University of Alberta

The Impact of Low Dissolved Oxygen and Recovery Patterns of Benthos in Northern Rivers

by

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A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Science
in
Environmental Science

Department of Civil and Environmental Engineering

Fall 2012
Edmonton, Alberta

ABSTRACT

An ecological risk assessment for the Athabasca River was done. We did a review of literature pertaining to ecological risk assessment in the Athabasca River. The focus of the risk assessment was on the ecological impact of low dissolved oxygen (DO), because mainly ice-cover and pulp mill effluent discharges on the Athabasca River may potentially cause a low DO event. The ecological impact of low DO was assessed for the benthic invertebrate community, specifically the Orders Ephemeroptera, Plecoptera and Trichoptera (EPT), which are sensitive to low DO, and the Order Diptera. Based on the literature review, an ecological risk assessment involved: 1) using electroshocking to simulate low DO in the Athabasca River and determining recovery of benthic invertebrates following electroshocking and ice-out; 2) using a laboratory flume to determine the relationship between DO level and benthic invertebrate drift rate.

ACKNOWLEDGEMENTS

I would like to thank P McEachern and M Spafford for help with the experimental procedure and field sampling for Chapter 2, and P McEachern and T Yu for providing research papers, figures and presentations and helping with the revision of this manuscript. I would like to acknowledge D Zhu for the use of the hydraulics laboratory, P Fedun for setting up the flume and technical assistance in the hydraulics laboratory, and N Gutierrez for help with the experimental procedure for Chapter 3. I would like to thank N Serediak and B Saunders for sorting and identifying the benthic invertebrate samples. I would like to thank Natural Sciences and Engineering Research Council of Canada (NSERC), Alberta Environment, Alberta Pacific Forest Industries Inc. (ALPAC), Alberta Newsprint Co., Hinton Pulp, Millar Western Forest Products Ltd. and Slave Lake Pulp for funding the research.

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CHAPTER 1

THE IMPACT OF LOW DISSOLVED OXYGEN AND RECOVERY PATTERNS OF BENTHOS IN NORTHERN RIVERS: PROJECT BACKGROUND AND LITERATURE REVIEW

INTRODUCTION

The major sources of dissolved oxygen (DO) in the Athabasca River are re-aeration from the atmosphere and photosynthetic activity of plants; the major sinks are the biological oxidation of organic material and chemical oxidation of reduced metals and ammonium. Ice-cover prevents re-aeration and limits light penetration of the Athabasca River (Chambers et al. 2000b), and dissolved oxygen concentrations subsequently decline through the winter period. The current Alberta water quality guideline requires the maintenance of 6.5 mg/L DO or greater (chronic) in order to protect sensitive aquatic biota (Lowell and Culp 1999). The guideline was established based on mesocosm studies showing impacts to *Baetis* species and to mountain whitefish eggs at a concentration of 5 mg/L (Chambers et al. 2006). The guideline was derived from this, combined with a likely differential of approximately 1 mg/L between the water column and the sediments where impacts would occur. The guideline ensures a very low risk of impact, however the Athabasca River has seen conditions where DO concentrations remained below the chronic guideline. DO concentrations for the period of 1989-2003 showed a decline along the Athabasca River and a decline upstream of Grand Rapids throughout the winter period (Alberta Environment 2004). Minimum DO values (~8 mg/L) were reached at Grand Rapids in mid to late February during 1989-2003. The lowest DO levels in 1989-2003 occurred in February and March of 2003 when DO concentrations fell below the 6.5 mg/L guideline (~5.8 mg/L) for over a month (Alberta Environment 2004). DO concentration fell below the 6.5 mg/L guideline only twice for the period of 1989-2003. In 2002 DO fell below the chronic guideline for three consecutive days and in 2003 DO fell below the chronic guideline for 42 consecutive days (Alberta Environment 2004). This led to concern about the ecological impact of a low DO event in late winter, addressed in this study. As low dissolved oxygen concentrations occur infrequently and for short periods, there is a need for further research on the ecological impacts of low DO, the resilience of benthic invertebrate communities to these events and the rate of recovery likely to occur following return to concentrations above the guideline. The impact on the benthic invertebrate community below the guideline and over the entire DO scale will be determined, to have a better understanding of the mechanism of the impact of a low DO event on the benthic invertebrate community.

This study will utilize electroshocking to simulate low DO conditions to determine the effect of low DO on benthic invertebrate abundance and percent reference (abundance at the electroshocking site / abundance at the reference site X 100 %). The recovery time and pattern of benthic invertebrates following a low DO event will also be determined.

Ice-cover usually develops on the Athabasca River in November. The ice-cover is open for sections downstream of pulp mill and sewage discharges and at the water rapids at Grand Rapids (Fig. 1-1). The open rapids at Grand Rapids are a natural reaeration zone. Average ice-cover is 1 m thick in January with up to 1 m of snow on top (Chambers et al. 2000b). Ice-out of the Athabasca River occurs in late March. During ice-out, river discharge increases from an average about

130 m^3/s to as much as 4000 m^3/s (Ft. McMurray gauge). Ice breakup is exceedingly dynamic with large ice sheets and pans scouring the banks and bed of the river. Ice-out likely has a large ecological impact on the benthic invertebrate community with increased mortality and drift rate, and changes to total abundance and number of taxa similar to the impacts of anthropogenic activities. There is limited research on the effect of ice-out on the benthic invertebrate communities, and this will be addressed in this study.

The operating hypothesis examined in this research follows from the established pattern that benthic community indicators (mortality, total abundance, EPT abundance, total number of taxa, or number of EPT taxa) decline in response to stressors be they chemical (pollution, low DO) or physical (high flow, ice scour). I further hypothesize that recovery from a late winter low DO event may occur prior to ice-out and therefore have no lasting impact or the low DO and ice-out events may overlap and have an additive impact. If additive, this could have lasting ecological significance in the system through summer months. Figure 1-2 is a pictorial representation of the hypothetical trajectory for benthic invertebrate response following low DO and ice-out. It shows that if there is adequate DO in the late winter months (>6.5 mg/L), the only effect on the benthic parameter is the ice-out period. Figure 1-2 also shows potentially what could happen if a low DO event occurred before ice-out. If there is low DO during the late winter months, the recovery pattern following the low DO event may be a fast recovery that does not combine with ice-out, or a slow recovery that combines with the ice-out period to cause cumulative stress on the benthic invertebrate community.

Addressing this question determines the urgency and extent of management response to a low DO event.

The following is a review of the literature pertaining to ecological risk assessment in ice-covered rivers, specifically the Athabasca River. This review of the literature will develop an understanding of ecological impacts of low DO and pulp mill effluents, parameters of measurement for ecological risk assessment and use of different bioindicators for ecological risk assessment. Also there is an assessment of different methods of inducing low DO conditions. Reviewing these issues will allow the development of specific problems that require further study in the ecological risk assessment of the Athabasca River.

LITERATURE REVIEW

Nutrient loading increases primary production and the resulting increase in plant growth accentuates diel swings in DO (increased daytime oxygen production from photosynthesis and night-time oxygen consumption from respiration). However, primary production mainly increases sediment oxygen demand (SOD) due to bacterial decomposition of dead plant material. Algal and plant biomass effect DO levels in a river, but the environmental stress caused by nutrient loading and increased primary production occurs further up the aquatic food web. The increased primary production causes increased food availability for secondary producers but lower DO levels that cause stress for primary and secondary consumers (Chambers et al. 1997). It is better to measure environmental stress on primary and secondary consumers to manage ecological risk in the Athabasca River for this study.

DO in ice-covered rivers decreases along the length of the Athabasca River and throughout the winter months, due to lack of re-aeration from ice-cover and increased SOD from pulp mill and sewage effluent. Low DO levels (<6.5 mg/L) cause stress for higher trophic levels of the aquatic food web, specifically for different fish species. Many studies have been done in the Athabasca River and other rivers in northern Alberta to show the effects of low DO on different fish species. Barton and Taylor (1996) grouped fish species in northern Alberta rivers into four categories based on their acute tolerance to DO (the minimum DO concentration causing mortality): 1) sensitive (acute limit >2 mg/L DO; includes all salmonids, longnose sucker (*Catostomus catostomus*) and burbot (*Lota lota*)); 2) intermediate (acute limit 1-2 mg/L DO; includes walleye (*Stizostedion vitreum*), white sucker (*Catostomus commersoni*), brook stickleback, goldeye (*Hiodon alosoides*) and cyprinids except fathead minnow (*Platygobio gracilis*)); (3) tolerant (acute limit <1 mg/L DO; includes fathead minnow, northern pike (*Esox lucius*) and yellow perch); and (4) unknown (insufficient information available; includes largescale sucker, ninespine stickleback, all sculpins, trout-perch). Chambers et al. (2000b) did a study to test the previous DO guideline of 5 mg/L on larval development of fall (mountain whitefish, *Prosopium williamsoni*, and bull trout, *Salvelinus confluentus*) and winter (burbot, *Lota lota*) spawning fish species common in Northern Alberta rivers. Mountain whitefish eggs incubated at 6.5 mg/L DO, took much longer to hatch than eggs incubated at higher DO concentrations. Bull trout alevins hatched at 5.0 mg/L DO were smaller and less likely to survive. Burbot at 6.0 mg/L DO experienced extended spawning up to five weeks. These results led the government of Alberta to adopt a DO guideline of 6.5 mg/L to protect adult fishes, and a DO guideline of 9.5 mg/L during spring weeks to protect early life stages (fish eggs and alevins) (Alberta Environment 1999).

The nutrient-enhanced food supply from nutrient loading has a positive effect on piscivores fish. Spoonhead sculpin (*Cottus ricei*) downstream of the Hinton pulp mill and longnose sucker (*Catastomus catastomus*) downstream of the Wapiti River pulp mill responded to the nutrient-enhanced food supply with increased energy storage measured as elevated condition factors, increased liver size and fat storage (Swanson et al. 1994; Gibbons et al. 1998).

Low DO negatively affects several parameters, but nutrient loading positively affects some parameters for benthic invertebrates. Lowell and Culp (1999) exposed mayflies (*Baetis tricaudatus* Dodds) to one of two DO levels (5 mg/L or 11 mg/L), in the presence and absence of mixed effluent (pulp mill and sewage). In the presence of low DO, grazing (for food) intensity was reduced by 80 % and after two weeks of exposure survival was reduced by 60-90 %. The low DO treatment changed the positioning of mayflies in the stream with a 250-350 % greater proportion of mayflies moving into regions of higher current velocity. The negative effect of low DO is countered by the positive effect of nutrient enrichment from pulp mill effluent on invertebrate grazing and survival. The 1 %

effluent treatment slightly stimulated grazing intensity. The effluent may have increased feeding rate, increased the nutritive value of the periphyton, and/or stimulated growth hormones via compounds in the pulp mill effluent (Lowell and Culp 1999). But this effect was non-significant and did not compensate for the large decrease in grazing intensity due to the low DO treatment (Lowell and Culp 1999), therefore there is an overall negative effect on benthic invertebrate grazing and survival due to low DO. The low DO causes chronic stress on oxygen delivery to the gills and reduced food intake by benthic invertebrates. These factors lead to increased mortality of benthic invertebrates (Lowell and Culp 1999). Mortality gradually and continuously increased in the low DO treatment indicating a chronic response. The previous Alberta guideline for the protection of aquatic life in northern rivers was 5 mg/L. The study by Lowell and Culp (1999) and several others that were part of the Northern Rivers Basin Study recommended modifying the DO guideline for the protection of aquatic cold-water species to 6.5 mg/L. Although the 5 mg/L DO guideline is sufficient to prevent acute mortality, chronic stress is caused at 6.5 mg/L DO. Due to these studies the government of Alberta in 1997 adopted the Canadian Council of Resource and Environment Ministers DO chronic guideline of a 7-d mean of 6.5 mg/L for the protection of aquatic life in northern rivers (Lowell and Culp 1999).

Alberta Environment (2004) sampled benthic invertebrates upstream and downstream of Grand Rapids, to determine the effects of low DO on benthic invertebrate communities. These samples were taken in the winters of 1998 (mean upstream DO = 9.6 mg/L), 1999 (mean upstream DO = 7.6 mg/L), 2002 (mean upstream DO = 6.5 mg/L) and 2003 (mean upstream DO = 5.8 mg/L). This study tested the 6.5 mg/L DO chronic guideline, because the DO concentrations at the upstream site were below 6.5 mg/L for three consecutive days in 2002 and 42 consecutive days in 2003 (Alberta Environment 2004). Total counts, community composition, number of benthic invertebrate taxa (number of EPT taxa), and density of EPT invertebrates were compared between upstream and downstream sites for each year (Chambers et al. 2006). EPT are taxa of the Orders Ephemeroptera, Plecoptera and Trichoptera, which are more sensitive to low DO (Alberta Environment 2004). EPT act as a specific bioindicator, and the ecological impact on the EPT can be compared to the impact on unsensitive species of the Order Diptera and all of the species of benthic invertebrates. This is an advantage of using benthic invertebrates as bioindicators (Munro and Taccogna 1994).

Alberta Environment (2004) identified fifty benthic invertebrate taxa in the Grand Rapids area of the Athabasca River. The total number of invertebrates ranged from 1673 animals/m^2 upstream of Grand Rapids in 2002 to 3871 animals/m^2 downstream of Grand Rapids in 2003 (Alberta Environment 2004). In three of the four study years mean total number of invertebrates and mean total number of taxa was greater at the downstream site. In 1999 mean total number of invertebrates was greater at the upstream site than the downstream site. Also in 1998 mean total number of taxa was greater at the upstream site than the downstream site. The community composition changed from the upstream to the downstream site, with a large increase in the proportion of EPT Orders. The mean number of EPT taxa was greater at the downstream site than the upstream site in 1999, 2002 and 2003. Abundance of EPT invertebrates was significantly higher downstream of Grand Rapids for all four years (Alberta Environment 2004). Generally, for all four study years (at both upstream and downstream sites) the lower the DO, the lower the total number of taxa, the total number of invertebrates, the number of EPT taxa, and the abundance of EPT invertebrates. This effect was the strongest for EPT abundance and the proportional contribution of EPT taxa. For example, EPT was 21.6 % of total number of invertebrates in the upstream site in the study year with the highest DO concentration (1999), and was 4.6 % in the study year with the lowest DO concentration (2003) (Alberta Environment 2004). The differences between the upstream and the downstream site were most pronounced in 2003 when DO averaged 5.8 mg/L for a 42 day low period. In 2003 all benthic invertebrate parameters, except for total abundance, were significantly lower upstream of Grand Rapids compared to the downstream site. In 2003 mean EPT abundance remained within an expected unimpacted range downstream compared to the upstream site, where the mean EPT abundance was one-eighth the downstream site. Mainly EPT taxa were stressed at a DO level of 5.8 mg/L, compared to other taxa. For example, chironimids and midges were not affected because they can adjust to DO levels as low as 2.0 mg/L (Alberta Environment 2004). This is consistent with the results of Lowell and Culp (1999) that found that mayflies (Ephemeroptera) are stressed at 5.0 mg/L DO.

The main advantages of using benthic invertebrates over fish as bioindicators are practical. The effects of low DO on fish are measured in terms of physiological and life cycle parameters. The effects of low DO on benthic invertebrates can be measured in terms of physiological and life cycle parameters, but also parameters that can be quickly and easily measured such as abundance, number of taxa and drift rates (Culp et al. 2000b). Also sampling benthic invertebrates provides larger samples for more accurate results.

Drift is the flow of invertebrates in a river, and drift rate is the amount of invertebrate individuals that flow passed a particular point or area over time. Many studies have shown there is a correlation between low DO and increased drift in benthic invertebrates. Low DO can cause benthic invertebrates to not be able to respire. This can induce benthic invertebrates to change position and/or modify physiological regulation. If changing position and physiological regulation do not fulfill the respiratory needs of benthic invertebrates, they will actively drift (Brittain and Eikeland 1988). Light has also been shown to effect benthic invertebrate drift rate in a diel pattern. Benthic invertebrate drift is increased during the night and decreased during the day (Graesser and Lake 1984; Rader and Ward 1990; Allan et al. 1986).

Addition of pulp and paper mill wastewater to aquatic ecosystems can cause changes in numerical abundance, biomass, and diversity of benthic invertebrate communities. Also it can cause changes in biomass and diversity of benthic algal communities and physiological and reproductive parameters of wild fish (Chambers et al. 2000a). Historically there was only primary treatment of pulp mill wastewater. Ecological effects were determined by measuring the reduction of photosynthesis of primary producers caused by effluent colour and abundance of organisms at higher trophic levels. Also acute toxicity caused by chlorinated organic compounds, and fatty acids in fish species were measured. Culp et al. (1992) speculated that diel fluctuations in DO concentration due to macrophyte photosynthesis and respiration along with high ammonia concentration led to fish kills prior to the advent of secondary treatment. However, with the advent of secondary treatment, environmental problems from organochlorines and colour have largely been eliminated (Chambers et al. 2000a). Therefore measuring acute toxicity and reduction of primary producers is not vital for ecological risk management for pulp mill effluents in the Athabasca River. The main effect of pulp mill wastewater (secondary treatment) is nutrient loading causing eutrophication. The typical pulp mill on the Athabasca River releases 50000 to 150000 m^3 of effluent containing high concentrations of nitrogen and phosphorous. The growth of algae and aquatic plants can increase BOD in the water column and biological and chemical oxidation of the organic component of bottom sediment of the river and oxygen diffusion into the bottom sediment (sediment oxygen demand). Coupled with ice-cover in winter that prevents re-aeration, this can significantly decrease DO levels (Chambers et al. 2000a). Therefore parameters that determine the effects of nutrient loading and low DO on bioindicators should be measured for ecological risk management.

There are multiple sewage treatment plants and pulp mills for 800 km of the Athabasca River. The municipalities of Jasper, Edson, Whitecourt, Barrhead, Slave Lake, Athabasca, Lac La Biche, Fort McMurray and Fort Chipewyan discharge sewage effluent continuously to the Athabasca River or its tributaries.

The town of Hinton discharges its sewage effluent with the Hinton pulp mill (Fig. 1-1) (Chambers et al. 2006). There is a pulp mill at Hinton, two chemi-thermomechanical mills at Whitecourt, one chemi-thermomechanical mill at Slave Lake, and one bleached kraft pulp mill at the town of Athabasca (Fig. 1-1). The first bleached kraft pulp mill began operation in 1957 at Hinton. This first pulp mill originally only used primary treatment. The combined effluent was treated in a facultative settling pond and had a BOD_5 that averaged approximately 24000 kg/d. Secondary treatment (primary clarifier and aerated lagoons) was introduced at Hinton in 1967, and aerated lagoons were expanded in 1975. Oxygen delignification and chlorine dioxide substitution were introduced and aerated lagoons and the effluent clarifier were upgraded in 1990 at Hinton. Between August 1988 and late 1990 the three chemi-thermomechanical mills began operation. The bleached kraft pulp mill at Athabasca became operational in September 1993. BOD_5 load from all pulp mills averaged 3727 kg/d in 1989-1995 (Chambers et al. 2000b). Effluents from pulp mills and municipal sewage treatment plants are major point sources of toxicants and nutrient loading therefore there is extensive environmental monitoring. There is a 16-fold increase of algal biomass downstream of Jasper sewage effluent and a 4-fold increase downstream of the Hinton pulp mill. There is a large increase of algal biomass downstream of the two pulp mills and sewage at Whitecourt, and very small increases after 20 km downstream of Whitecourt, at the town of Athabasca (Chambers et al. 2000a). Twelve studies in the United States measured periphyton production downstream of pulp mill effluents and two reported enhanced growth, six observed no effects and four reported a decrease in production (NCASI 1989). Algal biomass distribution due to nutrient loading also follows a weak pattern along the Athabasca River. This may be due to different light penetration at different sites (Chambers et al. 2000a). Also high flows during the summer remove any effects of point-source nutrient loading due to dilution (Chambers et al. 2000a). Generally a river benthic chl*a* concentration of >10 μgcm^{-2} is considered excessive, but the Athabasca River is significantly lower. This is not an appropriate guideline because it is too high, and currently no benthic chl*a* guideline exists for the Athabasca River (Chambers et al. 2006). Overall there is no simple pattern for the effect of nutrient loading on benthic algal biomass, and benthic chl*a* levels are not an ecological risk in the Athabasca River. Also the literature shows that nutrient loading from sewage and pulp mill effluent has no effect or negative effects on algal species composition or species abundance (Welch 1992; Culp et al. 1996; Livingston 2007). Algal biomass, species composition and species abundance are not suitable parameters for determining the effect of nutrient loading for ecological risk management. Nutrient loading by itself does not strongly impact primary production indicators in a consistent way.

Downstream of the pulp mill discharge at Grande Prairie on the Wapiti River (Fig. 1-1), nitrogen (N) and phosphorous (P) concentrations are increased in benthic algal species. Also the abundance of benthic algae is increased. Upstream of the pulp mill discharge at Grande Prairie on the Wapiti River (Fig. 1-1), the benthic algal growth is N and P limited (Chambers et al. 2006). Therefore there is a simple relationship at the pulp mill discharge at Grande Prairie to the Wapiti

River. However, in the Athabasca River annual concentrations of P (measured as TP and TDP) and N (measured as TN and TIN) increase along the length of the river. Data from 1993, 1994, and 1998-2000 showed benthic algae was P-limited upstream of Jasper and Hinton (Fig. 1-1). However, along the lower reach of the Athabasca River, P concentrations are increased in benthic algal species and growth is N-limited (Chambers et al. 2006). Sewage has high N concentration and pulp mill effluent has high P concentration.

Rivers that receive effluents with very high concentrations of N and P nutrients may show a decrease in biodiversity of benthic invertebrates in the vicinity of the effluent streams (Minshall and Andrews 1973; Lang 2000). There may be a decline in sensitive species and an increase in pollution tolerant taxa such as midges and oligochaetes (Minshall and Andrews 1973; Anger 1977; Lang 2000). However, Culp et al. (2000a) found pulp mill effluent nutrients have no effect on benthic invertebrate diversity in the Athabasca River. Using a stream-side microcosm, samples of benthic invertebrate communities were tested in a river water control, a 1 % bleached kraft mill effluent (BKME) (directly taken from the Hinton pulp mill effluent), and a 1 % N + 1 % P solution. Total insect abundance increased in the 1 % BKME and 1 % N + 1 % P solutions. Family richness was statistically the same between all three samples. Field measurements for insect abundance and family richness were also done upstream and downstream of the Hinton pulp mill effluent. The abundance of benthic invertebrates was increased downstream of the Hinton pulp mill effluent. There was no statistical difference in family richness between the upstream and downstream sites (Culp et al. 2000a). Within certain boundaries, these results show the stimulatory effect of nutrient loading on growth and abundance of benthic invertebrates.

A 1 % sewage effluent and 1 % sewage + 3 % pulp mill effluent had more than twice the chl*a* content compared to a 3 % pulp mill effluent (Chambers et al. 2006). This showed that algal biomass (expressed as chl*a* content) in the Athabasca River is more strongly related to sewage effluent than to pulp mill effluent. Sewage effluent has high N concentration and low P concentration. Therefore algal biomass in the Athabasca River is more strongly related to N concentration than to P concentration. Algal biomass is more likely higher downstream of sewage discharge compared to pulp mill discharge. Therefore low DO events are highly uncommon downstream of pulp mill discharges in the Athabasca River in the winter. Where the algal biomass food source increases, the benthic invertebrate abundance also increases. A 1 % sewage effluent, a 3 % pulp mill effluent, and a 1 % sewage + 3 % pulp mill effluent all had significantly higher production of insects than a reference treatment. The 1 % sewage + 3 % pulp mill effluent had three times higher insect emergence than the reference treatment. This indicates that sewage effluent and pulp mill effluent synergistically increase insect emergence within certain conditions (Chambers et al. 2006).

ASSESSMENT OF METHODS OF SIMULATING LOW DISSOLVED OXYGEN CONDITIONS

a. Electroshocking

Electric current (applied via an electroshocker) is extensively used to stun and capture freshwater fish. Electroshocking is also known to stun benthic invertebrate species and increase drifting. Elliot and Bagenal (1972) found that electroshocking increased drift in Plecoptera, Ephemeroptera, and *Gammarus pulex*. Bisson (1976) found that electroshocking elevated drift rates by tenfold for nearly all benthic invertebrate taxa.

Kruzic et al. (2005) found that electroshocking significantly increases drift of benthic invertebrates compared to walking on substrate. The electroshocking elevated drift rates by approximately four-fold when the drift distance was between 2.5 and 5 m. But when the drift distances were between 10 and 30 m there was no significant difference between the electroshocking treatment and the control. Also large taxa such as Pteronarcyidae (Plecoptera) only drifted short distances compared to smaller taxa (Kruzic et al. 2005). Therefore to observe the effect of electroshocking on benthic invertebrates the drift nets need to be set up within 5 m of the treatment. Also Ephemeroptera, Plecoptera and Trichoptera were the only taxa affected by electroshocking, similarly to the effect of low DO on benthic invertebrates. Some taxa such as Heptageniidae and Ephemerellidae (Ephemeroptera), and Nemouridae (Plecoptera) had very high drift rates over short drift distances. While other taxa such as Chironomidae (Diptera), mites

(Acaria) and psephenids (Coleoptera) had similar drift rates regardless of treatment or drift distance (Kruzic et al. 2005).

Taylor et al. (2001) used electroshocking as a sampling method, and found it to be a more efficient sampling method than standard Hess and surber sampling. Electroshocking over a specific area (8 m^2) provided approximately a twofold increase in an estimate of invertebrate density compared to surber sampling. There was an approximate twofold increase in an estimate of Ephemeroptera invertebrate density for electroshocking compared to surber sampling, an approximate threefold increase in an estimate of Plecoptera density for electroshocking compared to surber sampling, and a twofold increase in an estimate of invertebrate density for all other taxa for electroshocking compared to surber sampling. There was an approximate threefold increase in an estimate of Plecoptera density for electroshocking compared to Hess sampling. The electroshocking increased drift rates for nearly all taxa, but increased drift rates for sensitive Ephemeroptera, Plecoptera, and Trichoptera by the largest margin (Taylor et al. 2001). Taylor et al. (2001) measured the effect of electroshocking on survival, growth and development of a particular species, *Baetis bicaudatus*, in a circular flow-through tank. There was no effect on survival, growth rate and development. Therefore electroshocking is effective in stimulating drift in benthic invertebrates, but does not affect other parameters.

The effect of electroshocking on benthic invertebrate drift is similar to the effect of low DO on benthic invertebrate drift. Both cause an increase in drift rates of nearly all taxa and a large impact on drift rates of EPT taxa. The EPT taxa are very sensitive to electroshocking and low DO and are the main taxa that have highly elevated drift rates. The magnitude of impact of electroshocking depends on the time and voltage of the electroshocking. The magnitude of impact of electroshocking compared to low DO on invertebrate drift rates is not clear. In general, electroshocking seems to display a larger magnitude of impact on benthic invertebrate drift rates than a low DO event in the range of 5.0-6.5 mg/L. The exact DO range that electroshocking (of varying time and voltage) simulates is not known, but can be predicted to simulate DO in a range close to 0 mg/L. Therefore using electroshocking in a river is a simple and effective method of simulating a crude low DO event in a DO range close to 0 mg/L. Electroshocking is used to simulate a low DO event during winter in this environmental risk assessment for the Athabasca River.

b. Stream Microcosm

A microcosm can be used to study the effects of anthropogenic toxicants on different bioindicators. Microcosms of different sizes can be implemented depending on the bioindicator being studied and the parameters being measured. A larger microcosm would be required for an individual fish species study compared to an individual benthic invertebrate species study. Microcosm studies can operate on different time scales. For example, the timeline for a study testing the effect of a toxicant on the life cycle stages of a species would depend on the standard life cycle length of the species. In a microcosm study large amounts of replicates are possible. Also all relevant variables can be controlled in a microcosm to discern a cause-and-effect relationship of a specific pollutant on a specific parameter (Culp et al. 2000b).

There are different types of microcosms that can be used in a bioindicator study. A non-circulating stream-side microcosm can be set up beside a river to utilize the natural river water flow rate (Taylor et al. 2001). An artificial stream can also be set up in a laboratory. The artificial stream can be a re-circulating or non-circulating system. A laboratory flume can be used to measure the specific effects of the physical parameters of the flowing water on the bioindicators in the artificial stream. Environmental realism must be applied when designing the microcosm study in a laboratory flume. The physicochemical conditions must be set to near-ambient levels and a natural food source must be present for the specific bioindicator (Culp et al. 2000b). An artificial ice-cover is not possible in a laboratory flume, but temperature can be set as in an ice-covered river.

A microcosm study can be conducted using only one specific fish or benthic invertebrate species. The single-species microcosm study has increased accuracy due to strong control over extrinsic variables and is used for measuring population parameters such as mortality, growth, physiological responses, development, fecundity, behaviour, population production and bioconcentration (Culp et al. 2000b). A microcosm study can also be conducted using a community of benthic invertebrate species (Culp et al. 2000b). The multi-species microcosm study has reduced accuracy, but it allows for the measurement of community-level interactions and has greater environmental realism (simulates food web dynamics). The multi-species microcosm study can be used for measuring individual population parameters and comparing between species. In Chapter 3, the effect of low DO on benthic invertebrate drift rates is measured in a laboratory microcosm and compared between species, specifically comparing EPT species to the other species. Also the multi-species microcosm study can be used for measuring community structure parameters such as abundance, species composition, and species diversity (Culp et al. 2000b).

Culp et al. (2000b) recommends that microcosm studies be integrated with field experimental and monitoring data. The microcosm study can provide realistic response patterns to isolated environmental stressors. This is not possible in a field experiment where extrinsic variables cannot be controlled to observe a cause-and-effect relationship. But the microcosm is a simulation that attempts to mimic the conditions of the field site, and cannot fully supplement field experimental and monitoring data. It is recommended that the same ecological parameters be measured in microcosm and field studies for concordance of results. The concordance of results between microcosm and field studies can provide weight-of-evidence that can influence management action and the setting of guidelines by environmental authorities (Culp et al. 2000b).

CONCLUSIONS

The major impact of secondary treated pulp mill discharges in the Athabasca River is eutrophication, which lowers DO. The ice on the Athabasca River in the winter months further contributes to low DO by preventing re-aeration. Low DO causes stress in secondary consumers such as benthic invertebrate and fish species (Chambers et al. 2006). Benthic invertebrates are used as bioindicators to assess the ecological impact of low DO in this study. The effects of low DO on benthic invertebrates can be measured by physiological and life cycle parameters, but also parameters that can be conveniently measured such as abundance, number of taxa and drift rates. Sampling benthic invertebrates provides larger sample sizes for more accurate results compared to sampling fish. The benthic invertebrate EPT taxa are very sensitive to moderately low DO (<6.5 mg/L), and should be measured separately (Alberta Environment 2004). Therefore the effects of low DO on benthic invertebrates are assessed using parameters such as abundance, taxa drift rates, EPT abundance, and EPT drift rates.

An electroshocker can be used to simulate a low DO event in a river by stimulating drift. Therefore an electroshocker was used in the Athabasca River in this study to simulate a low DO event. Benthic invertebrate samples can be taken over time following the low DO simulation to determine the recovery time and pattern of the benthic invertebrate community. Other impacts such as ice-out produce similar results through increased river discharge and large ice sheets and pans scouring the banks and bed of the river. Recovery from these natural events can be compared to those from a low DO event. This comparison puts the impacts of a low DO event in context with other natural disturbances and allows decision makers latitude in determining if and how DO remediation is necessary.

A laboratory microcosm can be used to discern a cause-and-effect relationship of a specific pollutant on a specific population or community structure parameter (Culp et al. 2000b). A microcosm attempts to mimic the conditions of the field site, and cannot fully supplement field experimental and monitoring data. Microcosms of different sizes and types, and different time scales can be implemented. A microcosm study can be conducted using only one specific fish or benthic invertebrate species, or using a community of benthic invertebrate species (Culp et al. 2000b).

In conclusion, the problems that require further research are: 1) simulating low DO in the Athabasca River and determining recovery times and patterns of the benthic invertebrate community following low DO events and ice-out; 2) using a laboratory microcosm to determine the effect of low DO on benthic invertebrate drift rate and to determine the DO range that electroshocking simulates. The first problem is addressed in Chapter 2 and the second problem is addressed in Chapter 3.

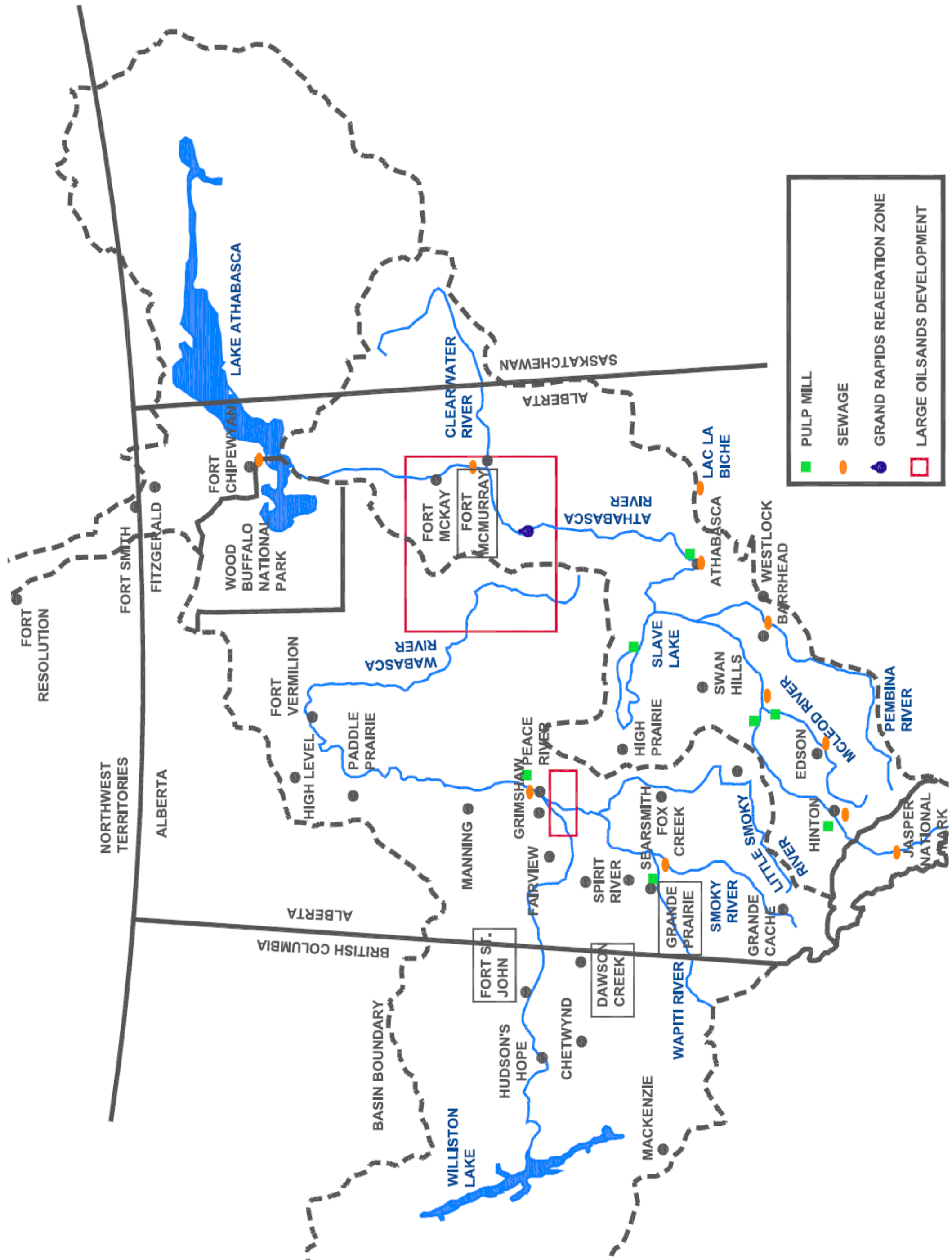

FIGURE 1-1 Overview map of the Athabasca River highlighting the locations of pulp mills, sewage treatment plants, the Grand Rapids reaeration zone and areas with large oilsands development

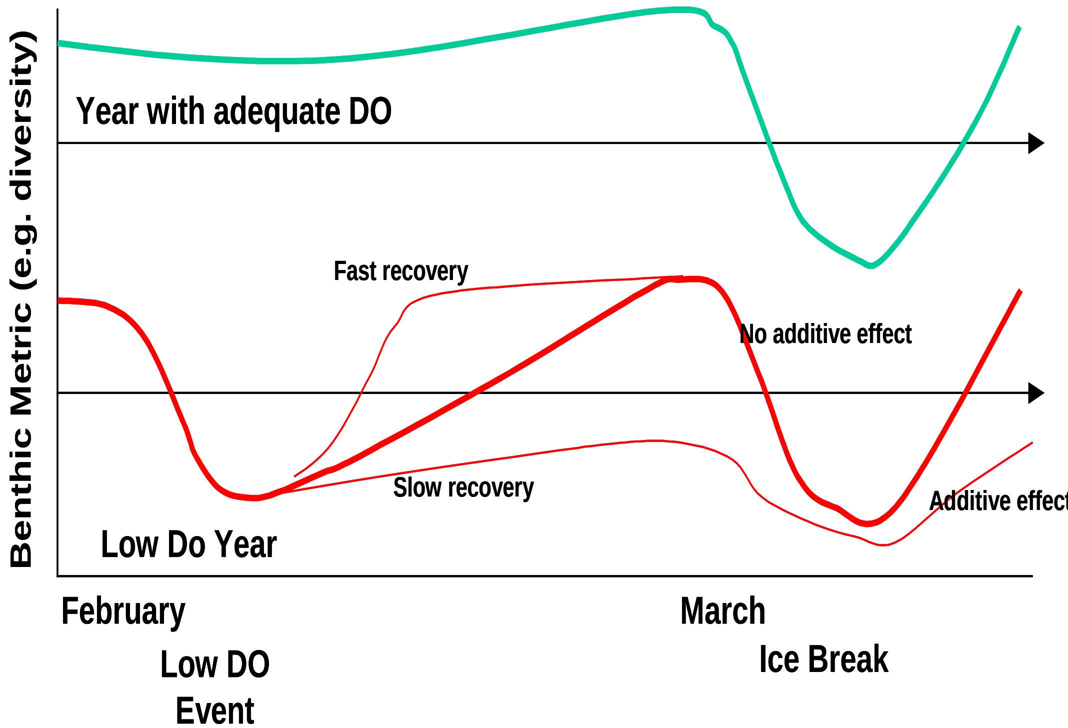

FIGURE 1-2 Theoretical impact and recovery pattern of a benthic parameter in a year with adequate oxygen (top) compared to a year with the added impact of a low DO event (bottom). There are several potential trajectories for recovery from the low DO event. There could be a fast recovery (approximately 1 week) or a slow recovery that has an additive effect on the benthic parameter to the effect from ice-out

CHAPTER 2

PATTERNS IN BENTHIC INVERTEBRATE RECOVERY FOLLOWING LOW DISSOLVED OXYGEN AND ICE-OUT EVENTS IN A NORTHERN RIVER

INTRODUCTION

The Athabasca River, like other northern rivers in Canada, experiences ice-cover for four to six months, restricting reaeration and causing declines in dissolved oxygen (DO) concentration. Late-winter DO in the Athabasca River generally remains above the chronic effects guideline of 6.5 mg/L, however, occasional severe winters have resulted in areas of the river with DO below guidelines.

Nutrient loading along the Athabasca River from pulp mill and sewage effluent enhances biological and chemical oxidation exacerbating the frequency and duration of reduced dissolved oxygen concentrations during late winter (Noton and Allan 1994). Labile carbon is rapidly oxidized such that noticeable reductions in DO concentration occur downstream of each effluent plume in the Athabasca River (Chambers et al. 2000). As virtually no reaeration occurs the effect of these nutrient loads is cumulative along the length of the Athabasca River. Dissolved oxygen declines from a winter average of 11-12 mg/L at Hinton to a low of 6.5-10 mg/L above Grand Rapids some 800 km downstream (Noton and Allan 1994).

Previous studies have tested the effect of low DO on benthic invertebrate communities in a laboratory setting and in the Athabasca River. Lowell and Culp (1999) exposed mayflies (*Baetis tricaudatus*) to one of two DO levels (5 mg/L and 11 mg/L). The low DO treatment changed the mayfly distribution, decreased mayfly grazing intensity, and reduced mayfly survival by 60-90 %. Combined with other evidence, Alberta subsequently adopted a chronic (7-d mean) DO guideline of 6.5 mg/L for the protection of aquatic life (Lowell and Culp 1999). Following a particularly severe winter and for 3 subsequent years, Alberta Environment sampled benthic invertebrates upstream and downstream of Grand Rapids to determine the effects of low DO on benthic invertebrates. In three of the four study years mean total number of invertebrates and mean total number of taxa were greater at the downstream site where DO was 3-5 mg/L higher on average. The mean number of EPT taxa (taxa of the Orders Ephemeroptera, Plecoptera and Trichoptera) was greater at the downstream site three of the four study years. The proportion of EPT species and abundance of EPT invertebrates were greater at the downstream site in all four study years (Alberta Environment 2004). The lower the DO was in the upstream site, the lower was the number of taxa, the total number of invertebrates, the number of EPT taxa and the abundance of EPT invertebrates. The impact of low DO was the strongest on EPT abundance and the proportional contribution of EPT taxa. Also the impact of low DO was the strongest in 2003 where DO fell below the 6.5 mg/L chronic guideline for 42 days (Alberta Environment 2004). The study accounted for habitat and other factors, while the differences were for the most part not significant, they did confirm the link between low DO and reduced benthic invertebrate community metrics.

There are several ways to simulate the benthic invertebrate community response to a low DO event. These traditionally have included physical removal in situ, chemically induced methods and installation of artificial substrates (Culp et al. 2000). Physical removal is time consuming and can alter the habitat (e.g. epiphytes) invalidating comparisons to reference conditions. Chemical methods are difficult to control and require regulatory approval, which can be difficult in Canada. Electroshocking has been proposed as a simple method for removal but has not been widely tested. Kruzic et al. (2005) showed that electroshocking in a Northern river stunned benthic invertebrates causing an increase in drift rates of all benthic invertebrate taxa, and a larger impact on drift rates of EPT taxa by two to three-fold (Taylor et al. 2001). In this work, we tested the effect of electroshocking on benthic invertebrate abundance and confirm its utility to mimic the effects of low DO, which similarly causes enhanced drift of EPT taxa and reduced site abundance.

The objective of this study was to determine the recovery of benthic invertebrate abundance in the Athabasca River following a simulated low DO event prior to ice-out and following ice-out itself. Ice-out is the break up of large ice sheets and pans that scour the banks and bed of the river causing increased benthic invertebrate drift and decreased abundance. Of paramount importance to management was to test the hypotheses that low DO and ice-out were synergistic resulting in a combined impact on benthic invertebrates more severe than in a year where ice-out was the only impact. The possibility for cumulative impact is important because, depending on the relative severity of the two events or their combination, the only management response currently available is to shut down effluent discharges. An associated project is examining other alternatives such as oxygen injection in effluent streams where again necessity is informed by the results of the work presented here.

METHODS

The Athabasca River originates in the Rocky Mountains in west-central Alberta. It flows northeast 1400 km across boreal foothills and mixed-wood forests of Alberta and has a drainage area of 155000 km^2. The study sites (N 54^{o}56’93.9”/W 112^{o}57’93”), located near the town of Athabasca and the last pulp mill on the river (Fig. 2-1), have mean daily discharges of 407 m^3/s with typical ice-out discharges averaging 500 m^3/s. The lowest discharges, when dissolved oxygen concentrations can be compromised, occur in February (62 m^3/s). There are multiple treated sewage discharges and 5 pulp mills within the first 800 km of the Athabasca River. The experimental sites were chosen for small and medium substrate in a low to medium-energy erosional zone.

Sampling occurred over 3 years, 2007-2009. In 2007 the focus was on the period before ice-out to understand the recovery from simulated low DO. In 2008 sampling focused on ice-out only to extend the results observed in 2007 and in 2009, sampling again focused on the experimental simulation of low DO to confirm 2007 results. In all years, ice between 0.3 and 0.7 m thick was removed from approximately 12 m^2 areas to expose test sites using a chainsaw equipped with a 4’ bar with no chain oil (AENV winter sampling standard operating procedure) (Fig. 2-7). In 2007 and 2009, benthic invertebrates were cleared from shallow (< 0.5 m water) and deep (1.5 m water) sites by applying a strong electrical current (Smith Root Electrofisher Backpack Model LR-24) using a 50 second pulse at 350 volts and 4 amps for 5 minutes (Fig. 2-2). References sites (1 m x 2 m) were located on similar substrate 9 m upstream of treatment sites (Figs.

2-5 and 2-6). Three reference and treatment samples were collected from each of shallow and deep sites resulting in 12 samples per day. Samples were collected at time zero, every seven days for 4 weeks, every 14 days until ice-out and again every 14 days after ice-out, once ice was sufficiently cleared to allow safe access to the sites. A Neill cylinder (0.1 m^2 sampling area, 212 μm mesh size) fitted with a skirt was used for sample collection (Figs. 2-3 and 2-4). The daily discharge during the electroshocking recovery that occurred February and March was at a steady minimum (Fig. 2-9). Drift nets (0.14 m^2 average mouth area, 363 μm mesh size) were installed under ice at the upstream, outer edges of the ice-free sections such that they captured drift passing the edges of the reference site area but did not interfere with the reference sites themselves (Fig. 2-8). Drift nets were initially set for 18-24 hours.

In 2008 samples were reduced to 3 shallow and 3 deep per day and collected at time zero, every seven days for 3 weeks, every 14 days until ice-out and again after ice out, once flows allowed safe access to the sites. The samples were divided into 3 shallow site samples and 3 deep site samples. In summer, Neill cylinder sampling was repeated. Surber net sampling was done for 40 minutes, and drift net sampling was done for 45 minutes. The net sampling times were very short due to the high flow of the Athabasca River.

In 2009, samples were collected at time zero, every seven days for 3 weeks, every 14 days until ice-out and again twice after ice out.

Invertebrates were removed from organic and inorganic material. Then they were passed through a 1 mm and 200 μm sieve to separate the samples into coarse and fine size fractions. All of the fractions were examined portion-by-portion on a gridded petri dish under a dissecting microscope. Fine size fractions of large samples were sub-sampled according to the methods of Wrona et al. (1982). Benthic invertebrates were identified to the lowest practical taxonomic level, typically genus for most invertebrates within the Class Insecta, with the exception of the Chironomidae (Diptera). Chironomids were identified to subfamily or tribe. Small, early instar animals were identified to the lowest level possible, generally to family (Alberta Environment 1990). The benthic invertebrate identification was done using the recognized taxonomic keys, Clifford (1991) and Merritt, Cummins and Berg (2008) by a certified lab and a single technician (Streamline Environmental).

For every year, the data from Neill cylinder sampling were separated into five categories based on benthic invertebrate Order (Diptera, Ephemeroptera, Plecoptera, Trichoptera and a fifth category for all species). For each category the reference samples, shallow site treatment samples and deep site treatment samples were totalled. 2007 and 2009 data were divided by the reference totals to give normalized response at each sample event. For analysis of recovery following experimental removal, 2007 and 2009 data were combined. The drift and surber net data were converted into individuals m^{-2} $day^{-1}$and totaled for five categories based on benthic invertebrate Order. The drift rates were calculated as the number of individual benthic invertebrates that passed the square metre rim of the drift or surber net over a period of one day. Site abundance numbers were compared to the drift rates for each Order by correlation (Pearson- r).

RESULTS

Electroshocking was more effective at shallow sites compared to deep sites with reduced benthic invertebrates abundances of 12-36 % at shallow sites when compared to reference sites depending on the Order. For example, for Diptera, removal was moderate at 64 % removed (abundance 36 % of reference) at the shallow site and 24 % (abundance 76 % of reference) for the deep site (Fig. 2-10). Ephemeroptera and Plecoptera displayed greatest sensitivity to the electrical treatment with abundance of 15 % and 12 % of reference, respectively, for the shallow site and 47 % and 30 %, respectively, for the deep site (Fig. 2-11 and 2-12). Similar to the known response of EPT taxa to low DO, EPT taxa also appeared to be the most sensitive to the electrical treatment. All non-EPT taxa had an average abundance of 37 % for the shallow site and 75 % for the deep site (Fig. 2-14). Diptera began to recover quickly with abundance of 157 % by the first week (Fig. 2-10). However, fluctuations lead us to conclude recovery extended out to week 4 (Fig. 2-10). Benthic invertebrates of the Orders Ephemeroptera, Plecoptera, Trichoptera and all species show full recovery in the shallow site in week 4 (Figs. 2-11, 2-12, 2-13, and 2-14). The Order Ephemeroptera also recovered by week 4 in the shallow site and the deep site (Fig. 2-11). Benthic invertebrates of the Order Plecoptera in the deep site show no full combined recovery following electroshocking, although 88 % reference is reached at week 4 (Fig. 2-12). Benthic invertebrates of all species in the deep site show full combined recovery after 4 weeks following electroshocking (Fig. 2-14).

The reference and the drift rate showed a sporadic pattern throughout the six recovery weeks for the four Orders and all of the species of benthic invertebrates. There was a weak but significant negative correlation between the drift rate and reference site abundance ($r = -0.46$; $P < 0.05$) throughout the six recovery weeks in 2007 for the four Orders. There was a weak but significant negative correlation between the drift rate and the shallow site treatment total ($r = -0.46$; $P < 0.05$), and between the drift rate and the deep site treatment total ($r = -0.59$; $P < 0.05$). There was a stronger correlation between daily drift rates and deep site totals ($r = -0.59$; $P < 0.05$) than between daily drift rates and shallow site totals ($r = -0.46$; $P < 0.05$). Therefore, the deep site percent references were more affected by daily drift rates than the shallow site percent references.

For all four Orders the average number of invertebrates following an electroshocking event and ice-out was higher than the number following just ice-out in the month of May. For the Order Diptera, the May average number of invertebrates following electroshocking and ice-out was 13, and following just ice-out was 4.2. For the Order Ephemeroptera, the May average number of invertebrates following electroshocking and ice-out was 10, and following just ice-out was 6.2. For the Order Plecoptera, the May average number of invertebrates following electroshocking and ice-out was 13, and following just ice-out was zero. For the Order Trichoptera, the May average number of invertebrates following electroshocking and ice-out was 4.7, and following just ice-out was 0.17. For all species, the May average number of invertebrates following electroshocking and ice-out was 91, and following just ice-out was 78.

There was no difference in the impact, as a loss of invertebrates per Neill cylinder unit, between the electroshocking/ice-out event and just the ice-out event. For presentation in patterns of response through late Winter to Fall, all data were combined (Figs. 2-15 - 2-19). For the Orders Diptera and Trichoptera, the drastic drop in abundance from electroshocking, was followed by a partial recovery before the ice-out of the Athabasca River. This recovery was followed by a further drop due to ice-out (Figs. 2-15 and 2-18). For the Orders Ephemeroptera and Plecoptera, the drop in abundance was sustained throughout ice-out (Figs. 2-16 and 2-17). All other species of benthic invertebrates followed a pattern similar to Diptera (Fig. 2-19). Minimum abundance for all Orders (except for Plecoptera) occurred on May 8 corresponding to an increase in river discharge (Fig. 2-9).

Recovery in abundance following ice-out was protracted for all Orders. For Plecoptera, abundance did not recover to pre ice-out numbers by 161 days (Fig. 2-17). Ephemeroptera abundance recovered after 107 days (Fig. 2-16). Diptera, Trichoptera and other Order abundances recovered after 161 days (Fig. 2-15, 2-18, 2-19). The general rise in abundance through the summer to Fall maxima corresponds to decreasing hydraulic energy and increased epiphytic biomass thus representing presumably more favorable habitat conditions.

DISCUSSION

Electroshocking caused immediate reductions in EPT abundance similar to and more extensive than what has been observed due to low dissolved oxygen concentrations (Alberta Environment 2004). Electroshocking appeared to be more effective in shallow sites compared to deep sites, which is consistent with the dynamics of an electrical field created by a standard backpack unit. Recovery in abundance was surprisingly rapid. Diptera immediately recolonized the experimental sites (Fig. 2-10) while more generically all EPT recovery occurred over 4 weeks (Figs. 2-11 – 2-13). The reasons for rapid recovery are likely due to the high drift rates and therefore ability to recolonize available sites once favorable conditions occur. The magnitude of drift affects the recovery of any area of impact, therefore a 25 m^2 test section can be extrapolated to the area of a DO sag zone in the Athabasca River. Given the magnitude of drift, a DO sag zone would recover in 4 weeks.

Recovery at deep sites appeared to be slower than at shallow sites. This may be due to the generally poorer quality substrate in the deep site. Therefore, fewer invertebrates were likely to settle on the river substrate in the deep site than the shallow site over time (Wantzen 2006). The recovery in the deep site for the Order Plecoptera (Fig. 2-12) and the Order Trichoptera (Fig. 2-13) was erratic compared to the shallow site. Neill cylinder sampling was more consistent in the shallow site than in the deep site, because it was easier to lock the Neill cylinder in the sediment in the shallow site due to a lower river discharge, and it was easier to consistently shovel the sediment within the Neill cylinder in the shallow site.

When the discharge decreases in early July less invertebrates settle on the sediment, but proportionally less are lost so recruitment begins to occur. Ice-out of the Athabasca River appeared to impact the benthic invertebrate community more, in terms of recovery time, than the electroshocking experiment designed to mimic a low DO event. This may be because the electroshocking lasted 5 minutes while ice-out lasts 15-20 days resulting in a longer recovery, and the ice-out is followed by a period of high flow till September, which causes slower recolonization.

Ice-out caused a drop in the number of benthic invertebrates in April and May due to a high daily discharge rate (Fig. 2-9), which decreased the number of benthic invertebrates in the sediment. Full recovery appears to occur within 4 weeks following a low DO event. There is a relatively fast recovery following a low DO event (4 weeks), but there may not be full recovery before the impact of ice-out (Figs. 2-15 – 2-19). If the low DO event occurs within 4 weeks of the ice-out of the Athabasca River there is a combined impact on the benthic invertebrate community. However, we found the impact of ice-out, as a loss of invertebrates per Neill cylinder unit, was the same across years regardless if there was a simulated low DO event (2009) or not (2008). There is no additive effect of the low DO event on the impact of ice-out hence the combination of the data from 2008 and 2009 (Figs. 2-15 – 2-19).

This research suggests the relative ecological impact, in terms of recovery time, of a low DO event is small compared to the annual impacts of ice-out in the Athabasca River. Further, electroshock removal, similar to a low DO event, prior to ice-out had no affect on the impact of ice-out, as a loss of invertebrates per Neill cylinder unit, or on the recovery trajectory of benthic invertebrates following ice-out, either because there had been full recovery prior to ice-out, or because ice-out was so intrusive the prior loss was insignificant. We conclude from this work that the ecological risks associated with a low DO event prior to ice-out are low and fully recoverable. We further recommend that a risk management approach be developed for future low DO events in the Athabasca River that includes DO monitoring for <7 km, which is the average Athabasca River DO sag zone length (Chambers et al. 2000b), following pulp mill effluent discharges and decreased pulp mill effluent discharges in February and March on the Athabasca River, or more effective management alternatives should be developed than simply turning off discharges should a low DO event occur. However, it is recommended that remediation of low DO, such as oxygen injection in effluent streams by the Alberta pulp mill industry, should not be done because the cost is too high for eliminating the small ecological impact of a low DO event.

CONCLUSIONS

Using electroshocking to simulate a low DO event, the recovery time of the benthic invertebrate community was 4 weeks. It was determined the Order Diptera, the Order Trichoptera and all of the species of benthic invertebrates require up to 161 days to recover following the ice-out period of the Athabasca River. The Order Ephemeroptera requires 107 days to recover following ice-out, and the Order Plecoptera requires over 161 days to recover following ice-out. Recovery from ice-out occurs in September due to a decreasing daily discharge rate. The benthic invertebrate community takes longer to recover from naturally occuring ice-out every year than from a low DO event. The relative ecological impact of a low DO event from pulp mill effluent discharge is small with immediate recovery compared to ice-out of the Athabasca River. However, if a low DO event occurs within 4 weeks of the ice-out of the Athabasca River there is a combined impact on the benthic invertebrate community. The combined impact is more common because low DO events occur in February and March. But the combined ecological impact of low DO and ice-out of the Athabasca River is not stronger than the ecological impact of ice-out on the benthic invertebrate community. To prevent low DO events and consequent combined impact there should be DO monitoring for <7 km following pulp mill effluent discharges and decreased pulp mill effluent discharges in February and March on the Athabasca River. However, it is recommended that remediation of low DO by the Alberta pulp mill industry should not be done.

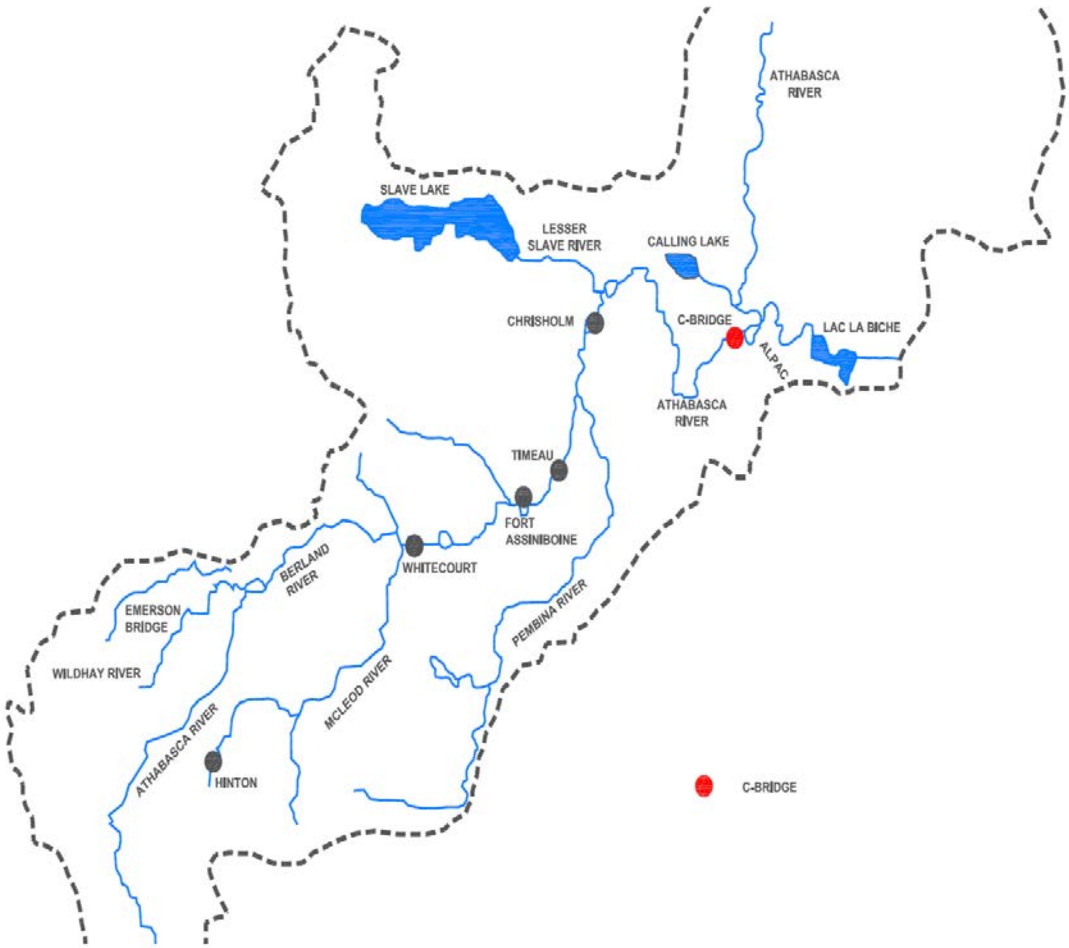

FIGURE 2-1 Overview map of the Athabasca River highlighting the location of the C-bridge experimental site where this experiment was conducted and samples were collected

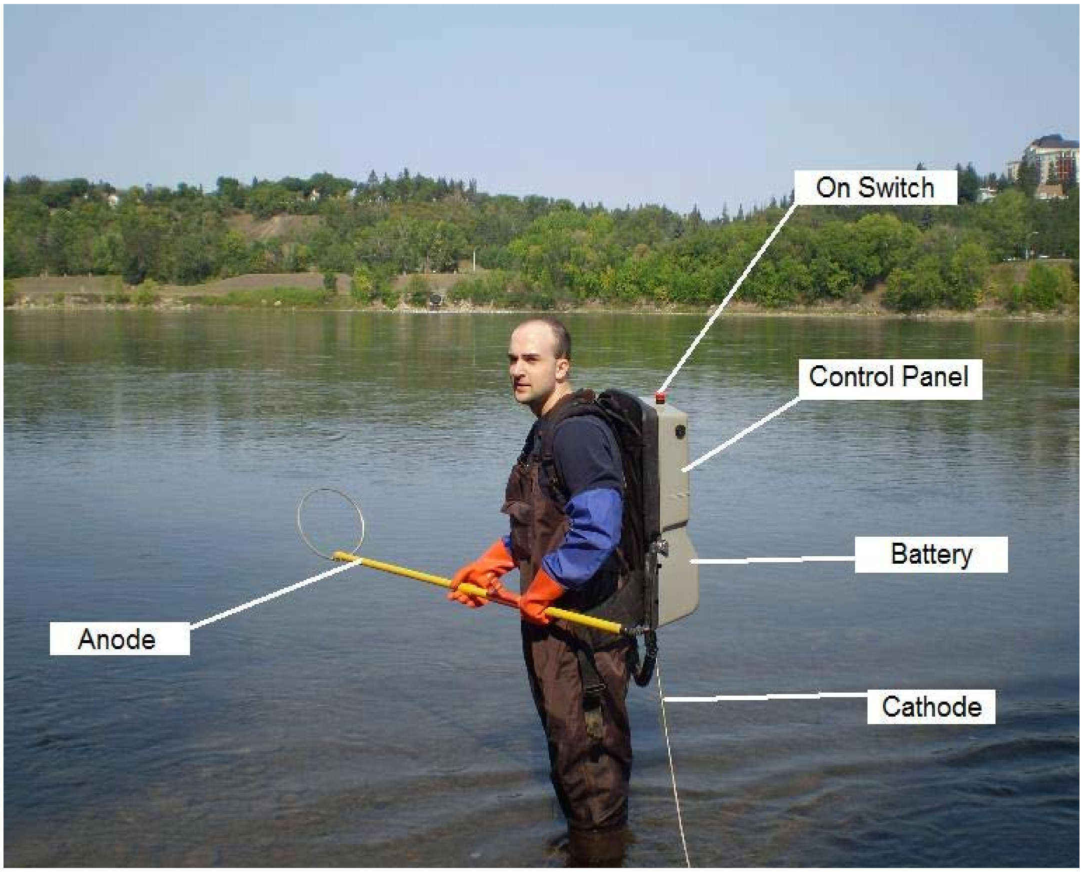

FIGURE 2-2 Photo of how to properly handle an electroshocker and with all the most important parts of the electroshocker highlighted (anode, on switch, control panel, battery, and cathode)

FIGURE 2-3 a) Front view of a Neill cylinder showing the grate, foot bars on the bottom of the sides and handlebars on the sides; b) Top view of a Neill cylinder showing the top opening with an attached covering, handlebars, and the drift net wrapped around into the top from the back with a clamp at the end for attaching a 1L nalgene bottle

FIGURE 2-4 a) Proper technique for using the Neill cylinder: The Neill cylinder is firmly locked in the sediment with the grate fully engulfed and facing the river current and the drift net and nalgene bottle submerged in the back. The sediment is stirred with a shovel put in the top opening for two minutes; b) Following sampling in the river the Neill cylinder is taken to the riverbank and placed on its side with the drift net and 1L nalgene bottle still in the river. The drift net is washed with river water so that the remaining debris goes into the nalgene bottle

FIGURE 2-5 a) Drilled holes in the ice in the Athabasca River at the corners of a 1m X 2m section; b) A chainsaw is used to cut open the ice along the perimeter of the 1m X 2m section; c) The 1m X 2m section is sawed into ice blocks using a chainsaw

FIGURE 2-6 a) The ice blocks are loosened using an ice pick; b) The ice blocks are removed using ice tongs; c) The 1m X 2m section is free of ice once all the ice blocks are removed

FIGURE 2-7 a) and b) Two photos of a 3m X 4m section free of ice in the Athabasca River following sawing the section into ice blocks using a chainsaw and removing the ice blocks using ice tongs and placing them around the section

FIGURE 2-8 a) Photo of a drift net (lower) and a surber net (higher) in the Athabasca River attached to rebar drilled into the sediment and to ropes that are tied to ice blocks on the surface; b) Close-up photo of the drift net in the opening in the ice in the Athabasca River; c) Close-up photo of the surber net in the opening in the ice in the Athabasca River

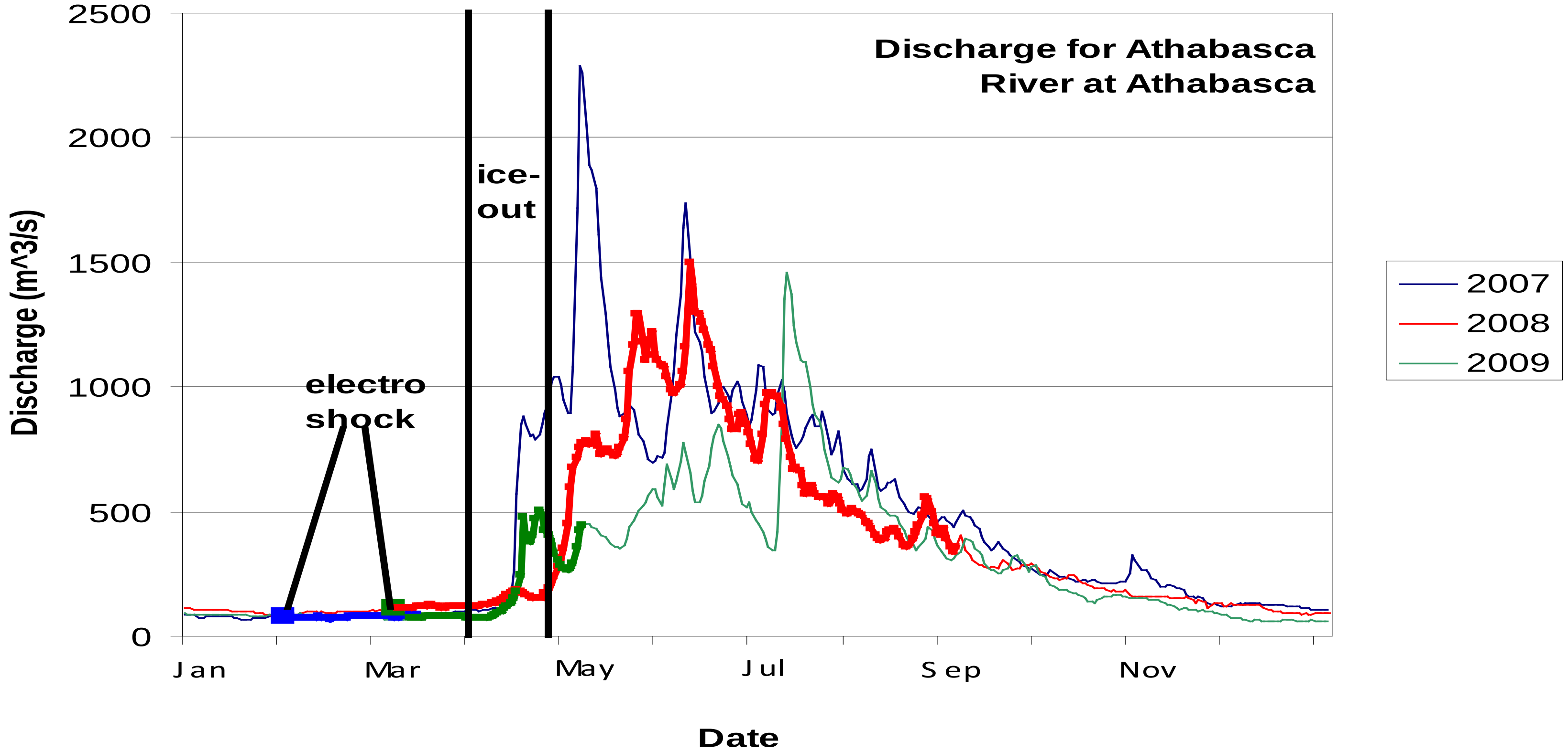

FIGURE 2-9 Daily discharge rates (m^3/s) at the Athabasca River at Athabasca over a full year. There are three different-coloured lines for three years, 2007, 2008 and 2009. Fattened portions of the lines represent the study period for 2007, 2008 and 2009. Low DO simulation via electroshocking is pointed out for 2007 and 2009. The ice-out period of the Athabasca River is the area between the black lines

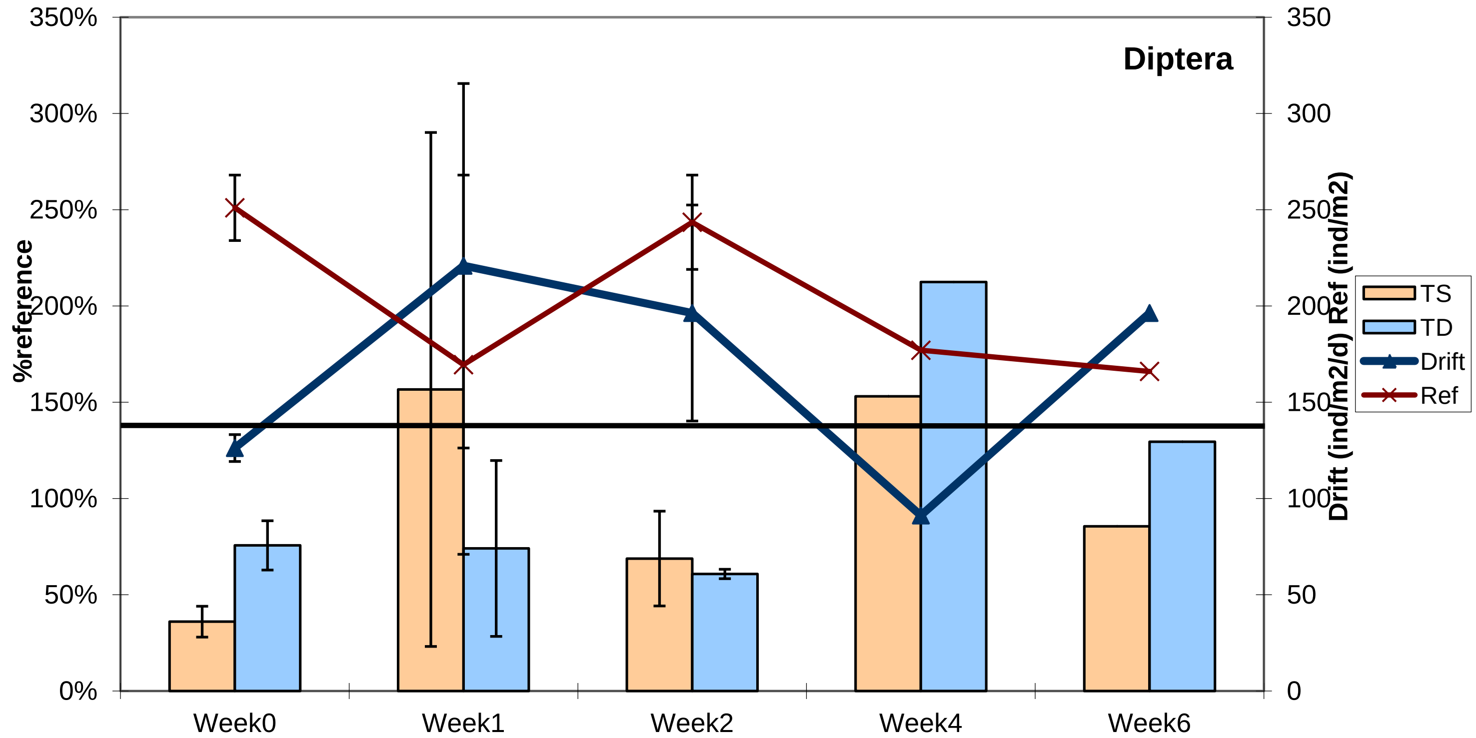

FIGURE 2-10 Recovery of benthic invertebrates of the Order Diptera following a low DO event simulated via electroshocking treatment, measured as the total number of invertebrates in the shallow treatment site (TS) and the deep treatment site (TD) per total number in the reference site (%reference). The recovery spans 6 weeks compiled from February to March 2007 and March 2009 at the Athabasca River C-bridge experimental site. 100% reference (full recovery) is marked as a black line. Also shown is the drift rate (measured as individuals m^{-2} day^{-1}) and reference (measured as individuals m^{-2}) for every measurement week

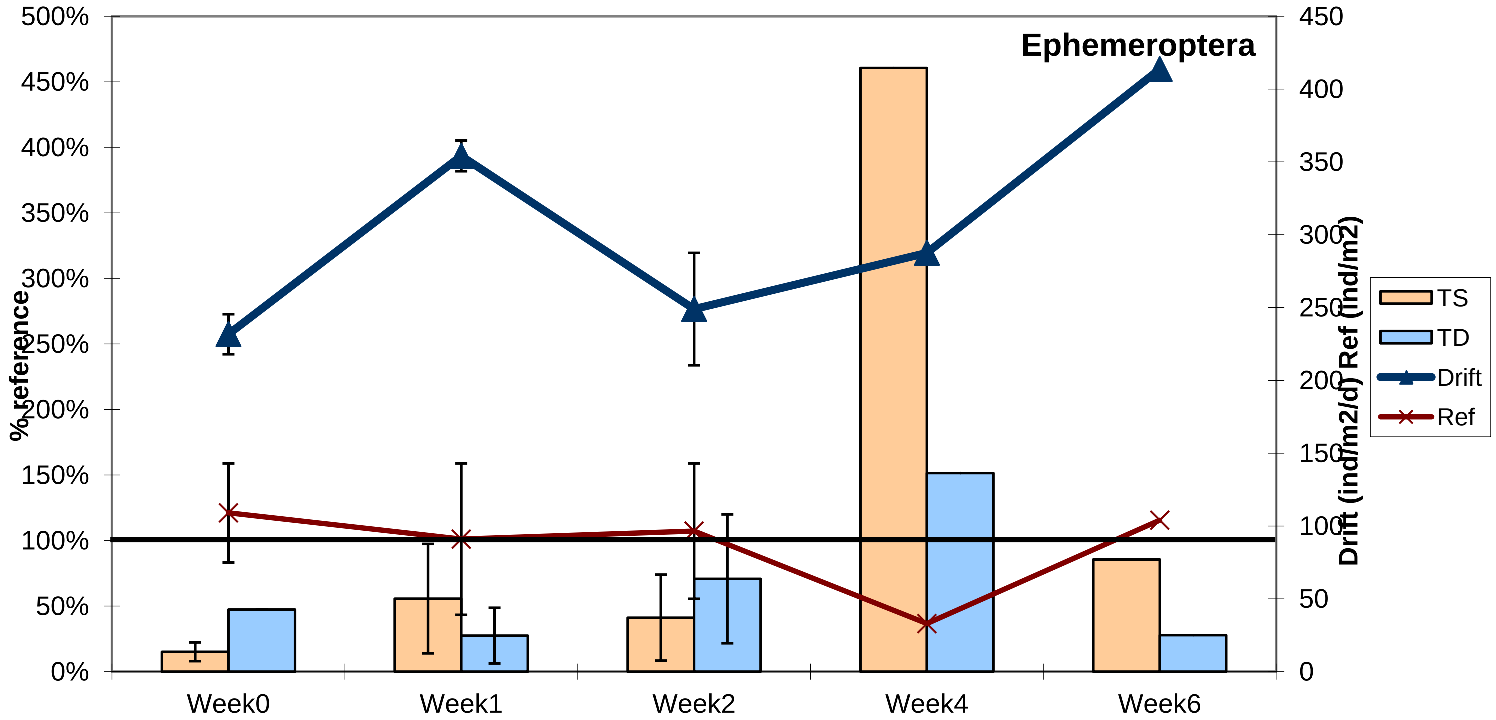

FIGURE 2-11 Recovery of benthic invertebrates of the Order Ephemeroptera following a low DO event simulated via electroshocking treatment, measured as the total number of invertebrates in the shallow treatment site (TS) and the deep treatment site (TD) per total number in the reference site (%reference). The recovery spans 6 weeks compiled from February to March 2007 and March 2009 at the Athabasca River C-bridge experimental site. 100% reference (full recovery) is marked as a black line. Also shown is the drift rate (measured as individuals m^{-2} day^{-1}) and reference (measured as individuals m^{-2}) for every measurement week

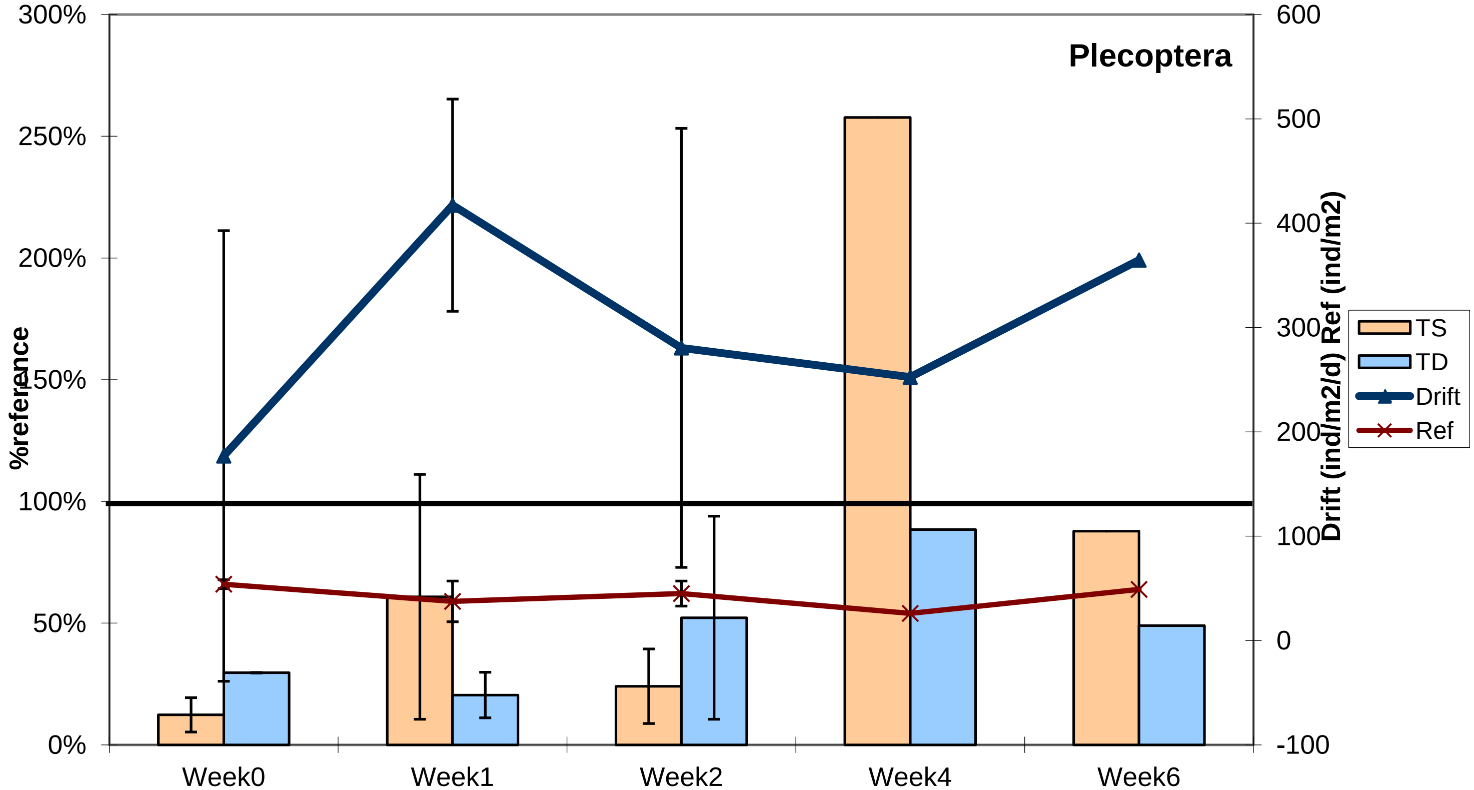

FIGURE 2-12 Recovery of benthic invertebrates of the Order Plecoptera following a low DO event simulated via electroshocking treatment, measured as the total number of invertebrates in the shallow treatment site (TS) and the deep treatment site (TD) per total number in the reference site (%reference). The recovery spans 6 weeks compiled from February to March 2007 and March 2009 at the Athabasca River C-bridge experimental site. 100% reference (full recovery) is marked as a black line. Also shown is the drift rate (measured as individuals m^{-2} day^{-1}) and reference (measured as individuals m^{-2}) for every measurement week

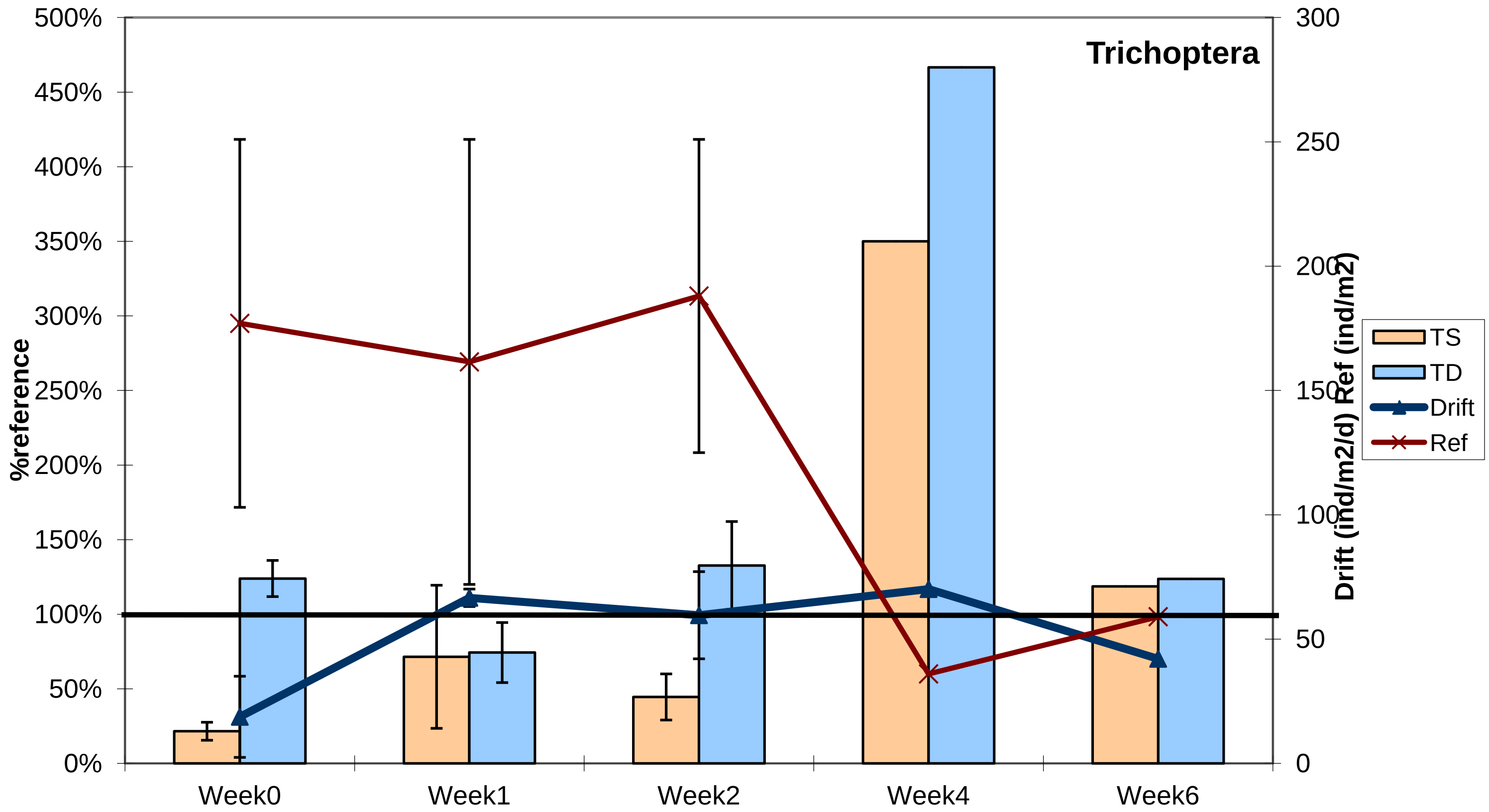

FIGURE 2-13 Recovery of benthic invertebrates of the Order Trichoptera following a low DO event simulated via electroshocking treatment, measured as the total number of invertebrates in the shallow treatment site (TS) and the deep treatment site (TD) per total number in the reference site (%reference). The recovery spans 6 weeks compiled from February to March 2007 and March 2009 at the Athabasca River C-bridge experimental site. 100% reference (full recovery) is marked as a black line. Also shown is the drift rate (measured as individuals m^{-2} day^{-1}) and reference (measured as individuals m^{-2}) for every measurement week

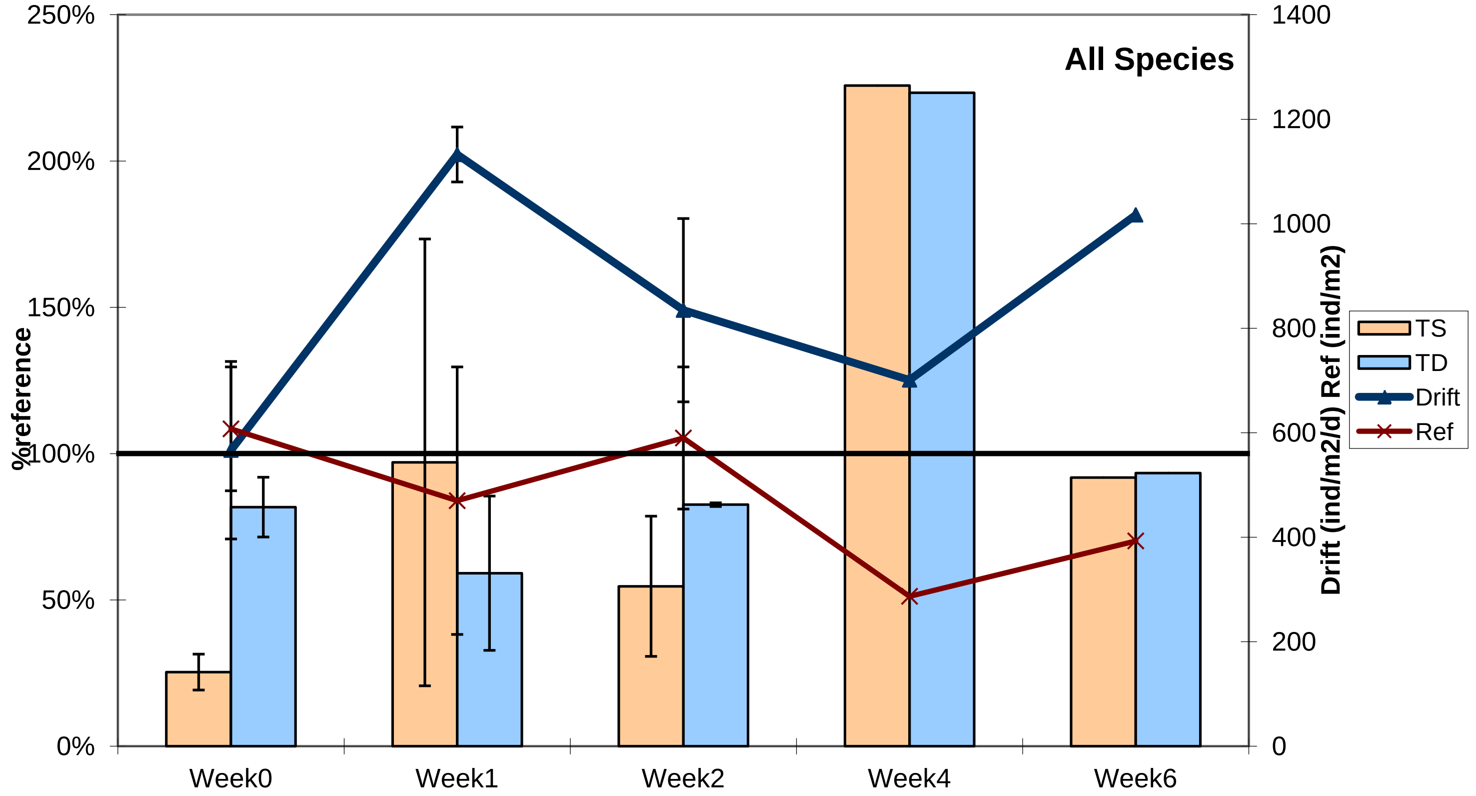

FIGURE 2-14 Recovery of all species of benthic invertebrates following a low DO event simulated via electroshocking treatment, measured as the total number of invertebrates in the shallow treatment site (TS) and the deep treatment site (TD) per total number in the reference site (%reference). The recovery spans 6 weeks compiled from February to March 2007 and March 2009 at the Athabasca River C-bridge experimental site. 100% reference (full recovery) is marked as a black line. Also shown is the drift rate (measured as individuals m^{-2} day^{-1}) and reference (measured as individuals m^{-2}) for every measurement week

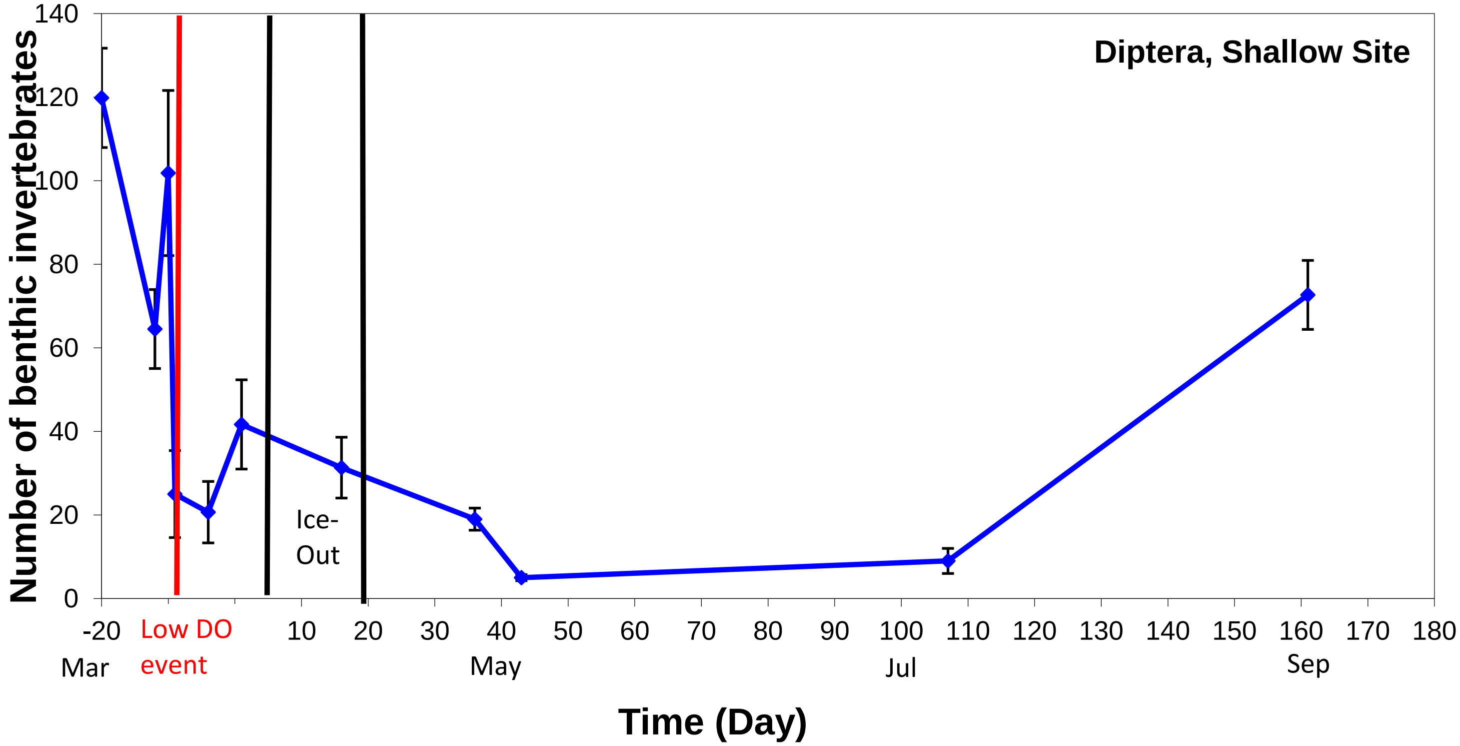

FIGURE 2-15 The effect of a low DO event simulated via electroshocking (red line) and the ice-out period of the Athabasca River (the area between the black lines) on the number of benthic invertebrates of the Order Diptera at the C-bridge experimental shallow site in 2008 and 2009 combined

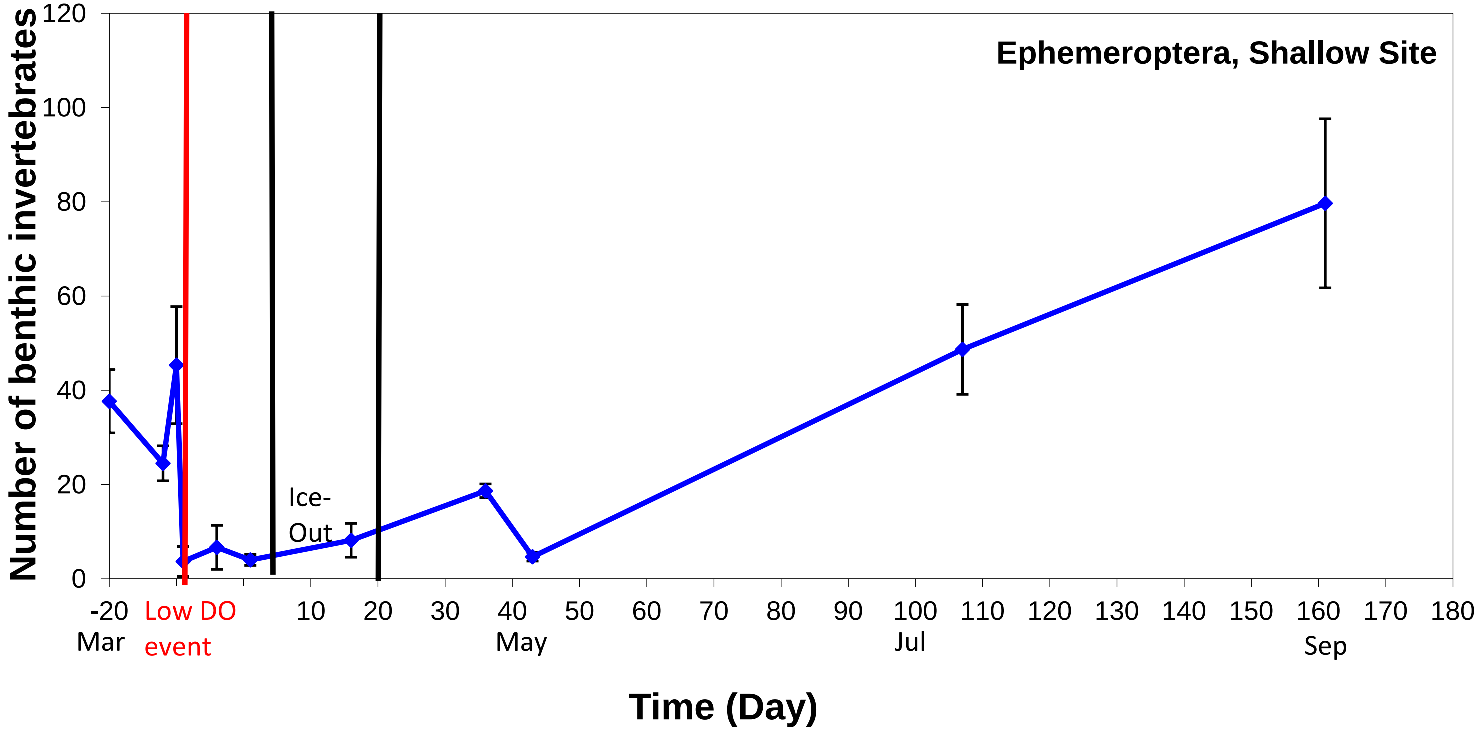

FIGURE 2-16 The effect of a low DO event simulated via electroshocking (red line) and the ice-out period of the Athabasca River (the area between the black lines) on the number of benthic invertebrates of the Order Ephemeroptera at the C-bridge experimental shallow site in 2008 and 2009 combined

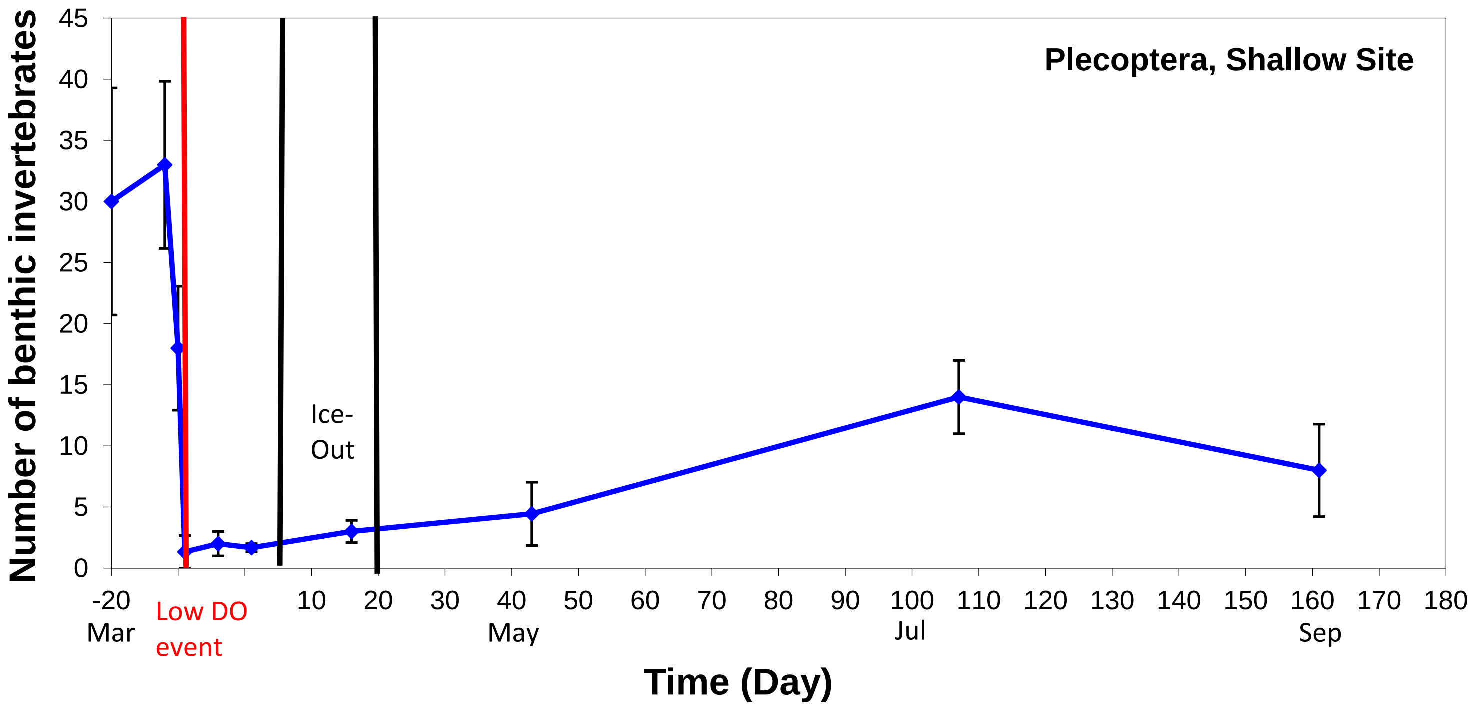

FIGURE 2-17 The effect of a low DO event simulated via electroshocking (red line) and the ice-out period of the Athabasca River (the area between the black lines) on the number of benthic invertebrates of the Order Plecoptera at the C-bridge experimental shallow site in 2008 and 2009 combined

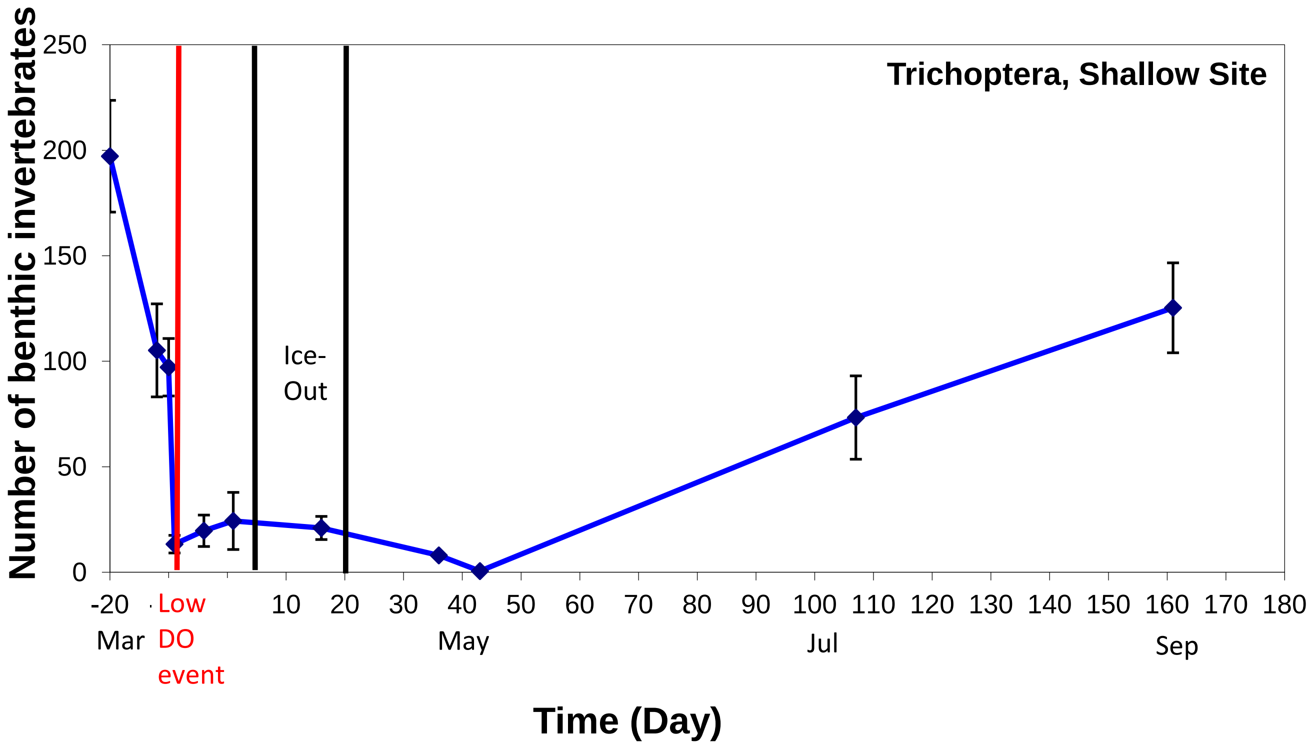

FIGURE 2-18 The effect of a low DO event simulated via electroshocking (red line) and the ice-out period of the Athabasca River (the area between the black lines) on the number of benthic invertebrates of the Order Trichoptera at the C-bridge experimental shallow site in 2008 and 2009 combined

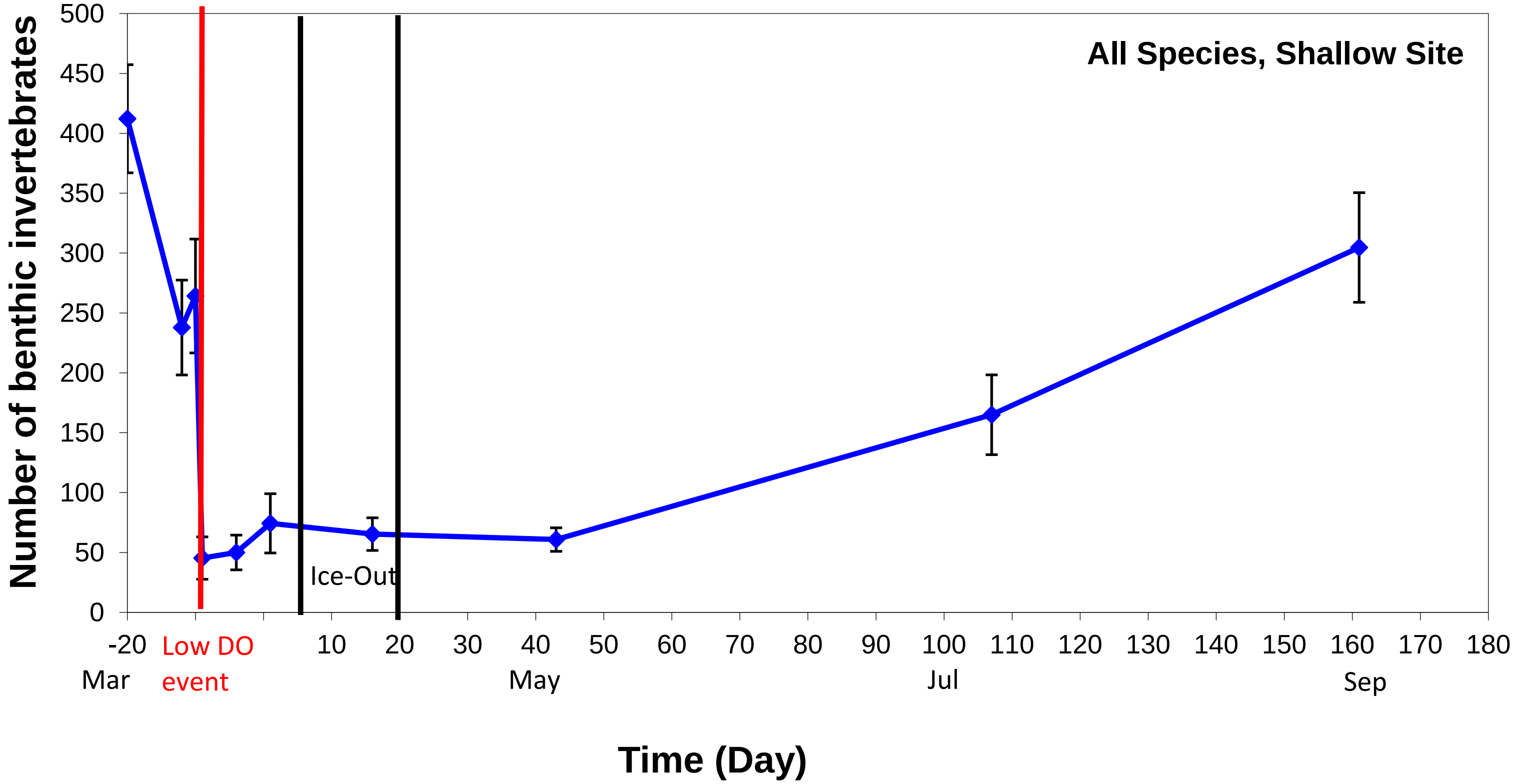

FIGURE 2-19 The effect of a low DO event simulated via electroshocking (red line) and the ice-out period of the Athabasca River (the area between the black lines) on the number of benthic invertebrates of all species at the C-bridge experimental shallow site in 2008 and 2009 combined

CHAPTER 3

DEVELOPMENT OF THE RELATIONSHIP BETWEEN DISSOLVED OXYGEN AND BENTHIC INVERTEBRATE DRIFT RATE

INTRODUCTION

The main impact of pulp mill and sewage effluent discharges in the Athabasca River is nutrient loading. Nutrient loading from pulp mill effluent causes eutrophication. This causes an increase in biological and chemical oxidation of organic matter, which decreases oxygen. Noticeable declines in dissolved oxygen (DO) concentration occur downstream of each effluent plume on the Athabasca River. Also DO decreases along the length of the Athabasca River (Chambers et al. 2000). Ice-cover restricts reaeration in the Athabasca River for four to six months, causing declines in DO concentration over time in winter. The combination of ice-cover and nutrient loading may potentially lower the DO level in the Athabasca River to guideline levels in the late winter months (February and March). This was observed in February of 2003 when the DO level in the Athabasca River fell below the chronic guideline (6.5 mg/L) for over a month (Chambers et al. 2006). Low DO can potentially cause an ecological impact on the benthic invertebrate community in an ice-covered river.

Mayflies (*Baetis tricaudatus*) exposed to low DO (5 mg/L) experienced modified distribution, decreased grazing intensity, and reduced survival (Lowell and Culp 1999). The Alberta Surface water quality chronic (7-d mean) DO guideline is 6.5 mg/L for the protection of aquatic life (Lowell and Culp 1999). Alberta Environment (2004) reported a decrease in benthic invertebrate abundance and diversity when the Athabasca River experienced low DO (5.8 mg/L).

A correlation between low DO and increased drift in benthic invertebrates has been shown (Brittain and Eikeland 1988). In this chapter I tested benthic invertebrate response to experimental manipulations of DO, turbulence, shear/velocity, water depth, flow rate and temperature. A laboratory microcosm was set up as an artificial stream in a re-circulating system that simulates abiotic parameters that influence benthic invertebrate drift rate. Light was not measured as a factor that affected benthic invertebrate drift rate because benthic invertebrate drift rate is only affected by light in a diel pattern (Graesser and Lake 1984; Rader and Ward 1990; Allan et al. 1986). Salinity was also not measured as a factor that affected benthic invertebrate drift rate, because salinity does not affect benthic invertebrate drift rate below approximately 1500 mg/L (Goetsch and Palmer 1997).

Benthic invertebrates of the EPT Orders (Orders Ephemeroptera, Plecoptera and Trichoptera) are more sensitive to low DO than benthic invertebrates of the Order Diptera and other benthic invertebrates. Alberta Environment (2004) showed that EPT abundance and diversity was more adversely affected by low DO in the Athabasca River, compared to other benthic invertebrate Orders. The effect of DO on the drift of EPT Orders was developed in this study, and compared to the Order Diptera and all of the species of benthic invertebrates.

Kruzic et al. (2005) showed that electroshocking induces benthic invertebrate drift similar to a low DO event. In this study I compared the impacts of electroshocking (50 second pulse, 350 volts and 4 amps for 5 minutes) and low

DO on the benthic invertebrate drift rate, to determine the DO range simulated by electroshocking.

The ecological impact over the entire DO scale, and the mechanism of the ecological impact of a low DO event in an ice-covered river were determined in this study. The Athabasca River has experienced DO levels between the chronic (6.5 mg/L) and acute (5.0 mg/L) guidelines (Chambers et al. 2006). The relationship between the DO level and the benthic invertebrate drift rate was developed for the sensitive range of 5.0-6.5 mg/L DO, to determine the ecological impact in this important DO range and assess its consequences.

METHODS

A flume was run without a benthic invertebrate sample using regular tap water. The flume was non-sloped, approximately 6 m in length and 1 m in height with clear plastic siding, and it was elevated off the ground by approximately one metre (Fig. 3-1). The flume was set up in a re-circulating system where 500 L of regular tap water were placed in a 1 m^3 water holding reservoir (Fig. 3-2), and pumped into a tube connected to the far end of the flume. The re-circulating system of the flume was attached to a flow meter (Figs. 3-1, 3-2 and 3-4) that measured the flow rate of the system. The flow rate and the depth of the water inside the flume were altered using the flume wier adjustment wheel at the top of the flume (Fig. 3-1). A Nitex seine net (500 μm mesh size) was cut to a size of approximately 0.5 m X 0.5 m and placed inside the flume at the end of the section of gravel (Fig. 3-2). A Nitex drift net (363 μm mesh size) was modified at its end by cutting open a slit to fit over the cap of a 1 L nalgene bottle. The cap was modified by cutting a large hole in it to allow benthic invertebrates to enter the 1 L nalgene bottle. This drift net was placed inside the flume a couple centimetres downstream of the seine net (Figs. 3-3b and 3-5). A Field Case Hach HQ 40D DO probe was placed in the section of gravel for measuring the DO level (Figs. 3-4 and 3-5). Ice blocks were put in the water holding reservoir and in the section of gravel, to lower the temperature to within a range of 0 ^{o}C to 5 ^{o}C. A thermometer was placed in the section of gravel. 750 mg/L of sodium sulphite was added to decrease DO from approximately 10 to 0 mg/L.

Benthic invertebrates and substrate were collected from the North Saskatchewan River. A 0.5 m X 0.455 m section of the river was sampled. Large stones were carefully removed and placed in an experimental tray. This was to ensure the associated periphyton and benthic invertebrates remained with the stones. Then the substratum beneath the stones was disturbed by kicking it into a bottom kick net (Nitex model, 40 inch handle, 500 μm mesh size) to collect any benthic invertebrates in the substrate. The sample was placed in an 8 L container that was well-aerated by mixing and transported to the laboratory.

Because the benthic invertebrate drift rate would be at a maximum at a DO level of zero, 750 g of sodium sulphite were added to the water holding reservoir and mixed using a shovel (Fig. 3-3a). The seine net was initially removed and the drift net was submerged along with an attached nalgene bottle. The substrate sample was placed on the gravel (0.5 m X 0.455 m X 0.08 m space) in the flume to create an artificial substrate (Figs. 3-3b, 3-4a and 3-5). After adding the sample the timer was immediately started. Every thirty seconds the nalgene bottle on the drift net was replaced for 600 seconds total. The seine net was placed back in front of the drift net. The replicates were individually analyzed under a dissecting microscope. For the 30-second replicates, only total benthic invertebrate counts were done (Fig. 3-6). This exact same procedure was repeated, except replicates were taken every 40 seconds. Total benthic invertebrate counts corresponded to drift rates. Both of the experimental runs showed that an appropriate acclimation period was 80 seconds when the drift rate decreased exponentially. Also both of the experimental runs showed 280 seconds to be the maximum allowable length of an experimental run, where the drift rate was constant, before the drift rate began to follow a quadratic decay.

Ice was put into the flume and water holding reservoir and the substrate sample was placed on the gravel in the flume to create an artificial substrate (Figs. 3-3b, 3-4a and 3-5). The timer was allowed to run 80 seconds (acclimation period), at which point the seine net was removed, rotated 180^{o}, and attached to the flume walls at the other end of the artificial substrate. The flume wier adjustment wheel (Fig. 3-1) was randomly turned in either direction, either partially or fully, to randomly modify the water depth and flow rate. During the 80-second replicate, the DO level (mg/L) was measured using the DO probe (Figs. 3-1, 3-4 and 3-5), the temperature (^{o}C) was measured using the thermometer (Figs. 3-4a and 3-5), the water depth (cm) was measured using a metre stick, and the flow rate (L/s) was measured using the flow meter (Fig. 3-4).

After 80 seconds the nalgene bottle attached to the drift net was removed and replaced by another nalgene bottle and two more replicates were performed. After the third replicate, the seine net was removed and placed back in front of the drift net. The three replicates were analyzed using a dissecting microscope. Two examples of increments of a replicate in a gridded petri dish are shown in Figure 3-7. The benthic invertebrates were identified to the level of Order for Ephemeroptera, Plecoptera, Trichoptera, and Diptera, and identified as “Other” for all other benthic invertebrates, using the recognized taxonomic keys, Clifford (1991) and Merritt, Cummins and Berg (2008). Then the replicates were placed back in the artificial substrate and approximately 90 g of sodium sulphite were added to the water holding reservoir (Fig. 3-3a). Another experimental run was performed at the corresponding DO level. This procedure was repeated for continuously larger doses of sodium sulphite, until DO was lowered to approximately zero. For some of the experimental runs only two replicates were taken. Finally the artificial substrate was shovelled into an 8 L container. This exact same procedure was repeated three times for a total of 20 experimental runs and 42 replicates. The sodium sulphite dosage wasn’t always in multiples of 90 g for each experimental run, but varied in an attempt to have a wide variety of experimental runs with different DO levels between zero and ambient DO. A larger amount of experimental runs were done in the DO range of 5.0-6.5 mg/L (7 experimental runs).

Electroshocking was done on the North Saskatchewan River using a Smith Root Electrofisher Backpack (Model LR-24). Electroshocking was done with a 50 second pulse for 5 minutes at 350 volts and 4 amps. Three Neill cylinder samples were taken in the electroshocked section. Upstream of the section that was electroshocked, three more Neill cylinder samples were taken as reference samples.

For the samples in 8 L containers rocks were separated and discarded from the debris and benthic invertebrates. Invertebrates were removed from organic and inorganic material. Then they were passed through 2 mm, 1 mm, 500 µm and 180 µm sieves to separate the samples into coarse (2 mm and 1 mm sieves) and fine size fractions (500 µm and 180 µm sieves). All of the fractions were examined portion-by-portion on a gridded petri dish under a dissecting microscope. Fine size fractions of large samples were sub-sampled according to the methods of Wrona et al. (1982). Benthic invertebrates were identified to the lowest practical taxonomic level, typically genus for most invertebrates within the Class Insecta, with the exception of the Chironomidae (Diptera). Chironomids were identified to subfamily or tribe. Small, early instar animals were identified to the lowest level possible, generally to family (Alberta Environment 1990). The benthic invertebrate identification was done using the recognized taxonomic keys, Clifford (1991) and Merritt, Cummins and Berg (2008) by a hired independent benthic invertebrate taxonomist.

For the electroshocking and reference samples, percent drift per minute was calculated for Ephemeroptera, Plecoptera, Trichoptera, Diptera, other benthic invertebrate species, and all benthic invertebrate species. For each flume sample the totals for Ephemeroptera, Plecoptera, Trichoptera, Diptera, other benthic invertebrates, and all benthic invertebrates were determined. For each replicate for the flume samples, velocity (m/s) was determined using the following formula:

$$V = \frac{F/(d * 0.455\text{m})}{1000}$$

V = velocity (m/s)

F = flow rate (L/s)

d = water depth (m)

For each replicate the shear velocity (m/s) was estimated as one-tenth of the velocity. Also for each replicate the turbulence (Re) was determined using the following formula:

$$Re = \frac{VRh}{v}$$

V = velocity (m/s)

Rh = $\frac{Area}{Perimeter}$ = $\frac{d*0.455\text{m}}{2d+0.91}$

d = water depth (m)

$$v = \frac{\mu}{\rho}$$

μ = viscosity of water (kg/(m * s)) $= e^{-1.94-4.80\left(\frac{T0}{T}\right)+6.74\left(\frac{T0}{T}\right)\hat{}2}\mu_0$

μ_0 = 0.001792 kg/(m*s)

T = temperature (K)

T_0 = 273.16 K

ρ = density of water (kg/m^3) = 1000 kg/m^3 at T = 0-10 ^oC

For each replicate the counts for Ephemeroptera, Plectoptera, Trichoptera, Diptera, other benthic invertebrate species and total benthic invertebrate species were converted to percent drift per minute. Percent drift per minute was used because percent drift accounted for differences between sample totals, and the percent drift was per minute because minute was the closest single unit to an 80-second replicate. Regressions for the variables DO, temperature, shear velocity, water depth, flow rate and turbulence versus percent drift per minute were done for each of the Orders, other benthic invertebrate species and all benthic invertebrate species. The variables, the squares of the variables (to account for the quadratic regressions), and variable interaction effects were put in a GLS (generalized least squares) linear regression with each of the Orders, other benthic invertebrate species and all benthic invertebrate species using the program IBM SPSS Statistics 19. The non-significant variables were removed, and the linear regressions (WLS (weighted least squares) for no correlating variables and GLS for correlating variables) were re-run in SPSS to determine the strongest linear regression for each Order, other benthic invertebrate species and all benthic invertebrate species. Also some of the linear regressions were improved by running them at DO<5 mg/L.

RESULTS

Table 3-1 gives descriptive parameters for the electroshocking and reference samples for the Orders Ephemeroptera, Plecoptera, Trichoptera, Diptera, other benthic invertebrate species and all benthic invertebrate species. The drift rates for these Orders, other benthic invertebrate species and all benthic invertebrate species are highlighted in Table 3-1. These drift rates can be compared to calculated drift rates at low DO from the regression equations.

The Plecoptera totals for the flume samples were between 1 and 3, which didn't allow for a large range of drift rates that could be developed into a significant pattern with the independent variables. Therefore regression equations between the independent variables and the benthic invertebrate drift rate were not developed for the Order Plecoptera.

The baseline drift rate at ambient DO, similar to expectations in a river, for the Order Ephemeroptera was 1.7 %drift/min, for the Order Trichoptera was 4.2 %drift/min, for the Order Diptera was 0.035 %drift/min, and for all benthic invertebrate species was 0.68 %drift/min.

For the individual regressions between Ephemeroptera drift rate and the independent variables DO level, temperature, turbulence, water depth, flow rate and shear, the only significant linear regression was with turbulence ($P<0.01$). Figure 3-9 shows this significant linear regression ($R^2 = 0.21$) with the regression equation, drift rate = 0.016(turbulence) – 28. The linear regression for Ephemeroptera drift rate versus DO level was non-significant (Fig. 3-8). For the individual regressions between Trichoptera drift rate and the independent variables, the only significant linear regression was with the DO level (R^2 = 0.27; P<0.01) (Fig. 3-11). For the individual regressions between Diptera drift rate and the independent variables, the only significant linear regression was with the DO level (R^2 = 0.24; P<0.01). The regression equation was drift rate = -0.047(DO) + 0.53 (Fig. 3-12). There was no significant regression between drift rate of the other benthic invertebrate species and the independent variables. But the strongest regression between the drift rate for the other benthic invertebrate species and an independent variable was a quadratic regression between drift rate and temperature (R^2 = 0.19). For the individual regressions between the drift rate for all benthic invertebrate species and the independent variables, there was a non-significant linear regression with the DO level (R^2 = 0.17; P>0.01) (Fig. 3-13).

For the WLS linear regression between Ephemeroptera drift rate and DO level and turbulence, the adjusted R^2 was improved without being significantly different from the R^2 (R^2 = 0.25). Therefore a better regression model for Ephemeroptera drift rate is drift rate = 0.018(turbulence) – 0.27(DO) – 31. For the WLS linear regression between Trichoptera drift rate and DO level and shear, the adjusted R^2 was improved without being significantly different from the R^2 (R^2 = 0.37). The formula is drift rate = -0.52(DO) + 1452 (shear) – 2.2. For the WLS linear regression between Diptera drift rate and DO level and temperature (quadratic), the adjusted R^2 was improved without being significantly different from the R^2 (R^2 = 0.39). Therefore an alternate regression model for Diptera is drift rate = -0.057(DO) + 0.082(temperature)^2 – 1.1(temperature) + 4.0. The GLS linear regression between the other invertebrate species drift rate with the independent variables DO level, temperature, turbulence, water depth and shear (including squares and interaction effects) was non-significant. For the WLS linear regression for the drift rate for all species versus DO level (linear) and temperature (quadratic), the improved formula is 0.13(temperature)^2 – 1.6(temperature) – 1.0(DO) + 6.2. The regression had the highest possible adjusted R^2 without being significantly different from the R^2 (R^2 = 0.33).

The linear regressions for Ephemeroptera and all species were improved when using a portion of the data. These linear regressions were appropriate for Ephemeroptera and all species because they were based on the hypothesis that the regression equation has a slope that changes from zero to a positive number at a particular DO point as the DO level decreases. The linear regression equation for the Ephemeroptera drift rate and the DO level at DO<5 mg/L is drift rate = -1.6(DO) + 9.1 (R^2 = 0.35) (Fig. 3-10). The linear regression equation for the Ephemeroptera drift rate and the DO level and turbulence for DO<5 mg/L is drift rate = 0.010(turbulence) – 1.5(DO) - 12 (R^2 = 0.39). There is no pattern for the Ephemeroptera drift rate between 5 mg/L DO and ambient DO, and at ambient DO the baseline drift rate is 1.7 %drift/min. The linear regression equation for the drift rate for all species and the DO level at DO<5 mg/L is drift rate = –0.19(DO) + 1.4 (R^2 = 0.23) (Fig. 3-14). The regression equation for the drift rate for all species and the DO level and temperature for DO<5 mg/L is drift rate = –0.28(DO) + 0.23(temperature)^2 – 3.0(temperature) + 11 (R^2 = 0.37). There is no pattern for the drift rate for all species between 5 mg/L DO and ambient DO, and at ambient DO the baseline drift rate is 0.68 %drift/min. Table 3-2 is a summary of all of the regression equations' coefficients, constants and R^2 values.

DISCUSSION

The only significant independent variable that affected the drift rate of benthic invertebrates of the Order Ephemeroptera was the turbulence in a linear regression. But there was a significant regression equation for the Order Ephemeroptera drift rate and the DO level with DO<5 mg/L ($R^2 = 0.34$) (Fig. 3-10), matching the hypothesis that the drift rate becomes sloped at a particular DO level (DO = 5 mg/L). The optimal regression for the drift rate of the Order Ephemeroptera included both the independent variables turbulence and the DO level with DO<5 mg/L ($R^2 = 0.39$). The only significant independent variable that affected the drift rate for benthic invertebrates of the Orders Trichoptera and Diptera was the DO level. The DO level causes a particular drift rate above the ambient DO drift rate (4.2 %drift/min for the Order Trichoptera and 0.035 %drift/min for the Order Diptera), and lower DO levels cause higher drift in a linear pattern. Low DO induces benthic invertebrates to change position. If changing position and physiological regulation do not fulfill the respiratory needs of benthic invertebrates, they will actively start drifting. The Trichoptera drift rate had a strong linear regression with DO level ($R^2 = 0.27$), and was improved with the addition of a linear shear term ($R^2 = 0.37$). The Diptera drift rate had a weak linear regression with DO level ($R^2 = 0.24$), and was significantly improved with the addition of quadratic temperature terms (R^2 = 0.39). The drift rate for the other benthic invertebrates could not significantly be explained by any of the independent variables, but the strongest independent variable that affected the drift rate was temperature in a quadratic relationship (R^2 = 0.19). The optimal regression for the drift rate of all of the species of benthic invertebrates included the independent variables DO level and temperature (R^2 = 0.33). The drift rate for all species had a linear regression with DO level at DO<5 mg/L (R^2 = 0.23), and was significantly improved with the addition of quadratic temperature terms (R^2 = 0.37). For the Order Ephemeroptera and all species of benthic invertebrates DO causes a particular drift rate below 5 mg/L DO, and lower DO levels cause higher drift in a linear pattern. There is no pattern between 5 mg/L DO and the ambient DO, and at ambient DO the baseline drift rate is 1.7 %drift/min for the Order Ephemeroptera and 0.68 %drift/min for all of the species.

When the electroshocking-induced Trichoptera drift rate of 7.5 %drift/min (Table 3-1) is put into the Trichoptera regression equation, the DO is 0.90 mg/L. When the electroshocking-induced drift rates for Ephemeroptera (11 %drift/min), Diptera (5.2 %drift/min) and all species (6.5 %drift/min) (Table 3-1) are put into their respective regression equations, the DO values are all negative. Therefore the electroshocking simulated a DO close to zero for Ephemeroptera, Diptera and all species. The electroshocking-induced drift rates for Ephemeroptera, Diptera and all species are higher than the drift rates caused by minimum DO in the regression equations. This shows that the ecological impact of electroshocking on

Ephemeroptera, Diptera and all species is stronger than the impact of a low DO event.

The linear regression equation for all species is improved when DO is less than 5 mg/L. This is exemplified by both the Ephemeroptera dataset (Fig. 3-10) and more generally by the dataset as a whole (Fig. 3-14). This shows that benthic invertebrate species are significantly affected by low DO at approximately the acute guideline (5 mg/L). This verifies the government of Alberta acute DO guideline (5 mg/L) for the protection of aquatic life in northern rivers.

The Diptera regression that used DO level as the independent variable was weak (R^2 = 0.24) and was significantly improved (R^2 = 0.39) with the addition of quadratic terms for temperature. The regression equations with two independent variables for Diptera and all species include quadratic temperature terms. Also the strongest independent variable that affected the drift rate for the other benthic invertebrate species was temperature in a quadratic relationship (R^2 = 0.19). Therefore temperature affects non-EPT benthic invertebrates in a quadratic relationship. There is an optimal temperature, and if the temperature is increased or decreased from the optimal temperature the drift rate exponentially increases. This optimal temperature for the Order Diptera was approximately 6.6 ^{o}C, and for all of the benthic invertebrate species was approximately 6.3 ^{o}C. Increasing temperature has been shown to exponentially increase benthic invertebrate drift rate (Pearson and Franklin 1968; Brittain and Eikeland 1988). However, most of the studies that showed this were done in rivers with water temperatures above the optimal temperature, so the decrease in drift rate from increasing temperatures below the optimal temperature was not observed. Also all studies were done in rivers, where the correlation between temperature and DO could not be removed like was done in this study. Therefore, when the temperatures decreased (below the optimal temperature), the DO increased and the high DO was a stronger influence than the low temperature in overall decreasing the drift rate. Therefore the drift rate increased as temperature increased over the entire temperature range, even below the optimal temperature.

The effect of lowering DO on the drift rate of benthic invertebrates of the Order Ephemeroptera follows no pattern for the entire DO scale (non-significant regression) (Fig. 3-8). There is a maximum ecological impact of 1.6 %drift/min over the entire DO range for the Order Ephemeroptera. For DO<5 mg/L (significant regression) there is a maximum ecological impact of 8.1 %drift/min. The ecological impact of lowering DO for the Order Diptera is an insignificant linear increase in Diptera drift rate to a maximum impact of approximately 0.47 %drift/min at 0 mg/L DO. A maximum ecological impact of 0.47 %drift/min for the entire DO scale is very weak. For the Order Trichoptera, the ecological impact on the drift rate linearly increases to a maximum impact of 5.2 %drift/min at 0 mg/L DO. For all species of benthic invertebrates, the ecological impact on the drift rate linearly increases from 5 mg/L to 0 mg/L to a maximum impact of 0.96 %drift/min at 0 mg/L DO. The ecological impact of lowering DO is the most significant for Ephemeroptera and Trichoptera, the EPT Orders. The Orders Ephemeroptera (8.1 %drift/min increase) and Trichoptera (5.2 %drift/min increase) experience the strongest ecological impact for the entire DO scale. This shows that the EPT taxa are more adversely affected by low DO compared to the Order Diptera and all benthic invertebrate species, as was shown by Munro and Taccogna (1994).

The ecological impacts predicted from the regression equations can be cautiously applied to the Athabasca River. However, the use of the regression equations as a benthic invertebrate drift model would have to be done with caution based on the R^2 values of the regression equations. Although the regression equations give insight into the effect of DO and the other independent variables on benthic invertebrate drift rate, they require further development. The regression model for the effect of DO on the drift rate of the Order Plecoptera would need to be developed, possibly using a laboratory culture of benthic invertebrates of the Order Plecoptera. The R^2 values of the regression equations could be improved in several ways. The regression models could be further improved by controlling for size of the benthic invertebrates. The length of the benthic invertebrates could be measured, or laboratory cultures of a particular benthic invertebrate size range could be used. The regression models could be further improved by measuring the impact of a larger temperature scale (>10 ^{o}C). Also the regression models could be further improved by measuring the impact of a larger velocity and turbulence scale. The experiment was run for a minimum Athabasca River winter velocity and turbulence range (Beak 1995). The effect of the entire Athabasca River velocity and turbulence range on the benthic invertebrate drift rate could be determined. The model would need to be verified using a second data set from a different site. All of these improvements would be necessary before the regression equations could be used for a benthic invertebrate drift rate model.

CONCLUSIONS

The drift rates of the Orders Diptera and Trichoptera are significantly affected by DO level. The drift rates of the Order Ephemeroptera and all species of benthic invertebrates are significantly affected by DO level for DO<5 mg/L. This verifies the government of Alberta acute DO guideline (5 mg/L) for the protection of aquatic life in northern rivers. The Orders Ephemeroptera and Trichoptera experienced the strongest ecological impact for the entire DO scale, showing that EPT Orders are more sensitive to low DO.

The regression equations in this study can be cautiously applied to the Athabasca River to determine ecological impacts of low DO. But the regression equations require improvement for the development of a benthic invertebrate drift rate model. A regression equation needs to be developed for the Order Plecoptera, and R^2 values could be improved by controlling for the size of benthic invertebrates. The effect of larger temperature, velocity and turbulence ranges on benthic invertebrate drift rates needs to be measured. Also the model would need to be verified using a second data set from a different site.

TABLE 3-1 Descriptive parameters for the electroshocking and reference samples from the North Saskatchewan River.

Order	Reference Total Count	Treatment Total Count	Total Drift	Drift Rate (%drift/min)
Ephemeroptera	692	305	387	11
Plecoptera	6	4.7	1.3	4.4
Trichoptera	276.5	173	103.5	7.5
Diptera	4757	3517	1240	5.2
Other Species	985	563	422	8.6
Total Species	3282	2215	1067	6.5

TABLE 3-2 Summary of coefficients and R^2 values for the significant regression equations for the Orders Ephemeroptera, Trichoptera, Diptera, and total species.

Order	DO coefficient	Temperature squared coefficient	Temperature coefficient	Turbulence coefficient	Shear coefficient	Constant	R^2
Ephemeroptera (turb)	N/A	N/A	N/A	0.016	N/A	28	0.21
Ephemeroptera (turb, DO)	0.27	N/A	N/A	0.018	N/A	31	0.25
Ephemeroptera (DO)(DO<5 mg/L)	-1.6	N/A	N/A	N/A	N/A	9.1	0.34
Ephemeroptera (turb, DO)(DO<5 mg/L)	-1.5	N/A	N/A	0.010	N/A	-12	0.39
Trichoptera (DO)	-0.52	N/A	N/A	N/A	N/A	6.6	0.27
Trichoptera (DO, shear)	-0.52	N/A	N/A	N/A	1452	-2.2	0.37
Diptera (DO)	-0.047	N/A	N/A	N/A	N/A	0.53	0.24
Diptera (DO, temp)	-0.057	0.082	-1.1	N/A	N/A	4.0	0.39
Total (DO, temp)	-1.0	0.13	-1.6	N/A	N/A	6.2	0.33
Total (DO) (DO<5 mg/L)	-0.19	N/A	N/A	N/A	N/A	1.4	0.23
Total (DO, temp) (DO<5 mg/L)	-0.28	0.23	-3.0	N/A	N/A	11	0.37

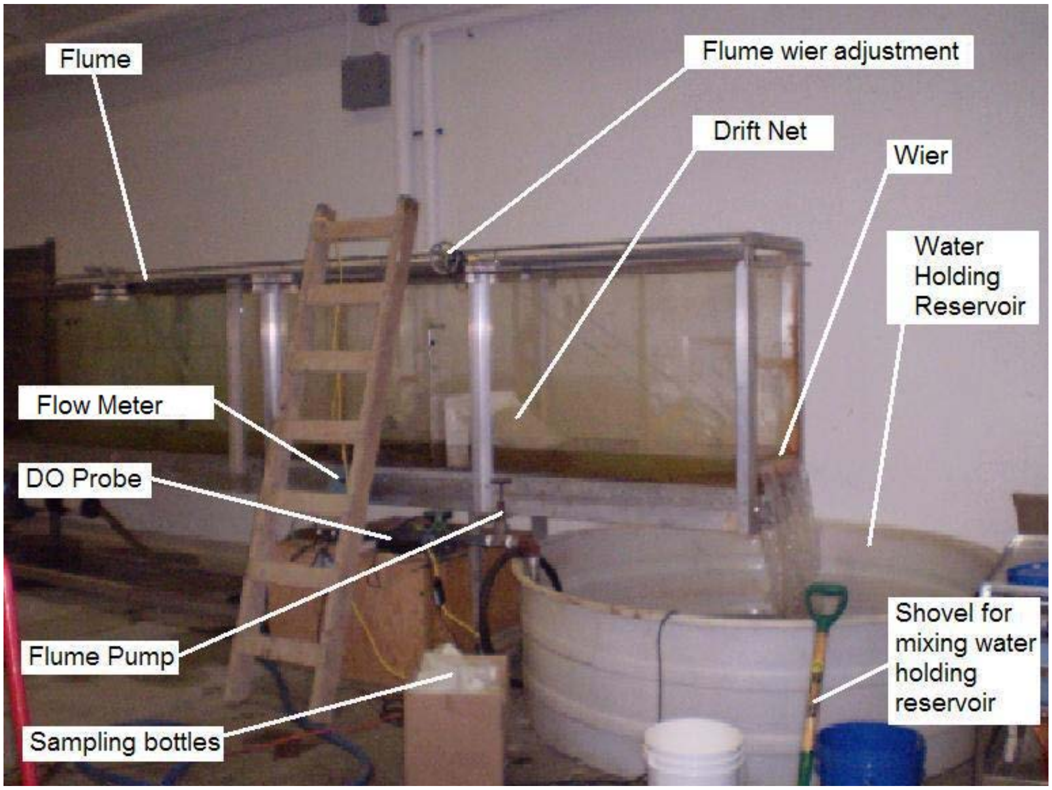

FIGURE 3-1 Photo of the flume re-circulating system with the key components highlighted (flume wier adjustment, wier, water holding reservoir, flume pump and flow meter), and some accessories to the experiment also highlighted (drift net, shovel, sampling bottles, and DO probe)

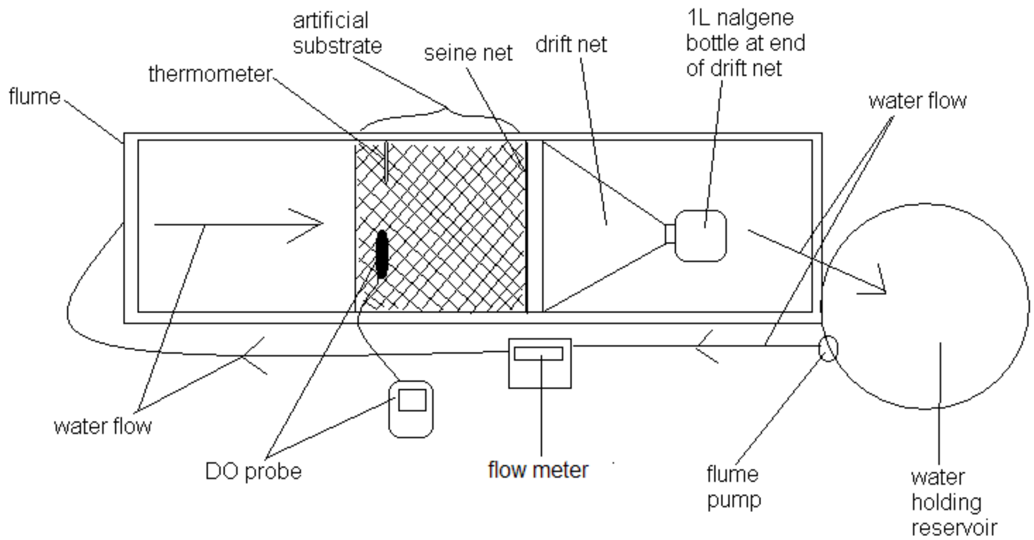

FIGURE 3-2 Schematic diagram of the flume re-circulating system with the key components highlighted (water holding reservoir, flume pump and flow meter), and some accessories to the experiment also highlighted (drift net, seine net, thermometer, artificial substrate, nalgene bottle and DO probe)

FIGURE 3-3 a) Close-up of the water holding reservoir, showing water entering from the flume and being pumped out by the flume pump. During the experiment sodium sulphite was added to the water holding reservoir and the water holding reservoir was mixed with a shovel; b) Close-up of the configuration of the seine net and drift net downstream of the artificial substrate, where the seine net blocks the entrance of the drift net when the experimental run is not occurring

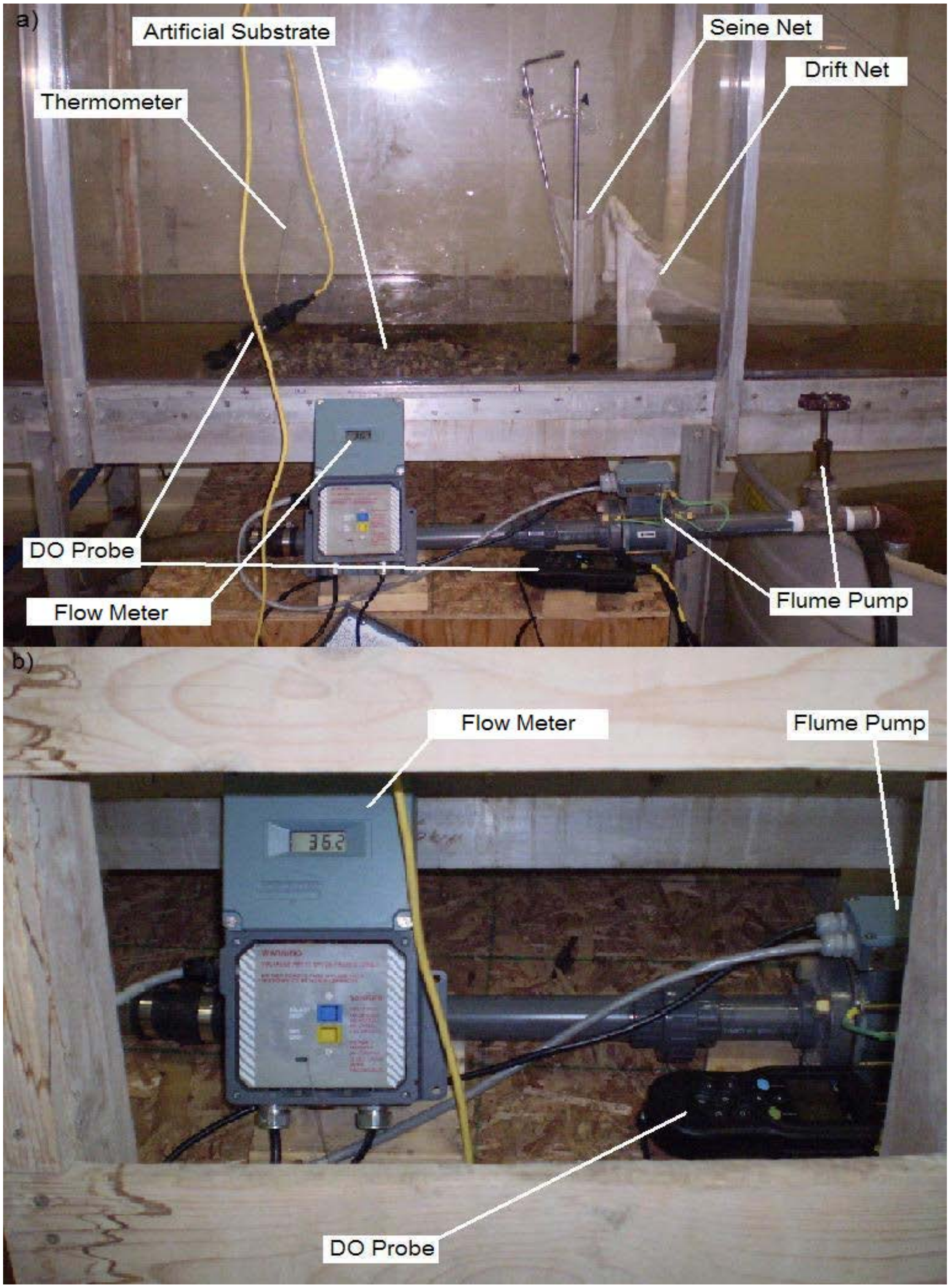

FIGURE 3-4 a) The middle of the flume with the artificial substrate with the seine and drift net downstream and the thermometer and DO probe upstream. Below the flume runs the flume pump connected to a metal pipe that runs through the flow meter that is connected to a tube; b) Close-up of the flume pump connected to a metal pipe that runs through the flow meter

FIGURE 3-5 a) Side view of the section of artificial substrate in the middle of the flume with the thermometer and DO probe upstream and the seine and drift net downstream; b) Top view of the section of artificial substrate in the middle of the flume with the thermometer and DO probe upstream and the seine and drift net downstream. The drift net end with a nalgene bottle cap secured with duct tape is visible here

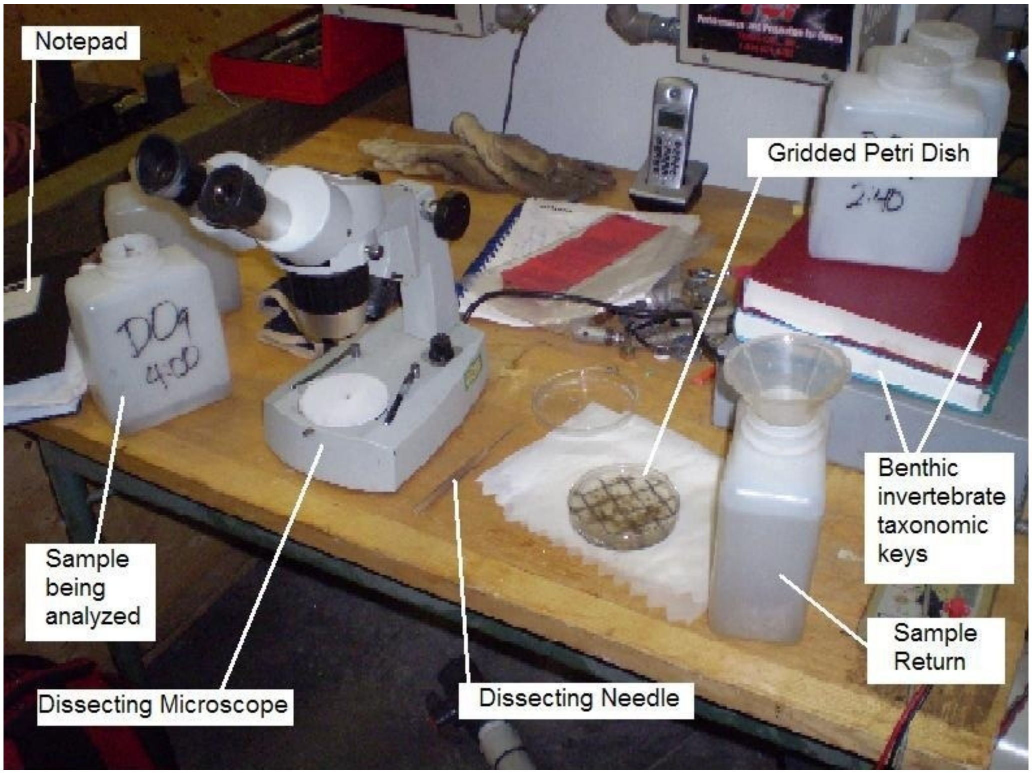

FIGURE 3-6 Photo of the dissecting microscope where replicates are analyzed. Replicates are incrementally placed in a gridded petri dish and analyzed under the dissecting microscope using a dissecting needle, and then incrementally placed in another 1L nalgene bottle after being analyzed. The Ephemeroptera, Plecoptera, Trichoptera, Diptera, other benthic invertebrate species and total benthic invertebrate species are identified using benthic invertebrate taxonomic keys and tallied in a notepad

FIGURE 3-7 a) Close-up of a typical increment of a replicate in the gridded petri dish. The gridded petri dish is placed under the dissecting microscope and each square of the grid is observed for benthic invertebrates, using the dissecting needle to move debris and benthic invertebrates if necessary b) Close-up of an increment with a large amount of debris and a large benthic invertebrate visible to the naked eye (*Pteronarcys* sp. of the Order Plecoptera)

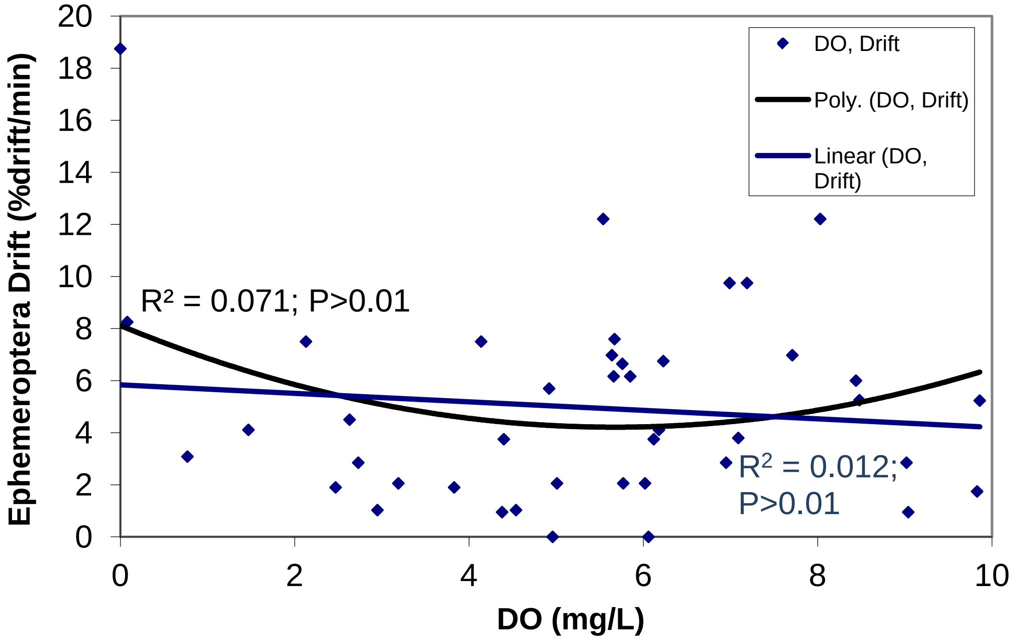

FIGURE 3-8 The relationship between the independent variable DO (mg/L) and the dependent variable, drift rate (% drift/min) for the Order Ephemeroptera. Both the linear regression (R^2 = 0.012) and the quadratic regression (R^2 = 0.071) are insignificant

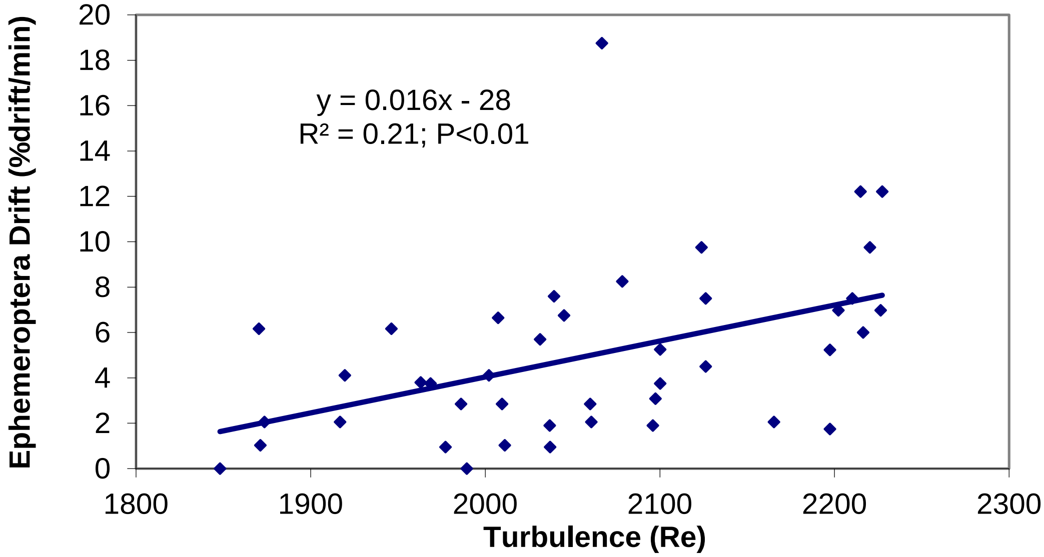

FIGURE 3-9 The relationship between the independent variable turbulence (Re) and the dependent variable, drift rate (% drift/min) for the Order Ephemeroptera. The linear regression ($R^2 = 0.21$) is significant and the regression equation is shown

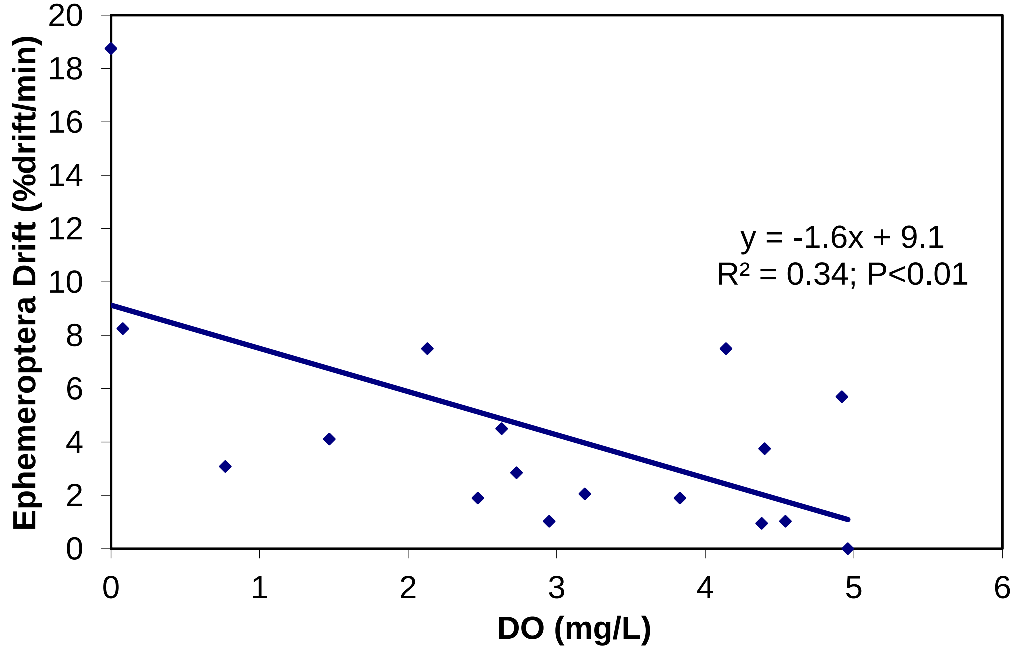

FIGURE 3-10 The relationship between the independent variable DO (mg/L) and the dependent variable, drift rate (% drift/min) for the Order Ephemeroptera. The linear regression is for DO<5 mg/L, because the DO sharply increases at DO=5 mg/L. The linear regression is significant (R^2 = 0.34) and the regression equation is shown

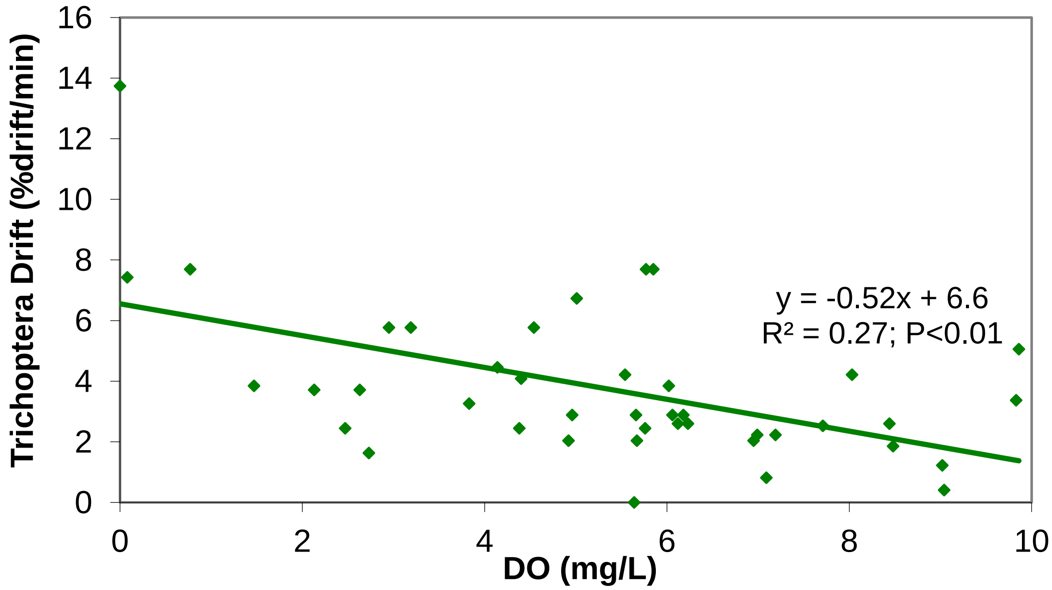

FIGURE 3-11 The relationship between the independent variable DO (mg/L) and the dependent variable, drift rate (% drift/min) for the Order Trichoptera. The linear regression (R^2 = 0.27) is significant

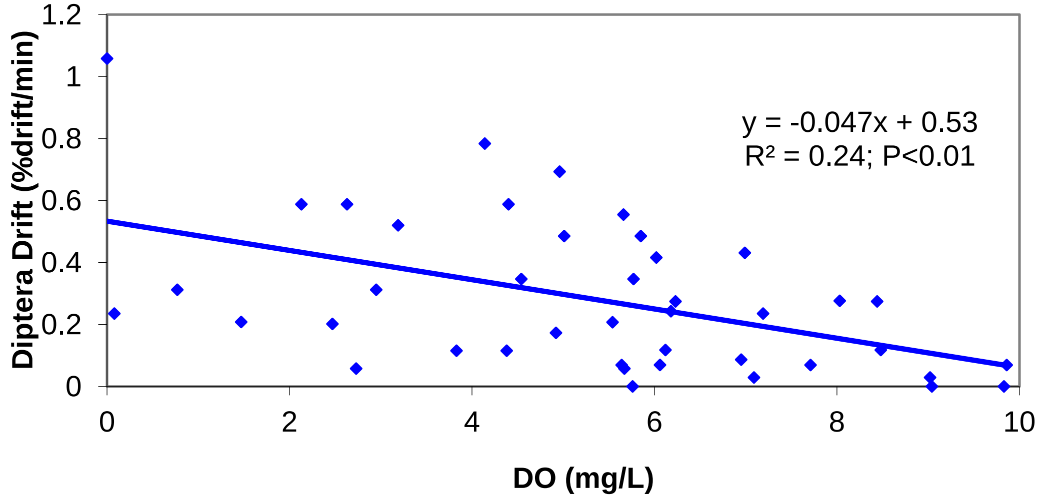

FIGURE 3-12 The relationship between the independent variable DO (mg/L) and the dependent variable, drift rate (% drift/min) for the Order Diptera. The linear regression (R^2 = 0.24) is significant and the regression equation is shown

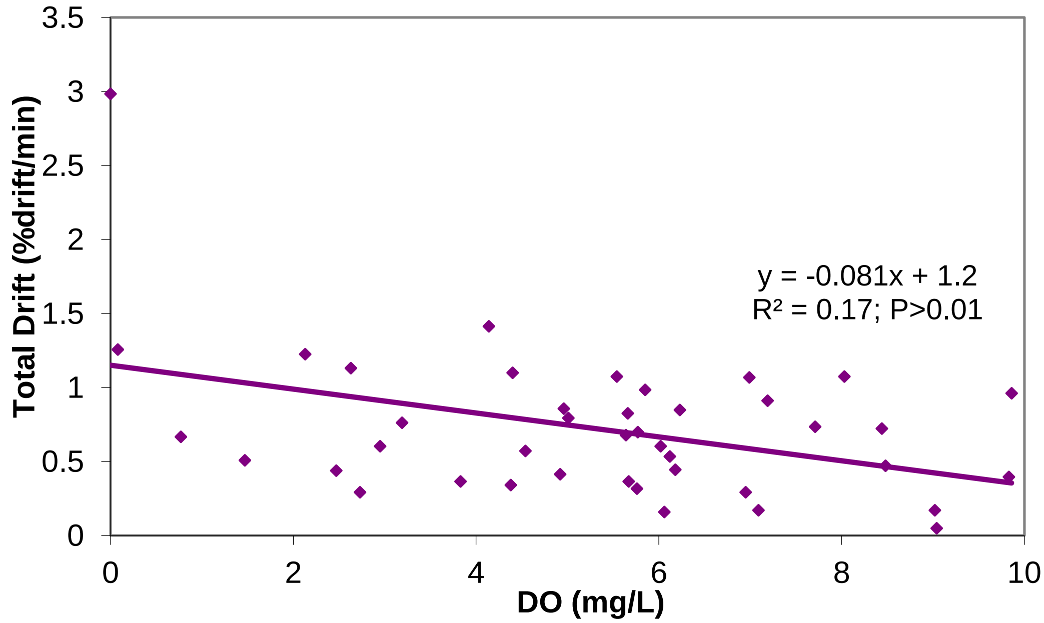

FIGURE 3-13 The relationship between the independent variable DO (mg/L) and the dependent variable, drift rate (% drift/min) for all of the benthic invertebrate species. The linear regression (R^2 = 0.17) is not significant

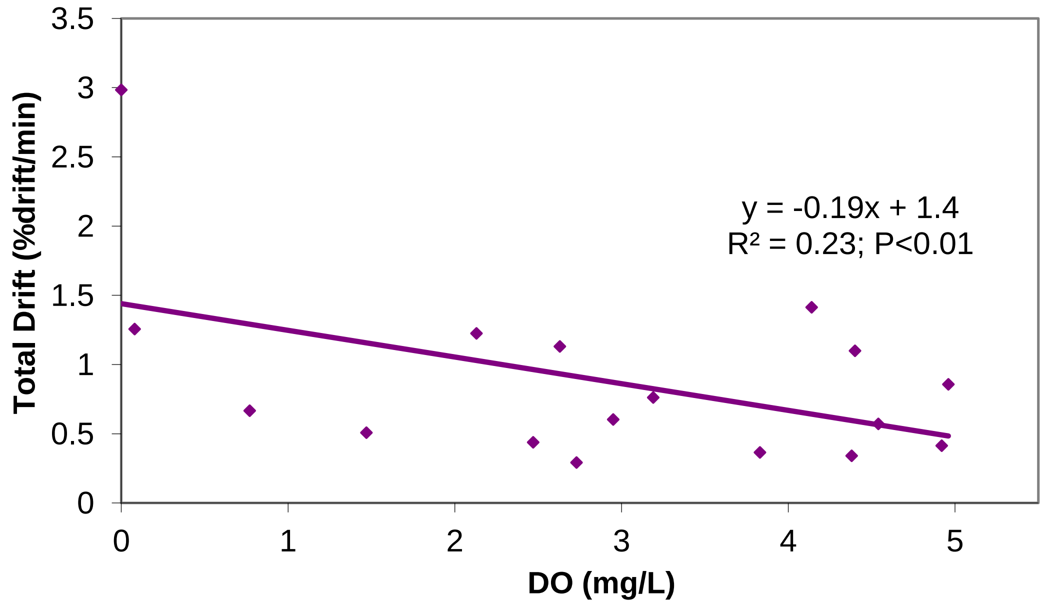

FIGURE 3-14 The relationship between the independent variable DO (mg/L) and the dependent variable, drift rate (% drift/min) for all of the benthic invertebrate species. The linear regression is for DO<5 mg/L, because the DO sharply increases at DO=5 mg/L. The linear regression is significant (R^2 = 0.23) and the regression equation is shown

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APPENDIX A

BENTHIC INVERTEBRATE TALLIES AND DESCRIPTIVE STATISTICS

FOR SAMPLES FROM THE C-BRIDGE EXPERIMENTAL SITE TAKEN

OCTOBER 30, 2006 TO MAY 8, 2009

TABLE A1 Raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken October 30 to November 1, 2006, and descriptive statistics

									Mean	Mean	Max
Order	**Family**	**Genera (unless noted)**	Ref 1	Ref 2	Ref 3	Treat 1	Treat 2	Treat 3	Ref	Treat	Ref
Diptera	Chironomidae	SF Tanypondinae	27	13	23	5	10		21	8	27
		other chironomids	31	89	69	22	13	7	63	14	89
		pupae	1	1							
	Simuliidae		1								
	Ceratopogonidae		2	2	13	2	2	1	6	2	13
	Empididae		23	19	3	1			15	1	23
	Tipulidae				1						
	Dolichopodidae (?)		1								
Ephemeroptera	imm. Ephemeropterans			1	1						
	Heptageniidae	imm. or dam. Heptageniids	13	18	21	14	9	4	17	9	21
		Stenonema	6	6	16	3	3	2	9	3	16
		Heptagenia	6	8	8	3	3	1	7	2	8
		Cinygma	12	23	22	10	7	4	19	7	23
		Rithrogena			21	4	4		21	4	21
	Metretopodidae	Siphloplecton		3		2	10	1	3	4	3
	Leptophlebiidae	Paraleptophlebia		1		6			1	6	1
	Ephermerellidae	imm.	5	3			1		4	1	5
	Siphloneuridae	Parameletus			5	2	1	2	5	2	5
	Baetidae	imm. or dam. Baetids	7	5	10	3	2		7	3	10
		Centroptilum	1	1			3		1	3	1
Plecoptera	imm. Plecopterans		14	5	3	3	7	3	7	4	14
	Chloroperlidae		4		7	1			6	1	7
	Perlodidae		7	3	2	1	1		4	1	7
Trichoptera	Hydrophychidae	imm. Hydropsychid		1					1	0	1
		Hydropsyche	6				1		6	1	6
	Lepidostomatidae	Lepidostoma				1			0	1	0
	Brachycentridae	imm.	1						1	0	1

Hemiptera	Corixidae	dam. Corixid		3					3	0	3
		Callicorixa females	116	53	74	34	59	7	81	33	49
		Callicorixa males	13	43	53	34	34	9	36	26	26
		Sigara females				2			0	2	0
		Sigara males				2			0	2	0
		Palmacorixa (?)	1	1					1	0	1
Coleoptera	Dytiscidae	Liodessus					1		0	1	1
Odonata	Gomphidae	Ophiogomphus	1	1	1		1		1	1	1
Amphipoda		Hyalella azteca	1						1	0	1
Oligochaeta		Lumbriculidae	18	39	114	35	21	9	57	22	29
Bivalvia		Sphaeridae	3	6	2				4	0	4
Ostracoda			2			3	1	1	2	2	1
Copepoda							1		0	1	1
Cladocera		Daphnia		1		8	3		1	6	2
Nematoda				1					1	0	1
Terrestrials			1						1	0	1

TABLE A2 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken October 30 to November 1, 2006 (continued)

			Max	Min	Min	Mean	Max	Min	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	Treat	Ref	Treat	trea/ref	trea/ref	trea/ref	ref	treat	trea/ref%
Diptera	Chironomidae	SF Tanypondinae	10	13	5	36%	37%	38%	319	63	20
		other chironomids	22	31	7	22%	25%	23%			
		pupae									
	Simuliidae										
	Ceratopogonidae		2	2	1	29%	15%	50%			
	Empididae		1	3	1	7%	4%	33%			
	Tipulidae										
	Dolichopodidae (?)										
Ephemeroptera	imm. Ephemeropterans								223	104	47
	Heptageniidae	imm. or dam. Heptageniids	14	13	4	52%	67%	31%			
		Stenonema	3	6	2	29%	19%	33%			
		Heptagenia	3	6	1	32%	38%	17%			
		Cinygma	10	12	4	37%	43%	33%			
		Rithrogena	4	21	4	19%	19%	19%			
	Metretopodidae	Siphloplecton	10	3	1	144%	333%	33%			
	Leptophlebiidae	Paraleptophlebia	6	1	6	600%	600%	600%			
	Ephermerellidae	imm.	1	3	1	25%	20%	33%			
	Siphloneuridae	Parameletus	2	5	1	33%	40%	20%			
	Baetidae	imm. or dam. Baetids	3	5	2	34%	30%	40%			
		Centroptilum	3	1	3	300%	300%	300%			
Plecoptera	imm. Plecopterans		7	3	3	59%	50%	100%	45	16	36
	Chloroperlidae		1	4	1	18%	14%	25%			
	Perlodidae		1	2	1	25%	14%	50%			
Trichoptera	Hydrophychidae	imm. Hydropsychid	0	1	0	0%	0%	0%	8	2	25
		Hydropsyche	1	6	1	17%	17%	17%			
	Lepidostomatidae	Lepidostoma	1	0	1	0%	0%	0%			
	Brachycentridae	imm.	0	1	0	0%	0%	0%			

Hemiptera	Corixidae	dam. Corixid	2	2	2	2	2	2	548	265	48
		Callicorixa females	40	54	41	48	45	48			
		Callicorixa males	24	29	25	27	26	27			
		Sigara females	1	1	1	1	1	1			
		Sigara males	1	1	1	1	1	1			
		Palmacorixa (?)	1	1	1	1	1	1			
Coleoptera	Dytiscidae	Liodessus	1	1	1	1	1	1			
Odonata	Gomphidae	Ophiogomphus	1	1	1	1	1	1			
Amphipoda		Hyalella azteca	1	1	1	1	1	1			
Oligochaeta		Lumbriculidae	29	36	27	31	31	31			
Bivalvia		Sphaeridae	2	2	2	3	2	2			
Ostracoda			2	2	2	2	2	2			
Copepoda			1	1	1	1	1	1			
Cladocera		Daphnia	3	3	4	3	3	3			
Nematoda			1	1	1	1	1	1			
Terrestrials			1	1	1	1	1	1			
							All Species		1143	450	39

TABLE A3 Raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 3, 2007

		Date collected:	Feb 2/07	Feb 2/07	Feb 2/07	Feb 2/07	Feb 2/07	Feb 2/07	Feb 3/07	Feb 3/07	Feb 3/07	Feb 3/07	Feb 3/07	Feb 3/07
Order	**Family**	**Genera (unless noted)**	AR Ref 1	AR Ref 2	AR Ref 3	AR Ref 4	AR DN	AR DS	AR TS 1	AR TS2	AR TS3	AR TD1	AR TD2	AR TD3
Diptera	Chironomidae	SF Tanypondinae	50	31	37	33	2	1	25	26	21	22	36	19
		other chironomids	34	28	6	14			17	18	8	10	11	8
	Simuliidae		2		1	3	15	8			2			
	Empididae		16	16	13	14			3	4	8	14	18	9
	Dixidae					2			1					
Ephemeroptera				1			6	1						
	Heptageniidae		4	1	3	1	8	3		1	1	2	6	1
		Stenonema	3				1						2	
		Heptagenia	7											
		Rithrogena	6		3	2	1	1		1			1	
	Leptophlebiidae		2								2			
	Ephemerellidae		5		6	1						3	7	
		Ephemerella										3	2	
	Baetidae		18	1	10		11			6	6	2	6	1
		Baetis	3	2		2	8	10						
Plecoptera			14	3	5	5	19	6		1	4	2	1	3
	Chloroperlidae		4	1	1		2	3		2	1	1	2	2
	Perlodidae		7	1	1	1	10	5				1	2	
		Isogenoides			1			1						
		Isoperla												
	Taeniopterygidae				6	1	14	8		1			1	
		Oemopteryx	2				2	4						
	Nemouridae		5											
Trichoptera			1			1	3	1		2			2	1
	Hydropsychidae											1		
		Hydropsyche	24	11	64	44	2	6	10	6	5	31	35	39
	Psychomyiidae	Psychomyia			1				1	1		2		2
	Glossosomatidae				1					3		1		
	Brachycentridae											1		
	Rhyacophilidae	Rhyacophila	1											
Oligochaeta	Lumbriculidae		5	8		3			1	3	1		1	1

Bivalvia	Sphaeridae		5	1	3	2			1		2			3
Gastropoda									1	2				
	Ancyllidae	Ferrissia			3	1				2				1
Copepoda							1							
Nematoda				1					1	1			1	1
Hydrachnidia						2								
Hirundinea														1

TABLE A4 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 3, 2007 (continued)

			Mean	Mean	Mean	Max	Max	Max	Min	Min	Min	Mean	Max	Min
Order	**Family**	**Genera (unless noted)**	ref	TS	TD	ref	TS	TD	ref	TS	TD	TS/ref	TS/ref	TS/ref
Diptera	Chironomidae	SF Tanypondinae	39	24	26	50	26	36	31	21	19	61%	52%	68%
		other chironomids	23	14	9. 7	34	18	11	6	8	8	63%	53%	133%
	Simuliidae		2	2	0	2	2	0	1	2	0	133%	100%	200%
	Empididae		15	5	14	16	8	18	13	3	9	33%	50%	23%
	Dixidae		0	1	0	0	1	0	0	1	0	0%	0%	0%
Ephemeroptera			1	0	0	1	0	0	1	0	0	0%	0%	0%
	Heptageniidae		3	1	3	4	1	6	1	1	1	38%	25%	100%
		Stenonema	3	0	2	3	0	2	3	0	2	0%	0%	0%
		Heptagenia	7	0	0	7	0	0	7	0	0	0%	0%	0%
		Rithrogena	5	1	1	6	1	1	3	1	1	22%	17%	33%
	Leptophlebiidae		2	2	0	2	2	0	2	2	0	100%	100%	100%
	Ephemerellidae		6	0	5	6	0	7	5	0	3	0%	0%	0%
		Ephemerella	0	0	2.5	0	0	3	0	0	2	0%	0%	0%
	Baetidae		10	6	3	18	6	6	1	6	1	62%	33%	600%
		Baetis	3	0	0	3	0	0	2	0	0	0%	0%	0%
Plecoptera			7	3	2	14	4	3	3	1	1	34%	29%	33%
	Chloroperlidae		2	2	1.7	4	2	2	1	1	1	75%	50%	100%
	Perlodidae		3	0	1.5	7	0	2	1	0	1	0%	0%	0%
		Isogenoides	1	0	0	1	0	0	1	0	0	0%	0%	0%
		Isoperla	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Taeniopterygidae		6	1	1	6	1	1	6	1	1	17%	17%	17%
		Oemopteryx	2	0	0	2	0	0	2	0	0	0%	0%	0%
	Nemouridae		5	0	0	5	0	0	5	0	0	0%	0%	0%
Trichoptera			1	2	1.5	1	2	2	1	2	1	200%	200%	200%
	Hydropsychidae		0	0	1	0	0	1	0	0	1	0%	0%	0%
		Hydropsyche	33	7	35	64	10	39	11	5	31	21%	16%	45%
	Psychomyiidae	Psychomyia	1	1	2	1	1	2	1	1	2	100%	100%	100%
	Glossosomatidae		1	3	1	1	3	1	1	3	1	300%	300%	300%
	Brachycentridae		0	0	1	0	0	1	0	0	1	0%	0%	0%
	Rhyacophilidae	Rhyacophila	1	0	0	1	0	0	1	0	0	0%	0%	0%
Oligochaeta	Lumbriculidae		7	2	1	8	3	1	5	1	1	26%	38%	20%

Bivalvia	Sphaeridae		3	2	3	5	2	3	1	1	3	50%	40%	100%
Gastropoda			0	2	0	0	2	0	0	1	0	0%	0%	0%
	Ancyllidae	Ferrissia	3	2	1	3	2	1	3	2	1	67%	67%	67%
Copepoda			0	0	0	0	0	0	0	0	0	0%	0%	0%
Nematoda			1	1	1	1	1	1	1	1	1	100%	100%	100%
Hydrachnidia			0	0	0	0	0	0	0	0	0	0%	0%	0%
Hirundinea			0	0	1	0	0	1	0	0	1	0%	0%	0%

TABLE A5 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 3, 2007 (continued)

			Mean	Max	Min	Total	Total	Total	Drift	Surber	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TD/ref	TD/ref	TD/ref	Ref	TS	TD	(ind/m2/day)	(ind/m2/day)	Drift	TS/ref %	TD/ref%	Drift/ref%
Diptera	Chironomidae	SF Tanypondinae	65%	72%	61%	234	103	147	14	11	119	44	63	51
		other chironomids	43%	32%	133 %				0	0				
	Simuliidae		0%	0%	0%				105	89				
	Empididae		91%	113 %	69%				0	0				
	Dixidae		0%	0%	0%				0	0				
Ephemeroptera			0%	0%	0%	75	17	36	42	11	245	23	48	327
	Heptageniidae		113%	150 %	100 %				56	33				
		Stenonema	67%	67%	67%				7	0				
		Heptagenia	0%	0%	0%				0	0				
		Rithrogena	22%	17%	33%				7	11				
	Leptophlebiidae		0%	0%	0%				0	0				
	Ephemerellidae		91%	117 %	60%				0	0				
		Ephemerella	0%	0%	0%				0	0				
	Baetidae		31%	33%	100 %				77	0				
		Baetis	0%	0%	0%				56	111				
Plecoptera			27%	21%	33%	51	9	15	133	67	330	18	29	646
	Chloroperlidae		83%	50%	100 %				14	33				
	Perlodidae		50%	29%	100 %				70	56				
		Isogenoides	0%	0%	0%				0	11				
		Isoperla	0%	0%	0%				0	0				
	Taeniopterygidae		17%	17%	17%				98	89				
		Oemopteryx	0%	0%	0%				14	44				
	Nemouridae		0%	0%	0%				0	0				
Trichoptera			150%	200	100	103	28	115	21	11	35	27	112	34

				%	%									
	Hydropsychidae		0%	0%	0%				0	0				
		Hydropsyche	106%	61%	282 %				14	67				
	Psychomyiidae	Psychomyia	200%	200 %	200 %				0	0				
	Glossosomatidae		100%	100 %	100 %				0	0				
	Brachycentridae		0%	0%	0%				0	0				
	Rhyacophilidae	Rhyacophila	0%	0%	0%				0	0				
Oligochaeta	Lumbriculidae		15%	13%	20%	26	15	9	0	0				
Bivalvia	Sphaeridae		100%	60%	300 %				0	0				
Gastropoda			0%	0%	0%				0	0				
	Ancyllidae	Ferrissia	33%	33%	33%				0	0				
Copepoda			0%	0%	0%				7	0				
Nematoda			100%	100 %	100 %				0	0				
Hydrachnidia			0%	0%	0%				0	0				
Hirundinea			0%	0%	0%				0	0				
				All Species		489	172	322			736	35	66	151

TABLE A6 Raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 9, 2007, and some descriptive statistics

		Date collected:	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07	Feb 9/07
Order	Family	Genera (unless noted)	AR Ref 1	AR Ref 2	AR Ref 3	AR DN	AR DS	AR TS 1	AR TS2	AR TS3	AR TD1	AR TD2	AR TD3
Diptera	Chironomidae	SF Tanypondinae	6	7	11	2		7	43	55	6	25	6
		other chironomids	5	10	14			10	25	34	6	14	9
	Simuliidae				3	16	8		1	6			
		blackfly pupa					1						
	Empididae		6	3	6			2	8	13	5	13	1
	Dixidae									1			
	Ceratopogonidae								1				
Ephemeroptera			4			1			1	2			
	Heptageniidae		2	1	3	8	2		1	5		5	1
		Stenonema					2			1		2	
		Rithrogena	1	2	2	3	2			3		1	
		Cinygma			1					1		4	
	Leptophlebiidae						1						
	Ephemerellidae		2									4	
		Ephemerella			2				4				
	Baetidae		3	3	8	17	14	1	9	5	1	1	
		Baetis	2		2	15	2		1	1	1	1	
		Centroptilum			1	1							
	Metretopodidae	Siphloplecton				2							
	Oligoneuridae	Isonychia				2							
	Siphloneuridae							1					
		Parameletus								2			
Plecoptera			8	1	1	32	26	1	1	7		1	
	Chloroperlidae						1				1	1	
	Perlodidae		1	1		7	9	2		1			
		Isogenoides	2			1	1		1	1			
		Isoperla			1	2	2						
	Taeniopterygidae			1		1	3		1	1			
		Oemopteryx			1	9	4		1				
		Taenionema				9	1						
	Nemouridae				1	2			1	3			

	Capniidae					10	6		1				
	Leuctridae					1							
Trichoptera			1	1	1	2		2				1	
	Trichop pupa(e)												1
	Hydropsychidae				1				10	1			2
		Hydropsyche	21	9	35	6	3	8	30	35	5	52	9
	Psychomyiidae	Psychomyia	1		1	1			1	1			
	Glossosomatidae								1				
	Brachycentridae											1	
		Brachycentrus			1				1	1		2	
Odonata	Gomphidae	Ophiogomphus								2			
Hemiptera	Corixidae				1	2							
Oligochaeta	Lumbriculidae		2	1	2	2		1	4	5		2	3
Bivalvia	Sphaeridae			1	2			1		3		1	
Gastropoda	Limnaidae				2				1				
	Ancyllidae	Ferrissia		1					2				
Hydrachnidia											1		
Nematoda				1	1			1		1	1	1	

TABLE A7 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 9, 2007 (continued)

			Mean	Mean	Mean	Max	Max	Max	Min	Min	Min	Mean	Max	Min
Order	Family	Genera (unless noted)	ref	TS	TD	ref	TS	TD	ref	TS	TD	TS/ref	TS/ref	TS/ref
Diptera	Chironomidae	SF Tanypondinae	8	35	12	11	55	25	6	7	6	438%	500%	117%
		other chironomids	10	23	9.7	14	34	14	5	10	6	238%	243%	200%
	Simuliidae		3	4	0	3	6	0	3	1	0	117%	200%	33%
		blackfly pupa	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Empididae		5	8	6.3	6	13	13	3	2	1	153%	217%	67%
	Dixidae		0	1	0	0	1	0	0	1	0	0%	0%	0%
	Ceratopogonidae		0	1	0	0	1	0	0	1	0	0%	0%	0%
Ephemeroptera			4	2	0	4	2	0	4	1	0	38%	50%	25%
	Heptageniidae		2	3	3	3	5	5	1	1	1	150%	167%	100%
		Stenonema	0	1	2	0	1	2	0	1	2	0%	0%	0%
		Rithrogena	2	3	1	2	3	1	1	3	1	180%	150%	300%
		Cinygma	1	1	4	1	1	4	1	1	4	100%	100%	100%
	Leptophlebiidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
	Ephemerellidae		2	0	4	2	0	4	2	0	4	0%	0%	0%
		Ephemerella	2	4	0	2	4	0	2	4	0	200%	200%	200%
	Baetidae		5	5	1	8	9	1	3	1	1	107%	113%	33%
		Baetis	2	1	1	2	1	1	2	1	1	50%	50%	50%
		Centroptilum	1	0	0	1	0	0	1	0	0	0%	0%	0%
	Metretopodidae	Siphloplecton	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Oligoneuridae	Isonychia	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Siphloneuridae		0	1	0	0	1	0	0	1	0	0%	0%	0%
		Parameletus	0	2	0	0	2	0	0	2	0	0%	0%	0%
Plecoptera			3	3	1	8	7	1	1	1	1	90%	88%	100%
	Chloroperlidae		0	0	1	0	0	1	0	0	1	0%	0%	0%
	Perlodidae		1	2	0	1	2	0	1	1	0	150%	200%	100%
		Isogenoides	2	1	0	2	1	0	2	1	0	50%	50%	50%
		Isoperla	1	0	0	1	0	0	1	0	0	0%	0%	0%
	Taeniopterygidae		1	1	0	1	1	0	1	1	0	100%	100%	100%
		Oemopteryx	1	1	0	1	1	0	1	1	0	100%	100%	100%
		Taenionema	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Nemouridae		1	2	0	1	3	0	1	1	0	200%	300%	100%
	Capniidae		0	1	0	0	1	0	0	1	0	0%	0%	0%
	Leuctridae		0	0	0	0	0	0	0	0	0	0%	0%	0%

Trichoptera			1	2	1	1	2	1	1	2	1	200%	200%	200%
	Trichop pupa(e)		0	0	1	0	0	1	0	0	1	0%	0%	0%
	Hydropsychidae		1	6	2	1	10	2	1	1	2	550%	1000%	100%
		Hydropsyche	22	24	22	35	35	52	9	8	5	112%	100%	89%
	Psychomyiidae	Psychomyia	1	1	0	1	1	0	1	1	0	100%	100%	100%
	Glossosomatidae		0	1	0	0	1	0	0	1	0	0%	0%	0%
	Brachycentridae		0	0	1	0	0	1	0	0	1	0%	0%	0%
		Brachycentrus	1	1	2	1	1	2	1	1	2	100%	100%	100%
Odonata	Gomphidae	Ophiogomphus	0	2	0	0	2	0	0	2	0	0%	0%	0%
Hemiptera	Corixidae		1	0	0	1	0	0	1	0	0	0%	0%	0%
Oligochaeta	Lumbriculidae		2	3	2.5	2	5	3	1	1	2	200%	250%	100%
Bivalvia	Sphaeridae		2	2	1	2	3	1	1	1	1	133%	150%	100%
Gastropoda	Limnaidae		2	1	0	2	1	0	2	1	0	50%	50%	50%
	Ancyllidae	Ferrissia	1	2	0	1	2	0	1	2	0	200%	200%	200%
Hydrachnidia			0	0	1	0	0	1	0	0	1	0%	0%	0%
Nematoda			1	1	1	1	1	1	1	1	1	100%	100%	100%

TABLE A8 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 9, 2007 (continued)

			Mean	Max	Min	Total	Total	Total	Drift	Surber	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TD/ref	TD/ref	TD/ref	Ref	TS	TD	(ind/m2/day)	(ind/m2/day)	Drift	TS/ref %	TD/ref%	Drift/ref %
Diptera	Chironomidae	SF Tanypondinae	154%	227%	100%	71	206	85	14	0	126	290	120	178
		other chironomids	100%	100%	120%				0	0				
	Simuliidae		0%	0%	0%				112	89				
		blackfly pupa	0%	0%	0%				0	11				
	Empididae		127%	217%	33%				0	0				
	Dixidae		0%	0%	0%				0	0				
	Ceratopogonidae		0%	0%	0%				0	0				
Ephemeroptera			0%	0%	0%	39	38	19	7	0	344	97	49	881
	Heptageniidae		150%	167%	100%				56	22				
		Stenonema	0%	0%	0%				0	22				
		Rithrogena	60%	50%	100%				21	22				
		Cinygma	400%	400%	400%				0	0				
	Leptophlebiidae		0%	0%	0%				0	11				
	Ephemerellidae		200%	200%	200%				0	0				
		Ephemerella	0%	0%	0%				0	0				
	Baetidae		21%	13%	33%				119	156				
		Baetis	50%	50%	50%				105	22				
		Centroptilum	0%	0%	0%				7	0				
	Metretopodidae	Siphloplecton	0%	0%	0%				14	0				
	Oligoneuridae	Isonychia	0%	0%	0%				14	0				
	Siphloneuridae		0%	0%	0%				0	0				
		Parameletus	0%	0%	0%				0	0				
Plecoptera			30%	13%	100%	18	20	2	224	289	519	111	11	2883
	Chloroperlidae		0%	0%	0%				0	11				
	Perlodidae		0%	0%	0%				49	100				
		Isogenoides	0%	0%	0%				7	11				
		Isoperla	0%	0%	0%				14	22				
	Taeniopterygidae		0%	0%	0%				7	33				
		Oemopteryx	0%	0%	0%				63	44				

		Taenionema	0%	0%	0%				63	11				
	Nemouridae		0%	0%	0%				14	0				
	Capniidae		0%	0%	0%				70	67				
	Leuctridae		0%	0%	0%				7	0				
Trichoptera			100%	100%	100%	72	86	68	14	0	63	119	94	88
	Trichop pupa(e)		0%	0%	0%				0	0				
	Hydropsychidae		200%	200%	200%				0	0				
		Hydropsyche	102%	149%	56%				42	33				
	Psychomyiidae	Psychomyia	0%	0%	0%				7	0				
	Glossosomatidae		0%	0%	0%				0	0				
	Brachycentridae		0%	0%	0%				0	0				
		Brachycentrus	200%	200%	200%				0	0				
Odonata	Gomphidae	Ophiogomphus	0%	0%	0%	14	21	9	0	0				
Hemiptera	Corixidae		0%	0%	0%				14	0				
Oligochaeta	Lumbriculidae		150%	150%	200%				14	0				
Bivalvia	Sphaeridae		67%	50%	100%				0	0				
Gastropoda	Limnaidae		0%	0%	0%				0	0				
	Ancyllidae	Ferrissia	0%	0%	0%				0	0				
Hydrachnidia			0%	0%	0%				0	0				
Nematoda			100%	100%	100%				0	0				
				All Species		214	371	183			1080	173	86	505

TABLE A9 Raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 15, 2007

		Date collected:	Feb 15/07	Feb 15/07	Feb 15/07	Feb 16/07	Feb 16/07	Feb 15/07	Feb 15/07	Feb 15/07	Feb 15/07	Feb 15/07	Feb 15/07
Order	**Family**	**Genera (unless noted)**	AR Ref 1	AR Ref 2	AR Ref 3	AR DN	AR DS	AR TS 1	AR TS2	AR TS3	AR TD1	AR TD2	AR TD3
Diptera	Chironomidae	SF Tanypondinae	35	29	45	2		36	54	13	5	30	38
		other chironomids	26	27	19			26	28	18	8	21	21
	Simuliidae		4	2		17	7		1			1	
		blackfly pupa				1							
	Empididae		10	11	10			12	13	8	1	6	7
	Dixidae		1					1					
	Ceratopogonidae											1	
Ephemeroptera			4			1	1		2			2	
	Heptageniidae		3	1		3	2	1			1	12	13
		Stenonema	1					1	1			1	1
		Rithrogena	6			2	4	4	2	3		3	
		Cinygma											2
		Stenacron						4					
	Leptophlebiidae												
	Ephemerellidae		2		2			1	2				1
		Ephemerella	5		1			2	5		1	1	8
	Baetidae		13	6	3	27	18	8	10	1		9	3
		Baetis		2	1	3	9	2	7			1	3
		Centroptilum											
	Metretopodidae	Siphloplecton				3							
	Oligoneuridae	Isonychia				1							
	Siphloneuridae												
		Parameletus						2	2				
		Siphlonurus(?)				1							
Plecoptera			8	3	4	16	21	1	2			1	3
	Chloroperlidae		1			1	1		2	1		2	
	Perlodidae		4	5		24	10	1	4		1	2	4
		Isogenoides				4		1					2
		Isoperla				1							
	Taeniopterygidae					2		2				1	
		Oemopteryx				2	3	1					1

		Taenionema											
		Taeniopteryx					1						
	Nemouridae		8			4	6	4	3			3	10
	Capniidae					12	6						1
	Leuctridae					4	4	2					1
Trichoptera			2	1		2		2				3	8
	Trichop pupa(e)		1							2			
	Hydropsychidae		1	2				2	5	1	1	2	1
		Hydropsyche	46	19	47	3		22	28	23	10	42	66
	Psychomyiidae												1
		Psychomyia						1	2			2	3
	Glossosomatidae		2				2	1	1	1			
		Anagapetus					1						
	Brachycentridae								1			1	
		Brachycentrus	2	1	1								
	Hydroptilidae												
		Hydroptila				1							
Odonata	Gomphidae	Ophiogomphus	1								1		
Hemiptera	Corixidae					7							
Coleoptera	Elmidae	larva			1			1					
Oligochaeta	Lumbriculidae		5	2	3			2	6	3		5	2
Bivalvia	Sphaeridae		1	3	1				1	2	1		
Gastropoda				3									
	Limnaidae			1						2			
	Ancyllidae	Ferrissia	4					1		1			
Hydrachnidia													
Nematoda			1	1				1		2		1	3

TABLE A10 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 15, 2007 (continued)

									Min	Min	Min	Mean	Max	Min
			Mean	Mean	Mean	Max	Max	Max	ref	TS	TD	TS/ref	TS/ref	TS/ref
Order	**Family**	**Genera (unless noted)**	ref	TS	TD	ref	TS	TD	29	13	5	94%	120%	45%
Diptera	Chironomidae	SF Tanypondinae	36	34	24.3	45	54	38	19	18	8	100%	104%	95%
		other chironomids	24	24	16.7	27	28	21	2	1	1	33%	25%	50%
	Simuliidae		3	1	1	4	1	1	0	0	0	0%	0%	0%
		blackfly pupa	0	0	0	0	0	0	10	8	1	106%	118%	80%
	Empididae		10	11	4.7	11	13	7	1	1	0	100%	100%	100%
	Dixidae		1	1	0	1	1	0	0	0	1	0%	0%	0%
	Ceratopogonidae		0	0	1	0	0	1	4	2	2	50%	50%	50%
Ephemeroptera			4	2	2	4	2	2	1	1	1	50%	33%	100%
	Heptageniidae		2	1	87	3	1	13	1	1	1	100%	100%	100%
		Stenonema	1	1	1	1	1	1	6	2	3	50%	67%	33%
		Rithrogena	6	3	3	6	4	3	0	0	2	0%	0%	0%
		Cinygma	0	0	2	0	0	2	0	4	0	0%	0%	0%
		Stenacron	0	4	0	0	4	0	0	0	0	0%	0%	0%
	Leptophlebiidae		0	0	0	0	0	0	2	1	1	75%	100%	50%
	Ephemerellidae		2	2	1	2	2	1	1	2	1	117%	100%	200%
		Ephemerella	3	4	3.3	5	5	8	3	1	3	86%	77%	33%
	Baetidae		7	6	6	13	10	9	1	2	1	300%	350%	200%
		Baetis	2	5	2	2	7	3	0	0	0	0%	0%	0%
		Centroptilum	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Metretopodidae	Siphloplecton	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Oligoneuridae	Isonychia	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Siphloneuridae		0	0	0	0	0	0	0	2	0	0%	0%	0%
		Parameletus	0	2	0	0	2	0	0	0	0	0%	0%	0%
		Siphlonurus(?)	0	0	0	0	0	0	3	1	1	30%	25%	33%
Plecoptera			5	2	2	8	2	3	1	1	2	150%	200%	100%
	Chloroperlidae		1	2	2	1	2	2	4	1	1	56%	80%	25%
	Perlodidae		5	3	2.3	5	4	4	0	1	2	0%	0%	0%
		Isogenoides	0	1	2	0	1	2	0	0	0	0%	0%	0%
		Isoperla	0	0	0	0	0	0	0	2	1	0%	0%	0%
	Taeniopterygidae		0	2	1	0	2	1	0	1	1	0%	0%	0%
		Oemopteryx	0	1	1	0	1	1	0	0	0	0%	0%	0%
		Taenionema	0	0	0	0	0	0	0	0	0	0%	0%	0%

		Taeniopteryx	0	0	0	0	0	0	8	3	3	44%	50%	38%
	Nemouridae		8	4	6.5	8	4	10	0	0	1	0%	0%	0%
	Capniidae		0	0	1	0	0	1	0	2	1	0%	0%	0%
	Leuctridae		0	2	1	0	2	1	1	2	3	133%	100%	200%
Trichoptera			2	2	5.5	2	2	8	1	2	0	200%	200%	200%
	Trichop pupa(e)		1	2	0	1	2	0	1	1	1	178%	250%	100%
	Hydropsychidae		2	3	1.3	2	5	2	19	22	10	65%	60%	116%
		Hydropsyche	37	24	39.3	47	28	66	0	0	1	0%	0%	0%
	Psychomyiidae		0	0	1	0	0	1	0	1	2	0%	0%	0%
		Psychomyia	0	2	2.5	0	2	3	2	1	0	50%	50%	50%
	Glossosomatidae		2	1	0	2	1	0	0	0	0	0%	0%	0%
		Anagapetus	0	0	0	0	0	0	0	1	1	0%	0%	0%
	Brachycentridae		0	1	1	0	1	1	1	0	0	0%	0%	0%
		Brachycentrus	1	0	0	2	0	0	0	0	0	0%	0%	0%
	Hydroptilidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
		Hydroptila	0	0	0	0	0	0	1	0	1	0%	0%	0%
Odonata	Gomphidae	Ophiogomphus	1	0	1	1	0	1	0	0	0	0%	0%	0%
Hemiptera	Corixidae		0	0	0	0	0	0	1	1	0	100%	100%	100%
Coleoptera	Elmidae	larva	1	1	0	1	1	0	2	2	2	110%	120%	100%
Oligochaeta	Lumbriculidae		3	4	3.5	5	6	5	1	1	1	90%	67%	100%
Bivalvia	Sphaeridae		2	2	1	3	2	1	3	0	0	0%	0%	0%
Gastropoda			3	0	0	3	0	0	1	2	0	200%	200%	200%
	Limnaidae		1	2	0	1	2	0	4	1	0	25%	25%	25%
	Ancyllidae	Ferrissia	4	1	0	4	1	0	0	0	0	0%	0%	0%
Hydrachnidia			0	0	0	0	0	0	1	1	1	150%	200%	100%
Nematoda			1	2	2	1	2	3	Min	Min	Min	Mean	Max	Min

TABLE A11 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken February 15, 2007 (continued)

			Mean	Max	Min	Total	Total	Total	Drift	Surber	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TD/ref	TD/ref	TD/ref	Ref	TS	TD	(ind/m2/day)	(ind/m2/day)	Drift	TS/ref %	TD/ref%	Drift/ref%
Diptera	Chironomidae	SF Tanypondinae	67%	84%	17%	219	210	139	14	0	140	96	64	64
		other chironomids	69%	78%	42%				0	0				
	Simuliidae		33%	25%	50%				119	78				
		blackfly pupa	0%	0%	0%				7	0				
	Empididae		45%	64%	10%				0	0				
	Dixidae		0%	0%	0%				0	0				
	Ceratopogonidae		0%	0%	0%				0	0				
Ephemeroptera			50%	50%	50%	50	37	60	7	11	288	74	120	575
	Heptageniidae		433%	433%	100%				21	22				
		Stenonema	100%	100%	100%				0	0				
		Rithrogena	50%	50%	50%				14	44				
		Cinygma	0%	0%	0%				0	0				
		Stenacron	0%	0%	0%				0	0				
	Leptophlebiidae		0%	0%	0%				0	0				
	Ephemerellidae		50%	50%	50%				0	0				
		Ephemerella	111%	160%	100%				0	0				
	Baetidae		82%	69%	100%				189	200				
		Baetis	133%	150%	100%				21	100				
		Centroptilum	0%	0%	0%				0	0				
	Metretopodidae	Siphloplecton	0%	0%	0%				21	0				
	Oligoneuridae	Isonychia	0%	0%	0%				7	0				
	Siphloneuridae		0%	0%	0%				0	0				
		Parameletus	0%	0%	0%				0	0				
		Siphlonurus(?)	0%	0%	0%				7	0				
Plecoptera			40%	38%	33%	33	13	31	112	233	491	39	94	1488
	Chloroperlidae		200%	200	200%				7	11				

				%											
	Perlodidae		52%	80%	25%				168	111					
		Isogenoides	0%	0%	0%				28	0					
		Isoperla	0%	0%	0%				7	0					
	Taeniopterygidae		0%	0%	0%				14	0					
		Oemopteryx	0%	0%	0%				14	33					
		Taenionema	0%	0%	0%				0	0					
		Taeniopteryx	0%	0%	0%				0	11					
	Nemouridae		81%	125 %	38%				28	67					
	Capniidae		0%	0%	0%				84	67					
	Leuctridae		0%	0%	0%				28	44					
Tricho ptera			367%	400 %	300%	125	75	129	14	0	42	60	103	34	
	Trichop pupa(e)		0%	0%	0%				0	0					
	Hydropsychidae		89%	100 %	100%				0	0					
		Hydropsyche	105%	140 %	53%				21	0					
	Psychomyiidae		0%	0%	0%				0	0					
		Psychomyia	0%	0%	0%				0	0					
	Glossosomatidae		0%	0%	0%				0	22					
		Anagapetus	0%	0%	0%				0	11					
	Brachycentridae		0%	0%	0%				0	0					
		Brachycentrus	0%	0%	0%				0	0					
	Hydroptilidae		0%	0%	0%				0	0					
		Hydroptila	0%	0%	0%				7	0					
Odonat a	Gomphidae	Ophiogomphus	100%	100 %	100%	27	22	13	0	0					
Hemipt era	Corixidae		0%	0%	0%				49	0					
Coleop tera	Elmidae	larva	0%	0%	0%				0	0					
Oligoc haeta	Lumbriculidae		105%	100 %	100%				0	0					
Bivalvi a	Sphaeridae		60%	33%	100%				0	0					
Gastro poda			0%	0%	0%				0	0					
	Limnaidae		0%	0%	0%				0	0					
	Ancyllidae	Ferrissia	0%	0%	0%				0	0					

Hydrachnidia			0%	0%	0%				0	0				
Nematoda			200%	300%	100%				0	0				
				All Species		454	357	372			1010	79	82	222

TABLE A12 Raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 2, 2007

		Date collected:	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07	Mar 2/07
Order	**Family**	**Genera (unless noted)**	AR Ref 1	AR Ref 2	AR Ref 3	AR DN	AR DS	AR TS 1	AR TS2	AR TS3	AR TD1	AR TD2	AR TD3
Diptera	Chironomidae	SF Tanypondinae	23	16	36			47	20	63	55	53	34
		other chironomids	33	23	25	1		36	18	50	64	75	27
	Simuliidae					12	4				1		
		blackfly pupa											
	Empididae		10	4	7			12	5	19	23	20	23
	Dixidae									1			1
	Ceratopogonidae												
Ephemeroptera			1	1				2	1	1	7		
	Heptageniidae				3	7	2	3	15	6	26	18	7
		Stenonema						5	3	7	6	4	2
		Rithrogena	1	2	2	2	1	3	6	2	5	1	3
		Cinygma							9	4	2		1
		Heptagenia											
		Stenacron											
	Leptophlebiidae												
	Ephemerellidae		1		1	2			2	1	3		
		Ephemerella				1		3	3	5	9	3	2
	Baetidae		7	1	10	23	10	3	4	5	9	4	4
		Baetis	1	1	1	3	5		1	3	4		1
		Centroptilum											
	Metretopodidae	Siphloplecton											
	Oligoneuridae	Isonychia											
	Siphloneuridae					1							
		Parameletus				2			3				
		Siphlonurus(?)											
Plecoptera						6	5		3	2	2	4	2
	Chloroperlidae		2			1		3	2	2	3	1	2
	Perlodidae		2	1	5	15	12	2	5	2	3		1
		Isogenoides				1			1	1	2		
		Isoperla											

	Taeniopterygidae				1	1			1				
		Oemopteryx			1	3	2	1	3	2	1	1	
		Taenionema				2							
		Taeniopteryx											
	Nemouridae		3		10	2	5	9	12	9	11	2	10
	Capniidae			1		5	2						
	Leuctridae												
Trichoptera								2		1	7	5	
	Trichop pupa(e)											1	
	Hydropsychidae					10	4			1	1	2	3
		Hydropsyche	10	14	11			20	12	52	40	101	46
	Psychomyiidae												
		Psychomyia						2		6		1	1
	Glossosomatidae			1					1				1
		Anagapetus											
	Brachycentridae									1	2	2	2
		Brachycentrus								1	1	1	2
	Hydroptilidae							1					
		Hydroptila											
Odonata	Gomphidae	Ophiogomphus							1	1		1	
Hemiptera	Corixidae						1				2		1
Coleoptera	Elmidae	larva						1					
Megaloptera	Sialidae	Sialis								1			
Oligochaeta	Lumbriculidae			2	2			3	7	1	2		2
Bivalvia	Sphaeridae		3	3				1	1	1	2	4	4
Gastropoda													
	Limnaidae							1	2			3	
	Ancyllidae	Ferrissia	2	1	1								1
Hydrachnidia									1				
Nematoda									2	8	1		1
Copepoda	Cyclopoid		1										

TABLE A13 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 2, 2007 (continued)

			Mean	Mean	Mean	Max	Max	Max	Min	Min	Min	Mean	Max	Min
Order	**Family**	**Genera (unless noted)**	ref	TS	TD	ref	TS	TD	ref	TS	TD	TS/ref	TS/ref	TS/ref
Diptera	Chironomidae	SF Tanypondinae	25	43	47	36	63	55	16	20	34	173%	175%	125%
		other chironomids	27	35	55	33	50	75	23	18	27	128%	152%	78%
	Simuliidae		0	0	1	0	0	1	0	0	1	0%	0%	0%
		blackfly pupa	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Empididae		7	12	22	10	19	23	4	5	20	171%	190%	125%
	Dixidae		0	1	1	0	1	1	0	1	1	0%	0%	0%
	Ceratopogonidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
Ephemeroptera			1	1	7	1	2	7	1	1	7	133%	200%	100%
	Heptageniidae		3	8	17	3	15	26	3	3	7	267%	500%	100%
		Stenonema	0	5	4	0	7	6	0	3	2	0%	0%	0%
		Rithrogena	2	4	3	2	6	5	1	2	1	220%	300%	200%
		Cinygma	0	7	2	0	9	2	0	4	1	0%	0%	0%
		Heptagenia	0	0	0	0	0	0	0	0	0	0%	0%	0%
		Stenacron	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Leptophlebiidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
	Ephemerellidae		1	2	3	1	2	3	1	1	3	150%	200%	100%
		Ephemerella	0	4	5	0	5	9	0	3	2	0%	0%	0%
	Baetidae		6	4	6	10	5	9	1	3	4	67%	50%	300%
		Baetis	1	2	3	1	3	4	1	1	1	200%	300%	100%
		Centroptilum	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Metretopodidae	Siphloplecton	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Oligoneuridae	Isonychia	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Siphloneuridae		0	0	0	0	0	0	0	0	0	0%	0%	0%
		Parameletus	0	3	0	0	3	0	0	3	0	0%	0%	0%
		Siphlonurus(?)	0	0	0	0	0	0	0	0	0	0%	0%	0%
Plecoptera			0	3	3	0	0	0	0	0	0	0%	0%	0%
	Chloroperlidae		2	2	2	0	3	4	0	2	2	117%	0%	0%
	Perlodidae		3	3	2	2	3	3	2	2	1	113%	150%	100%
		Isogenoides	0	1	2	5	5	3	1	2	1	0%	100%	200%
		Isoperla	0	0	0	0	1	2	0	1	2	0%	0%	0%
	Taeniopterygidae		1	1	0	0	0	0	0	0	0	100%	0%	0%
		Oemopteryx	1	2	1	1	1	0	1	1	0	200%	100%	100%
		Taenionema	0	0	0	1	3	1	1	1	1	0%	300%	100%

		Taeniopteryx	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Nemouridae		7	10	8	0	0	0	0	0	0	154%	0%	0%
	Capniidae		1	0	0	10	12	11	3	9	2	0%	120%	300%
	Leuctridae		0	0	0	1	0	0	1	0	0	0%	0%	0%
Trichoptera			0	2	6	0	0	0	0	0	0	0%	0%	0%
	Trichop pupa(e)		0	0	1	0	2	7	0	1	5	0%	0%	0%
	Hydropsychidae		0	1	2	0	0	1	0	0	1	0%	0%	0%
		Hydropsyche	12	28	62	0	1	3	0	1	1	240%	0%	0%
	Psychomyiidae		0	0	0	14	52	101	10	12	40	0%	371%	120%
		Psychomyia	0	4	1	0	0	0	0	0	0	0%	0%	0%
	Glossosomatidae		1	1	1	0	6	1	0	2	1	100%	0%	0%
		Anagapetus	0	0	0	1	1	1	1	1	1	0%	100%	100%
	Brachycentridae		0	1	2	0	0	0	0	0	0	0%	0%	0%
		Brachycentrus	0	1	1	0	1	2	0	1	2	0%	0%	0%
	Hydroptilidae		0	1	0	0	1	2	0	1	1	0%	0%	0%
		Hydroptila	0	0	0	0	1	0	0	1	0	0%	0%	0%
Odonata	Gomphidae	Ophiogomphus	0	1	1	0	0	0	0	0	0	0%	0%	0%
Hemiptera	Corixidae		0	0	2	0	1	1	0	1	1	0%	0%	0%
Coleoptera	Elmidae	larva	0	1	0	0	0	2	0	0	1	0%	0%	0%
Megaloptera	Sialidae	Sialis	0	1	0	0	1	0	0	1	0	0%	0%	0%
Oligochaeta	Lumbriculidae		2	4	2	0	1	0	0	1	0	183%	0%	0%
Bivalvia	Sphaeridae		3	1	3	2	7	2	2	1	2	33%	350%	50%
Gastropoda			0	0	0	3	1	4	3	1	2	0%	33%	33%
	Limnaidae		0	2	3	0	0	0	0	0	0	0%	0%	0%
	Ancyllidae	Ferrissia	1	0	1	0	2	3	0	1	3	0%	0%	0%
Hydrachnidia			0	1	0	2	0	1	1	0	1	0%	0%	0%
Nematoda			0	5	1	0	1	0	0	1	0	0%	0%	0%
Copepoda	Cyclopoid		1	0	0	0	8	1	0	2	1	0%	0%	0%

TABLE A14 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 2, 2007 (continued)

			Mean	Max	Min	Total	Total	Total	Drift	Surber	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TD/ref	TD/ref	TD/ref	Ref	TS	TD	(ind/m2/day)	(ind/m2/day)	Drift	TS/ref %	TD/ref%	Drift/ref%
Diptera	Chironomidae	SF Tanypondinae	189%	153%	213%	177	271	376	0	0	91	153	212	52
		other chironomids	205%	227%	117%				7	0				
	Simuliidae		0%	0%	0%				84	44				
		blackfly pupa	0%	0%	0%				0	0				
	Empididae		314%	230%	500%				0	0				
	Dixidae		0%	0%	0%				0	0				
	Ceratopogonidae		0%	0%	0%				0	0				
Ephemeroptera			700%	700%	700%	33	152	50	0	0	288	461	152	871
	Heptageniidae		567%	867%	233%				49	22				
		Stenonema	0%	0%	0%				0	0				
		Rithrogena	180%	250%	100%				14	11				
		Cinygma	0%	0%	0%				0	0				
		Heptagenia	0%	0%	0%				0	0				
		Stenacron	0%	0%	0%				0	0				
	Leptophlebiidae		0%	0%	0%				0	0				
	Ephemerellidae		300%	300%	300%				14	0				
		Ephemerella	0%	0%	0%				7	0				
	Baetidae		94%	90%	400%				161	111				
		Baetis	250%	400%	100%				21	56				
		Centroptilum	0%	0%	0%				0	0				
	Metretopodidae	Siphloplecton	0%	0%	0%				0	0				
	Oligoneuridae	Isonychia	0%	0%	0%				0	0				
	Siphloneuridae		0%	0%	0%				7	0				
		Parameletus	0%	0%	0%				14	0				
		Siphlonurus(?)	0%	0%	0%				0	0				
Plecoptera			0%	0%	0%	26	67	23	42	56	252	258	89	971
	Chloroperlida		100%	0%	0%				7	0				

	e													
	Perlodidae		75%	150%	50%				105	133				
		Isogenoides	0%	60%	100%				7	0				
		Isoperla	0%	0%	0%				0	0				
	Taeniopterygi dae		0%	0%	0%				7	0				
		Oemopteryx	100%	0%	0%				21	22				
		Taenionema	0%	100%	100%				14	0				
		Taeniopteryx	0%	0%	0%				0	0				
	Nemouridae		118%	0%	0%				14	56				
	Capniidae		0%	110%	67%				35	22				
	Leuctridae		0%	0%	0%				0	0				
Trichoptera			0%	0%	0%	36	126	168	0	0	70	350	467	195
	Trichop pupa(e)		0%	0%	0%				0	0				
	Hydropsychid ae		0%	0%	0%				70	44				
		Hydropsyche	534%	0%	0%				0	0				
	Psychomyiida e		0%	721%	400%				0	0				
		Psychomyia	0%	0%	0%				0	0				
	Glossosomatid ae		100%	0%	0%				0	0				
		Anagapetus	0%	100%	100%				0	0				
	Brachycentrid ae		0%	0%	0%				0	0				
		Brachycentrus	0%	0%	0%				0	0				
	Hydroptilidae		0%	0%	0%				0	0				
		Hydroptila	0%	0%	0%				0	0				
Odonata	Gomphidae	Ophiogomphus	0%	0%	0%	15	32	24	0	0				
Hemiptera	Corixidae		0%	0%	0%				0	11				
Coleoptera	Elmidae	larva	0%	0%	0%				0	0				
Megalopter a	Sialidae	Sialis	0%	0%	0%				0	0				
Oligochaeta	Lumbriculidae		100%	0%	0%				0	0				

Bivalvia	Sphaeridae		111%	100%	100%				0	0				
Gastropoda			0%	133%	67%				0	0				
	Limnaidae		0%	0%	0%				0	0				
	Ancyllidae	Ferrissia	75%	0%	0%				0	0				
Hydrachnidia			0%	50%	100%				0	0				
Nematoda			0%	0%	0%				0	0				
Copepoda	Cyclopoid		0%	0%	0%				0	0				
				All Species		287	648	641			701	226	223	244

TABLE A15 Raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 16, 2007

		Date collected:	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07	Mar 16/07
Order	**Family**	**Genera (unless noted)**	AR Ref 1	AR Ref 2	AR Ref 3	AR DN	AR DS	AR TS 1	AR TS2	AR TS3	AR TD1	AR TD2	AR TD3
Diptera	Chironomidae	SF Tanypondinae	11	12	19	2	1	5	5	30	31	24	18
		other chironomids	29	28	14	2		27	19	43	35	30	31
	Simuliidae		1	9	13	24	7			1	2	1	1
		blackfly pupa											
	Empididae		5	14	9			4	1	7	10	14	11
	Dixidae			1							1	5	
	Ceratopogonidae		1										1
Ephemeroptera				9	2		1			1	1	1	
	Heptageniidae		1	3	1	4	2		1	6	11	3	
		Stenonema	1	1		1				3	1	1	
		Rithrogena	3	4	3	2	7	1	1	7	5	3	2
		Cinygma								1		2	
		Heptagenia							1				
		Stenacron											
	Leptophlebiidae												
	Ephemerellidae			1	1			2		3	1	1	
		Ephemerella								1	1	4	
	Baetidae		12	32	19	34	20	4		13	9	5	2
		Baetis	4	1	5	17	15	3			4	1	1
		Centroptilum											
	Metretopodidae	Siphloplecton					1						
	Oligoneuridae	Isonychia											
	Siphloneuridae												
		Parameletus	1				2	1		6	12		3
		Siphlonurus(?)											
		Ameletus				1							
Plecoptera			1	7		5	3			1	1	2	
	Chloroperlidae					2				3	2		2
	Perlodidae		5	4	6	29	14	1		3	4	4	1
		Isogenoides				1					2	1	
		Isoperla				1	1			1			1

	Taeniopterygidae		1	5									
		Oemopteryx		1		1	1		1			2	
		Taenionema	2		2	2	2				3	1	
		Taeniopteryx											
	Nemouridae		4	2	9	8	2	5	1	8	6	8	1
	Capniidae					3	1		1	1			
	Leuctridae										4	1	
	Pteronarcydae	Pteronarcys									1		
Trichoptera						1		1	2				
	Trichop pupa(e)				2			1					
	Hydropsychidae							2					
		Hydropsyche	12	21	17	5			7	9	45	39	31
	Psychomyiidae												
		Psychomyia						1		1			
	Glossosomatidae		1		1						2	1	
		Anagapetus											
	Brachycentridae			1					2				
		Brachycentrus	1	3				1	1		1	2	
	Hydroptilidae												
		Hydroptila											
Odonata	Gomphidae									1	1		
		Ophiogomphus	1									1	
		Gomphus									1		
Hemiptera	Corixidae												
Coleoptera	Elmidae	larva											
Megaloptera	Sialidae	Sialis										1	
Oligochaeta	Lumbriculidae							1	3	1	5	3	3
	Naididae			1									
Bivalvia	Sphaeridae		5	1				2		3	4	3	
Gastropoda													
	Limnaidae								1		1		
	Ancyllidae	Ferrissia	2	3				1			1		
Hydrachnidia								1					
Nematoda					2			1	1	1		1	1

TABLE A16 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 16, 2007 (continued)

			Mean	Mean	Mean	Max	Max	Max	Min	Min	Min	Mean	Max	Min
Order	**Family**	**Genera (unless noted)**	ref	TS	TD	ref	TS	TD	ref	TS	TD	TS/ref	TS/ref	TS/ref
Diptera	Chironomidae	SF Tanypondinae	14	13	24	19	30	31	11	5	18	95%	158%	45%
		other chironomids	24	30	32	29	43	35	14	19	30	125%	148%	136%
	Simuliidae		8	1	1	13	1	2	1	1	1	13%	8%	100%
		blackfly pupa	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Empididae		9	4	12	14	7	14	5	1	10	43%	50%	20%
	Dixidae		1	0	3	1	0	5	1	0	1	0%	0%	0%
	Ceratopogonidae		1	0	1	1	0	1	1	0	1	0%	0%	0%
Ephemeroptera			6	1	1	9	1	1	2	1	1	18%	11%	50%
	Heptageniidae		2	4	7	3	6	11	1	1	3	210%	200%	100%
		Stenonema	1	3	1	1	3	1	1	3	1	300%	300%	300%
		Rithrogena	3	3	3	4	7	5	3	1	2	90%	175%	33%
		Cinygma	0	1	2	0	1	2	0	1	2	0%	0%	0%
		Heptagenia	0	1	0	0	1	0	0	1	0	0%	0%	0%
		Stenacron	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Leptophlebiidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
	Ephemerellidae		1	3	1	1	3	1	1	2	1	250%	300%	200%
		Ephemerella	0	1	3	0	1	4	0	1	1	0%	0%	0%
	Baetidae		21	9	5	32	13	9	12	4	2	40%	41%	33%
		Baetis	3	3	2	5	3	4	1	3	1	90%	60%	300%
		Centroptilum	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Metretopodidae	Siphloplecton	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Oligoneuridae	Isonychia	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Siphloneuridae		0	0	0	0	0	0	0	0	0	0%	0%	0%
		Parameletus	1	4	8	1	6	12	1	1	3	350%	600%	100%
		Siphlonurus(?)	0	0	0	0	0	0	0	0	0	0%	0%	0%
		Ameletus	0	0	0	0	0	0	0	0	0	0%	0%	0%
Plecoptera			4	1	2	7	1	2	1	1	1	25%	14%	100%
	Chloroperlidae		0	3	2	0	3	2	0	3	2	0%	0%	0%
	Perlodidae		5	2	3	6	3	4	4	1	1	40%	50%	25%
		Isogenoides	0	0	2	0	0	2	0	0	1	0%	0%	0%
		Isoperla	0	1	1	0	1	1	0	1	1	0%	0%	0%
	Taeniopterygidae		3	0	0	5	0	0	1	0	0	0%	0%	0%
		Oemopteryx	1	1	2	1	1	2	1	1	2	100%	100%	100%

		Taenionema	2	0	2	2	0	3	2	0	1	0%	0%	0%
		Taeniopteryx	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Nemouridae		5	5	5	9	8	8	2	1	1	93%	89%	50%
	Capniidae		0	1	0	0	1	0	0	1	0	0%	0%	0%
	Leuctridae		0	0	3	0	0	4	0	0	1	0%	0%	0%
	Pteronarcydae	Pteronarcys	0	0	1	0	0	1	0	0	1	0%	0%	0%
Trichoptera			0	2	0	0	2	0	0	1	0	0%	0%	0%
	Trichop pupa(e)		2	1	0	2	1	0	2	1	0	50%	50%	50%
	Hydropsychidae		0	2	0	0	2	0	0	2	0	0%	0%	0%
		Hydropsyche	17	8	38	21	9	45	12	7	31	48%	43%	58%
	Psychomyiidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
		Psychomyia	0	1	0	0	1	0	0	1	0	0%	0%	0%
	Glossosomatidae		1	0	2	1	0	2	1	0	1	0%	0%	0%
		Anagapetus	0	0	0	0	0	0	0	0	0	0%	0%	0%
	Brachycentridae		1	2	0	1	2	0	1	2	0	200%	200%	200%
		Brachycentrus	2	1	2	3	1	2	1	1	1	50%	33%	100%
	Hydroptilidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
		Hydroptila	0	0	0	0	0	0	0	0	0	0%	0%	0%
Odonata	Gomphidae		0	1	1	0	1	1	0	1	1	0%	0%	0%
		Ophiogomphus	1	0	1	1	0	1	1	0	1	0%	0%	0%
		Gomphus	0	0	1	0	0	1	0	0	1	0%	0%	0%
Hemiptera	Corixidae		0	0	0	0	0	0	0	0	0	0%	0%	0%
Coleoptera	Elmidae	larva	0	0	0	0	0	0	0	0	0	0%	0%	0%
Megaloptera	Sialidae	Sialis	0	0	1	0	0	1	0	0	1	0%	0%	0%
Oligochaeta	Lumbriculidae		0	2	4	0	3	5	0	1	3	0%	0%	0%
	Naididae		1	0	0	1	0	0	1	0	0	0%	0%	0%
Bivalvia	Sphaeridae		3	3	4	5	3	4	1	2	3	83%	60%	200%
Gastropoda			0	0	0	0	0	0	0	0	0	0%	0%	0%
	Limnaidae		0	1	1	0	1	1	0	1	1	0%	0%	0%
	Ancyllidae	Ferrissia	3	1	1	3	1	1	2	1	1	40%	33%	50%
Hydrachnidia			0	1	0	0	1	0	0	1	0	0%	0%	0%
Nematoda			2	1	1	2	1	1	2	1	1	50%	50%	50%

TABLE A17 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 16, 2007 (continued)

			Mean	Max	Min	Total	Total	Total	Drift	Surber	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TD/ref	TD/ref	TD/ref	Ref	TS	TD	(ind/m2/day)	(ind/m2/day)	Drift	TS/ref%	TD/ref%	Drift/ref%
Diptera	Chironomidae	SF Tanypondinae	174%	163%	164%	166	142	215	14	11	196	86	130	118
		other chironomids	135%	121%	214%				14	0				
	Simuliidae		17%	15%	100%				168	78				
		blackfly pupa	0%	0%	0%				0	0				
	Empididae		125%	100%	200%				0	0				
	Dixidae		300%	500%	100%				0	0				
	Ceratopogonidae		100%	100%	100%				0	0				
Ephemeroptera			18%	11%	50%	104	89	29	0	11	414	86	28	398
	Heptageniidae		420%	367%	300%				28	22				
		Stenonema	100%	100%	100%				7	0				
		Rithrogena	100%	125%	67%				14	78				
		Cinygma	0%	0%	0%				0	0				
		Heptagenia	0%	0%	0%				0	0				
		Stenacron	0%	0%	0%				0	0				
	Leptophlebiidae		0%	0%	0%				0	0				
	Ephemerellidae		100%	100%	100%				0	0				
		Ephemerella	0%	0%	0%				0	0				
	Baetidae		25%	28%	17%				238	222				
		Baetis	60%	80%	100%				119	167				
		Centroptilum	0%	0%	0%				0	0				
	Metretopodidae	Siphloplecton	0%	0%	0%				0	11				
	Oligoneuridae	Isonychia	0%	0%	0%				0	0				
	Siphloneuridae		0%	0%	0%				0	0				
		Parameletus	750%	1200%	300%				0	22				
		Siphlonurus(?)	0%	0%	0%				0	0				
		Ameletus	0%	0%	0%				7	0				
Plecoptera			38%	29%	100%	49	43	24	35	33	365	88	49	744
	Chloroperlidae		0%	0%	0%				14	0				
	Perlodidae		60%	67%	25%				203	156				
		Isogenoides	0%	0%	0%				7	0				
		Isoperla	0%	0%	0%				7	11				

	Taeniopterygidae		0%	0%	0%				0	0				
		Oemopteryx	200%	200%	200%				7	11				
		Taenionema	100%	150%	50%				14	22				
		Taeniopteryx	0%	0%	0%				0	0				
	Nemouridae		100%	89%	50%				56	22				
	Capniidae		0%	0%	0%				21	11				
	Leuctridae		0%	0%	0%				0	0				
	Pteronarcydae	Pteronarcys	0%	0%	0%				0	0				
Trichoptera			0%	0%	0%	59	70	73	7	0	42	119	124	71
	Trichop pupa(e)		0%	0%	0%				0	0				
	Hydropsychidae		0%	0%	0%				0	0				
		Hydropsyche	230%	214%	258%				35	0				
	Psychomyiidae		0%	0%	0%				0	0				
		Psychomyia	0%	0%	0%				0	0				
	Glossosomatidae		150%	200%	100%				0	0				
		Anagapetus	0%	0%	0%				0	0				
	Brachycentridae		0%	0%	0%				0	0				
		Brachycentrus	75%	67%	100%				0	0				
	Hydroptilidae		0%	0%	0%				0	0				
		Hydroptila	0%	0%	0%				0	0				
Odonata	Gomphidae		0%	0%	0%	15	17	26	0	0				
		Ophiogomphus	100%	100%	100%				0	0				
		Gomphus	0%	0%	0%				0	0				
Hemiptera	Corixidae		0%	0%	0%				0	0				
Coleoptera	Elmidae	larva	0%	0%	0%				0	0				
Megaloptera	Sialidae	Sialis	0%	0%	0%				0	0				
Oligochaeta	Lumbriculidae		0%	0%	0%				0	0				
	Naididae		0%	0%	0%				0	0				
Bivalvia	Sphaeridae		117%	80%	300%				0	0				
Gastropoda			0%	0%	0%				0	0				
	Limnaidae		0%	0%	0%				0	0				
	Ancyllidae	Ferrissia	40%	33%	50%				0	0				
Hydrachnidia			0%	0%	0%				0	0				
Nematoda			50%	50%	50%				0	0				
				All Species		393	361	367			1017	92	93	259

TABLE A18 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken March 6, 2008 and drift net samples taken March 7, and 12, 2008

		Date collected:	Mar 6 2008	Mar 6 2008	Mar 6 2008	Mar 6 2008	Mar 6 2008	Mar 6 2008	Mar 7 2008	Mar 12 2008
Order	**Family**	**Genera (unless noted)**	AR SS1	AR SS2	AR SS3	AR SS4	AR SS5	AR SS6	DN1	DN2
Diptera	Chironomidae	SF Tanypondinae	33	37	26	36	29	56	1	
		other chironomids	61	56	77	53	40	96		1
	Simuliidae			5	3		2	4		1
		Ectemnia	1	1		1			39	4
	Empididae		17	12	10	19	19	20		
	Ceratopogonidae		1	1		1				
	Dixidae		2							
	Sciomyzidae									
	Chaoboridae	Chaoborus								
Ephemeroptera					1	1		5		
	Heptageniidae		19	8	21	25	1	24		3
		Stenonema	1	2	1	1		1		
		Rithrogena	10	4	2	5		7	2	
		Heptagenia	15			4		5		
		Stenacron			1			1		
	Ephemerellidae		6	10	4	5	4	10		
		Ephemerella		1						
	Baetidae		1	3	2	3	8	3	8	1
		Baetis							1	
		Centroptilum								
	Leptophlebiidae									
		Leptophlebia								
	Siphloneuridae									
		Analetris						1		
	Metretopodidae									
		Metretopus							1	
		Siphloplecton								
Plecoptera			1		4			7		6
	Chloroperlidae		3	3	5	4	7	6		4
	Perlodidae		8	6	8	2	4	28	18	7
		Isogenoides		1			1	1		
		Isoperla								
		Shipsa	1							

	Taeniopterygidae		1		1		1	2		
		Taenia								1
		Taenionema		1						
		Oemopteryx							1	
	Nemouridae		10	4			4	2	9	1
		Podmosta		10	9	6		29		
Trichoptera			1	4	2	2		1		
	Hydropsychidae		1	1		2		2		
		Hydropsyche	105	157	147	229	229	278	2	12
	Glossosomatidae							1		
		Glossosoma								1
	Brachycentridae		1	1	5		1	1		
		Brachycentrus				1	2			
	Polycentropodidae		1				1			
		Polycentropus				5				
	Rhyachophyllidae				2					
Hemiptera										
	Corixidae		1	2	1	4				
		Corisella	1	5	1	3		1	2	1
		Sigara						2		
		Callicorixa							1	
	Belostomatidae									
		Lethocerus americanus								
Odonata										
	Gomphidae									
		Ophiogomphus	1		3		1	1		
		Gomphus		1	1	1		1		
Coleoptera										
	Dytiscidae									
		Liodessus				1		1		
	Elmidae									
		Heterlimnius								
	Hydrophilidae									
		Helophorus								
	Haliplidae									
		Brychius								
	Chrysomelidae									
	Curculionidae									
Megaloptera										
	Sialidae									

		Sialis								
Oligochaeta	Lumbriculidae		14	21	15	35	18	21		
Bivalvia	Sphaeridae			2	1	1		1		
Gastropoda										
	Ancyllidae									
Copepoda									2	
Nematoda						1	1			
Hydrachnidia							1			
Anostraca									11	
Arachnida										
terrestrial fly										
immature fish fry										

TABLE A19 Raw data following benthic invertebrate identfication for drift net samples from the C-Bridge experimental site taken March 15, and 17, 2008, and descriptive statistics (continued)

		Date collected:	Mar 15 2008	Mar 17 2008							
					Mean	Max	Min	Total	Mean	Drift	Total
Order	**Family**	**Genera (unless noted)**	DN3	BFDN	TS	TS	TS	TS	Drift	(ind/m2/day)	Drift
Diptera	Chironomidae	SF Tanypondinae			36	56	26	343	1	7.0	180
		other chironomids	1		64	96	40		1	7.0	
	Simuliidae				3.5	5	2		1	7.0	
		Ectemnia	25		1	1	1		23	159	
	Empididae				16	20	10		0	0	
	Ceratopogonidae				1	1	1		0	0	
	Dixidae				2	2	2		0	0	
	Sciomyzidae				0	0	0		0	0	
	Chaoboridae	Chaoborus			0	0	0		0	0	
Ephemeroptera			5		2.3	5	1	112	5	35	125
	Heptageniidae		2	2	16	25	1		2.3	16	
		Stenonema			1.2	2	1		0	0	
		Rithrogena		3	5.6	10	2		2.5	18	
		Heptagenia		2	8	15	4		2	14	
		Stenacron			1	1	1		0	0	
	Ephemerellidae				6.5	10	4		0	0	
		Ephemerella			1	1	1		0	0	
	Baetidae		2	1	3.3	8	1		3	21	
		Baetis	1		0	0	0		1	7.0	
		Centroptilum			0	0	0		0	0	
	Leptophlebiidae				0	0	0		0	0	
		Leptophlebia			0	0	0		0	0	
	Siphloneuridae				0	0	0		0	0	
		Analetris			1	1	1		0	0	
	Metretopodidae				0	0	0		0	0	
		Metretopus			0	0	0		1	7.0	
		Siphloplecton		1	0	0	0		1	7.0	
Plecoptera			1	1	4	7	1	76	2.7	19	159
	Chloroperlidae		1		4.7	7	3		2.5	18	
	Perlodidae		5	7	9.3	28	2		9.3	65	

		Isogenoides			1	1	1		0	0	
		Isoperla			0	0	0		0	0	
		Shipsa			1	1	1		0	0	
	Taeniopterygidae				1.25	2	1		0	0	
		Taenia			0	0	0		1	7.0	
		Taenionema		1	1	1	1		1	7.0	
		Oemopteryx			0	0	0		1	7.0	
	Nemouridae		1	10	5	10	2		5.3	37	
		Podmosta			14	29	6		0	0	
Trichoptera					2	4	1	428	0	0	65
	Hydropsychidae			2	1.5	2	1		2	14	
		Hydropsyche	1	6	191	278	105		5.3	37	
	Glossosomatidae				1	1	1		0	0	
		Glossosoma			0	0	0		1	7.0	
	Brachycentridae				1.8	5	1		0	0	
		Brachycentrus		1	1.5	2	1		1	7.0	
	Polycentropodidae				1	1	1		0	0	
		Polycentropus			5	5	5		0	0	
	Rhyachophyllidae				2	2	2		0	0	
Hemiptera					0	0	0	70	0	0	98
	Corixidae				2	4	1		0	0	
		Corisella		36	2.2	5	1		13	91	
		Sigara			2	2	2		0	0	
		Callicorixa			0	0	0		1	7.0	
	Belostomatidae				0	0	0		0	0	
		Lethocerus americanus			0	0	0		0	0	
Odonata					0	0	0		0	0	
	Gomphidae				0	0	0		0	0	
		Ophiogomphus			1.5	3	1		0	0	
		Gomphus			1	1	1		0	0	
Coleoptera					0	0	0		0	0	
	Dytiscidae				0	0	0		0	0	
		Liodessus			1	1	1		0	0	
	Elmidae				0	0	0		0	0	
		Heterlimnius			0	0	0		0	0	
	Hydrophilidae				0	0	0		0	0	
		Helophorus			0	0	0		0	0	
	Haliplidae				0	0	0		0	0	
		Brychius			0	0	0		0	0	
	Chrysomelidae				0	0	0		0	0	

	Curculionidae				0	0	0		0	0	
Megaloptera					0	0	0		0	0	
	Sialidae				0	0	0		0	0	
		Sialis			0	0	0		0	0	
Oligochaeta	Lumbriculidae				21	35	14		0	0	
Bivalvia	Sphaeridae				1.3	2	1		0	0	
Gastropoda					0	0	0		0	0	
	Ancyllidae				0	0	0		0	0	
Copepoda					0	0	0		2	14	498
Nematoda					1	1	1		0	0	
Hydrachnidia					1	1	1		0	0	
Anostraca				127	0	0	0		69	484	
Arachnida					0	0	0		0	0	
terrestrial fly					0	0	0		0	0	
immature fish fry					0	0	0		0	0	
						All Species		1029			1125

TABLE A20 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken March 14, 2008, and descriptive statistics

		Date collected:	Mar 14 2008	Mar 14 2008	Mar 14 2008	Mar 14 2008	Mar 14 2008	Mar 14 2008							
									Mean	Max	Min	Total	Mean	Drift	Total
Order	**Family**	**Genera (unless noted)**	AR SS1	AR SS2	AR SS3	AR SS4	AR SS5	AR SS6	TS	TS	TS	TS	Drift	(ind/m 2/day)	Drift
Diptera	Chironomidae	SF Tanypondinae	36	46	28	5	26	17	26	46	5	239	1	7.0	180
		other chironomids	20	24	42	16	29	20	25	42	16		1	7.0	
	Simuliidae			3	1			2	2	3	1		1	7.0	
		Ectemnia	7	1	1	1	1	5	3.0	7	1		23	159	
	Empididae		6	10	12	1	15	9	8.8	15	1		0	0	
	Ceratopogonidae			1		1			1	1	1		0	0	
	Dixidae			1					1	1	1		0	0	
	Sciomyzidae								0	0	0		0	0	
	Chaoboridae	Chaoborus							0	0	0		0	0	
Ephemeroptera			3	1	1			1	1.5	3	1	71	5	35	125
	Heptageniidae			7	8	12	1	7	7	12	1		2.3	16	
		Stenonema	1	3	2	1	1	1	1.5	3	1		0	0	
		Rithrogena		3	1	1	4	4	2.6	4	1		2.5	18	
		Heptagenia	1		1	3		1	1.5	3	1		2	14	
		Stenacron							0	0	0		0	0	

	Ephemerellidae		2	9	12	2	8	6	6.5	12	2		0	0	
		Ephemerella		3	1		2		2	3	1		0	0	
	Baetidae		3	4	3	1	3	12	4.3	12	1		3	21	
		Baetis	1						1	1	1		1	7.0	
		Centroptilum						1	1	1	1		0	0	
	Leptophlebiidae								0	0	0		0	0	
		Leptophlebia							0	0	0		0	0	
	Siphloneuridae								0	0	0		0	0	
		Analetris	1					4	2.5	4	1		0	0	
	Metretopodidae								0	0	0		0	0	
		Metretopus							0	0	0		1	7.0	
		Siphloplecton							0	0	0		1	7.0	
Plecoptera			2	7	4			2	3.8	7	2	134	2.7	19	159
	Chloroperlidae		1	9	4			4	4.5	9	1		2.5	18	
	Perlodidae		13	13	22	3	11	14	13	22	3		9.3	65	
		Isogenoides	2						2	2	2		0	0	
		Isoperla		1				1	1	1	1		0	0	
		Shipsa							0	0	0		0	0	
	Taeniopterygidae		1			1		2	1.3	2	1		0	0	
		Taenia							0	0	0		1	7.0	
		Taenionema							0	0	0		1	7.0	
		Oemopteryx							0	0	0		1	7.0	
	Nemourid		1		3	1	1	1	1.4	3	1		5.3	37	

	ae														
		Podmosta	15	21	15		13	10	15	21	10		0	0	
Trichoptera					2	1	1		1.3	2	1	395	0	0	65
	Hydropsychidae		1	2					1.5	2	1		2	14	
		Hydropsyche	73	172	139	26	127	77	102	172	26		5.3	37	
	Glossosomatidae			1	1				1	1	1		0	0	
		Glossosoma		1					1	1	1		1	7.0	
	Brachycentridae		2			1	1		1.3	2	1		0	0	
		Brachycentrus		1				1	1	1	1		1	7.0	
	Polycentropodidae								0	0	0		0	0	
		Polycentropus						1	1	1	1		0	0	
	Rhyachophyllidae								0	0	0		0	0	
Hemiptera									0	0	0	42	0	0	98
	Corixidae		1						1	1	1		0	0	
		Corisella		1					1	1	1		13	91	
		Sigara							0	0	0		0	0	
		Callicorixa							0	0	0		1	7.0	
	Belostomatidae								0	0	0		0	0	
		Lethocerus americanus							0	0	0		0	0	
Odonata									0	0	0		0	0	
	Gomphidae								0	0	0		0	0	
		Ophiog	1		2	1			1.3	2	1		0	0	

		omphus													
		Gomphus		1					1	1	1		0	0	
Coleoptera									0	0	0		0	0	
	Dytiscidae								0	0	0		0	0	
		Liodessus							0	0	0		0	0	
	Elmidae								0	0	0		0	0	
		Heterlimnius							0	0	0		0	0	
	Hydrophilidae								0	0	0		0	0	
		Helophorus							0	0	0		0	0	
	Haliplidae								0	0	0		0	0	
		Brychius							0	0	0		0	0	
	Chrysomelidae								0	0	0		0	0	
	Curculionidae								0	0	0		0	0	
Megaloptera									0	0	0		0	0	
	Sialidae								0	0	0		0	0	
		Sialis			1		1		1	1	1		0	0	
Oligochaeta	Lumbriculidae		6	5	12	4	3	9	6.5	12	3		0	0	
Bivalvia	Sphaeridae			1	2		1	3	1.8	3	1		0	0	
Gastropoda									0	0	0		0	0	
	Ancyllidae				1				1	1	1		0	0	
Copepoda									0	0	0		2	14	498
Nematoda			3	2	2				2.3	3	2		0	0	
Hydrachnidia					1				1	1	1		0	0	

Anostraca									0	0	0		69	484	
Arachnida									0	0	0		0	0	
terrestrial fly									0	0	0		0	0	
immature fish fry									0	0	0		0	0	
										All Species		881			1125

TABLE A21 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken May 8, 2008, and descriptive statistics

		Date collected:	May 8 2008	May 8 2008	May 8 2008	May 8 2008	May 8 2008	May 8 2008		
									Mean	Mean
Order	**Family**	**Genera (unless noted)**	AR DS1	AR DS2	AR DS3	AR SS1	AR SS2	AR SS3	TS	TD
Diptera	Chironomidae	SF Tanypondinae		1	1		1	1	1	1
		other chironomids		4	1	4	3	2	3	2.5
	Simuliidae				1				0	1
		Ectemnia							0	0
	Empididae		2			1			1	2
	Ceratopogonidae								0	0
	Dixidae						1		1	0
	Sciomyzidae							1	1	0
	Chaoboridae	Chaoborus			1				0	1
Ephemeroptera							2		2	0
	Heptageniidae								0	0
		Stenonema							0	0
		Rithrogena							0	0
		Heptagenia	2						0	2
		Stenacron							0	0
	Ephemerellidae								0	0
		Ephemerella							0	0
	Baetidae			3	2	1			1	2.5
		Baetis							0	0
		Centroptilum							0	0
	Leptophlebiidae			1					0	1
		Leptophlebia	2	2	6	7	5	4	5.3	3.3
	Siphloneuridae								0	0
		Analetris							0	0
	Metretopodidae								0	0
		Metretopus							0	0
		Siphloplecton							0	0
Plecoptera			3	1		2	1	1	1.3	2
	Chloroperlidae				1				0	1
	Perlodidae		7	6	6	4	2	3	3	6.3
		Isogenoides							0	0
		Isoperla	10	7	6		1	1	1	7.7

		Shipsa							0	0
	Taeniopterygidae								0	0
		Taenia							0	0
		Taenionema							0	0
		Oemopteryx							0	0
	Nemouridae		7	2	2	1		3	2	3.7
		Podmosta	46	51	34	36	43	23	34	44
Trichoptera									0	0
	Hydropsychidae								0	0
		Hydropsyche		1					0	1
	Glossosomatidae								0	0
		Glossosoma							0	0
	Brachycentridae								0	0
		Brachycentrus							0	0
	Polycentropodidae								0	0
		Polycentropus							0	0
	Rhyachophyllidae								0	0
Hemiptera									0	0
	Corixidae						1	2	1.5	0
		Corisella		1	1	3	1	2	2	1
		Sigara				2			2	0
		Callicorixa							0	0
	Belostomatidae								0	0
		Lethocerus americanus	1						0	1
Odonata									0	0
	Gomphidae								0	0
		Ophiogomphus							0	0
		Gomphus							0	0
Coleoptera									0	0
	Dytiscidae								0	0
		Liodessus							0	0
	Elmidae								0	0
		Heterlimnius	2	2				1	1	2
	Hydrophilidae								0	0
		Helophorus		1					0	1
	Haliplidae								0	0
		Brychius				1			1	0
	Chrysomelidae					1			1	0
	Curculionidae						1		1	0

Megaloptera									0	0
	Sialidae								0	0
		Sialis							0	0
Oligochaeta	Lumbriculidae		2	7	5	1	3	1	1.7	4.7
Bivalvia	Sphaeridae								0	0
Gastropoda				10	4	3	3	2	2.7	7
	Ancyllidae								0	0
Copepoda			2	4	5	1	1	4	2	3.7
Nematoda									0	0
Hydrachnidia									0	0
Anostraca									0	0
Arachnida				1					0	1
terrestrial fly				2					0	2
immature fish fry				1	3	2	1	3	2	2

TABLE A22 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken May 8, 2008 (continued)

			Max	Max	Min	Min	Total	Total	Mean	Drift	Total
Order	**Family**	**Genera (unless noted)**	TS	TD	TS	TD	TS	TD	Drift	(ind/m 2/day)	Drift
Diptera	Chironomidae	SF Tanypondinae	1	1	1	1	14	11	1	7.0	180
		other chironomids	4	4	2	1			1	7.0	
	Simuliidae		0	1	0	1			1	7.0	
		Ectemnia	0	0	0	0			23	159	
	Empididae		1	2	1	2			0	0	
	Ceratopogonidae		0	0	0	0			0	0	
	Dixidae		1	0	1	0			0	0	
	Sciomyzidae		1	0	1	0			0	0	
	Chaoboridae	Chaoborus	0	1	0	1			0	0	
Ephemerop tera			2	0	2	0	19	18	5	35	125
	Heptageniidae		0	0	0	0			2.3	16	
		Stenonema	0	0	0	0			0	0	
		Rithrogena	0	0	0	0			2.5	18	
		Heptagenia	0	2	0	2			2	14	
		Stenacron	0	0	0	0			0	0	
	Ephemerellidae		0	0	0	0			0	0	
		Ephemerella	0	0	0	0			0	0	
	Baetidae		1	3	1	2			3	21	
		Baetis	0	0	0	0			1	7.0	
		Centroptilum	0	0	0	0			0	0	
	Leptophlebiidae		0	1	0	1			0	0	
		Leptophlebia	7	6	4	2			0	0	
	Siphloneuridae		0	0	0	0			0	0	
		Analetris	0	0	0	0			0	0	
	Metretopodidae		0	0	0	0			0	0	
		Metretopus	0	0	0	0			1	7.0	
		Siphloplecton	0	0	0	0			1	7.0	
Plecoptera			2	3	1	1	121	189	2.7	19	159
	Chloroperlidae		0	1	0	1			2.5	18	
	Perlodidae		4	7	2	6			9.3	65	
		Isogenoides	0	0	0	0			0	0	
		Isoperla	1	10	1	6			0	0	
		Shipsa	0	0	0	0			0	0	
	Taeniopterygidae		0	0	0	0			0	0	

		Taenia	0	0	0	0			1	7.0	
		Taenionema	0	0	0	0			1	7.0	
		Oemopteryx	0	0	0	0			1	7.0	
	Nemouridae		3	7	1	2			5.3	37	
		Podmosta	43	51	23	34			0	0	
Trichoptera			0	0	0	0	0	1	0	0	65
	Hydropsychidae		0	0	0	0			2	14	
		Hydropsyche	0	1	0	1			5.3	37	
	Glossosomatidae		0	0	0	0			0	0	
		Glossosoma	0	0	0	0			1	7.0	
	Brachycentridae		0	0	0	0			0	0	
		Brachycentrus	0	0	0	0			1	7.0	
	Polycentropodidae		0	0	0	0			0	0	
		Polycentropus	0	0	0	0			0	0	
	Rhyachophyllidae		0	0	0	0			0	0	
Hemiptera			0	0	0	0	40	54	0	0	98
	Corixidae		2	0	1	0			0	0	
		Corisella	3	1	1	1			13	91	
		Sigara	2	0	2	0			0	0	
		Callicorixa	0	0	0	0			1	7.0	
	Belostomatidae		0	0	0	0			0	0	
		Lethocerus americanus	0	1	0	1			0	0	
Odonata			0	0	0	0			0	0	
	Gomphidae		0	0	0	0			0	0	
		Ophiogomphus	0	0	0	0			0	0	
		Gomphus	0	0	0	0			0	0	
Coleoptera			0	0	0	0			0	0	
	Dytiscidae		0	0	0	0			0	0	
		Liodessus	0	0	0	0			0	0	
	Elmidae		0	0	0	0			0	0	
		Heterlimnius	1	2	1	2			0	0	
	Hydrophilidae		0	0	0	0			0	0	
		Helophorus	0	1	0	1			0	0	
	Haliplidae		0	0	0	0			0	0	
		Brychius	1	0	1	0			0	0	
	Chrysomelidae		1	0	1	0			0	0	
	Curculionidae		1	0	1	0			0	0	
Megalopter a			0	0	0	0			0	0	
	Sialidae		0	0	0	0			0	0	

		Sialis	0	0	0	0			0	0	
Oligochaeta	Lumbriculidae		3	7	1	2			0	0	
Bivalvia	Sphaeridae		0	0	0	0			0	0	
Gastropoda			3	10	2	4			0	0	
	Ancyllidae		0	0	0	0			0	0	
Copepoda			4	5	1	2			2	14	498
Nematoda			0	0	0	0			0	0	
Hydrachnidia			0	0	0	0			0	0	
Anostraca			0	0	0	0			69	484	
Arachnida			0	1	0	1			0	0	
terrestrial fly			0	2	0	2			0	0	
immature fish fry			3	3	1	1			0	0	
					All Species		194	273			1125

TABLE A23 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken July 11, 2008, and descriptive statistics

		Date collected:	Jul 11 2008	Jul 11 2008	Jul 11 2008	Jul 11 2008	Jul 11 2008	Jul 11 2008	Jul 11 2008		
										Mean	Mean
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-DS1	AR-DS2	AR-DS3	SN	Jul11TS	Jul11TD
Diptera	Chironomidae	SF Tanypondinae	2	4	2	10	6	8		2.7	8
		other chironomids	4	10	4	3	4	6	2	6	4.3
	Empididae									0	0
	Ceratopogonidae			1						1	0
	Dixidae									0	0
Ephemeroptera			4	6	5	1	2	9		5	4
	Heptageniidae		8	30	4	19	18	20	3	14	19
		Stenonema								0	0
		Rithrogena	1		5		2			3	2
		Heptagenia	1	11	9	3	14	11	3	7	9.3
		Stenacron							1	0	0
	Ephemerellidae		2			1		1		2	1
		Ephemerella						1	1	0	1
	Baetidae		11	18	14	14	8	17	25	14	13
		Baetis			3	6	6	14		3	8.7
		Centroptilum	8	2	4	6	6	5	4	4.7	5.7
	Leptophlebiidae									0	0
		Leptophlebia								0	0
	Siphloneuridae									0	0
		Analetris							1	0	0
	Metretopodidae									0	0
	Tricorythidae									0	0
		Tricorythodes								0	0
Plecoptera			5	1			1			3	1
	Chloroperlidae			1						1	0
	Perlodidae		2	2	2	2	2	3		2	2.3
		Isogenoides		1		1	2	2		1	1.7
		Isoperla	13	6	9	5	5	5	6	9.3	5
Trichoptera			19	44	28	34	45	37		30	39
	pupa(e)				1	1	1			1	1
	Hydropsychidae		19	53	13	30	43	34		28	36

		Hydropsyche	22	14	5	54	49	48	13	14	50
	Glossosomatidae									0	0
		Glossosoma								0	0
	Brachycentridae									0	0
		Brachycentrus				3	21			0	12
	Rhyacophilidae									0	0
	Hydroptilidae		1	1						1	0
		Mayatrichia				1				0	1
		Neotrichia								0	0
Hemiptera			1	1						1	0
	Corixidae					1			3	0	1
		Sigara							5	0	0
	Mesovelliidae (with wings)									0	0
Odonata						2	1	1		0	1.3
	Gomphidae									0	0
		Ophiogomphus				1		1		0	1
		Gomphus				2	1			0	1.5
Coleoptera									1	0	0
	Chrysomelidae									0	0
Oligochaeta	Lumbriculidae		5	3	4	20	13	11		4	15
Bivalvia	Sphaeridae									0	0
Gastropoda					4					4	0
	Limnaeidae			2	2			1		2	1
Ostracoda						1		1		0	1
Nematoda			9		1		4	4		5	4
Hydrachnidia										0	0
Arachnida										0	0
Hymenoptera										0	0
terrestrial fly			2	4	4		1	5	33	3.3	3
fish fry				2		1	1		18	2	1
fertilized fish eggs				14				3		14	3
Hydra			1		1	2	5	1		1	2.7

TABLE A24 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken July 11, 2008 (continued)

			Max	Max	Min	Min	Total	Total	Surber	Total
Order	**Family**	**Genera (unless noted)**	Jul11TS	Jul11TD	Jul11TS	Jul11TD	Jul11TS	Jul11TD	(ind/m2/day)	Surber
Diptera	Chironomidae	SF Tanypondinae	4	10	2	6	27	37	0	796
		other chironomids	10	6	4	3			796	
	Empididae		0	0	0	0			0	
	Ceratopogonidae		1	0	1	0			0	
	Dixidae		0	0	0	0			0	
Ephemeroptera			6	9	4	1	146	184	0	15124
	Heptageniidae		30	20	4	18			1194	
		Stenonema	0	0	0	0			0	
		Rithrogena	5	2	1	2			0	
		Heptagenia	11	14	1	3			1194	
		Stenacron	0	0	0	0			398	
	Ephemerellidae		2	1	2	1			0	
		Ephemerella	0	1	0	1			398	
	Baetidae		18	17	11	8			9950	
		Baetis	3	14	3	6			0	
		Centroptilum	8	6	2	5			1592	
	Leptophlebiidae		0	0	0	0			0	
		Leptophlebia	0	0	0	0			0	
	Siphloneuridae		0	0	0	0			0	
		Analetris	0	0	0	0			398	
	Metretopodidae		0	0	0	0			0	
	Tricorythidae		0	0	0	0			0	
		Tricorythodes	0	0	0	0			0	
Plecoptera			5	1	1	1	42	28	0	2388
	Chloroperlidae		1	0	1	0			0	
	Perlodidae		2	3	2	2			0	
		Isogenoides	1	2	1	1			0	
		Isoperla	13	5	6	5			2388	
Trichoptera			44	45	19	34	220	401	0	5174
	pupa(e)		1	1	1	1			0	
	Hydropsychidae		53	43	13	30			0	
		Hydropsyche	22	54	5	48			5174	
	Glossosomatidae		0	0	0	0			0	
		Glossosoma	0	0	0	0			0	

	Brachycentridae		0	0	0	0			0	
		Brachycentrus	0	21	0	3			0	
	Rhyacophilidae		0	0	0	0			0	
	Hydroptilidae		1	0	1	0			0	
		Mayatrichia	0	1	0	1			0	
		Neotrichia	0	0	0	0			0	
Hemiptera			1	0	1	0	60	84	0	23880
	Corixidae		0	1	0	1			119	
		Sigara	0	0	0	0			1990	
	Mesovelliidae (with wings)		0	0	0	0			0	
Odonata			0	2	0	1			0	
	Gomphidae		0	0	0	0			0	
		Ophiogomphus	0	1	0	1			0	
		Gomphus	0	2	0	1			0	
Coleoptera			0	0	0	0			398	
	Chrysomelidae		0	0	0	0			0	
Oligochaeta	Lumbriculidae		5	20	3	11			0	
Bivalvia	Sphaeridae		0	0	0	0			0	
Gastropoda			4	0	4	0			0	
	Limnaeidae		2	1	2	1			0	
Ostracoda			0	1	0	1			0	
Nematoda			9	4	1	4			0	
Hydrachnidia			0	0	0	0			0	
Arachnida			0	0	0	0			0	
Hymenoptera			0	0	0	0			0	
terrestrial fly			4	5	2	1			13134	
fish fry			2	1	2	1			7164	
fertilized fish eggs			14	3	14	3			0	
Hydra			1	5	1	1			0	
					All Species		495	734		47363

TABLE A25 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken September 3, 2008, and descriptive statistics

		Date collected:	Sept 3 2008	Sept 3 2008	Sept 3 2008	Sept 3 2008	Sept 3 2008	Sept 3 2008	Sept 3 2008		
										Mean	Mean
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-DS1	AR-DS2	AR-DS3	DN	Sept3TS	Sept3TD
Diptera	Chironomidae	SF Tanypondinae	49	44	52	57	60	55		48	57
		other chironomids	21	8	16	7	5	2		15	4.7
	Empididae		6	5	16	13	14	12		9	13
	Ceratopogonidae					1				0	1
	Dixidae				1				4	1	0
Ephemeroptera				1	5	6	3	4		3	4.3
	Heptageniidae		57	20	59	59	59	46	25	45	55
		Stenonema	8	2	1	2	4	4	1	3.7	3.3
		Rithrogena	25	7	9	25	17	22	1	14	21
		Heptagenia	10	13	12	13	7	7	11	12	9
		Stenacron	2							2	0
	Ephemerellidae									0	0
		Ephemerella								0	0
	Baetidae			2	1	3	6	2	4	1.5	3.7
		Baetis								0	0
		Centroptilum								0	0
	Leptophlebiidae		1					1		1	1
		Leptophlebia								0	0
	Siphloneuridae									0	0
		Analetris								0	0
	Metretopodidae		1							1	0
	Tricorythidae									0	0
		Tricorythodes	1		2	2				1.5	2
Plecoptera			3		4	5	6	8		3.5	6.3
	Chloroperlidae		1		1		1			1	1
	Perlodidae		11	2	2	1	4	5	1	5	3.3
		Isogenoides				1		2		0	1.5
		Isoperla								0	0
Trichoptera						6	1	3	1	0	3.3
	pupa(e)									0	0
	Hydropsychidae		14	1	1	13	8	8		5.3	9.7

		Hydropsyche	103	90	164	198	187	142	10	119	176
	Glossosomatidae					3		1		0	2
		Glossosoma								0	0
	Brachycentridae						1			0	1
		Brachycentrus	2	1					1	1.5	0
	Rhyacophilidae						1			0	1
	Hydroptilidae					2	3	2		0	2.3
		Mayatrichia								0	0
		Neotrichia							1	0	0
Hemiptera										0	0
	Corixidae								2	0	0
		Sigara								0	0
	Mesovelliidae (with wings)								1	0	0
Odonata										0	0
	Gomphidae								1	0	0
		Ophiogomphus	1				1	1	1	1	1
		Gomphus								0	0
Coleoptera										0	0
	Chrysomelida								1	0	0
Oligochaeta	Lumbriculidae		14	11	4	4	11	8		9.7	7.7
Bivalvia	Sphaeridae					1				0	1
Gastropoda						1				0	1
	Limnaeidae		1	5	1			1	1	2.3	1
Ostracoda			1	1						1	0
Nematoda			7	1	6	8	8	7		4.7	7.7
Hydrachnidia					1					1	0
Arachnida						1				0	1
Hymenoptera									1	0	0
t fly					3	3	2		22	3	2.5
fish fry										0	0
ffeggs										0	0
Hydra										0	0

TABLE A26 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken September 3, 2008 (continued)

			Max	Max	Min	Min	Total	Total	Drift	Total
Order	**Family**	**Genera (unless noted)**	Sept3TS	Sept3TD	Sept3TS	Sept3TD	Sept3TS	Sept3TD	(ind/m2/day)	Drift
Diptera	Chironomidae	SF Tanypondinae	52	60	44	55	218	226	0	898
		other chironomids	21	7	8	2			0	
	Empididae		16	14	5	12			0	
	Ceratopogonidae		0	1	0	1			0	
	Dixidae		1	0	1	0			898	
Ephemeroptera			5	6	1	3	239	292	0	9425
	Heptageniidae		59	59	20	46			5610	
		Stenonema	8	4	1	2			224	
		Rithrogena	25	25	7	17			224	
		Heptagenia	13	13	10	7			2468	
		Stenacron	2	0	2	0			0	
	Ephemerellidae		0	0	0	0			0	
		Ephemerella	0	0	0	0			0	
	Baetidae		2	6	1	2			898	
		Baetis	0	0	0	0			0	
		Centroptilum	0	0	0	0			0	
	Leptophlebiidae		1	1	1	1			0	
		Leptophlebia	0	0	0	0			0	
	Siphloneuridae		0	0	0	0			0	
		Analetris	0	0	0	0			0	
	Metretopodidae		1	0	1	0			0	
	Tricorythidae		0	0	0	0			0	
		Tricorythodes	2	2	1	2			0	
Plecoptera			4	8	3	5	24	33	0	224
	Chloroperlidae		1	1	1	1			0	
	Perlodidae		11	5	2	1			224	
		Isogenoides	0	2	0	1			0	
		Isoperla	0	0	0	0			0	
Trichoptera			0	6	0	1	376	579	224	2917
	pupa(e)		0	0	0	0			0	
	Hydropsychidae		14	13	1	8			0	
		Hydropsyche	164	198	90	142			2244	
	Glossosomatidae		0	3	0	1			0	
		Glossosoma	0	0	0	0			0	

	Brachycentridae		0	1	0	1			0	
		Brachycentrus	2	0	1	0			224	
	Rhyacophilidae		0	1	0	1			0	
	Hydroptilidae		0	3	0	2			0	
		Mayatrichia	0	0	0	0			0	
		Neotrichia	0	0	0	0			224	
Hemiptera			0	0	0	0	57	57	0	6732
	Corixidae		0	0	0	0			449	
		Sigara	0	0	0	0			0	
	Mesovelliidae (with wings)		0	0	0	0			224	
Odonata			0	0	0	0			0	
	Gomphidae		0	0	0	0			224	
		Ophiogomphus	1	1	1	1			224	
		Gomphus	0	0	0	0			0	
Coleoptera			0	0	0	0			0	
	Chrysomelida		0	0	0	0			224	
Oligochaeta	Lumbriculidae		14	11	4	4			0	
Bivalvia	Sphaeridae		0	1	0	1			0	
Gastropoda			0	1	0	1			0	
	Limnaeidae		5	1	1	1			224	
Ostracoda			1	0	1	0			0	
Nematoda			7	8	1	7			0	
Hydrachnidia			1	0	1	0			0	
Arachnida			0	1	0	1			0	
Hymenoptera			0	0	0	0			224	
t fly			3	3	3	2			4937	
fish fry			0	0	0	0			0	
ffeggs			0	0	0	0			0	
Hydra			0	0	0	0			0	
					All Species		914	1187		20196

TABLE A27 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken March 14, 2009, and descriptive statistics

		Date collected:	Mar-14	Mar-14	Mar-14	Mar-14	Mar-14	Mar-14				
									Mean	Max	Min	Total
Order	**Family**	**Genera (unless noted)**	Ref 1	Ref 2	Ref 3	Ref 4	Ref 5	Ref 6	Ref	Ref	Ref	Ref
Diptera	Chironomidae	SF Tanypondinae	30	14	2	16	27	8	17	30	2	268
		SF Chironominae			1	7		6	4.7	7	1	
		Diamesinae(?)							0	0	0	
		other chironomids	79	74	27	63	111	41	66	111	27	
	Empididae		19	15	3	20	32	6	16	32	3	
	Simuliidae		2	1					1.5	2	1	
		Ectemnia							0	0	0	
	Ceratopogonidae				1	1		1	1	1	1	
	Dixidae					4			4	4	4	
Ephemeroptera			14	5	1	9	23	5	9.5	23	1	143
	Heptageniidae		21	23		11	16	13	17	23	11	
		Stenonema	10	7		6	4	1	5.6	10	1	
		Rithrogena	4	1				1	2	4	1	
		Heptagenia	3	2			3		2.7	3	2	
	Ephemerellidae		9	10	1	5	11	3	6.5	11	1	
	Baetidae		16	10		1	15	2	8.8	16	1	
		Baetis	3						3	3	3	
	Leptophlebiidae			3					3	3	3	
	Siphloneuridae								0	0	0	
		Ameletus							0	0	0	
		Parameletus							0	0	0	
Plecoptera				1		4	1	6	3	6	1	57
	Chloroperlidae		4	2	1	2			2.3	4	1	
	Perlodidae		14	4		1	15	1	7	15	1	
		Isogenoides	2				1		1.5	2	1	
		Isoperla							0	0	0	
	Nemouridae		17	6	1		6	4	6.8	17	1	
	Taenipterygidae		3			5	2	2	3	5	2	
	Perlidae			1					1	1	1	
	Pteronarcydae	Pteronarcys	1				1		1	1	1	
	Leuctridae(?)								0	0	0	
	Capniidae(?)								0	0	0	

Trichoptera			2	3	1	2	4		2.4	4	1	251
	pupa(e)								0	0	0	
	Hydropsychidae		13	16	5	22	11	32	17	32	5	
		Hydropsyche	99	77	29	65	115	79	77	115	29	
	Glossosomatidae		1						1	1	1	
	Brachycentridae								0	0	0	
		Brachycentrus	1	1	1				1	1	1	
	Rhyacophilidae		1	1			1		1	1	1	
	Hydroptilidae							1	1	1	1	
	Polycentropodidae								0	0	0	
	Lepidostomatidae(?)								0	0	0	
	Limnephilidae(?)								0	0	0	
Hemiptera									0	0	0	7
	Corixidae					1			1	1	1	
Odonata									0	0	0	
	Gomphidae		1						1	1	1	
		Ophiogomphus		1					1	1	1	
Oligochaeta	Lumbriculidae				2				2	2	2	
Bivalvia	Sphaeridae								0	0	0	
Gastropoda									0	0	0	
	Limnaeidae		1						1	1	1	
Ostracoda									0	0	0	
Megaloptera		Sialis		1					1	1	1	
Nematoda					1			1	1	1	1	
Hydrachnidia							1	1	1	1	1	
	Pionidae								0	0	0	

TABLE A28 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken March 17, 2009, and descriptive statistics

		Date collected:	Mar-17	Mar-17	Mar-17	Mar-17	Mar-17	Mar-17					
									Mean	Mean	Max	Max	Min
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-DS1	AR-DS2	AR-DS3	TSMar17	TDMar17	TSMar17	TDMar17	TSMar17
Diptera	Chironomidae	SF Tanypondinae	5	5	1	2	16	17	3.7	12	5	17	1
		SF Chironominae		2				11	2	11	2	11	2
		Diamesinae (?)						32	0	32	0	32	0
		other chironomids	10	34	8	31	94		17	63	34	94	8
	Empididae		5	4	1	2	24	7	3.3	11	5	24	1
	Simuliidae								0	0	0	0	0
		Ectemnia							0	0	0	0	0
	Ceratopogonidae								0	0	0	0	0
	Dixidae						1		0	1	0	1	0
Ephemeroptera				4				1	4	1	4	1	4
	Heptageniidae		1	4			14	11	2.5	13	4	14	1
		Stenonema				3	5	5	0	4.3	0	5	0
		Rithrogena					1		0	1	0	1	0
		Heptagenia		2			1	2	2	1.5	2	2	2
	Ephemerellidae					2	7	6	0	5	0	7	0
	Baetidae					2	2	4	0	2.7	0	4	0
		Baetis						1	0	1	0	1	0
	Leptophlebiidae								0	0	0	0	0
	Siphloneuri								0	0	0	0	0

	dae												
		Ameletus							0	0	0	0	0
		Parameletus							0	0	0	0	0
Plecoptera				2			1	1	2	1	2	1	2
	Chloroperlidae								0	0	0	0	0
	Perlodidae			1		1	2	1	1	1.3	1	2	1
		Isogenoides				3		1	0	2	0	3	0
		Isoperla					1		0	1	0	1	0
	Nemouridae					1	1	3	0	1.7	0	3	0
	Taeniopterygidae								0	0	0	0	0
	Perlidae							1	0	1	0	1	0
	Pteronarcydae	Pteronarcys							0	0	0	0	0
	Leuctridae(?)			1					1	0	1	0	1
	Capniidae(?)								0	0	0	0	0
Trichoptera					1		5		1	5	1	5	1
	pupa(e)								0	0	0	0	0
	Hydropsychidae		15	5	2	13	10	48	7.3	24	15	48	2
		Hydropsyche	1	12	2	73	176	14	5	88	12	176	1
	Glossosomatidae		1				1	1	1	1	1	1	1
	Brachycentridae								0	0	0	0	0
		Brachycentrus							0	0	0	0	0
	Rhyacophilidae					1			0	1	0	1	0
	Hydroptilidae								0	0	0	0	0
	Polycentropodidae								0	0	0	0	0

	Lepidostomatidae(?)								0	0	0	0	0
	Limnephilidae(?)			1					1	0	1	0	1
Hemiptera									0	0	0	0	0
	Corixidae			1					1	0	1	0	1
Odonata									0	0	0	0	0
	Gomphidae							1	0	1	0	1	0
		Ophiogomphus					2		0	2	0	2	0
Oligochaeta	Lumbriculidae			1	1		4		1	4	1	4	1
Bivalvia	Sphaeridae				1				1	0	1	0	1
Gastropoda					2				2	0	2	0	2
	Limnaeidae								0	0	0	0	0
Ostracoda									0	0	0	0	0
Megaloptera		Sialis							0	0	0	0	0
Nematoda									0	0	0	0	0
Hydrachnidia									0	0	0	0	0
	Pionidae							1	0	1	0	1	0

TABLE A29 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 17, 2009 (continued)

			Min	Mean	Max	Min	Mean	Max	Min	Total	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TDMar17	TSMar17/ref	TSMar17/ref	TSMar17/ref	TDMar17/ref	TDMar17/ref	TDMar17/ref	TSMar17	TDMar17	TS/ref%	TD/ref%	Drift/ref%
Diptera	Chironomidae	SF Tanypondinae	2	0.23	0.17	0.5	0.72	0.57	1	75	237	28	88	50%
		SF Chironominae	11	0.43	0.29	2	2.36	1.57	11					
		Diamesinae(?)	32	0	0	0	0	0	0					
		other chironomids	31	0.26	0.31	0.30	0.95	0.85	1.2					
	Empididae		2	0.21	0.16	0.3	0.69	0.75	0.7					
	Simuliidae		0	0	0	0	0	0	0					
		Ectemnia	0	0	0	0	0	0	0					
	Ceratopogonidae		0	0	0	0	0	0	0					
	Dixidae		1	0	0	0	0.25	0.25	0.25					
Ephemeroptera			1	0.42	0.17	4	0.11	0.04	1	11	67	7.7	47	152%
	Heptageniidae		11	0.15	0.17	0.09	0.74	0.61	1					
		Stenonema	3	0	0	0	0.77	0.5	3					
		Rithrogena	1	0	0	0	0.5	0.25	1					
		Heptagenia	1	0.75	0.67	1	0.56	0.67	0.5					
	Ephemerellidae		2	0	0	0	0.77	0.64	2					
	Baetidae		2	0	0	0	0.30	0.25	2					
		Baetis	1	0	0	0	0.33	0.33	0.33					
	Leptophlebiidae		0	0	0	0	0	0	0					
	Siphloneuridae		0	0	0	0	0	0	0					
		Ameletus	0	0	0	0	0	0	0					
		Parameletus	0	0	0	0	0	0	0					
Plecoptera			1	0.67	0.33	2	0.33	0.17	1	4	17	7.0	30	42%
	Chloroperlidae		0	0	0	0	0	0	0					
	Perlodidae		1	0.14	0.07	1	0.19	0.13	1					
		Isogenoides	1	0	0	0	1.33	1.5	1					
		Isoperla	1	0	0	0	0	0	0					
	Nemouridae		1	0	0	0	0.25	0.18	1					
	Taenipterygidae		0	0	0	0	0	0	0					
	Perlidae		1	0	0	0	1	1	1					
	Pteronarcydae	Pteronarcys	0	0	0	0	0	0	0					
	Leuctridae(?)		0	0	0	0	0	0	0					

	Capniidae(?)		0	0	0	0	0	0	0					
Trichoptera			5	0.42	0.25	1	2.1	1.3	5	40	342	16	136	1%
	pupa(e)		0	0	0	0	0	0	0					
	Hydropsychidae		10	0.44	0.47	0.4	1.4	1.5	2					
		Hydropsyche	14	0.06	0.10	0.03	1.1	1.5	0.48					
	Glossosomatidae		1	1	1	1	1	1	1					
	Brachycentridae		0	0	0	0	0	0	0					
		Brachycentrus	0	0	0	0	0	0	0					
	Rhyacophilidae		1	0	0	0	1	1	1					
	Hydroptilidae		0	0	0	0	0	0	0					
	Polycentropodidae		0	0	0	0	0	0	0					
	Lepidostomatidae(?)		0	0	0	0	0	0	0					
	Limnephilidae(?)		0	0	0	0	0	0	0					
Hemiptera			0	0	0	0	0	0	0	6	8			
	Corixidae		0	1	1	1	0	0	0					
Odonata			0	0	0	0	0	0	0					
	Gomphidae		1	0	0	0	1	1	1					
		Ophiogomphus	2	0	0	0	2	2	2					
Oligochaeta	Lumbriculidae		4	0.5	0.5	0.5	2	2	2					
Bivalvia	Sphaeridae		0	0	0	0	0	0	0					
Gastropoda			0	0	0	0	0	0	0					
	Limnaeidae		0	0	0	0	0	0	0					
Ostracoda			0	0	0	0	0	0	0					
Megaloptera		Sialis	0	0	0	0	0	0	0					
Nematoda			0	0	0	0	0	0	0					
Hydrachnidia			0	0	0	0	0	0	0					
	Pionidae		1	0	0	0	0	0	0					
								All Species		136	671	19	92	55

TABLE A30 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken March 22, 2009, and descriptive statistics

		Date collected:	Mar-22	Mar-22	Mar-22	Mar-22	Mar-22	Mar-22					
									Mean	Mean	Max	Max	Min
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-DS1	AR-DS2	AR-DS3	TSMar22	TDMar22	TS Mar 22	TDMar22	TSMar22
Diptera	Chironomidae	SF Tanypondinae	8		5	3	7	2	6.5	4	8	7	5
		SF Chironominae							0	0	0	0	0
		Diamesinae(?)							0	0	0	0	0
		other chironomids	16	5	22	5	30	17	14	17	22	30	5
	Empididae		3	1	2		5	4	2	4.5	3	5	1
	Simuliidae								0	0	0	0	0
		Ectemnia							0	0	0	0	0
	Ceratopogonidae						1	1	0	1	0	1	0
	Dixidae					1			0	1	0	1	0
Ephemeroptera					1				1	0	1	0	1
	Heptageniidae		2	1	6		1	3	3	2	6	3	1
		Stenonema			3		1		3	1	3	1	3
		Rithrogena							0	0	0	0	0
		Heptagenia				1			0	1	0	1	0
	Ephemerellidae				2				2	0	2	0	2
	Baetidae			1	4		2		2.5	2	4	2	1
		Baetis							0	0	0	0	0
	Leptophlebiidae								0	0	0	0	0
	Siphloneuridae							1	0	1	0	1	0
		Ameletus							0	0	0	0	0
		Parameletus							0	0	0	0	0
Plecoptera				1	2		2	1	1.5	1.5	2	2	1
	Chloroperlidae								0	0	0	0	0
	Perlodidae			2			1		2	1	2	1	2
		Isogenoides				5	1	2	0	2.7	0	5	0
		Isoperla					1	1	0	1	0	1	0
	Nemouridae							2	0	2	0	2	0
	Taenipterygidae				1		1		1	1	1	1	1
	Perlidae								0	0	0	0	0
	Pteronarcydae	Pteronarcys							0	0	0	0	0
	Leuctridae(?)								0	0	0	0	0

	Capniidae(?)								0	0	0	0	0
Trichoptera			1	1	1	2			1	2	1	2	1
	pupa(e)		3						3	0	3	0	3
	Hydropsychidae		5	1	2	5	12	16	2.7	11	5	16	1
		Hydropsyche	25	7	11	15	49	34	14	33	25	49	7
	Glossosomatidae						1		0	1	0	1	0
	Brachycentridae								0	0	0	0	0
		Brachycentrus					1		0	1	0	1	0
	Rhyacophilidae				1				1	0	1	0	1
	Hydroptilidae					1			0	1	0	1	0
	Polycentropodidae								0	0	0	0	0
	Lepidostomatidae(?)				1				1	0	1	0	1
	Limnephilidae(?)								0	0	0	0	0
Hemiptera									0	0	0	0	0
	Corixidae								0	0	0	0	0
Odonata									0	0	0	0	0
	Gomphidae								0	0	0	0	0
		Ophiogomphus			1				1	0	1	0	1
Oligochaeta	Lumbriculidae			1					1	0	1	0	1
Bivalvia	Sphaeridae		1						1	0	1	0	1
Gastropoda									0	0	0	0	0
	Limnaeidae								0	0	0	0	0
Ostracoda									0	0	0	0	0
Megaloptera		Sialis							0	0	0	0	0
Nematoda									0	0	0	0	0
Hydrachnidia									0	0	0	0	0
	Pionidae								0	0	0	0	0

TABLE A31 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 22, 2009 (continued)

			Min	Mean	Max	Min	Mean	Max	Min	Total	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TD Mar 22	TSMar22/ref	TSMar22/ref	TS Mar 22/ref	TDMar22/ref	TD Mar 22/ref	TDMar22/ref	TSMar22	TDMar22	TS/ref%	TD/ref%	Drift/ref%
Diptera	Chironomidae	SF Tanypondinae	2	0.40	0.27	2.5	0.25	0.23	1	62	76	23	28	118%
		SF Chironominae	0	0	0	0	0	0	0					
		Diamesinae(?)	0	0	0	0	0	0	0					
		other chironomids	5	0.22	0.20	0.19	0.26	0.27	0.19					
	Empididae		4	0.13	0.09	0.33	0.28	0.16	1.33					
	Simuliidae		0	0	0	0	0	0	0					
		Ectemnia	0	0	0	0	0	0	0					
	Ceratopogonidae		1	0	0	0	1	1	1					
	Dixidae		1	0	0	0	0.25	0.25	0.25					
Ephemeroptera			0	0.11	0.043	1	0	0	0	20	9	14	6.3	255%
	Heptageniidae		1	0.18	0.26	0.09	0.12	0.13	0.09					
		Stenonema	1	0.54	0.3	3	0.18	0.1	1					
		Rithrogena	0	0	0	0	0	0	0					
		Heptagenia	1	0	0	0	0.38	0.33	0.5					
	Ephemerellidae		0	0.31	0.18	2	0	0	0					
	Baetidae		2	0.28	0.25	1	0.23	0.125	2					
		Baetis	0	0	0	0	0	0	0					
	Leptophlebiidae		0	0	0	0	0	0	0					
	Siphloneuridae		1	0	0	0	0	0	0					
		Ameletus	0	0	0	0	0	0	0					
		Parameletus	0	0	0	0	0	0	0					
Plecoptera			1	0.5	0.33	1	0.5	0.33	1	6	17	11	30	554%
	Chloroperlidae		0	0	0	0	0	0	0					
	Perlodidae		1	0.29	0.13	2	0.14	0.07	1					
		Isogenoides	1	0	0	0	1.78	2.5	1					
		Isoperla	1	0	0	0	0	0	0					
	Nemouridae		2	0	0	0	0.29	0.12	2					
	Taenipterygidae		1	0.33	0.2	0.5	0.33	0.2	0.5					
	Perlidae		0	0	0	0	0	0	0					
	Pteronarcydae	Pteronarcys	0	0	0	0	0	0	0					

	Leuctridae(?)		0	0	0	0	0	0	0					
	Capniidae(?)		0	0	0	0	0	0	0					
Trichoptera			2	0.42	0.25	1	0.83	0.5	2	59	136	24	54	28%
	pupa(e)		0	0	0	0	0	0	0					
	Hydropsychidae		5	0.16	0.16	0.2	0.67	0.5	1					
		Hydropsyche	15	0.19	0.22	0.24	0.42	0.43	0.52					
	Glossosomatidae		1	0	0	0	1	1	1					
	Brachycentridae		0	0	0	0	0	0	0					
		Brachycentrus	1	0	0	0	1	1	1					
	Rhyacophilidae		0	1	1	1	0	0	0					
	Hydroptilidae		1	0	0	0	1	1	1					
	Polycentropodidae		0	0	0	0	0	0	0					
	Lepidostomatidae(?)		0	0	0	0	0	0	0					
	Limnephilidae(?)		0	0	0	0	0	0	0					
Hemiptera			0	0	0	0	0	0	0	3	0			
	Corixidae		0	0	0	0	0	0	0					
Odonata			0	0	0	0	0	0	0					
	Gomphidae		0	0	0	0	0	0	0					
		Ophiogomphus	0	1	1	1	0	0	0					
Oligochaeta	Lumbriculidae		0	0.5	0.5	0.5	0	0	0					
Bivalvia	Sphaeridae		0	0	0	0	0	0	0					
Gastropoda			0	0	0	0	0	0	0					
	Limnaeidae		0	0	0	0	0	0	0					
Ostracoda			0	0	0	0	0	0	0					
Megaloptera		Sialis	0	0	0	0	0	0	0					
Nematoda			0	0	0	0	0	0	0					
Hydrachnidia			0	0	0	0	0	0	0					
	Pionidae		0	0	0	0	0	0	0					
								All Species		150	238	21	33	163

TABLE A32 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken March 27, 2009, and descriptive statistics

		Date collected:	Mar-27	Mar-27	Mar-27	Mar-27	Mar-27	Mar-27					
									Mean	Mean	Max	Max	Min
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-DS1	AR-DS3	AR-DS3b	TSMar27	TDMar27	TS Mar 27	TDMar27	TSMar27
Diptera	Chironomidae	SF Tanypondinae	4	5	9	5	6	32	6	14	9	32	4
		SF Chironominae		1	2	1	5	2	1.5	2.7	2	5	1
		Diamesinae(?)		1					1	0	1	0	1
		other chironomids	14	23	40	25	12	40	26	26	40	40	14
	Empididae		4	12	8	5	4	18	8	9	12	18	4
	Simuliidae								0	0	0	0	0
		Ectemnia							0	0	0	0	0
	Ceratopogonidae		1						1	0	1	0	1
	Dixidae				1			2	1	2	1	2	1
Ephemeroptera				1	1	2	2		1	2	1	2	1
	Heptageniidae		1		2	4	4	8	1.5	5.3	2	8	1
		Stenonema	1						1	0	1	0	1
		Rithrogena			1		2		1	2	1	2	1
		Heptagenia							0	0	0	0	0
	Ephemerellidae				1	1	1	1	1	1	1	1	1
	Baetidae		2	1		3	1	1	1.5	1.7	2	3	1
		Baetis							0	0	0	0	0
	Leptophlebiidae								0	0	0	0	0
	Siphloneuridae					1			0	1	0	1	0
		Ameletus							0	0	0	0	0
		Parameletus			1				1	0	1	0	1
Plecoptera				1	1			3	1	3	1	3	1
	Chloroperlidae								0	0	0	0	0
	Perlodidae		1		1	1			1	1	1	1	1
		Isogenoides							0	0	0	0	0
		Isoperla							0	0	0	0	0
	Nemouridae		1			1			1	1	1	1	1
	Taenipterygidae					1			0	1	0	1	0
	Perlidae								0	0	0	0	0
	Pteronarcydae	Pteronarcys							0	0	0	0	0
	Leuctridae(?)								0	0	0	0	0
	Capniidae(?)								0	0	0	0	0

Trichoptera					1		3		1	3	1	3	1
	pupa(e)								0	0	0	0	0
	Hydropsychidae		1	9	15	60	30	37	8.3	42	15	60	1
		Hydropsyche	6	6	34	42	129	104	15	92	34	129	6
	Glossosomatidae				1				1	0	1	0	1
	Brachycentridae								0	0	0	0	0
		Brachycentrus					1		0	1	0	1	0
	Rhyacophilidae								0	0	0	0	0
	Hydroptilidae								0	0	0	0	0
	Polycentropodidae						1		0	1	0	1	0
	Lepidostomatidae(?)								0	0	0	0	0
	Limnephilidae(?)								0	0	0	0	0
Hemiptera									0	0	0	0	0
	Corixidae								0	0	0	0	0
Odonata									0	0	0	0	0
	Gomphidae								0	0	0	0	0
		Ophiogomphus			1				1	0	1	0	1
Oligochaeta	Lumbriculidae		3	2	2			2	2.3	2	3	2	2
Bivalvia	Sphaeridae								0	0	0	0	0
Gastropoda									0	0	0	0	0
	Limnaeidae								0	0	0	0	0
Ostracoda									0	0	0	0	0
Megaloptera		Sialis							0	0	0	0	0
Nematoda								1	0	1	0	1	0
Hydrachnidia									0	0	0	0	0
	Pionidae								0	0	0	0	0

TABLE A33 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken March 27, 2009 (continued)

			Min	Mean	Max	Min	Mean	Max	Min	Total	Total	Total	Total	Total
Order	**Family**	**Genera (unless noted)**	TDMar27	TSMar27/ref	TSMar27/ref	TSMar27/ref	TDMar27/ref	TDMar27/ref	TDMar27/ref	TSMar27	TDMar27	TS/ref%	TD/ref%	Drift/ref%
Diptera	Chironomidae	SF Tanypondinae	5	0.37	0.3	2	0.89	1.07	2.5	125	157	47	59	94%
		SF Chironominae	1	0.32	0.29	1	0.57	0.71	1					
		Diamesinae(?)	0	0	0	0	0	0	0					
		other chironomids	12	0.39	0.36	0.52	0.39	0.36	0.44					
	Empididae		4	0.51	0.38	1.3	0.57	0.56	1.3					
	Simuliidae		0	0	0	0	0	0	0					
		Ectemnia	0	0	0	0	0	0	0					
	Ceratopogonidae		0	1	1	1	0	0	0					
	Dixidae		2	0.25	0.25	0.25	0.5	0.5	0.5					
Ephemeroptera			2	0.11	0.04	1	0.21	0.09	2	12	31	8.4	22	147%
	Heptageniidae		4	0.09	0.09	0.09	0.32	0.35	0.36					
		Stenonema	0	0.18	0.1	1	0	0	0					
		Rithrogena	2	0.5	0.25	1	1	0.5	2					
		Heptagenia	0	0	0	0	0	0	0					
	Ephemerellidae		1	0.15	0.09	1	0.15	0.09	1					
	Baetidae		1	0.17	0.13	1	0.19	0.19	1					
		Baetis	0	0	0	0	0	0	0					
	Leptophlebiidae		0	0	0	0	0	0	0					
	Siphloneuridae		1	0	0	0	0	0	0					
		Ameletus	0	0	0	0	0	0	0					
		Parameletus	0	0	0	0	0	0	0					
Plecoptera			3	0.33	0.17	1	1	0.5	3	5	6	8.8	11	123%
	Chloroperlidae		0	0	0	0	0	0	0					
	Perlodidae		1	0.14	0.07	1	0.14	0.07	1					
		Isogenoides	0	0	0	0	0	0	0					
		Isoperla	0	0	0	0	0	0	0					
	Nemouridae		1	0.15	0.06	1	0.15	0.06	1					
	Taenipterygidae		1	0	0	0	0.33	0.2	0.5					
	Perlidae		0	0	0	0	0	0	0					
	Pteronarcydae	Pteronarcys	0	0	0	0	0	0	0					
	Leuctridae(?)		0	0	0	0	0	0	0					

	Capniidae(?)		0	0	0	0	0	0	0					
Trichoptera			3	0.42	0.25	1	1.3	0.75	3	73	407	47	59	94%
	pupa(e)		0	0	0	0	0	0	0					
	Hydropsychidae		30	0.51	0.47	0.2	2.57	1.9	6					
		Hydropsyche	42	0.20	0.30	0.21	1.2	1.1	1.5					
	Glossosomatidae		0	1	1	1	0	0	0					
	Brachycentridae		0	0	0	0	0	0	0					
		Brachycentrus	1	0	0	0	1	1	1					
	Rhyacophilidae		0	0	0	0	0	0	0					
	Hydroptilidae		0	0	0	0	0	0	0					
	Polycentropodidae		1	0	0	0	0	0	0					
	Lepidostomatidae(?)		0	0	0	0	0	0	0					
	Limnephilidae(?)		0	0	0	0	0	0	0					
Hemiptera			0	0	0	0	0	0	0	8	3	8.4	22	147%
	Corixidae		0	0	0	0	0	0	0					
Odonata			0	0	0	0	0	0	0					
	Gomphidae		0	0	0	0	0	0	0					
		Ophiogomphus	0	1	1	1	0	0	0					
Oligochaeta	Lumbriculidae		2	1.2	1.5	1	1	1	1					
Bivalvia	Sphaeridae		0	0	0	0	0	0	0					
Gastropoda			0	0	0	0	0	0	0					
	Limnaeidae		0	0	0	0	0	0	0					
Ostracoda			0	0	0	0	0	0	0					
Megaloptera		Sialis	0	0	0	0	0	0	0					
Nematoda			1	0	0	0	1	1	1			8.8	11	123%
Hydrachnidia			0	0	0	0	0	0	0					
	Pionidae		0	0	0	0	0	0	0					
								All Species		223	604	31	83	91

TABLE A34 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken April 11, 2009, and descriptive statistics

		Date collected:	Apri l-11	April-11	Apri l-11	April-11	April-11	April-11		
									Mean	Mean
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-SS4	AR-SS5	AR-SS6	ref	TS
Diptera	Chironomidae	SF Tanypondinae	3	1	7	2	14	4	16	5.2
		SF Chironominae		1	4			1	4.7	2
		other chironomids	7	10	14	17	42	23	0	19
	Empididae		6	1	9	5	6	7	66	5.7
	Simuliidae						1		16	1
	Ceratopogonidae		1		1				1.5	1
	Dixidae			1					0	1
Ephemeroptera							4	1	1	2.5
	Heptageniidae			2	1		8		4	3.7
		Stenonema	2		1		1		9.5	1.3
		Rithrogena	2		2	1	2		17	1.8
		Heptagenia	1				1		5.6	1
	Ephemerellidae					1	1	3	2	1.7
		Ephemerella					1		2.7	1
	Baetidae					3	7	2	6.5	4
		Baetis		1			1		8.8	1
Plecoptera			2						3	2
	Chloroperlidae						2	1	3	1.5
	Perlodidae					2	1	1	0	1.3
		Isogenoides	1		1		1		0	1
	Nemouridae					1	2	1	0	1.3
	Taenipterygidae		1						3	1
	Capniidae						1		2.3	1
Trichoptera									7	0
	pupae			1					1.5	1
	Hydropsychidae		9	8	39	12	8	16	0	15
		Hydropsyche		1	3	3	9	15	6.8	6.2
	Brachycentridae							1	3	1
		Brachycentrus						1	1	1
Hemiptera									1	0

	Corixidae				1			1	0	1
Odonata									0	0
	Gomphida		1				1		2.4	7
									0	0
Oligochaeta	Lumbriculidae			2		1		2	1	1.7
Gastropoda							1		77	1
Nematoda							1		1	1

TABLE A35 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken April 11, 2009 (continued)

			Max	Max	Min	Min	Mean	Max	Min	Total
Order	**Family**	**Genera (unless noted)**	ref	TS	ref	TS	TS/ref	TS/ref	TS/ref	TS
Diptera	Chironomidae	SF Tanypondinae	30	14	2	1	0.32	0.47	0.5	188
		SF Chironominae	7	4	1	1	0.43	0.57	1	
		other chironomids	0	42	0	7	0	0	0	
	Empididae		111	9	27	1	0.09	0.08	0.04	
	Simuliidae		32	1	3	1	0.06	0.03	0.33	
	Ceratopogonidae		2	1	1	1	0.67	0.5	1	
	Dixidae		0	1	0	1	0	0	0	
Ephemeroptera			1	4	1	1	2.5	4	1	49
	Heptageniidae		4	8	4	1	0.92	2	0.25	
		Stenonema	23	2	1	1	0.14	0.09	1	
		Rithrogena	23	2	11	1	0.10	0.09	0.09	
		Heptagenia	10	1	1	1	0.18	0.1	1	
	Ephemerellidae		4	3	1	1	0.83	0.75	1	
		Ephemerella	3	1	2	1	0.38	0.33	0.5	
	Baetidae		11	7	1	2	0.62	0.64	2	
		Baetis	16	1	1	1	0.11	0.06	1	
Plecoptera			3	2	3	2	0.67	0.67	0.67	18
	Chloroperlidae		3	2	3	1	0.5	0.67	0.33	
	Perlodidae		0	2	0	1	0	0	0	
		Isogenoides	0	1	0	1	0	0	0	
	Nemouridae		0	2	0	1	0	0	0	
	Taenipterygidae		6	1	1	1	0.33	0.17	1	
	Capniidae		4	1	1	1	0.44	0.25	1	
Trichoptera			15	0	1	0	0	0	0	126
	pupae		2	1	1	1	0.67	0.5	1	
	Hydropsychidae		0	39	0	8	0	0	0	
		Hydropsyche	17	15	1	1	0.91	0.88	1	
	Brachycentridae		5	1	2	1	0.33	0.2	0.5	
		Brachycentrus	1	1	1	1	1	1	1	
Hemiptera			1	0	1	0	0	0	0	11
	Corixidae		0	1	0	1	0	0	0	
Odonata			0	0	0	0	0	0	0	

	Gomphida		4	1	1	1	0.42	0.25	1	
			0	0	0	0	0	0	0	
Oligochaeta	Lumbriculidae		32	2	5	1	0.10	0.06	0.2	
Gastropoda			115	1	29	1	0.01	0.01	0.03	
Nematoda			1	1	1	1	1	1	1	
								All Species		392

TABLE A36 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken May 1, 2009, and descriptive statistics

		Date collected:	May -01	May -01	May -01	May-01	May-01	May-01	
									Mean
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-DS1	AR-DS2	AR-DS3	TSMay1
Diptera	Chironomidae	SF Tanypondinae	2	1	2	3	1	14	1.7
		SF Chironominae		1				1	1
		other chironomids	7	2		29	10	33	4.5
		pupa(e)			1				1
	Empididae		14	11	14	19	10	17	13
	Simuliidae								0
		Ectemnia				1			0
	Dixidae		1		1			1	1
Ephemeroptera			4			1	1		4
	Heptageniidae		4	7	4	11	8	9	5
		Stenonema					1	1	0
		Rithrogena	9	4	4	2	5	4	5.7
		Heptagenia	2	1	1				1.3
	Ephemerellidae				1			1	1
	Baetidae		2	4	5	13	1		3.7
		Baetis		1				1	1
	Siphloneuridae								0
		Parameletus		2	1				1.5
Plecoptera			2		1	2		2	1.5
	Chloroperlidae			2	1		1		1.5
	Perlodidae		1	5	10	3	5	6	5.3
		Isogenoides	6	1	3		1	2	3.3
		Isoperla	15	24	5	6	1	1	15
	Nemouridae		14	50	19	18	2	4	28
	Taenipterygidae		1		1	6	3	4	1
		Taenionema		1					1
Trichoptera									0
	pupa(e)				1			1	1
	Hydropsychidae		1	1	1	2	7	12	1
		Hydropsyche	6	4	6	17	9	7	5.3
	Brachycentridae								0
		Brachycentrus	1	2	1	1	1	1	1.3
	Rhyacophilidae					2			0

Hemiptera									0
	Corixidae		1	39	110	81		11	50
Odonata									0
	Gomphidae								0
		Ophiogomphus							0
Coleoptera									0
	Elmidae	Heterlimnius?	1						1
Lepidoptera									0
Oligochaeta	Lumbriculidae		4				1	1	4
Bivalvia	Sphaeridae								0
Gastropoda						1			0
	Limnaeidae		2				4		2
Megaloptera		Sialis							0
Nematoda			1			4		2	1
Terrestrials			4		1			1	2.5
fish fry				1					1

TABLE A37 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken May 1, 2009 (continued)

			Mean	Max	Max	Min	Min	Total	Total
Order	**Family**	**Genera (unless noted)**	TDMay1	TSMay1	TDMay1	TSMay1	TDMay1	TSMay1	TDMay1
Diptera	Chironomidae	SF Tanypondinae	6	2	14	1	1	57	139
		SF Chironominae	1	1	1	1	1		
		other chironomids	24	7	33	2	10		
		pupa(e)	0	1	0	1	0		
	Empididae		15	14	19	11	10		
	Simuliidae		0	0	0	0	0		
		Ectemnia	1	0	1	0	1		
	Dixidae		1	1	1	1	1		
Ephemeroptera			1	4	1	4	1	56	59
	Heptageniidae		9.3	7	11	4	8		
		Stenonema	1	0	1	0	1		
		Rithrogena	3.7	9	5	4	2		
		Heptagenia	0	2	0	1	0		
	Ephemerellidae		1	1	1	1	1		
	Baetidae		7	5	13	2	1		
		Baetis	1	1	1	1	1		
	Siphloneuridae		0	0	0	0	0		
		Parameletus	0	2	0	1	0		
Plecoptera			2	2	2	1	2	162	67
	Chloroperlidae		1	2	1	1	1		
	Perlodidae		4.7	10	6	1	3		
		Isogenoides	1.5	6	2	1	1		
		Isoperla	2.7	24	6	5	1		
	Nemouridae		8	50	18	14	2		
	Taenipterygidae		4.3	1	6	1	3		
		Taenionema	0	1	0	1	0		
Trichoptera			0	0	0	0	0	24	60
	pupa(e)		1	1	1	1	1		
	Hydropsychidae		7	1	12	1	2		
		Hydropsyche	11	6	17	4	7		
	Brachycentridae		0	0	0	0	0		
		Brachycentrus	1	2	1	1	1		
	Rhyacophilidae		2	0	2	0	2		
Hemiptera			0	0	0	0	0	164	106

	Corixidae		46	110	81	1	11		
Odonata			0	0	0	0	0		
	Gomphidae		0	0	0	0	0		
		Ophiogomphus	0	0	0	0	0		
Coleoptera			0	0	0	0	0		
	Elmidae	Heterlimnius?	0	1	0	1	0		
Lepidoptera			0	0	0	0	0		
Oligochaeta	Lumbriculidae		1	4	1	4	1		
Bivalvia	Sphaeridae		0	0	0	0	0		
Gastropoda			1	0	1	0	1		
	Limnaeidae		4	2	4	2	4		
Megaloptera		Sialis	0	0	0	0	0		
Nematoda			3	1	4	1	2		
Terrestrials			1	4	1	1	1		
fish fry			0	1	0	1	0		
						All Species		463	431

TABLE A38 Raw data following benthic invertebrate identfication for Neill cylinder samples from the C-Bridge experimental site taken May 8, 2009, and descriptive statistics

		Date collected:	May-08	May-08	May-08	May-08	May-08	May-08	
									Mean
Order	**Family**	**Genera (unless noted)**	AR-SS1	AR-SS2	AR-SS3	AR-DS1	AR-DS2	AR-DS3	TSMay8
Diptera	Chironomidae	SF Tanypondinae				2			0
		SF Chironominae	10			2			10
		other chironomids		1	4	3	5	5	2.5
		pupa(e)							0
	Empididae			3	2	10	3	1	2.5
	Simuliidae								0
		Ectemnia							0
	Dixidae								0
Ephemeroptera									0
	Heptageniidae		1		1	2	3	1	1
		Stenonema				2			0
		Rithrogena		1	2	2	1	2	1.5
		Heptagenia				3		2	0
	Ephemerellidae					2			0
	Baetidae					1	1		0
		Baetis							0
	Siphloneuridae								0
		Parameletus							0
Plecoptera			1						1
	Chloroperlidae		1		1	1			1
	Perlodidae			1	5	4		3	3
		Isogenoides				2	1		0
		Isoperla		12	13	12		4	13
	Nemouridae		3	1	2			4	2
	Taenipterygidae							1	0
		Taenionema							0
Trichoptera							1		0
	pupa(e)								0
	Hydropsychidae		1				3		1
		Hydropsyche	3			5	10	3	3
	Brachycentridae								0
		Brachycentrus							0
	Rhyacophilidae								0

Hemiptera									0
	Corixidae				1	6			1
Odonata									0
	Gomphidae								0
		Ophiogomphus			1				1
Coleoptera									0
	Elmidae	Heterlimnius?				2			0
Lepidoptera							1		0
Oligochaeta	Lumbriculidae		3	2		2			2.5
Bivalvia	Sphaeridae								0
Gastropoda			1			1	1		1
	Limnaeidae		3			3	3		3
Megaloptera		Sialis							0
Nematoda									0
Terrestrials						1			0
fish fry									0

TABLE A39 Descriptive statistics for raw data following benthic invertebrate identfication for samples from the C-Bridge experimental site taken May 8, 2009 (continued)

			Mean	Max	Max	Min	Min	Total	Total
Order	**Family**	**Genera (unless noted)**	TDM ay8	TSMa y8	TDM ay8	TSMa y8	TDM ay8	TSMa y8	TDM ay8
Diptera	Chironomidae	SF Tanypondinae	2	0	2	0	2	20	31
		SF Chironominae	2	10	2	10	2		
		other chironomids	4.3	4	5	1	3		
		pupa(e)	0	0	0	0	0		
	Empididae		4.7	3	10	2	1		
	Simuliidae		0	0	0	0	0		
		Ectemnia	0	0	0	0	0		
	Dixidae		0	0	0	0	0		
Ephemeroptera			0	0	0	0	0	5	22
	Heptageniidae		2	1	3	1	1		
		Stenonema	2	0	2	0	2		
		Rithrogena	1.7	2	2	1	1		
		Heptagenia	2.5	0	3	0	2		
	Ephemerellidae		2	0	2	0	2		
	Baetidae		1	0	1	0	1		
		Baetis	0	0	0	0	0		
	Siphloneuridae		0	0	0	0	0		
		Parameletus	0	0	0	0	0		
Plecoptera			0	1	0	1	0	40	32
	Chloroperlidae		1	1	1	1	1		
	Perlodidae		3.5	5	4	1	3		
		Isogenoides	1.5	0	2	0	1		
		Isoperla	8	13	12	12	4		
	Nemouridae		4	3	4	1	4		
	Taenipterygidae		1	0	1	0	1		
		Taenionema	0	0	0	0	0		
Trichoptera			1	0	1	0	1	4	22
	pupa(e)		0	0	0	0	0		
	Hydropsychidae		3	1	3	1	3		
		Hydropsyche	6	3	10	3	3		
	Brachycentridae		0	0	0	0	0		
		Brachycentrus	0	0	0	0	0		
	Rhyacophilidae		0	0	0	0	0		
Hemiptera			0	0	0	0	0	11	20

	Corixidae		6	1	6	1	6		
Odonata			0	0	0	0	0		
	Gomphidae		0	0	0	0	0		
		Ophiogomphus	0	1	0	1	0		
Coleoptera			0	0	0	0	0		
	Elmidae	Heterlimnius?	2	0	2	0	2		
Lepidoptera			1	0	1	0	1		
Oligochaeta	Lumbriculidae		2	3	2	2	2		
Bivalvia	Sphaeridae		0	0	0	0	0		
Gastropoda			1	1	1	1	1		
	Limnaeidae		3	3	3	3	3		
Megaloptera		Sialis	0	0	0	0	0		
Nematoda			0	0	0	0	0		
Terrestrials			1	0	1	0	1		
fish fry			0	0	0	0	0		
						All Species		80	127

TABLE A40 Raw data following benthic invertebrate identfication for surber and drift net samples from the C-Bridge experimental site taken March 10, 18, 23, 28, April 12, May 1 and 8, 2009

		Date collected:	Mar-10	Mar-18	Mar-23	Mar-28	Mar-10	Mar-18	Mar-23	Mar-28	April-12	May-01	May-08
Order	**Family**	**Genera (unless noted)**	SmN	DN	SN	SN	DN	DN2	DN	DN	DN2	DN	DN
Diptera	Chironomidae	SF Tanypondinae		1			1		2				
		SF Chironominae	1				1		1				
		other chironomids				2			1	3	1		
	Empididae						1		2				
	Simuliidae		2	8	5	2	5	49	22	14	1		
		Ectemnia	4	1	3	7	6	5	17	19	2		
		pupa(e)						1					
Ephemeroptera						2		2			1		
	Heptageniidae		6	3	1	1	1		7	1	1		
		Stenonema	1							1			
		Rithrogena	2	1					2	1			
		Cinygmula	1										
	Ephemerellidae					1			1				
	Baetidae		16	5	3	1	12	82	41	26	12		
		Baetis	2							1	1		
		Centroptilum						6					
		Ameletus							1				
	Metretopodidae	Siphloplecton	2										
Plecoptera			5		2	1		2	6		1	3	48
	Chloroperlidae		1						1	1	1		
	Perlodidae		7	8		2		2	12	4			
		Isogenoides								1			
		Isoperla	1	1					3				
	Nemouridae		7		1		3	5	12	3	2	34	544
	Taenipterygidae		2		2	3			11	1			
	Capniidae(?)						1	1					

Trichoptera				1									
	Hydropsychidae		5				3	1	7	3			
		Hydropsyche	3	4			2		3	6	1		
	Rhyacophilidae									2			
Hemiptera													
	Corixidae		8				2	6	13	4		435	6960
Anostraca		Branchinecta(?)	5	3	1			2	4	3		1	16
Collembola											3		
Terrestrials											4	2	32

TABLE A41 Descriptive statistics for raw data following benthic invertebrate identfication for surber and drift net samples from the C-Bridge experimental site taken March 10, 18, 23 and 28, 2009

		Date collected:	Mar-23	Mar-23	Mar-28	Mar-28	Mar-10	Mar-10	Mar-18	Mar-18
			Surber	Total	Surber	Total	Drift	Total	Drift	Total
Order	**Family**	**Genera (unless noted)**	(ind/m 2/day)	Surber	(ind/m 2/day)	Surber	(ind/m 2/day)	Drift	(ind/m 2/day)	Drift
Diptera	Chironomidae	SF Tanypondinae	0	89	0	133	2.3	33	0	133
		SF Chironominae	0		0		2.3		0	
		other chironomids	0		24		0		0	
	Empididae		0		0		2.3		0	
	Simuliidae		56		24		12		119	
		Ectemnia	33		85		14		12	
		pupa(e)	0		0		0		2.4	
Ephemeroptera			0	44	24	61	0	30	4.8	218
	Heptageniidae		11		12		2.3		0	
		Stenonema	0		0		0		0	
		Rithrogena	0		0		0		0	
		Cinygmula	0		0		0		0	
	Ephemerellidae		0		12		0		0	
	Baetidae		33		12		28		199	
		Baetis	0		0		0		0	
		Centroptilum	0		0		0		14.5	
		Ameletus	0		0		0		0	
	Metretopodidae	Siphloplecton	0		0		0		0	
Plecoptera			22	56	12	73	0	9.4	4.8	24
	Chloroperlidae		0		0		0		0	
	Perlodidae		0		24.2		0		4.84	
		Isogenoides	0		0		0		0	
		Isoperla	0		0		0		0	
	Nemouridae		11		0		7.0		12	
	Taenipterygidae		22		36		0		0	
	Capniidae(?)		0		0		2.3		2.4	
Trichoptera			0	0	0	0	0	12	0	2.4
	Hydropsychidae		0		0		7.0		2.4	
		Hydropsyche	0		0		4.7		0	
	Rhyacophilidae		0		0		0		0	
Hemiptera			0		0		0	4.7	0	19
	Corixidae		0		0		4.7		15	
Anostraca		Branchinecta(?)	11		0		0		4.8	

Collembola			0		0		0		0	
Terrestrials			0		0		0		0	
All Species				189		267		89		397

TABLE A42 Descriptive statistics for raw data following benthic invertebrate identfication for surber and drift net samples from the C-Bridge experimental site taken March 23, 28, April 12, May 1 and 8, 2009

		Date collected:	Mar-23	Mar-23	Mar-28	Mar-28	April-12	April-12	May-01	May-08
			Drift	Total	Drift	Total	Drift	Total	Drift	Total
Order	**Family**	**Genera (unless noted)**	(ind/m 2/day)	Drift	(ind/m2/ day)	Drift	(ind/m2/ day)	Drift	(ind/m2/ day)	Drift
Diptera	Chironomidae	SF Tanypondinae	14	316	0	253	0	673	0	0
		SF Chironominae	7.0		0		0		0	
		other chironomids	7.0		21		168		0	
	Empididae		14		0		0		0	
	Simuliidae		154		98		168		0	
		Ectemnia	119		133		337		0	
		pupa(e)	0		0		0		0	
Ephemeroptera			0	365	0	210	168	2525	0	0
	Heptageniidae		49		7.0		168		0	
		Stenonema	0		7.0		0		0	
		Rithrogena	14		7.0		0		0	
		Cinygmula	0		0		0		0	
	Ephemerellidae		7.0		0		0		0	
	Baetidae		288		182		2020		0	
		Baetis	0		7.0		168		0	
		Centroptilum	0		0		0		0	
		Ameletus	7.0		0		0		0	
	Metretopodidae	Siphloplecton	0		0		0		0	
Plecoptera			42	316	0	70	168	673	337	4152
	Chloroperlidae		7.0		7.0		168		0	
	Perlodidae		84		28		0		0	
		Isogenoides	0		7.0		0		0	
		Isoperla	21		0		0		0	
	Nemouridae		84		21		337		3815	
	Taenipterygidae		77		7.0		0		0	
	Capniidae(?)		0		0		0		0	
Trichoptera			0	70	0	77	0	168	0	0
	Hydropsychidae		49		21		0		0	
		Hydropsyche	21		42		168		0	
	Rhyacophilidae		0		14		0		0	
Hemiptera			0	119	0	49	0	1178	0	49144
	Corixidae		91		28		0		48808	
Anostraca		Branchinecta(?)	28		21		0		112	

Collembola			0		0		505		0	
Terrestrials			0		0		673		224	
All Species				118		659		5217		53296

APPENDIX B

BENTHIC INVERTEBRATE TALLIES FOR REFERENCE AND

ELECTROSHOCKING SAMPLES FROM THE NORTH SASKATCHEWAN

RIVER TAKEN SEPTEMPER 1, 2009

TABLE B1 Raw data following benthic invertebrate identification for reference samples from the North Saskatchewan River taken September 1, 2009

Taxa	Sample 1				Sample 2				Mean
	Coarse	Fine	Fine X20	Total	Coarse	Fine	Fine X20	Total	Total
EPHEMEROPTERA									
Acentrella sp.			0	0			0	0	**0.0**
Acerpenna sp.	1	4	80	81	5	4	80	85	**83**
Baetis sp.	1	1	20	21	3		0	3	**12**
*Fallceon*sp.	2		0	2	6	1	20	26	**14**
Plauditus sp.	1		0	1	6	2	40	46	**24**
Baetisca sp.			0	0			0	0	**0.0**
Ephemerella sp.			0	0	1	1	20	21	**11**
Ephemera sp.			0	0			0	0	**0.0**
Heptagenia sp.	1		0	1	12	3	60	72	**37**
Maccaffertium sp.	9		0	9	10	1	20	30	**20**
Rhithrogena sp.			0	0			0	0	**0.0**
Tricorythodes sp.	7	5	100	107	12	8	160	172	**140**
PLECOPTERA									
Acroneuria sp.			0	0			0	0	**0.0**
Isogenoides sp.	3		0	3	3		0	3	**3.0**
Isoperla sp.			0	0			0	0	**0.0**
Pteronarcys dorsata			0	0			0	0	**0.0**
TRICHOPTERA									
Brachycentrus sp.			0	0	2		0	2	**1.0**
Glossosoma sp.			0	0			0	0	**0.0**
Cheumatopsyche sp.	3		0	3	1		0	1	**2.0**
Hydropsyche sp.	30	1	20	50	74	4	80	154	**102**
Hydroptila sp.			0	0			0	0	**0.0**
Lepidostoma sp.			0	0			0	0	**0.0**
Oecetis sp.	10		0	10	12	2	40	52	**31**
Neureclipsis sp.			0	0	1		0	1	**0.5**
Psychomia sp.			0	0			0	0	**0.0**
ODONATA									

Ophiogomphus sp.	1		0	1			0	0	**0.5**
HEMIPTERA									
Callicorixa audeni			0	0			0	0	**0.0**
Sigara sp.			0	0			0	0	**0.0**
COLEOPTERA									
Liodessus sp.			0	0			0	0	**0.0**
Dubiraphia sp.			0	0			0	0	**0.0**
DIPTERA									
Bezzia/Palpomyia gp.			0	0			0	0	**0.0**
Chelifera sp.			0	0			0	0	**0.0**
Hemerodromia sp.	39	5	100	139	67	4	80	147	**143**
Psychodidae			0	0			0	0	**0.0**
Hexatoma sp.			0	0			0	0	**0.0**
Chironomidae									
Chironomus sp.			0	0			0	0	**0.0**
Cryptochironomus sp.			0	0		1	20	20	**10**
Demicryptochironomus sp.			0	0		1	20	20	**10**
Microtendipes sp.	11	6	120	131	17	8	160	177	**154**
Nilothauma sp.			0	0			0	0	**0.0**
Paralauterborniella sp.			0	0			0	0	**0.0**
Polypedilum spp.	2	11	220	222	1	15	300	301	**262**
Cladotanytarsus sp.		1	20	20		5	100	100	**60**
Micropsectra sp.			0	0		1	20	20	**10**
Paratanytarsus sp.			0	0			0	0	**0.0**
Rheotanytarsus sp.			0	0		2	40	40	**20**
Stempellinella sp.			0	0		1	20	20	**10**
Sublettea sp.			0	0			0	0	**0.0**
Tanytarsus sp.			0	0			0	0	**0.0**
Potthastia longimana gp.			0	0	3	1	20	23	**12**
Orthocladiinae			0	0			0	0	**0.0**
Corynoneura			0	0			0	0	**0.0**

sp.									
Cricotopus/Orthocladius spp.		64	1280	1280	1	66	1320	1321	**1301**
Epoicocladius sp.			0	0			0	0	**0.0**
Eukiefferiella sp.			0	0			0	0	**0.0**
Lopescladius sp.			0	0	2	2	40	42	**21**
Nanocladius sp.		1	20	20		2	40	40	**30**
Parakiefferiella sp.		1	20	20	1	6	120	121	**71**
Synorthocladius sp.	1		0	1		2	40	40	**21**
Tvetenia sp.			0	0		1	20	20	**10**
Telopelopia sp.			0	0			0	0	**0.0**
Thienemannimyia gp.	6	5	100	106	14	12	240	254	**180**
COLLEMBOLA			0	0			0	0	**0.0**
ARACHNIDA									
Hydracarina	3	14	280	283	4	19	380	384	**334**
CRUSTACEA									
Copepoda									
Cyclopoida			0	0			0	0	**0.0**
Ostracoda									
Candona sp.			0	0			0	0	**0.0**
Ilyocypris sp.		1	20	20		1	20	20	**20**
Limnocythere sp.			0	0			0	0	**0.0**
Amphipoda									
Gammarus lacustris	1		0	1			0	0	**0.5**
Hyalella azteca			0	0	1		0	1	**0.5**
Decapoda									
Orconectes virilis	1		0	1			0	0	**0.5**
OLIGOCHAETA									
Enchytraeidae			0	0		1	20	20	**10**
Naididae			0	0			0	0	**0.0**
Tubificidae			0	0			0	0	**0.0**
GASTROPODA									
Ferrissia sp.	10	1	20	30	18		0	18	**24**
PELECYPODA									
Pisidium sp.	2		0	2			0	0	**1.0**

NEMATODA		5	100	100	1	4	80	81	**91**
Total Taxa	**22**	**16**	**16**	**28**	**26**	**30**	**30**	**37**	**33**
Total Numbers	**145**	**126**	**2520**	**2665**	**278**	**181**	**3620**	**3898**	**3282**

TABLE B2 Raw data following benthic invertebrate identification for electroshocking samples from the North Saskatchewan River taken Septmember 1, 2009

Taxa	Sample 1				Sample 2	
	Coarse	**Fine**	**FineX20**	**Total**	**Coarse**	**Fine**
EPHEMEROPTERA						
Acentrella sp.			0	0		
Acerpenna sp.	1	4	80	81		2
Baetis sp.	1		0	1		1
*Fallceon*sp.			0	0	1	
Plauditus sp.	1	1	20	21		
Baetisca sp.			0	0		
Ephemerella sp.			0	0		
Ephemera sp.	1		0	1		
Heptagenia sp.	1	3	60	61	1	
Maccaffertium sp.	5	3	60	65	2	
Rhithrogena sp.			0	0		
Tricorythodes sp.	13	1	20	33	7	3
PLECOPTERA						
Acroneuria sp.			0	0		
Isogenoides sp.	3		0	3		
Isoperla sp.	2		0	2	1	
Pteronarcys dorsata			0	0		
TRICHOPTERA						
Brachycentrus sp.	2		0	2		
Glossosoma sp.			0	0		
Cheumatopsyche sp.	2		0	2		
Hydropsyche sp.	19	1	20	39	15	5
Hydroptila sp.			0	0		
Lepidostoma sp.			0	0		
Oecetis sp.	7	1	20	27	3	1
Neureclipsis sp.			0	0		
Psychomia sp.			0	0	1	

ODONATA						
Ophiogomphus sp.			0	0		
HEMIPTERA						
Callicorixa audeni			0	0		
Sigara sp.			0	0		
COLEOPTERA						
Liodessus sp.			0	0		
Dubiraphia sp.			0	0		
DIPTERA						
Bezzia/Palpomyia gp.	1		0	1		
Chelifera sp.			0	0		
Hemerodromia sp.	38	5	100	138	30	4
Psychodidae			0	0		
Hexatoma sp.			0	0		
Chironomidae						
Chironomus sp.			0	0		1
Cryptochironomus sp.	1		0	1		1
Demicryptochironomus sp.			0	0		
Microtendipes sp.	8	2	40	48	6	7
Nilothauma sp.			0	0		
Paralauterborniella sp.			0	0		
Polypedilum spp.	3	10	200	203	1	18
Cladotanytarsus sp.			0	0		7
Micropsectra sp.			0	0		
Paratanytarsus sp.			0	0		
Rheotanytarsus sp.			0	0		
Stempellinella sp.			0	0		
Sublettea sp.		1	20	20		
Tanytarsus sp.		2	40	40		2
Potthastia longimana gp.	2	1	20	22	1	1

Orthocladiinae			0	0		
Corynoneura sp.			0	0	1	1
Cricotopus/Orthocladius spp.	3	58	1160	1163	4	75
Epoicocladius sp.			0	0		
Eukiefferiella sp.			0	0		1
Lopescladius sp.	2		0	2	3	
Nanocladius sp.			0	0		2
Parakiefferiella sp.	3	2	40	43	2	16
Synorthocladius sp.	1	2	40	41		1
Tvetenia sp.			0	0		
Telopelopia sp.			0	0		
Thienemannimyia gp.	7	2	40	47	5	7
COLLEMBOLA			0	0		
ARACHNIDA						
Hydracarina	2	12	240	242	2	15
CRUSTACEA						
Copepoda						
Cyclopoida			0	0		
Ostracoda						
Candona sp.			0	0		
Ilyocypris sp.			0	0		1
Limnocythere sp.			0	0		
Amphipoda						
Gammarus lacustris			0	0		
Hyalella azteca			0	0		
Decapoda						
Orconectes virilis			0	0		
OLIGOCHAETA						
Enchytraeidae		1	20	20		
Naididae			0	0		
Tubificidae			0	0		
GASTROPODA						

Ferrissia sp.	7		0	7	9	1
PELECYPODA						
Pisidium sp.			0	0		
NEMATODA	1	3	60	61		
Total Taxa	**27**	**20**	**20**	**30**	**19**	**23**
Total Numbers	**137**	**115**	**2300**	**2437**	**95**	**173**

TABLE B3 Raw data following benthic invertebrate identification for electroshocking samples from the North Saskatchewan River taken Septmember 1, 2009 (continued)

Taxa	Sample 2		Sample 3				Mean
	FineX10	Total	Coarse	Fine	FineX20	Total	Total
EPHEMEROPTERA							
Acentrella sp.	0	0			0	0	**0.0**
Acerpenna sp.	20	20		1	20	20	**40**
Baetis sp.	10	10		1	20	20	**10**
*Fallceon*sp.	0	1			0	0	**0.3**
Plauditus sp.	0	0	1		0	1	**7.3**
Baetisca sp.	0	0			0	0	**0.0**
Ephemerella sp.	0	0			0	0	**0.0**
Ephemera sp.	0	0			0	0	**0.3**
Heptagenia sp.	0	1			0	0	**21**
Maccaffertium sp.	0	2	2	1	20	22	**30**
Rhithrogena sp.	0	0			0	0	**0.0**
Tricorythodes sp.	30	37	9	2	40	49	**40**
PLECOPTERA							
Acroneuria sp.	0	0			0	0	**0.0**
Isogenoides sp.	0	0			0	0	**1.0**
Isoperla sp.	0	1	1		0	1	**1.3**
Pteronarcys dorsata	0	0			0	0	**0.0**
TRICHOPTERA							
Brachycentrus sp.	0	0	1		0	1	**1.0**
Glossosoma sp.	0	0			0	0	**0.0**
Cheumatopsyche sp.	0	0	3		0	3	**1.7**
Hydropsyche sp.	50	65	31	3	60	91	**65**
Hydroptila sp.	0	0			0	0	**0.0**
Lepidostoma sp.	0	0	1		0	1	**0.3**
Oecetis sp.	10	13	9		0	9	**16**
Neureclipsis sp.	0	0			0	0	**0.0**
Psychomia sp.	0	1			0	0	**0.3**

ODONATA							
Ophiogomphus sp.	0	0			0	0	**0.0**
HEMIPTERA							
Callicorixa audeni	0	0			0	0	**0.0**
Sigara sp.	0	0			0	0	**0.0**
COLEOPTERA							
Liodessus sp.	0	0			0	0	**0.0**
Dubiraphia sp.	0	0			0	0	**0.0**
DIPTERA							
Bezzia/Palpomyia gp.	0	0			0	0	**0.3**
Chelifera sp.	0	0			0	0	**0.0**
Hemerodromia sp.	40	70	63	7	140	203	**137**
Psychodidae	0	0			0	0	**0.0**
Hexatoma sp.	0	0			0	0	**0.0**
Chironomidae							
Chironomus sp.	10	10			0	0	**3.3**
Cryptochironomus sp.	10	10			0	0	**3.7**
Demicryptochironomus sp.	0	0			0	0	**0.0**
Microtendipes sp.	70	76	18	3	60	78	**67**
Nilothauma sp.	0	0			0	0	**0.0**
Paralauterborniella sp.	0	0			0	0	**0.0**
Polypedilum spp.	180	181	6	11	220	226	**203**
Cladotanytarsus sp.	70	70		1	20	20	**30**
Micropsectra sp.	0	0			0	0	**0.0**
Paratanytarsus sp.	0	0			0	0	**0.0**
Rheotanytarsus sp.	0	0		1	20	20	**6.7**
Stempellinella sp.	0	0			0	0	**0.0**
Sublettea sp.	0	0		1	20	20	**13**
Tanytarsus sp.	20	20			0	0	**20**
Potthastia longimana gp.	10	11	1		0	1	**11**

Orthocladiinae	0	0			0	0	**0.0**
Corynoneura sp.	10	11			0	0	**3.7**
Cricotopus/Orthocladius spp.	750	754	11	52	1040	1051	**989**
Epoicocladius sp.	0	0			0	0	**0.0**
Eukiefferiella sp.	10	10			0	0	**3.3**
Lopescladius sp.	0	3	2		0	2	**2.3**
Nanocladius sp.	20	20			0	0	**6.7**
Parakiefferiella sp.	160	162	5	5	100	105	**103**
Synorthocladius sp.	10	10	1	1	20	21	**24**
Tvetenia sp.	0	0			0	0	**0.0**
Telopelopia sp.	0	0			0	0	**0.0**
Thienemannimyia gp.	70	75	8	5	100	108	**77**
COLLEMBOLA	0	0			0	0	**0.0**
ARACHNIDA							
Hydracarina	150	152	4	13	260	264	**219**
CRUSTACEA							
Copepoda							
Cyclopoida	0	0			0	0	**0.0**
Ostracoda							
Candona sp.	0	0			0	0	**0.0**
Ilyocypris sp.	10	10			0	0	**3.3**
Limnocythere sp.	0	0			0	0	**0.0**
Amphipoda							
Gammarus lacustris	0	0			0	0	**0.0**
Hyalella azteca	0	0			0	0	**0.0**
Decapoda							
Orconectes virilis	0	0			0	0	**0.0**
OLIGOCHAETA							
Enchytraeidae	0	0		1	20	20	**13**
Naididae	0	0			0	0	**0.0**
Tubificidae	0	0			0	0	**0.0**
GASTROPODA							

Ferrissia sp.	10	19	23		0	23	**16**
PELECYPODA							
Pisidium sp.	0	0			0	0	**0.0**
NEMATODA	0	0	3		0	3	**21**
Total Taxa	**23**	**29**	**21**	**17**	**17**	**27**	**29**
Total Numbers	**1730**	**1825**	**203**	**109**	**2180**	**2383**	**2215**

APPENDIX C

BENTHIC INVERTEBRATE TALLIES FOR THE FLUME SAMPLES AND CALCULATED INDEPENDENT VARIABLES AND DEPENDENT DRIFT RATES FOR THE REPLICATES FROM THE FLUME SAMPLES FROM THE EXPERIMENT TO DETERMINE THE VARIABLES THAT AFFECT BENTHIC INVERTEBRATE DRIFT RATE

TABLE C1 Raw data following benthic invertebrate identification for the flume samples from the experiment to determine the variables that affect benthic invertebrate drift rate

Taxa	**Sample 1 09/10/21**				**Sample 2 09/10/30**			
	Coarse	**Fine**	**FineX8**	**Total**	**Coarse**	**Fine**	**FineX20**	**Total**
EPHEMEROPTERA								
Acentrella sp.			0	0			0	0
Acerpenna sp.	1		0	1	1		0	1
Baetis sp.			0	0	3		0	3
*Fallceon*sp.			0	0			0	0
Plauditus sp.			0	0			0	0
Baetisca sp.			0	0			0	0
Ephemerella sp.			0	0	3		0	3
Ephemera sp.	1		0	1	2		0	2
Heptagenia sp.	4		0	4	2	1	20	22
Maccaffertium sp.	7		0	7	6		0	6
Rhithrogena sp.	2		0	2	1		0	1
Tricorythodes sp.	20	1	8	28	21	1	20	41
PLECOPTERA								
Acroneuria sp.			0	0			0	0
Isogenoides sp.			0	0			0	0
Isoperla sp.	3		0	3	1		0	1
Pteronarcys dorsata			0	0			0	0
TRICHOPTERA								
Brachycentrus sp.			0	0	1		0	1
Glossosoma sp.	1	1	8	9	1		0	1
Cheumatopsyche sp.			0	0	2		0	2
Hydropsyche sp.	45	3	24	69	89	1	20	109
Hydroptila sp.			0	0			0	0
Lepidostoma sp.			0	0	1		0	1
Oecetis sp.	10		0	10	46	1	20	66
Neureclipsis sp.			0	0	2		0	2
Psychomia sp.	1		0	1	2		0	2

ODONATA								
Ophiogomphus sp.			0	0			0	0
HEMIPTERA								
Callicorixa audeni			0	0	1		0	1
Sigara sp.			0	0			0	0
COLEOPTERA								
Liodessus sp.			0	0			0	0
Dubiraphia sp.	1		0	1			0	0
DIPTERA								
Bezzia/Palpomyia gp.	1	1	8	9	1		0	1
Chelifera sp.			0	0	1		0	1
Hemerodromia sp.	52	3	24	76	40		0	40
Psychodidae	1		0	1			0	0
Hexatoma sp.	1		0	1			0	0
Chironomidae								
Chironomus sp.			0	0			0	0
Cryptochironomus sp.	5		0	5		3	60	60
Demicryptochironomus sp.			0	0			0	0
Microtendipes sp.	23	1	8	31	37	4	80	117
Nilothauma sp.		1	8	8			0	0
Paralauterborniella sp.	1	2	16	17			0	0
Polypedilum spp.	14	29	232	246	1	12	240	241
Cladotanytarsus sp.		4	32	32		1	20	20
Micropsectra sp.		1	8	8			0	0
Paratanytarsus sp.			0	0			0	0
Rheotanytarsus sp.	1	1	8	9			0	0
Stempellinella sp.			0	0			0	0
Sublettea sp.			0	0		2	40	40
Tanytarsus sp.		2	16	16		2	40	40
Potthastia longimana gp.	2		0	2	1		0	1
Orthocladiinae			0	0			0	0

Corynoneura sp.			0	0			0	0
Cricotopus/Orthocladius spp.	9	58	464	473	33	85	1700	1733
Epoicocladius sp.			0	0			0	0
Eukiefferiella sp.			0	0			0	0
Lopescladius sp.			0	0	1		0	1
Nanocladius sp.		1	8	8			0	0
Parakiefferiella sp.	1	7	56	57	1	6	120	121
Synorthocladius sp.			0	0		1	20	20
Tvetenia sp.	2		0	2	9		0	9
Telopelopia sp.	1		0	1			0	0
Thienemannimyia gp.	20	8	64	84	18	7	140	158
COLLEMBOLA			0	0			0	0
ARACHNIDA								
Hydracarina	3	1	8	11	3	1	20	23
CRUSTACEA								
Copepoda								
Cyclopoida			0	0			0	0
Ostracoda								
Candona sp.			0	0			0	0
Ilyocypris sp.			0	0			0	0
Limnocythere sp.			0	0			0	0
Amphipoda								
Gammarus lacustris			0	0			0	0
Hyalella azteca			0	0			0	0
Decapoda								
Orconectes virilis			0	0			0	0
OLIGOCHAETA								
Enchytraeidae			0	0		1	20	20
Naididae		10	80	80		6	120	120
Tubificidae			0	0			0	0
GASTROPODA								

Ferrissia sp.	6		0	6	10		0	10
PELECYPODA								
Pisidium sp.			0	0			0	0
NEMATODA		1	8	8		2	40	40
Total Taxa	**29**	**20**	**20**	**36**	**31**	**18**	**18**	**39**
Total Numbers	**239**	**136**	**1088**	**1327**	**341**	**137**	**2740**	**3081**

TABLE C2 Raw data following benthic invertebrate identification for the flume samples from the experiment to determine the variables that affect benthic invertebrate drift rate (continued)

Taxa	**Sample 3 09/11/16**				**Sample 4 09/11/11**				**Mean**
	Coarse	**Fine**	**FineX10**	**Total**	**Coarse**	**Fine**	**FineX20**	**Total**	**Total**
EPHEMEROPTERA									
Acentrella sp.			0	0			0	0	**0.0**
Acerpenna sp.			0	0	1	1	20	21	**15**
Baetis sp.	1	1	10	11	3	1	20	23	**11**
*Fallceon*sp.			0	0			0	0	**0.0**
Plauditus sp.			0	0			0	0	**0.0**
Baetisca sp.			0	0			0	0	**0.2**
Ephemerella sp.	3	2	20	23	8		0	8	**7.0**
Ephemera sp.			0	0			0	0	**0.6**
Heptagenia sp.	5	1	10	15	4		0	4	**9.4**
Maccaffertium sp.	11		0	11	6		0	6	**10**
Rhithrogena sp.	2		0	2	1		0	1	**1.6**
Tricorythodes sp.	18	2	20	38	10		0	10	**34**
PLECOPTERA									
Acroneuria sp.			0	0			0	0	**0.0**
Isogenoides sp.			0	0			0	0	**0.0**
Isoperla sp.	2		0	2	2		0	2	**1.8**
Pteronarcys dorsata			0	0	1		0	1	**0.2**
TRICHOPTERA									
Brachycentrus sp.	2		0	2	2		0	2	**1.0**
Glossosoma sp.	4	1	10	14	4		0	4	**5.8**
Cheumatopsyche sp.	2		0	2	2		0	2	**1.2**
Hydropsyche sp.	84	6	60	144	61		0	61	**87**
Hydroptila sp.	1		0	1	1		0	1	**0.4**
Lepidostoma sp.			0	0			0	0	**0.4**
Oecetis sp.	17	1	10	27	6		0	6	**30**
Neureclipsis sp.	1		0	1	2		0	2	**3.6**
Psychomia sp.	1	1	10	11			0	0	**5.0**

ODONATA									
Ophiogomphus sp.			0	0			0	0	**0.0**
HEMIPTERA									
Callicorixa audeni			0	0			0	0	**0.2**
Sigara sp.	1		0	1			0	0	**0.2**
COLEOPTERA									
Liodessus sp.			0	0			0	0	**0.2**
Dubiraphia sp.			0	0			0	0	**0.2**
DIPTERA									
Bezzia/Palpomyia gp.			0	0			0	0	**2.2**
Chelifera sp.			0	0			0	0	**0.2**
Hemerodromia sp.	29	3	30	59	18	1	20	38	**60**
Psychodidae			0	0			0	0	**0.2**
Hexatoma sp.			0	0			0	0	**0.2**
Chironomidae									
Chironomus sp.			0	0			0	0	**0.0**
Cryptochironomus sp.			0	0	1		0	1	**16**
Demicryptochironomus sp.			0	0			0	0	**2.0**
Microtendipes sp.	17	6	60	77	32	2	40	72	**84**
Nilothauma sp.			0	0			0	0	**1.6**
Paralauterborniella sp.		1	10	10			0	0	**5.4**
Polypedilum spp.	2	13	130	132	4	15	300	304	**220**
Cladotanytarsus sp.			0	0			0	0	**11**
Micropsectra sp.			0	0			0	0	**1.6**
Paratanytarsus sp.			0	0			0	0	**0.0**
Rheotanytarsus sp.		1	10	10	1	2	40	41	**12**
Stempellinella sp.			0	0			0	0	**0.0**
Sublettea sp.		1	10	10	1	1	20	21	**16**
Tanytarsus sp.			0	0		1	20	20	**17**
Potthastia longimana gp.	2	2	20	22	1		0	1	**7.4**
Orthocladiinae		1	10	10			0	0	**2.0**

Corynoneura sp.			0	0			0	0	**0.0**
Cricotopus/Orthocladius spp.	31	128	1280	1311	67	71	1420	1487	**1207**
Epoicocladius sp.			0	0			0	0	**0.2**
Eukiefferiella sp.			0	0			0	0	**0.0**
Lopescladius sp.			0	0	1		0	1	**0.4**
Nanocladius sp.			0	0			0	0	**3.6**
Parakiefferiella sp.	1	13	130	131		2	40	40	**92**
Synorthocladius sp.			0	0			0	0	**4.0**
Tvetenia sp.	5	1	10	15	12		0	12	**15**
Telopelopia sp.			0	0			0	0	**0.2**
Thienemannimyia gp.	7	12	120	127	6	6	120	126	**141**
COLLEMBOLA			0	0			0	0	**2.0**
ARACHNIDA									
Hydracarina	3	5	50	53	2	1	20	22	**23**
CRUSTACEA									
Copepoda									
Cyclopoida			0	0			0	0	**0.0**
Ostracoda									
Candona sp.		1	10	10			0	0	**2.0**
Ilyocypris sp.			0	0			0	0	**0.0**
Limnocythere sp.			0	0			0	0	**0.0**
Amphipoda									
Gammarus lacustris			0	0			0	0	**0.0**
Hyalella azteca			0	0			0	0	**0.0**
Decapoda									
Orconectes virilis			0	0			0	0	**0.0**
OLIGOCHAETA									
Enchytraeidae		2	20	20			0	0	**8.8**
Naididae	1	7	70	71		1	20	20	**72**
Tubificidae			0	0			0	0	**0.0**
GASTROPODA									

Ferrissia sp.	5		0	5	3		0	3	**10**
PELECYPODA									
Pisidium sp.			0	0			0	0	**0.0**
NEMATODA		1	10	10			0	0	**12**
Total Taxa	**27**	**25**	**25**	**34**	**29**	**13**	**13**	**32**	**36**
Total Numbers	**258**	**213**	**2130**	**2388**	**263**	**105**	**2100**	**2363**	**2278**

TABLE C3 Calculated independent variables for all of the replicates from the flume experiment to determine the variables that affect benthic invertebrate drift rate

DO(mg/L)	Temperature(^oC)	Depth(m)	Area(m^2)	V (m/s)	Perimeter(m)	μ(kg(m*s))	ρ (kg/m^3)
9.83	8	0.12	0.053	0.066	1.1	0.0014	1000
9.86	8	0.12	0.053	0.066	1.1	0.0014	1000
7.71	8	0.12	0.056	0.064	1.2	0.0014	1000
8.03	8.5	0.12	0.056	0.063	1.2	0.0014	1000
5.54	8.5	0.12	0.056	0.063	1.2	0.0014	1000
5.64	8.5	0.12	0.055	0.065	1.2	0.0014	1000
4.38	6	0.13	0.059	0.060	1.2	0.0015	1000
3.83	6	0.13	0.061	0.059	1.2	0.0015	1000
4.92	6	0.13	0.059	0.060	1.2	0.0015	1000
6.95	6	0.14	0.062	0.057	1.2	0.0015	1000
7.09	5	0.14	0.062	0.057	1.2	0.0015	1000
9.02	6	0.13	0.059	0.061	1.2	0.0015	1000
9.04	6	0.15	0.066	0.054	1.2	0.0015	1000
5.67	6	0.13	0.059	0.060	1.2	0.0015	1000
5.76	6	0.14	0.064	0.056	1.2	0.0015	1000
2.47	6	0.12	0.054	0.066	1.1	0.0015	1000
2.73	6	0.14	0.066	0.054	1.2	0.0015	1000
6.12	5	0.13	0.060	0.059	1.2	0.0015	1000
6.23	6	0.13	0.059	0.060	1.2	0.0015	1000
0.08	6	0.12	0.054	0.066	1.1	0.0015	1000
0	6	0.12	0.054	0.065	1.1	0.0015	1000
2.13	8	0.14	0.064	0.056	1.2	0.0014	1000
2.63	8	0.14	0.064	0.056	1.2	0.0014	1000
8.44	8	0.12	0.054	0.066	1.1	0.0014	1000
8.48	8	0.14	0.066	0.054	1.2	0.0014	1000
6.99	8	0.12	0.054	0.067	1.1	0.0014	1000
7.19	8	0.14	0.063	0.056	1.2	0.0014	1000
4.14	8	0.12	0.054	0.066	1.1	0.0014	1000
4.4	8	0.14	0.066	0.054	1.2	0.0014	1000

5.01	5	0.12	0.054	0.062	1.1	0.0015	1000
4.54	5	0.13	0.061	0.056	1.2	0.0015	1000
4.96	4.5	0.13	0.061	0.056	1.2	0.0015	1000
5.85	5	0.11	0.051	0.067	1.1	0.0015	1000
5.66	5	0.14	0.061	0.055	1.2	0.0015	1000
5.77	5	0.13	0.061	0.056	1.2	0.0015	1000
6.02	7	0.12	0.053	0.065	1.1	0.0014	1000
6.06	7	0.13	0.061	0.056	1.2	0.0014	1000
6.18	7	0.13	0.060	0.057	1.2	0.0014	1000
0.77	7	0.11	0.048	0.071	1.1	0.0014	1000
1.47	7	0.15	0.068	0.050	1.2	0.0014	1000
3.19	8	0.10	0.047	0.073	1.1	0.0014	1000
2.95	8	0.14	0.066	0.052	1.2	0.0014	1000

TABLE C4 Calculated independent variables and dependent benthic invertebrate drift rates for Ephemeroptera (E), Plecoptera (P), Trichoptera (T), Diptera (D), other benthic invertebrate species (O) and total benthic invertebrate species (To), for all of the replicates from the flume experiment to determine the variables that affect benthic invertebrate drift rate (continued)

Turbulence(Re)	Shear(m/s)	E(%drift/min)	P(%drift/min)	T(%drift/min)	D(%drift/min)	O(%drift/min)	To(%drift/min)
2197	0.0066	1.7	25	3.4	0	0.71	0.40
2197	0.0066	5.2	75	5.1	0.069	2.8	0.96
2202	0.0064	7.0	75	2.5	0.069	1.4	0.73
2227	0.0063	12	75	4.2	0.28	0	1.1
2215	0.0063	12	75	4.2	0.21	1.4	1.1
2226	0.0065	7.0	75	0	0.069	2.8	0.68
2037	0.0060	0.95	75	2.4	0.12	0.70	0.34
2037	0.0059	1.9	75	3.3	0.12	0	0.37
2031	0.0060	5.7	0	2.0	0.17	0	0.41
2010	0.0057	2.8	75	2.0	0.086	0	0.29
1963	0.0057	3.8	0	0.82	0.029	0	0.17
2060	0.0061	2.8	0	1.2	0.029	0	0.17
1977	0.0054	0.95	0	0.41	0	0	0.049
2039	0.0060	7.6	0	2.0	0.058	0	0.37
2007	0.0056	6.6	0	2.4	0	0	0.32
2096	0.0066	1.9	75	2.4	0.20	0.70	0.44
1986	0.0054	2.8	75	1.6	0.058	0.70	0.29
1969	0.0059	3.8	75	2.6	0.12	0	0.53
2045	0.0060	6.8	75	2.6	0.27	0.88	0.85
2078	0.0066	8.3	75	7.4	0.24	0.44	1.3
2066	0.0065	19	75	14	1.1	1.8	3.0
2126	0.0056	7.5	75	3.7	0.59	0.88	1.2
2126	0.0056	4.5	75	3.7	0.59	1.3	1.1
2216	0.0066	6.0	38	2.6	0.27	0	0.72
2100	0.0054	5.3	0	1.9	0.12	0	0.47

2220	0.0067	9.8	75	2.2	0.43	0.88	1.1
2124	0.0056	9.8	75	2.2	0.24	0.88	0.91
2210	0.0066	7.5	75	4.5	0.78	0.44	1.4
2100	0.0054	3.8	75	4.1	0.59	0.88	1.1
1917	0.0062	2.1	25	6.7	0.49	1.7	0.79
1871	0.0056	1.0	25	5.8	0.35	0	0.57
1848	0.0056	0	75	2.9	0.69	1.7	0.86
1946	0.0067	6.2	75	7.7	0.49	0	0.98
1870	0.0055	6.2	25	2.9	0.55	0	0.83
1874	0.0056	2.1	50	7.7	0.35	0	0.70
2061	0.0065	2.1	25	3.8	0.42	0	0.60
1989	0.0056	0	0	2.9	0.069	0	0.16
2002	0.0057	4.1	0	2.9	0.24	0	0.44
2097	0.0070	3.1	0	7.7	0.31	1.7	0.67
1920	0.0050	4.1	25	3.8	0.21	1.7	0.51
2165	0.0073	2.1	0	5.8	0.52	1.7	0.76
2011	0.0052	1.0	50	5.8	0.31	1.7	0.60