Ecosystem impact of nutrient enrichment by Kokanee in the Williston Reservoir Watershed

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Final Report

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EXECUTIVE SUMMARY

The Williston Reservoir and its tributaries are highly nutrient limited. From 1990 to 1998 over 3,000,000 Kokanee were stocked into rivers that flow into the Williston Reservoir in an attempt to increase the productivity of the reservoir ecosystem, and to also create a potential sport fishery for Kokanee and the fish that eat them. Aerial counts a decade later showed major runs of Kokanee in the Finlay, Ingenika, Omineca, Osilinka, and Germanson Rivers. Kokanee in these rivers potentially can provide a major new source of nutrients, impacting other fish species, stream-living macroinvertebrates, and the adjacent riparian zone. The goal of the project is to determine the impact of the introduction of Kokanee into the Williston Reservoir on the nutrient dynamics and the complex web of interactions between Kokanee, stream-living macroinvertebrates (aquatic insects), and the surrounding riparian zone (lichen communities). This project aligns with the Peace Fish and Wildlife Compensation Program's Stream Action Plan Objective 2a – "Understand the effects of Kokanee introductions on the aquatic food web", and Objective 2a-1 – "Undertake a Kokanee assessment study to summarize status, trends, and aquatic and terrestrial ecosystem impacts and potential risks of Kokanee introductions - Develop appropriate recommendations for actions, as needed."

The distribution of spawning Kokanee in tributaries to the Williston Reservoir is extensive - but it is clear that one of the few watersheds where Kokanee have not colonized is the Parsnip River system, although there are reports of Kokanee spawning in tributaries to the system that are close to the reservoir. Due to the wide spatial separation of our control and experimental sites in 2016, we selected additional control and experimental sites for 2017 (year 2 of this 3 year project).

The transfer of nutrients into streams in the Williston watershed was assessed using two target groups, namely aquatic insects and riparian lichen communities to assess differences in abundance and community composition. Diversity of aquatic invertebrates within tributaries to the Williston Reservoir and species lichen in riparian areas adjacent to these streams is extensive. We found undocumented species from our taxonomic surveys extending the known range for these organisms to central BC.

We also collected samples for stable isotope analysis to track the potential delivery of nutrients from the reservoir to tributary streams and their riparian ecosystems using three functional groups;

1. slimy sculpin (*Cottus cognatus*), a stream resident fish,
2. aquatic insects that dominated the stream macroinvertebrate community belonging to the Orders Ephemeroptera, Plecoptera, and Trichoptera (EPT), and
3. a stem dwelling foliose green algal lichen *Parmelia squarrosa*.

Carbon varied by study streams, but was depleted in $\delta^{13}C$ from streams where Kokanee spawn and highly variable in control streams where Kokanee have not been documented to spawn. This pattern was seen in benthic stream resident fish, aquatic invertebrates – primarily Ephemeroptera, and the lichen samples. Nitrogen also varied among the samples – $\delta^{15}N$ was enriched in Kokanee from the Williston Reservoir that were spawning in tributary streams and depleted in samples collected from sculpin, aquatic insects and lichen. Stable isotopes of hydrogen were variable among sculpin samples, but generally depleted in $\delta^{2}H$ for samples from

streams where Kokanee spawn and with increasing latitude. Oxygen signatures were strongly correlated with latitude and do not appear to reflect nutrient contribution, but the spatial distribution of Kokanee spawning pattern in the Williston Reservoir watershed. Overall, our findings are strongly suggestive that Kokanee provide a source of nutrients to tributary streams where they spawn.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Temperate freshwater systems are highly oligotrophic. Flooding of land following the building of a dam and the creation of a reservoir results in leaching of nutrients from the newly submerged soils and productivity can be quite high during the early life of a reservoir. Reservoir dynamics in temperate regions, however, can lead to a gradual loss of nutrients. Consequently, over time reservoirs in temperate regions become less productive and are often characterized as ultra-oligotrophic. Fertilization projects for reservoirs in the Canadian portion of the Columbia River watershed have shown considerable success in enhancing productivity; but the size of the reservoirs created in the Columbia Basin are relatively small.

The Williston Reservoir was created in 1968 following the construction of the WAC Bennett Dam and impounding the Peace River in the canyon near Hudson's Hope, BC for hydroelectric generation. With a surface area of 1,779 km2, the Williston Reservoir is the largest lentic freshwater system in British Columbia. Attempts to increase productivity in the watershed have been limited, but a fertilization project on the Mesilinka River during the 1990's met with moderate success. Additionally, Kokanee (*Oncorhynchus nerka*) were stocked into Williston Reservoir from 1990 to 1998 to create a Kokanee sport fishery and a prey source for large piscivorous fish species. During this time, over three million juvenile Kokanee were stocked into five rivers that flow into the Williston Reservoir. The five systems were: Carbon Creek, Davis River, Dunlevy Creek, Manson River, and Nation River; three systems on the east side of the reservoir and two rivers that flow into the southwest portion of the reservoir.

An aerial enumeration study conducted from 2002 to 2006 found that the distribution and abundance of Kokanee in tributaries to the Williston Reservoir poorly reflected the stocking patterns from the 1990's. Systems with the greatest abundance of Kokanee were found to be Russell Creek (Finlay River tributary), Ingenika River, Omineca River, Osilinka River, and Germanson River – some years with up to 250 000 spawners within a single river (Langston 2012). Spawning Kokanee, therefore, have selected tributaries in the Williston watershed that flow into the north-western portion of the reservoir – not the regions originally stocked. The introduced Kokanee to the Williston Watershed have the potential to dramatically affect the flow of nutrients due to their semelparous life history and a complex web of interactions between the fish, stream-living macroinvertebrates, and the surrounding riparian zone.

Anadromous Pacific salmon are a source of nutrients from the marine environment that are released to spawning streams after they die (Naiman et al. 2002), enriching not only the streams, but also the surrounding riparian areas (Quinn et al. 2018). The potential transfer of nutrients into regional stream systems in the Williston watershed via Kokanee migration should also have large impacts on a range of other biota and ecosystem processes, both aquatic and terrestrial. Nutrient transfer and its effect on riparian habitat and Kokanee populations will be assessed using two additional target groups, namely aquatic insects and riparian lichen communities. Both of these assemblages have previously been used as biological indicators of ecosystem integrity and function and have well-developed monitoring methodologies published in the literature.

All three groups of organisms – Kokanee, terrestrial lichens, and aquatic insects – affect each other in a complex web of interactions. Aquatic insects, particularly in their immature stages, provide food for fish. Aquatic insect feeding activities – often processing allochthonous organic matter – affect stream productivity and other characteristics (Vannote et al. 1980). Aquatic insects alter and maintain stream characteristics that provide habitat for the fish. Emergent adult aquatic insects influence surrounding riparian areas through substantial deposition of nutrients (Dreyer et al. 2015). In addition to affecting surrounding forests, aquatic insect assemblages are also themselves affected by the riparian forest characteristics and the resulting allochthonous input into their streams (Compson et al., 2013).

Kokanee Nutrient Transfers. The fate of nutrient transfer from the Williston Reservoir to reaches of rivers – including terrestrial habitat (Helfield and Naiman 2001) – where Kokanee spawn is unknown, but considering previous research on the topic, are likely to be appreciable.

Impact on other taxa. The transfer of nutrients into regional stream systems in the Williston watershed potentially may also have large impacts on a range of other biota and ecosystem processes. These will be assessed using three target groups, stream resident fish, aquatic insects and riparian lichen communities. These groups have previously been used as biological indicators and have well-developed biomonitoring methodologies published in the literature.

Stream resident fish are represented by the slimy sculpin (*Cottus cognatus*) has the widest North American distribution among fish belonging to the family Cottidae, but exhibits limited movement as they get older, thus integrating environmental conditions of localized areas. Diet of Cottidae in streams where semelparous Pacific salmon spawn has previously been shown to shift from aquatic invertebrates and small stream fishes to salmon eggs during the spawning season (Swain et al. 2014). Thus, Kokanee may provide a direct source of nutrients to stream resident fish in addition to the potential influx of reservoir-derived nutrient contributions to the stream ecosystem.

Aquatic insect feeding activities process organic matter affecting stream productivity and other characteristics. Aquatic insects, particularly in their immature stages, form the major portion of the diet of resident fish and also alter and maintain stream characteristics that provide habitat for fish. Emergent adult aquatic insects influence surrounding riparian areas through substantial deposition of nutrients. Development of a baseline record of commonly assessed insect taxa [Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddsiflies)] is important both for further research in this area and for ongoing and future monitoring activities. Quantitation and comparisons of aquatic insect taxonomic diversity and functional diversity among streams with or without active Kokanee populations will provide information on the effect of Kokanee in watersheds on aquatic insect diversity and macro invertebrate assemblage functional ecology and ecosystem services.

Epiphytic lichens obtain their nutrients directly from through-flow precipitation that flows over their surface, much of which derives from leachates released from bark and leaf surfaces. As a result, they are highly sensitive to changes in the nutrient status of the host trees upon which they grow. Additionally, measurements of nutrient status within lichen thalli will provide a direct indication of changes in factors such as nitrogen content.

Our results will provide both baseline data (e.g., species lists, abundance, and diversity measures) and new tools (e.g., biodiversity indicators, monitoring methods, forecasting models) for fisheries and forest managers working in the Williston Reservoir watershed region.

GOALS AND OBJECTIVES

The goal of the project is to determine the impact of the introduction of Kokanee into the Williston Reservoir on the nutrient dynamics and the web of interactions between Kokanee, aquatic insects, and the surrounding riparian zone. This project aligns with the Peace Fish and Wildlife Compensation Program's Stream Action Plan Objective 2a – "Understand the effects of Kokanee introductions on the aquatic food web", and Objective 2a-1 – "Undertake a Kokanee assessment study to summarize status, trends, and aquatic and terrestrial ecosystem impacts and potential risks of Kokanee introductions - Develop appropriate recommendations for actions, as needed."

In year 1 (2016-17) of the project we used a questionnaire to determine Kokanee occurrence in tributaries of the Williston Reservoir. The questionnaire was distributed to local First Nations in the region by our First Nations project partners. We also distributed the survey to guide outfitters within the region and recreational anglers. The survey provided a qualitative assessment of Kokanee presence/absence and relative abundance. The information gathered successfully informed our choice of study sites for sampling resident fish, aquatic macroinvertebrates, and lichens in two systems without, and five systems with Kokanee for species checklists (insects) and to use stable isotope methods to track nutrient flow (fish and insects).

In year 2 (2017-18) we continued to investigate nutrient inputs from Kokanee through the stream and riparian ecosystems using stable isotope analysis to assess source, sink, and process relationships. We continued our survey of records and collections to develop an historical understanding of aquatic insect biodiversity in the area. Iterative quantitative sampling of insects will be conducted in the systems to temporally refine checklists and to compare diversity between streams with and without Kokanee. Lichen community composition in the stream riparian areas will be assessed using time-limited survey approaches within fixed plots. Collection and stable isotope analysis of fish, insects, and lichens in the systems will help to refine our understanding of Kokanee nutrient transfers.

In year 3 (2018-19) of the project we will conduct additional sampling to fill in data gaps, complete the analysis of the collected samples, and develop and deliver extension activities (e.g., publications, journal articles, an extension note, and a brochure, and presentations).

Our results will provide baseline data (e.g., species lists, abundance, diversity) and can be used to support development of new tools (e.g., biodiversity indicators, monitoring methods, predictive models) for fisheries and forest managers working in the region.

Working in partnership with Chu Cho Environmental (Tsay Keh Dene First Nation) and Northern Spruce Contracting (McLeod Lake Indian Band) this research provides important training opportunities for both local community members and UNBC students alike.

STUDY AREA

Sampling locations

The results of our survey questionnaire conducted in 2016 revealed that Kokanee distribution in tributaries to the Williston Reservoir is extensive. In fact, establishing control sites where Kokanee do not spawn remains a concern – but it is clear that one of the few watersheds where Kokanee have not colonized is the Parsnip River system, although there are reports of Kokanee spawning in tributaries to the system that are close to the reservoir.

Due to the wide spatial separation of our control and experimental sites in 2016, we selected additional control and experimental sites for 2017 (Figure 1). We included the Wichika River (WI), an upper Parsnip River tributary as a control stream. We also included the Wooyadilinka River (WO), a tributary to the Parsnip River closer to the Williston Reservoir than our other control streams, as an additional control stream. We spent considerable effort to find additional experimental streams that were closer geographically to our control streams. Consequently, in addition to experimental streams in the Ospika River watershed, Aley Creek and Stevenson Creek, and streams in the Omineca River watershed, Osilinka River and Tenakihi Creek, but closer in proximity to the control streams. We sampled two streams that flow into the Parsnip Reach of the Williston Reservoir. Mugaha Creek, a stream that was stocked with Kokanee through the salmonids in the classroom program, and Cut Thumb Creek, where

Kokanee had previously been observed to spawn (Langston 2012) were included as experimental streams. To assess temporal variation in our study and control streams, we sampled streams in both summer and fall 2017.

METHODS

Kokanee escapement

An aerial reconnaissance flight on 11 September 2017 was conducted to document spawning Kokanee in our experimental streams. High water levels and turbidity in tributaries to the Parsnip Reach, Mugaha Creek and Cut Thumb Creek, prevented observation of spawners in these two streams. Spawner abundance was high in Aley and Stevenson Creek in the Ospika River watershed. Kokanee were not observed in the Ospika River, however, water clarity in the mainstem was low and limited our ability to detect fish. We also flew rivers on the west side of the Williston Reservoir. Our aerial flight revealed large numbers of Kokanee in the Osilinka River from approximately km 8 on the Osilinka FSR to km 25. Few Kokanee were observed above this location and none were observed in Tenakihi Creek. Kokanee were not observed in the lower section of the Mesilinka River, Manson River or Nation River. On 18 September 2017, we surveyed streams flowing into the east side of the Parsnip reach on the ground. Kokanee spawners were observed in Cut Thumb Creek, however, they were not abundant. We did not observe spawners in the other streams surveyed. We repeated the ground survey on 25 September 2017 to the east side Parsnip reach tributaries, but did not observe Kokanee.

Sample collection

We tested for temporal changes in species composition and nutrient signatures in 2017. Macroinvertebrates, stream resident fish, and riparian lichen were collected from all study locations in July and late October/early November. Access in the fall was difficult due to weather and high-water levels which protracted our sampling dates considerably later in fall 2017 than we had originally planned. Consequently, Osilinka River and Tenakihi Creek were sampled on October 14, and Cut Thumb and Mugaha Creeks were sampled on October 15 – but precipitation resulted in substantial increase in flows and we could not sample the Parsnip River tributaries the next day. Due to the early snowfall, we planned to fly to the Ospika River tributaries on October 17 – but low cloud cover made it unsafe to fly. We sampled the Parsnip River tributaries on October 28 and the Ospika River tributaries on November 2.

We targeted benthic fish based on our results from 2016 where pelagic species showed greater range of stable isotope signatures for each river system. Fish were captured using a Smith Root L24 backpack electrofisher (Vancouver WA). We progressed upstream while electrofishing until eight specimens were collected or for approximately 500 m. After capture fish were transferred to a bucket containing 100 mg $\cdot$ L^{-1} tricaine methanesulfonate buffered with 200 mg $\cdot$ L^{-1} sodium bicarbonate for sampling. Length (to 0.1 cm) and mass (to 0.01 g) were measured for each fish prior to being placed in a bag on ice or in a portable freezer until transfer to a freezer for storage. A summary of fish collected in the study is given in Table 1. In July 2017, Chu Cho Environmental collected Kokanee from Thutade Lake and donated some to this study. These

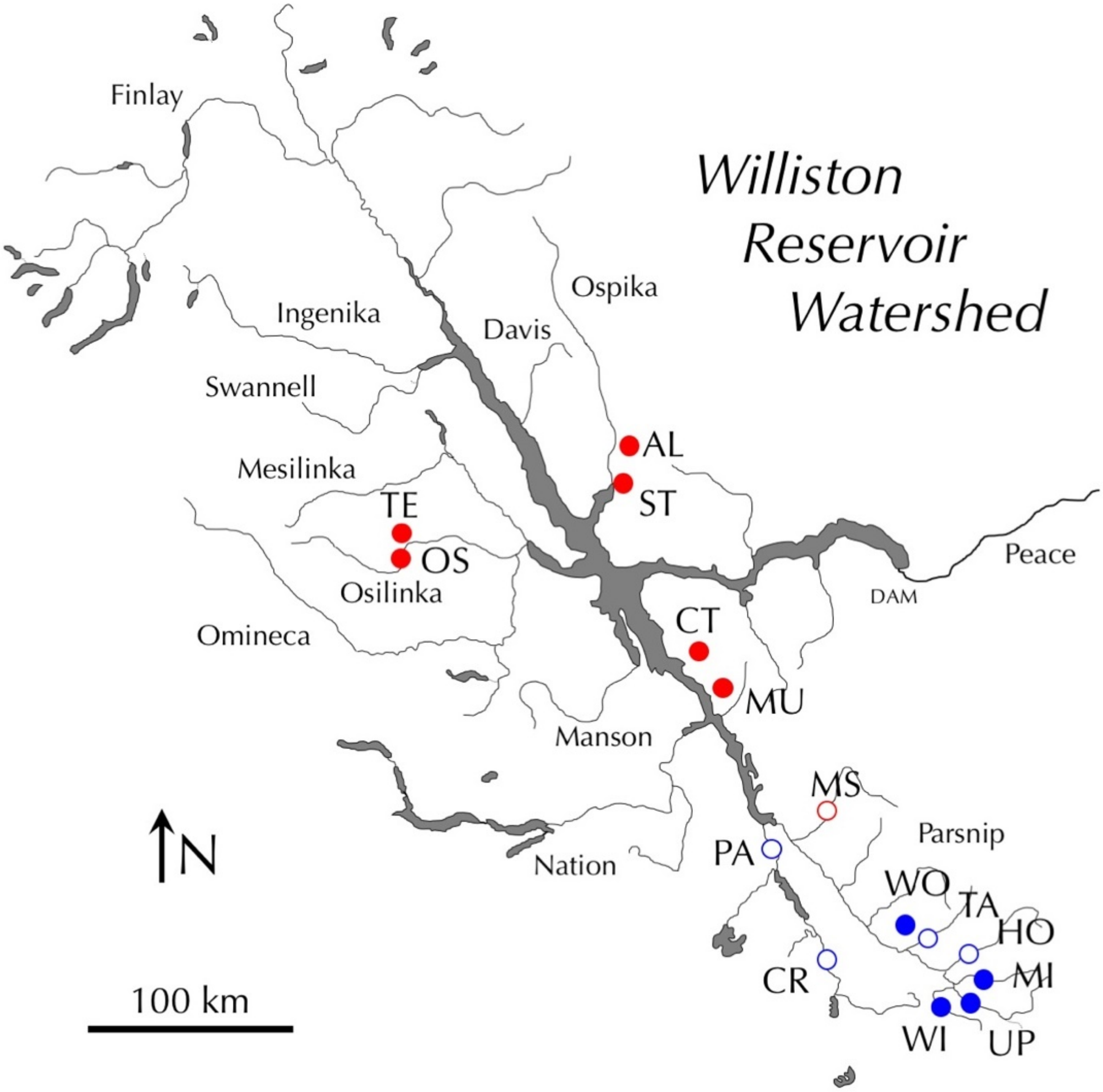

Figure 1. Map of sampling locations for benthic fish and aquatic macroinvertebrates in fall 2016, summer and fall 2017. Missinka (MI), Wichcika (WI), Wooyadilinka (WO), Table (TA), Hominka (HO), Upper Parsnip (UP), Crooked (CR), and Pack (PA) watersheds (blue symbols) were control systems where Kokanee have not been observed to spawn. Missinchinka (MS), Cut Thumb (CT), Mugaha (MU), Osilinka (OS), Tenakihi (TE), Aley (AL), and Stevenson (ST) watersheds (red symbols) were systems where Kokanee spawned. Closed symbols are where benthic invertebrates, fish and lichen were sampled; open symbols are locations where only lichen were surveyed.

fish were tested to see if the stable isotope signatures were consistent between Lake and Reservoir fish. Kokanee were also collected from Aley Creek (10) and Stevenson Creek (10) in September 2017 to replicate the sampling performed in 2016.

Kick-netting for invertebrates was carried out in both years 1 and 2, in the same reaches of the same systems as was the electrofishing. Kick-netting was done in an upstream direction for about 10 minutes and about 15 - 30 m of stream bed, or until the kick net was substantially full. Three samples were taken at each location. Each sample was placed immediately into a sealed, labelled container of stream water. All containers were labeled on the outside, and an identical paper-and-pencil label was also placed inside to ensure correct curation of samples. Samples were placed into a freezer in our truck in the field and were immediately transferred to a lab freezer upon return to UNBC. At each stream, Surber samples were collected from five sites. Surber sampling was only done in year 2 of the project. Sample collection started downstream and proceeded upstream to minimize disturbance and avoid contamination between sites, with each replicate Surber samples collected at each of the five sites. Benthic invertebrates were sampled using a Surber net (Dynamic Aqua Supply, Surrey, BC) with a 30 x 30 cm frame (0.09 m^2) and 250-micron mesh size, using methods adapted from the Canadian Aquatic Benthic Invertebrate Network (CABIN) Field Manual (Reynoldson et al. 2003).

Lichen survey

Lichen community composition was assessed using time-limited survey approaches within fixed plots, an approach previously used to assess the response of central interior British Columbia lichen communities to regional gradients in air pollution (Coxson et al. 2013). Streamside habitats were chosen to minimize other environmental co-variates, i.e. assessments were conducted within similar successional stages. The riparian habitat alongside major rivers lends itself well to this approach, as other disturbances such as fire and forest harvesting are typically absent from this zone and forest age can be controlled by choice of microsites within the floodplain. 2016 assessments were from east-side stream and river reaches with few or no known kokanee, on the Upper Parsnip River, Table River, and the Hominka River. At each of these locations between three and five sub-plots were chosen, depending on their availability, each sub-plot located in a separate late successional riparian forest stand. Each species observed was given an overall abundance rating based on the assessment of their general abundance within the search area using a five-point scale (after Goward and Arsenault 1997): 1, two or fewer thalli per tree (and associated branches); 2, three to five thalli per tree; 3, six thalli or up to 20% cover; 4, from 21% to 50% cover; and 5, 51% cover or greater. We used an ordination approach to determine the ecological similarity of the entire lichen community. Non-metric multidimensional scaling (NMS) is an ordination method that is well suited to data that are non-normal or have discontinuous or otherwise arbitrary data sets (McCune & Mefford 1999). NMS is a distance-based ordination technique where a solution is based on minimizing stress, this is defined as a measure of the poorness of fit between the ordination and measured ecological distances. NMS was run using the ordination routines of PC-ORD Version 6.0 (MJM Software Design, Gleneden Beach, OR).

Biotic Response to Nutrient Inputs

We tested whether nutrient inputs from Kokanee can be tracked through the stream and riparian ecosystems using stable isotope analysis. Dual-isotope approaches have proven useful in assessing nutrient inputs with nitrogen isotopes measurements functioning as trophic level indicators and carbon isotope measurements indicating sources of nutrition (Peterson and Fry 1987). Such approaches can be helpful in identifying allocthonous inputs to aquatic food webs. Values for $\delta^{13}C$ are useful because of the wide range of $\delta\ ^{13}C$ of algae at the base of food webs. The other major source of energy in river food webs, terrestrial detritus, has a much more constrained ^{13}C signature, so that these two carbon sources are often isotopically distinct (Finlay 2001). Hydrogen stable isotope ratios ($\delta\ ^{2}H$) have recently been used as endogenous markers to improve the ability to quantify the relative importance of allochthonous input of organic material into aquatic ecosystems (Voigt et al. 2015). Oxygen stable isotope ratios ($\delta\ ^{18}O$) in combination with $\delta\ ^{2}H$ have increasingly been used to determine the origin and movement of animals (Bowen et al. 2005). Using a multiple-isotope approach, we examined whether food webs differed in stable isotope ratios ($\delta\ ^{2}H$, $\delta\ ^{13}C$, $\delta\ ^{15}N$, $\delta\ ^{18}O$) according to the ecosystem (river with large numbers of Kokanee spawners, river with few Kokanee spawners, and river without Kokanee). The ratios of isotopes will reveal the source of nutrients, but does not indicate the quantity of nutrients introduced to the system. The sampling location, species and numbers of fish caught for each river systems are shown in Table 2.

Stable isotope analysis was conducted on pooled aquatic invertebrate samples, individual muscle samples from fish, and lichen collected from our control and study streams. Dried, ground and homogeneous samples were weighed into tin capsules and analyzed for $\delta\ ^{13}C$ and $\delta\ ^{15}N$ by an Elemental Analyzer (EA) coupled to a DeltaPlus XP – Conflo III Continuous Flow-Isotope Ratio Mass Spectrometer (Thermo Finnigan, Bremen, Germany). Samples for $\delta\ ^{2}H$ and $\delta\ ^{18}O$ were weighed into silver capsules and loaded into a Costech Zeroblank autosampler. Samples were converted to hydrogen (H_2) gas by pyrolysis using a Thermo-Finnigan High Temperature Conversion Elemental Analyzer (TC/EA). All analyses were conducted at the Stable Isotopes in Nature Laboratory at the University of New Brunswick. Stable isotope signatures for fish, aquatic invertebrates and lichen were differentiated using discriminant function analysis with jack-knife re-sampling. A multivariate combination of $\delta\ ^{2}H$, $\delta\ ^{13}C$, $\delta\ ^{15}N$, and $\delta\ ^{18}O$ were used to discriminate locations using the different sample types.

RESULTS

Fish

Slimy sculpin were caught in all river systems sampled and were often the only species captured (Table 1). Catch per unit effort varied among the watersheds, but there was no apparent pattern in relation to streams where Kokanee did or did not spawn.

Aquatic invertebrates

Kick net sampling revealed that aquatic invertebrates predominantly belonged to the orders Ephemeroptera, Plecoptera and Trichoptera (EPT); although there was considerable variation among samples ranging from 18 to 97%, the average EPT was 78% (Table 2). Number of specimens also varied among orders, but generally mayflies were the most abundant, followed by stoneflies, and in some samples no caddis flies were found. Specimens from each sample were separated into their respective orders and submitted for stable isotope analysis (Appendix 1). Not all kick net samples contained sufficient number of individuals for analysis (particularly Trichoptera), and within a stream some samples were pooled. Analysis of the Surber samples collected at each of the study sites in ongoing and will be reported on in our report for Year 3.

Lichens

A total of 229 lichen taxa were observed in the 6 Peace-Williston river- and stream-side riparian forests that were examined in 2016 and 2017 (Appendix 2). A relatively small proportion of the lichen species were found at all study sites (14.9%), but many were found at multiple locations; 10.5% found at 5 sites, 9.65% found at 4 sites, 9.65% found at 3 sites, and 15.8% found at just two sites. A large number of lichen were only found at a single site (39.5%).

The 2016 assessments revealed a previously undocumented population of one federally listed rare species, *Collema coniophilum* (listed under the Species at Risk Act, or SARA, ranked by the Committee on the Status of Endangered Wildlife in Canada, or COSEWIC). Additionally, *Collema quadrifidum* was found, red-listed by the B.C. Conservation Data Centre, and *Nephroma isidiosum*, Blue-listed species by the BC CDC. The 2017 sampling found 3 additional populations of *Collema coniophilum* that previously were unknown. This species has now been found at all sites, except the upper Parsnip. The other conservation-ranked species found in 2017 is *Phaeophyscia nigricans*, found at the Missinchinka site (Appendix 2).

Two groups of lichen taxa in these watersheds bear special attention. Both the Teloschistaceae and Physciaceae are often regarded as indicators of nitrogen enriched habitats. Species of nutrient indicating Physciaceae found in the study plots were *Rinodina capensis*, *R. colobina*, *R. degeliana*, *R. disjuncta*, *R. efflorescens*, *R. flavosoralifera*, *R. griseosoralifera*, *R. metaboliza*, *R. orculata*, *R. oregana*, *R. pyrina*, *R. stictica*, and *R. trevisanii*. Teloschistaceae species were *Caloplaca ahtii*, *Caloplaca atrosanguinea*, *Caloplaca cf. oleicola*, *Caloplaca flavorubescens*, *Caloplaca pyracea*, *Caloplaca sorocarpa*, *Caloplaca tricolor*, *Caloplaca urceolata*, *Chaenotheca chrysocephala*, *Chaenotheca phaeocephala*, *Xanthomendoza fallax*, *X. fulva*, *Xanthoria Candelaria*, *X. fallax*, *X. fulva*, and *Xanthoria kaernefeltii*. The study plot with the highest number of the Teloschistaceae and Physciaceae was the Pack River at 19 (Table 3), followed closely by the Hominka and Missinchinka (17 and 18 respectively). The upper Parsnip and Table were intermediate (14 and 15), while the Crooked River was much lower, at 8 species. The one Kokanee-run stream (Missinchinka) fell among the richest set of sites. The Crooked River was the most species impoverished site for Teloschistaceae and Physciaceae.

Interesting, there is a strong separation of the Pack River samples from all others along Axis 1 of the ordination. The Pack and Crooked River sites are the two most impoverished sites for total number of lichen species.

Stable Isotopes

To assess differences in stable isotopes of hydrogen, carbon, nitrogen and oxygen for slimy sculpin (Figure 3a) and Kokanee (Figure 3b), we plotted $\delta^{13}C$ verses $\delta^{15}N$ (Figure 3c) and $\delta^{2}H$ verses $\delta^{18}O$ (Figure 3d) for each stream where the fish were caught. Data is given as means ± standard error. For slimy sculpin, streams where Kokanee spawned were generally depleted in ^{13}C and also had lower $\delta^{15}N$ than the control streams where no Kokanee spawned – although this pattern was not particularly strong. Kokanee captured in tributaries to the Williston and also Kokanee from Thutade Lake had $\delta^{13}C$ signatures that overlapped values for slimy sculpin caught in streams from the Ospika Reach of the Williston Reservoir; streams where densities of spawning Kokanee were high for 2016 and 2017. Streams with low escapement of Kokanee spawners were generally intermediate to the control and high spawner streams. Values for $\delta^{15}N$ were enriched for Kokanee compared to sculpins. There were considerable differences in $\delta^{2}H$ among sculpins caught from the different streams, but values did not group by presence of absence of spawning Kokanee. In contrast $\delta^{18}O$ was generally low for slimy sculpin caught in stream where Kokanee spawn and Kokanee spawners in Williston Reservoir tributaries, intermediate for slimy sculpin from streams where Kokanee do not spawn, and high in Kokanee from Thutade Lake. Incorporating stable isotope from all four elements into a Canonical discriminant function analysis indicated reasonable separation among the different groups (Figure 3e). There was considerable overlap in the clusters for slimy sculpin caught in Kokanee spawning streams. Consequently, of the 124 sculpins sampled from streams where Kokanee spawn, 115 (93%) were assigned to their stream of capture or to a different Kokanee spawning stream. The assignment was lower (74%) for sculpins from non-Kokanee streams (Table 4). Kokanee from the Williston Reservoir clearly cluster together, but apart from all the sculpin sampled and also the Kokanee from Thutade Lake.

Stable isotope values showed considerable variation among the aquatic insect samples and no clear pattern was observed until we separated the data by Order. Ephemeroptera (Figure 4a,

Table 1. Summary of sample dates, locations, species of fish caught, mean length (cm) with maximum, minimum, and number captured. Catch per unit effort (CPUE) is given for slimy sculpin from each river and where multiple species were caught in a river, CPUE is provided for all species in parentheses. "K–" indicates rivers where Kokanee do not spawn and "K+" indicates rivers where Kokanee have been observed to spawn.

	Date	River	Site Type	Species	length	max	min	n	CPUE
Fall 2016	5-Oct-2016	Missinka	K–	Slimy sculpin	5.5	8	3.9	14	2.51
	5-Oct-2016	Parsnip	K–	Slimy sculpin	7.9	9.7	6.9	3	0.51
	5-Oct-2016	Parsnip	K–	Arctic grayling	6.4			2	(1.27)
	5-Oct-2016	Parsnip	K–	Mountain whitefish	6.1				
	5-Oct-2016	Parsnip	K–	Redside shiner	5.3	6.2	4.6	5	
	12-Oct-2016	Tenakihi	K+	Slimy sculpin	3.9	5	2.2	3	0.74
	12-Oct-2016	Tenakihi	K+	Burbot	11.1			1	
	12-Oct-2016	Osilinka	K+	Slimy sculpin	5.9	7.8	3.9	10	7.69
	12-Oct-2016	Osilinka	K+	Burbot	11.7	12.6	10.7	2	
	22-Sep-2016	Osilinka	K+	Kokanee	21.2	23.9	18.4	19	
	11-Oct-2016	Bruin	K+	Slimy sculpin	6.5	7.6	5.6	6	1.90
	11-Oct-2016	Bruin	K+	Bull trout	11.8	21.3	5.4	3	(2.99)
	11-Oct-2016	Bruin	K+	Rainbow trout	9.7			1	
	11-Oct-2016	Aley	K+	Slimy sculpin	7.7	8.7	6	4	0.45
	22-Sep-2016	Aley	K+	Kokanee	22.1	24.4	20	10	
	11-Oct-2016	Stevenson	K+	Slimy sculpin	4.8	8.2	2.2	9	1.57
	11-Oct-2016	Stevenson	K+	Bull trout	4.3			1	(1.88)
	11-Oct-2016	Stevenson	K+	Rainbow trout	8.2			1	
	22-Sep-2016	Stevenson	K+	Kokanee	22.6	24.4	19.2	13	
Summer 2017	24-Jul-2017	Wichcika	K–	Slimy sculpin	6.3	8.7	4.6	18	1.50
	24-Jul-2017	Wichcika	K–	Rainbow trout	13.9			1	
	24-Jul-2017	Missinka	K–	Slimy sculpin	5.7	7.4	4.2	20	7.27
	31-Jul-2017	Cut Thumb	K+	Slimy sculpin	4.2	5.5	3.2	3	0.37
	31-Jul-2017	Mugaha	K+	Slimy sculpin	5.2	8.5	3.2	20	9.57
	26-Jul-2017	Tenakihi	K+	Slimy sculpin	6.4	9.3	4.4	10	3.31
	26-Jul-2017	Osilinka	K+	Slimy sculpin	5.6	8.5	4.6	20	3.75
	26-Jul-2017	Osilinka	K+	Burbot	15.0	16.0	14.3	3	
	26-Jul-2017	Osilinka	K+	Rainbow trout	20.0			1	
	27-Jul-2017	Aley	K+	Slimy sculpin	5.5	8	3.3	11	1.23
	27-Jul-2017	Aley	K+	Bull trout	5.0	9.0	3.1	3	
	27-Jul-2017	Stevenson	K+	Slimy sculpin	6.2	7.8	3.8	13	1.81
	27-Jul-2017	Stevenson	K+	Bull trout	9.4	13.2	7.2	4	
	15-Jul-2017	Thutade Lk	K+	Kokanee	19.2	21.5	17.5	10	
Fall 2017	30-Oct-17	Wichcika	K–	Slimy sculpin	5.5	8.9	2.6	8	1.02
	30-Oct-17	Wooyadilinka	K–	Slimy sculpin	4.8	8.3	2.7	9	3.50
	15-Oct-2017	Cut Thumb	K+	Slimy sculpin	6.0	9.1	4.2	13	2.59
	15-Oct-2017	Cut Thumb	K+	Rainbow trout	5.7	5.7	5.7	2	
	15-Oct-2017	Mugaha	K+	Slimy sculpin	5.1	8.4	3.7	9	7.44
	14-Oct-2017	Tenakihi	K+	Slimy sculpin	6.9	9	4.8	8	1.39
	14-Oct-2017	Osilinka	K+	Slimy sculpin	6.4	8.7	4	8	1.48
	02-Nov-17	Stevenson	K+	Slimy sculpin	7.6	9	5.7	6	1.29
	12-Sep-2017	Stevenson	K+	Kokanee	22.2	22.9	20.6	10	
	02-Nov-17	Aley	K+	Slimy sculpin	7.3	9.3	6.2	10	1.34
	02-Nov-17	Aley	K+	Bull trout	11.0			1	
	12-Sep-2017	Aley	K+	Kokanee	21.1	23	19.5	10	

Table 2. Sample dates and number of macroinvertebrate specimens collected from triplicate kick net samples for each study stream in the summer and fall of 2017. Total number of Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) individuals within a sample were also summarized and expressed as a percentage of the total number of individuals in the sample.

Stream	Date Collected	Net #	Ephemeroptera (Mayflies)	Plecoptera (Stoneflies)	Trichoptera (Caddisflies)	Diptera and Others (Flies, beetles, etc.)	**TOTAL**	Total EPT	%EPT
Wichcika	24-07-2017	1	752	171	38	165	**1126**	961	85.35
Wichcika	24-07-2017	2	469	71	25	73	**638**	565	88.56
Wichcika	24-07-2017	3	373	52	15	77	**517**	440	85.11
Wichcika	30-10-2017	1	123	82	**0**	9	**214**	205	95.79
Wichcika	30-10-2017	2	210	142	**0**	10	**362**	352	97.24
Wichcika	30-10-2017	3	142	108	3	18	**271**	253	93.36
Missinka	24-07-2017	1	54	37	10	189	**290**	101	34.83
Missinka	24-07-2017	2	65	49	8	361	**483**	122	25.26
Missinka	24-07-2017	3	20	9	3	145	**177**	32	18.08
Wooyadilinka	30-10-2017	1	279	400	80	147	**906**	759	83.77
Wooyadilinka	30-10-2017	2	214	288	57	106	**665**	559	84.06
Wooyadilinka	30-10-2017	3	354	471	28	154	**1007**	853	84.71
Tenakihi	26-07-2017	1	160	41	6	26	**233**	207	88.84
Tenakihi	26-07-2017	2	325	109	13	100	**547**	447	81.72
Tenakihi	26-07-2017	3	200	51	8	34	**293**	259	88.40
Tenakihi	14-10-2017	1	679	627	36	204	**1546**	1342	86.80
Tenakihi	14-10-2017	2	335	343	57	182	**917**	735	80.15
Tenakihi	14-10-2017	3	318	301	30	61	**710**	649	91.41
Osilinka	26-07-2017	1	154	48	1	165	**368**	203	55.16
Osilinka	26-07-2017	2	61	19	3	35	**118**	83	70.34
Osilinka	26-07-2017	3	86	37	1	37	**161**	124	77.02
Osilinka	14-10-2017	1	253	229	3	100	**585**	485	82.91
Osilinka	14-10-2017	2	310	212	6	166	**694**	528	76.08
Osilinka	14-10-2017	3	381	161	9	320	**871**	551	63.26

Table 2 (continued). Sample dates and number of macroinvertebrate specimens collected from triplicate kick net samples for each study stream in the summer and fall of 2017. Total number of Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) individuals within a sample were also summarized and expressed as a percentage of the total number of individuals in the sample.

Stream	Date Collected	Net #	Ephemeroptera (Mayflies)	Plecoptera (Stoneflies)	Trichoptera (Caddisflies)	Diptera and Others (Flies, beetles, etc.)	**TOTAL**	Total EPT	%EPT
Aley	27-07-2017	1	119	32	**0**	50	**201**	151	75.12
Aley	27-07-2017	2	149	38	**0**	163	**350**	187	53.43
Aley	27-07-2017	3	262	49	2	274	**587**	313	53.32
Aley	02-11-2017	1	64	12	**0**	8	**84**	76	90.48
Aley	02-11-2017	2	15	**0**	**0**	4	**19**	15	78.95
Aley	02-11-2017	3	15	7	**0**	6	**28**	22	78.57
Stevenson	27-07-2017	1	120	8	1	33	**162**	129	79.63
Stevenson	27-07-2017	2	304	22	1	32	**359**	327	91.09
Stevenson	27-07-2017	3	313	20	4	65	**402**	337	83.83
Stevenson	02-11-2017	1	123	266	4	90	**483**	393	81.37
Stevenson	02-11-2017	2	130	145	**0**	75	**350**	275	78.57
Stevenson	02-11-2017	3	372	292	4	68	**736**	668	90.76
Cut Thumb	31-07-2017	1	290	17	12	75	**394**	319	80.96
Cut Thumb	31-07-2017	2	311	8	7	32	**358**	326	91.06
Cut Thumb	31-07-2017	3	342	17	7	43	**409**	366	89.49
Cut Thumb	15-10-2017	1	35	21	9	15	**80**	65	81.25
Cut Thumb	15-10-2017	2	29	17	5	19	**70**	51	72.86
Cut Thumb	15-10-2017	3	31	56	**1**	105	**193**	88	45.60
Mugaha	31-07-2017	1	1050	134	11	166	**1361**	1195	87.80
Mugaha	31-07-2017	2	368	42	5	63	**478**	415	86.82
Mugaha	31-07-2017	3	435	59	13	67	**574**	507	88.33
Mugaha	15-10-2017	1	514	185	36	64	**799**	735	91.99
Mugaha	15-10-2017	2	150	199	13	21	**383**	362	94.52
Mugaha	15-10-2017	3	273	209	31	55	**568**	513	90.32

Table 3. Number of lichen species by functional group for Peace-Williston study sites.

Lichen group		Number of Lichen Species					
		Crooked	Hominka	Missinchinka	Pack	Upper Parsnip	Table
		n = 5	n = 5	n = 5	n = 5	n = 3	n = 5
Macrolichen	Chloro	30	32	39	27	27	28
Macrolichen	Cyano	11	20	13	10	13	16
Microlichen	Calicioid	3	8	5	3	2	3
Microlichen	Trebouxioid	51	69	67	41	24	59
Microlichen	Trentepohlioid	1	3	4	1	0	1
Total		96	132	128	82	66	107
Macrolichen and Microlichen	Nutrient indicating Physciaceae & Teloschistaceae	8	17	18	19	14	15

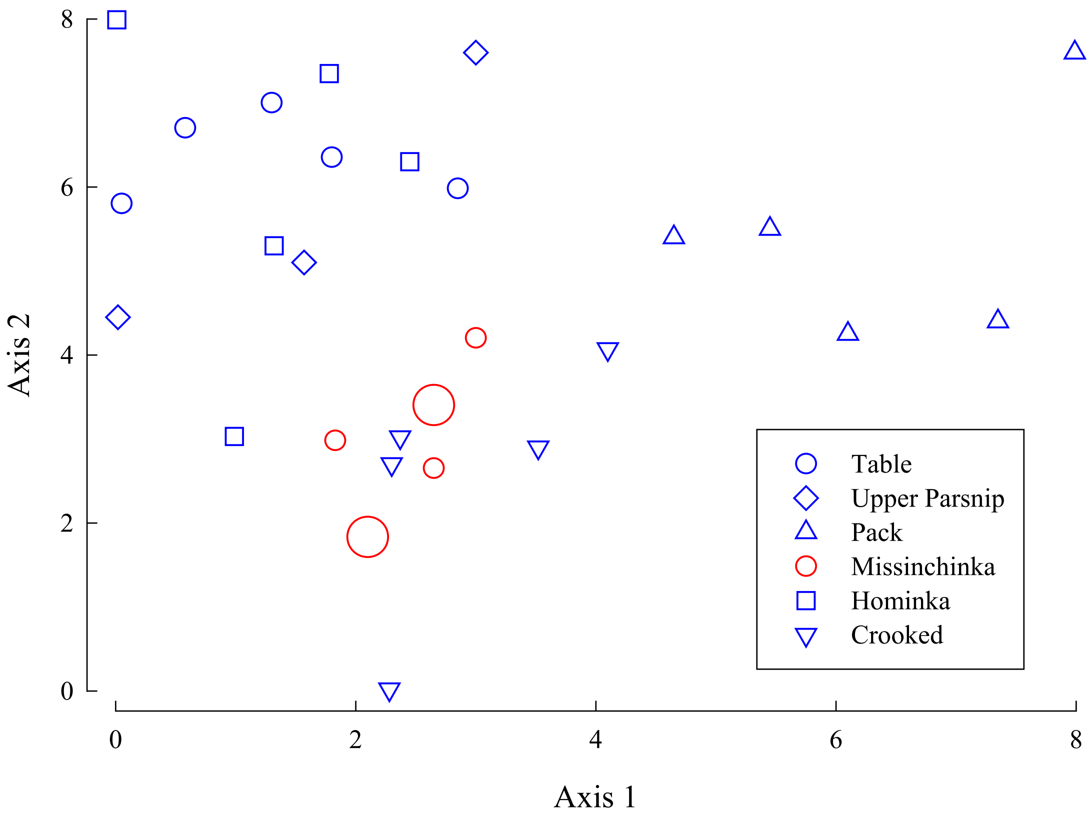

Figure 2. Non-metric multidimensional scaling ordination plot (Axis 1 verses Axis 2) for lichen plots on tributary streams to the Williston Reservoir.

4b) showed a pattern that was similar to the slimy sculpin. Mayfly nymphs collected from streams where Kokanee spawn tended to be depleted in ^{13}C and ^{15}N, although the absolute values for the samples differed temporally (Figure 4c). Mayfly nymphs also showed a pattern similar to the stream fish for $\delta^{2}H$ and $\delta^{18}O$; considerable variation among streams for $\delta^{2}H$ and considerable separation by presence of Kokanee for $\delta^{18}O$ (Figure 4d), however date of sample collection had a marked effect on the values for $\delta^{18}O$. Canonical discriminant function analysis for the stable isotope data showed considerable overlap among the Kokanee and non-Kokanee streams (Figure 4e; Table 5), however the overlap was less for samples collected in the summer than the fall. Aquatic insects belonging to the Order Plecoptera (Figure 5a, 5b) did not a clear pattern by Kokanee presence (Figure 5c, 5d) – although there were appreciable differences by sample date. There was considerable overlap among the streams by watershed and Kokanee presence for the discriminant function analysis (Figure 5e; Table 6). Trichoptera (Figure 6a, 6b) were less plentiful in the study streams and fewer samples were submitted for stable isotope analysis. No clear patterns were evident among the study streams for the stable isotopes (Figures 6c, 6d) of the discriminant function analysis (Figure 6e; Table 7).

Differences in stable isotopes were also found in lichen collected from trees within the riparian areas adjacent to our study streams in the Williston Reservoir. We targeted the species (*Parmelia squarrosa*) for the analysis as it was most consistently collected from vegetation adjacent to each of the streams where we sampled for fish and aquatic insects (Figure 7a). Generally, lichen collected from streams where Kokanee spawn were depleted in ^{2}H, ^{13}C, ^{15}N, and ^{18}O compared to the streams sampled where Kokanee have not been observed to spawn (Figure 7b, 7c). Differences in stable isotope signatures for each of the elements analyzed resulted in considerable separation of groups in the discriminant function analysis (Figure 7e) and also for the classification matrix (Table 8).

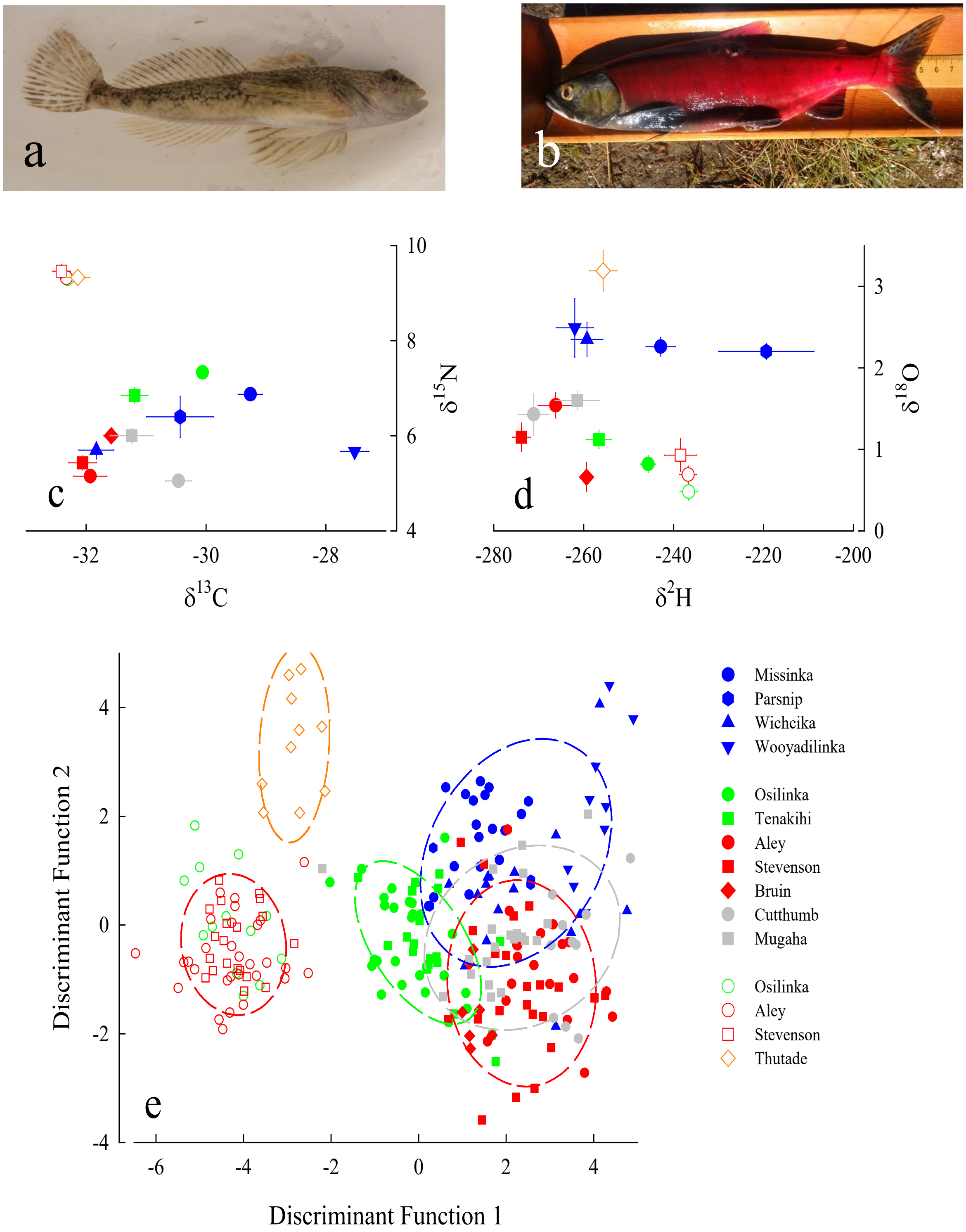

Figure 3. (a) Slimy sculpin from Aley Creek (M. Shrimpton). (b) Kokanee spawner from the Osilinka River (L. Anderson). Stable isotope, $\delta^{13}C$ verses $\delta^{15}N$ (c) and $\delta^{2}H$ verses $\delta^{18}O$ (d), from fish caught in tributary streams to the Williston Reservoir. (e) Canonical discriminant function analysis using Jackknife resampling for $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$. Closed symbols are slimy sculpin; blue symbols are non-Kokanee streams and red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Open symbols are for spawning Kokanee captured in tributary streams to the Williston Reservoir or non-spawning Kokanee from Thutade Lake.

Table 4. Classification matrix from discriminant function analysis for stable isotope analysis of δ^2H, $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ with jackknifed resampling for Slimy sculpin and Kokanee. Slimy sculpin samples were collected from streams where Kokanee have not been documented to spawn (Missinka, Upper Parsnip, Wichcika, and Wooyadilinka) and where Kokanee have been observed to spawn (Osilinka, Tenakihi, Aley, Stevenson, Bruin, Cut Thumb and Mugaha). % T is the % classification by treatment (Slimy sculpin captured in non-Kokanee spawning systems, Slimy sculpin captured in systems where Kokanee spawn by major watershed, spawning Kokanee captured in tributary streams to the Williston Reservoir, or Kokanee caught in Thutade Lake). Parsnip are tributaries that flow into the Parsnip River before it flows into the Willistron Reservoir, and Mackenzie are tributary streams north of Mackenzie that flow into the Parsnip reach of the Williston Reservoir.

	Slimy sculpin											Kokanee				
	Non-Kokanee				Kokanee spawning systems											
	Parsnip				Osilinka		Ospika			Mackenzie						
	M	P	Wi	Wo	O	T	A	S	B	C	Mu	Ok	Ak	Sk	Tk	%T
Missinka (M)	13			1	1	1					2					74
Parsnip (P)		3				1										
Wichcika (Wi)	1	1	7				2	1			4					
Wooyadilinka (Wo)				9												
Osilinka (O)	1				21	3			1							87
Tenakihi (T)					6	9		1	2		1					
Aley (A)	1		2				8	3	2		3					63
Stevenson (S)			3		1		2	8	2	2	4					
Bruin (B)									5		2					
Cut Thumb (C)							1	1		8						52
Mugaha (Mu)	2				2		1	8			8					
Osilinka (Ok)												4	5	4		98
Aley (Ak)												4	16	8	1	
Stevenson (Sk)												9	10	1		
Thutade (Tk)															10	100
	18	4	12	10	31	14	14	22	12	10	24	17	31	13	11	74

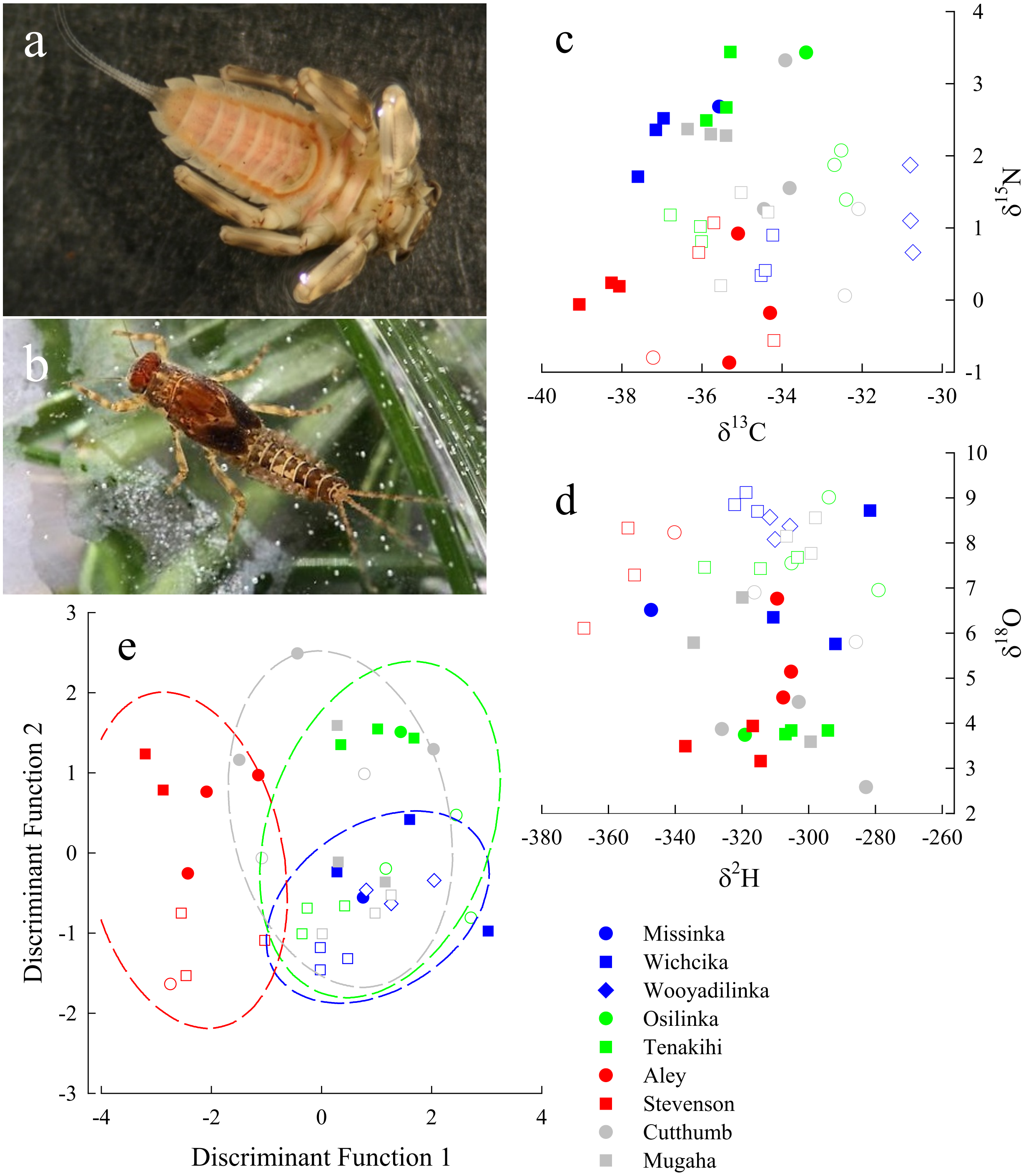

Figure 4. Representative aquatic insects belonging to the Order Ephemeroptera collected in tributaries to the Williston Reservoir; (a) *Drunella doddsii* (C. Shrimpton) and (b) *Ephemerella dorothea* (BOLD). Stable isotope, $\delta^{13}C$ verses $\delta^{15}N$ (c) and $\delta^{2}H$ verses $\delta^{18}O$ (d), from pooled samples of Ephemeroptera collected from tributary streams to the Williston Reservoir. (e) Canonical discriminant function analysis using Jackknife resampling for $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$. Blue symbols are non-Kokanee streams; red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Closed symbols are samples collected in July 2017 and open symbols are samples collected in October 2017.

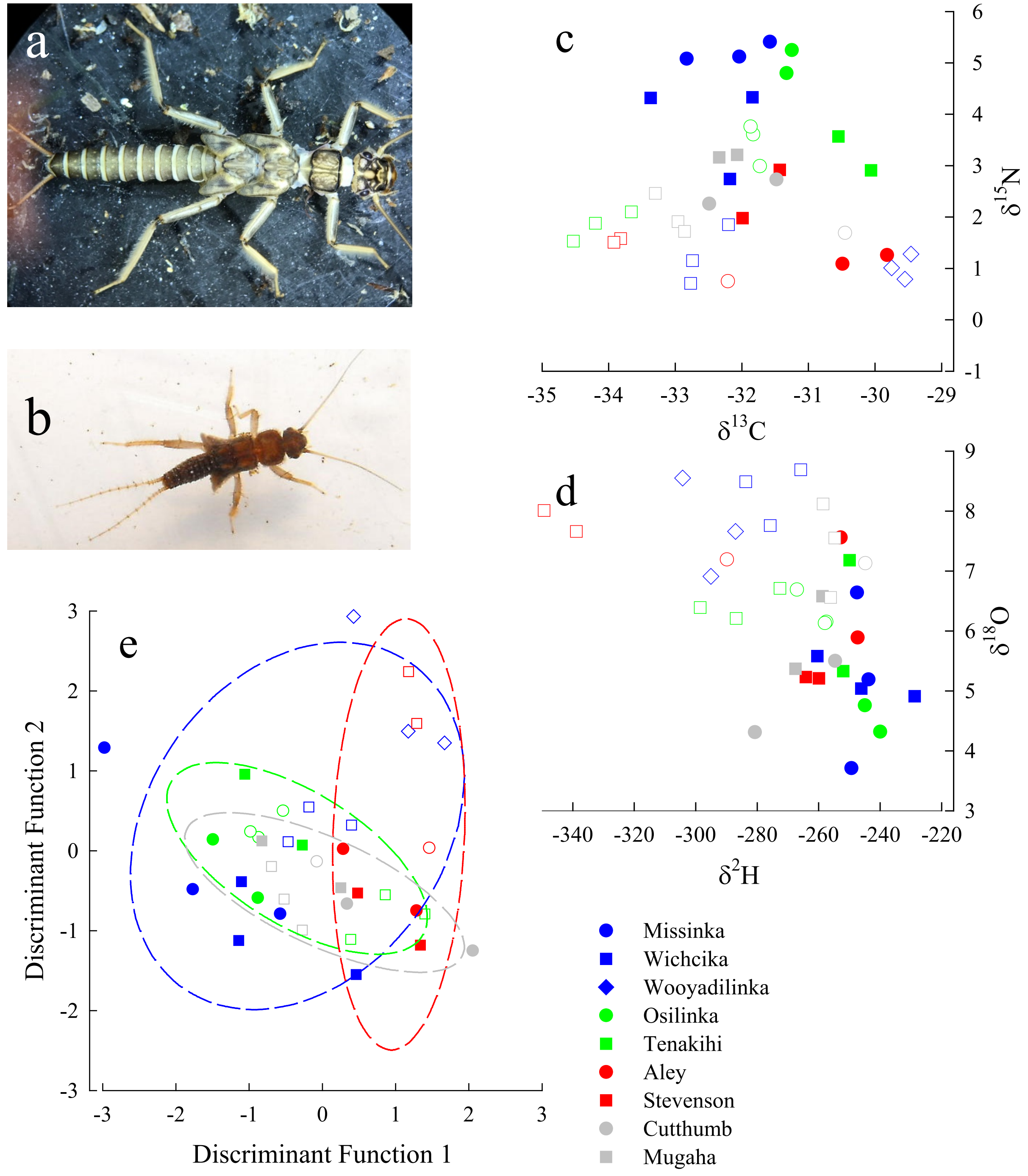

Figure 5. Representative aquatic insects belonging to the Order Plecoptera collected in tributaries to the Williston Reservoir; (a) *Hesperoperla pacifica* (A. Thielman) and (b) *Zapada cinctipes* (BOLD). Stable isotope, $\delta^{13}C$ verses $\delta^{15}N$ (c) and $\delta^{2}H$ verses $\delta^{18}O$ (d), from pooled samples of Ephemeroptera collected from tributary streams to the Williston Reservoir. (e) Canonical discriminant function analysis using Jackknife resampling for $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$. Blue symbols are non-Kokanee streams; red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Closed symbols are samples collected in July 2017 and open symbols are samples collected in October 2017.

Table 5. Classification matrix from discriminant function analysis for stable isotope analysis of $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ with jackknifed resampling for aquatic insects belonging to the Order Ephemeroptera. Samples were collected from streams where Kokanee have not been documented to spawn (Missinka, Wichcika, and Wooyadilinka) and where Kokanee have been observed to spawn (Osilinka, Tenakihi, Aley, Stevenson, Cut Thumb and Mugaha). % T is the % classification by treatment and watershed (non-Kokanee spawning systems or systems where Kokanee spawn by major watershed). Parsnip are tributaries that flow into the Parsnip River before it flows into the Willistron Reservoir, and Mackenzie are tributary streams north of Mackenzie that flow into the Parsnip reach of the Williston Reservoir.

	Non-Kokanee			Kokanee spawning systems						
	Parsnip			Osilinka		Ospika		Mackenzie		
	M	Wi	Wo	Os	T	A	S	C	Mu	% T
Missinka (M)					1					40
Wichcika (Wi)		1			2				3	
Wooyadilinka (Wo)			3							
Osilinka (O)				3				1		40
Tenakihi (T)		3			1				2	
Aley (A)						2	1	1		80
Stevenson (S)	1					2	3			
Cut Thumb (C)			1	1		1		2		27
Mugaha (Mu)	1	2			2				1	
Total	2	6	4	4	6	5	4	4	6	47

Table 6. Classification matrix from discriminant function analysis for stable isotope analysis of $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ for aquatic insects belonging to the Order Plecoptera. Samples were collected from streams where Kokanee have not been documented to spawn (Missinka, Wichcika, and Wooyadilinka) and where Kokanee have been observed to spawn (Osilinka, Tenakihi, Aley, Stevenson, Cut Thumb and Mugaha). % T is the % classification by treatment and watershed (non-Kokanee spawning systems or systems where Kokanee spawn by major watershed). Parsnip are tributaries that flow into the Parsnip River before it flows into the Willistron Reservoir, and Mackenzie are tributary streams north of Mackenzie that flow into the Parsnip reach of the Williston Reservoir.

	Non-Kokanee			Kokanee spawning systems						
	Parsnip			Osilinka		Ospika		Mackenzie		
	M	Wi	Wo	Os	T	A	S	C	Mu	% T
Missinka (M)	2			1						46
Wichcika (Wi)	1			1	3				1	
Wooyadilinka (Wo)			3							
Osilinka (O)	1			3	1					70
Tenakihi (T)				1	2			1	1	
Aley (A)						2		1		57
Stevenson (S)							2	2		
Cut Thumb (C)						1	1	1		38
Mugaha (Mu)		2			1				2	
Total	3	2	3	6	7	3	3	5	5	53

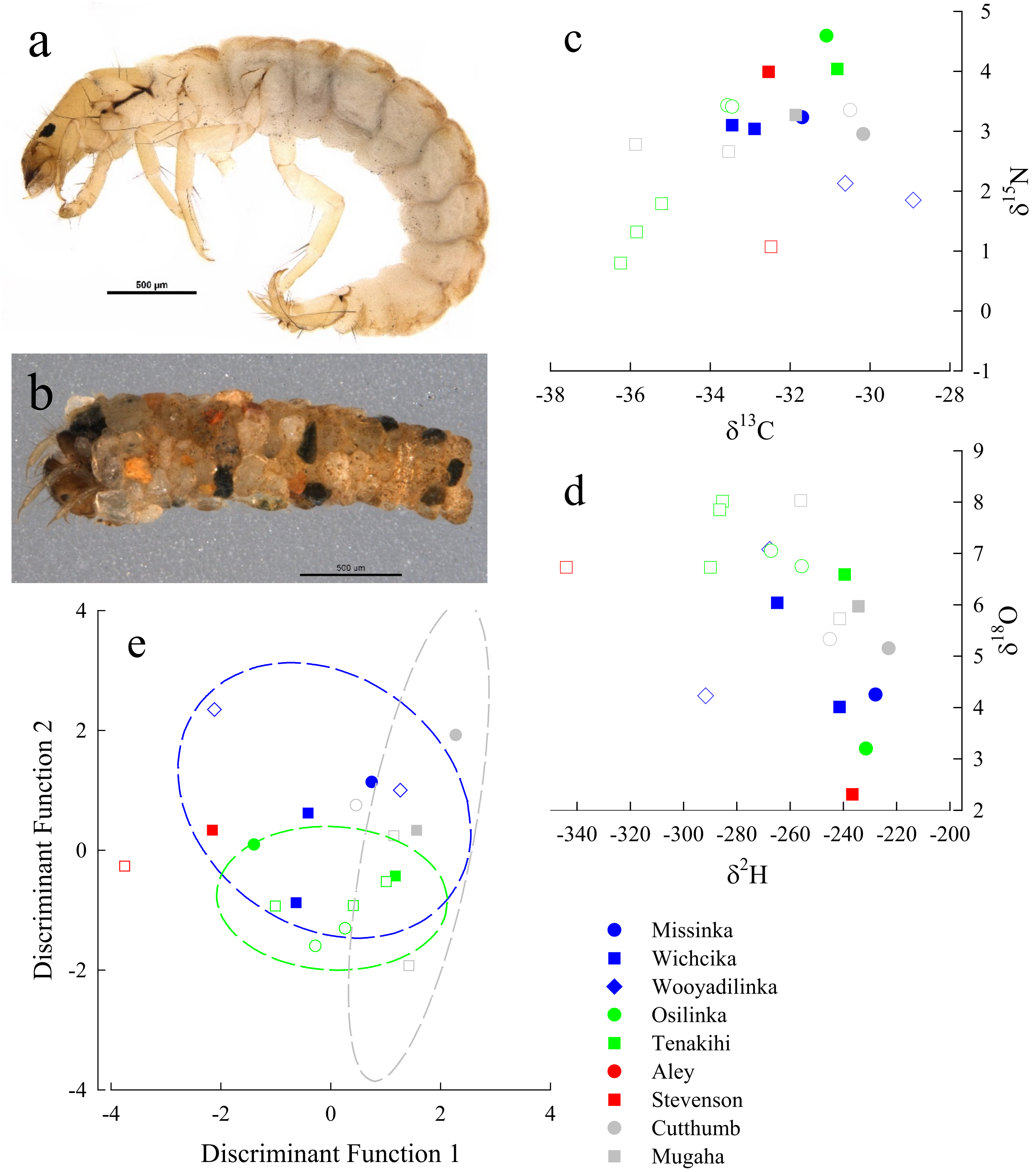

Figure 6. Representative aquatic insects belonging to the Order Trichoptera collected in tributaries to the Williston Reservoir; (a) *Phyacophila pellisa* (BOLD) and (b) *Lepidostoma* (BOLD). Stable isotope, δ^{13}C verses δ^{15}N (c) and δ^{2}H verses δ^{18}O (d), from pooled samples of Ephemeroptera collected from tributary streams to the Williston Reservoir. (e) Canonical discriminant function analysis using Jackknife resampling for δ^{2}H, δ^{13}C, δ^{15}N, and δ^{18}O. Blue symbols are non-Kokanee streams; red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Closed symbols are samples collected in July 2017 and open symbols are samples collected in October 2017.

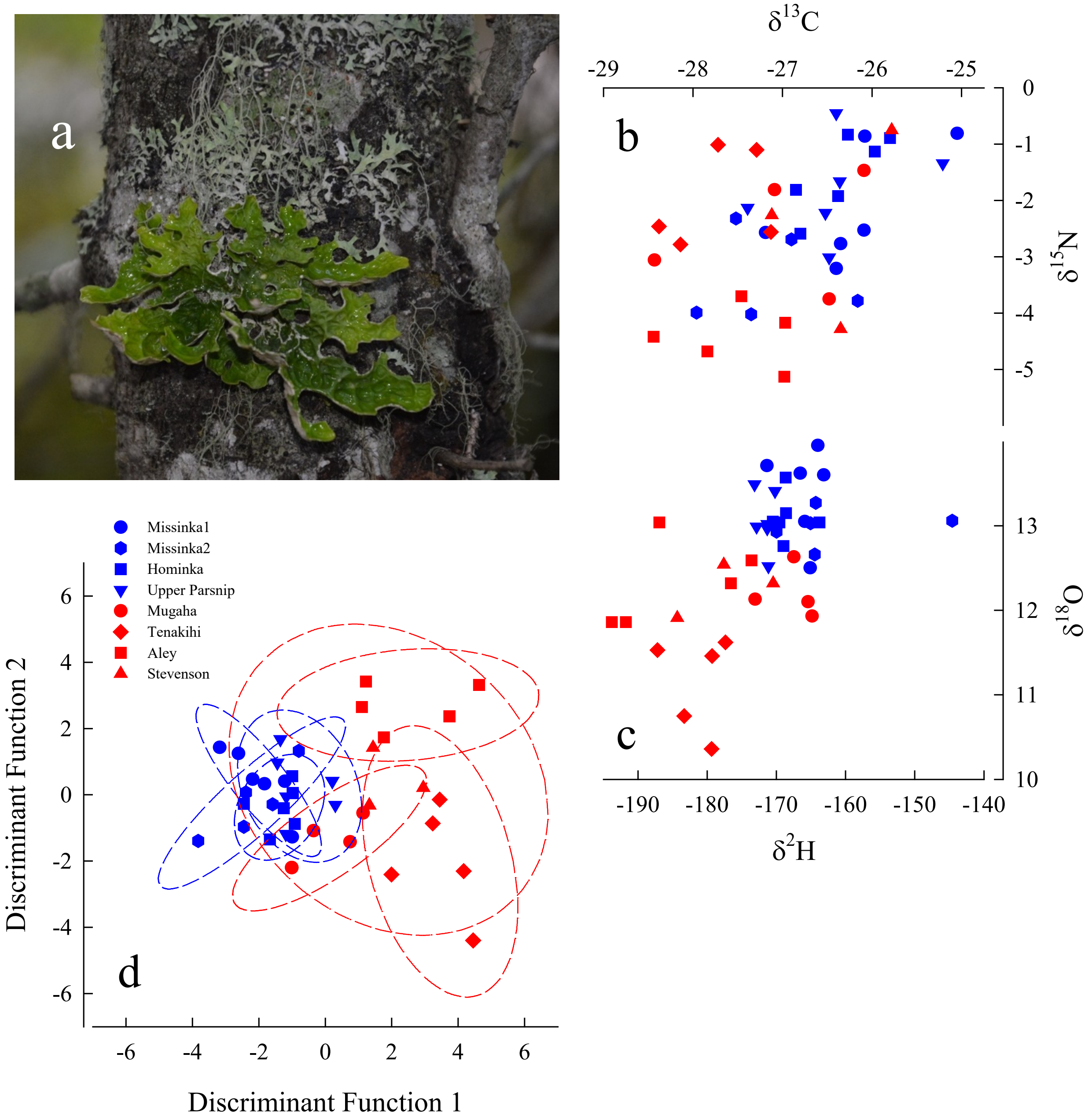

Figure 7. (a) Lichen growing on a deciduous tree in the riparian area of a tributary stream to the Williston Reservoir (M. Shrimpton); *Lobaria pulmonaria* (green, leafy), *Alectoria* sp. (hair lichen) and *Parmelia squarrosa* (light blue, square lobes). Stable isotope, $\delta^{13}C$ verses $\delta^{15}N$ (c) and $\delta^{2}H$ verses $\delta^{18}O$ (c), from lichen (*Parmelia squarrosa*) samples collected from tributary streams to the Williston Reservoir. (d) Canonical discriminant function analysis using Jackknife resampling for $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$. Red symbols are from systems where Kokanee spawn and blue symbols are from systems where Kokanee do not spawn.

Table 7. Classification matrix from discriminant function analysis for stable isotope analysis of $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ for aquatic insects belonging to the Order Trichoptera. Samples were collected from streams where Kokanee have not been documented to spawn (Missinka, Wichcika, and Wooyadilinka) and where Kokanee have been observed to spawn (Osilinka, Tenakihi, Aley, Stevenson, Cut Thumb and Mugaha). % T is the % classification by treatment and watershed (non-Kokanee spawning systems or systems where Kokanee spawn by major watershed). Parsnip are tributaries that flow into the Parsnip River before it flows into the Willistron Reservoir, and Mackenzie are tributary streams north of Mackenzie that flow into the Parsnip reach of the Williston Reservoir.

	Non-Kokanee			Kokanee spawning systems						
		Parsnip		Osilinka		Ospika		Mackenzie		
	M	Wi	Wo	Os	T	A	S	C	Mu	% T
Missinka (M)								1		20
Wichcika (Wi)	1			1						
Wooyadilinka (Wo)							1	1		
Osilinka (O)		1		2						43
Tenakihi (T)		1			1			1	1	
Aley (A)						0				0
Stevenson (S)		1	1							
Cut Thumb (C)	2									0
Mugaha (Mu)	2			1						
Total	5	3	1	4	1	0	1	3	1	16

Table 8. Classification matrix from discriminant function analysis for stable isotope analysis of $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ for lichen (*Parmelia squarrosa*) samples collected from riparian zones of streams where Kokanee have not been documented to spawn (Missinka, Hominka, and Upper Parsnip) and where Kokanee have been observed to spawn (Mugaha, Tenakihi, Aley and Stevenson). The Missinka River was sample in 2016 and 2017 and results shown separately. % R is the % classification by River system. % T is the % classification by treatment (non-Kokanee spawning systems or systems where Kokanee spawn).

	Non-Kokanee systems				Kokanee spawning systems					
	M1	M2	H	UP	Mu	T	A	S	% R	% T
Missinka1 (M1)	5				1				83	90
Missinka2 (M2)		5							100	
Hominka (H)			4	2					67	
UParsnip (UP)	1		2	2				1	33	
Mugaha (M)		1	1		2				50	88
Tenakihi (T)						5			100	
Aley (A)							5		100	
Stevenson (S)								3	100	
Total	6	6	7	4	3	5	5	4	50	

DISCUSSION

Assemblage of study species

We sampled tributary streams in the Williston Reservoir watershed from a number of the major sub-watersheds; the Parsnip watershed, the Parsnip reach, the Osilinka watershed, and the Ospika watershed. We found considerable diversity of aquatic invertebrates within the stream, large diversity of lichen within the riparian areas adjacent to the streams, but relatively few fish.

From our DNA barcode survey of aquatic invertebrate biodiversity in 2016, we found a total of 115 species (Coxson et al. 2017). Diptera were the most diverse group, followed by Plecoptera and Ephemeroptera. Due to the sampling approach used in 2016, the number represents a conservative estimate for total biodiversity at each sampling location. Only three species of aquatic invertebrates, however, were found in all seven streams: *Zapada cinctipes* (Plecoptera), *Drunella grandis* (Ephemeroptera), and *Ephemerella* sp.3 (Ephemeroptera). Quite a few were found in only one or a small subset of streams even though we sampled in reasonably similar habitat in each stream (riffles or rapid flow and rocky bottoms). This is indicative of a high level of beta-diversity within the region. Most of the species that were identified down to species via DNA barcode annotation have previously been collected in British Columbia. Although one species, *Apatania comosa*, had not been previously recorded in British Columbia and its range is currently considered so limited (portions of ID, MT, UT, WY) that it is ranked as “G2 - Imperiled” by NatureServe. If *A. comosa* exists in the Williston region, it would greatly expand that range extent and would perhaps indicate a more secure conservation rank.

In contrast to the DNA barcode survey, morphological identification of specimens to determine abundance revealed that the aquatic invertebrate samples were dominated by the Orders Ephemeroptera, Plecoptera and Trichoptera (EPT’s; 78%) – particularly Ephemeroptera. Samples collected by kick netting, however, are less quantitative than other methods such as Surber or Hess sampling, but the findings reveal some interesting patterns. Relative abundance changed among the study streams, but there were also differences between the samples collected in the summer and the fall samples. Ephemeroptera comprised 60.7 ± 4.6% of the total number of aquatic insects in the summer; 45.7 ± 3.0% from the kick net samples collected in the fall. Although specimens of Plecoptera were large, they were not particularly abundant in the summer (10.9 ± 1.1%); but were smaller and more abundant in the fall (34.5 ± 2.6%). Trichoptera were considerably less abundant in the samples; just 2.3 ± 0.4% of the specimens in all samples collected in summer and fall. All other aquatic invertebrates including Dipterans composed 21.8 ± 2.6% in the summer and fall samples.

Lichen collected from tributary streams to the Parsnip River and streams flowing into the Parsnip Reach of the reservoir showed an impressive level of diversity including a number of rare species of conservation concern. Of the 229 lichen taxa observed in the 6 study sites, a previously undocumented federally listed rare species of cyano macrolichen, *Collema coniophilum* (listed under the Species at Risk Act, or SARA, ranked by the Committee on the Status of Endangered Wildlife in Canada) was found at all sites except for the Upper Parsnip location. Additionally, a species red-listed by the BC Conservation Data Centre (CDC), *Collema quadrifidum*, was found in the Hominka River watershed, a blue-listed lichen, *Nephroma isidiosum*, was found in the Upper Parsnip, and a conservation-ranked species of calicioid microlichen, *Phaeophyscia nigricans*, was found at the Missinchinka site. Consequently, our survey has greatly increased our understanding of lichen distribution in central BC.

All the study plots were rich in number of the Teloschistaceae and Physciaceae, except for the Crooked River which was the most species impoverished site for Teloschistaceae and Physciaceae. A pattern that may reflect either the lower precipitation at this site (683 mm) or past disturbance history. The one Kokanee-run stream (Missinchinka) fell among the richest set of sites. Interesting, there was a strong separation of the Pack River samples from all others along Axis 1 of the Non-metric multidimensional scaling (NMS) ordination. The Pack and Crooked River sites were the two most impoverished sites for total number of lichen species, and are the two driest sites in our data set, reinforcing the importance of precipitation availability as an ecological variate in the BC interior (Coxson et al. 2013). The NMS results show that the one Kokanee-run stream, the Missinchinka, shares strong ecological ties with all of the other high-precipitation sites (Figure 2).

The assemblage of fish species showed little diversity and relatively low abundance in our study streams. A single species from the family Cottidae, the slimy sculpin, was the most commonly captured fish and often the only species found while electrofishing the study streams. Sizes of slimy sculpin was similar among the study streams, however our sampling was designed to catch larger slimy sculpin as we have previously demonstrated that larger fish tend to be relatively sedentary (Clarke et al. 2015). Two species of Salmonidae were found in several streams, bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncoryhunchus mykiss*). There was considerable range of size for slimy sculpin caught in each system, indicating multiple year classes of fish, whereas bull trout and rainbow trout were typically small and likely young-of-the-year or one-year old fish. Occasionally, larger trout were captured – but often only a single fish per stream. Our findings are not surprising as many of the study streams are known systems for both bull trout and rainbow trout to spawn (Hagen and Pillipow 2014) and would, therefore, be restricted to younger age classes of fish outside the spawning seasons – the times when we surveyed each stream. Diversity of fish species was greater in the two largest systems surveyed; Parsnip River and Osilinka River. Fish belonging to other families were also caught in these rivers; Gadidae, Cyprinidae, and Thymallidae.

Stable isotope signatures

We used stable isotopes to track the potential delivery of nutrients by Kokanee from the reservoir to tributary streams and their riparian ecosystems using a benthic species of fish, stream dwelling aquatic insects, and a foliose green algal lichen. Intragravel flow of water carries nutrients to riparian vegetation, aquatic insects and stream resident fish feed on eggs and dead fish, which in turn feed numerous other organisms.

Slimy sculpin have the widest distribution among the family Cottidae in North America and have been increasingly used in impact assessment studies as they are relatively sedentary as adults with a small home range (Gray et al. 2018). Consequently, they are a useful model species for integrating environmental conditions of localized areas. Limited movement for older life stages of slimy sculpin (Clarke et al. 2015) make this species a good choice for looking at elemental signatures indicative of trophic influence and nutrient sources to the study streams. Although there was variation in the stable isotope signatures within each system, signatures from slimy sculpin collected in systems with high numbers of Kokanee spawners showed separation from signatures of fish collected from streams with no Kokanee for δ^2H, $\delta^{13}C$, and particularly $\delta^{18}O$. In contrast, $\delta^{15}N$ values for slimy sculpin overlapped considerably among Kokanee and non-Kokanee streams. There was overlap in $\delta^{13}C$ and $\delta^{18}O$ between the spawning Kokanee from the Williston Reservoir and sculpin caught in streams where Kokanee spawned – signatures quite distinct from the sculpin caught in tributary streams to the Parsnip River where Kokanee do not spawn. Carbon isotope measurements indicate dietary sources of nutrition (Peterson and Fry 1987). The considerable differences among sculpins sampled from the different systems suggests difference in source carbon, but sculpin sampled from streams where high numbers of Kokanee spawned had $\delta^{13}C$ values that were depleted and similar to values for Kokanee. Nitrogen isotopes function as trophic level indicators (Peterson and Fry 1987) and indicate that Kokanee are eating at a higher trophic level than the sculpins. In contrast $\delta^{18}O$ showed considerable difference across streams; Kokanee from the Williston Reservoir and slimy sculpin caught in Kokanee spawning streams were depleted in ^{18}O compared to slimy sculpin caught in Williston Reservoir streams where Kokanee do not spawn. Additionally, Kokanee from Thutade Lake were enriched in ^{18}O compared to all fish from the Williston Reservoir watershed.

Stable isotope analysis also included replicates of the major orders of aquatic insects, Ephemeroptera, Plecoptera and Trichoptera, to assess potential variation within each group, but also potential functional differences among groups. Ephemeroptera showed a pattern similar to the sculpin, but the pattern was less clear for Plecoptera and Trichoptera. For the aquatic invertebrate samples, there was also temporal variation in isotope signature for $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, but less so for δ^2H. The isotopic composition of a specific animal tissue is controlled mainly by local dietary inputs, although various tissues integrate local diet over different temporal scales (Hobson 1999). Temporal differences among the aquatic invertebrates may represent stage of development as the nymphs collected represent different instars between the sampled collected in July and October. July specimens were larger than October – likely indicating that the nymphs represented different feeding guilds and trophic levels – reflected in the shifts in stable isotope signatures among the seasons.

Perhaps most strikingly, the stable isotope data for the samples of *Parmelia squarrosa* showed separation between streams where Kokanee spawn and do not spawn for $\delta^{13}C$ and $\delta^{15}N$ suggesting transfer of reservoir nutrients beyond the stream and into the adjacent riparian areas. Our samples analyzed for stable isotopes were of stem dwelling Parmeliaceae, foliose green algal lichens that grow widely in the region (*Parmelia squarrosa*). This species represents a good model to assess potential nutrient transfer from the reservoir to riparian vegetation adjacent to streams where Kokanee spawn as they should be highly sensitive to nitrogen enrichment. Interestingly, lichen samples from streams where Kokanee spawn were depleted in ^{15}N – a pattern similar to that seen in slimy sculpin and mayflies.

Samples collected for fish, invertebrates and lichen from streams where Kokanee spawn were depleted in ^{2}H, ^{13}C, ^{18}O compared to streams where Kokanee did not spawn. There were considerable differences in locations around the Williston Reservoir where Kokanee spawn and the Parsnip River tributaries that we used as non-Kokanee control streams. Some stable isotope signatures have been shown to strongly vary by region, particularly for $\delta^{18}O$ and $\delta^{2}H$ which are influenced by environmental water (Soto et al. 2013). Recent work has indicated that $\delta\,^{2}H$ can improve the ability to track the source of organic material into aquatic food webs (Voigt et al. 2015) and is also strongly influenced by dietary sources of protein and lipids (Soto et al. 2013). Geographic location of the study streams likely played a role in the differences in stable isotope signatures among our study sites for $\delta^{2}H$, but particularly for $\delta^{18}O$. Stable oxygen and hydrogen isotope ratios in precipitation show a continent-wide pattern in North America with a general gradient of relatively enriched values in the south to more depleted values in the north (Hobson 1999). In fact, the greatest potential for applying hydrogen and oxygen isotope ratios as markers of animal movement exists in mid- to high-latitude continental regions, where strong spatial isotope gradients exist (Hobson 1999). The strong correlation between latitude and $\delta^{18}O$ (Appendix 3) indicates that location is driving the differences for $\delta^{18}O$ rather than diet. Wang et al. (2009) showed that oxygen isotopes from chironomid larvae reflect past habitat water isotopic signatures than hydrogen; 69.0 ± 0.4% of oxygen and 30.8 ± 2.6% of hydrogen in chironomid larvae was derived from habitat water. Measurements of $\delta^{2}H$ may be a complementary trophic tracer in food web studies. While $\delta^{18}O$ measurements do not provide any trophic information, they can be useful for linking tissue to environmental water where was grown (Bowen et al. 2005). The lack of significant relationships between $\delta^{2}H$ and latitude in our study supports the link between nutrient source and $\delta^{2}H$.

Differences in $\delta^{13}C$ were appreciable for fish, aquatic invertebrates and lichen among the different streams examined in our study. Interestingly, the streams where Kokanee spawn showed less variation than non-Kokanee streams – particularly for samples from slimy sculpin. Streams where Kokanee spawn were sampled from a wide geographic range, streams from the Parsnip reach, Omineca watershed and Osilinka watershed, yet only varied in $\delta^{13}C$ by 2‰. In contrast, the non-Kokanee streams we sampled were exclusively from the Parnsip River watershed and varied in $\delta^{13}C$ by more than 4‰. Stable carbon isotope ratios of C3 terrestrial plant detritus in streams are relatively constant at about –28‰ (France 1995), similar to the values we found for Missinka River and Wooyadilinka Creek. Freshwater algae $\delta^{13}C$, however, can range between –47 and –12‰ (France 1995; Finlay et al. 1999). There was little variation in $\delta^{13}C$ for Kokanee spawners from both the Williston Reservoir and from Thutade Lake with an average value of –32.3‰ suggesting a fairly consistent carbon source for these systems. The overlap in $\delta^{13}C$ between Kokanee from the reservoir and for fish, aquatic invertebrates and even the depleted $\delta^{13}C$ values for lichen suggests Kokanee introduce carbon to streams where they spawn, but the variation in $\delta^{13}C$ for Parnsip River watershed streams is less clear. Freshwater benthic algae typically exhibit $\delta^{13}C$ values of approximately –26 ± 3‰, whereas phytoplankton typically exhibit $\delta^{13}C$ of approximately –32 ± 3‰ (France 1995). Depletion of ^{13}C for samples collected from the Parnsip River may represent autochthonous phytoplankton within the environment. Depletion of ^{13}C in samples from Wichcika Creek, however, are not as easy to explain. Wicheeda Lake flows into Wichcika Creek and may be a source of depleted ^{13}C, although the confluence for the stream is below where we sampled. The marshy area at the headwaters of Wichcika Creek, however, is the type of habitat with still waters where algae incorporate carbon depleted in ^{13}C (Finlay et al. 1999).

The overlap in $\delta^{13}C$ values for sculpin from streams where Kokanee spawn and Kokanee spawners, therefore, indicates that a potential source of nutrients in these streams is from the reservoir – suggesting that Kokanee are a source of nutrients to tributary streams where they spawn. Kokanee like sockeye salmon may be enhancing the productivity of the river systems where they spawn (Quinn et al. 2018). Sculpin diets for two coastal species, Prickly sculpin (*Cottus asper*) and Coastrange sculpin (*C. aleuticus*) shifted from invertebrates and juvenile salmonids to salmon eggs when salmon arrived in autumn, with salmon-derived nutrient contributions to diets and sculpin condition increasing with increasing biomass of spawning salmon among streams (Swain et al. 2014).

RECOMMENDATIONS

This report is based on the findings from Year 1 and Year 2 of our 3-year project. We identified additional study and control streams for sampling in 2017. For each of the locations, we sampled for aquatic invertebrates, benthic stream dwelling fish, and lichen within the riparian areas adjacent to the streams. Our analysis revealed tremendous diversity of aquatic insects and riparian lichen among all sites and stable isotope signatures depleted in ^{13}C – indicative of a nutrient influx from the reservoir by spawning Kokanee. The wide-spread geographic distribution of spawning Kokanee throughout tributaries flowing into the northern portions of the reservoir and absence of Kokanee in the southern-most watersheds has created a spatial bias to our study design – exemplified by the strong correlation between $\delta^{18}O$ measurements and latitude. For Year 3, we incorporated additional sites to compare Kokanee-spawning streams with non-Kokanee streams. Our Year 3 research is also designed to provide a synthesis of project findings and develop major recommendations. In collaboration with our research partners, we plan to disseminate our findings to local communities within the Williston Reservoir watershed, to the FWCP – Peace Region Board members, and also prepare manuscripts for submission to peer-reviewed journals.

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Appendix 1. Summary of Kick Net samples submitted for stable isotope analysis from each study stream. Three kick net samples were collected per stream and sorted into aquatic macroinvertebrate orders. Where sufficient mass of a specific order was not obtained, samples were pooled within a study stream.

Isotope Sample	Sample Code	Creek Name	Date	Kick Net	Insect Order	Samples	Pooled
1	WIC170724K1 E	Wichcika	24-07-2017	1	Ephemeroptera	1	
2	WIC170724K2 E	Wichcika	24-07-2017	2	Ephemeroptera	2	
3	WIC170724K3 E	Wichcika	24-07-2017	3	Ephemeroptera	3	
4	MIS170724K1 E	Missinka	24-07-2017	1	Ephemeroptera	pooled	4+5+6
	MIS170724K2 E	Missinka	24-07-2017	2	Ephemeroptera		
	MIS170724K3 E	Missinka	24-07-2017	3	Ephemeroptera		
7	TEN170726K1 E	Tenakihi	26-07-2017	1	Ephemeroptera	7	
8	TEN170726K2 E	Tenakihi	26-07-2017	2	Ephemeroptera	8	
9	TEN170726K3 E	Tenakihi	26-07-2017	3	Ephemeroptera	9	
10	OSS170726K1 E	Osilinka	26-07-2017	1	Ephemeroptera	pooled	10+11+12
	OSS170726K2 E	Osilinka	26-07-2017	2	Ephemeroptera		
	OSS170726K3 E	Osilinka	26-07-2017	3	Ephemeroptera		
13	ALE170727K1 E	Aley	27-07-2017	1	Ephemeroptera	13	
14	ALE170727K2 E	Aley	27-07-2017	2	Ephemeroptera	14	
15	ALE170727K3 E	Aley	27-07-2017	3	Ephemeroptera	15	
16	STE170727K1 E	Stevenson	27-07-2017	1	Ephemeroptera	16	
17	STE170727K2 E	Stevenson	27-07-2017	2	Ephemeroptera	17	
18	STE170727K3 E	Stevenson	27-07-2017	3	Ephemeroptera	18	
19	MUG170731K1 E	Mugaha	31-07-2017	1	Ephemeroptera	19	
20	MUG170731K2 E	Mugaha	31-07-2017	2	Ephemeroptera	20	
21	MUG170731K3 E	Mugaha	31-07-2017	3	Ephemeroptera	21	
22	CTB170731K1 E	Cut Thumb	31-07-2017	1	Ephemeroptera	22	
23	CTB170731K2 E	Cut Thumb	31-07-2017	2	Ephemeroptera	23	
24	CTB170731K3 E	Cut Thumb	31-07-2017	3	Ephemeroptera	24	
25	WIC170724K1 P	Wichcika	24-07-2017	1	Plecoptera	25	
26	WIC170724K2 P	Wichcika	24-07-2017	2	Plecoptera	26	
27	WIC170724K3 P	Wichcika	24-07-2017	3	Plecoptera	27	
28	MIS170724K1 P	Missinka	24-07-2017	1	Plecoptera	28	
29	MIS170724K2 P	Missinka	24-07-2017	2	Plecoptera	29	
30	MIS170724K3 P	Missinka	24-07-2017	3	Plecoptera	30	
31	TEN170726K1 P	Tenakihi	26-07-2017	1	Plecoptera	pooled	31+33
	TEN170726K3 P	Tenakihi	26-07-2017	3	Plecoptera		
32	TEN170726K2 P	Tenakihi	26-07-2017	2	Plecoptera	32	
34	OSS170726K1 P	Osilinka	26-07-2017	1	Plecoptera	pooled	34+36
	OSS170726K3 P	Osilinka	26-07-2017	3	Plecoptera		
35	OSS170726K2 P	Osilinka	26-07-2017	2	Plecoptera	35	

Appendix 1 (continued). Summary of Kick Net samples submitted for stable isotope analysis from each study stream. Three kick net samples were collected per stream and sorted into aquatic macroinvertebrate orders. Where sufficient mass of a specific order was not obtained, samples were pooled within a study stream.

Isotope Sample	Sample Code	Creek Name	Date	Kick Net	Insect Order	Samples	Pooled
37	ALE170727K1 P	Aley	27-07-2017	1	Plecoptera	pooled	37+39
	ALE170727K3 P	Aley	27-07-2017	3	Plecoptera		
38	ALE170727K2 P	Aley	27-07-2017	2	Plecoptera	38	
40	STE170727K1 P	Stevenson	27-07-2017	1	Plecoptera	pooled	40+42
	STE170727K3 P	Stevenson	27-07-2017	3	Plecoptera		
41	STE170727K2 P	Stevenson	27-07-2017	2	Plecoptera	41	
43	MUG170731K1 P	Mugaha	31-07-2017	1	Plecoptera	43	
44	MUG170731K2 P	Mugaha	31-07-2017	2	Plecoptera	pooled	44+45
	MUG170731K3 P	Mugaha	31-07-2017	3	Plecoptera		
46	CTB170731K1 P	Cut Thumb	31-07-2017	1	Plecoptera	pooled	46+48
	CTB170731K3 P	Cut Thumb	31-07-2017	3	Plecoptera		
47	CTB170731K2 P	Cut Thumb	31-07-2017	2	Plecoptera	47	
49	WIC170724K1 T	Wichcika	24-07-2017	1	Trichoptera	49	
50	WIC170724K2 T	Wichcika	24-07-2017	2	Trichoptera	pooled	50+51
	WIC170724K3 T	Wichcika	24-07-2017	3	Trichoptera		
52	MIS170724K1 T	Missinka	24-07-2017	1	Trichoptera	pooled	52+53+54
	MIS170724K2 T	Missinka	24-07-2017	2	Trichoptera		
	MIS170724K3 T	Missinka	24-07-2017	3	Trichoptera		
55	TEN170726K1 T	Tenakihi	26-07-2017	1	Trichoptera	pooled	55+56+57
	TEN170726K2 T	Tenakihi	26-07-2017	2	Trichoptera		
	TEN170726K3 T	Tenakihi	26-07-2017	3	Trichoptera		
58	OSS170726K1 T	Osilinka	26-07-2017	1	Trichoptera	pooled	58+59+60
	OSS170726K2 T	Osilinka	26-07-2017	2	Trichoptera		
	OSS170726K3 T	Osilinka	26-07-2017	3	Trichoptera		
61	ALE170727K3 T	Aley	27-07-2017	3	Trichoptera	*insufficient sample*	
62	STE170727K1 T	Stevenson	27-07-2017	1	Trichoptera	pooled	62+63+64
	STE170727K2 T	Stevenson	27-07-2017	2	Trichoptera		
	STE170727K3 T	Stevenson	27-07-2017	3	Trichoptera		
65	MUG170731K1 T	Mugaha	31-07-2017	1	Trichoptera	pooled	65+66+67
	MUG170731K2 T	Mugaha	31-07-2017	2	Trichoptera		
	MUG170731K3 T	Mugaha	31-07-2017	3	Trichoptera		
68	CTB170731K1 T	Cut Thumb	31-07-2017	1	Trichoptera	pooled	68+69+70
	CTB170731K2 T	Cut Thumb	31-07-2017	2	Trichoptera		
	CTB170731K3 T	Cut Thumb	31-07-2017	3	Trichoptera		

APPENDIX 1 (continued). Summary of Kick Net samples submitted for stable isotope analysis from each study stream. Three kick net samples were collected per stream and sorted into aquatic macroinvertebrate orders. Where sufficient mass of a specific order was not obtained, samples were pooled within a study stream.

Isotope Sample	Sample Code	Creek Name	Date	Kick Net	Insect Order	Samples	Pooled
71	TEN171014K1 E	Tenakihi	14-10-2017	1	Ephemeroptera	71	
72	TEN171014K2 E	Tenakihi	14-10-2017	2	Ephemeroptera	72	
73	TEN171014K3 E	Tenakihi	14-10-2017	3	Ephemeroptera	73	
74	OSS171014K1 E	Osilinka	14-10-2017	1	Ephemeroptera	74	
75	OSS171014K2 E	Osilinka	14-10-2017	2	Ephemeroptera	75	
76	OSS171014K3 E	Osilinka	14-10-2017	3	Ephemeroptera	76	
77	MUG171015K1 E	Mugaha	15-10-2017	1	Ephemeroptera	77	
78	MUG171015K2 E	Mugaha	15-10-2017	2	Ephemeroptera	78	
79	MUG171015K3 E	Mugaha	15-10-2017	3	Ephemeroptera	79	
80	CUT171015K1 E	Cut Thumb	15-10-2017	1	Ephemeroptera	80	
81	CUT171015K2 E	Cut Thumb	15-10-2017	2	Ephemeroptera	pooled	81+82
	CUT171015K3 E	Cut Thumb	15-10-2017	3	Ephemeroptera		
83	WIC171030K1 E	Wichcika	30-10-2017	1	Ephemeroptera	83	
84	WIC171030K2 E	Wichcika	30-10-2017	2	Ephemeroptera	84	
85	WIC171030K3 E	Wichcika	30-10-2017	3	Ephemeroptera	85	
86	W00171030K1 E	Wooyadilinka	30-10-2017	1	Ephemeroptera	86	
87	W00171030K2 E	Wooyadilinka	30-10-2017	2	Ephemeroptera	87	
88	W00171030K3 E	Wooyadilinka	30-10-2017	3	Ephemeroptera	88	
89	ALE171102K1 E	Aley	02-11-2017	1	Ephemeroptera	pooled	89+90+91
	ALE171102K2 E	Aley	02-11-2017	2	Ephemeroptera		
	ALE171102K31 E	Aley	02-11-2017	3	Ephemeroptera		
92	STE171102K2 E	Stevenson	02-11-2017	1	Ephemeroptera	92	
93	STE171102K3 E	Stevenson	02-11-2017	2	Ephemeroptera	93	
94	STE171102K1 E	Stevenson	02-11-2017	3	Ephemeroptera	94	
95	TEN171014K1 P	Tenakihi	14-10-2017	1	Plecoptera	95	
96	TEN171014K2 P	Tenakihi	14-10-2017	2	Plecoptera	96	
97	TEN171014K3 P	Tenakihi	14-10-2017	3	Plecoptera	97	
98	OSS171014K1 P	Osilinka	14-10-2017	1	Plecoptera	98	
99	OSS171014K2 P	Osilinka	14-10-2017	2	Plecoptera	99	
100	OSS171014K3 P	Osilinka	14-10-2017	3	Plecoptera	100	
101	MUG171015K1 P	Mugaha	15-10-2017	1	Plecoptera	101	
102	MUG171015K2 P	Mugaha	15-10-2017	2	Plecoptera	102	
103	MUG171015K3 P	Mugaha	15-10-2017	3	Plecoptera	103	
104	CUT171015K1 P	Cut Thumb	15-10-2017	1	Plecoptera	pooled	104+105
	CUT171015K2 P	Cut Thumb	15-10-2017	2	Plecoptera		

APPENDIX 1 (continued). Summary of Kick Net samples submitted for stable isotope analysis from each study stream. Three kick net samples were collected per stream and sorted into aquatic macroinvertebrate orders. Where sufficient mass of a specific order was not obtained, samples were pooled within a study stream.

Isotope Sample	Sample Code	Creek Name	Date	Kick Net	Insect Order	Samples	Pooled
106	CUT171015K3 P	Cut Thumb	15-10-2017	3	Plecoptera	106	
107	WIC171030K1 P	Wichcika	30-10-2017	1	Plecoptera	107	
108	WIC171030K2 P	Wichcika	30-10-2017	2	Plecoptera	108	
109	WIC171030K3 P	Wichcika	30-10-2017	3	Plecoptera	109	
110	W00171030K1 P	Wooyadilinka	30-10-2017	1	Plecoptera		
111	W00171030K2 P	Wooyadilinka	30-10-2017	2	Plecoptera		
112	W00171030K3 P	Wooyadilinka	30-10-2017	3	Plecoptera		
113	ALE171102K1 P	Aley	02-11-2017	1	Plecoptera	113	113+114
	ALE171102K31 P	Aley	02-11-2017	2	Plecoptera		
115	STE171102K2 P	Stevenson	02-11-2017	1	Plecoptera	115	
116	STE171102K3 P	Stevenson	02-11-2017	2	Plecoptera	116	
117	STE171102K1 P	Stevenson	02-11-2017	3	Plecoptera	117	
118	TEN171014K1 T	Tenakihi	14-10-2017	1	Trichoptera	118	
119	TEN171014K2 T	Tenakihi	14-10-2017	2	Trichoptera	119	
120	TEN171014K3 T	Tenakihi	14-10-2017	3	Trichoptera	120	
121	OSS171014K1 T	Osilinka	14-10-2017	1	Trichoptera	pooled	121+122
	OSS171014K2 T	Osilinka	14-10-2017	2	Trichoptera		
123	OSS171014K3 T	Osilinka	14-10-2017	3	Trichoptera	123	
124	MUG171015K1 T	Mugaha	15-10-2017	1	Trichoptera	pooled	124+126
	MUG171015K3 T	Mugaha	15-10-2017	3	Trichoptera		
125	MUG171015K2 T	Mugaha	15-10-2017	2	Trichoptera	125	
127	CUT171015K1 T	Cut Thumb	15-10-2017	1	Trichoptera	pooled	127+128 +129
	CUT171015K2 T	Cut Thumb	15-10-2017	2	Trichoptera		
	CUT171015K3 T	Cut Thumb	15-10-2017	3	Trichoptera		
130	WIC171030K3 T	Wichcika	30-10-2017	3	Trichoptera	*insufficient sample*	
131	W00171030K1 T	Wooyadilinka	30-10-2017	1	Trichoptera	pooled	131+132
	W00171030K2 T	Wooyadilinka	30-10-2017	2	Trichoptera		
133	W00171030K3 T	Wooyadilinka	30-10-2017	3	Trichoptera	133	
134	STE171102K1 T	Stevenson	02-11-2017	1	Trichoptera	pooled	134+135
	STE171102K3 T	Stevenson	02-11-2017	3	Trichoptera		

APPENDIX 2. Lichen species list by functional group for Peace-Williston study sites; Crooked River (CR), Hominka River (HR), Missinchinka River (MR), Pack River (PR), Upper Parsnip River (UP), and Table River (TR).

Group	Subgroup	Species	CR	HR	MR	PR	UP	TR
Macrolichen	Chloro	*Alectoria sarmentosa*	–	–	+	–	–	–
Macrolichen	Chloro	*Bryoria chalybeiformis (aurea form)*	–	–	–	–	+	–
Macrolichen	Chloro	*Bryoria fremontii*	–	–	–	+	–	–
Macrolichen	Chloro	*Bryoria fuscescens*	+	+	+	+	+	+
Macrolichen	Chloro	*Bryoria glabra*	+	+	+	–	–	+
Macrolichen	Chloro	*Bryoria pikei*	+	+	+	–	+	+
Macrolichen	Chloro	*Bryoria pseudofuscescens*	+	–	–	–	–	–
Macrolichen	Chloro	*Bryoria yellow soralia*	–	–	–	–	+	–
Macrolichen	Chloro	*Cladonia carneola*	–	–	+	–	–	–
Macrolichen	Chloro	*Cladonia cenotea*	–	–	–	–	+	–
Macrolichen	Chloro	*Cladonia coniocraea*	+	+	+	+	+	–
Macrolichen	Chloro	*Cladonia fimbriata*	+	+	+	–	+	–
Macrolichen	Chloro	*Cladonia sulphurea*	–	–	–	–	+	–
Macrolichen	Chloro	*Hypogymnia recurva (coll)*	–	–	–	–	+	–
Macrolichen	Chloro	*Hypogymnia bitteri*	+	–	+	–	–	–
Macrolichen	Chloro	*Hypogymnia enteromorpha*	+	–	+	–	–	–
Macrolichen	Chloro	*Hypogymnia occidentalis*	+	+	+	–	+	+
Macrolichen	Chloro	*Hypogymnia physodes*	+	+	+	+	+	+
Macrolichen	Chloro	*Hypogymnia protea*	–	–	+	–	+	–
Macrolichen	Chloro	*Hypogymnia rugosa*	–	–	–	–	+	+
Macrolichen	Chloro	*Hypogymnia tubulosa*	+	+	+	–	+	+
Macrolichen	Chloro	*Hypogymnia vittata*	–	–	–	–	+	–
Macrolichen	Chloro	*Hypogymnia wilfiana*	–	–	–	–	+	–
Macrolichen	Chloro	*Melanelixia glabratula*	+	+	+	+	+	+
Macrolichen	Chloro	*Melanelixia subaurifera*	+	+	+	+	+	+
Macrolichen	Chloro	*Melanohalea exasperatula*	+	–	+	–	+	–
Macrolichen	Chloro	*Melanohalea glabratula*	–	+	–	–	–	–
Macrolichen	Chloro	*Melanohalea multispora*	+	+	+	+	+	+
Macrolichen	Chloro	*Melanohalea septentrionalis*	–	–	–	–	+	+
Macrolichen	Chloro	*Melanohalea subaurifera*	+	–	–	–	–	–
Macrolichen	Chloro	*Micarea denigrata*	–	–	+	+	–	–
Macrolichen	Chloro	*Parmelia hygrophila*	+	+	+	+	+	+
Macrolichen	Chloro	*Parmelia sulcata*	+	+	+	+	+	+
Macrolichen	Chloro	*Parmelia sulymae*	+	–	+	+	+	–
Macrolichen	Chloro	*Parmeliopsis ambigua*	+	+	+	+	+	+
Macrolichen	Chloro	*Parmeliopsis hyperopta*	+	+	+	+	+	+
Macrolichen	Chloro	*Physcia alnophila*	+	+	+	+	+	+
Macrolichen	Chloro	*Physcia caesia*	–	+	–	–	–	–
Macrolichen	Chloro	*Physcia stellaris*	–	–	–	+	–	–
Macrolichen	Chloro	*Physconia enteroxantha*	–	–	–	+	–	–
Macrolichen	Chloro	*Physconia perisidiosa*	–	+	–	–	–	+
Macrolichen	Chloro	*Platismatia glauca*	+	+	+	–	+	+
Macrolichen	Chloro	*Ramalina ameriana*	–	–	–	+	–	–
Macrolichen	Chloro	*Ramalina dilacerata*	–	+	+	+	–	+
Macrolichen	Chloro	*Ramalina farinacea*	–	–	–	+	–	–
Macrolichen	Chloro	*Ramalina intermedia*	–	+	–	–	–	–
Macrolichen	Chloro	*Ramalina obtusata*	+	+	+	+	+	+
Macrolichen	Chloro	*Ramalina thrausta*	+	+	+	+	+	+

Group	Subgroup	Species	CR	HR	MR	PR	UP	TR
Macrolichen	Chloro	*Tuckermannopsis chlorophylla*	+	+	+	+	+	+
Macrolichen	Chloro	*Usnea barbara f. isidiomorpha*	–	+	–	–	+	+
Macrolichen	Chloro	*Usnea barbata f. scabrata*	–	+	–	–	+	+
Macrolichen	Chloro	*Usnea cavernosa*	–	–	+	–	–	–
Macrolichen	Chloro	*Usnea chaetophora*	+	–	+	–	–	–
Macrolichen	Chloro	*Usnea dasopoga*	–	+	–	–	–	–
Macrolichen	Chloro	*Usnea filipendula*	–	–	+	–	–	–
Macrolichen	Chloro	*Usnea glabrata*	–	–	–	–	–	+
Macrolichen	Chloro	*Usnea lapponica*	+	+	–	–	–	+
Macrolichen	Chloro	*Usnea scabrata*	+	–	+	+	–	–
Macrolichen	Chloro	*Usnea subfloridana*	–	–	+	–	–	–
Macrolichen	Chloro	*Usnea substerilis*	–	–	+	–	–	+
Macrolichen	Chloro	*Vulpicida pinastri*	+	+	+	+	–	+
Macrolichen	Chloro	*Xanthomendoza fallax*	–	–	–	+	+	–
Macrolichen	Chloro	*Xanthomendoza fulva*	–	+	+	+	–	–
Macrolichen	Chloro	*Xanthoria candelaria*	–	–	+	+	–	–
Macrolichen	Chloro	*Xanthoria fallax*	–	–	–	–	+	–
Macrolichen	Chloro	*Xanthoria kaernefeltii*	–	–	–	–	+	–
Macrolichen	Cyano	*Collema coniophilum*	+	+	+	+	–	+
Macrolichen	Cyano	*Collema quadrifidum*	–	+	–	–	–	–
Macrolichen	Cyano	*Collema striatum*	–	–	–	–	–	+
Macrolichen	Cyano	*Collema subflaccidum*	–	+	+	+	+	+
Macrolichen	Cyano	*Collema subfuscum*	–	–	–	–	–	+
Macrolichen	Cyano	*Leptogium cellulosum*	+	+	+	+	+	+
Macrolichen	Cyano	*Leptogium compactum*	–	–	–	–	–	+
Macrolichen	Cyano	*Leptogium cookii*	+	–	–	+	–	–
Macrolichen	Cyano	*Leptogium saturninum*	+	+	+	+	+	+
Macrolichen	Cyano	*Leptogium teretiusculum*	+	+	+	+	–	+
Macrolichen	Cyano	*Lobaria hallii*	–	+	+	+	+	+
Macrolichen	Cyano	*Lobaria pulmonaria*	+	+	+	+	+	+
Macrolichen	Cyano	*Lobaria scrobiculata*	+	+	+	–	+	–
Macrolichen	Cyano	*Nephroma bellum*	+	+	+	–	+	+
Macrolichen	Cyano	*Nephroma isidiosum*	–	–	–	–	+	–
Macrolichen	Cyano	*Nephroma parile*	+	+	+	+	+	+
Macrolichen	Cyano	*Nephroma resupinatum*	+	+	+	–	+	–
Macrolichen	Cyano	*Parmeliella triptophylla*	–	+	–	–	–	–
Macrolichen	Cyano	*Peltigera aphthosa*	–	+	–	–	–	–
Macrolichen	Cyano	*Peltigera collina*	+	+	+	+	+	+
Macrolichen	Cyano	*Peltigera membranacea*	–	+	–	–	+	+
Macrolichen	Cyano	*Pseudocyphellaria anomala*	–	+	–	–	+	+
Macrolichen	Cyano	*Santessoniella saximontana*	–	+	–	–	–	–
Macrolichen	Cyano	*Sticta fuliginosa*	–	+	–	–	–	+
Macrolichen	Cyano	*Sticta sylvatica*	–	+	+	–	–	–
Microlichen	Calicioid	*Calicium adaequatum*	–	–	–	–	+	–
Microlichen	Calicioid	*Calicium parvum*	–	–	+	+	+	–
Microlichen	Calicioid	*Calicium viride*	+	+	+	+	+	+
Microlichen	Calicioid	*Chaenotheca cinerea*	–	+	–	–	–	–
Microlichen	Calicioid	*Chaenotheca hispidula*	–	–	–	–	–	+
Microlichen	Calicioid	*Chaenotheca trichialis*	–	+	–	–	–	–
Microlichen	Calicioid	*Chaenothecopsis populicola*	–	+	–	–	–	–
Microlichen	Calicioid	*Chaenothecopsis sp. unknown*	–	+	–	–	–	–
Microlichen	Calicioid	*Mycocalicium subtile*	+	–	–	–	–	–
Microlichen	Calicioid	*Phaeocalicium compressulum*	–	+	+	–	–	+
Microlichen	Calicioid	*Phaeophyscia kairamoi*	–	+	–	–	–	–

Group	Subgroup	Species	CR	HR	MR	PR	UP	TR
Microlichen	Calicioid	*Phaeophyscia nigricans*	–	–	+	–	–	–
Microlichen	Calicioid	*Stenocybe pullatula*	+	+	+	+	–	–
Microlichen	Trebouxioid	*Arthonia apatetica*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Arthonia edgewoodensis*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Arthonia leptalea ined.*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Arthonia lignariella*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Arthonia muscigena*	+	–	–	–	–	–
Microlichen	Trebouxioid	*Bacidia beckhausii*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Bacidia circumspecta*	+	+	+	+	–	–
Microlichen	Trebouxioid	*Bacidia idahoensis*	+	–	+	–	–	–
Microlichen	Trebouxioid	*Bacidia laurocerasi s. str.*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Bacidia rosellizans*	–	–	+	–	–	+
Microlichen	Trebouxioid	*Bacidia subincompta*	–	+	–	–	–	+
Microlichen	Trebouxioid	*Bacidia subintricata*	–	–	–	+	–	–
Microlichen	Trebouxioid	*Bacidia vermifera*	–	+	–	–	–	+
Microlichen	Trebouxioid	*Biatora efflorescens*	–	–	+	–	+	+
Microlichen	Trebouxioid	*Biatora pallens*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Biatora rufidula*	+	–	+	–	–	–
Microlichen	Trebouxioid	*Biatora subduplex*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Biatora vacciniicola*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Biatoridium delitescens*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Biatoridium delitescens*	–	+	–	–	+	+
Microlichen	Trebouxioid	*Bilimbia sabuletorum*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Buellia arborea*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Buellia disciformis*	+	+	+	+	–	+
Microlichen	Trebouxioid	*Buellia griseovirens*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Buellia nicolaensis ined.*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Buellia penichra*	–	+	–	–	+	+
Microlichen	Trebouxioid	*Buellia punctata*	–	+	+	+	–	–
Microlichen	Trebouxioid	*Buellia triphragmioides*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Buellia unknown species (erumpent)*	+	+	–	–	–	–
Microlichen	Trebouxioid	*Caloplaca ahtii*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Caloplaca atrosanguinea*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Caloplaca cf. oleicola*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Caloplaca flavorubescens*	–	+	+	+	–	–
Microlichen	Trebouxioid	*Caloplaca pyracea*	+	–	+	+	–	+
Microlichen	Trebouxioid	*Caloplaca sorocarpa*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Caloplaca tricolor*	–	–	–	+	+	–
Microlichen	Trebouxioid	*Caloplaca urceolata*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Candelariella efflorescens*	+	+	–	+	–	+
Microlichen	Trebouxioid	*Candelariella reflexa*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Catinaria atropurpurea*	–	–	–	–	–	+
Microlichen	Trebouxioid	*Chaenotheca chrysocephala*	+	–	–	–	–	–
Microlichen	Trebouxioid	*Chaenotheca phaeocephala*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Chrysothrix candelaris*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Cliostomum griffithii*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Cliostomum pulchellum ined.*	+	–	+	+	–	–
Microlichen	Trebouxioid	*Cliostomum spribillei*	+	+	+	–	–	+
Microlichen	Trebouxioid	*Cyphelium inquinans*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Japewia subaurifera*	+	–	–	–	–	+
Microlichen	Trebouxioid	*Japewia tornoensis*	–	–	+	–	–	+
Microlichen	Trebouxioid	*Lambiella caeca*	–	–	–	+	–	–
Microlichen	Trebouxioid	*Lecania cyrtellina*	–	+	–	–	–	–

Group	Subgroup	Species	CR	HR	MR	PR	UP	TR
Microlichen	Trebouxioid	*Lecania madida*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Lecanora allophana f. allophana*	+	+	–	+	–	–
Microlichen	Trebouxioid	*Lecanora allophana f. soralifera*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Lecanora cadubriae*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Lecanora chlarotera*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Lecanora farinaria*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Lecanora farinaria cfr. (cottonwood form)*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Lecanora fuscescens*	–	–	–	–	+	–
Microlichen	Trebouxioid	*Lecanora hagenii*	–	–	–	+	–	–
Microlichen	Trebouxioid	*Lecanora hybocarpa*	+	+	+	+	–	+
Microlichen	Trebouxioid	*Lecanora impudens*	–	+	+	+	+	+
Microlichen	Trebouxioid	*Lecanora phaeostigma*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Lecanora pulicaris*	+	–	+	–	–	–
Microlichen	Trebouxioid	*Lecanora symmicta*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Lecidea albohyalina*	–	–	–	–	+	+
Microlichen	Trebouxioid	*Lecidea betulicola*	–	–	–	–	+	–
Microlichen	Trebouxioid	*Lecidea erythrophaea*	+	+	+	+	–	+
Microlichen	Trebouxioid	*Lecidea hypnorum*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Lecidea leprarioides*	+	–	+	–	+	+
Microlichen	Trebouxioid	*Lecidea nylanderi*	+	–	+	–	–	+
Microlichen	Trebouxioid	*Lecidea pullata*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Lecidella euphorea*	+	–	+	–	+	–
Microlichen	Trebouxioid	*Lepraria torii*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Leptorhaphis epidermidis*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Lopadium disciforme*	–	+	+	–	+	–
Microlichen	Trebouxioid	*Micarea paupercula ined.*	–	+	–	–	+	–
Microlichen	Trebouxioid	*Micarea prasina group*	–	+	+	–	+	+
Microlichen	Trebouxioid	*Mycobilimbia carneoalbida*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Mycobilimbia epixanthoides*	+	+	+	+	–	+
Microlichen	Trebouxioid	*Mycobilimbia tetramera*	+	+	+	+	–	–
Microlichen	Trebouxioid	*Mycoblastus affinis*	+	+	+	–	+	+
Microlichen	Trebouxioid	*Mycoblastus alpinus cfr.*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Mycoblastus sanguinarioides*	+	+	+	–	+	–
Microlichen	Trebouxioid	*Mycoblastus sanguinarius*	–	+	–	–	+	–
Microlichen	Trebouxioid	*Ochrolechia androgyna*	+	+	+	–	+	+
Microlichen	Trebouxioid	*Ochrolechia juvenalis*	+	–	+	–	–	–
Microlichen	Trebouxioid	*Ochrolechia oregonensis*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Ochrolechia szatalaensis*	+	+	+	–	+	+
Microlichen	Trebouxioid	*Pertusaria amara*	–	–	+	–	+	+
Microlichen	Trebouxioid	*Pertusaria carneopallida*	+	+	+	–	+	+
Microlichen	Trebouxioid	*Pertusaria multipuncta*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Pertusaria ophthalmiza*	+	+	+	–	+	+
Microlichen	Trebouxioid	*Pertusaria pupillaris*	+	–	–	–	–	–
Microlichen	Trebouxioid	*Pertusaria sommerfeltii*	–	+	–	–	–	–
Microlichen	Trebouxioid	*Pertusaria stenhammari*	+	+	+	–	+	–
Microlichen	Trebouxioid	*Phlyctis argena*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Phlyctis speirea*	–	–	+	–	–	+
Microlichen	Trebouxioid	*Physcia adscendens*	+	–	+	+	–	–
Microlichen	Trebouxioid	*Physcia aipolia*	+	–	+	–	–	–
Microlichen	Trebouxioid	*Pycnora sorophora*	–	–	+	–	–	–
Microlichen	Trebouxioid	*Ramboldia cinnabarina*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Rinodina capensis*	+	+	+	+	+	+
Microlichen	Trebouxioid	*Rinodina colobina*	–	+	–	+	–	–

Group	Subgroup	Species	CR	HR	MR	PR	UP	TR
Microlichen	Trebouxioid	*Rinodina degeliana*	+	+	+	+	−	+
Microlichen	Trebouxioid	*Rinodina disjuncta*	−	−	+	+	+	+
Microlichen	Trebouxioid	*Rinodina efflorescens*	−	−	+	−	−	−
Microlichen	Trebouxioid	*Rinodina flavosoralifera*	−	+	+	+	+	−
Microlichen	Trebouxioid	*Rinodina griseosoralifera*	−	−	+	+	+	+
Microlichen	Trebouxioid	*Rinodina metaboliza (coll)*	−	−	−	+	+	−
Microlichen	Trebouxioid	*Rinodina orculata*	+	+	+	−	+	+
Microlichen	Trebouxioid	*Rinodina oregana*	−	+	+	+	+	−
Microlichen	Trebouxioid	*Rinodina pyrina*	−	−	−	−	−	+
Microlichen	Trebouxioid	*Rinodina stictica*	−	+	−	−	−	+
Microlichen	Trebouxioid	*Rinodina trevisanii*	−	+	−	−	−	+
Microlichen	Trebouxioid	*Schaereria corticola*	+	+	+	−	+	+
Microlichen	Trebouxioid	*Toensbergia leucococca*	−	+	+	+	−	+
Microlichen	Trebouxioid	*Varicellaria rhodocarpa*	+	−	−	−	−	−
Microlichen	Trentepohlioid	*Arthonia didyma*	−	+	−	−	−	+
Microlichen	Trentepohlioid	*Arthonia dispersa*	−	−	+	−	−	−
Microlichen	Trentepohlioid	*Arthonia radiata*	+	+	+	−	−	+
Microlichen	Trentepohlioid	*Arthonia vivida ined.*	−	−	+	−	−	−
Microlichen	Trentepohlioid	*Bacidina arceutina*	−	−	+	+	−	−
Microlichen	Trentepohlioid	*Opegrapha varia*	−	+	−	−	−	−

APPENDIX 3. Relationships between stable isotope ratios for fish, aquatic invertebrates and lichen as a function of latitude.

Figure A3.1 is for slimy sculpin (*Cottus cognatus*) and Kokanee (*Oncorhynchus nerka*).
Figure A3.2 is for aquatic insects belonging to the Order Ephemeroptera.
Figure A3.3 is for aquatic insects belonging to the Order Plecoptera.
Figure A3.4 is for aquatic insects belonging to the Order Trichoptera.
Figure A3.5 is for the lichen (*Parmelia squarrosa*).

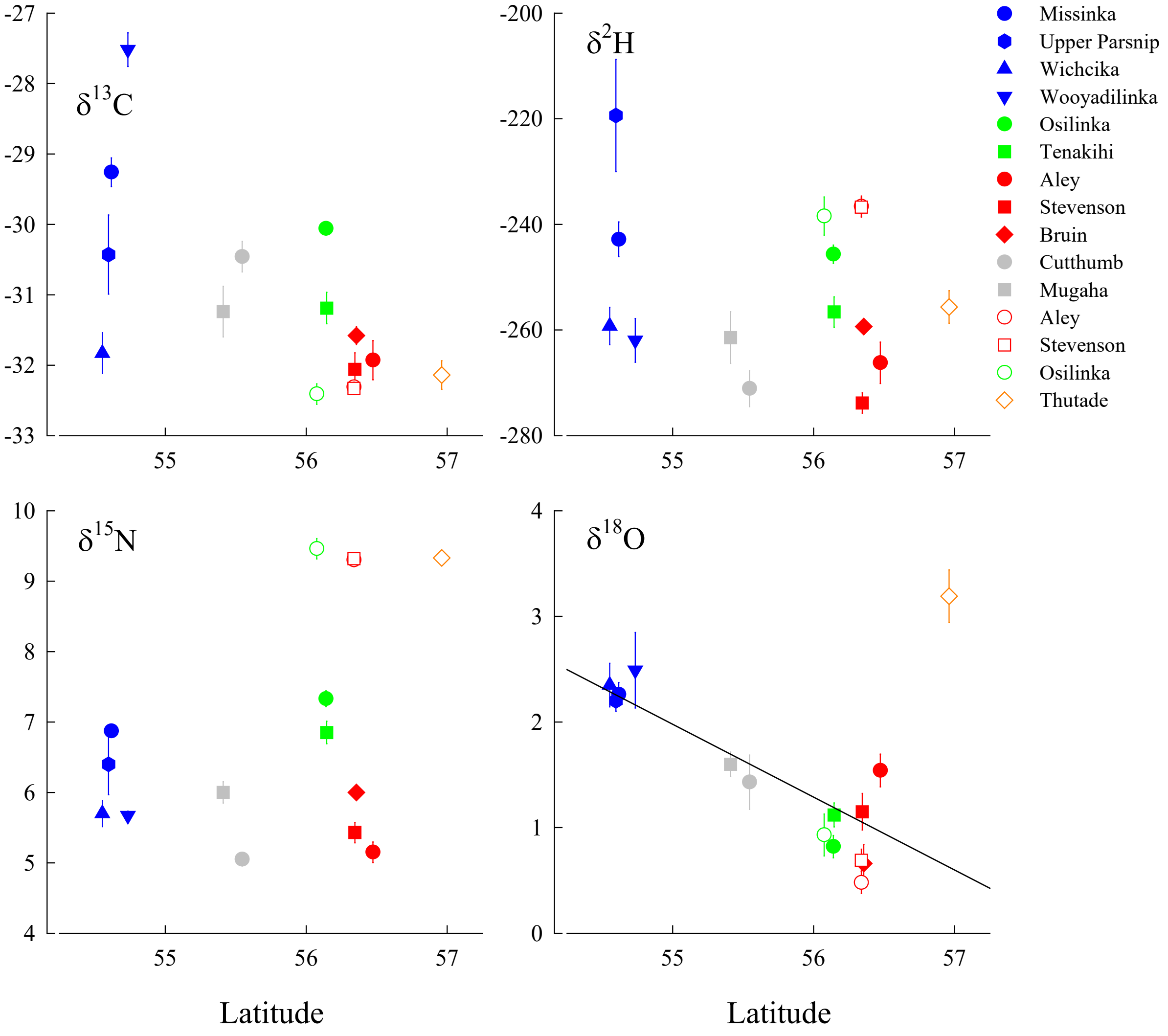

Figure A3.1. Stable isotope ratios for $\delta^{13}C$, $\delta^{15}N$, $\delta^{2}H$, and $\delta^{18}O$ from fish caught in tributary streams to the Williston Reservoir. Closed symbols are slimy sculpin; blue symbols are non-Kokanee streams and red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Open symbols are for spawning Kokanee captured in tributary streams to the Williston Reservoir or non-spawning Kokanee from Thutade Lake. There was a significant relationship between latitude and $\delta^{18}O$ for slimy sculpin sampled Williston Reservoir tributaries ($F_{1,9} = 38.54$; $P < 0.001$); there were no relationships between latitude and any of the other stable isotope relationships for slimy sculpin. Within the Parsnip River watershed, Analysis of Variance (ANOVA) revealed significant differences among $\delta^{13}C$ measurements ($F_{3,49} = 45.74$; $P < 0.001$), $\delta^{15}N$ measurements ($F_{3,49} = 19.03$; $P < 0.001$), $\delta^{2}H$ ($F_{3,49} = 13.09$; $P < 0.001$), but not for $\delta^{18}O$ measurements ($F_{3,49} = 0.25$; $P = 0.86$).

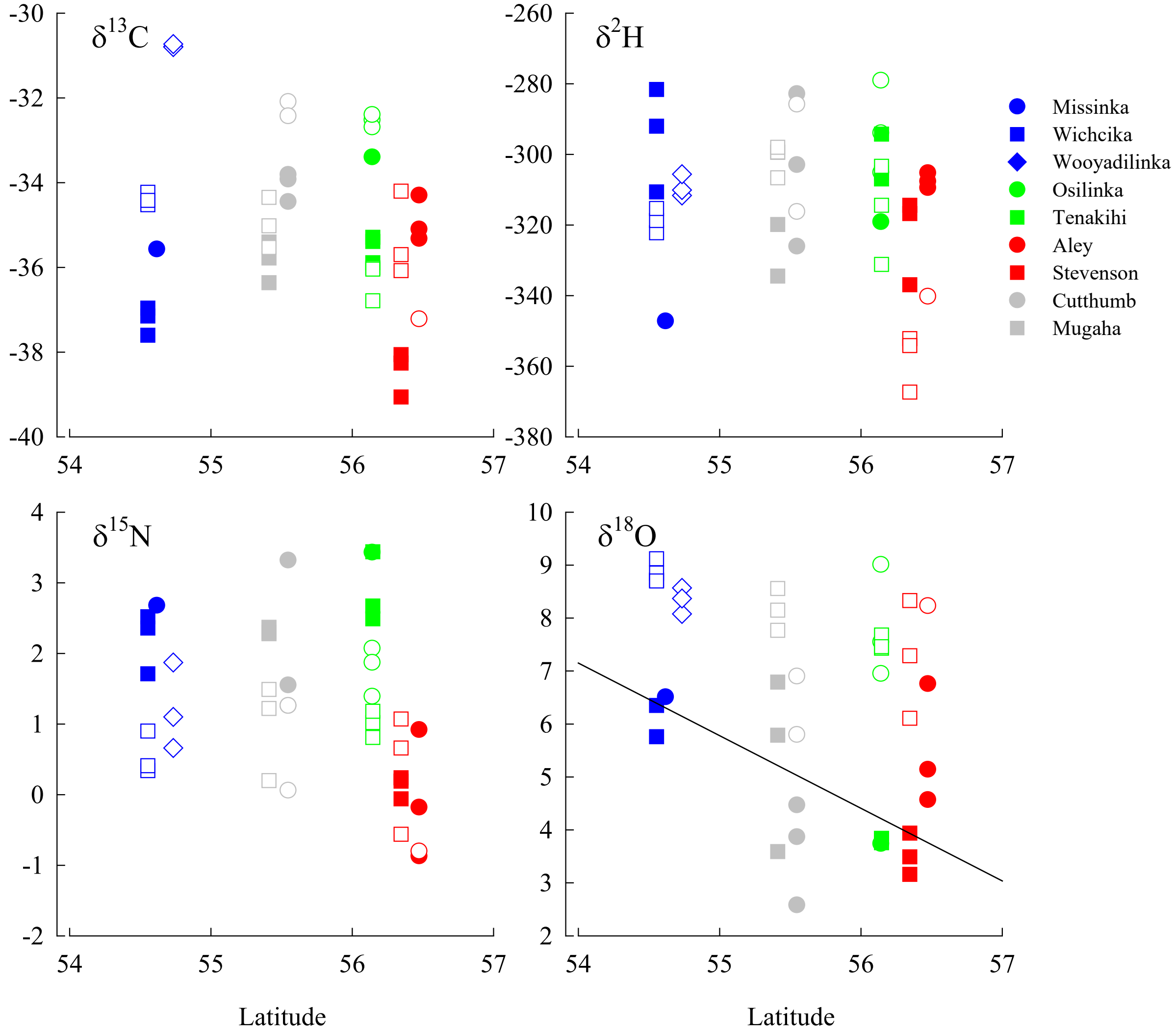

Figure A3.2. Stable isotope ratios for $\delta^{13}C$, $\delta^{15}N$, $\delta^{2}H$, and $\delta^{18}O$ from aquatic insects, Order Ephemeroptera, caught in tributary streams to the Williston Reservoir. Blue symbols are non-Kokanee streams; red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Closed symbols are samples collected in July 2017 and open symbols are samples collected in October 2017. There was a significant relationship between latitude and $\delta^{18}O$ for mayflies sampled in Williston Reservoir tributaries during the summer ($F_{1,6} = 7.68$; $P < 0.05$); there were no relationships between latitude and any of the other stable isotope relationships for mayflies sampled in the summer or fall.

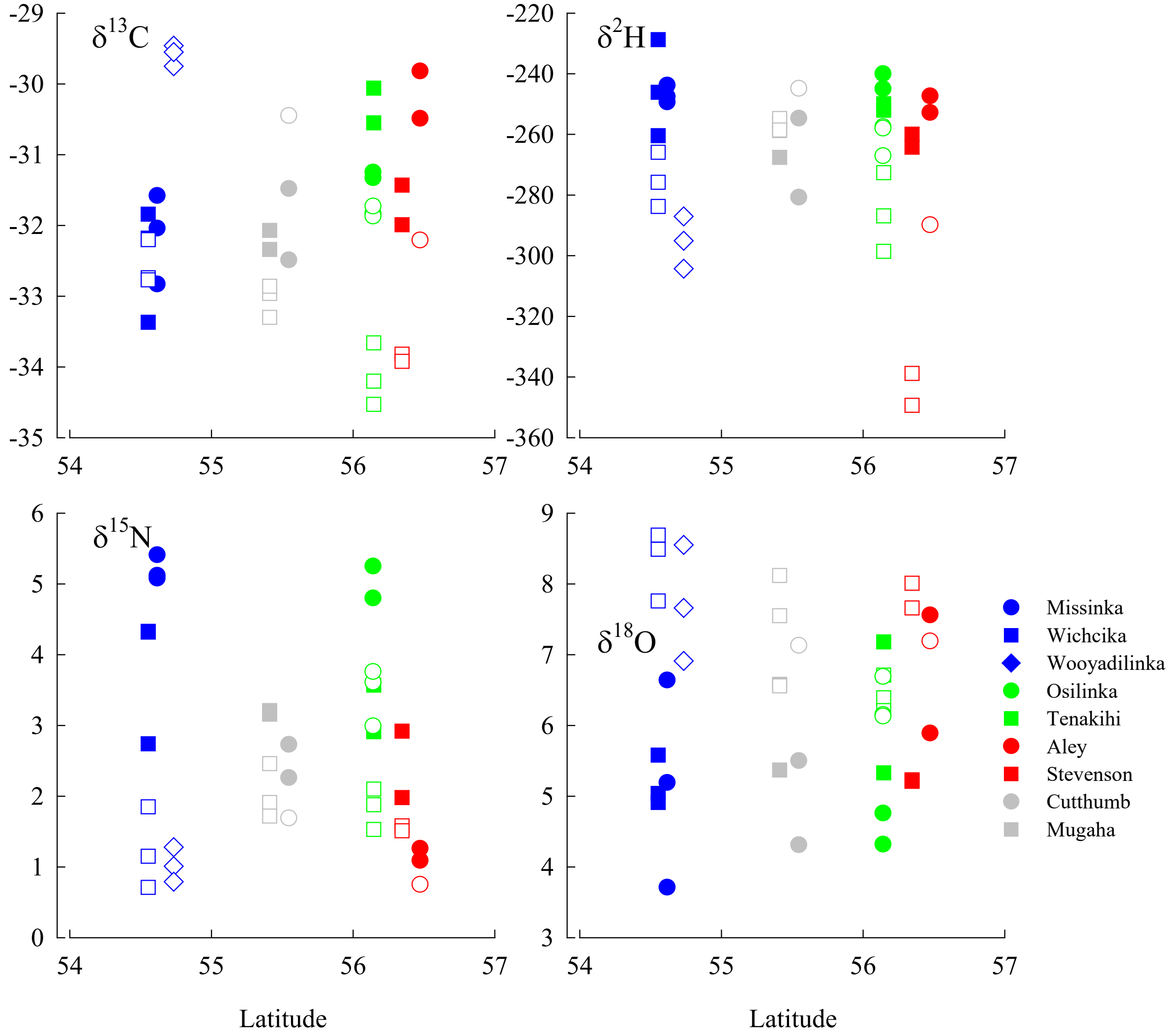

Figure A3.3. Stable isotope ratios for $\delta^{13}C$, $\delta^{15}N$, $\delta^{2}H$, and $\delta^{18}O$ from aquatic insects, Order Plecoptera, caught in tributary streams to the Williston Reservoir. Blue symbols are non-Kokanee streams; red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Closed symbols are samples collected in July 2017 and open symbols are samples collected in October 2017. There were no relationships between latitude and any of the stable isotope ratios for stoneflies sampled in the summer or fall.

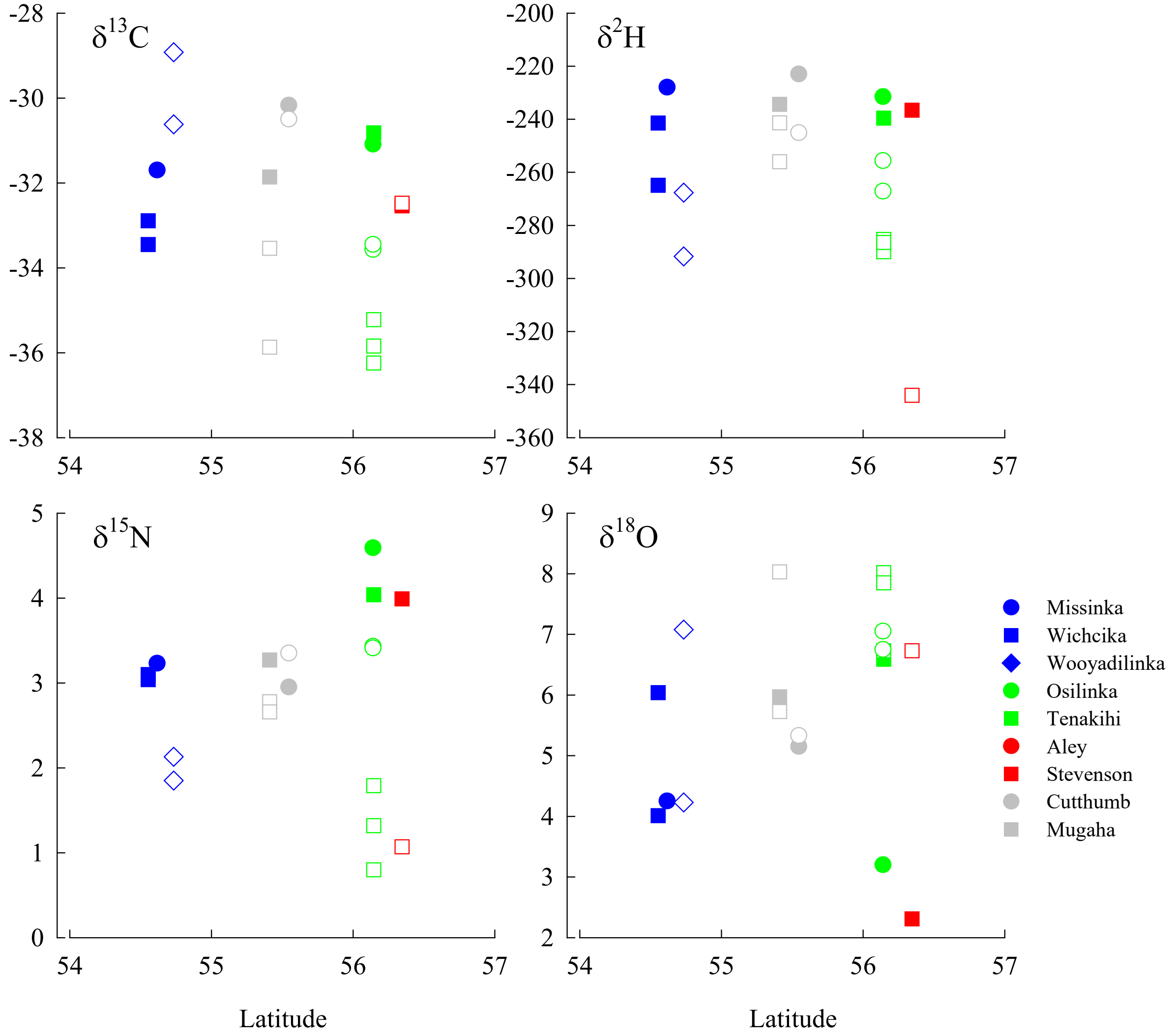

Figure A3.4. Stable isotope ratios for $\delta^{13}C$, $\delta^{15}N$, $\delta^{2}H$, and $\delta^{18}O$ from aquatic insects, Order Trichoptera, caught in tributary streams to the Williston Reservoir. Blue symbols are non-Kokanee streams; red, green and grey symbols are from systems where Kokanee spawn separated by major watershed. Closed symbols are samples collected in July 2017 and open symbols are samples collected in October 2017. There were no relationships between latitude and any of the stable isotope ratios for caddisflies sampled in the summer or fall.

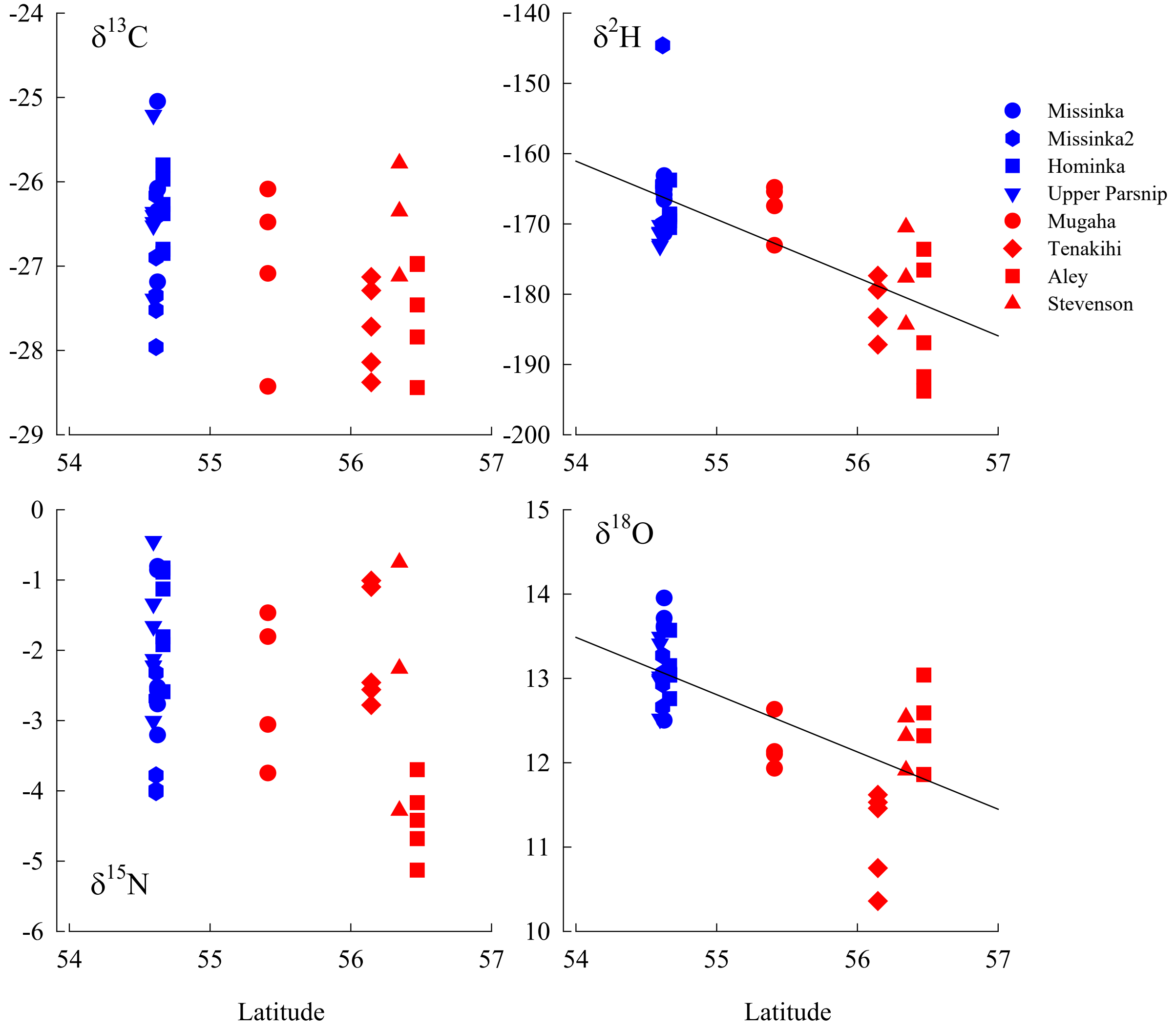

Figure A3.5. Stable isotope ratios for $\delta^{13}C$, $\delta^{15}N$, $\delta^{2}H$, and $\delta^{18}O$ from lichen, (*Parmelia squarrosa*), collected from riparian areas of tributary streams to the Williston Reservoir. Blue symbols are non-Kokanee streams; red symbols are from systems where Kokanee spawn. There was a significant relationship between latitude and $\delta^{2}H$ for lichen sampled from riparian areas associated with Williston Reservoir tributaries ($F_{1,6} = 19.55$; $P < 0.005$). There was also a significant relationship between latitude and $\delta^{18}O$ for lichen sampled from riparian areas associated with Williston Reservoir tributaries ($F_{1,6} = 9.63$; $P < 0.05$). There was no relationship between latitude and $\delta^{13}C$ or $\delta^{15}N$ for *Parmelia squarrosa*.