REPORT ON BENTHIC MACROINVERTEBRATES 2021

For the Athabasca Watershed Council

ABSTRACT

The assemblage of collected benthic macroinvertebrates from the Athabasca Watershed was assessed using several standard metrics.

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Executive Summary

Test sites in the Athabasca Watershed collected in 2021 were assessed for water quality using both abiotic and biotic measurements. In this report the biotic measures were drawn from the types and abundance of benthic macroinvertebrates resident at each site. Macroinvertebrates are long term *in-situ* monitors of water quality. We have evaluated and commented on the taxonomic resolution and the following metrics: Hilsenhoff Biotic Index (BI), Abundance, Richness, Shannon-Wiener Diversity Index, compositional measures and % shredders. These are useful and appropriate metrics that will provide practical information now and for future studies in this watershed.

The Hilsenhoff BI was our cornerstone in this analysis as it incorporates the concepts of richness, evenness, and abiotic pollution tolerance and was used to evaluate the community disturbances of these sites. Using this metric, we have divided the sites into two groups: Gregg River, Whitehorse Creek and McLeod River having excellent water quality and Solomon Creek having very good water quality. Abundance and Richness were variable and may have a subsampling bias. Abundance data weakly concurred with the Hilsenhoff ranking whereas Richness did not. Diversity and evenness measured by the Shannon-Wiener Diversity Index also did not strongly support the Hilsenhoff BI groupings. The compositional measures revealed that there were several pathways to excellent and very good water quality. The compositional measures also revealed a large percentage of the Chironomidae *Polypedilum* at Solomon Creek. reinforcing the Hilsenhoff BI designation of only very good water quality. Percentage shredders provide an insight on the riparian conditions at each site. % Shedders were variable among the sites and this metric will be interesting to follow from these sites over time. Interestingly, Solomon Creek had the highest percentage of Shredders, about double compared to the other groups. This 2021 sampling is a first look at these sites. The water quality appears to be excellent to very good at the sites and this data will provide a baseline to monitor any future changes at these sites in this watershed.

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Attribution

Working and living in Calgary, we would like to acknowledge the traditional territories of the people of the Treaty 7 region in Southern Alberta, which includes the Tsuut'ina First Nation, and the Stoney Nakoda (including the Chiniki, Bearspaw, and Wesley First Nations), as well as the Blackfoot Confederacy (comprising the Siksika, Piikani, and Kainai First Nations). The City of Calgary is also home to Métis Nation of Alberta, Region 3.

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Introduction

The health of an aquatic system is commonly assessed by both spot abiotic measurements (e.g., pH, dissolved oxygen, turbidity, nitrates) and by the resident assemblage of benthic macroinvertebrates. The strength of using macroinvertebrates is they are *in-situ* monitors of water quality, constantly integrating the changes in water quality over long stretches of time. This utility of benthic macroinvertebrates has long been known and it is used in bioassessment protocols around the world including Canada (Gray 2020a). The CABIN (Canadian Aquatic Biomonitoring Network) protocols are a national standardization initiative to allow evaluations of relative impacts of anthropogenic changes on aquatic systems. CABIN depends on the availability of an unimpacted reference site (Gray 2020b) and the degree of divergence of the test sites from the reference site. To our knowledge there is currently no reference site for the Athabasca watershed. Thus, the issue becomes how to assess the water quality of the test sites in the Athabasca watershed.

There is a long history of evaluating water quality without comparing to a reference site (Mazor et al. 2019, Carter and Resh 2013). Gray (2020c), Carter and Resh (2013), Johnson et al. (2006) discusses the many metrics that can be used to assess water quality using benthic invertebrates. In the report below we have chosen metrics based on the most current scientific literature and merits of the supplied data. Hilsenhoff Biotic Index, Abundance, Richness, Shannon-Weiner Diversity Index and selected taxonomic compositional measures were chosen to evaluate each site's water quality. Additionally, % Shredders – a functional feeding group metric will provide an ecosystem perspective for each site. We feel these metrics are firmly based in this history of aquatic biomonitoring and are robust enough to allow comparisons among the sites and among sampling intervals as an annual monitoring program progresses and will provide meaningful information to the Athabasca Watershed Council to evaluate the relative qualities of 2021 test sites.

Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (Hilsenhoff BI) is used to evaluate the water quality of freshwater systems. Hilsenhoff BI distills the entire assemblage of aquatic invertebrates to a value or score that allows a judgement of organic pollution and water quality. Organisms collected from a site are given a rating between 0 to 10, with 0 being taxa intolerant to organic pollution and 10 being organisms that have been reported to be highly tolerant to organic pollution. This approach is weighted where the higher the number of organisms at any given tolerance, the greater their influence on the final value. Once a Hilsenhoff BI value or score is obtained for a site it can be compared to known ranges that correspond to water quality. Excellent water quality falls into a range of 0 to 3.5, corresponding to no apparent organic pollution (Hilsenhoff 1978). Very good is 4.51 to 5.50 with possible slight organic pollution (Hilsenhoff 1978). Good is 5.51 to 6.50, some organic pollution, with Fair 6.51 to 7.50 indicating fairly significant organic pollution (Hilsenhoff 1978). Poor and Very Poor are above 7.51 and 8, respectively and correspond to significant organic pollution (Hilsenhoff 1978). Accordingly, a low Hilsenhoff BI value will correspond to less organic pollution. Hilsenhoff BI can be carried out at the family and/or genus level, but its results will be more precise to the genus level as tolerance values of some genera deviate substantially from the tolerance values of their family.

Hilsenhoff BI's indicated that the water quality was excellent to very good in these Athabasca watershed sites. Gregg River, Whitehorse Creek, and McLeod River exhibited Hilsenhoff BI values of 3.3, 2.8 and 2.4, respectively and received a rating of Excellent (<3.5) water quality (Figure 1). These sites are considered to have no apparent organic pollution. The remaining site, Solomon Creek, with a Hilsenhoff BI score of 3.9, receives a rating of Very Good (4.50 to 3.51). This score indicates possible slight organic pollution (Figure 1). The Hilsenhoff BI values here were low, and perhaps they would be expected to, given the wide application Hilsenhoff BI was designed to be applied to. For example, a study of watersheds in Toronto and Region recorded their "best" Family Biotic Index (FBI) of 5.19 on the Humber River and their worst was 9.14 on the Don River (TRCA 2011). These sites are in heavily urbanized areas, with many more and different impacts than the Athabasca watershed would have. The Hilsenhoff BI is one tool to evaluate water quality, its strength is it nicely distills to a "score" allowing easy interpretation and comparisons. It is prudent to base findings of water quality on the examination of several metrics. In the following sections we will attempt to unravel these differences in apparent water quality.

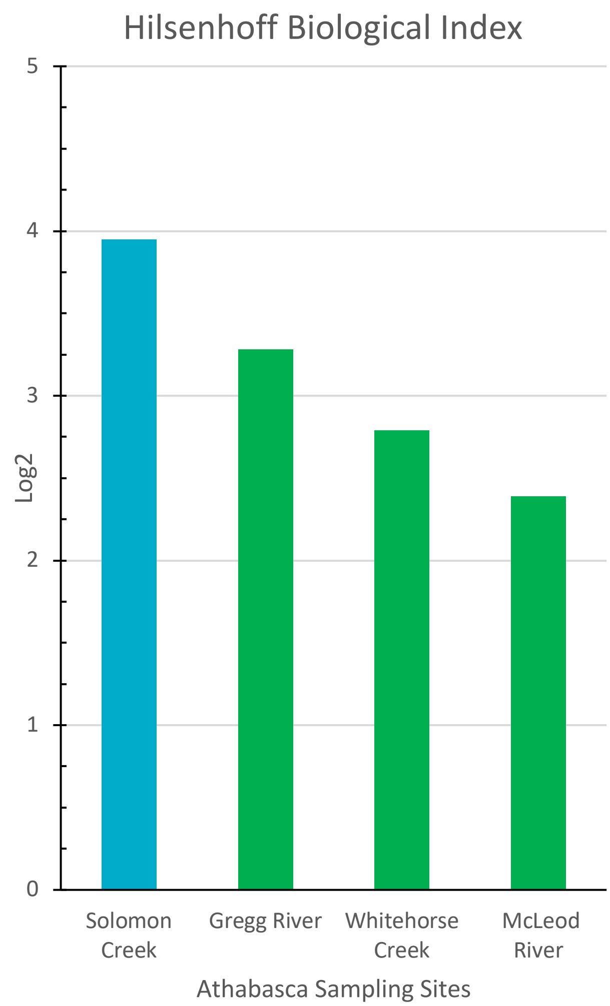


Figure 1. Overall water quality ranking based on the Hilsenhoff Biotic Index from the Athabasca Watershed 2021. The green bars represent 'Excellent' water quality and blue bars 'Very Good' water quality.

Abundance

Abundance is the total count of individuals in a sample. As a generality, the higher the number of organisms the more productive a river is. Abundance can be influenced by many other factors such as: collection time of year, anthropogenic activities, natural events, rainfall/dryness, cobble size, vegetation cover and by field and lab techniques. Even though CABIN sampling requires a timed collecting pattern, the vigorousness of the sample collector can also have an impact on the amount of material collected. Abundance was markedly greater at Whitehorse Creek with Solomon Creek and Gregg River being about the same, and McLeod River was the lowest (Figure 2). In fact, the site at McLeod River exhibited less than half the abundance of Whitehorse Creek. The abundance data weakly concurred with the Hilsenhoff ranking with Whitehorse Creek not conforming by having the greatest abundance.

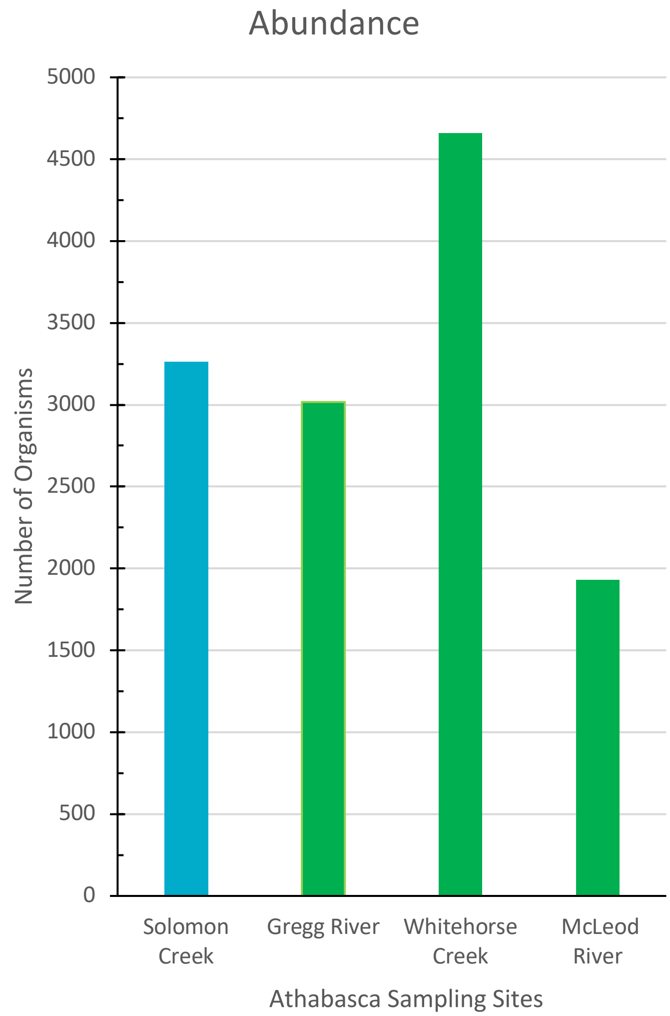


Figure 2. Abundance (number of individual organisms) from sites in the Athabasca Watershed 2021. The blue bar is 'Good' water quality, and the green is 'Excellent' water quality from the Hilsenhoff BI.

Abundance doesn't distinguish among individuals that are known to be tolerant to poor water quality and those that are intolerant. Furthermore, in poor water quality, conditions such as with nutrification, a proliferation of taxa will thrive in such conditions, as to skew abundance measures outside of the general rule of 'high abundance' means 'better' water quality. The best Hilsenhoff BI was 2.4 for the McLeod River site which exhibited substantially less abundance than did the Solomon Creek site. The Hilsenhoff BI for the Solomon Creek was 3.9. The nature of these differences will be discussed in the following sections.

Richness

Richness is the number of unique taxa recorded per site with more taxa indicating a less disturbed site. In general, the greater the abundance the greater the probability of finding unique/rare taxa. The richness exhibited in Figure 2 was not as variable as the abundance among the sites. The sites at Solomon Creek and Whitehorse Creek exhibited a lower number of unique taxa (lower than 30) compared to Gregg River and McLeod River, which were above 33 unique taxa. As with the abundance data, the richness data don't strongly concur with the findings of the Hilsenhoff analysis. An interesting observation is that richness and abundance seem to be inversely related (Figures 2 and 3). A high abundance seems to correspond with a low richness, especially for Whitehorse Creek, and a high richness corresponds to a low abundance at McLeod River. They sites will be interesting to follow in the coming years.

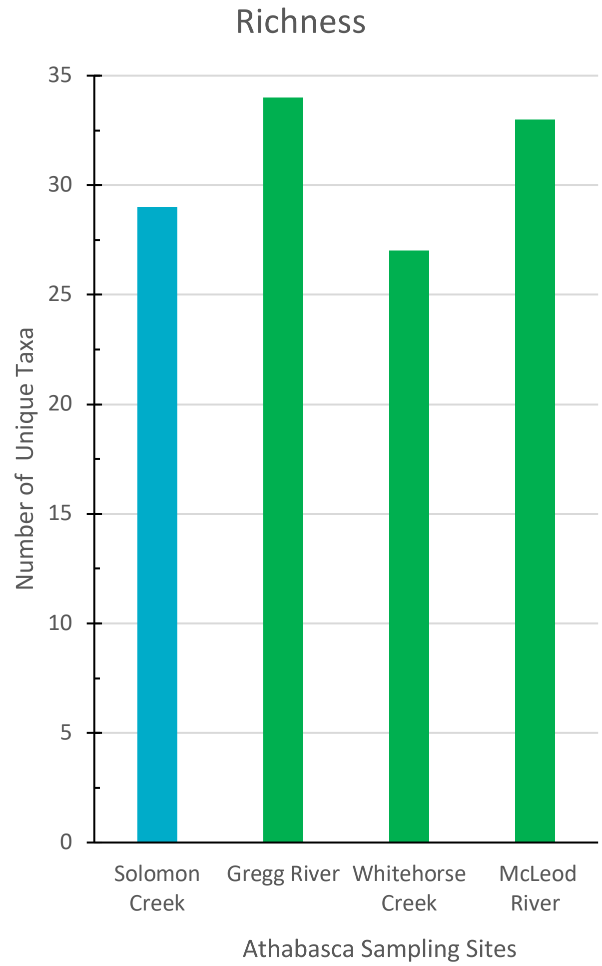


Figure 3. Richness (number of unique taxa) from sites in the Athabasca Watershed 2021. The blue bar is 'Good' water quality, and the green is 'Excellent' water quality from the Hilsenhoff BI.

Richness and abundance can be biased by subsampling. CABIN allows for as little as 5% of the sample to be analyzed, with the results being scaled up to the full sample (CABIN 2014). The protocol reads that the number of subsamples must be a minimum of 5% and proceed subsample by subsample until the count reaches 300 organisms of the included taxa. If 300 organisms are not reached by the 50^{th} subsample, then the entire sample must be analyzed. It is important to point out that the premise of subsampling is so full taxonomy can be carried out on the organisms in a reasonable amount of time. It follows that the smaller the number of subsamples taken the probability of intercepting rare taxa becomes lower. As well, scaling up can lead to extrapolation errors in the abundance (Frazao 2019). McLeod River and Gregg River had 16% and 12% of their sample analyzed, the others were 10% (Solomon Creek) and 7% (Whitehorse Creek). We suspect that Whitehorse Creek data might have suffered somewhat from subsampling bias, but it is impossible to say definitively with only four samples to evaluate.

Shannon-Wiener Diversity Index

Shannon-Wiener Diversity index (H) accounts for both richness and evenness. As the number and distribution of individuals to the taxa increases, so will the value of H. Accordingly, a higher H value will reflect better water quality. Shannon-Wiener Diversity index was about 2.7 for Solomon Creek, Gregg River, and McLeod River, 25% higher than for Whitehorse Creek (2.02). Whitehorse Creek has a substantially higher abundance (Figure 2) and a somewhat lower richness (Figure 3), which lead to this lower value for H. Interestingly, McLeod River had the opposite: a low abundance but high richness yielding one of the higher H values. These data don't closely follow the Hilsenhoff analysis mainly because the H value of Whitehorse Creek was lower than would be predicted. However, these measures are providing additional information.

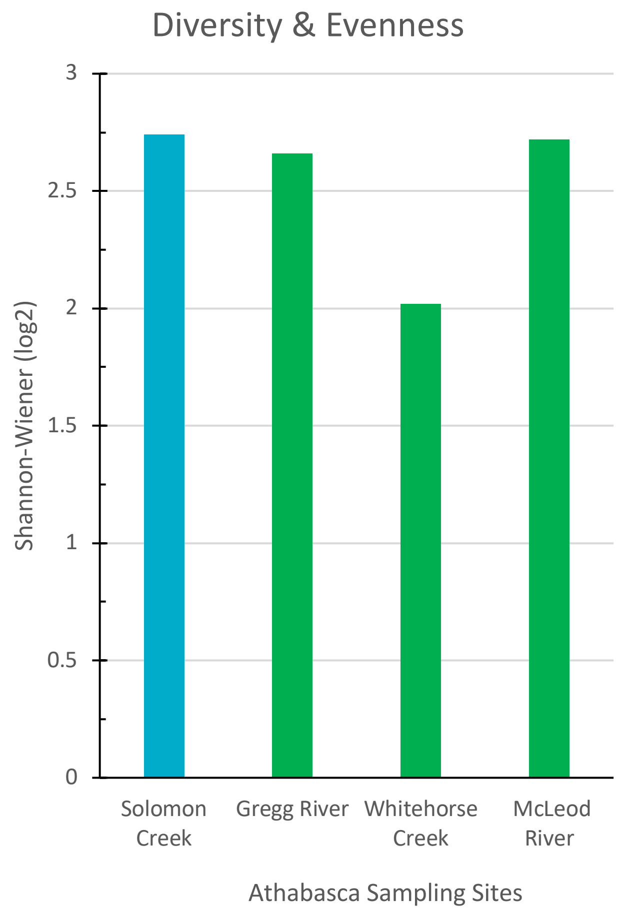


Figure 4. Shannon-Wiener (H) measure of diversity and evenness from sites in the Athabasca Watershed 2021. The blue bar is 'Good' water quality, and the green is 'Excellent' water quality from the Hilsenhoff BI.

Composition measures

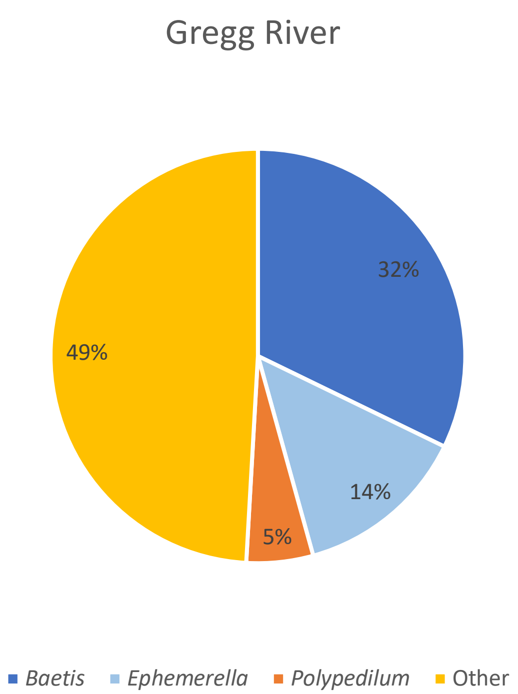
Compositional measures are indices that provide a breakdown of the most abundant taxa in each assemblage. Common measures are the % Chironomidae and % EPT (Ephemeroptera, Plecoptera and Trichoptera) (Table 1). More in-depth information is the presentation of the top three taxa per assemblage (Figures 4 to 6). A high percentage of EPT suggest a high-quality aquatic environment because EPT have low tolerances to poor water quality with family tolerance values that range from 0 to 4. Samples with these assemblages would have low Hilsenhoff BI values. A high percentage of Chironomidae is typically an indication of poor water quality, as they have high tolerances (family tolerance value of 6) to poor water quality. Accordingly, 'Excellent' water quality should have assemblages with a low percentage of chironomids and high percentage of EPT (Barbour et al. 1999, Gray 2020c). Decreased water quality will exhibit an increase in the chironomid fraction and a decrease in the EPT fraction (Barbour et al. 1999, Gray 2020c). Solomon Creek with only a Very Good rating exhibited double the number of chironomids and at least 20% less EPT compared to the sites with Excellent water quality.

Table 1. Composition measures and overall water quality ranking based on Hilsenhoff Biotic Index from Athabasca Watershed 2021.

	Sample Collection Sites Athabasca Watershed - 2021			
Site	**Solomon Creek**	**Gregg River**	**Whitehorse Creek**	**McLeod River**
% chironomid	34.4	13.0	16.2	9.2
% EPT	51.5	75.7	81.5	79.3
Hilsenhoff BI Water Quality	Very Good	Excellent	Excellent	Excellent

EPT – Ephemeroptera, Plecoptera and Trichoptera

'Excellent' sites: Gregg River, Whitehorse Creek, and McLeod River



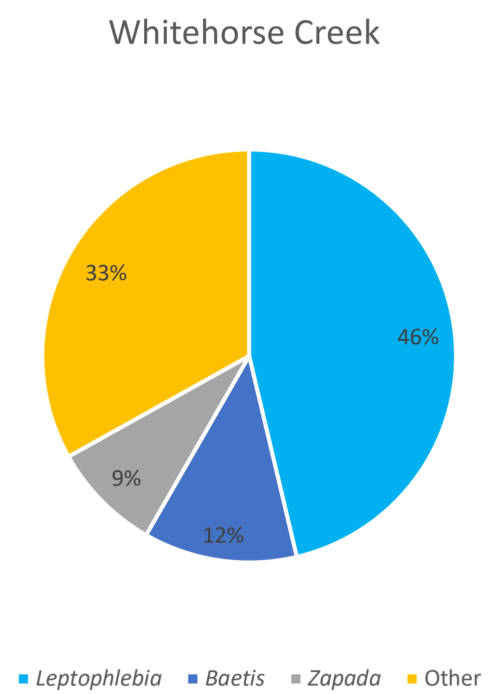


Figure 5. The top three dominant families and the remainder (Other) as a percentage of the assemblage for Gregg River and Whitehorse Creek from the Athabasca sampling sites in 2021. Both these sites had 'Excellent' water quality based on their Hilsenhoff values.

There are many routes to Excellent water quality. The sites in the 'Excellent group' Gregg River, Whitehorse Creek, and McLeod River each had distinct composition of taxa. All sites had significant amounts of Ephemeroptera with common genera of *Baetis* and *Leptophlebia*. Within the EPT the genus *Baetis* has a tolerance score of 5, much higher than *Ephemerella, Leptophlebia* and *Drunella* which are 1, 2 and 0, respectively. The Plecoptera genera *Zapada* and *Tanenionema* also have low tolerance scores of 2. Gregg River had a higher Hilsenhoff score than Whitehorse Creek and McLeod River, the composition of the dominate genera of *Baetis* and the chironomid genus *Polypedilum* point to this. At Whitehorse Creek, the three dominate genera *Leptophlebia, Baetis* and *Zapada* accounted for 67% of the taxa with only 33% for the remainder. With such dominate genera this explains why richness and therefore H were so low.

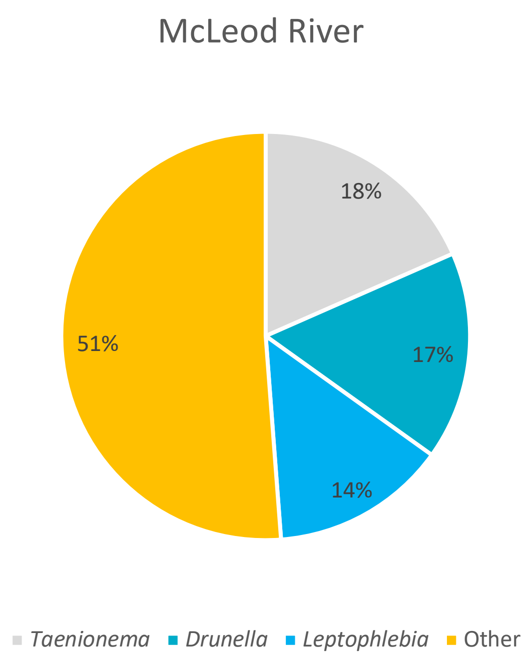


Figure 6. The top three dominant families and the remainder (Other) as a percentage of the assemblage for McLeod River from the Athabasca sampling sites in 2021. This site had 'Excellent' water quality based on its Hilsenhoff value.

'Very Good' sites Solomon Creek

The composition of Solomon Creek was dominated *by Baetis* and the Chironomidae *Polypedilum* (tolerance of 6). Many these genera with their high tolerances would shift the Hilsenhoff to higher values.

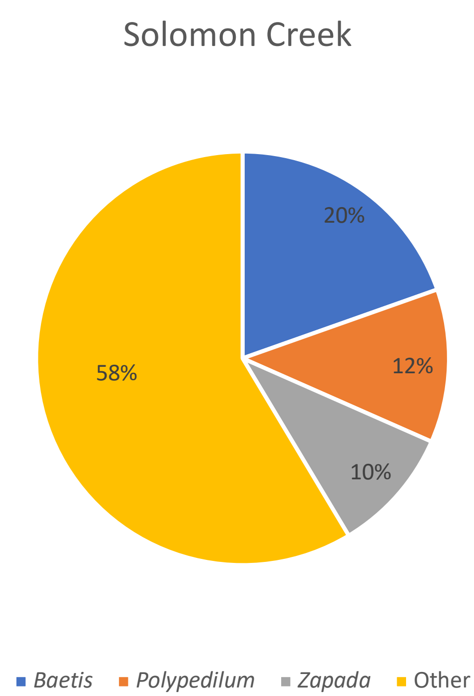


Figure 7. The top three dominant families and the remainder (Other) as a percentage of the assemblage for Solomon Creek from the Athabasca sampling sites in 2021. This site had 'Very Good' water quality based on its Hilsenhoff value.

Percentage Shredders

In the previous section we have provided several measures of the taxonomic composition of these sites in the Athabasca watershed. By knowing the taxonomic composition, we can also explore the functional aspects of these sites and determine how these invertebrates "make their living". One important aspect of how organisms "make their living" is feeding strategies. As these sites are being re-vegetated a key functional metric to examine is % Shredders. Shredders are invertebrates that breakdown plant material and recycle carbon.

Key taxa that are shredders are: Plecoptera (stoneflies), Trichoptera (caddisflies), Lepidoptera (butterflies and moths), Coleoptera (beetles) and Diptera (flies). Across all sites there were no collected Lepidoptera and the only Coleoptera (Elmidae) collected are not shredders. The shredder organisms found in this study are the Diptera Chironomidae (genera: *Brillia*, *Cricotopus, Polypedilum*) and the Plecoptera (Capniidae, Leuctriae, Nemouridae). Shredders varied from a low of almost 5% at McLeod River to a high of 36% at Solomon Creek (due to a high number of *Polypedilum* and *Zapada* (figure 8)).

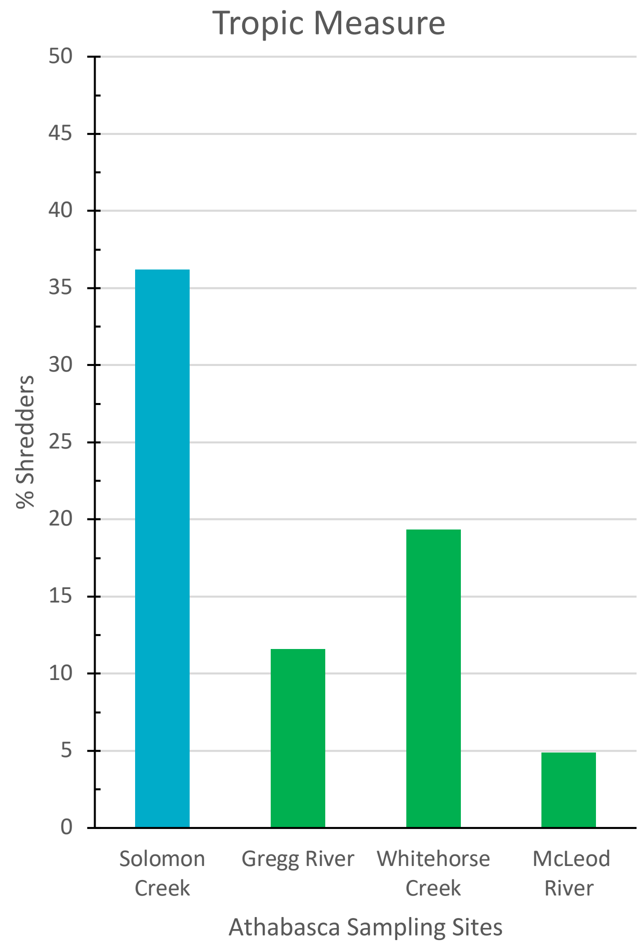


Figure 8. Percent Shredders (percentage of organisms using a shredding feeding style) from the Athabasca Watershed sampling sites in 2021. The blue bar is 'Good' water quality, and the green is 'Excellent' water quality from the Hilsenhoff BI.

Discussion

Our approach for the analysis of the taxonomic data was to start with the Hilsenhoff BI and move on to analyze other measures of aquatic health. Carter and Resh (2013) note that Hilsenhoff BI is a top index and third most popular metric used in U.S. biomonitoring programs. In Canada, Hilsenhoff BI is one of the standard indices in CABIN (Gray 2020c). Hilsenhoff BI provides water quality classifications that give a measure of pollution tolerance to assess water quality. These tolerance values are based on the survival of macroinvertebrates to abiotic stressors such as pH, nutrients, organics, O_2 levels, temperature, and turbidity (Beck 1977, Hubbard and Peters 1978, Surdick and Gaufin 1978). Macroinvertebrates being relatively stationary act as long-term monitors of water quality as opposed to the above-mentioned water quality point measurement collected during invertebrate sampling. With the Hilsenhoff BI we were able to use all the available data to generate a water quality score at each site. While these scores are not absolute, and can vary with time, they were useful for grouping these test sites. Based on the Hilsenhoff BI scores, three sites (McLeod River, Whitehorse Creek, and Gregg River) were considered to have excellent water quality, and Solomon Creek exhibited very good water quality. These are useful findings, as this is the first year of monitoring so the 'true' value of the score at each site is unknown.

The other measures presented here, examine different aspects of watershed health. Abundance and richness were variable among the samples, which is not very surprising as invertebrate populations are affected by factors beyond water stressors such as collection effort and time of year. These measures did not strongly concur with the Hilsenhoff BI values. Both abundance and richness are affected by the subsampling protocol employed by the CABIN methodology. Subsampling can lead to the omission of the rare taxa and the inflation of the abundance due to extrapolation. The advantage of subsampling is that reasonable number of invertebrates are obtained thus permitting full taxonomy. The Shannon-Wiener diversity index (H) was similar for all sites but Whitehorse Creek. Whitehorse Creek exhibited higher abundance and lower taxon richness causing an approximately 25% lowering in diversity and evenness (Shannon-Wiener Index) compared to the other sites including Solomon Creek. Solomon Creek had a rating of Very Good water quality whereas the others were Excellent. In terms of the composition, Solomon Creek with higher chironomids and lower EPT (Table 1) did indicate poorer water quality compared to the other sites. From the compositional data the breakdown of genera it is apparent that each site has a unique assemblage of fauna and there are many ways to achieve excellent water quality. This 2021 sampling is a first look at these sites. The water quality appears to be excellent to very good at the sites and this data will provide a baseline to monitor any future changes at these sites in this watershed.

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