log_{10}$ (x + 1), ±1 SE) at gabion-weir (n = 2), nature-like (n = 1) and reference streams (n = 3) before (2009-2011) and after (2012-2013) manipulations. Standard error bars depict variation around treatment-year means.

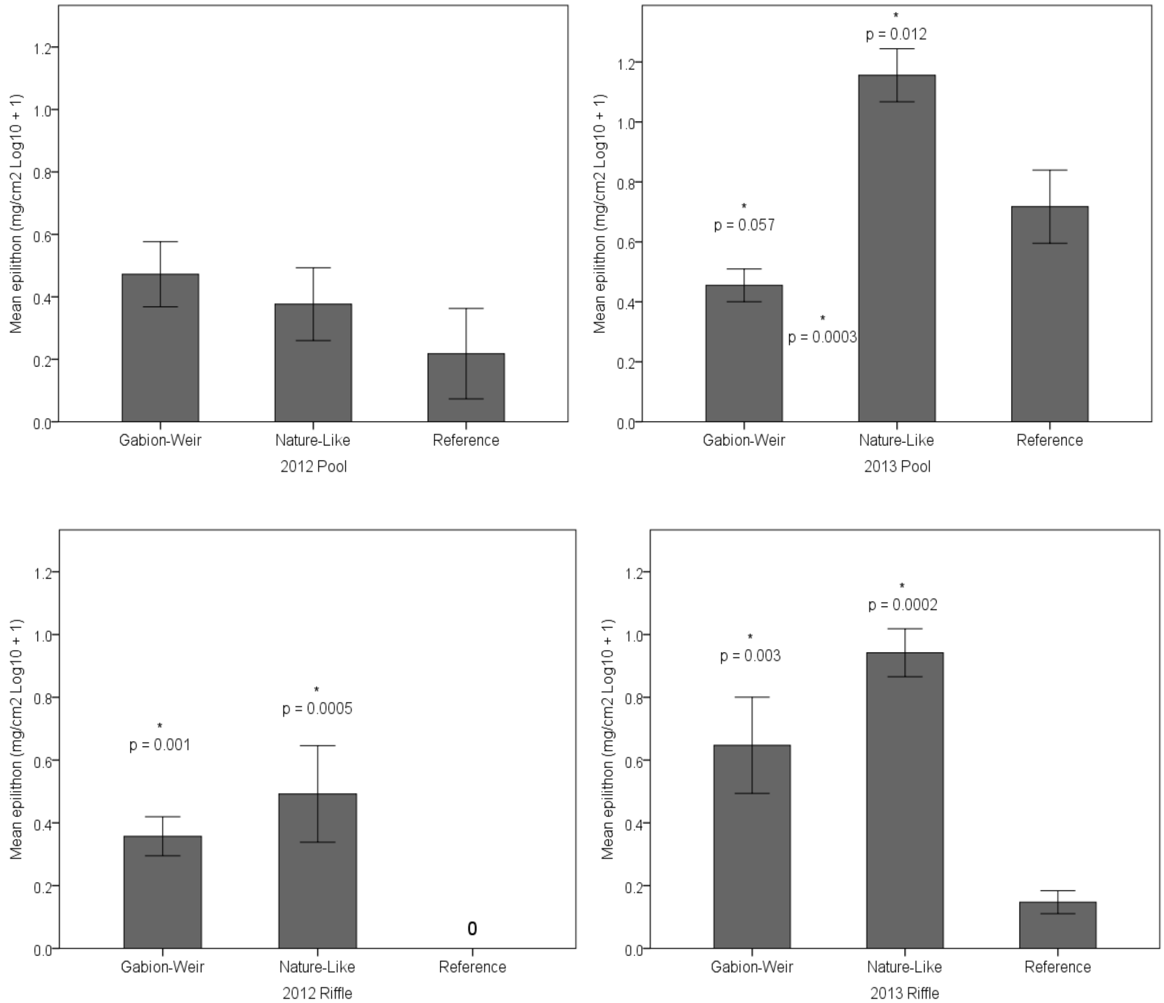

Figure 2-6. Mean epilithon growth (±1 SE) on pool tiles at gabion-weir (n = 10), nature-like (n = 5), and reference (n_{2012} = 8, n_{2013} = 10) streams, and riffle tiles at gabion-weir ($n_{2012, 2013}$ = 10), nature-like (n_{2012} = 3, n_{2013} = 5), and reference (n_{2012} = 6, n_{2013} = 10) streams in 2012 and 2013. Significant pairwise comparisons (LSD) are indicated by an asterisk and the associated p-value; above bar indicates difference from reference.

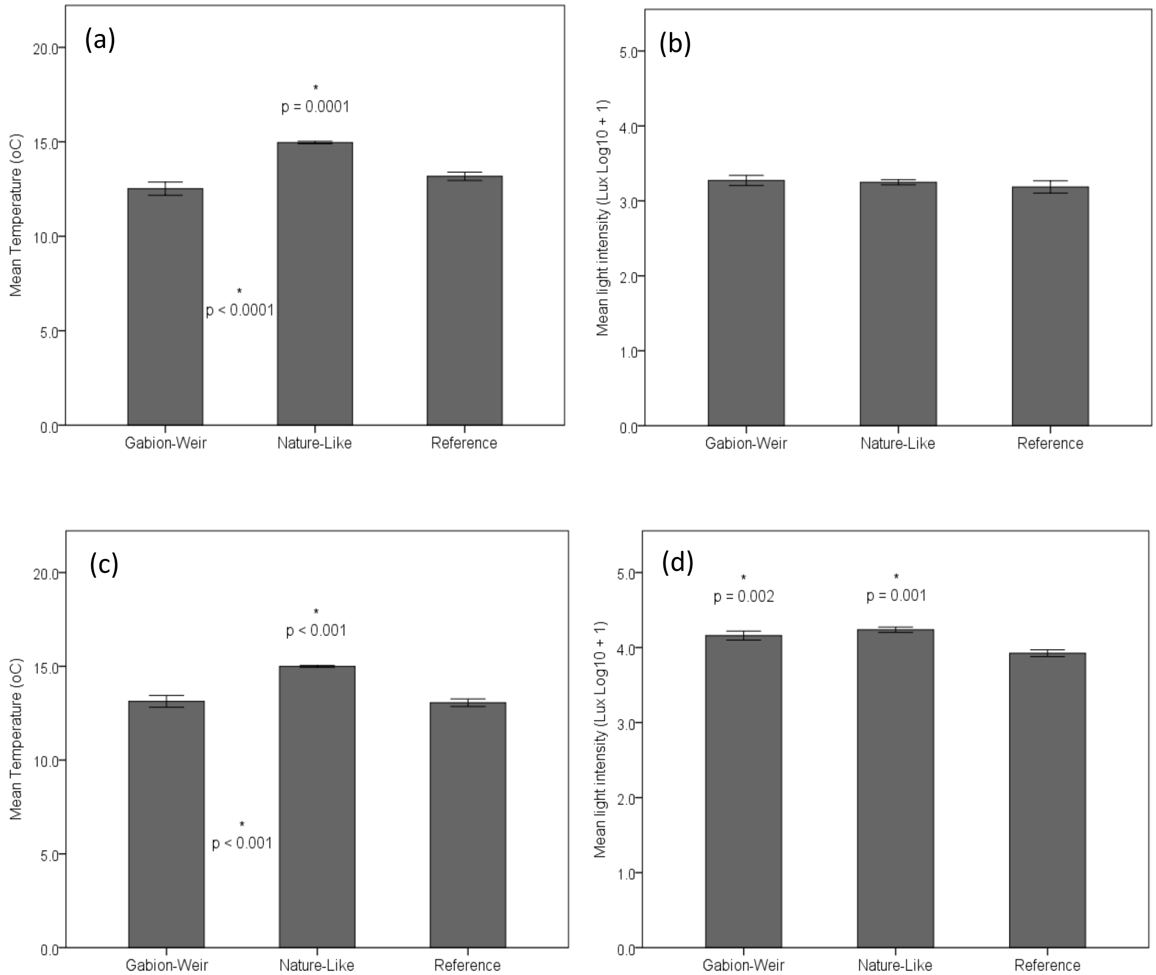

Figure 2-7. Mean temperature (left) and light intensity (right; ±1 standard error, SE) at pool (a and b) and riffle (c and d) tiles at gabion-weir (n = 10), nature-like (n = 5), and reference streams (n_{pool} = 9, n_{riffle} = 10). Significant pairwise comparisons (LSD) are indicated by an asterisk and the associated p-value; above bar indicates difference from reference and between bars indicates difference between treatments.

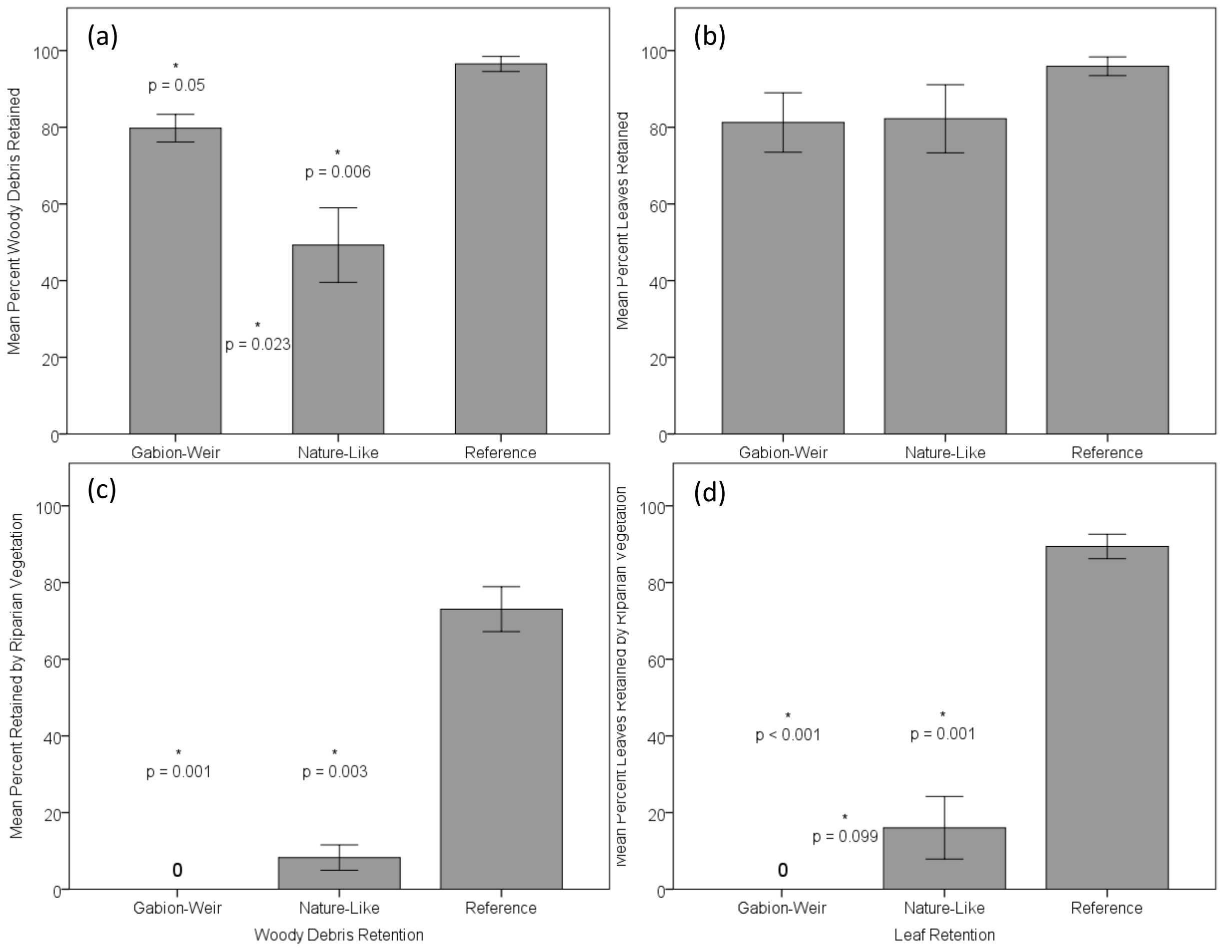

Figure 2-8. Mean overall retention (±1 standard error, SE) of artificial woody debris pieces (a) and artificial leaves (b) and percentage of wood pieces and leaves retained by riparian vegetation (c and d) observed at gabion-weir (n=2), nature-like (n=1), and reference (n=3) streams. Significant pairwise comparisons (LSD) are indicated by an asterisk and the associated p-value; above bar indicates difference from reference and between bars indicates difference between treatments.

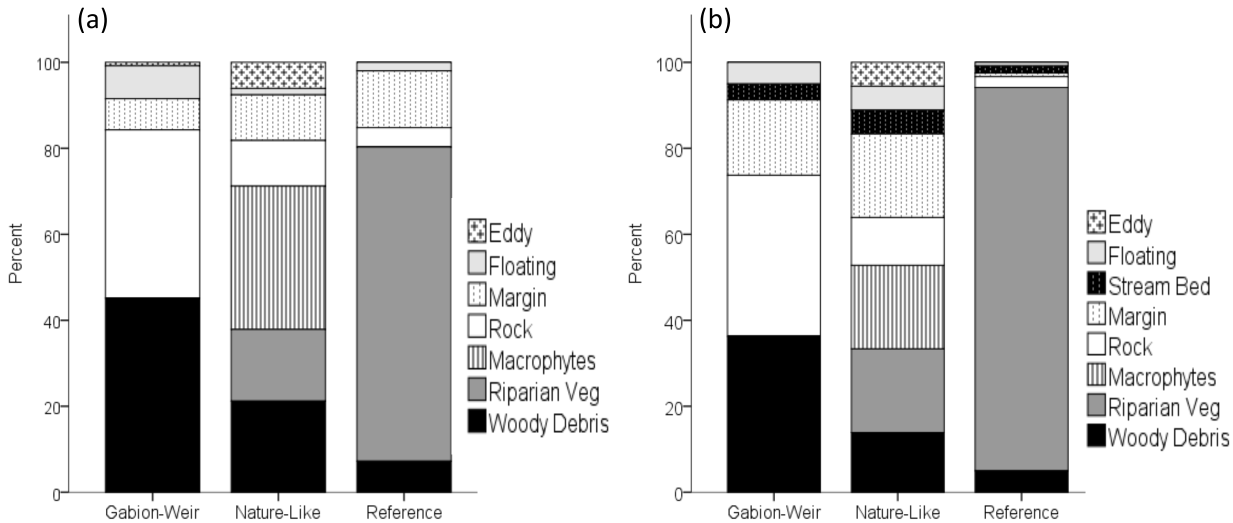

Figure 2-9. Distribution of retained artificial woody debris pieces (a) and artificial leaves (b) at gabion-weir, nature-like, and reference streams.

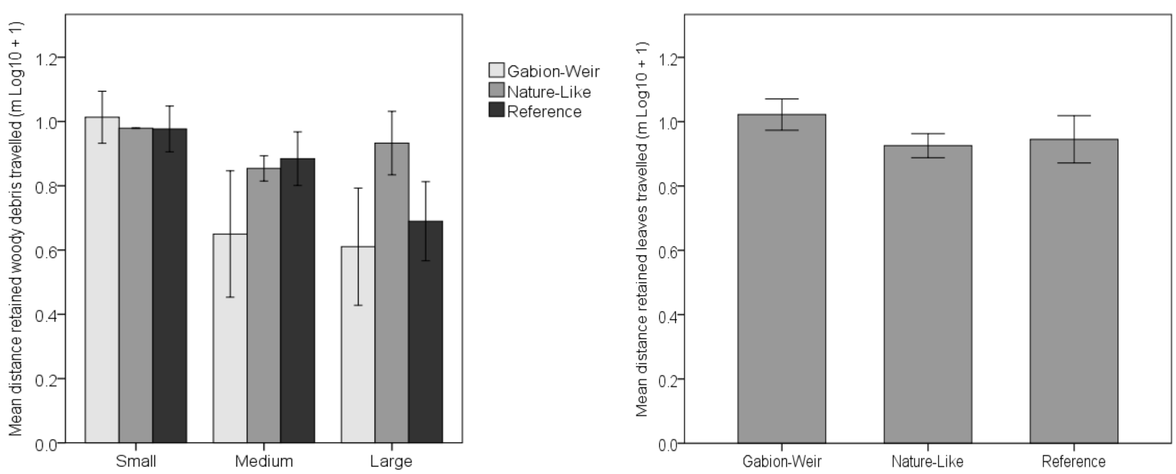

Figure 2-10. Mean distance travelled (Log_{10} (x + 1); ±1 SE) by artificial woody debris pieces (a.) and artificial leaves (b.) at gabion-weir (n = 2), nature-like (n = 1), and reference (n = 3) streams. Standard error bars depict variation among replicates within treatments.

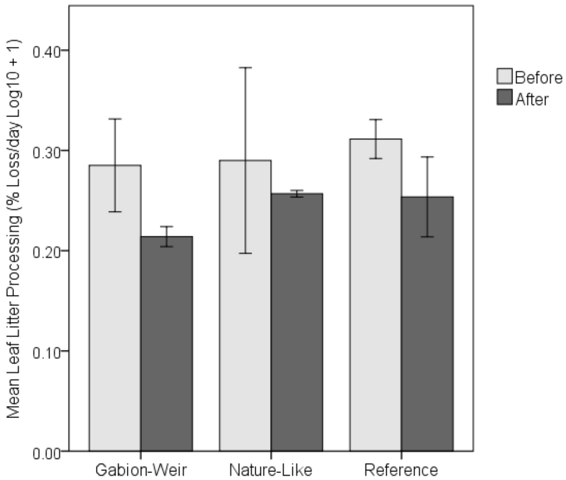

Figure 2-11. Mean leaf litter processing rate ($\log_{10}$ (x + 1), ±1 SE) at gabion-weir (n = 2), nature-like (n = 1), and reference streams (n = 3) before (2009, 2010) and after (2012, 2013) manipulation. Standard error bars depict variation around treatment-year means.

Chapter III: Macroinvertebrate Abundance, Diversity and Taxonomic Composition

INTRODUCTION

In many jurisdictions damage to aquatic ecosystems as a result of development requires habitat restoration or compensation measures (DFO, 1986). Habitat compensation is based on the premise that we understand the habitat needs and supporting ecosystems of the target species or communities. Aquatic ecosystem productivity and functioning, critical to consumers such as macroinvertebrates and fish, can be measured through proxies such as stream nutrients, epilithon growth, coarse particulate organic matter (CPOM), woody debris, and leaf litter decomposition (Chapter 2; Vincent and Hobbie, 2000; Wang *et al.*, 2007).

Macroinvertebrates are an important component in arctic stream ecosystem food webs; for example, Jones *et al*. (2003b) found they comprised greater than 79% of stomach contents in young-of-the-year Arctic Grayling (*Thymallus arcticus*) in Barrenland streams in the Lac de Gras, NWT watershed. Predation on benthic macroinvertebrates by young grayling, as well as nutrient status and hydrological regime, were also major factors influencing arctic tundra stream community dynamics in Alaska (Golden and Deegan, 1998).

Allochthonous inputs from riparian vegetation provide habitat and food for aquatic invertebrates, but organic matter availability can be naturally limited in tundra streams by low decomposition rates (Jones *et al.*, 2003b). Furthermore, construction activities during habitat compensation projects often result in extensive removal of riparian vegetation critical to macroinvertebrate production. Slow growth rates and short arctic growing seasons can delay re-establishment of riparian vegetation and limit the potential productivity of manipulated systems for extended time periods (Adams and Lamoureux, 2005; Scrimgeour et al., 2014). Shredders, an important macroinvertebrate feeding guild, feed on CPOM, including allochthonous leaf litter inputs, converting it into fine particulate organic matter (FPOM) used by collector or filterer guilds (Cummins *et al.*, 1989). Shredders may actually play a more important role in decomposition than temperature in arctic systems (Benstead and Huryn, 2011).

Due to potential food limitation because of the temporary loss of riparian vegetation, successful recolonization of shredders and collectors in streams created or modified as part of compensation projects may be low until riparian vegetation is reestablished (Jones *et al*., 2008). Riparian vegetation can also contribute to the formation of new and developing channels, increasing macroinvertebrate habitat and thus influencing the rate of recolonization (Milner and Gloyne-Phillips, 2005). At a larger scale, stressors, such as pollution, and large-scale watershed alterations, such as forestry and agriculture, can affect colonizer sources and in turn could limit recolonization of streams (Sunderman *et al.*, 2011). This suggests large scale mineral exploration and extraction such as that occurring in the Barrenlands, may be, or become a factor influencing colonization. Localized riparian disturbance, and larger scale watershed factors, can both influence and potentially delay the success of small scale, stream-based habitat compensation.

Other food sources such as epilithon can also influence macroinvertebrate assemblages (Braccia et al., 2014; Hawkins and Sedell, 1981). Epilithic chlorophyll-a serves as a proxy measure for primary production (Chapter 2); in turn, Hawkins and Sedell (1981) found an increase in abundance of scraper invertebrates with an increase in chlorophyll-a collected from epilithon growing on cobbles. Braccia *et al.* (2014) also found that scrapers increased in biomass with increased algal biomass. Scrapers, which feed on algae such as epilithon, can thus provide an indication of system primary productivity. Indeed, in cases where habitat compensation activities result in increased exposure to sunlight, which can lead to increases in epilithon at manipulated sites (e.g., Chapter 2), there may be an assemblage shift toward scraper macroinvertebrates. Because changes to important ecosystem components as a result of compensation activities may change consumer assemblages, including benthic macroinvertebrates, such changes need to be evaluated with respect to undisturbed systems in the area.

Aquatic habitat loss from development at Diavik Diamond Mine Inc. (DDMI) resulted in a compensation project focused on a set of small Barrenland lakes, referred to as M-Lakes, and their outlet streams in the Lac de Gras, NWT watershed, with the goal of improving existing aquatic habitat for fish. The stream compensation project constructed gabion-weir and nature-like fishways in the M-Lakes streams. Macroinvertebrate data were collected two years prior to and two years after construction. In this study, I examined macroinvertebrate abundance, diversity, and taxanomic composition to determine if, and how, recolonization of the study streams would occur. More specifically, I addressed the following questions: do macroinvertebrate assemblages in these manipulated arctic streams re-establish their natural (pre-manipulation) state within the first two post-manipulation years? If not, how does macroinvertebrate abundance, diversity, and taxanomic composition change after habitat manipulation activities?

In the M-lakes stream habitat manipulations, a reduction of organic matter was generally not observed (with the exception of CPOM in pool habitat at the gabion-weir streams) (Chapter 2). Willow stumps left on stream banks after construction allowed suckering to occur, and riparian vegetation re-established faster than had been anticipated, based on other studies (Adams and Lamoureux, 2005). Furthermore, impacts to physiochemical stream attributes, including temperature, total nitrogen, and total phosphorus were not observed (Chapter 2). Although I did not see a treatment*time interaction, eplithon growth was higher in the after period at manipulation sites, potentially causing shifts in macroinvertebrate assemblages. Observed changes to physical stream characteristics, such as increased pool size and depth, increased duration of flow (e.g., Courtice *et al.*, in press), and increased proportion of gravel substrate (Chapter 2) would be expected to improve stream habitat for macroinvertebrates (Muotka, *et al.*, 2002; Sarriquet *et al.*, 2007). Finally, the surrounding landscape is essentially pristine with abundant freshwater habitat, and would therefore be expected to provide many nearby sources of potential colonists (Sunderman *et al.*, 2011).

I therefore anticipated full macroinvertebrate re-colonization within the timeframe of this study and predicted little change in overall macroinvetebrate abundance and diversity after manipulations, relative to reference streams. I did, however, predict a shift in taxonomic composition towards taxa classified as scrapers due to the increased epilithon observed at manipulations sites post-construction.

STUDY AREA AND HABITAT MANIPULATIONS

Refer to Chapter One for detailed study area and habitat manipulation descriptions.

METHODS

Data were collected following protocols designed for the pre (2010-2011) and post (2012-2013) manipulation monitoring. Habitat stations were established along stream banks and chosen to include representation of both riffle and pool habitats. Depending on stream length, four to six stations were spaced along each channel, half in riffle and half in pool habitat. Photo documentation was taken at each station in mid to late July each year. The number of sample replicates (one per station) were chosen within the constraints of the small size of the streams.

Field Sampling

Benthic aquatic invertebrate samples were taken at each habitat station on each stream using a 243µm Surber net to collect invertebrates released from the stream sediment by disturbing a 30cm x 30cm area immediatly in front of the net approximately 5cm deep into the sediment. The first sample was collected at the most downstream station with each consecutive sample collected at the next upstream station to prevent contamination. Surber samples were transfered to 500ml plastic sample jars and preserved in the field in 95% ethanol until returned to the lab. When excessive amounts of sediment and organic matter created a very large sample, samples were split and sub sampled in the field. Samples were taken in June and July at approximatey the same time period each year to minimize seasonal variablility and to maximize the probability of capturing the greatest diversity of invertebrates. Streams, or sections of the streams, were often dry by mid/late July therefore, only June samples could be collected some years. All samples were analyzed by Cordillera Consulting, Summerland, British Columbia.

Sample Analysis

Sample analysis methods were as described by Cordillera Consulting (2011), using methods of Benke *et al*. (1999) and Caton (1991). Samples were elutriated by swirling sample contents in a bucket with water to separate sand and gravel from organic material. Suspended organic material was sieved through a 250µm sieve. Samples were elutriated up to five times to ensure all organics had been removed. Sand and gravel material was examined under low power microscope to find any mollucs or trichopterans lost to the elutriate. Following initial inspection under a dissecting scope, samples estimated to contain > 600 invertebrates were subsampled using a 39x32 cm Caton Tray. A minimum subsample of at least 300 invertebrates was identified to family. In samples with < 600 estimated individuals, all invertebrates were identified. For fragmented organisms, only the heads were counted; posterior body fragments, empty snail or clams shells, larval and pupal exuviae, fully emerged aerial adults, and terrestrial organisms were not counted. Prior to further identification, samples were sorted into groups (Chrionomidae, Ephemeroptera, Plecoptera, Diptera, Trichoptera, and 'other') and 10% were checked by a different sorter for sorting efficiency at 95% or greater (Environment Canada, 2012b). Taxa were identified to the finest practical level, some to genus and species, but many to coarser levels of classification (usually family or order).

__Statistical Analysis__

To maximize diversity, samples collected in July were normally used for analysis. When July samples were not available, June samples were used. Ostracoda, Cladocera, Rotifera, Copepoda, Nematoda, and Platyhelminthes were excluded from all analyses because of inadequate sampling using the Surber net, and/or not being considered as part of the benthos (Environment Canada, 2012b) (Table A1-4). Not all taxa were identified to the same classification level and were therefore grouped for analysis according to the highest identification level that allowed for the inclusion of all individuals. For example, Ephemeroptera included individuals identified to genus and species but also many that could only be identified to order, therefore all individuals were lumped into order and order was used for analysis. Exceptions were made for abundant taxonomic groups, such as dipterans and oligochaetes, where most individuals were identified to family or finer levels; these groups were analyzed by family plus “others” (identifiable to order only) (Tables A1-2 and A1-3).

Individual Surber samples from replicate riffles and replicate pools were each averaged to arrive at one habitat-specific value of total abundance (no. $\cdot$ m^{-2}), and individual taxon abundance for each stream-year before and after manipulations. Shannon's Diversity Index (H) was calculated for each individual sample using PC-ORD (Version 6, McCune and Mefford, 2011) and averaged to get one value for each stream-year by habitat (riffle and pool) before and after manipulations (taxa included and data can be found in Tables A1-5 - A1-8). I used linear mixed models (SPSS Version 21, SPSS Inc., Chicago, IL, U.S.A.) to test the interaction between time (Before and After) and treatment (Control and Impact), with year as a repeated factor and stream as the subject. Data were tested for normality using a Kolomogrov-Smirnov test and homogeneity of variances using Levene's test, and abundance data were log transformed ($\log_{10}$ x+1) prior to analysis to normalize the data distributions.

I used Student's t-tests to compare diversity calculated for individual samples before and after manipulations for each habitat type within each treatment. Variances were checked for equality using an F-test.

I used non-metric multidimensional scaling (NMS) analysis in PC-ORD (Version 6, McCune and Mefford, 2011) to analyze patterns in macroinvertebrate taxonomic compositions in riffle and pool habitats before and after habitat manipulations at the manipulation and reference sites. Taxonomic groups were excluded from the analysis if they were found in only one replicate sample site; subsequently, PC-ORD did not identify any taxa as outliers (greater than 2.5 standard deviations from the mean) in any of the analyses. Individual samples collected within each treatment were not averaged by stream as done for previous analyses and all samples within each treatment were used in the ordinations with the exception of one outlier: the abundance sample at M3S X-4 riffle habitat in 2011 (Tables A1-5 and A1-6). Outliers were identified as being greater than 2.5 standard deviations from the mean. The number of samples collected and ordinated varied from year to year, between habitats and among treatments depending on stream conditions. Data were log transformed ($\log_{10}$ x+1) to help normalize the data distribution. Sorensen's (Bray Curtis) distance measure was used starting from a random coordinate for 50 runs of real data. A randomization test was used to determine the final dimensionality by evaluating the percentage of 200 randomized runs having stress values equal or less than the observed stress (McCune and Mefford, 2011). Final ordinations were graphed in 2D and Varimax rotations were used for ease of interpretation. For 3D solutions, the two axes explaining the most variation, or the highest r^2 values, were graphed.

Taxa used to calculate percentage composition were first grouped into categories for simplification. Chironomidae and Simulidae were most abundant, warranting their inclusion as separate families. All other dipterans were lumped together to form the group Diptera (other). Ephemeroptera, Plecoptera, and Trichoptera were grouped to form EPT, all Oligochaeta taxa were grouped together, Coleoptera and Hemiptera were included as individual orders, and all other taxa included in analyses were included as "other" as described above. Mean total abundance was calculated for each of the eight groups (EPT, Diptera (other), Chironomidae, Simuliidae, Coleoptera, Hemiptera, Oligochaeta, and other). Individual samples and streams were averaged to arrive at one value for each treatment and the reference streams before and after manipulations. These values were used to establish the percentage that each group contributed to the total abundance of the streams.

RESULTS

Total Macroinvertebrate Abundance

The treatment*time interaction for total macroinvertebrate abundance in pools was not significant ($p > 0.1$), although abundances increased somewhat at gabion-weir streams after manipulations and decreased at the nature-like stream (Fig. 3-1). In riffles, although abundance decreased at reference streams and remained constant at gabion-weir and nature-like streams, the treatment*time interaction was again not significant ($p > 0.1$; Fig. 3-1).

Taxonomic Diversity and Composition

After manipulations, diversity (H) increased marginally at the gabion-weir streams in riffle habitat (t-test, $p < 0.1$). There was no treatment*time interactions with reference streams ($p > 0.1$; Fig. 3-2).

Ordinations showed very little change in the reference assemblages. Although no obvious overall patterns emerged from the ordinations of taxonomic composition before and after manipulations in treatment streams, some shifts in composition were observed in most of the analyses (Figure 3-3). Composition at the nature-like stream shifted away from Chironomidae and Simuliidae in pools (Fig. 3-4). In gabion-weir streams, riffle assemblages had a large shift (non-overlapping convex hulls) away from Simuliidae and towards aquatic Trombidiformes (Fig. 3-3).

Taxonomic composition of most assemblages was heavily dominated (numerically) by Chironomidae (Fig. 3-4). Although gabion-weir and reference riffle habitats were dominated by Simuliidae before manipulations, chironomids dominated after manipulations, with correspondingly large decreases of Simuliidae. In pool habitat, Chironomidae dominated all streams before and after manipulations, although "other Diptera" nearly disappeared at gabion-weir streams, and Simuliidae were all but lost from reference stream pools (Fig. 3-4).

Individual Taxa BACI

Many taxa, particularly of Diptera, showed significant or marginally significant treatment*time interactions in BACI analyses ($p < 0.1$; Table 3-1). In gabion-weir streams, chironomid abundance (riffles) increased to a greater extent than reference streams. Simuliidae abundance in pool habitats decreased to a lesser extent in both treatments than in references, but decreased to a greater extent than references in gabion-weir riffles. "Other Diptera" disappeared from riffle habitat at the nature-like stream while increasing in reference streams.

Among other taxa, Hemiptera, Gastropoda, and Lumbriculidae showed significant or marginally significant treatment*time interactions in BACI analyses with the reference streams ($p < 0.1$; Table 3-1). Hemiptera abundance at the nature-like stream pool habitat increased to a greater extent than reference streams. In riffle habitat, Hemiptera (Corixidae) increased from zero at the gabion-weir and nature-like streams, while reference streams remained at zero before and after manipulations. Gastropoda abundance dropped to zero at all streams. Lumbriculidae in the nature-like stream in riffle habitat increased to a greater extent than reference.

DISUCUSSION

The focus of my research was to establish if and how macroinvertebrate assemblages would re-establish in manipulated study streams in the first two years post-construction relative to their natural (pre-manipulation) state. Macroinvertebrate assemblages showed many changes in the initial post-manipulation years; however, as predicted, full macroinvertebrate re-colonization was observed and no treatment*time interactions were observed for total abundance. There were many shifts in taxonomic composition of the assemblages for both treatments in riffle and pool habitat, but no easily distinguished overall patterns emerged from ordinations. However, abundance-based convex hulls did not overlap at gabion-weir riffle sites. Small shifts in riffle habitat assemblages also occurred at reference streams, indicating some natural variation in the assemblages.

Changes to taxonomic percent composition were more obvious, namely increases in relative abundance of Chironomidae at most streams, including a significant treatment*time interaction at the gabion-weir stream (riffle habitat). Coincident with increased chironomid relative abundance, decreases in Simuliidae and Diptera (other) were observed.

The food base is an important factor influencing macroinvertebrate assemblages (Benstead and Huryn, 2011; Cummins *et al.*, 1989; Jones *et al.*, 2008). Thus, in this study, I predicted a shift away from taxa known to include shredders and collectors towards scrapers due to decreased riparian vegetation and associated allocthonous inputs as a result of construction activities, and increased algal growth (epilithon) from increased light availability (Chapter 2). Consistent with this, I observed shifts away from EPT, particularly Trichoptera at the nature-like stream, and a large shift in abundance at both treatments towards Chironomidae, of which many are considered scrapers (Monakov, 1972).

In addition to expected changes directly associated with shifts in the food base, there can be unexpected shifts due to trophic cascades. For example, Gastropoda are known algae feeders (Clifford, 1991) and increases in Dytiscidae that feed on grazing gastropods can cause trophic cascades when the increases cause a decrease in snails, and therefore an increase in algae growth (Cobbaert *et al.*, 2010). Consistent with this, I observed a post-manipulation increase in Coleoptera (predominantly Dytiscidae) abundance (from zero prior to manipulations), a decrease in Gastropoda (gastropod abundance dropped to zero at all streams), and a marginal increase in epilithon growth.

Substrate also can affect macroinvertebrate assemblages (Cummins and Lauff, 1969; Reice, 1980; Sarriquet *et al.*, 2007). Reice (1980) observed Chironomidae spp. had a preference for larger substrata (pebbles ≈ 2.5cm diameter, and cobbles ≈ 8.5cm diameter), and Simuliidae (*Simulium* spp.) preferred cobbles to attach to for filter feeding. In general, after manipulations finer substrates decreased and coarser substrates (gravel and cobble) increased at manipulation streams (Chapter 2), possibly contributing to the observed shifts in taxonomic composition.

Despite potential improvements in substrate, Simuliidae abundance decreased at the gabion-weir treatment and were not present in any of the manipulation streams during the initial year post manipulations (2012). However, after retrofitting of the gabion-weirs, flows improved in 2013 (Courtice *et al.*, in press) and Simuliidae reappeared in M1S. In fact, abundance in M1S was higher in 2013 than in pre-manipulation samples (but also in two of the three reference streams). The overall decrease for the gabion-weir treatment was the result of Simuliidae not colonizing M3S post manipulations, likely due to its much lower flows unable to support the filter feeding strategy of Simuliidae. Indeed, "riffles" in M3S were more like run habitat, and had very little flow (albeit more than pools). Additionally, many chironomids are known to survive well in conditions of stagnant/slow water (Clifford, 1991), and the observed increase in Chironomidae abundance in riffle habitat was attributable to the M3 stream; in contrast, M1S chironomid abundance remained relatively constant following manipulations.

Observed decreases in Diptera, particularly Simuliidae abundances may be of concern because these taxa are an important food source for fish (Jones *et al.*, 2003a). Arctic Grayling, *Thymallus arcticus*, use these small, arctic lake outlet streams as spawning habitat and in turn rearing habitat for young-of-the-year (YOY) (Jones *et al.*, 2003a). Benthic foraging is not considered a significant food source for YOY grayling but Simullidae in the drift are (Jones *et al.*, 2003a). YOY grayling select for both Simuliidae and Chironomidae (Jones *et al.*, 2003a), however, so potential impacts of reduced Simuliidae may be compensated by the observed increase in Chironomidae. Additionally, Arctic Grayling were not observed in M3S, where the decrease in Simuliidae was attributed to, and the manipulations to that channel were deemed unsuccessful for fish passage (Cahill, in prep). In 2012, after manipulations and prior to retro-fitting, Simuliidae and YOY grayling were also absent from M1S. Simuliidae recolonized M1S after weir structures were retro-fitted to increase flow and improve fish passage (Courtice *et al.*, in press).

The ability of these streams to be re-colonized so rapidly can be attributed to a number of factors. The availability of good quality habitat to which macroinvertabrates can disperse is likely one of them. No impacts of the compensation on water quality were observed. Removal of the riparian vegetation during manipulations might have decreased stream organic matter, but this was not the case. In fact, riparian vegetation was re-establishing faster than expected, and the only observed impact on organic matter was a reduction in CPOM in the pool habitat at gabion-weir streams, where invertebrate abundance actually increased. However, other changes were made to the stream that may have counteracted the effects of a reduction in CPOM, such as increased pool size, depth, and duration of flow (Courtice *et al.*, in press), and increased gravel substrate (Chapter 2). These changes would be expected to improve stream habitat for many macroinvertebrates (Sarriquet *et al.*, 2007; Muotka, *et al.*, 2002).

The nature of the surrounding landscape plays an important role providing a source of re-colonizers (Sunderman *et al.*, 2011); the pristine nature of the landscape surrounding the study streams and the abundance of nearby aquatic habitat likely provided aerial sources for re-colonization via ovipositing adult insects. In addition, the small size of these streams means they are largely influenced by the lakes they drain (Kling *et al.*, 2000), which were largely or completely unaffected by the stream habitat construction (A. Erwin and C. Cahill, unpublished data and personal observations). In contrast, although the 3.3 km stream constructed at Ekati Diamond Mine in the NWT also had close sources of potential colonizers from the surrounding landscape, it did not see the immediate re-colonization success we did (Jones *et al*., 2008). This was likely in part due to a reduced influence from the source lake because of the much longer stream length. Drift is known to play a key role in re-colonization (Williams and Hynes, 1976; Bird and Hynes, 1981), and is an important source in the Barrenlands region, more so than oviposition from aerial dispersing adult insects (B. Lunn, unpublished data). Finally, unlike the Ekati stream channel, which was blasted out of bedrock (Jones *et al*., 2008), the substrate in the M-Lakes streams, although disturbed during the manipulations, was not completely displaced, potentially leaving some benthos intact.

BACI analysis of abundance and individual taxa, with support of multivariate assemblage ordinations and diversity measures, have allowed me to interpret the extent to which changes observed in the macroinvertebrate assemblage can be attributed to manipulations. Two years post manipulation the changes observed did not appear to be overly significant ecologically. The taxonomic shifts as discussed are not expected to ultimately impact present and potential future fish populations. Given time and the natural regrowth of the riparian vegetation, I would expect macroinvertebrate assemblages to return to their pre-manipulation state. However, the frequent natural disturbance patterns associated with these arctic systems (complete and extended freeze up, anchor ice, large seasonal and daily temperature fluctuations, and highly variable discharge)(Miller and Stout, 1989) lead to apparently stochastic community composition, especially at the habitat level (Reice, 1981 as cited in Miller and Stout, 1989). As with any habitat compensation project, long term monitoring is recommended to evaluate the recovery and stability of macroinvertebrate assemblages and their ability to support fish in the ecosystem.

LITERATURE CITED

Adams, P.W., S. Lamoureux. 2005. A literature review of the use of native northern plants for the re-vegetation of arctic mine tailings and mine waste. Government of Northwest Territories Environment and Natural Resources. Available at http://www.enr.gov.nt.ca/_live/documents/content/WKSS_Northern_Plants_Re-vegetation-2005.pdf (accessed March 27, 2012).

Benke, A. C., A. D. Huryn, L. A. Smock, and J. B. Wallace. 1999. Length-mass relationships for freshwater macroinvertebrates in North America with particular reference to the southeastern United States. Journal of the North American Benthological Society 18:308–343.

Benson, E.R., M.S. Wipfli, J.E. Clapcott, N.F. Hughes. 2013. Relationships between ecosystem metabolism, benthic macroinvertebrate densities, and environmental variables in a sub-arctic Alaskan river. Hydrobiologia 701: 189-207.

Bird, G.A., and H.B.N. Hynes. 1981. Movement of immature aquatic insects in lotic habitat. Hydrobiologia 77: 103-112.

Braccia, A., S.L. Eggert, and N. King. 2014. Macroinvertebrate colonization dynamics on artificial substrates along an algal resource gradient. Hydrobiologia 727: 1-18.

Cahill, C.L., A.C. Erwin, K.L. Howland, M.F. Hulsman, B.D. Lunn, W.M. Tonn, A.B. Baki, G. Courtice, D.Z. Zhu. In prep. Assessing the Responses of Fish to Habitat Enhancement in Barrenlands Streams, NWT, Canada.

Caton, L.W. 1991. Improved Subsampling Methods for the EPA "Rapid Bioassessment" Benthic Protocols. Bulletin of the North American Benthological Society of America 8:317-319.

Clifford, H.F. 1991. Aquatic invertebrates of Alberta. Edmonton, Alberta: The University of Alberta Press.

Cobbaert, D., S.E. Bayley, and J. Greter. 2010. Effects of a top invertebrate predator (*Dytiscus alakanus*; Coleoptera: Dytiscidae) on fishless pond ecosystems. Hydrobiologia 644: 103-114.

Cordillera Consulting. 2011. Benthic invertebrate analysis method report.

Cummins, K.W., and G.H. Lauff. 1969. The influence of substrate particle size on the microdistribution of stream macrobenthos. Hydrobiologia 34: 145-181.

Cummins, K.W., M.A. Wilzbach, D.M. Gates, J.B. Perry, and W.B. Taliaferro. 1989. Shredders and riparian vegetation. BioScience 39: 24-30.

Environment Canada. 2012a. Canadian climate normals 1971-2000. Ottawa. Available at: http://www.climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=1706&lang=e&dCode=1&province=NWT&provBut=Search&month1=0&month2=12 (accessed March 6, 2014).

Environment Canada. 2012b. CABIN laboratory methods; processing, taxonomy, and quality control of benthic macroinvertebrate samples. Canadian Aquatic Biomonitoring Network. Available at http://publications.gc.ca/site/eng/422977/publication.html (accessed June 11, 2014).

Golden, H.E., L.A. Deegan. 1998. The trophic interactions of young Arctic grayling (*Thymallus arcticus*) in an Arctic tundra stream. Freshwater Biology 39: 637-648.

Hawkins, C.P., and J.R. Sedell. 1981. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology 62: 387-397.

Jones, N.E., W.M. Tonn, and G.J. Scrimgeour. 2003a. Selective feeding of age-0 Arctic grayling in lake-outlet streams of the Northwest Territories, Canada. Environmental Biology of Fishes 67: 169-178.

Jones, N.E., W.M. Tonn, G.J. Scrimgeour, C. Katopodis. 2003b. Productive capacity of an artificial stream in the Canadian Arctic: assessing the effectiveness of fish habitat compensation. Canadian Journal of Fisheries and Aquatic Sciences 60: 849-863.

Jones, N.E., W.M., Scrimgeour, W.M. Tonn. 2008. Assessing the effectiveness of a constructed arctic stream using multiple biological attributes. Environmental Management 42: 1064-1076.

Kling, G.W., G.W. Kipphut, M.M. Miller, and W.J. O'Brien. 2000. Integration of lakes and streams in a landscape perspective; the importance of material processing on spatial patterns and temporal coherence. Freshwater Biology 43: 477-497.

McCune, B. and M.J. Mefford. 2011. PC-ORD. Multivariate Analysis of Ecological Data. MjM Software Design, Glenden Beach, Oregon.

Miller, M.C., and J.R. Stout. 1989. Variability of macroinvertebrate community composition in an arctic and subarctic stream. Hydrobiologia 172: 111-127.

Milner, A.M., and I.T. Gloyne-Phillips. 2005. The role of riparian vegetation and woody debris in the development of macroinvertebrate assemblages in streams. River Research and Applications 21: 403-420.

Monakov, A.V. 1972. Review of studies on feeding of aquatic invertebrates conducted at the Institute of Biology of Inland Waters, Academy of Science, USSR. Journal Fisheries Research Board of Canada 29: 363-383.

Muotaka, T., R. Paavola, A. Haapala, M. Novikmec, and P. Laasonen. 2002. Long-term recovery of stream habitat structure and benthic invertebrate communities from in-stream restoration. Biological Conservation 105: 243-253.

Reice, S.R. 1980. The role of substratum in benthic macroinvertebrate microdistribution and litter decomposition in a woodland stream. Ecology 61: 580-590.

Reice, S.R. 1981. Interspecific associations in a woodland stream. Canadian Journal of Fisheries and Aquatic Sciences 38: 1271-1280.

Sarriquet, P.E., P. Bordenave, and P. Marmonier. 2007. Effects of bottom sediment restoration on interstitial habitat characteristics and benthic macroinvertebrate assemblages in a headwater stream. River Research and Applications 23: 815-828.

Scrimgeour, G., W. Tonn, and N. Jones. 2014. Quantifying effective restoration: reassessing the productive capacity of a constructed stream 14 years after construction. Canadian Journal of Fisheries and Aquatic Sciences 71: 589-601.

Sunderman, A., S. Stoll, P. Haase. 2011. River restoration success depends on the species pool of the immediate surroundings. Ecological Applications 21: 1962-1971.

Vincent, W.F., and J.E. Hobbie. 2000. Ecology of arctic lakes and rivers In M. Nuttal and T.V. Callaghan, The Arctic: Environment, People, Policy (pp. 647). Amsterdam: Harwood Academic Publishers

Wang, L., D.M. Robertson, and P.J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. Environmental Management 39: 194-212.

Williams, D.D., and H.B.N. Hynes. 1976. The recolonization mechanisms of stream benthos. Oikos 27: 265-272.

TABLES AND FIGURES

Table 3-1. Results of univariate BACI tests showing significant ($p < 0.05$) or marginally significant ($p < 0.1$) treatment*time interactions and direction of change for abundance of particular taxa (no. · m^{-2}) at gabion-weir and nature-like (treatment) streams in pool and riffle habitat.

Abundance											
Pool						Riffle					
Gabion-Weir			Nature-Like			Gabion-Weir			Nature-Like		
Taxa	Direction	p	Taxa	Direction	p	Taxa	Direction	p	Taxa	Direction	p
Simuliidae	↓	0.003	Simuliidae	↓	0.031	Coleoptera	↑	0.021	Diptera	↓	0.014
Naididae	↓	0.013	Hemiptera	↑	0.025	Chironomidae	↑	0.084	Hemiptera	↑	0.003
Im. Tubificinae	↑	0.005	Bivalvia	↓	0.008	Culicidae	↓	0.055	Valvatidae	↑	0.003
Gastropoda	↓	0.068	Im. Tubificinae	↑	0.031	Empididae	↑	0.039	Lumbiculidae	↑	0.035
			Naididae	↓	0.089	Simuliidae	↓	0.051			
						Hemiptera	↑	0.001			
						Trombidiformes	↑	0.086			
						Valvatidae	↓	0.02			

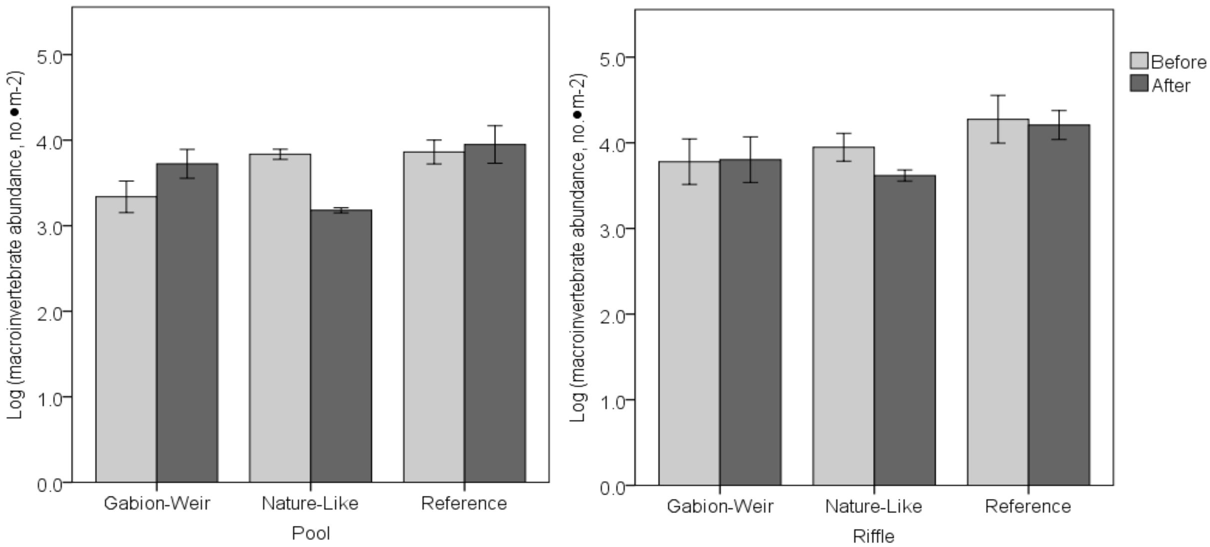

Figure 3-1. Mean ($\log_{10}x$+1, ±1 SE) total macroinvertebrate abundance (no. · m^{-2}) at gabion-weir (n = 2), nature-like (n = 1), and reference stream sites (n = 3) before (2010-2011) and after (2012-2013) manipulations at pool and riffle habitats. Standard error bars depict variation around treatment-year means.

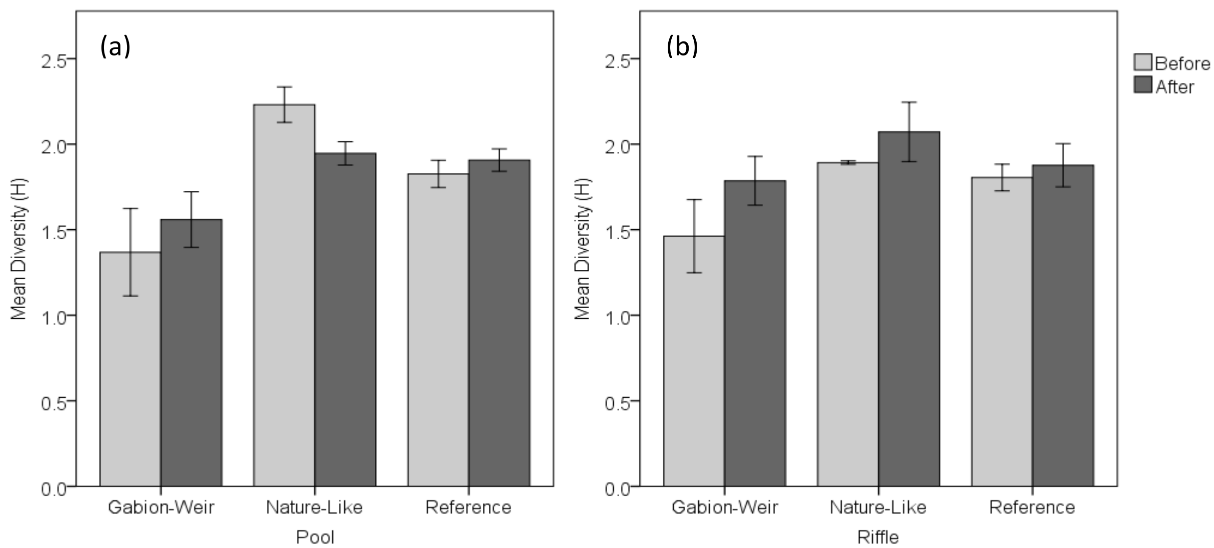

Figure 3-2. Shannon's diversity index (H, ±1 SE) for taxonomic abundance at gabion-weir (n = 2), nature-like (n = 1), and reference (n = 3) streams in pool (a) and riffle (b) habitat before (2010-2011) and after (2012-2013) manipulations.

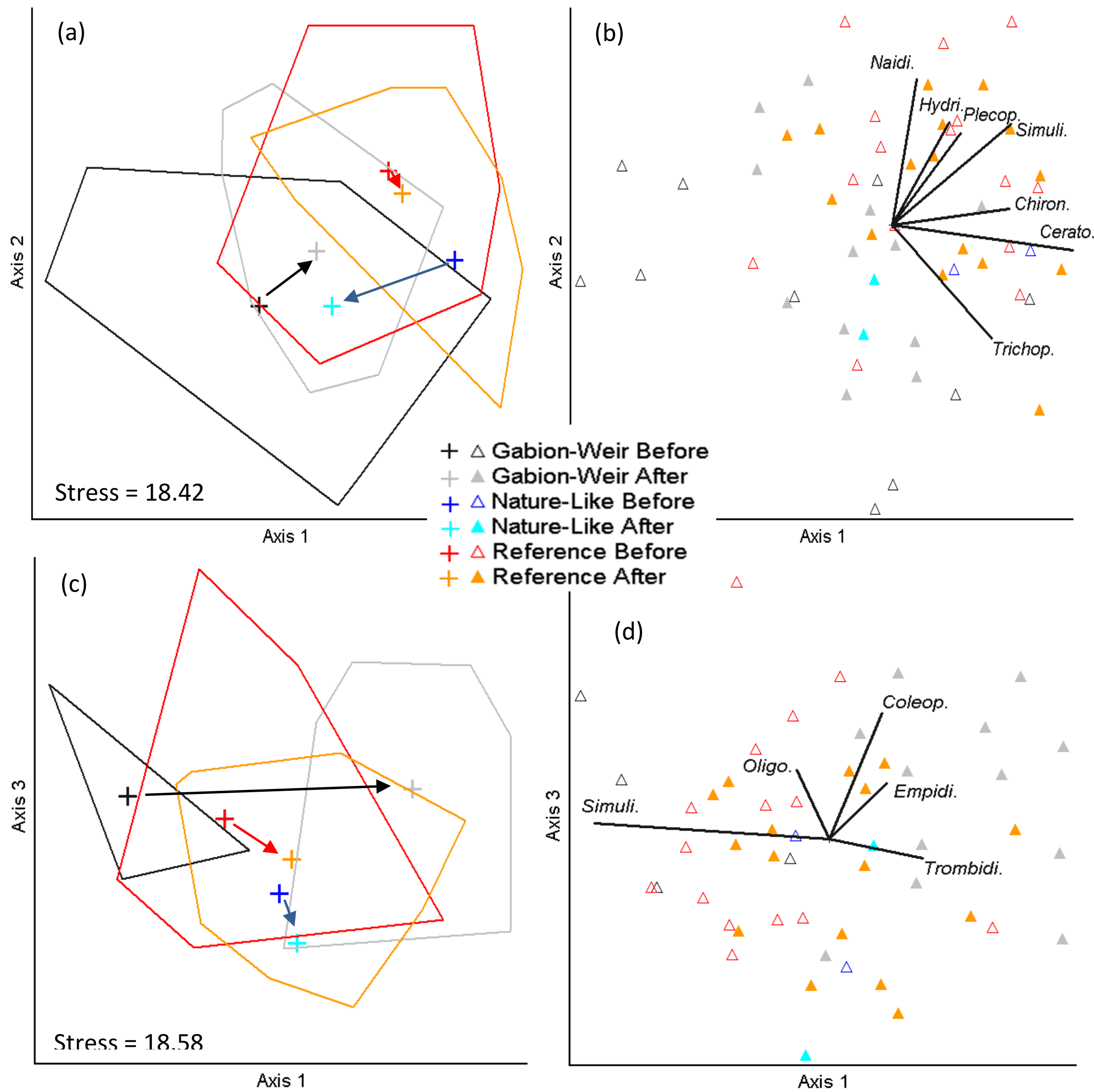

Figure 3-3. Non-metric multidimensional scaling scatter plots of macroinvertebrate taxonomic composition ($\log_{10}$x+1) using abundance (no. · m^{-2}) at pool (a and b) and riffle (c and d) habitats, at gabion-weir (n = 2), nature-like (n = 1), and reference streams (n = 3) before (2010-2011) and after (2012-2013) manipulations. A 3D solution was recommended for pool and riffle habitat; graphs depict axes 1 and 2 for pool habitat and 1 and 3 for riffle habitat. Lines depict convex hulls (a and c) all-encompassing individual sample sites within each treatment and arrows connect before and after

means (represented as "+") for a given treatment. Note that the nature-like treatment (before and after) had only two points so lacked convex hulls. Biplot vector (b and d) r2 cutoff = 0.2 and vectors are scaled at 200% (b) and 150% (d). Taxon abbreviation translations can be found in Table A2-1 in Appendix II.

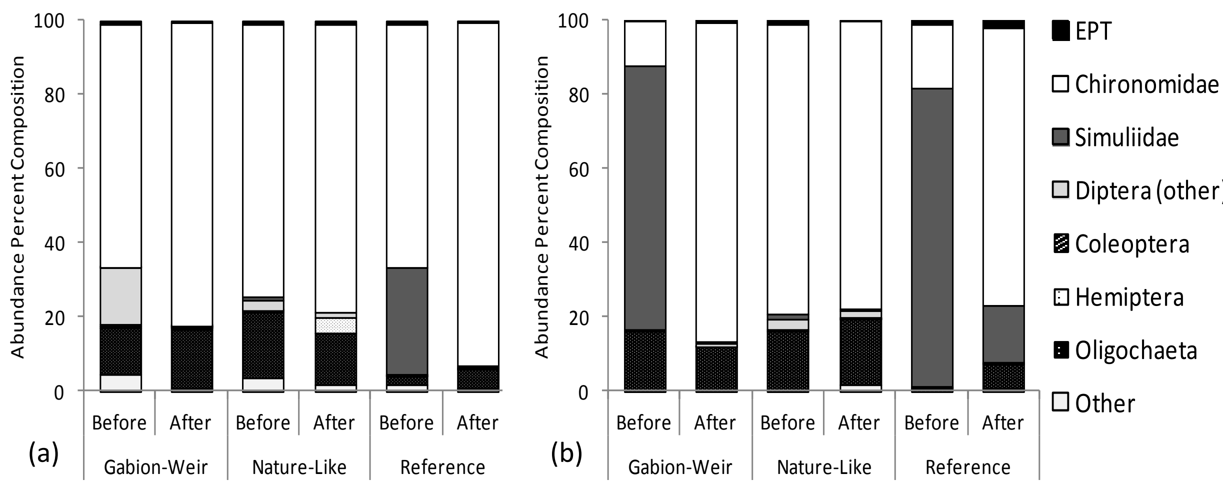

Figure 3-4. Percent composition by abundance at pool (a) and riffle (b) sites before (2010-2011) and after (2012-2013) manipulations. EPT includes Ephemeroptera, Plecoptera, and Trichoptera.

Chapter IV: Concluding Discussion

Natural resource development is expanding in the Canadian arctic, consequently so is the need for fish habitat compensation projects that incorporate rigorous evaluation and assessments as ecological experiments (Quigley and Harper, 2006; Roni *et al*., 2008; Underwood, 1991, 1993). My research evaluated several stream ecosystem components (habitat attributes, stream function, and macroinvertebrate assemblages) of a fish habitat compensation project in the Canadian arctic. This research provides important insights to the ability of these types of projects to succeed in an arctic setting and contributes to the limited pool of arctic baseline data.

The compensation project applied two treatments to three streams. Two streams were modified with multiple gabion-style pool-weir structures, and the other received a nature-like choke-pool. Stream manipulations were designed to increase flow, connectivity and fish passage between three small adjacent lakes (Golder, 2001). Three unmanipulated streams with similar characteristics to the original study streams were selected as reference sites. Using the underutilized Before-After-Control-Impact (BACI) design (Quigley and Harper, 2006, Roni *et al*., 2008) I was able to look for potential impacts to the ecosystem associated with the habitat manipulations.

Many impacts resulted from the manipulations, but few were of concern. The removal of riparian vegetation during construction best explains the reduction in stream organic matter, specifically course particulate organic matter (CPOM), observed at the gabion-weir treatment streams after manipulations. Fortunately the stumps from the willow shrubs removed were left intact on the stream banks, and riparian willows were reestablishing within the first two years post manipulations. However, to minimize the effects of reduced organic matter it is recommended to take added measures to preserve the riparian vegetation as much as possible during construction activities.

Arctic plant taxa are well adapted to the challenging growing conditions of their environment including low air and soil temperatures, nutrient deficiencies, short growing season, dry growing conditions, and grazing and trampling (Billings, 1987). Hence local sources should be used if considering re-vegetation as an option. Rapid colonization at mesic sites can be expected if the organic tundra mat is left at least partially intact post-construction (Cargill and Chapin III, 1987). This mat provides a bank of native seeds and a slow release of nutrients if the insulating vegetation has been removed, allowing more rapid decomposition of organic matter. However, during construction at the M-Lakes streams, particularly the gabion-style pool-weir streams, this layer was completely removed leaving bare soil and therefore limiting nutrient availability. The stream banks should be kept intact as much as possible during construction or the organic tundra mat should be removed and stored to be replaced following construction.

Disturbance to the riparian area from construction activities was greater at the gabion-weir streams than the nature-like streams (A. Erwin, pers. obs.), and was reflected in my results with lower riparian vegetation cover, CPOM, and woody debris at the gabion-weir streams relative to the nature-like stream. The construction at the nature-like stream was done manually and did not require the use of heavy machinery, resulting in reduced disturbance (A. Erwin, pers. obs.). Given the importance of riparian vegetation to oligotrophic stream systems (Cowan and Oswood, 1983; Cummins, 1974), the lighter impact of manual construction methods is recommended in these small Arctic streams. However, dense willow growth choking out sections of stream channels was a factor limiting connectivity for fish prior to manipulations. Willow growth rates in the arctic, and the risk of channels modified for habitat compensation once again becoming choked with vegetation growth, should be considered when establishing long term monitoring programs, and determining long term effectiveness of compensation activities.

Given the significance of allochthonous inputs to these systems (Cowan and Oswood, 1983; Cummins, 1974) and the sometimes unavoidable impact of construction activities to the riparian area, additional studies monitoring and evaluating riparian restoration/re-vegetation strategies would contribute to a gap in the literature regarding riparian restoration in the arctic. Extensive literature exists for temperate climates; in their global review of stream habitat rehabilitation techniques, Roni *et al.* (2008) reviewed 48 studies from seven countries examining the effectiveness of riparian rehabilitation. Although studies are lacking regarding rehabilitation of Arctic riparian habitats, a few studies of restoration in other Arctic terrestrial habitats have been conducted. For example, successional theory has been applied to restoration of mesic and xeric terrestrial arctic tundra sites (Cargill and Chapin III, 1987); Forbes and Jefferies (1999) reviewed constraints and applications of re-vegetating disturbed terrestrial arctic sites; and Jorgenson and Joyce (1994) had success restoring disturbed land to wetland habitat but suggested restoration of moist and dry sites would likely involve considerably more effort.

Allochthonous matter retention was evaluated as part of this study and good retention rates were found in the manipulated streams. Therefore, manually placing sticks and/or leaves into the channels may help to balance the temporary reduction in organic inputs and CPOM accumulation in the years immediately following construction. But to retain organic matter, our results, as well as those of Scrimgeour et al. (2014), indicate that streams often need to already have some matter, creating a positive feedback system. In the absence of riparian vegetation, instream structures such as large rocks and boulders aided retention of CPOM (Chapter 2); retention can be improved by wedging branches removed during construction between and under large boulders (A. Erwin, pers. obs.).

The stream habitat rehabilitation review by Roni *et al.* (2008) also examined nine studies that used organic nutrient additions (salmon carcasses) as part of stream rehabilitation to increase productivity, all of which resulted in positive responses in the biota (fish, plants, or macroinvertebrates).

Salmon carcasses may not be appropriate for our study streams, but the streams' oligotrophic nature suggests other methods of nutrient addition (organic/inorganic) may be worth investigating. Nine additional studies were examined that used inorganic nutrient additions and all nine also saw positive biotic responses including increased periphyton and macroinvertebrate abundance.

Changes to allochthonous and authochthonous organic matter, such as reduced CPOM and increased epilithon growth, that result from habitat alterations involving the addition of structures likely explain observed shifts in macroinvertebrate assemblages, not the structures themselves. Roni *et al.* (2008) reviewed 32 studies and found a large variation in macroinvertebrate responses to habitat complexity improvements that used similar structures to those used in the M-Lakes streams. They concluded macroinvertebrates were probably limited by primary productivity and may not be sensitive to additions of structures such as weirs, boulders, and wood, a concept also supported by Palmer *et al.* (2009) who found only two of 78 studies they reviewed showed significant increases in macroinvertebrate biodiversity on projects which increased habitat heterogeneity. However, I found that structures such as boulders helped retain CPOM (Chapter 2), which provides nutrients to the system and food and habitat for macroinvertebrates. In this study, increased epilithon growth and low flow rates in the M3 stream were the most probable explanations for the shift towards Chironomidae, a family known to include many species of scrapers and be tolerant of stagnant water. Roni *et al.* (2008) suggested the variability they found may indicate that macroinvertebrates may not be appropriate indicators for evaluating fish habitat enhancement projects. However, they also suggested projects need to consider watershed scale issues and larger system processes, making the inclusion of macroinvertebrates, in addition to other habitat measures, critical.

The design of this compensation project was intended to improve stream habitat for fish, with the focus on fish movement and their ability to navigate and utilize the manipulated streams to access new habitat. To build on and advance the designs discussed in my research, future studies could also incorporate specific measures and designs to enhance habitat for lower trophic levels such as macroinvertebrates. Habitat components of key taxa, such as Simuliidae, which is a food source for young-of-the-year Arctic Grayling (*Thymallus arcticus*), could be targeted for improvement, followed by science-based monitoring to determine project effectiveness. Based on the review by Roni *et al.* (2008), oligotrophic streams such as the ones I studied may exhibit favorable responses by the macroinvertebrate assemblages (e.g., increased abundance) if designs focused on increasing primary productivity are used.

CONCLUDING REMARKS

My research project was set up as an ecological experiment (BACI design) to evaluate fish habitat compensation; in this it is a relative rarity, as post-manipulation assessment and reference sites are often missing in compensation projects (Harper and Quigley, 2005). The science-based approach used in this research can be employed by other compensation projects in conjunction with recommendations like those by Palmer *et al.* (2005) and Roni *et al.* (2008) that emphasize an ecological perspective at a watershed scale, assessing projects before and after implementation, not causing lasting damage during construction, and establishing standardized effective monitoring programs. My design measured up well to recommendations for compensation evaluations but could be improved if more reference streams were incorporated, providing more statistical power and a broader application of my results to other systems (Underwood, 1991). A common problem with compensation evaluations is a short timescale. Long-term, large-scale monitoring, although ideal and strongly emphasized as lacking in most studies (Roni *et al.*, 2008), is not feasible in the time frame of a masters project. Additionally, work to better understand the limiting factors and mechanisms of this arctic system would prove beneficial. However, the contribution of this research to understanding instream habitat and functioning, and macroinvertebrate assemblages is valuable as resource expansion in the arctic continues, coinciding with the need to considerably enhance our pool of baseline data and understanding of arctic ecosystems.

Although a reduction in some organic matter was observed and there were shifts in the macroinvertebrate assemblages, my research suggested that the compensation manipulations at the M-Lakes were largely successful in maintaining ecosystem structure and function, with some room for improvement. Similar work done by Jones *et al.* (2003) and Scrimgeour *et al.* (2014) at the nearby Ekati Diamond Mine did not see as high a success rate in stream function following manipulations. The major difference between the two projects was the Ekati manipulation stream was blasted from bed rock, fundamentally starting the ecosystem from scratch. By modifying existing streams such as in our project, the components of the lower trophic levels can be retained following manipulations, provided that disturbance during construction is not too intense, particularly as observed in the nature-like stream using manual construction methods. Preservation of riparian vegetation should be incorporated into compensation plans and time and budget must be allocated to long-term, effective monitoring.

LITERATURE CITED

Billings, W.D. 1987. Constraints to plant growth, reproduction and establishment in arctic environments. Arctic and Alpine Research 19: 357-365.

Cargill, S.M., and F.S. Chapin III. 1987. Application of successional theory to tundra restoration: a review. Arctic and Alpine Research 19: 366-372.

Cowan, C.A., and M.W. Oswood. 1983. Input and storage of benthic detritus in an Alaskan subarctic stream. Polar Biology 2: 35-40.

Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience 24: 631-641.

Forbes, B.C., and R.L. Jefferies. 1999. Revegetation of disturbed arctic sites: constraints and applications. Biological Conservation 88: 15-24.

Golder and Associates. 2001. Conceptual design and compensation workplan for the fish habitat compensation program, Diavik Diamond Mines Inc. Lac de Gras.

Harper, D.J.,and J.T. Quigley. 2005. No net loss of fish habitat: A review and analysis of habitat compensation in Canada. Environmental Management 36: 343-355.

Jorgenson, M.T., and M.R. Joyce. 1994. Six strategies for rehabilitating land disturbed by oil development in arctic Alaska. Arctic 47: 374-390.

Jones, N.E., W.M. Tonn, G.J. Scrimgeour, C. Katopodis. 2003. Productive capacity of an artificial stream in the Canadian Arctic: assessing the effectiveness of fish habitat compensation. Canadian Journal of Fisheries and Aquatic Sciences 60: 849-863.

Palmer, M.A., E.S. Bernhardt, J.D. Allan, P.S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C.N. Dahm, J. Follstad Shah, D.L. Galat, S.G. Loss, P. Goodwin, D.D. Hart, B. Hassett, R. Jenkinson, G.M. Kondolf, R. Lave, J.L. Meyer, T.K. O'Donnell, L. Pagano, and E. Sudduth. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42: 208-217.

Palmer, M.A., H.L. Menninger, and E. Bernhardt. 2009. River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice? Freshwater Biology 55: 1-18.

Quigley, J.T., D.J. Harper. 2006. Effectiveness of fish habitat compensation in Canada in achieving No Net Loss. Environmental Management 37 (3): 351-366.

Roni, P., K. Hanson, and T. Beechie. 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management 28: 856-890.

Scrimgeour, G., W. Tonn, and N. Jones. 2014. Quantifying effective restoration: reassessing the productive capacity of a constructed stream 14 years after construction. Canadian Journal of Fisheries and Aquatic Sciences 71: 589-601.

Underwood, A.J. 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42: 569-587.

Underwood, A.J. 1993. The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. Australian Journal of Ecology 18: 99-116.

Appendix I

Keys used for Identification of Freshwater Benthic Invertebrates

Cordillera Consulting

Brook, Arthur R. and Leonard A. Kelton. 1967. Aquatic and semiaquatic Heteroptera of Alberta, Saskatchewan and Manitoba (Hemiptera) Memoirs of the Entomological Society of Canada. No. 51.

Brown HP & White DS (1978) Notes on Seperation and Identification of North

American Riffle Beetles (Coleoptera: Dryopidea: Elmidae).Entomological News 89 (1&2): 1-13

Clifford, Hugh F. 1991. Aquatic Invertebrates of Alberta. University of Alberta Press Edmonton, Alberta.

Epler, John. 2001 The Larval Chironomids of North and South Carolina. http://home.earthlink.net/~johnepler/

Epler, John. Identification Manual for the Water Beetles of Florida. http://home.earthlink.net/~johnepler/

Epler, John. Identification Manual for the Aquatic and Semi-aquatic Heteroptera of Florida. http://home.earthlink.net/~johnepler/

Jacobus, Luke and Pat Randolph. 2005. Northwest Ephemeroptera Nymphs. Manual from Northwest Biological Assessment Working Group. Moscow Idaho 2005. Not Published.

Jacobus LM, McCafferty WP (2004) Revisionary Contributions to the Genus Drunella (Ephemeroptera : Ephemerellidae). Journal of the New York Entomological Society 112: 127-147

Jacobus LM, McCafferty WP (2003) Revisionary Contributions to North American Ephemerella and Serratella (Ephemeroptera : Ephemerellidae). Journal of the New York Entomological Society 111 (4): 174-193.

Kathman,R.D., R.O. Brinkhurst. 1999. Guide to the Freshwater Oligochaetes of North America. Aquatic Resources Center, College Grove, Tennessee.

Larson, D.J., Y. Alarie, R.E. Roughly.2005. Predaceous Diving Beetles (Coleoptera: Dytiscidae) of the Neararctic Region. NRC-CNRC Research Press. Ottawa.

Merritt, R.W., K.W. Cummins (eds.). 2007. An introduction to the aquatic insects of North America, 4th. Kendall/Hunt, Dubuque, IA.

Morihara DK, McCafferty WP (1979) The Baetis Larvae of North American (Ephemeroptera: Baetidae). Transactions of the American Entomological Society 105: 139-221.

Needham, James, M. May, M. Westfall Jr. 2000. Dragonflies of North America. Scientific Publishers. Gainsville FL.

Prescott David, R.C.and Medea M. Curteanu.2004. Survey of Aquatic Gastropods of Alberta. Species at Risk Report No. 104. ISSN: 1496-7146 (Online Edition)

Needham, K. 1996. An Identification Guide to the Nymphal Mayflies of British Columbia. Publication #046 Resource Inventory Committee, Government of British Columbia.

Oliver, Donald R. and Mary E. Roussel. 1983. The Insects and Arachnids of Canada Part 11. The Genera of larval midges of Canada. Biosystematics Research Institute. Ottawa, Ontario. Research Branch, Agriculture Canada. Publication 1746.

Proctor, H. The ‘Top 18’ Water Mite Families in Alberta. Zoology 351. University of Alberta, Edmonton, Alberta.

Rogers, D.C. and M. Hill, 2008. Key to the Freshwater Malacostraca (Crustacea) of the mid-Atlantic Region. EPA-230-R-08-017. US Environmental Protection Agency, Office of Environmental Information, Washington, DC.

Stewart, Kenneth W. and Bill Stark. 2002. The Nymphs of North American Stonefly Genera (Plecoptera). The Caddis Press. Columbus Ohio.

Stewart, Kenneth W. and Mark W. Oswood. 2006 The Stoneflies (Plecoptera) of Alaska and Western Canada. The Caddis Press.

Stonedahl, Gary and John D. Lattin. 1986. The Corixidae of Oregon and Washington (Hemiptera: Heteroptera). Technical Bulletin 150. Oregon State University, Corvalis Oregon.

Thorpe, J. H. and A. P. Covich [Eds.] 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego.

Tinerella, Paul P. and Ralph W. Gunderson.2005. The Waterboatmen (Insecta: Heteroptera: Corixidae) of Minisota. Publication No.23 Dept. Of Entomology, North Dakota State University, Fargo, North Dakota, USA.

Weiderholm, Torgny (Ed.) 1983. The larvae of Chironomidae (Diptera) of the Holartic region. Entomologica Scaninavica. Supplement No. 19.

Westfall, Minter J. Jr. and May, Michael L. 1996. Damselflies of North America. Scientific Publishers, Gainesville, FL.

Wiggins, Glenn B. 1998. Larvae of the North American Caddisfly Genera (Tricoptera) 2nd ed. University of Toronto Press. Toronto Ontario.

Appendix II

Table A2-1. Taxonomic abbreviations used in ordinations (Figure 3-3).

Abbreviation	Taxa
Cerato.	Ceratopogonidae
Chiron.	Chironomidae
Coleop.	Coleoptera
Ehphem.	Ephemeroptera
Empidi.	Empidiidae
Enchytr.	Enchytraeidae
Hydri.	Hydridae
Lumb.	Lumbriculida
Lumbri.	Lumbriculidae
Naidi.	Naididae
Oligo.	Oligochaeta
Plecop.	Plecoptera
Simuli.	Simuliidae
Trichop.	Trichoptera
Trombidi.	Trombidiformes

Table A2-2. Taxonomic classifications used in ordination analyses.

Abundance	
Pool	Riffle
Ephemerptera	Ephemerptera
Plecoptera	Plecoptera
Trichoptera	Trichoptera
Coleoptera	Coleoptera
U. Diptera	U. Diptera
Ceratopogonidae	Ceratopogonidae
Chironomidae	Chironomidae
Culicidae	-
Dixidae	Dixidae
Dolichopodidae	Dolichopodidae
Empididae	Empididae
-	Muscidae
Simuliidae	Simuliidae
Tipulidae	Tipulidae
Hemiptera	Hemiptera
Trombidiformes	Trombidiformes
-	-
Sphaeriidae	Sphaeriidae
Pisidiidae	Pisidiidae
U. Gastropoda	-
Valvatidae	Valvatidae
U. Oligochaeta	U. Oligochaeta
U. Lumbriculida	-
Lumbriculidae	Lumbriculidae
-	-
Enchytraeidae	Enchytraeidae
Naididae	Naididae
Tubificinae immature	Tubificinae immatu
Hydridae	Hydridae

Table A2-3. Taxonomic classifications used in individual taxon and total abundance BACI analyses.

Abundance			
Pool		Riffle	
Gabion-Weir	Nature-Like	Gabion-Weir	Nature-Like
Ephemerptera	Ephemerptera	Ephemerptera	Ephemerptera
Plecoptera	Plecoptera	Plecoptera	Plecoptera
Trichoptera	Trichoptera	Trichoptera	Trichoptera
Coleoptera	Coleoptera	Coleoptera	Coleoptera
U. Diptera	U. Diptera	U. Diptera	U. Diptera
Ceratopogonidae	Ceratopogonidae	Ceratopogonidae	Ceratopogonidae
Chironomidae	Chironomidae	Chironomidae	Chironomidae
Culicidae	-	Culicidae	-
Dixidae	Dixidae	Dixidae	Dixidae
Dolichopodidae	Dolichopodidae	Dolichopodidae	Dolichopodidae
Empididae	Empididae	Empididae	Empididae
-	-	Muscidae	Muscidae
Simuliidae	Simuliidae	Simuliidae	Simuliidae
Tipulidae	Tipulidae	Tipulidae	Tipulidae
Hemiptera	Hemiptera	Hemiptera	Hemiptera
Trombidiformes	Trombidiformes	Trombidiformes	Trombidiformes
-	U. Bivalvia	-	-
Sphaeriidae	Sphaeriidae	Sphaeriidae	Sphaeriidae
Pisidiidae	Pisidiidae	Pisidiidae	Pisidiidae
U. Gastropoda	U. Gastropoda	-	-
Valvatidae	-	Valvatidae	Valvatidae
U. Oligochaeta	U. Oligochaeta	U. Oligochaeta	U. Oligochaeta
U. Lumbriculida	U. Lumbriculida	-	-
Lumbriculidae	Lumbriculidae	Lumbriculidae	Lumbriculidae
-	-	-	-
Enchytraeidae	Enchytraeidae	Enchytraeidae	Enchytraeidae
Naididae	Naididae	Naididae	Naididae
Tubificinae immatu	Tubificinae immatu	Tubificinae immatu	Tubificinae immatu
Hydridae	Hydridae	Hydridae	Hydridae

Table A2-4. Taxonomic groupings used in percent composition analyses and taxa present in samples excluded from analyses.

Percent Composition Taxa Groupings		Taxa Present but Excluded from Analyses
EPT	Other	Collembola
Ephemeroptera	All other taxa present.	Ostracoda
Plecoptera		Daphniidae
Trichoptera		Amphipoda
		Copepoda
Diptera (other)		Oribatida
Ceratopogonidae		Sarcoptiformes
Culicidae		Nemata
Dixidae		Platyhelminthes
Dolichopodidae		Tardigrada
Empididae		
Muscidae		
Tipulidae		
Oligochaeta		
U. Oligochaeta		
U. Lumbriculida		
Lumbriculidae		
Tubificidae		
Enchytraeidae		
Naididae		
Tubificinae immature		
Individual Taxa		
Chironomidae		
Simuliidae		
Coleoptera (Dytiscidae, Hydrophilidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Psephenidae)		
Hemiptera (Corixidae)		

Table A2-5. Abundance (no. · m-2) data used in pool habitat ordinations and Shannon's diversity index (H). Stream sites were averaged to get one value per stream for BACI analyses.

Stream	M1S	M1S	M2S	M3S	M3S	M3S	R6S1	R6S1	R6S2	R6S2	R2S
Site	X1	X2	X1	X1	X2	X3	X2	X4	X3	X6	X2
Year	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010
Ephemerptera								88.88889	144.4444	100	
Plecoptera								577.7778			
Trichoptera	11.11111	122.2222	44.44444	66.66667			33.33333		22.22222		
Coleoptera				177.7778			11.11111				44.44444
Diptera		122.2222	11.11111								
Ceratopogonidae	66.66667	744.4444	166.6667				22.22222	44.44444			
Chironomidae	33.33333	2344.444	6266.667	1655.556	666.6667	88.88889	2188.889	4222.222	6133.333	1222.222	1822.222
Culicidae											
Dixidae											
Dolichopodidae											
Empididae								177.7778			88.88889
Muscidae											
Simuliidae							877.7778	2888.889	22.22222	377.7778	400
Tipulidae				11.11111							
Hemiptera											
Trombidiformes	22.22222		144.4444						100		
Bivalvia			144.4444								
Sphaeriidae			155.5556				222.2222				44.44444
Pisidiidae											
Gastropoda		122.2222									
Valvatidae											
Oligochaeta											
Lumbriculida				266.6667			177.7778				
Lumbriculidae		866.6667	11.11111					44.44444	22.22222		
Tubificida											
Enchytraeidae											44.44444
Naididae			888.8889		22.22222	22.22222	33.33333	222.2222	333.3333	255.5556	88.88889
Imm. Tubificinae											
Hydridae								44.44444			

Stream	R2S	M1S	M1S	M2S	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S2	R6S2
Site	X6	X1	X2	X1	X1	X2	X3	X2	X4	X5	X2	X3
Year	2010	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011
Ephem.												
Plecop.				44.44444				88.88889	233.3333	44.44444		
Trichop.	44.44444		77.77778	44.44444	11.11111			88.88889		22.22222	88.88889	
Coleop.			22.22222	22.22222						22.22222		
Dipt.					11.11111							
Cerato.		1200	1388.889	177.7778				88.88889		88.88889		22.22222
Chirono.	4800	1988.889	6377.778	3877.778	1622.222	1744.444	411.1111	36355.56	20377.78	5733.333	933.3333	7377.778
Culic.					222.2222	111.1111						
Dixid.												
Dolichop.											11.11111	
Empid.												
Musc.												
Simuli.			55.55556	155.5556	11.11111			711.1111	233.3333	44.44444	11.11111	
Tipul.				22.22222								
Hemip.			22.22222	22.22222								
Trombid.		66.66667	22.22222	22.22222	11.11111			711.1111	55.55556	66.66667		88.88889
Bivalv.												
Sphaeri.								88.88889				
Pisidi.												
Gastrop.			111.1111	44.44444						22.22222		
Valvat.		388.8889	344.4444									
Oligo.												22.22222
Lumbri.												
Lumbri.		33.33333			144.4444	11.11111				22.22222		66.66667
Tubific.												
Enchytrae.	266.6667											
Naid.	266.6667	211.1111	1766.667	1533.333				177.7778	233.3333	222.2222	22.22222	288.8889
Imm. Tubif.												
Hydr.	177.7778								177.7778	755.5556		

Stream	R6S2	R2S	R2S	R2S	M1S	M1S	M1S	M2S	M3S	M3S	M3S	R6S1
Site	X6	X1	X2	X6	X1	X3	X4	X4	X1	X2	X6	X2
Year	2011	2011	2011	2011	2012	2012	2012	2012	2012	2012	2012	2012
Ephem.												
Plecop.												66.66667
Trichop.	11.11111		22.22222	44.44444	11.11111	133.3333	122.2222	22.22222		77.77778		144.4444
Coleop.			22.22222	11.11111	11.11111	55.55556	11.11111				33.33333	66.66667
Dipt.				22.22222								
Cerato.	44.44444	88.88889	122.2222	22.22222		11.11111	11.11111	11.11111				
Chirono.	1822.222	4888.889	4888.889	1077.778	544.4444	2766.667	2911.111	1255.556	7966.667	11411.11	12788.89	20566.67
Culic.												
Dixid.				122.2222								
Dolichop.												
Empid.												
Musc.												
Simuli.	11.11111	38577.78	933.3333									144.4444
Tipul.												
Hemip.						11.11111	22.22222	122.2222			33.33333	
Trombid.	44.44444	88.88889			11.11111	88.88889	88.88889	22.22222		111.1111	66.66667	355.5556
Bivalv.												
Sphaeri.			233.3333									
Pisidi.								11.11111				
Gastrop.												
Valvat.												
Oligo.								33.33333				
Lumbri.												
Lumbri.				11.11111			11.11111			33.33333		66.66667
Tubific.												
Enchytrae.											66.66667	
Naid.	222.2222	88.88889	55.55556	144.4444	22.22222	11.11111		144.4444	100			355.5556
Imm. Tubif.												
Hydr.												277.7778

Stream	R6S1	R6S1	R6S2	R6S2	R2S	R2S	R2S	M1S	M1S	M1S	M2S	M3S
Site	X4	X5	X3	X6	X1	X2	X6	X1	X3	X4	X2	X1
Year	2012	2012	2012	2012	2012	2012	2012	2013	2013	2013	2013	2013
Ephem.	22.22222	22.22222										
Plecop.	44.44444	88.88889										
Trichop.	44.44444	166.6667		11.11111	444.4444		77.77778		11.11111	66.66667	11.11111	
Coleop.					222.2222				11.11111	44.44444		66.66667
Dipt.												
Cerato.			22.22222	22.22222			44.44444		11.11111	22.22222	33.33333	
Chirono.	7400	4111.111	4344.444	955.5556	84222.22	105711.1	11488.89	233.3333	1666.667	2955.556	1100	5488.889
Culic.												
Dixid.							122.2222					
Dolichop.												
Empid.								11.11111		44.44444		
Musc.												
Simuli.		100	155.5556	11.11111			44.44444	11.11111	11.11111	88.88889		
Tipul.			22.22222									
Hemip.											11.11111	33.33333
Trombid.	166.6667	88.88889	44.44444	22.22222				11.11111		66.66667	22.22222	33.33333
Bivalv.												
Sphaeri.												
Pisidi.					222.2222	311.1111						
Gastrop.												
Valvat.												
Oligo.					4444.444							
Lumbri.												
Lumbri.	44.44444		211.1111	11.11111								
Tubific.												
Enchytrae.	22.22222				222.2222	155.5556		11.11111	11.11111			
Naid.	100	166.6667	988.8889	66.66667	2666.667	1266.667	1322.222	300	433.3333	3777.778	188.8889	6588.889
Imm. Tubif.											44.44444	
Hydr.	100	466.6667	22.22222							22.22222		

Stream Site Year	M3S X2 2013	M3S X6 2013	R6S1 X2 2013	R6S1 X4 2013	R6S1 X5 2013	R6S2 X2 2013	R6S2 X3 2013	R6S2 X6 2013	R2S X1 2013	R2S X2 2013
Ephem.								11.11111		
Plecop.										
Trichop.		88.88889		44.44444	133.3333			11.11111		
Coleop.			77.77778							22.22222
Dipt.						11.11111		11.11111		
Cerato.			222.2222	177.7778	66.66667	11.11111	433.3333	122.2222		
Chirono.	2177.778	12955.56	12877.78	12800	19600	4755.556	1533.333	2000	566.6667	4744.444
Culic.										
Dixid.										
Dolichop.								11.11111		
Empid.	11.11111	88.88889	33.33333	133.3333	66.66667			11.11111		11.11111
Musc.										
Simuli.			188.8889					44.44444	22.22222	
Tipul.						11.11111				
Hemip.									11.11111	
Trombid.		44.44444	33.33333	177.7778			44.44444	11.11111	22.22222	11.11111
Bivalv.										
Sphaeri.										
Pisidi.			77.77778							66.66667
Gastrop.										
Valvat.										
Oligo.										
Lumbri.										
Lumbri.							122.2222	22.22222	22.22222	
Tubific.										
Enchytrae.				44.44444	66.66667					
Naid.	477.7778	600	111.1111				77.77778		11.11111	122.2222
Imm. Tubif.	11.11111		333.3333	222.2222	200	877.7778	511.1111	222.2222	111.1111	
Hydr.				88.88889		166.6667	277.7778			

Table A2-6. Abundance (no. · m-2) data used in riffle habitat ordinations and Shannon's diversity index (H). Stream sites were averaged to get one value per stream for BACI analyses.

Stream	M1S	M1S	M2S	R6S1	R6S1	R6S2	R6S2	R2S	R2S	M1S	M1S
Site	X3	X4	X2	X1	X6	X4	X5	X3	X5	X-3	X-4
Year	2010	2010	2010	2010	2010	2010	2010	2010	2010	2011	2011
Ephemerptera						1177.778	533.3333				
Plecoptera						22.22222			44.44444		
Trichoptera	11.11111		22.22222	533.3333	11.11111	11.11111	55.55556				
Coleoptera								22.22222	44.44444		
Diptera		44.44444	111.1111								
Ceratopogonidae		44.44444	244.4444		44.44444	33.33333	55.55556				
Chironomidae	166.6667	355.5556	3666.667	8066.667	1311.111	3844.444	3077.778	1200	1955.556	3733.333	433.3333
Culicidae											
Dixidae								66.66667			
Dolichopodidae											
Empididae			22.22222					22.22222	88.88889		
Muscidae											
Simuliidae	3044.444	577.7778		211533.3	744.4444	4000	422.2222	4666.667	88.88889	31377.78	
Tipulidae	66.66667										
Hemiptera											
Trombidiformes											
Bivalvia											
Sphaeriidae			55.55556		111.1111						
Pisidiidae											
Gastropoda											
Valvatidae	11.11111										
Oligochaeta								177.7778		88.88889	
Lumbriculida											
Lumbriculidae							55.55556				
Tubificida											
Enchytraeidae									622.2222		
Naididae	88.88889	6488.889	1966.667	533.3333	55.55556	22.22222	111.1111		177.7778		366.6667
Imm. Tubificinae											
Hydridae	11.11111	88.88889						22.22222	88.88889		66.66667

Stream	M2S	M3S	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R2S	R2S	R2S	M1S
Site	X-2	X-4	X-1	X-3	X-6	X-1	X-4	X-5	X-3	X-4	X-5	X-2
Year	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2012
Ephem.				88.88889		88.88889	222.2222	11.11111				
Plecop.				2488.889	44.44444	1244.444						
Trichop.	211.1111	11.11111		622.2222	133.3333	88.88889	22.22222		11.11111	155.5556	22.22222	33.33333
Coleop.	66.66667							22.22222	11.11111	66.66667	77.77778	33.33333
Dipt.	66.66667											11.11111
Cerato.	66.66667		1611.111	177.7778		266.6667	111.1111	11.11111	111.1111	444.4444	11.11111	11.11111
Chirono.	11133.33	1288.889	26655.56	14933.33	1055.556	46222.22	6644.444	611.1111	1888.889	5733.333	3066.667	811.1111
Culic.		211.1111										
Dixid.												
Dolichop.						88.88889						
Empid.						88.88889						22.22222
Musc.							22.22222					
Simuli.	288.8889		362833.3	3377.778		5066.667	333.3333	111.1111	477.7778	155.5556	388.8889	
Tipul.												
Hemip.												
Trombid.					22.22222		77.77778					
Bivalv.												
Sphaeri.		11.11111										
Pisidi.												
Gastrop.												
Valvat.												
Oligo.								11.11111				
Lumbri.												
Lumbri.		666.6667										
Tubific.												
Enchytrae.										177.7778		
Naid.	1066.667		811.1111	622.2222	66.66667	1333.333	477.7778	155.5556	44.44444		177.7778	
Imm. Tubif.												
Hydr.					22.22222	88.88889						

Stream	M1S	M1S	M2S	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2
Site	X-5	X-6	X-1	X-3	X-4	X-5	X-1	X-3	X-6	X-1	X-4	X-5
Year	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Ephem.										22.22222	344.4444	144.4444
Plecop.							833.3333	1366.667	122.2222	55.55556		22.22222
Trichop.	44.44444	88.88889		44.44444		111.1111	555.5556	1355.556	1433.333	22.22222	33.33333	
Coleop.	11.11111	11.11111		44.44444	22.22222			66.66667	44.44444	11.11111		
Dipt.												
Cerato.			100						122.2222		111.1111	33.33333
Chirono.	900	1844.444	3588.889	2522.222	4755.556	18888.89	39611.11	16733.33	10644.44	3888.889	7155.556	3000
Culic.												
Dixid.					22.22222	55.55556						
Dolichop.					11.11111							
Empid.	55.55556	77.77778		11.11111					44.44444			
Musc.							422.2222	122.2222				
Simuli.							1955.556	922.2222				
Tipul.									44.44444			
Hemip.	11.11111		33.33333	11.11111								
Trombid.		22.22222		11.11111	133.3333	111.1111	288.8889	133.3333	355.5556	66.66667	233.3333	33.33333
Bivalv.												
Sphaeri.												
Pisidi.			55.55556						44.44444			
Gastrop.												
Valvat.			33.33333									
Oligo.												
Lumbri.												
Lumbri.			177.7778			55.55556	144.4444				200	22.22222
Tubific.												
Enchytrae.	11.11111											
Naid.	33.33333		822.2222	22.22222	22.22222		422.2222			122.2222	777.7778	122.2222
Imm. Tubif.												
Hydr.							144.4444			277.7778	33.33333	

Stream	R2S	R2S	M1S	M1S	M1S	M2S	M3S	M3S	M3S	R6S1	R6S1	R6S1
Site	X-3	X-4	x-2	x-5	x-6	x-4	x-3	x-4	x-5	x-1	x-3	x-6
Year	2012	2012	2013	2013	2013	2013	2013	2013	2013	2013	2013	2013
Ephem.							44.44444		100			
Plecop.												
Trichop.			33.33333		111.1111	22.22222	88.88889			100	155.5556	22.22222
Coleop.	222.2222		88.88889	11.11111	33.33333	22.22222	77.77778					11.11111
Dipt.												
Cerato.		166.6667	11.11111			55.55556				100	77.77778	44.44444
Chirono.	82888.89	23422.22	2644.444	477.7778	3922.222	2933.333	9133.333	29255.56	31822.22	6666.667	8488.889	4100
Culic.												
Dixid.											77.77778	
Dolichop.												
Empid.			77.77778	22.22222	66.66667				200			11.11111
Musc.												
Simuli.	3333.333	88.88889	22.22222	44.44444	144.4444	22.22222				30100	13577.78	322.2222
Tipul.							44.44444	366.6667				
Hemip.			11.11111					88.88889				
Trombid.			33.33333	11.11111		33.33333				200		44.44444
Bivalv.												
Sphaeri.												
Pisidi.												33.33333
Gastrop.												
Valvat.												
Oligo.												
Lumbri.												
Lumbri.		88.88889		22.22222	111.1111	22.22222						
Tubific.												
Enchytrae.			22.22222	11.11111					100		233.3333	166.6667
Naid.	10888.89	3588.889	1911.111	88.88889	3700	233.3333	3966.667	1944.444	200	500	633.3333	111.1111
Imm. Tubif.			22.22222	655.5556	1300	200				100	633.3333	144.4444
Hydr.					33.33333	22.22222						11.11111

Stream	R6S2	R6S2	R6S2	R2S	R2S
Site	x-1	x-4	x-5	x-3	x-4
Year	2013	2013	2013	2013	2013
Ephem.		344.4444	166.6667		
Plecop.			22.22222		
Trichop.				11.11111	
Coleop.			11.11111	44.44444	
Dipt.		44.44444		44.44444	
Cerato.	88.88889	444.4444	55.55556		
Chirono.	8177.778	2033.333	1700	5744.444	25800
Culic.					
Dixid.					
Dolichop.					
Empid.			33.33333		
Musc.					
Simuli.	211.1111	11.11111	277.7778	11.11111	155.5556
Tipul.			11.11111		
Hemip.					
Trombid.	88.88889	222.2222	44.44444		
Bivalv.					
Sphaeri.					
Pisidi.					
Gastrop.					
Valvat.					
Oligo.					
Lumbri.					
Lumbri.			55.55556	22.22222	
Tubific.					
Enchytrae.	33.33333			33.33333	
Naid.	122.2222		22.22222	722.2222	311.1111
Imm. Tubif.	266.6667	644.4444	355.5556		
Hydr.	266.6667				

Table A2-7. Raw 2010 macroinvertebrate abundance data.

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	R6S1	R6S1
Sample:	X-1 July	2 July	X-3 July	4 July	XS 1 July	XS 2 July	1 July	2 July	3 July	1 July	2 July
CC#:	CC120840	CC111090	CC120842	CC120844	CC111092	CC111073	CC111070	CC111071	CC111072	CC111097	CC111098
Phylum: Arthropoda											
Subphylum: Hexapoda											
| Class: Insecta											
| Order: Ephemeroptera											
| Family: Baetidae											
Baetis sp.											
Baetis tricaudatus											
| Family: Ephemerellidae											
| Family: Heptageniidae											
Rhithrogena sp.											
| Order: Plecoptera											
| Family: Capniidae											
| Family: Nemouridae											
Nemoura											
Ostrocerca sp.											
Zapada sp.											
| Family: Perlodidae											
| Order: Trichoptera			1				4				
| Family: Hydroptilidae											
Oxyethira sp.											
| Family: Limnephilidae	1				3						
Clostoeca disjuncta											
Grammotaulius sp.		11					2				
Limnephilus sp.						2				48	2
Nemotaulius sp.					1						
| Family: Molannidae											
Molanna flavicornis											1
| Order: Coleoptera											
| Family: Dytiscidae							16				1

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	R6S1	R6S1
Sample:	X-1 July	2 July	X-3 July	4 July	XS 1 July	XS 2 July	1 July	2 July	3 July	1 July	2 July
CC#:	CC120840	CC111090	CC120842	CC120844	CC111092	CC111073	CC111070	CC111071	CC111072	CC111097	CC111098
Agabus sp.											
Oreodytes sp.											
| Family: Elmidae											
Optioservus sp.											
| Family: Haliplidae											
Peltodytes sp.											
| Family: Hydrophilidae											
Hydrochus sp.											
| Order: Diptera		11		4	1	10					
| Family: Ceratopogonidae											
Bezzia sp.	2				14						1
Culicoides sp.		11				15					
Dasyhelea sp.	4	56		4	1						
Mallochohelea											
Probezzia sp.						7					1
Sphaeromias sp.											
| Family: Chironomidae					500					769	
| Subfamily: Chironominae											
| Tribe: Chironomini											
Chironomus sp.											
Cryptochironomus sp.											
Endochironomus sp.											
Microtendipes sp.											
Paratendipes sp.											
Phaenopsectra sp.											
Polypedilum sp.		67									
Stictochironomus sp.											7
Tribelos sp.											
| Tribe: Tanytarsini											
Cladotanytarsus sp.	2						27	16			
Micropsectra sp.		100			122	31	16				129

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	R6S1	R6S1
Sample:	X-1 July	2 July	X-3 July	4 July	XS 1 July	XS 2 July	1 July	2 July	3 July	1 July	2 July
CC#:	CC120840	CC111090	CC120842	CC120844	CC111092	CC111073	CC111070	CC111071	CC111072	CC111097	CC111098
Paratanytarsus sp.		44	3								15
Rheotanytarsus sp.											
Tanytarsus sp.			1	8		5					
| Subfamily: Diamesinae											
Protanypus											
| Tribe: Diamesini											
Potthastia longimana group											
| Subfamily: Orthocladiinae				8		105	16		8		
Brillia sp.											
Cricotopus sp.											
Diplocladius cultriger											
Diplocladius sp.											
Eukiefferiella sp.											
Heleniella sp.											
Heterotanytarsus sp.											
Heterotrissocladius sp.					336						
Hydrobaenus sp.											
Limnophyes sp.			2								
Metriocnemus sp.											
Orthocladius complex			8								4
Parametriocnemus sp.											
Paraphaenocladius sp.						128					
Psectrocladius sp.				12	41			12			24
Psectrocladius(Psectrocladius) p											
Pseudosmittia sp.						46	14	8			
Rheocricotopus sp.											
Tvetenia bavarica group											
Tvetenia vitracies											
Zalutschia tatrica group							68	24			
Zalutschia zalutschicola											
| Tribe: Corynoneurini											

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	R6S1	R6S1
Sample:	X-1 July	2 July	X-3 July	4 July	XS 1 July	XS 2 July	1 July	2 July	3 July	1 July	2 July
CC#:	CC120840	CC111090	CC120842	CC120844	CC111092	CC111073	CC111070	CC111071	CC111072	CC111097	CC111098
Corynoneura sp.	1			4		15	8				
| Tribe: Orthocladiini											
Chaetocladius sp.			1								
| Subfamily: Podonominae											
Paraboreochlus sp.											
Trichotanypus sp.											
| Subfamily: Prodiamesinae											
Prodiamesa sp.											
| Subfamily: Tanypodinae											
| Tribe: Pentaneurini											
Ablabesmyia sp.											
Thienemannimyia group					40						1
| Tribe: Procladiini											
Djalmabatista sp.											
Procladius sp.					25						17
| Family: Culicidae											
| Family: Dixidae											
Dixella sp.											
| Family: Dolichopodidae											
| Family: Empididae											
Clinocera sp.						2					
Oreogeton sp.											
| Family: Muscidae											
Limnophora sp.											
| Family: Simuliidae			182	44						769	
Simulium sp.			92	8						18269	79
| Family: Tipulidae			6								
Hesperoconopa sp.							1				
Limnophila sp.											
Ormosia sp.											

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	R6S1	R6S1
Sample:	X-1 July	2 July	X-3 July	4 July	XS 1 July	XS 2 July	1 July	2 July	3 July	1 July	2 July
CC#:	CC120840	CC111090	CC120842	CC120844	CC111092	CC111073	CC111070	CC111071	CC111072	CC111097	CC111098
| Order: Lepidoptera											
| Order: Odonata											
| Class: Entognatha											
| Order: Collembola											
| Family: Poduridae			1		1	8				48	
| Family: Sminthuridae											
Subphylum: Crustacea											
| Class: Ostracoda		22	8	16		339					12
| Class: Branchiopoda											
| Order: Cladocera											
| Family: Daphniidae											
Daphnia sp.	117	133	55	84	254	33	70				154
| Class: Copepoda						285					
| Order: Calanoida	283	33	289	1000	184				4		
| Order: Cyclopoida		56			50		8				33
| Order: Harpacticoida		78			101						17
Subphylum: Chelicerata											
| Class: Arachnida											
| Order: Trombidiformes											
| Family: Arrenuridae											
Arrenurus sp.											
| Family: Lebertiidae											
Lebertia sp.	2										
| Family: Oxidae											
Oxus sp.											
| Family: Unionicolidae											
Neumania sp.					13						

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	R6S1	R6S1
Sample:	X-1 July	2 July	X-3 July	4 July	XS 1 July	XS 2 July	1 July	2 July	3 July	1 July	2 July
CC#:	CC120840	CC111090	CC120842	CC120844	CC111092	CC111073	CC111070	CC111071	CC111072	CC111097	CC111098
Suborder: Prostigmata			2								16
| Order: Oribatei											
| Family: Halacaridae											
| Order: Sarcoptiformes											
| Family: Hydrozetidae	12	278	6	48	163	148	17	4		96	52
Phylum: Mollusca											
| Class: Bivalvia					13						
| Order: Veneroida											
| Family: Sphaeriidae					14	5					16
Pisidium sp.											4
Sphaerium sp.											
| Class: Gastropoda		11									
| Order: Heterostropha											
| Family: Valvatidae											
Valvata sincera			1								
Phylum: Annelida											
Subphylum: Clitellata											
| Class: Oligochaeta		78					24				16
| Order: Lumbriculida											
| Family: Lumbriculidae					1						
Rhynchelmis sp.											
| Order: Tubificida											
| Family: Enchytraeidae											
Enchytraeus	2		5					56	4		
| Family: Lumbricidae											

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	R6S1	R6S1
Sample:	X-1 July	2 July	X-3 July	4 July	XS 1 July	XS 2 July	1 July	2 July	3 July	1 July	2 July
CC#:	CC120840	CC111090	CC120842	CC120844	CC111092	CC111073	CC111070	CC111071	CC111072	CC111097	CC111098
| Family: Naididae			8	584	80	177			2	48	3
Chaetogaster sp.											
Phylum: Nemata	49	2444	8	36	1244	2440	978	804	638	288	276
Phylum: Platyhelminthes											
| Class: Turbellaria											
Phylum: Cnidaria											
| Class: Hydrozoa											
| Order: Anthoathecatae											
| Family: Hydridae											
Hydra sp.			1	8							
Phylum: Tardigrada	4					15					

Site:	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	6 July	4 July	3 July	4 July	5 July	6 July	3 July	2 July	5 July	6 July
CC#:	CC111099	CC120826	CC111105	CC111106	CC111107	CC111108	CC120835	CC120836	CC120837	CC120838
Phylum: Arthropoda										
Subphylum: Hexapoda										
| Class: Insecta										
| Order: Ephemeroptera										
| Family: Baetidae										
Baetis sp.			13	106	48	9				
Baetis tricaudatus		8								
| Family: Ephemerellidae										
| Family: Heptageniidae										
Rhithrogena sp.										
| Order: Plecoptera										
| Family: Capniidae										
| Family: Nemouridae									4	
Nemoura		4		2						
Ostrocerca sp.										
Zapada sp.		48								
| Family: Perlodidae										
| Order: Trichoptera										
| Family: Hydroptilidae										
Oxyethira sp.										
| Family: Limnephilidae										
Clostoeca disjuncta										
Grammotaulius sp.										
Limnephilus sp.	1		2	1	5					4
Nemotaulius sp.										
| Family: Molannidae										
Molanna flavicornis										
| Order: Coleoptera							2			
| Family: Dytiscidae								4		

Site:	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	6 July	4 July	3 July	4 July	5 July	6 July	3 July	2 July	5 July	6 July
CC#:	CC111099	CC120826	CC111105	CC111106	CC111107	CC111108	CC120835	CC120836	CC120837	CC120838
Agabus sp.										
Oreodytes sp.										
| Family: Elmidae										
Optioservus sp.										
| Family: Haliplidae										
Peltodytes sp.										
| Family: Hydrophilidae										
Hydrochus sp.									4	
| Order: Diptera										
| Family: Ceratopogonidae										
Bezzia sp.										
Culicoides sp.										
Dasyhelea sp.										
Mallochohelea	4	4		2	5					
Probezzia sp.				1						
Sphaeromias sp.										
| Family: Chironomidae						36				
| Subfamily: Chironominae										
| Tribe: Chironomini										
Chironomus sp.			100							
Cryptochironomus sp.										
Endochironomus sp.										
Microtendipes sp.										
Paratendipes sp.										
Phaenopsectra sp.										
Polypedilum sp.										
Stictochironomus sp.			14		5	5				
Tribelos sp.										
| Tribe: Tanytarsini										
Cladotanytarsus sp.										
Micropsectra sp.	5		355	5						

Site:	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	6 July	4 July	3 July	4 July	5 July	6 July	3 July	2 July	5 July	6 July
CC#:	CC111099	CC120826	CC111105	CC111106	CC111107	CC111108	CC120835	CC120836	CC120837	CC120838
Paratanytarsus sp.	112									
Rheotanytarsus sp.							8			
Tanytarsus sp.		184						104	48	420
| Subfamily: Diamesinae										
Protanypus			2							
| Tribe: Diamesini										
Potthastia longimana group										
| Subfamily: Orthocladiinae							12	16	12	
Brillia sp.										
Cricotopus sp.				48	105	8				
Diplocladius cultriger										
Diplocladius sp.										
Eukiefferiella sp.				118	81	18				
Heleniella sp.										
Heterotanytarsus sp.			27							
Heterotrissocladius sp.										
Hydrobaenus sp.			20							
Limnophyes sp.										
Metriocnemus sp.										
Orthocladius complex		176					8			
Parametriocnemus sp.										
Paraphaenocladius sp.										
Psectrocladius sp.	1				24			36		
Psectrocladius(Psectrocladius) p										
Pseudosmittia sp.										
Rheocricotopus sp.				3		18				
Tvetenia bavarica group				130	62					
Tvetenia vitracies										
Zalutschia tatrica group							4			
Zalutschia zalutschicola										
| Tribe: Corynoneurini										

Site:	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	6 July	4 July	3 July	4 July	5 July	6 July	3 July	2 July	5 July	6 July
CC#:	CC111099	CC120826	CC111105	CC111106	CC111107	CC111108	CC120835	CC120836	CC120837	CC120838
Corynoneura sp.		8	6	2			76	8	116	12
| Tribe: Orthocladiini										
Chaetocladius sp.				40		25				
| Subfamily: Podonominae			18							
Paraboreochlus sp.		12								
Trichotanypus sp.										
| Subfamily: Prodiamesinae										
Prodiamesa sp.										
| Subfamily: Tanypodinae										
| Tribe: Pentaneurini										
Ablabesmyia sp.										
Thienemannimyia group										
| Tribe: Procladiini										
Djalmabatista sp.										
Procladius sp.			10							
| Family: Culicidae										
| Family: Dixidae										
Dixella sp.							6			
| Family: Dolichopodidae										
| Family: Empididae										
Clinocera sp.		16							8	
Oreogeton sp.							2	8		
| Family: Muscidae										
Limnophora sp.										
| Family: Simuliidae	16	20		6			122	16	8	
Simulium sp.	51	240	2	354	38	34	298	20		
| Family: Tipulidae										
Hesperoconopa sp.										
Limnophila sp.										
Ormosia sp.										

Site:	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	6 July	4 July	3 July	4 July	5 July	6 July	3 July	2 July	5 July	6 July
CC#:	CC111099	CC120826	CC111105	CC111106	CC111107	CC111108	CC120835	CC120836	CC120837	CC120838
| Order: Lepidoptera										
| Order: Odonata										
| Class: Entognatha										
| Order: Collembola										
| Family: Poduridae		4							4	
| Family: Sminthuridae		16					6		4	
Subphylum: Crustacea										
| Class: Ostracoda	16	28	423	8		9	20	76	60	460
| Class: Branchiopoda										
| Order: Cladocera										
| Family: Daphniidae										
Daphnia sp.	4	144	2				460	1744	284	340
| Class: Copepoda										
| Order: Calanoida			15	11		3	136	20	4	24
| Order: Cyclopoida	4	356	9	8	5		52	244	72	4
| Order: Harpacticoida	4	76						28		
Subphylum: Chelicerata										
| Class: Arachnida										
| Order: Trombidiformes										
| Family: Arrenuridae										
Arrenurus sp.										
| Family: Lebertiidae										
Lebertia sp.										
| Family: Oxidae										
Oxus sp.										
| Family: Unionicolidae										
Neumania sp.			9							

Site:	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	6 July	4 July	3 July	4 July	5 July	6 July	3 July	2 July	5 July	6 July
CC#:	CC111099	CC120826	CC111105	CC111106	CC111107	CC111108	CC120835	CC120836	CC120837	CC120838
Suborder: Prostigmata	8	12		1				4		
| Order: Oribatei										
| Family: Halacaridae		8								
| Order: Sarcoptiformes										
| Family: Hydrozetidae	44	40	11	8			18	8	32	12
Phylum: Mollusca										
| Class: Bivalvia										
| Order: Veneroida										
| Family: Sphaeriidae	9							4		
Pisidium sp.	1									
Sphaerium sp.										
| Class: Gastropoda										
| Order: Heterostropha										
| Family: Valvatidae										
Valvata sincera										
Phylum: Annelida										
Subphylum: Clitellata										
| Class: Oligochaeta							16			
| Order: Lumbriculida										
| Family: Lumbriculidae		4	2		5					
Rhynchelmis sp.										
| Order: Tubificida										
| Family: Enchytraeidae										
Enchytraeus								4	56	24
| Family: Lumbricidae		4								

Site:	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	6 July	4 July	3 July	4 July	5 July	6 July	3 July	2 July	5 July	6 July
CC#:	CC111099	CC120826	CC111105	CC111106	CC111107	CC111108	CC120835	CC120836	CC120837	CC120838
| Family: Naididae	5	20	30	2	10	23		8	16	24
Chaetogaster sp.										
Phylum: Nemata	59			130	52	12	52	548	632	356
Phylum: Platyhelminthes										
| Class: Turbellaria										
Phylum: Cnidaria										
| Class: Hydrozoa										
| Order: Anthoathecatae										
| Family: Hydridae										
Hydra sp.		4					2		8	16
Phylum: Tardigrada			9							4

Table A2-8. Raw 2011 macroinvertebrate abundance data.

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	M3S	R6S1
Sample:	1 July	2 July	3 June	4 July	1 July	2 June	1 June	2 June	3 June	4 June	1 June
CC#:	CC121490	CC121491	CC121492	CC121493	CC121494	CC121495	CC121496	CC121497	CC121498	CC121499	CC121506
Phylum: Arthropoda	0		0		0		0		0		0
Subphylum: Hexapoda	0		0		0		0		0		0
| Class: Insecta	0		0		0		0		0		0
| Order: Ephemeroptera	0		0		0		0		0		0
| Family: Baetidae	0		0		0		0		0		0
Acerpenna pygmaea	0		0		0		0		0		0
Baetis sp.	0		0		0		0		0		0
Baetis tricaudatus group	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Plecoptera	0		0		2		0		0		0
| Family: Nemouridae	0		0		0		0		0		0
Amphinemura sp.	0		0		0		0		0		0
Malenka sp.	0		0		0		0		0		0
| Family: Taeniopterygidae	0		0		0		0		0		0
Taeniopteryx nivalis	0		0		2		0		0		0
	0		0		0		0		0		0
| Order: Trichoptera	0		0		0		0		0		0
| Family: Hydroptilidae	0		0		0		0		0		0
Agraylea sp.	0		0		0		0		0		0
| Family: Lepidostomatidae	0		0		0		0		0		0
Lepidostoma sp.	0	5	0		0		0		0		0
| Family: Limnephilidae	0		0		4	19	1		0		0
Clostoeca disjuncta	0		0		0		0		0	1	0
Ecclisomyia sp.	0		0		0		0		0		0
Limnephilus sp.	0	2	0		0		0		0		0
| Family: Phryganeidae	0		0		0		0		0		0
Agrypnia sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Coleoptera	0		0		0		0		0		0
| Family: Dytiscidae	0		0		0	6	0		0		0
Colymbetes sp.	0		0		0		0		0		0
| Family: Elmidae	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	M3S	R6S1
Sample:	1 July	2 July	3 June	4 July	1 July	2 June	1 June	2 June	3 June	4 June	1 June
CC#:	CC121490	CC121491	CC121492	CC121493	CC121494	CC121495	CC121496	CC121497	CC121498	CC121499	CC121506
Dubiraphia sp.	0		0		2		0		0		0
| **Family: Haliplidae**	0		0		0		0		0		0
Haliplus sp.	0	2	0		0		0		0		0
| **Family: Hydraenidae**	0		0		0		0		0		0
Hydraena sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| **Order: Diptera**	0		0		0	6	1		0		0
| **Family: Ceratopogonidae**	0		0		0		0		0		0
Bezzia sp.	38	79	0		16	3	0		0		36
Dasyhelea sp.	70	46	0		0	3	0		0		0
Mallochohelea	0		0		0		0		0		73
Probezzia sp.	0		0		0		0		0		36
Sphaeromias sp.	0		0		0		0		0		0
| **Family: Chironomidae**	0		0		0		0		0		0
| **Subfamily: Chironominae**	42		0		0		0		0		0
Fissimentum sp.	0		0		0		0		0		0
| **Tribe: Chironomini**	0		0		0		0		0		0
Chironomus sp.	3		0	1	0		0		0		0
Cryptochironomus sp.	0		0		0		0		0		0
Glyptotendipes sp.	0		0		0		1		0		0
Microtendipes sp.	0		0		19		4		0		0
Phaenopsectra sp.	0		0		0		0		0		0
Polypedilum sp.	115		0		0		0		0		0
Stictochironomus sp.	0		0		0		0		0		0
| **Tribe: Tanytarsini**	0		0		0		0		0		0
Cladotanytarsus sp.	0		0		0		0		0		0
Micropsectra sp.	0		0		4		0		0		0
Paratanytarsus sp.	0		0		0	10	4		0		109
Tanytarsus sp.	16	32	0	10	5		0		0		545
| **Subfamily: Orthocladiinae**	0	496	112		0		0	25	2		727
Diplocladius cultriger	0		0		0		0		0		327
Eukiefferiella sp.	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	M3S	R6S1
Sample:	1 July	2 July	3 June	4 July	1 July	2 June	1 June	2 June	3 June	4 June	1 June
CC#:	CC121490	CC121491	CC121492	CC121493	CC121494	CC121495	CC121496	CC121497	CC121498	CC121499	CC121506
Georthocladius sp.	0		0		0		0		0		0
Heterotrissocladius sp.	0	6	0		0		0		0		0
Metriocnemus sp.	0		0		0		0		0		0
Orthocladius complex	0		0	28	0		0		0		509
Orthocladius sp.	0		0		0		0		0		0
Paralimnophyes arcticus	0		0		0	992	90	120	33	105	0
Psectrocladius sp.	0		0		0		0		0		0
Pseudosmittia sp.	0		0		0		4		0		0
Tvetenia sp.	0		0		0		0		0		0
Zalutschia briani	0		120		292		24		0		0
| Tribe: Corynoneurini	0		0		0		0		0		0
Corynoneura sp.	0	4	64		0		11	5	2	6	182
| Tribe: Orthocladiini	0		0		0		0		0		0
Chaetocladius sp.	0		40		0		0		0		0
| Subfamily: Podonominae	0		0		0		0		0		0
| Tribe: Boreochlini	0		0		0		0		0		0
Boreochlus sp.	0		0		0		8	7	0	5	0
| Subfamily: Tanypodinae	3	32	0		9		0		0		0
| Tribe: Pentaneurini	0		0		0		0		0		0
Ablabesmyia sp.	0		0		16		0		0		0
| Tribe: Procladiini	0		0		0		0		0		0
Procladius sp.	0	4	0		4		0		0		0
| Family: Culicidae	0		0		0		0		0		0
Aedes sp.	0		0		0		20	10	0	19	0
| Family: Dixidae	0		0		0		0		0		0
Dixella sp.	0		0		0		0		0		0
| Family: Dolichopodidae	0		0		0		0		0		0
Rhaphium sp.	0		0		0		0		0		0
| Family: Empididae	0		0		0		0		0		0
Clinocera sp.	0		0		0		0		0		0
| Family: Muscidae	0		0		0		0		0		0
Limnophora sp.	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	M3S	R6S1
Sample:	1 July	2 July	3 June	4 July	1 July	2 June	1 June	2 June	3 June	4 June	1 June
CC#:	CC121490	CC121491	CC121492	CC121493	CC121494	CC121495	CC121496	CC121497	CC121498	CC121499	CC121506
| Family: Simuliidae	0	5	0		0	26	1		0		32655
Simulium sp.	0		2824		14		0		0		0
| Family: Tipulidae	0		0		0		0		0		0
Erioptera sp.	0		0		0		0		0		0
Tipula sp.	0		0		2		0		0		0
	0		0		0		0		0		0
| Order: Hemiptera	0		0		0		0		0		0
| Family: Corixidae	0	2	0		2		0		0		0
Sigara sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Class: Entognatha	0		0		0		0		0		0
| Order: Collembola	0	5	8		0	3	0		1	1	0
	0		0		0		0		0		0
Subphylum: Crustacea	0		0		0		0		0		0
| Class: Ostracoda	99	7	8	12	2	3	1		0		0
| Class: Branchiopoda	0		0		0		0		0		0
| Order: Cladocera	0		0		0		0		0		0
| Family: Daphniidae	0		0		0		0		0		0
Daphnia sp.	3	7	8	1	2	3	1		0	1	0
	0		0		0		0		0		0
| Class: Copepoda	3	7	8	1	2	3	1	1	1	1	36
| Class: Malacostraca	0		0		0		0		0		0
| Order: Copepoda	0		0		0		0		0		0
Subphylum: Chelicerata	0		0		0		0		0		0
| Class: Arachnida	0		0		0		0		0		0
| Order: Trombidiformes	0	2	0		2		0		0		0
| Family: Arrenuridae	0		0		0		0		0		0
Arrenurus sp.	3		0		0		0		0		0
| Family: Hygrobatidae	0		0		0		0		0		0
Hygrobates sp.	0		0		0		1		0		0
| Family: Lebertiidae	0		0		0		0		0		0
Lebertia sp.	3		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	M3S	R6S1
Sample:	1 July	2 July	3 June	4 July	1 July	2 June	1 June	2 June	3 June	4 June	1 June
CC#:	CC121490	CC121491	CC121492	CC121493	CC121494	CC121495	CC121496	CC121497	CC121498	CC121499	CC121506
| Family: Limnesiidae	0		0		0		0		0		0
Limnesia sp.	0		0		0		0		0		0
| Family: Pionidae	0		0		0		0		0		0
Piona sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Oribatei	0		0		0		0		0		0
| Family: Halacaridae	0	11	0		0		0		0		0
	0		0		0		0		0		0
| Order: Sarcoptiformes	0		0		0		0		0		0
| Family: Hydrozetidae	605	1606	0	4	60		1	20	3	26	73
	0		0		0		0		0		0
Phylum: Mollusca	0		0		0		0		0		0
| Class: Bivalvia	0		0		0		0		0		0
| Order: Veneroida	0		0		0		0		0		0
| Family: Sphaeriidae	0		0		0		0		0		0
Pisidium sp.	0		0		0		0		0		0
Sphaerium sp.	0		0		0		0		0	1	0
	0		0		0		0		0		0
| Class: Gastropoda	0	10	0		0		0		0		0
| Order: Basommatophora	0		0		0		0		0		0
| Family: Planorbidae	0		0		4		0		0		0
	0		0		0		0		0		0
| Order: Heterostropha	0		0		0		0		0		0
| Family: Valvatidae	0		0		0		0		0		0
Valvata sincera	35	31	0		0		0		0		0
	0		0		0		0		0		0
Phylum: Annelida	0		0		0		0		0		0
Subphylum: Clitellata	0		0		0		0		0		0
| Class: Oligochaeta	0		8		0		0		0		0
| Order: Lumbriculida	0		0		0		0		0		0
| Family: Lumbriculidae	3		0		0		13	1	0	60	0
	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S	M3S	R6S1
Sample:	1 July	2 July	3 June	4 July	1 July	2 June	1 June	2 June	3 June	4 June	1 June
CC#:	CC121490	CC121491	CC121492	CC121493	CC121494	CC121495	CC121496	CC121497	CC121498	CC121499	CC121506
| Order: Tubificida	0		0		0		0		0		0
| Family: Enchytraeidae	0	17	0		0		0		0		0
| Family: Lumbricidae	0		0		0		0		0		0
| Family: Naididae	19	159	0	33	138	96	0		0		73
	0		0		0		0		0		0
Phylum: Nemata	3	7	8	1	0	3	1	1	1	1	0
Phylum: Platyhelminthes	0		0		0		0		0		0
| Class: Turbellaria	0		0		4		0		0		0
	0		0		0		0		0		0
Phylum: Cnidaria	0		0		0		0		0		0
| Class: Hydrozoa	0		0		0		0		0		0
| Order: Anthoathecatae	0		0		0		0		0		0
| Family: Hydridae	0		0		0		0		0		0
Hydra sp.	0		0	6	0		0		0		0
	0		0		0		0		0		0
Phylum: Tardigrada	13	176	0	2	0		3		0		0
All others	0		0		0		0		0		0

Site:	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	2 July	3 July	4 July	5 July	6 July	1 July	2 June	3 July	4 July	5 July	6 July
CC#:	CC121507	CC121508	CC121509	CC121510	CC121511	CC121512	CC121513	CC121514	CC121515	CC121516	CC121517
Phylum: Arthropoda		0		0		0		0		0	
Subphylum: Hexapoda		0		0		0		0		0	
| Class: Insecta		0		0		0		0		0	
| Order: Ephemeroptera		0		0		0		0		0	
| Family: Baetidae		0		0		0		0		0	
Acerpenna pygmaea		0		0		0		0		1	
Baetis sp.		0		0		0		0	11	0	
Baetis tricaudatus group		8		0		8		0	9	0	
		0		0		0		0		0	
| Order: Plecoptera	8	192	21	2	1	104		0		0	
| Family: Nemouridae		8		0		0		0		0	
Amphinemura sp.		24		2		8		0		0	
Malenka sp.		0		0	3	0		0		0	
| Family: Taeniopterygidae		0		0		0		0		0	
Taeniopteryx nivalis		0		0		0		0		0	
		0		0		0		0		0	
| Order: Trichoptera	8	56		0	10	0		0	2	0	
| Family: Hydroptilidae		0		0	1	0		0		0	
Agraylea sp.		0		0	1	0		0		0	1
| Family: Lepidostomatidae		0		0		0		0		0	
Lepidostoma sp.		0		0		0		0		0	
| Family: Limnephilidae		0		2		0	8	0		0	
Clostoeca disjuncta		0		0		0		0		0	
Ecclisomyia sp.		0		0		0		0		0	
Limnephilus sp.		0		0		0		0		0	
| Family: Phryganeidae		0		0		0		0		0	
Agrypnia sp.		0		0		8		0		0	
		0		0		0		0		0	
| Order: Coleoptera		0		0		0		0		0	
| Family: Dytiscidae		0		2		0		0		1	
Colymbetes sp.		0		0		0		0		0	
| Family: Elmidae		0		0		0		0		0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	2 July	3 July	4 July	5 July	6 July	1 July	2 June	3 July	4 July	5 July	6 July
CC#:	CC121507	CC121508	CC121509	CC121510	CC121511	CC121512	CC121513	CC121514	CC121515	CC121516	CC121517
Dubiraphia sp.		0		0		0		0		0	
| Family: Haliplidae		0		0		0		0		0	
Haliplus sp.		0		0		0		0		0	
| Family: Hydraenidae		0		0		0		0		0	
Hydraena sp.		0		0		0		0		1	
		0		0		0		0		0	
| Order: Diptera		0		0		0		0		0	
| Family: Ceratopogonidae		0		0		0		0		0	
Bezzia sp.	8	0		6		16		2	5	0	2
Dasyhelea sp.		0		0		0		0		0	
Mallochohelea		0		2		0		0	5	1	
Probezzia sp.		16		0		8		0		0	2
Sphaeromias sp.		0		0		0		0		0	
| Family: Chironomidae		0		0		0		0		0	
| Subfamily: Chironominae		0		0		0		0		0	
Fissimentum sp.		0		0		0		4	98	0	
| Tribe: Chironomini		0		0		0		0		0	
Chironomus sp.		0	11	0		0		10		0	
Cryptochironomus sp.		0		0		0		0		0	
Glyptotendipes sp.		0		0		0		0		0	
Microtendipes sp.	280	0	37	14		160		0		0	
Phaenopsectra sp.		0		0		0	19	40		0	
Polypedilum sp.		0		0		0		0		0	
Stictochironomus sp.	24	0	32	18		0		10	16	0	
| Tribe: Tanytarsini	200	480	693	250	20	1200		0		0	
Cladotanytarsus sp.		0		0		0		0		0	
Micropsectra sp.	240	0		16	24	80		490	434	32	94
Paratanytarsus sp.		0		0		0		0		0	
Tanytarsus sp.		0		0		0	35	0		0	
| Subfamily: Orthocladiinae	320	640	1013	180	13	1960		0		0	
Diplocladius cultriger		0		0		0		0		0	
Eukiefferiella sp.		0		0		0		0		0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	2 July	3 July	4 July	5 July	6 July	1 July	2 June	3 July	4 July	5 July	6 July
CC#:	CC121507	CC121508	CC121509	CC121510	CC121511	CC121512	CC121513	CC121514	CC121515	CC121516	CC121517
Georthocladius sp.		0		0		0	1	0		0	
Heterotrissocladius sp.	200	0		0		40	7	0		0	
Metriocnemus sp.		0		0		40		0		0	
Orthocladius complex		0		0		160		0		0	
Orthocladius sp.		0		0		0		0		0	
Paralimnophyes arcticus		0		0	15	240		0	11	0	
Psectrocladius sp.		0		0		0	10	56	25	0	7
Pseudosmittia sp.		0		0		0		0		0	
Tvetenia sp.		0		0		0		0		15	43
Zalutschia briani	2000	0		0	7	0		50		0	3
| Tribe: Corynoneurini		0		0		0		0		0	
Corynoneura sp.		224	48	36	14	280		0		8	17
| Tribe: Orthocladiini		0		0		0		0		0	
Chaetocladius sp.		0		0		0		0		0	
| Subfamily: Podonominae		0		0		0		0		0	
| Tribe: Boreochlini		0		0		0		0		0	
Boreochlus sp.		0		0		0	8	0		0	
| Subfamily: Tanypodinae		0		0		0		0		0	
| Tribe: Pentaneurini		0		0		0		0		0	
Ablabesmyia sp.		0		0		0		0		0	
| Tribe: Procladiini		0		0		0		0		0	
Procladius sp.	8	0		2	2	0	4	4	14	0	
| Family: Culicidae		0		0		0		0		0	
Aedes sp.		0		0		0		0		0	
| Family: Dixidae		0		0		0		0		0	
Dixella sp.		0		0		0		0		0	
| Family: Dolichopodidae		0		0		0		0		0	
Rhaphium sp.		0		0		8	1	0		0	
| Family: Empididae		0		0		0		0		0	
Clinocera sp.		0		0		8		0		0	
| Family: Muscidae		0		0		0		0		0	
Limnophora sp.		0		0		0		0	2	0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	2 July	3 July	4 July	5 July	6 July	1 July	2 June	3 July	4 July	5 July	6 July
CC#:	CC121507	CC121508	CC121509	CC121510	CC121511	CC121512	CC121513	CC121514	CC121515	CC121516	CC121517
| Family: Simuliidae	64	0	16	4		152		0	16	1	
Simulium sp.		304	5	0		304	1	0	14	9	1
| Family: Tipulidae		0		0		0		0		0	
Erioptera sp.		0		0		0		0		0	
Tipula sp.		0		0		0		0		0	
		0		0		0		0		0	
| Order: Hemiptera		0		0		0		0		0	
| Family: Corixidae		0		0		0		0		0	
Sigara sp.		0		0		0		0		0	
		0		0		0		0		0	
| Class: Entognatha		0		0		0		0		0	
| Order: Collembola		0		4	1	8		0	2	0	
		0		0		0		0		0	
Subphylum: Crustacea		0		0		0		0		0	
| Class: Ostracoda	8	8	5	2	1	8		2	2	1	1
| Class: Branchiopoda		0		0		0		0		0	
| Order: Cladocera		0		0		0		0		0	
| Family: Daphniidae		0		0		0		0		0	
Daphnia sp.	8	8	5	2	1	8		2	2	0	1
		0		0		0		0		0	
| Class: Copepoda	8	8		2	1	8	1	0	2	1	1
| Class: Malacostraca		0		0		0		0		0	
| Order: Copepoda		0	5	0		0		2		0	
Subphylum: Chelicerata		0		0		0		0		0	
| Class: Arachnida		0		0		0		0		0	
| Order: Trombidiformes	56	0	5	6	1	0		8	5	0	
| Family: Arrenuridae		0		0		0		0		0	
Arrenurus sp.		0		0		0		0		0	
| Family: Hygrobatidae		0		0		0		0		0	
Hygrobates sp.		0		0		0		0		0	
| Family: Lebertiidae		0		0		0		0		0	
Lebertia sp.	8	0		0		0		0	2	0	4

Site:	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	2 July	3 July	4 July	5 July	6 July	1 July	2 June	3 July	4 July	5 July	6 July
CC#:	CC121507	CC121508	CC121509	CC121510	CC121511	CC121512	CC121513	CC121514	CC121515	CC121516	CC121517
| Family: Limnesiidae		0		0		0		0		0	
Limnesia sp.		0		0	1	0		0		0	
| Family: Pionidae		0		0		0		0		0	
Piona sp.		0		0		0		0		0	
		0		0		0		0		0	
| Order: Oribatei		0		0		0		0		0	
| Family: Halacaridae	8	0		2		0		0		0	
		0		0		0		0		0	
| Order: Sarcoptiformes		0		0		0		0		0	
| Family: Hydrozetidae	24	192	27	58	3	64	11	14	34	3	7
		0		0		0		0		0	
Phylum: Mollusca		0		0		0		0		0	
| Class: Bivalvia		0		0		0		0		0	
| Order: Veneroida		0		0		0		0		0	
| Family: Sphaeriidae		0		0		0		0		0	
Pisidium sp.	8	0		0		0		0		0	
Sphaerium sp.		0		0		0		0		0	
		0		0		0		0		0	
| Class: Gastropoda		0		2		0		0		0	
| Order: Basommatophora		0		0		0		0		0	
| Family: Planorbidae		0		0		0		0		0	
		0		0		0		0		0	
| Order: Heterostropha		0		0		0		0		0	
| Family: Valvatidae		0		0		0		0		0	
Valvata sincera		0		0		0		0		0	
		0		0		0		0		0	
Phylum: Annelida		0		0		0		0		0	
Subphylum: Clitellata		0		0		0		0		0	
| Class: Oligochaeta		0		0		0		2		1	
| Order: Lumbriculida		0		0		0		0		0	
| Family: Lumbriculidae		0		2		0		6		0	
		0		0		0		0		0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	2 July	3 July	4 July	5 July	6 July	1 July	2 June	3 July	4 July	5 July	6 July
CC#:	CC121507	CC121508	CC121509	CC121510	CC121511	CC121512	CC121513	CC121514	CC121515	CC121516	CC121517
| Order: Tubificida		0		0		0		0		0	
| Family: Enchytraeidae		0		0		0		0		0	
| Family: Lumbricidae		0		0		0		0		0	
| Family: Naididae	16	56	21	20	6	120	2	26	43	14	20
		0		0		0		0		0	
Phylum: Nemata	8	8	5	2	1	8		2	2	1	1
Phylum: Platyhelminthes		0		0		0		0		0	
| Class: Turbellaria		0		0		0		0		0	
		0		0		0		0		0	
Phylum: Cnidaria		0		0		0		0		0	
| Class: Hydrozoa		0		0		0		0		0	
| Order: Anthoathecatae		0		0		0		0		0	
| Family: Hydridae		0		0		0		0		0	
Hydra sp.		0	16	68	2	8		0		0	
		0		0		0		0		0	
Phylum: Tardigrada		16		16		0		6	57	0	
All others		0		0		0		0		0	

Site:	R2S	R2S	R2S	R2S	R2S	R2S
Sample:	1 June	2 June	3 June	4 June	5 June	6 June
CC#:	CC121500	CC121501	CC121502	CC121503	CC121504	CC121505
Phylum: Arthropoda	0		0		0	
Subphylum: Hexapoda	0		0		0	
| Class: Insecta	0		0		0	
| Order: Ephemeroptera	0		0		0	
| Family: Baetidae	0		0		0	
Acerpenna pygmaea	0		0		0	
Baetis sp.	0		0		0	
Baetis tricaudatus group	0		0		0	
	0		0		0	
| Order: Plecoptera	0		0		0	
| Family: Nemouridae	0		0		0	
Amphinemura sp.	0		0		0	
Malenka sp.	0		0		0	
| Family: Taeniopterygidae	0		0		0	
Taeniopteryx nivalis	0		0		0	
	0		0		0	
| Order: Trichoptera	0		0		0	1
| Family: Hydroptilidae	0		0		0	
Agraylea sp.	0		0		0	
| Family: Lepidostomatidae	0		0		0	
Lepidostoma sp.	0		0		0	
| Family: Limnephilidae	0	2	1	12	2	2
Clostoeca disjuncta	0		0		0	
Ecclisomyia sp.	0		0	2	0	1
Limnephilus sp.	0		0		0	
| Family: Phryganeidae	0		0		0	
Agrypnia sp.	0		0		0	
	0		0		0	
| Order: Coleoptera	0		0		0	
| Family: Dytiscidae	0	2	1	6	7	1
Colymbetes sp.	0		0		0	
| Family: Elmidae	0		0		0	

Site:	R2S	R2S	R2S	R2S	R2S	R2S
Sample:	1 June	2 June	3 June	4 June	5 June	6 June
CC#:	CC121500	CC121501	CC121502	CC121503	CC121504	CC121505
Dubiraphia sp.	0		0		0	
| Family: Haliplidae	0		0		0	
Haliplus sp.	0		0		0	
| Family: Hydraenidae	0		0		0	
Hydraena sp.	0		0		0	
	0		0		0	
| Order: Diptera	0		0		0	2
| Family: Ceratopogonidae	0		0		0	
Bezzia sp.	8	11	10	40	1	2
Dasyhelea sp.	0		0		0	
Mallochohelea	0		0		0	
Probezzia sp.	0		0		0	
Sphaeromias sp.	0		0		0	
| Family: Chironomidae	0		0		0	
| Subfamily: Chironominae	0		0		0	
Fissimentum sp.	0		0		0	
| Tribe: Chironomini	0		0		0	
Chironomus sp.	0	2	0		0	
Cryptochironomus sp.	0		0		0	
Glyptotendipes sp.	0		0		0	
Microtendipes sp.	0		0		0	
Phaenopsectra sp.	0		0		0	
Polypedilum sp.	0		0	10	0	
Stictochironomus sp.	0		0		0	
| Tribe: Tanytarsini	0		0		0	12
Cladotanytarsus sp.	0		0		0	
Micropsectra sp.	0		0		0	
Paratanytarsus sp.	0		0		0	
Tanytarsus sp.	0	12	0		0	
| Subfamily: Orthocladiinae	32	267	0	350	63	25
Diplocladius cultriger	0		0		0	
Eukiefferiella sp.	16		0		0	

Site:	R2S	R2S	R2S	R2S	R2S	R2S
Sample:	1 June	2 June	3 June	4 June	5 June	6 June
CC#:	CC121500	CC121501	CC121502	CC121503	CC121504	CC121505
Georthocladius sp.	0		0		0	
Heterotrissocladius sp.	0		0		0	
Metriocnemus sp.	0		0		0	
Orthocladius complex	0	123	165	140	177	31
Orthocladius sp.	296		0		0	
Paralimnophyes arcticus	64		2		11	14
Psectrocladius sp.	0	36	0	10	0	
Pseudosmittia sp.	0		0		0	
Tvetenia sp.	0		0		0	
Zalutschia briani	0		0		17	15
| Tribe: Corynoneurini	0		0		0	
Corynoneura sp.	32		2	6	8	
| Tribe: Orthocladiini	0		0		0	
Chaetocladius sp.	0		0		0	
| Subfamily: Podonominae	0		0		0	
| Tribe: Boreochlini	0		0		0	
Boreochlus sp.	0		0		0	
| Subfamily: Tanypodinae	0		0		0	
| Tribe: Pentaneurini	0		0		0	
Ablabesmyia sp.	0		0		0	
| Tribe: Procladiini	0		0		0	
Procladius sp.	0		1		0	
| Family: Culicidae	0		0		0	
Aedes sp.	0		0		0	
| Family: Dixidae	0		0		0	
Dixella sp.	0		0		0	
| Family: Dolichopodidae	0		0		0	
Rhaphium sp.	0		0		0	
| Family: Empididae	0		0		0	
Clinocera sp.	0		0		0	
| Family: Muscidae	0		0		0	
Limnophora sp.	0		0		0	

Site:	R2S	R2S	R2S	R2S	R2S	R2S
Sample:	1 June	2 June	3 June	4 June	5 June	6 June
CC#:	CC121500	CC121501	CC121502	CC121503	CC121504	CC121505
| Family: Simuliidae	0		0		0	
Simulium sp.	3472	84	43	14	35	
| Family: Tipulidae	0		0		0	
Erioptera sp.	0		0		0	
Tipula sp.	0		0		0	
	0		0		0	
| Order: Hemiptera	0		0		0	
| Family: Corixidae	0		0		0	
Sigara sp.	0		0		0	
	0		0		0	
| Class: Entognatha	0		0		0	
| Order: Collembola	0	2	0		1	
	0		0		0	
Subphylum: Crustacea	0		0		0	
| Class: Ostracoda	0		1		0	1
| Class: Branchiopoda	0		0		0	
| Order: Cladocera	0		0		0	
| Family: Daphniidae	0		0		0	
Daphnia sp.	0		0		1	
	0		0		0	
| Class: Copepoda	8	2	1		0	1
| Class: Malacostraca	0		0		0	
| Order: Copepoda	0		0		1	
Subphylum: Chelicerata	0		0		0	
| Class: Arachnida	0		0		0	
| Order: Trombidiformes	8		0		0	
| Family: Arrenuridae	0		0		0	
Arrenurus sp.	0		0		0	
| Family: Hygrobatidae	0		0		0	
Hygrobates sp.	0		0		0	
| Family: Lebertiidae	0		0		0	
Lebertia sp.	0		0		0	

Site:	R2S	R2S	R2S	R2S	R2S	R2S
Sample:	1 June	2 June	3 June	4 June	5 June	6 June
CC#:	CC121500	CC121501	CC121502	CC121503	CC121504	CC121505
| Family: Limnesiidae	0		0		0	
Limnesia sp.	0		0		0	
| Family: Pionidae	0		0		0	
Piona sp.	0		0		0	
	0		0		0	
| Order: Oribatei	0		0		0	
| Family: Halacaridae	0		0		0	
	0		0		0	
| Order: Sarcoptiformes	0		0		0	
| Family: Hydrozetidae	0	5	17	30	15	16
	0		0		0	
Phylum: Mollusca	0		0		0	
| Class: Bivalvia	0		0		0	
| Order: Veneroida	0		0		0	
| Family: Sphaeriidae	0		0		0	
Pisidium sp.	0	21	0		0	
Sphaerium sp.	0		0		0	
	0		0		0	
| Class: Gastropoda	0		0		0	
| Order: Basommatophora	0		0		0	
| Family: Planorbidae	0		0		0	
	0		0		0	
| Order: Heterostropha	0		0		0	
| Family: Valvatidae	0		0		0	
Valvata sincera	0		0		0	
	0		0		0	
Phylum: Annelida	0		0		0	
Subphylum: Clitellata	0		0		0	
| Class: Oligochaeta	0		0		0	
| Order: Lumbriculida	0		0		0	
| Family: Lumbriculidae	0		0		0	1
	0		0		0	

Site:	R2S	R2S	R2S	R2S	R2S	R2S
Sample:	1 June	2 June	3 June	4 June	5 June	6 June
CC#:	CC121500	CC121501	CC121502	CC121503	CC121504	CC121505
| Order: Tubificida	0		0		0	
| Family: Enchytraeidae	0		0	16	0	
| Family: Lumbricidae	0		0		0	
| Family: Naididae	8	5	4		16	13
	0		0		0	
Phylum: Nemata	8	2	1		1	1
Phylum: Platyhelminthes	0		0		0	
| Class: Turbellaria	0		0		0	
	0		0		0	
Phylum: Cnidaria	0		0		0	
| Class: Hydrozoa	0		0		0	
| Order: Anthoathecatae	0		0		0	
| Family: Hydridae	0		0		0	
Hydra sp.	0		0		0	
	0		0		0	
Phylum: Tardigrada	0	4	0		0	
All others	0		0		0	

Table A2-9. Raw 2012 macroinvertebrate data.

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC130439	CC130440	CC130441	CC130442	CC130443	CC130444	CC130445	CC130446	CC130447	CC130448	CC130449
Phylum: Arthropoda	0		0		0		0		0		0
Subphylum: Hexapoda	0		0		0		0		0		0
| Class: Insecta	0		0		0		0		0		0
| Order: Ephemeroptera	0		0		0		0		0		0
| Family: Baetidae	0		0		0		0		0		0
Baetis sp.	0		0		0		0		0		0
Baetis tricaudatus group	0		0		0		0		0		0
| Family: Heptageniidae	0		0		0		0		0		0
Ironodes sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Plecoptera	0		0		0		0		0		0
| Family: Nemouridae	0		0		0		0		0		0
Amphinemura sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Trichoptera	0		0		0		0		0		0
| Family: Hydroptilidae	0		0		0		0		0		0
Agraylea sp.	0		0		0		0		0		0
Oxyethira sp.	0		0		0		0		0		0
| Family: Limnephilidae	1	3	12	11	4	8	0	2	0	7	4
Limnephilus sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Coleoptera	0		0		0		0		0		0
| Family: Dytiscidae	1	3	5	1	1	1	0		0		4
Agabus sp.	0		0		0		0		0		0
Hygrotus sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Diptera	0	1	0		0		0		0		0
| Family: Ceratopogonidae	0		0		0		0		0		0
Atrichopogon sp.	0		0	1	0		0		0		0
Bezzia sp.	0		1		0		9		0		0
Culicoides sp.	0		0		0		0	1	0		0
Mallochohelea	0	1	0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC130439	CC130440	CC130441	CC130442	CC130443	CC130444	CC130445	CC130446	CC130447	CC130448	CC130449
Sphaeromias sp.	0		0		0		0		0		0
| Family: Chironomidae	1		0		0		0		0		0
Orthocladiinae sp.	0		0		0		0		0		0
| Subfamily: Chironominae	0		0		0	11	36		0		0
| Tribe: Chironomini	0		0		0		0		0		0
Chironomus sp.	3		0		0		0	42	86	283	48
Cryptochironomus sp.	0		0		0		0		0		0
Microtendipes pedellus	0		0		0		10		0		0
Phaenopsectra sp.	0		0		0		0		0		0
Polypedilum sp.	0	12	0		0		0		0		0
Stictochironomus sp.	0		0		0		7		0		0
| Tribe: Pseudochironomini	0		0		0		0		0		0
Pseudochironomus sp.	0		0		0		3		0		0
| Tribe: Tanytarsini	0		0		0		0		0		0
Cladotanytarsus sp.	0		0		0		0		0		0
Micropsectra sp.	19		17	104	15	11	33	7	337	467	115
Paratanytarsus sp.	0		0		0		22		23		0
Tanytarsus sp.	8	36	40	57	21	76	0		244	250	45
| Subfamily: Diamesinae	0		0		0		0		0		0
Protanypus	0		0		0		0		0		0
| Subfamily: Orthocladiinae	6		0		0		0		0		0
Brillia sp.	0		0		0		0		2		0
Diplocladius cultriger	0		0		0		0		0		0
Eukiefferiella sp.	0	1	0		0		0		0		0
Heleniella sp.	0		1		0		0		0		0
Heterotanytarsus sp.	0		0		0		0		0		0
Heterotrissocladius sp.	0		0		0		0		0		0
Limnophyes sp.	0		0		0		0	1	0		2
Metriocnemus sp.	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC130439	CC130440	CC130441	CC130442	CC130443	CC130444	CC130445	CC130446	CC130447	CC130448	CC130449
Orthocladius complex	8	11	112	23	18	50	0	17	0		0
Parakiefferiella sp.	0		0		0		0		0		0
Psectrocladius sp.	0		13	2	1		30		9	7	0
Zalutschia sp.	0		9		0		109	34	0		0
| Tribe: Corynoneurini	0		0		0		0		0		0
Corynoneura sp.	0	1	2	22	8	5	51	12	16	17	16
| Subfamily: Podonominae	0		0		0		0		0		0
Trichotanypus sp.	0		0		0		0		0		0
| Subfamily: Tanypodinae	0		0		0		19		0		0
| Tribe: Pentaneurini	0		0		0		0		0		0
Ablabesmyia sp.	3	10	51	46	13	6	0		0		0
| Tribe: Procladiini	0		0		0		0		0		0
Procladius sp.	0		0		0		0		0		0
| Family: Culicidae	0		0		0		0		0	3	0
| Family: Dixidae	0		0		0		0		0		0
Dixella sp.	0		0		0		0		0		0
| Family: Dolichopodidae	0		0		0		0		0		0
Rhaphium sp.	0		0		0		0		0		0
| Family: Empididae	0		2	2	0	1	0		0		0
Clinocera sp.	1	2	2	6	5	6	3		0		1
| Family: Muscidae	0		0		0		0		0		0
Limnophora sp.	0		0		0		0		0		0
| Family: Simuliidae	0		0		0		0		0		0
Simulium sp.	0		0		0		0		0		0
| Family: Tipulidae	0		0		0		0		0		0
Erioptera sp.	0		0		0		0		0		0
Limnophila sp.	0		0		0		0		0		0
Tipula sp.	0		0		0		0		0		0
	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC130439	CC130440	CC130441	CC130442	CC130443	CC130444	CC130445	CC130446	CC130447	CC130448	CC130449
| Order: Hemiptera	0		0		0		0		0		0
| Family: Corixidae	0		1	2	1		3	10	0		1
Sigara sp.	0		0		0		0	1	0		0
	0		0		0		0		0		0
| Order: Lepidoptera	0		0		0		0		0		0
	0		0		0		0		0		0
Subphylum: Crustacea	0		0		0		0		0		0
| Class: Malacostraca	0		0		0		0		0		0
| Order: Amphipoda	0		0		0		0		0		0
	0		0		0		0		0		0
Subphylum: Chelicerata	0		0		0		0		0		0
| Class: Arachnida	0		0		0		0		0		0
| Order: Trombidiformes	1		1	6	0	2	0	2	0	10	0
| Family: Hydryphantidae	0		0		0		0		0		0
| Family: Hygrobatidae	0		0		0		0		0		0
Hygrobates sp.	0		0		0		0		0		0
| Family: Lebertiidae	0		0		0		0		0		0
Lebertia sp.	0		0	1	0		0		0		1
| Family: Pionidae	0		0		0		0		0		0
Piona sp.	0		7	1	0		0		0		0
	0		0		0		0		0		0
| Order: Oribatei	0		0		0		0		0		0
| Family: Halacaridae	0		0		0		0		2		0
	0		0		0		0		0		0
| Order: Sarcoptiformes	0		0		0		0		0		0
| Family: Hydrozetidae	1		2		0		6	5	0		1
	0		0		0		0		0		0
Phylum: Mollusca	0		0		0		0		0		0
| Class: Bivalvia	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC130439	CC130440	CC130441	CC130442	CC130443	CC130444	CC130445	CC130446	CC130447	CC130448	CC130449
| Order: Veneroida	0		0		0		0		0		0
| Family: Pisidiidae	0		0		0		4		0		0
Pisidium sp.	0		0		0		1		0		0
Sphaerium sp.	0		0		0		0	1	0		0
	0		0		0		0		0		0
| Class: Gastropoda	0		0		0		0		0		0
| Order: Heterostropha	0		0		0		0		0		0
| Family: Valvatidae	0		0		0		3		0		0
	0		0		0		0		0		0
Phylum: Annelida	0		0		0		0		0		0
Subphylum: Clitellata	0		0		0		0		0		0
| Class: Oligochaeta	0		0		0		0	3	0		0
| Order: Lumbriculida	0		0		0		0		0		0
| Family: Lumbriculidae	0		0	1	0		16		0	3	0
	0		0		0		0		0		0
| Order: Tubificida	0		0		0		0		0		0
| Family: Enchytraeidae	0		0		0		0		0		0
Enchytraeus	0		0		1		0		0		0
| Family: Lumbricidae	0		0		0		3		0		0
| Family: Naididae	0		0		1		70	7	2		0
Chaetogaster diaphanus	0		0		0		0		0		0
Chaetogaster sp.	0		0		0		0		0		0
Nais sp.	2		1		2		4	6	7		2
Pristina sp.	0		0		0		0		0		0
Phylum: Cnidaria	0		0		0		0		0		0
| Class: Hydrozoa	0		0		0		0		0		0
| Order: Anthoathecatae	0		0		0		0		0		0
| Family: Hydridae	0		0		0		0		0		0
Hydra sp.	0		0		0		0		0		0
Phylum: Tardigrada	0		0		0		0		0		0

Site:	M3S	M3S	M3S	R2S	R2S	R2S	R2S	R2S	R6S1	R6S1
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 6	Rep 1	Rep 2
CC#:	CC130450	CC130451	CC130452	CC130453	CC130454	CC130455	CC130456	CC130457	CC130458	CC130459
Phylum: Arthropoda		0		0		0		0		0
Subphylum: Hexapoda		0		0		0		0		0
| Class: Insecta		0		0		0		0		0
| Order: Ephemeroptera		0		0		0		0		0
| Family: Baetidae		0		0		0		0		0
Baetis sp.		0		0		0		0		0
Baetis tricaudatus group		0		0		0		0		0
| Family: Heptageniidae		0		0		0		0		0
Ironodes sp.		0		0		0		0		0
		0		0		0		0		0
| Order: Plecoptera		0		0		0		0	75	6
| Family: Nemouridae		0		0		0		0		0
Amphinemura sp.		0		0		0		0		0
		0		0		0		0		0
| Order: Trichoptera		0		0		0		0	25	0
| Family: Hydroptilidae		0		0		0		0		0
Agraylea sp.		0		0		0		0	25	13
Oxyethira sp.		0		0		0		0		0
| Family: Limnephilidae		10		0		0		0		0
Limnephilus sp.		0		40		0		7		0
		0		0		0		0		0
| Order: Coleoptera		0		0		0		0		0
| Family: Dytiscidae	2	0	3	20		20		0		6
Agabus sp.		0		0		0		0		0
Hygrotus sp.		0		0		0		0		0
		0		0		0		0		0
| Order: Diptera		0		0		0		0		0
| Family: Ceratopogonidae		0		0		0		0		0
Atrichopogon sp.		0		0		0		0		0
Bezzia sp.		0		0		0	15	0		0
Culicoides sp.		0		0		0		0		0
Mallochohelea		0		0		0		0		0

Site:	M3S	M3S	M3S	R2S	R2S	R2S	R2S	R2S	R6S1	R6S1
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 6	Rep 1	Rep 2
CC#:	CC130450	CC130451	CC130452	CC130453	CC130454	CC130455	CC130456	CC130457	CC130458	CC130459
Sphaeromias sp.		0		0		0		4		0
| Family: Chironomidae		0		0	4757	0		0		0
Orthocladiinae sp.		0		0		0		0		300
| Subfamily: Chironominae		0		0		0		0		169
| Tribe: Chironomini		0		0		0		0		0
Chironomus sp.	180	1125	90	0		0		4		0
Cryptochironomus sp.		0		0		0		0		0
Microtendipes pedellus		0		0		0		0		831
Phaenopsectra sp.		0		0		0		0		0
Polypedilum sp.		0		180		100	54	0		0
Stictochironomus sp.		0		0		0		0		0
| Tribe: Pseudochironomini		0		0		0		0		0
Pseudochironomus sp.		0		0		0		0		0
| Tribe: Tanytarsini		0		0		0		0		0
Cladotanytarsus sp.		0		0		0		0		0
Micropsectra sp.	127	375	1048	0		0		0		0
Paratanytarsus sp.	7	0		0		0		0	300	0
Tanytarsus sp.	90	175		7400	4757	7000	2038	1011	175	69
| Subfamily: Diamesinae		0		0		0		0		0
Protanypus		0		0		0		0		0
| Subfamily: Orthocladiinae		0		0		0		0		0
Brillia sp.		0		0		0		0		0
Diplocladius cultriger		0		0		0		0		0
Eukiefferiella sp.		0		0		0		0		0
Heleniella sp.		0		0		0		0		0
Heterotanytarsus sp.		0		0		0		0		0
Heterotrissocladius sp.		0		0		0		0		0
Limnophyes sp.	8	0		0		0	8	0		0
Metriocnemus sp.		0		0		0		0		0

Site:	M3S	M3S	M3S	R2S	R2S	R2S	R2S	R2S	R6S1	R6S1
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 6	Rep 1	Rep 2
CC#:	CC130450	CC130451	CC130452	CC130453	CC130454	CC130455	CC130456	CC130457	CC130458	CC130459
Orthocladius complex		0		0		0		0	563	0
Parakiefferiella sp.		0		0		0		0		125
Psectrocladius sp.		0		0		0		0		0
Zalutschia sp.		0		0		0		0		0
| **Tribe: Corynoneurini**		0		0		0		0		0
Corynoneura sp.	13	15	13	0		60		0	2313	344
| **Subfamily: Podonominae**		0		0		0		0		0
Trichotanypus sp.		0		0		0		0		0
| **Subfamily: Tanypodinae**		5		0		0		0		0
| **Tribe: Pentaneurini**		0		0		0		0		0
Ablabesmyia sp.		0		0		0		0		0
| **Tribe: Procladiini**		0		0		0		0		0
Procladius sp.		0		0		0		4		0
| **Family: Culicidae**		0		0		0		0		0
| **Family: Dixidae**		0		0		0		0		0
Dixella sp.	2	5		0		0		11		0
| **Family: Dolichopodidae**		0		0		0		0		0
Rhaphium sp.	1	0		0		0		0		0
| **Family: Empididae**		0		0		0		0		0
Clinocera sp.		0		0		0		0		0
| **Family: Muscidae**		0		0		0		0		0
Limnophora sp.		0		0		0		0	38	0
| **Family: Simuliidae**		0		0		20		4	176	13
Simulium sp.		0		0		280	8	0		0
| **Family: Tipulidae**		0		0		0		0		0
Erioptera sp.		0		0		0		0		0
Limnophila sp.		0		0		0		0		0
Tipula sp.		0		0		0		0		0

Site:	M3S	M3S	M3S	R2S	R2S	R2S	R2S	R2S	R6S1	R6S1
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 6	Rep 1	Rep 2
CC#:	CC130450	CC130451	CC130452	CC130453	CC130454	CC130455	CC130456	CC130457	CC130458	CC130459
| Order: Hemiptera		0		0		0		0		0
| Family: Corixidae		0	3	0		0		0		0
Sigara sp.		0		0		0		0		0
		0		0		0		0		0
| Order: Lepidoptera		0		0		0		0		0
		0		0		0		0		0
Subphylum: Crustacea		0		0		0		0		0
| Class: Malacostraca		0		0		0		0		0
| Order: Amphipoda		0		0		0		0		0
		0		0		0		0		0
Subphylum: Chelicerata		0		0		0		0		0
| Class: Arachnida		0		0		0		0		0
| Order: Trombidiformes	12	10	6	0		0		0		13
| Family: Hydryphantidae		0		0		0		0		0
| Family: Hygrobatidae		0		0		0		0		0
Hygrobates sp.		0		0		0		0	13	6
| Family: Lebertiidae		0		0		0		0		0
Lebertia sp.		0		0		0		0	13	13
| Family: Pionidae		0		0		0		0		0
Piona sp.		0		0		0		0		0
		0		0		0		0		0
| Order: Oribatei		0		0		0		0		0
| Family: Halacaridae		0		0		0		0		0
		0		0		0		0		0
| Order: Sarcoptiformes		0		0		0		0		0
| Family: Hydrozetidae	4	0		80	29	20	31	15	63	0
		0		0		0		0		0
Phylum: Mollusca		0		0		0		0		0
| Class: Bivalvia		0		0		0		0		0

Site:	M3S	M3S	M3S	R2S	R2S	R2S	R2S	R2S	R6S1	R6S1
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 6	Rep 1	Rep 2
CC#:	CC130450	CC130451	CC130452	CC130453	CC130454	CC130455	CC130456	CC130457	CC130458	CC130459
| Order: Veneroida		0		0		0		0		0
| Family: Pisidiidae		0		20		0		0		0
Pisidium sp.		0		0	14	0		0		0
Sphaerium sp.		0		0	14	0		0		0
		0		0		0		0		0
| Class: Gastropoda		0		0		0		0		0
| Order: Heterostropha		0		0		0		0		0
| Family: Valvatidae		0		0		0		0		0
		0		0		0		0		0
Phylum: Annelida		0		0		0		0		0
Subphylum: Clitellata		0		0		0		0		0
| Class: Oligochaeta		0		400		0		0		0
| Order: Lumbriculida		0		0		0		0		0
| Family: Lumbriculidae		5		0		0	8	0	13	6
		0		0		0		0		0
| Order: Tubificida		0		0		0		0		0
| Family: Enchytraeidae		0		0		0		0		0
Enchytraeus		0	6	20	14	0		0		0
| Family: Lumbricidae		0		0		0		0		0
| Family: Naididae		0		160	71	980	323	119	13	19
Chaetogaster diaphanus		0		0		0		0		0
Chaetogaster sp.		0		0		0		0		0
Nais sp.	2	0		80	43	0		0		13
Pristina sp.		0		0		0		0	25	0
Phylum: Cnidaria		0		0		0		0		0
| Class: Hydrozoa		0		0		0		0		0
| Order: Anthoathecatae		0		0		0		0		0
| Family: Hydridae		0		0		0		0		0
Hydra sp.		0		0		0		0	13	25
Phylum: Tardigrada		0		0	29	40	31	15	38	0

Site:	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 3	Rep 4	Rep 5	Rep 6
CC#:	CC130460	CC130461	CC130462	CC130463	CC130464	CC130465	CC130466	CC130467	CC130468
Phylum: Arthropoda		0		0		0		0	
Subphylum: Hexapoda		0		0		0		0	
| Class: Insecta		0		0		0		0	
| Order: Ephemeroptera		0		0		0		0	
| Family: Baetidae		0		0		0		0	
Baetis sp.		2		0		0	13	0	
Baetis tricaudatus group		0		0	2	0	18	13	
| Family: Heptageniidae		0		0		0		0	
Ironodes sp.		0	2	0		0		0	
		0		0		0		0	
| Order: Plecoptera	106	4	6	0	5	0		2	
| Family: Nemouridae		0	2	0		0		0	
Amphinemura sp.	17	0		11		0		0	
		0		0		0		0	
| Order: Trichoptera	111	4	12	129	2	0	3	0	
| Family: Hydroptilidae		0		0		0		0	
Agraylea sp.		0	3	0		0		0	
Oxyethira sp.	11	0		0		0		0	
| Family: Limnephilidae		0		0		0		0	1
Limnephilus sp.		0		0		0		0	
		0		0		0		0	
| Order: Coleoptera		0		0		0		0	
| Family: Dytiscidae		0		0		0		0	
Agabus sp.	6	0		4	1	0		0	
Hygrotus sp.		0		0		0		0	
		0		0		0		0	
| Order: Diptera		0		0		0		0	
| Family: Ceratopogonidae		0		0		0		0	
Atrichopogon sp.		0		0		0		0	
Bezzia sp.		0		11		2	10	3	2
Culicoides sp.		0		0		0		0	
Mallochohelea		0		0		0		0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 3	Rep 4	Rep 5	Rep 6
CC#:	CC130460	CC130461	CC130462	CC130463	CC130464	CC130465	CC130466	CC130467	CC130468
Sphaeromias sp.		0		0		0		0	
| Family: Chironomidae		0		0		0		0	
Orthocladiinae sp.		0		0		0		0	
| Subfamily: Chironominae		141		0		0		0	
| Tribe: Chironomini		0		0		0		0	
Chironomus sp.		0	51	0		30		0	
Cryptochironomus sp.		0		0		0		0	
Microtendipes pedellus	250	48	8	0		0		0	
Phaenopsectra sp.		0		0		0		0	
Polypedilum sp.		0		0		0		0	
Stictochironomus sp.		26		46	3	9		4	3
| Tribe: Pseudochironomini		0		0		0		0	
Pseudochironomus sp.		0		0		0		0	
| Tribe: Tanytarsini		0		0		0		0	
Cladotanytarsus sp.		0		0		0		0	
Micropsectra sp.		0		0	39	0	188	120	41
Paratanytarsus sp.		0		0		0		0	
Tanytarsus sp.	78	54	20	129		272	275	0	
| Subfamily: Diamesinae		0		0		0		0	
Protanypus		0		0		0		0	
| Subfamily: Orthocladiinae	167	54		0	180	0	50	20	
Brillia sp.		0		0		0		0	
Diplocladius cultriger		0		0		0		0	
Eukiefferiella sp.		0		0		0		0	
Heleniella sp.		0		0		0		0	
Heterotanytarsus sp.		0		0		25	13	3	7
Heterotrissocladius sp.		0		0		0		0	
Limnophyes sp.		0		0		0	3	0	
Metriocnemus sp.		0		0		2		0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 3	Rep 4	Rep 5	Rep 6
CC#:	CC130460	CC130461	CC130462	CC130463	CC130464	CC130465	CC130466	CC130467	CC130468
Orthocladius complex		0		0		0		0	
Parakiefferiella sp.		228		0	35	0		0	
Psectrocladius sp.		0		0		0		0	
Zalutschia sp.		0	208	536		0		85	15
| Tribe: Corynoneurini		0		0		0		0	
Corynoneura sp.	917	102	72	232	82	9	115	38	19
| Subfamily: Podonominae		0		0		0		0	
Trichotanypus sp.		0		0		0		0	
| Subfamily: Tanypodinae		13		0		0		0	
| Tribe: Pentaneurini		0		0		0		0	
Ablabesmyia sp.		0		0		0		0	
| Tribe: Procladiini		0		0		0		0	
Procladius sp.		0	2	0	11	28		0	
| Family: Culicidae		0		0		0		0	
| Family: Dixidae		0		0		0		0	
Dixella sp.		0		0		0		0	
| Family: Dolichopodidae		0		0		0		0	
Rhaphium sp.		0		0		0		0	
| Family: Empididae		0		0		0		0	
Clinocera sp.		0		4		0		0	
| Family: Muscidae		0		0		0		0	
Limnophora sp.	11	0		7		0		0	
| Family: Simuliidae	83	0	7	0		14		0	1
Simulium sp.		0	2	0		0		0	
| Family: Tipulidae		0		0		0		0	
Erioptera sp.		0		0		0		0	
Limnophila sp.		0		0		2		0	
Tipula sp.		0		4		0		0	
		0		0		0		0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 3	Rep 4	Rep 5	Rep 6
CC#:	CC130460	CC130461	CC130462	CC130463	CC130464	CC130465	CC130466	CC130467	CC130468
| Order: Hemiptera		0		0		0		0	
| Family: Corixidae		0		0		0		0	
Sigara sp.		0		0		0		0	
		0		0		0		0	
| Order: Lepidoptera		0		0		0		0	
		0		0		0		0	
Subphylum: Crustacea		0		0		0		0	
| Class: Malacostraca		0		0		0		0	
| Order: Amphipoda		0	2	0		0		0	
		0		0		0		0	
Subphylum: Chelicerata		0		0		0		0	
| Class: Arachnida		0		0		0		0	
| Order: Trombidiformes	6	15	8	7	3	4	13	3	2
| Family: Hydryphantidae		0		0	1	0		0	
| Family: Hygrobatidae		0		0		0		0	
Hygrobates sp.		0		0		0		0	
| Family: Lebertiidae		0		0		0		0	
Lebertia sp.	6	0		4	2	0	8	0	
| Family: Pionidae		0		0		0		0	
Piona sp.		0		21		0		0	
		0		0		0		0	
| Order: Oribatei		0		0		0		0	
| Family: Halacaridae		0	2	0		0		0	
		0		0		0		0	
| Order: Sarcoptiformes		0		0		0		0	
| Family: Hydrozetidae	89	2	5	18	14	12		1	
		0		0		0		0	
Phylum: Mollusca		0		0		0		0	
| Class: Bivalvia		0		0		0		0	

Site:	R6S1	R6S1	R6S1	R6S1	R6S2	R6S2	R6S2	R6S2	R6S2
Sample:	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 3	Rep 4	Rep 5	Rep 6
CC#:	CC130460	CC130461	CC130462	CC130463	CC130464	CC130465	CC130466	CC130467	CC130468
| Order: Veneroida		0		0		0		0	
| Family: Pisidiidae		0		0		0		0	
Pisidium sp.		0		4		0		0	
Sphaerium sp.		0		0		0		0	
		0		0		0		0	
| Class: Gastropoda		0		0		0		0	
| Order: Heterostropha		0		0		0		0	
| Family: Valvatidae		0		0		0		0	
		0		0		0		0	
Phylum: Annelida		0		0		0		0	
Subphylum: Clitellata		0		0		0		0	
| Class: Oligochaeta		0		0		0		0	
| Order: Lumbriculida		0		0		0		0	
| Family: Lumbriculidae		4		0		19	18	2	1
		0		0		0		0	
| Order: Tubificida		0		0		0		0	
| Family: Enchytraeidae		0		0		0		0	
Enchytraeus		2		0		0		0	
| Family: Lumbricidae		0		0		0		0	
| Family: Naididae		7	5	0	10	89	70	11	6
Chaetogaster diaphanus		0	2	0	1	0		0	
Chaetogaster sp.		0		0		0		0	
Nais sp.		2	2	0		0		0	
Pristina sp.		0	6	0		0		0	
Phylum: Cnidaria		0		0		0		0	
| Class: Hydrozoa		0		0		0		0	
| Order: Anthoathecatae		0		0		0		0	
| Family: Hydridae		0		0		0		0	
Hydra sp.		9	42	0	25	2	3	0	
Phylum: Tardigrada	11	0	9	4	7	7	3	3	1

Table A2-10. Raw 2013 macroinvertebrate data.

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 2	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC140071	CC140072	CC140073	CC140074	CC140075	CC140076	CC140077	CC140078	CC140079	CC140080	CC140081
Phylum: Arthropoda	0		0		0		0		0		0
Subphylum: Hexapoda	0		0		0		0		0		0
| Class: Insecta	0		0		0		0		0		0
| Order: Ephemeroptera	0		0		0		0		0		0
| Family: Baetidae	0		0		0		0		0		4
Baetis tricaudatus	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Plecoptera	0		0		0		0		0		0
| Family: Nemouridae	0		0		0		0		0		0
Amphinemura sp.	0		0		0		0		0		0
Zapada oregonensis group	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Trichoptera	0		0		0		0		0		0
| Family: Limnephilidae	0		0	2	0		0		0		4
Limnephilus sp.	0	3	1	4	0	10	1	2	0		4
| Family: Rhyacophilidae	0		0		0		0		0		0
Rhyacophila sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Coleoptera	0		0		0		0		0		0
| Family: Dytiscidae	0		0		0		0		0		0
Agabus sp.	0		0		0		0		3		0
| Subfamily: Hydroporinae	0	7	1	4	1	3	0	2	3		7
| Family: Gyrinidae	0		0		0		0		0		0
Dineutus sp.	0	1	0		0		0		0		0
| Family: Psephenidae	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 2	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC140071	CC140072	CC140073	CC140074	CC140075	CC140076	CC140077	CC140078	CC140079	CC140080	CC140081
| Order: Diptera	0		0		0		0		0		0
| Family: Ceratopogonidae	0		0		0		0		0		0
Atrichopogon sp.	0		0		0		0		0		0
Bezzia sp.	0	1	0	2	0		2	5	0		0
Dasyhelea sp.	0		1		0		1		0		0
Mallochohelea	0		0		0		0		0		0
| Family: Chironomidae	0		0		0		0		0		0
| Subfamily: Chironominae	0		0		0		0		0		0
| Tribe: Chironomini	0	95	38	46	0		0		103	12	0
Chironomus sp.	5	19	59		0		29	15	0	37	89
Cryptochironomus sp.	0		0		0		0	1	0		0
Endochironomus sp.	1		0		0		3		0		0
Glyptotendipes sp.	0		0		0		0		0		0
Microtendipes pedellus	0		0		0		12	15	0		0
Microtendipes sp.	0		0		0		0		0		0
Stictochironomus sp.	0		0		0		0		0		0
| Tribe: Tanytarsini	0		0		0		0		0		0
Cladotanytarsus sp.	0		0		0		0		0		0
Micropsectra sp.	4	45	45	80	18	93	20	145	155	95	543
Paratanytarsus sp.	0		0	30	0		0		0		0
Rheotanytarsus sp.	1		0		0		0		0		0
Stempellinella sp.	0		0		0		0		0		0
Tanytarsus sp.	0		0		0		0	11	93	24	107
| Subfamily: Diamesinae	0		0		0		0		0		0
Protanypus	0		0		0		0		0		0
| Tribe: Diamesini	0		0		0		0		0		0
Potthastia sp.	0		0		0		0		0		0
| Subfamily: Orthocladiinae	0		0		0	67	15		0		0
Cricotopus sp.	0		0		0		0		0		0
Eukiefferiella sp.	0		0		0		0		0		0
Heterotanytarsus sp.	0		0		0		0		0		0
Heterotrissocladius sp.	0	10	0	14	8	33	7	25	79	14	36
Limnophyes sp.	0		0		0		0		0		0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 2	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC140071	CC140072	CC140073	CC140074	CC140075	CC140076	CC140077	CC140078	CC140079	CC140080	CC140081
Nanocladius sp.	0		0		0		0		0		0
Orthocladius complex	0	55	0	24	10	150	0		0		0
Psectrocladius sp.	0		0	10	0		0	7	34		0
Pseudosmittia sp.	0		0		0		0		3		18
Tvetenia sp.	0		0		0		0		0		0
Zalutschia sp.	0		0		0		0		10		0
| Tribe: Corynoneurini	0		0		0		0		0		0
Corynoneura sp.	3	3	5	34	7	7	13	2	17	6	0
| Subfamily: Podonominae	0		0		0		0		0		0
| Tribe: Boreochlini	0		0		0		0		0		0
Boreochlus sp.	0		0		0		0		0		0
| Subfamily: Tanypodinae	0		0		0		0		0		0
| Tribe: Pentaneuriini	0		0		0		0	40	0		0
| Tribe: Pentaneurini	0		0		0		0		0		0
Ablabesmyia sp.	7	11	3	28	0	3	0		0		0
Nilotanypus sp.	0		0		0		0		0		0
| Tribe: Procladiini	0		0		0		0		0		0
Procladius sp.	0		0		0		0	3	0	8	29
| Family: Dixidae	0		0		0		0		0		0
| Family: Dolichopodidae	0		0		0		0		0		0
Rhaphium sp.	0		0		0		0		0		0
| Family: Empididae	1		0	2	0	3	0		0	1	0
Oreogeton sp.	0	7	0	2	2	3	0		0		0
| Family: Simuliidae	1	2	1		0	13	0		0		0
Simulium sp.	0		0	8	4		0	2	0		0
| Family: Tipulidae	0		0		0		0		0		0
Limnophila sp.	0		0		0		0		0		0
Tipula sp.	0		0		0		0		0		4

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 2	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC140071	CC140072	CC140073	CC140074	CC140075	CC140076	CC140077	CC140078	CC140079	CC140080	CC140081
| Order: Hemiptera	0		0		0		0		0		0
| Family: Corixidae	0	1	0		0		1		3		0
| Family: Gerridae	0		0		0		0		0		0
Gerris sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Lepidoptera	0		0		0		0		0		0
| Family: Noctuidae	0		0		0		0		0		0
	0		0		0		0		0		0
Subphylum: Chelicerata	0		0		0		0		0		0
| Class: Arachnida	0		0		0		0		0		0
| Order: Trombidiformes	1	3	0	6	1		2	2	0		0
| Family: Arrenuridae	0		0		0		0		0		0
Arrenurus sp.	0		0		0		0		0		0
| Family: Lebertiidae	0		0		0		0		0		0
Lebertia sp.	0		0		0		0	1	3		0
| Family: Limnocharidae	0		0		0		0		0		0
Limnochares sp.	0		0		0		0		0		0
| Family: Mideopsidae	0		0		0		0		0		0
Mideopsis sp.	0		0		0		0		0		0
| Family: Unionicolidae	0		0		0		0		0		0
Neumania sp.	0		0		0		0		0		0
	0		0		0		0		0		0
| Order: Oribatei	0		0		0		0		0		0
| Family: Halacaridae	0		0		0		0	1	0		0
	0		0		0		0		0		0
| Order: Sarcoptiformes	0		0		0		0		0		0
| Family: Hydrozetidae	0	9	7	10	0	10	5	3	0	1	0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 2	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC140071	CC140072	CC140073	CC140074	CC140075	CC140076	CC140077	CC140078	CC140079	CC140080	CC140081
Phylum: Mollusca	0		0		0		0		0		0
| Class: Bivalvia	0		0		0		0		0		0
| Order: Veneroida	0		0		0		0		0		0
| Family: Pisidiidae	0		0		0		0		0		0
Pisidium sp.	0		0		0		0		0		0
	0		0		0		0		0		0
Phylum: Annelida	0		0		0		0		0		0
Subphylum: Clitellata	0		0		0		0		0		0
| Class: Oligochaeta	0		0		0		0		0		0
| Order: Lumbriculida	0		0		0		0		0		0
| Family: Lumbriculidae	0		0		2	10	0	2	0		0
	0		0		0		0		0		0
| Order: Tubificida	0		0		0		0		0		0
| Family: Enchytraeidae	0		0		0		0		0		0
Enchytraeus	1	2	1		1		0		0		0
| Family: Lumbricidae	0		0		0		0		0		0
| Family: Naididae	0	28	0		0	83	0	16	0		0
Chaetogaster sp.	2	23	1		0		0		3	14	11
Nais sp.	25	121	38	340	8	250	17	5	590	29	346
| Family: Tubificidae	0		0		0		0		0		0
| Subfamily: Tubificinae imma	0	2	0		59	117	4	18	0	1	0
	0		0		0		0		0		0
Phylum: Cnidaria	0		0		0		0		0		0
| Class: Hydrozoa	0		0		0		0		0		0
| Order: Anthoathecatae	0		0		0		0		0		0
| Family: Hydridae	0		0		0		0		0		0
Hydra sp.	0		0	2	0	3	0	2	0		0
	0		0		0		0		0		0
Phylum: Tardigrada	0		0		1		1		0		0

Site:	M1S	M1S	M1S	M1S	M1S	M1S	M2S	M2S	M3S	M3S	M3S
Sample:	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 2	Rep 4	Rep 1	Rep 2	Rep 3
CC#:	CC140071	CC140072	CC140073	CC140074	CC140075	CC140076	CC140077	CC140078	CC140079	CC140080	CC140081
Phylum: Arthropoda	0		0		0		0		0		0
| Class: Entognatha	0		0		0		0		0		0
| Order: Collembola	0		1		1		1		0		0
	0		0		0		0		0		0
Subphylum: Crustacea	0		0		0		0		0		0
| Class: Ostracoda	1	1	1	2	0	3	1		0		4
| Class: Branchiopoda	0		0		0		0		0		0
| Order: Cladocera	0		0		0		0		0		0
| Family: Daphniidae	0		0		0		0		0		0
Daphnia sp.	1	1	1		1	3	1	1	3	1	4
	0		0		0		0		0		0
| Class: Copepoda	1	1	1	2	1	3	1	1	3	1	4
	0		0		0		0		0		0
Phylum: Nemata	0		1	2	1	3	1	1	3	1	0
Phylum: Platyhelminthes	0		0		0		0		0		0
| Class: Turbellaria	0		0		0		0		0		0

Site:	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1
CC#:	CC140082	CC140083	CC140084	CC140065	CC140066	CC140067	CC140068	CC140069	CC140070	CC140085
Phylum: Arthropoda		0		0		0		0		0
Subphylum: Hexapoda		0		0		0		0		0
| Class: Insecta		0		0		0		0		0
| Order: Ephemeroptera		0		0		0		0		0
| Family: Baetidae		9		0		0		0		0
Baetis tricaudatus		0		0		0		0		0
		0		0		0		0		0
| Order: Plecoptera		0		0		0		0		0
| Family: Nemouridae		0		0		0		0		0
Amphinemura sp.		0		0		0		0		0
Zapada oregonensis group		0		0		0		0		0
		0		0		0		0		0
| Order: Trichoptera		0		0		0		0		0
| Family: Limnephilidae		0	8	0		14		12	2	0
Limnephilus sp.		0		0		0	4	0		0
| Family: Rhyacophilidae		0		0		0		0		0
Rhyacophila sp.		0		9		0		0		0
		0		0		0		0		0
| Order: Coleoptera		0		0		0		0		0
| Family: Dytiscidae		0		0		0		0		0
Agabus sp.		0		0		0		0	1	0
| Subfamily: Hydroporinae		0		0	7	0		0		0
| Family: Gyrinidae		0		0		0		0		0
Dineutus sp.		0		0		0		0		0
| Family: Psephenidae		0		0		0		0		0

Site:	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1
CC#:	CC140082	CC140083	CC140084	CC140065	CC140066	CC140067	CC140068	CC140069	CC140070	CC140085
| Order: Diptera		0		0		0		0		0
| Family: Ceratopogonidae		0		0		0		0		0
Atrichopogon sp.		0		0		0		0		0
Bezzia sp.		0		9	17	7	16	6	2	8
Dasyhelea sp.		0		0	3	0		0	2	0
Mallochohelea		0		0		0		0		0
| Family: Chironomidae		0		0		0		0		0
| Subfamily: Chironominae		0		0		0		0		0
| Tribe: Chironomini	292	0		0		0	216	206	40	176
Chironomus sp.	25	136	12	0	10	0		35		0
Cryptochironomus sp.		0		0		0		0		0
Endochironomus sp.		0		0		0		0		0
Glyptotendipes sp.		0	100	0		0		0		0
Microtendipes pedellus		0		45	533	164	204	335		0
Microtendipes sp.		0		0		0		0		0
Stictochironomus sp.		0		0		0	12	0		0
| Tribe: Tanytarsini		0		0		0		0		0
Cladotanytarsus sp.		0		0		0	16	0		0
Micropsectra sp.	1583	2273	758	0	433	0	228	382	65	149
Paratanytarsus sp.		91	69	9		0		0		0
Rheotanytarsus sp.		0		0		0		0		0
Stempellinella sp.	42	0		0		0		0		0
Tanytarsus sp.	208	364	173	0	37	0	140	188	24	59
| Subfamily: Diamesinae		0		0		0		0		0
Protanypus		0		0		0		0		3
| Tribe: Diamesini		0		0		0		0		0
Potthastia sp.		0		0		0		0		0
| Subfamily: Orthocladiinae		0		0		464	140	0	185	284
Cricotopus sp.		0		255		0		241		0
Eukiefferiella sp.		0		0		0		0		0
Heterotanytarsus sp.		0		0		0		0	5	8
Heterotrissocladius sp.	83	0		0		0		0		41
Limnophyes sp.		0		9		0		0		0

Site:	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1
CC#:	CC140082	CC140083	CC140084	CC140065	CC140066	CC140067	CC140068	CC140069	CC140070	CC140085
Nanocladius sp.		0		0		0		0		0
Orthocladius complex	58	0		0		0		0		0
Psectrocladius sp.	58	0	23	55	133	50		0		0
Pseudosmittia sp.	100	0	19	0		0		0		0
Tvetenia sp.		0		0		0		0		0
Zalutschia sp.		0		82		0	160	312	30	0
| Tribe: Corynoneurini		0		0		0		0		0
Corynoneura sp.	67	0		145		86	32	53	17	8
| Subfamily: Podonominae		0		0		0		0		0
| Tribe: Boreochlini		0		0		0		0		0
Boreochlus sp.		0		0		0		0		0
| Subfamily: Tanypodinae		0		0		0		0		0
| Tribe: Pentaneuriini		0		0		0		0		0
| Tribe: Pentaneurini		0		0		0		0		0
Ablabesmyia sp.		0		0	13	0	4	12	2	0
Nilotanypus sp.		0		0		0		0		0
| Tribe: Procladiini		0		0		0		0		0
Procladius sp.	117	0	12	0		0		0	1	8
| Family: Dixidae		0		0		7		0		0
| Family: Dolichopodidae		0		0		0		0		0
Rhaphium sp.		0		0		0		0		0
| Family: Empididae		18	8	0		0		0		0
Oreogeton sp.		0		0	3	0	12	6	1	0
| Family: Simuliidae		0		1609		1036		0	13	19
Simulium sp.		0		1100	17	186		0	16	0
| Family: Tipulidae	33	0		0		0		0		0
Limnophila sp.		0		0		0		0		0
Tipula sp.		0		0		0		0		0

Site:	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1
CC#:	CC140082	CC140083	CC140084	CC140065	CC140066	CC140067	CC140068	CC140069	CC140070	CC140085
| Order: Hemiptera		0		0		0		0		0
| Family: Corixidae	8	0		0		0		0		0
| Family: Gerridae		0		0		0		0		0
Gerris sp.		0		0		0		0		0
		0		0		0		0		0
| Order: Lepidoptera		0		0		0		0		0
| Family: Noctuidae		0		0		0		0		0
		0		0		0		0		0
Subphylum: Chelicerata		0		0		0		0		0
| Class: Arachnida		0		0		0		0		0
| Order: Trombidiformes		0		0	3	0	16	0	1	5
| Family: Arrenuridae		0		0		0		0		0
Arrenurus sp.		0		0		0		0	1	0
| Family: Lebertiidae		0		0		0		0		0
Lebertia sp.		0		18		0		0	1	0
| Family: Limnocharidae		0		0		0		0		0
Limnochares sp.		0		0		0		0		0
| Family: Mideopsidae		0		0		0		0		0
Mideopsis sp.		0		0		0		0	1	0
| Family: Unionicolidae		0	4	0		0		0		0
Neumania sp.		0		0		0		0		3
		0		0		0		0		0
| Order: Oribatei		0		0		0		0		0
| Family: Halacaridae		0		0	3	0		0	1	0
		0		0		0		0		0
| Order: Sarcoptiformes		0		0		0		0		0
| Family: Hydrozetidae		0		27	73	129	28	59	16	24

Site:	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1
CC#:	CC140082	CC140083	CC140084	CC140065	CC140066	CC140067	CC140068	CC140069	CC140070	CC140085
Phylum: Mollusca		0		0		0		0		0
| Class: Bivalvia		0		0		0		0		0
| Order: Veneroida		0		0		0		0		0
| Family: Pisidiidae		0		0		0		0		0
Pisidium sp.		0		0	7	0		0	3	0
		0		0		0		0		0
Phylum: Annelida		0		0		0		0		0
Subphylum: Clitellata		0		0		0		0		0
| Class: Oligochaeta		0		0		0		0		0
| Order: Lumbriculida		0		0		0		0		0
| Family: Lumbriculidae		0		0		0		0		0
		0		0		0		0		0
| Order: Tubificida		0		0		0		0		0
| Family: Enchytraeidae		0		0		0		0		0
Enchytraeus		9		0		21	4	6	15	3
| Family: Lumbricidae		0		0		0		0		0
| Family: Naididae	108	0		0		0		0		0
Chaetogaster sp.		0		9	7	0		0		0
Nais sp.	67	18	54	36	3	57		0	10	11
| Family: Tubificidae		0		0		0		0		0
| Subfamily: Tubificinae imma		0		9	30	57	20	18	13	24
		0		0		0		0		0
Phylum: Cnidaria		0		0		0		0		0
| Class: Hydrozoa		0		0		0		0		0
| Order: Anthoathecatae		0		0		0		0		0
| Family: Hydridae		0		0		0		0		0
Hydra sp.		0		0		0	8	0	1	24
		0		0		0		0		0
Phylum: Tardigrada		0		0		0	20	0	8	0

Site:	M3S	M3S	M3S	R6S1	R6S1	R6S1	R6S1	R6S1	R6S1	R6S2
Sample:	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1
CC#:	CC140082	CC140083	CC140084	CC140065	CC140066	CC140067	CC140068	CC140069	CC140070	CC140085
Phylum: Arthropoda		0		0		0		0		0
| Class: Entognatha		0		0		0		0		0
| Order: Collembola	8	0		0		0		0	1	0
		0		0		0		0		0
Subphylum: Crustacea		0		0		0		0		0
| Class: Ostracoda		9	4	9		7		6	1	3
| Class: Branchiopoda		0		0		0		0		0
| Order: Cladocera		0		0		0		0		0
| Family: Daphniidae		0		0		0		0		0
Daphnia sp.		0	4	0	3	7	4	6	1	0
		0		0		0		0		0
| Class: Copepoda	8	9	4	9	3	7	4	6	1	3
		0		0		0		0		0
Phylum: Nemata	8	9	4	9	3	0		6	1	3
Phylum: Platyhelminthes		0		0		0		0		0
| Class: Turbellaria		0		0		0		0		0

Site:	R6S2	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4
CC#:	CC140086	CC140087	CC140088	CC140089	CC140090	CC140091	CC140092	CC140093	CC140094
Phylum: Arthropoda		0		0		0		0	
Subphylum: Hexapoda		0		0		0		0	
| Class: Insecta		0		0		0		0	
| Order: Ephemeroptera		0		0		0		0	
| Family: Baetidae		0		0		0		0	
Baetis tricaudatus		0	31	15	1	0		0	
		0		0		0		0	
| Order: Plecoptera		0		0		0		0	
| Family: Nemouridae		0		0		0		0	
Amphinemura sp.		0		2		0		0	
Zapada oregonensis group		0		0		0		0	
		0		0		0		0	
| Order: Trichoptera		0		0		0		0	
| Family: Limnephilidae		0		0		0		0	
Limnephilus sp.		0		0	1	0		1	
| Family: Rhyacophilidae		0		0		0		0	
Rhyacophila sp.		0		0		0		0	
		0		0		0		0	
| Order: Coleoptera		0		0		0		0	
| Family: Dytiscidae		0		0		0		0	
Agabus sp.		0		0		0		0	
| Subfamily: Hydroporinae		0		0		0	2	4	
| Family: Gyrinidae		0		0		0		0	
Dineutus sp.		0		0		0		0	
| Family: Psephenidae		0		1		0		0	

Site:	R6S2	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4
CC#:	CC140086	CC140087	CC140088	CC140089	CC140090	CC140091	CC140092	CC140093	CC140094
| Order: Diptera	1	0	4	0	1	0		4	
| Family: Ceratopogonidae		0		0		0		0	
Atrichopogon sp.	1	0		0		0		0	
Bezzia sp.		39	40	5	11	0		0	
Dasyhelea sp.		0		0		0		0	
Mallochohelea		0		0		0		0	
| Family: Chironomidae		0		0		0	3	1	14
| Subfamily: Chironominae		0		0		20		0	
| Tribe: Chironomini	95	24	15	13		0		0	
Chironomus sp.		0		0		14	14	8	29
Cryptochironomus sp.		0		0		0		0	
Endochironomus sp.		0		0		0		0	
Glyptotendipes sp.		0		0		0		0	
Microtendipes pedellus		0		0		0		0	
Microtendipes sp.		0		0		0		0	
Stictochironomus sp.	15	12	15	0		0		0	
| Tribe: Tanytarsini		0		0		0		0	
Cladotanytarsus sp.		0		0		0		0	
Micropsectra sp.	35	0	45	62	93	1		0	79
Paratanytarsus sp.		0		0		0		0	
Rheotanytarsus sp.		0		0		0		0	
Stempellinella sp.		0		0		0		0	
Tanytarsus sp.	25	0	21	0	32	13	402	426	2193
| Subfamily: Diamesinae		0		0		0		0	
Protanypus		0		0		0		0	
| Tribe: Diamesini		0		0		0		0	
Potthastia sp.		0		0		0	1	0	
| Subfamily: Orthocladiinae	115	40	38	0		0		78	
Cricotopus sp.		0		0		0		0	
Eukiefferiella sp.	1	0		34		0		0	
Heterotanytarsus sp.		0		0		0		0	
Heterotrissocladius sp.		0		5	12	0		0	7
Limnophyes sp.	2	0		0		0		0	

Site:	R6S2	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4
CC#:	CC140086	CC140087	CC140088	CC140089	CC140090	CC140091	CC140092	CC140093	CC140094
Nanocladius sp.		0		2		0		0	
Orthocladius complex		0		0		2	6	2	
Psectrocladius sp.		25	26	5	18	0		0	
Pseudosmittia sp.		0		0		0		0	
Tvetenia sp.		0		0		0		0	
Zalutschia sp.	55	0		29	22	0		0	
| Tribe: Corynoneurini		0		0		0		0	
Corynoneura sp.		0	21	3		1		0	
| Subfamily: Podonominae		0		0		0		0	
| Tribe: Boreochlini		0		0		0		0	
Boreochlus sp.		0		0		0		0	
| Subfamily: Tanypodinae		0		0		0		0	
| Tribe: Pentaneuriini		0		0		0		0	
| Tribe: Pentaneurini		0		0		0		0	
Ablabesmyia sp.		0		0		0		2	
Nilotanypus sp.		0		0		0		0	
| Tribe: Procladiini		0		0		0		0	
Procladius sp.	85	37	2	0	3	0	1	0	
| Family: Dixidae		0		0		0		0	
| Family: Dolichopodidae		0		0		0		0	
Rhaphium sp.		0		0	1	0		0	
| Family: Empididae		0		3	1	0	1	0	
Oreogeton sp.		0		0		0		0	
| Family: Simuliidae		0	1	0	1	2		1	14
Simulium sp.		0		25	3	0		0	
| Family: Tipulidae		0		1		0		0	
Limnophila sp.		0		0		0		0	
Tipula sp.	1	0		0		0		0	

Site:	R6S2	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4
CC#:	CC140086	CC140087	CC140088	CC140089	CC140090	CC140091	CC140092	CC140093	CC140094
| Order: Hemiptera		0		0		0		0	
| Family: Corixidae		0		0		0		0	
| Family: Gerridae		0		0		0		0	
Gerris sp.		0		0		1		0	
		0		0		0		0	
| Order: Lepidoptera		0		0		0		0	
| Family: Noctuidae		0		1		0		0	
		0		0		0		0	
Subphylum: Chelicerata		0		0		0		0	
| Class: Arachnida		0		0		0		0	
| Order: Trombidiformes		3	2	2		2	1	0	
| Family: Arrenuridae		0		0		0		0	
Arrenurus sp.		0		0		0		0	
| Family: Lebertiidae		0		0		0		0	
Lebertia sp.		1	18	1	1	0		0	
| Family: Limnocharidae		0		0		0		0	
Limnochares sp.		0		0		0		0	
| Family: Mideopsidae		0		0		0		0	
Mideopsis sp.		0		0		0		0	
| Family: Unionicolidae		0		0		0		0	
Neumania sp.		0		1		0		0	
		0		0		0		0	
| Order: Oribatei		0		0		0		0	
| Family: Halacaridae		0		0		0		0	
		0		0		0		0	
| Order: Sarcoptiformes		0		0		0		0	
| Family: Hydrozetidae	9	3	2	1	4	10	5	31	14

Site:	R6S2	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4
CC#:	CC140086	CC140087	CC140088	CC140089	CC140090	CC140091	CC140092	CC140093	CC140094
Phylum: Mollusca		0		0		0		0	
| Class: Bivalvia		0		0		0		0	
| Order: Veneroida		0		0		0		0	
| Family: Pisidiidae		0		0		0	6	0	
Pisidium sp.		0		0		0		0	
		0		0		0		0	
Phylum: Annelida		0		0		0		0	
Subphylum: Clitellata		0		0		0		0	
| Class: Oligochaeta		0		0		0		0	
| Order: Lumbriculida		0		0		0		0	
| Family: Lumbriculidae		11		5	2	2		2	
		0		0		0		0	
| Order: Tubificida		0		0		0		0	
| Family: Enchytraeidae		0		0		0		0	
Enchytraeus		0		0		0		3	
| Family: Lumbricidae		0	3	0	1	0		0	
| Family: Naididae		0		0		0		60	14
Chaetogaster sp.		0		0		0		0	
Nais sp.		7		2		1	11	5	14
| Family: Tubificidae		0		0		0		0	
| Subfamily: Tubificinae imma	79	46	58	32	20	10		0	
		0		0		0		0	
Phylum: Cnidaria		0		0		0		0	
| Class: Hydrozoa		0		0		0		0	
| Order: Anthoathecatae		0		0		0		0	
| Family: Hydridae		0		0		0		0	
Hydra sp.	15	25		0		0		0	
		0		0		0		0	
Phylum: Tardigrada	7	9		0	3	2		1	

Site:	R6S2	R6S2	R6S2	R6S2	R6S2	R2S	R2S	R2S	R2S
Sample:	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 1	Rep 2	Rep 3	Rep 4
CC#:	CC140086	CC140087	CC140088	CC140089	CC140090	CC140091	CC140092	CC140093	CC140094
Phylum: Arthropoda		0		0		0		0	
| Class: Entognatha		0		0		0		0	
| Order: Collembola		0	1	1		0		0	
		0		0		0		0	
Subphylum: Crustacea		0		0		0		0	
| Class: Ostracoda	1	1	1	1	1	1	1	1	7
| Class: Branchiopoda		0		0		0		0	
| Order: Cladocera		0		0		0		0	
| Family: Daphniidae		0		0		0		0	
Daphnia sp.	1	1	1	0	1	0		1	
		0		0		0		0	
| Class: Copepoda	1	1	1	1	1	1	1	1	7
		0		0		0		0	
Phylum: Nemata		1	1	0	1	1	1	1	7
Phylum: Platyhelminthes		0		0		0		0	
| Class: Turbellaria		0		0		0		0	7