THESIS

INFLUENCE OF WATER SOURCES ON VEGETATION AND GEOMORPHIC CONDITIONS OF FIRST ORDER STREAMS IN GLACIER NATIONAL PARK, MONTANA, USA

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ABSTRACT

INFLUENCE OF WATER SOURCES ON VEGETATION AND GEOMORPHIC CONDITIONS OF FIRST ORDER STREAMS IN GLACIER NATIONAL PARK, MONTANA, USA

In 1850 at the end of the Little Ice Age, 150 glaciers existed in Glacier National Park (GNP), MT. In 2010, only 25 remained. Climate warming in mid-high latitudes and mountain regions, like GNP, is occurring more rapidly than any other place on Earth. This warming is causing extensive loss of glaciers and snowpack and in high elevation watersheds, glacier melt water exerts substantial influence on hydrogeomorphic processes producing floods, landslides, and debris flows. Rising temperatures will have short term and long term effects on stream flow from melting glaciers including increases in peak flows, stream temperature, and an increased potential for hydrogeomorphic hazards like rock avalanches, landslides, rock fall, glacial moraine dam failure, and outburst floods. From an ecological perspective changes in stream flow and geomorphic activity are important disturbances that form and maintain riparian wetlands. Riparian wetlands occupy a relatively small percentage of mountain landscapes but are important and highly sensitive ecosystems worldwide. The goal of this study was to 1) assess geomorphic conditions of first order stream types 2) identify plant community composition along first order stream types and 3) determine the importance of hydrogeomorphic conditions, topography, and water chemistry in explaining high elevation riparian plant community patterns. To do this, I surveyed vegetation and geomorphic conditions of first order streams directly connected to glaciers, snowfields, and springs. Vegetation data was analyzed at reach and plot (1 m^2) scales. Reach scale vegetation was grouped into four plant communities and plot scale vegetation was grouped into seven communities using hierarchical cluster analysis and indicator species analysis. Two of both reach and plot scale communities were characterized by an abundance of *Salix* species (willow). Non-metric multidimensional scaling was used to investigate relationships between stream types and hydrogeomorphic variables as well as plant community occurrence and abiotic variables. Permanova analysis was used to identify statistically significant hydrogeomorphic and vegetation differences in stream types. Hydrogeomorphic variables, particularly stream discharge was a proxy for disturbance and important in explaining variation in plant community patterns. Glacier streams typically had higher stream discharge values and higher frequencies of *Salix* communities compared to snow or spring fed sites. This research demonstrates the importance of glaciers in controlling hydrogeomorphic conditions and riparian plant community patterns and addresses threats to riparian communities as a result of retreating glaciers. Understanding the potential influences of climate induced changes in the hydrologic drivers of riparian wetlands is a critical topic with implications for channel stability, flood control, water chemistry, and biodiversity, all high priority concerns for GNP.

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1. INTRODUCTION

Climate warming is occurring more rapidly in mid to high latitudes, tropical, and mountain regions than other parts of the world (Pederson et al. 2010) resulting in extensive loss of glaciers and snowpack globally (IPCC 2014). For example, the area now in Glacier National Park (GNP), in the Northern Rocky Mountains, USA supported 150 glaciers in 1850 (Carrara 1989). Temperatures have steadily increased since the early 20th century and by 2010 the number of glaciers had declined to 25 (NOROCK 2010, Pederson et al. 2010). Air temperatures are predicted to continue to increase during the 21st century (IPCC 2014), resulting in the loss of all remaining glaciers in the region by 2030 (Hall and Fagre 2003). In many mountain ranges, glaciers and seasonal snowpack strongly influence the hydrologic cycle (Beniston et al. 1997), and thus their decline or complete loss is expected have large impacts on hydrologic and geomorphic processes important to aquatic and wetland ecosystems (Barnett et al. 2005, Hauer et al. 2007).

In high elevation watersheds, hydrogeomorphic processes are controlled by glacial and seasonal snowpack induced floods and debris flows (Fountain and Tangborn 1985, Stahl and Moore 2006). The short term response of streams influenced by rapidly melting glaciers include higher peak flows and greater diurnal flow variation (Hock et al. 2005). However, the long-term responses could include reduced stream flows, increased stream temperature, and higher potential for hydrogeomorphic hazards such as rock avalanches, landslides, debris flows, and glacial moraine dam failures until glaciers develop a stable equilibrium or disappear (Smith et al. 2001, Hock et al. 2005, Moore et al. 2009).

Riparian wetlands are formed and maintained by the hydrogeomorphic disturbance processes of streams (Cooper et al. 2012). Periodic flooding influences riparian plant species distribution, establishment, and diversity (Naiman et al. 1993, Bendix and Hupp 2000, Cooper et al. 2003, Cline and McAllister 2012). Disturbance events reset successional trajectories and promote the establishment of pioneer species (Salo et al. 1986, Tabacchi et al. 1998, Bendix and Hupp 2000, Whited et al. 2007). Riparian vegetation can also influence hydrogeomorphic conditions by stabilizing stream banks, limiting erosion, mitigating floods, and colonizing fluvial deposits (Corenblit et al. 2009). Changes in disturbance regimes and reduced stream flows can trigger changes in vegetation composition through reduced seedling establishment, unsuccessful recruitment of juveniles, and increased invasion of upland and exotic species into riparian habitats (Johnson et al. 1976, Boles and Dick-Peddie 1983, Smith et al. 1991, Shafroth et al. 2002). These changes can shift riparian communities toward later seral stages (Johnson et al. 1976, Smith et al. 1991).

Riparian species occur in areas where species less tolerant of fluvial disturbances cannot persist, supporting distinctive biodiversity across the landscape (Poff et al. 1997). In mountain regions riparian ecosystems are narrow, dynamic, and complex habitats providing critical ecosystem services such as wildlife habitat, stream temperature moderation, and water quality protection (Gray and Eddinton 1969, Naiman et al. 1993, Vought et al. 1994, NRC 2002, Burt and Pinay. 2005, Dosskey et al. 2010).

While the ecological patterns created by altered fluvial disturbance regimes have been investigated on low elevation rivers, little research has focused on high elevation riparian vegetation influenced by altered flow regimes due to glacial recession. Glacial loss has been linked to shifts in alpine plant colonization, primary succession, and altered stream aquatic ecosystems (e.g. Reiners et al. 1971, Jones and Henry 2003, Robbins and Matthews 2009, Muhlfeld et al. 2011, Brown and Milner 2012, Giersch et al. 2015), but little is known about how riparian ecosystems could respond to these changes.

The main first order stream types in the northern Rocky Mountain region include glacier, snow, and spring-fed stream types and information on how each stream type will respond to future climate changes is critical for managers (Brittain and Milner 2001, Hauer et al. 2007). I investigated riparian ecosystems along these alpine stream types by addressing the following questions:

Question 1: Do streams connected to glaciers, permanent snowfields, and springs have different geomorphic characteristics?

Question 2: Do riparian communities occur at the same frequency along the major alpine stream types?

Question 3: Is fluvial disturbance, topographic setting, or water chemistry the most important factor in explaining patterns in high elevation riparian plant communities?

2. STUDY AREA

Glacier National Park (GNP) covers nearly 4000 km^2 in northwest Montana, USA (Figure 1). The area ranges from approximately 1000 to 3200 m elevation and is bounded on all sides by land administered by the U.S. and Canadian governments. The east side of GNP experiences dry, windy continental air masses while the west side, separated from the east by the highest peaks of the northern Rocky Mountains, is highly influenced by moist Pacific air masses. Steep rocky peaks and glacially carved valleys characterize the entire landscape. Research sites are primarily on the eastern slopes of GNP where the majority of glaciers occur in east and northeast-facing valleys (Figure 1).

GNP supports many high elevation riparian wetland complexes connected to glaciers that are experiencing rapid environmental changes due to rapid glacial melting and retreat. High elevation plant species are particularly sensitive to climate (Spicer and Chapman 1990, Walther 2003, Pucko et al. 2011) and changes in the range and distribution of high elevation plant species have already been detected in GNP (Lesica and McCune 2004). The selected study sites will form a baseline understanding of alpine riverine processes for long term monitoring in GNP by the Rocky Mountain Network (ROMN) of the National Park Service (NPS) (Schweiger et al. n.d., Britten et al. 2007).

3. METHODS

3. 1. ASSIGNMENT OF STREAM TYPES

Stream types were initially defined by water sources and identified as glacier-fed, snow-fed, and spring-fed streams, however, glacier fed streams of two different types were present in study watersheds and I subdivided glacier fed streams into two types, resulting in four stream types: glacier (steep), glacier (flat), snow, and spring-fed streams. A glacier must be ~0.1 km^2 (100,000 m^2) in size to move (NOROCK 2010). Snowfields may be smaller than glaciers, and lack ice features such as crevasses. Springs are sites of groundwater discharge, with water originating from a range of sources. Glacier (steep) streams are similar to snow and spring-fed streams, occurring on steep hillslopes with streambeds of large boulders and cobbles while glacier (flat) streams occupy wide, shallow, low gradient, bedrock channels occurring in glacier cirques. Glacier, snow, and spring-fed streams are the main stream types in high elevation watersheds (Brittain and Milner 2001, Hauer et al. 2007) and were selected to represent future climate change scenarios in GNP as a glacier will likely transition to a permanent snowfield and snowfields to springs where stream flow may be ephemeral or intermittent. Streams types were classified as glacier, snow, or spring only if visual confirmation of the water source was present in the field (i.e. we could see meltwater from the glacier flow through our site). Due to lack of random sampling of study sites, statistical inference from these data can only be extrapolated to sampled sites.

3. 2. SAMPLE FRAME DEVELOPMENT

A total of 1832 watersheds were created for GNP using Hydrology Tools in ArcGIS 10.1. The National Hydrology Dataset (NHD) stream layer for GIS was too coarse to identify first order streams. Therefore, I created a fine scale stream raster using a flow accumulation of 10,000 to produce 1832 watersheds for stratification and approximate the location of alpine streams. Watersheds were initially stratified based on land above 1981 m elevation (Lesica 2002) resulting in 1083 watersheds and the presence of existing glaciers and/or permanent snowfields from GNP GIS layers resulting in 239 watersheds. Watersheds containing streams connected to glaciers and snowfields also contained streams with no apparent permanent water source and were classified as spring-fed streams.

A cost surface model was then applied to determine the travel time to potential study watersheds. Based on prior knowledge of access and terrain, a watershed that contained 65% area that was accessible in at 10.5 hours or less based on Natural Breaks (Jenks) classification method in ArcGIS was deemed accessible and resulted in 151 watersheds with reasonable accessibility (Figure 1). Each watershed was examined for access limitations using 2012 areal imagery and by consulting experienced backcountry hikers. A total of 120 watersheds had sufficient accessibility and contained glaciers and/or snowfields and springs. Clusters of suitable watersheds occurred in the Many Glacier, Logan Pass, Gunsight Pass, Boulder Pass, Two Medicine Lakes, and Upper Camas areas (Figure 1). Streams in these watersheds were identified using Google Earth imagery and a stream layer created in ArcGIS.

Ten out of 120 watersheds contained glaciers and were a top priority for sampling. Nearby watersheds were selected if they contained streams supported by at least two water sources based on GNP glacier/snowfield GIS layers and the alpine stream raster. Clusters of watersheds were sampled to facilitate access, while maintaining a balanced survey of streams within each stream type.

3. 3. SAMPLE REACH SELECTION

To examine the relationships between water sources, hydrogeomorphic conditions, and riparian vegetation composition, all study sites were first order stream reaches directly supported by glaciers, permanent snowfields, or springs. First order channels in GNP are poorly or not mapped at all. Therefore, determining the actual location of a sampled reach was not possible *a priori*. The largest streams connected to distinct water sources were selected for sampling and were determined during field surveys. Stream reaches, typically 10 to 75 m long with consistent slope, channel form, bank structure, and substrates, connected to a single water source, were selected for sampling. Where substrate, channel morphology, or vegetation varied along the stream corridor, multiple reaches were surveyed.

3. 4. PLOT LAYOUT

All field sampling occurred in July – September 2013 and August 2014. Two or three transects perpendicular to the stream flow direction were established at each chosen study reach. Stream reach length was determined by averaging five bank full width measurements and multiplying by ten. Maximum reach length was 30 m for glacier (steep), snow, and spring-fed streams and chosen to reduce sample time and capture a representative stream reach. Glacier (flat) sites had channel widths as high as 27 m and were given maximum reach length of 75 m.

Three transects were established unless reach length was less than 30 m and composed of homogenous landforms or when stream flow direction shifted along fluvial landforms, causing transects to angle away from each other. Along each transect, channel form and vegetation composition was analyzed. Stream water electrical conductivity (EC) and pH were measured with a YSI Sonde at the furthest downstream transect (T1) to represent the entire stream reach. Hourly stream temperature loggers were installed in sample reaches. Onset HOBO pendant loggers were secured in the stream bank and set to record hourly temperature values. Duplicate loggers were also installed nearby (see Appendix E for stream temperature data).

Transects (T) were established at equal distances with T1 downstream, T3 upstream and T2 in the center (Appendix C Figure 12). Surveys occurred along transects extending several meters perpendicular to the channel to include all riparian vegetation and were used to quantify the channel cross section, longitudinal slope, and standard determinations for bankfull (Harrelson et al. 1994). Riparian vegetation was sampled in 1 m^2 plots on fluvial landforms influenced by stream flow, such as islands, bars, banks, and floodplains.

3. 5. QUANTIFYING HYDROGEOMORPHIC CONDITIONS

Channel cross section and profile surveys and roughness estimates were used to calculate estimates of bankfull discharge and shear stress, both important hydrogeomorphic variables that were used as a proxy for disturbance (Williams 1978, Macleod et al. 2006). No discharge or velocity measurements were recorded as sampled sites were one time visits on first order ungagged streams. All hydrogeomorphic characteristics were quantified from channel cross section and profile surveys and were used as estimated bankfull stages (see Appendix B Table 10 for list of calculated variables and equations). Survey points representing the channel bed are concentrated where distinct topographical shifts occur and landforms that characterize the flood plain and channel banks. Bank full height was estimated using depositional features like point bars and slope, topographic changes along the channel bank, and high water marks or the lower extent of lichens on boulders. A channel profile (or slope) was also measured at each site and followed bankfull at equal intervals. Roughness, a measure of channel resistance using Manning's N, was estimated from photographs (Yochum et al. 2014).

3. 6. VEGETATION

The number of plots per reach varied from 6-15 plots with more plots required on the larger and wider stream reaches and those with a higher number of vegetated landforms. Aerial canopy cover estimates of vascular plant species, bare ground, litter, water, and dominant substrate type were collected in each plot. Vascular plants species nomenclature follows Lesica (2012).

3. 7. STATISTICAL ANALYSIS

3.7.1. *Analysis of disturbance variables and stream types*

A total of 36 stream reaches were analyzed (glacier (steep) = 7, glacier (flat) = 7, snow = 12, spring =10). Multivariate analyses were used to validate the assignment of stream types in the statistical software Primer-E with PERMANOVA + add-on (Clarke and Gorley 2006, Anderson et al. 2008) and univariate non-parametric methods were used to compare differences in hydrogeomorphic conditions across stream types. Permanova analysis in Primer-E allows for the comparisons of unbalanced sampled designs and was used to determine if hydrogeomorphic conditions differed between the 4 stream types. A PermDisp procedure was used to determine equal dispersion or variance of stream types. Non-metric multidimensional scaling (NMS) and Pearson correlations (r) were used on a Bray-Curtis similarity matrix to identify variables that explained differences in stream types. Cumulative r^2 values were calculated by summing r^2 values across all NMS axes to identify the variables that had the highest importance in explaining variation in stream types. Levene's test for homogeneity of variance, Kruskal-Wallis one-way analysis of variance, and a Nemenyi test for pairwise comparisons with Chi-square corrections for ties were used to examine hydrogeomorphic variables across stream types (Hollander and Wolfe 1999).

3.7.2. *Identification of plant communities*

The vegetation composition of 298 1 m^2 sample plots was analyzed in PC-Ord using hierarchical agglomerative cluster analysis to determine groups of plots with similar vegetation composition (i.e. a community) and indicator species analysis (ISA) to determine which species had the highest fidelity to each group (McCune and Mefford 2006). The number of plant communities was determined from the groups of plots in the cluster analysis and by maximizing the ISA indicator value (IV) of each species within a group while still maintaining significance (p-value <0.05). IV represents the fidelity of a species to a community defined by groups in the cluster analysis. The higher IV for a species, the more likely that species is to occur exclusively in one community and that the species of interest occurs in all stands within the community. Indicator species are not necessarily the most abundant species in a community. Multi-response permutation procedures (MRPP) were used to identify distinct vegetation composition of communities.

3.7.2.1. Reach scale vegetation

For each sample reach I averaged vegetation cover for each species present in $1 m^2$ plots. Species that occurred only one time were removed resulting in 106 species in 36 reaches. A cluster analysis of 36 reaches and 106 species using relative Sorensen's distance and flexible beta (-0.25) was used to create a distance matrix and determine groups of reaches with similar vegetation. ISA and MRPP were used as stated above.

3.7.2.2. Plot scale vegetation

Plots were removed if they contained only one species. Rare species were those that occurred in less than 2% of plots and were removed from analysis resulting in 83 species and 254 $1 m^2$ plots for analysis. A relative Sorensen's distance and flexible beta (-0.25) was used to create a distance matrix for 254 plots that contained 83 species and was used in the cluster analysis. The cluster analysis, ISA, and MRPP were then used to determine the number of communities; the species that best represent communities, and identify distinct vegetation composition of each community.

3.7.3. *Plant communities by stream type*

3.7.3.1. Reach scale vegetation community occurrence by stream type

Multivariate analyses using a Bray-Curtis similarity matrix were used to compare community composition of stream types in Primer-E. Community composition was compared across stream reaches using a vegetation matrix of stream reaches and plant species cover. PermDisp and Permova analysis in PRIMER-E were used to identify distinct community composition of stream reaches.

3.7.3.2. Plot scale vegetation community occurrence by stream type

To account for multiple plot scale communities occurring at each stream reach, a vegetation matrix of stream reaches and community presence/absence was created and analyzed using multivariate analysis and a Bray-Curtis similarity matrix. PermDisp and Permanova analysis, in PRIMER-E, were used to identify differences in community occurrence at stream types.

3.7.4. *Abiotic variables influencing plant communities*

Topographic, water chemistry, and hydrogeomorphic variables were compared to the species matrix and community presence/absence matrix in NMS ordinations and Spearman rank correlation values with the ordination axes were calculated. I also tested for differences in abiotic variables between plant communities at the reach scale and plot scale using Levene's test for homogeneity of variance, Kruskal-Wallis one-way analysis of variance, and a Nemenyi test with Chi-square corrections for ties was used to evaluate pairwise comparisons (Hollander and Wolfe 1999). Non-parametric tests were used as all abiotic variables had a non-normal distribution.

The topographic variables elevation, slope, and aspect were determined for each site. Elevation was recorded on a Garmin GPS at each field site. Channel slope was calculated using the longitudinal profile survey data between T1 and T3 (2). Aspect was rescaled from 0-360 degree measurement to a 0-1 scale, and used to create a heat load index (HI) with zero representing the coolest (northeast) slope and one representing the warmest (southwest) aspect (McCune and Grace 2002).

4. RESULTS

4.1. ANALYSIS OF DISTURBANCE VARIABLES AND OF STREAM TYPES

The four stream types had different hydrogeomorphic characteristics (Permanova, $p = 0.001$) and the two glacier supporting stream types have statistically distinct geomorphologic features (Table 1). Shear stress, discharge, (w/d) ratio, and roughness were identified as independent variables (Pearson correlations $(r) < 0.70$) and used in all analyses.

Glacier (steep) and snow fed streams have similar hydrogeomorphic characteristics (Permanova, $p = 0.446$) including shear stress, discharge, channel roughness, and w/d ratios (Figure 2, Table 1). Glacier (flat) stream types are characterized by high w/d ratios and lower shear stress and roughness than other stream types. Spring-fed streams typically had lower discharge than other stream types (Appendix B Figure 11). Shear stress ($r = -0.92$) and stream discharge ($r = -0.85$) best explained variation of hydrogeomorphic variables along axis 1 of the two-dimensional NMS ordination (Figure 2) while w/d ratio ($r = -0.90$) was the best explanatory variable for NMS axis 2. Stream discharge was the most important variable in explaining variation in stream types ($r^2 = 0.90$, Table 2).

4.2. IDENTIFICATION OF PLANT COMMUNITIES

A total of 147 vascular plant species were identified; 14 species of shrubs, 35 species of grasses, sedges, and rushes, and 98 herbaceous dicots and monocots. Four plant communities were identified at the reach scale (Table 3) and seven plant communities (Table 4) were identified at the plot scale using cluster analysis (9.22% chaining – reach scale, 1.32% chaining – plot scale) and indicator species analysis and the communities were significantly different at both scales (MRPP, $p < 0.001$, $A = 0.24$ (reach), MRPP, $p < 0.001$, 0.28 (plot)). At both scales, two communities were characterized by high cover of *Salix* species while other communities were characterized by high cover of herbaceous species. The indicator species for all communities typically occupy meadows, riparian zones, and wetland margins (Lesica 2012).

4.3. PLANT COMMUNITY OCCURRENCE AND STREAM TYPES

4.3.1. *Reach scale communities and stream types*

Stands of Salix dominated communities occurred at all stream types, however *Salix drummondiana- Hedysarum sulphurescens* stands occurred at glacier (steep), glacier (flat) and at snow-fed streams, but not at spring-fed sites. Vegetation at each stream type differed significantly (Permanova, $p = 0.001$), however vegetation of snow-fed streams is similar to glacier (steep), glacier (flat), and spring-fed stream types (Figure 3, Table 5).

4.3.1.1. *Salix* communities

Two *Salix* communities occurred at higher frequencies along glacier-fed streams than snow or spring fed streams (Figure 3). Stands of the *Salix drummondiana – Hedysarum sulphurescens* community ($n = 8$ reaches) occurred at 57% of glacier (steep) sites and 29% of glacier (flat) sites. *Salix drummondiana* is tolerant of frequent disturbance caused by seasonal flooding and is often found in well aerated coarse textured soils along streams at mid-high elevations, along wetland boundaries, and on glacial moraines and talus (Uchytil 1991, Cooper et al. 2000, Lesica 2012). *Hedysarum sulphurescens* can occur in grasslands, gravel bars, and calcareous moraines (Lesica 2012).

Salix commutata – Castilleja occidentalis (n = 5 reaches), occurred at 43% of glacier (flat) sites (Figure 3). *Salix commutata* occurred along streams and in areas of late summer snowmelt and is an early successional species in recently de-glaciated landscapes (Wood and Moral 1987, Jumpponen et al. 2002, Lesica 2012). *Castilleja occidentalis* occurs in moist meadows and on moraines, in subalpine and alpine meadows, and along streams (Lesica 2012).

4.3.1.2. Herbaceous communities

Stands of *Mimulus lewisii- Veratrum viride* (n=3 reaches) occurred only at spring-fed sites (Figure 3). *Mimulus lewisii* and *Veratrum viride* can occur on moist sites in meadows, gravelly soils along streams, or in areas where water discharges to the surface (Lesica 2012). *Oxyria digyna- Ranunculus karelinii* (n = 20 reaches) communities occurred at all stream types (Figure 3), but were the most common stands at snow and spring-fed sites. *Oxyria digyna* and *Ranunculus karelinii* occur on stony, moist to wet soils (Lesica 2012).

4.3.2. *Plot scale communities and stream types*

Stands from all seven community types occurred at glacier (steep), glacier (flat), and snow-fed streams, while spring-fed sites had no occurrences of the *Salix drummondiana – Symphyotrichum foliaceum* community (Figure 4). The frequency of sampled stands of each community type varied significantly (Permanova, p = 0.001), however glacier (steep) and glacier (flat) sites support similar frequencies of each community (p = 0.335) and snow and spring sites had different proportions of each community type from each other and from glacier (steep) and glacier (flat) sites (Table 6).

4.3.2.1. *Salix* communities

Two *Salix* communities occurred at higher frequencies along glacier-fed streams than snow or spring fed streams (Figure 4). Stands of the *Salix drummondiana – Symphyotrichum foliaceum* community (n = 37 plots) occurred at 71% of glacier (steep) sites and 43% of glacier (flat) sites. While *Salix drummondiana* is tolerant of disturbance, *Symphyotrichum foliaceum* is a more general species and can occur in moist areas across all elevations (Lesica 2012). A second willow community, *Salix commutata – Carex podocarpa* (n = 18 plots), occurred at 57% of glacier (flat) sites (Figure 4). Both indicator species for this community occur in wet meadows and along streams (Lesica 2012).

4.3.2.2. Herbaceous communities

Stands of the *Chamerion latifolium – Epilobium anagallidifolium* (n = 37 plots) community occurred at 71% of glacier (flat) sites (Figure 4). *Chamerion latifolium* and *Epilobium anagallidifolium* are early colonizers and establish on recently de-glaciated areas as early as 10-40 years after deglaciation as well as on gravel bars and rocky slopes (Reiners et al. 1971, Jumpponen et al. 2002, Jones and Henry 2003, Robbins and Matthews 2009, 2010, Lesica 2012). *Epilobium anagallidifolium* is likely to occur in wet areas such as mossy or gravelly seeps, meadows, and along streams (Lesica 2012).

The *Hypericum formosum – Erigeron peregrinus* and *Mimulus tilingii – Epilobium clavatum* communities occur in moist and wet areas at all elevations. Stands of the *Hypericum* *formosum – Erigeron peregrinus* community (n = 65 plots) were found at 92% of snow and 90% of spring-fed stream sample sites (Figure 4). Both indicator species can dominate meadow ecosystems and are not limited to riparian and wetland habitats (Tardiff et al. 1998, Lesica 2012). *Mimulus tilingii – Epilobium clavatum* (n = 19 plots) stands were commonly found at glacier (flat) and snow-fed streams (Figure 4). Both indicator species overlap in habitat preferences and occupy moist to wet stony areas. *Mimulus tilingii* is more likely to occur along shallow streams while *Epilobium clavatum* can occur on moist glacial moraines and talus slopes (Lesica 2012).

Indicator species of the *Saxifraga lyallii – Veronica wormskjoldii* (n = 27) and *Senecio triangularis – Mimulus lewisii* (n = 51 plots) communities occur on moist sites with gravelly soils usually along streams or in meadows where water discharges to the surface (Lesica 2012). *Saxifraga lyallii – Veronica wormskjoldii* stands were found in higher frequencies along glacier (flat) and spring fed streams, while *Senecio triangularis – Mimulus lewisii* occurred frequently at snow and spring-fed streams (Figure 4).

4.4. ABIOTIC VARIABLES THAT INFLUENCE PLANT COMMUNITY OCCURRENCE

A combination of hydrogeomorphic and topographic variables were correlated with plant community composition at reach scales and with community occurrence at plot scales (Figure 5-7, Table 7). For reach and plot scales, channel slope, elevation, stream discharge, roughness, and w/d ratio had high correlations with NMS axes. Channel slope was highly correlated with shear stress (Pearson r = 0.79) and removed from the analysis of hydrogeomorphic conditions and stream types.

4.4.1. *Abiotic variables and reach scale vegetation*

Variation in vegetation composition on axis 1 of the three dimensional NMS ordination was best explained by elevation (ρ = -0.47) and stream discharge (ρ = 0.37). Roughness (ρ = 0.48), elevation (ρ = -0.46), and w/d ratio (ρ = -0.45) had the highest correlations with vegetation composition on axis 2 while axis 3 was best explained by channel slope (ρ = -0.33) and shear stress (ρ = -0.33). Water chemistry variables had low correlations with all three axes. No abiotic variables differed significantly between reach scale plant communities (Figure 8).

4.4.2. *Abiotic variables and plot scale vegetation*

Stream discharge (ρ = -0.45), elevation (ρ = 0.41), channel slope (ρ = 0.36), and w/d ratio (ρ = 0.30) had the highest correlations with axis 1of the three-dimensional NMS ordination. Differences in frequency of plant community occurrence on axis 2 was best explained by the hydrogeomorphic variables roughness (ρ = -0.42), w/d ratio (ρ = -0.41), and discharge (ρ = -0.33). No variables were highly correlated with axis 3. Elevation was the only abiotic variable that differed significantly between plant communities (Kruskal – Wallis, χ^2 = 13.74, p-value = 0.0469, Figure 9), however the results of pairwise comparisons offered no indication that elevation differed considerably between pairs of communities.

5. DISCUSSION

The spatial extent of riparian willow communities is influenced by the hydrogeomorphic conditions and disturbance regimes of streams driven by different water sources. Although two types of glacier fed streams occur in the study area, both stream types have high discharge and may experience similar hydrogeomorphic disturbances caused by retreating glaciers.

Hydrogeomorphic disturbance in glacier-fed streams constructs and modifies landforms resulting in an increase in suitable habitat for willows and the communities they dominate. *Salix* dominated communities are characteristic of glacier-fed streams and provide distinctive structure and functioning to these stream types. Snow-fed streams have similar hydrogeomorphic characteristics to some glacier-fed streams, but support few occurrences of willow communities. Spring-fed streams are typically stable streams with low disturbance and support habitat suitable for herbaceous species. Patterns of willow communities described by this study are likely representative of first order streams in GNP.

5.1. PLANT COMMUNITY PATTERNS AND HYDROGEOMORPHIC CONDITIONS AT STREAM TYPES

Glacier (steep) and glacier (flat) stream types have higher discharge and frequencies of willow communities at reach and plot scales than other stream types. Glaciers supporting these stream types have lost an average of 38% of their surface area since 1966 (NOROCK 2014), causing significant hydrologic and geomorphic disturbance (Moore et al. 2009). Retreating glaciers not only produce high flows and sediment loads that result in the deposition of alluvial and colluvial materials, but also remove vegetation through disturbance (Smith et al. 2001, Weekes et al. 2015). *Salix* species establish on bare and wet mineral soil surfaces and transform stream valleys into woodlands (Karrenberg et al. 2002, Corenblit et al. 2009, Cline and McAllister 2012). At the plot level, colonization of alluvial materials is most apparent at glacier (flat) sites as species from *Chamerion latifolium- Epilobium anagallidifolium* community occur in 20-40% of *Salix commutata- Carex podocarpa* stands suggesting overlap in habitat preference for these species as they colonize the understory of *Salix* dominated stands.

With the loss of glaciers in GNP predicted to occur by 2030, glacier-fed streams are likely to change into snow-fed streams, with distinctive shifts in hydrogeomorphic characteristics. Although this study indicates that some snow-fed streams share many hydrogeomorphic characteristics with glacier-fed streams, similarities are likely due to relic hydrogeomorphic processes in transition from glacier to snowpack, the decline of permanent snowpack, and stochastic rain on snow events (Hauer et al. 1997). Diminished discharge in snow-fed streams promotes favorable conditions for herbaceous communities that are less influenced by dynamic stream flows than willow communities (Karrenberg et al. 2002, Bruno et al. 2014). Relic conditions and stochastic flood events may sustain a slow decline in willow communities and explain low occurrences at snow-fed sites. Reach scale vegetation composition at snow-fed sites is similar to glacier and spring fed sites, indicating that snow-fed streams may represent an intermediate step in shifting water sources, hydrogeomorphic conditions, and vegetation successional patterns across stream types.

Spring fed streams have hydrogeomorphic characteristics and occurrences of plant communities that are highly distinctive. Spring fed sites have the lowest discharge of all stream types and support primarily herbaceous communities with only scattered patches of *Salix* communities at both reach and plot scales. Low colonization success of *Salix* communities along spring-fed streams is likely influenced by a combination of abiotic and biotic interactions. Low disturbance regimes allow mosses to proliferate on cobbles and boulders within and adjacent to streams, and on bare ground thereby reducing suitable habitat for willows but creating habitat for herbaceous species (Englund 1991).

In this study, bankfull discharge is a measurement of maximum flow allowed by the channel structure and does not reflect variation in stream flow patterns that are important for biota (Poff et al. 1997). Although this research assumes that current vegetation is a result of bankfull hydrogeomorphic conditions, headwater mountain streams in GNP likely receive bankfull discharge during spring and early summer runoff due to the larger accumulation of snow at high elevations than at low elevations. In summer months retreating glaciers may provide higher peak flows than spring- fed sites due to rising temperatures that deplete glacier and snowfield water storage at higher rates than in spring runoff (Hinzman et al. 2005).

5.2. ABIOTIC VARIABLES INFLUENCING PLANT COMMUNITY OCCURRENCE

My findings that hydrogeomorphic patterns are strongly related to riparian plant community patterns are supported by theoretical and empirical evidence (Gregory et al. 1991, Naiman and Decamps 1997, Bendix and Hupp 2000, Rivaes et al. 2013). After large and destructive disturbance events, *Salix* species can establish on the bare mineral surfaces of snow-fed streams, but if stream flows diminish due to reductions in winter snowpack or a shift from a glacier-fed stream to a permanent snowfield fed stream, willow communities may not persist (Tabacchi et al. 2000, Corenblit et al. 2009). If glaciers transition to snowfields and then to springs under future climate conditions, the decline of willow communities will likely occur along first order riparian streams due to changes in hydrogeomorphic conditions and reduced stream flows (Nilsson and Berggren 2000, Lyon and Gross 2005).

Shifts in riparian community structure from shrubs (willows) to herbaceous vegetation can result in a loss of biodiversity across the landscape. Continued monitoring of sampled sites will provide valuable information not only on vegetation changes, but also how stream structure and function may change over time as water sources change.

Although elevation was highly correlated with riparian plant community occurrence, it alone does not explain the low frequencies or absence of stands of *Salix* communities at snow and spring-fed sites. Stands of reach and plot scale *Salix drummondiana* communities occur at their highest elevation at 1976 m along a glacier (steep) fed stream. Snow and spring-fed stream sites range from 1679 to 2217 m and 1854 to 2186 m respectively, well within the elevation range of *Salix drummondiana.* It is most likely that elevation is correlated to plant community occurrence because *Salix drummondiana* is most common at glacier (steep) streams that typically occur at lower elevations (Figure 3, Figure 4, Appendix B Figure 11) instead of explaining patterns of vegetation composition or plant community occurrence. While elevation influences riparian vegetation at a macro-scale (Baker 1989), it is an unlikely driver in this study where sample sites are located in a narrow elevation range (1679 – 2290 m).

Channel slope was calculated for the stream reach, however channel slope does not reflect the slope of in stream microhabitats occupied by riparian vegetation (Naiman and Decamps 1997, Bendix and Hupp 2000). Channel slope was removed from the suite of hydrogeomorphic variables in initial comparisons of streams types as it was highly correlated with shear stress (Pearson correlation ≥ 0.7) suggesting that channel slope may be better suited as a hydrogeomorphic variable instead of a topographic variable for first order streams (Montgomery and Buffington 1997).

While pH and EC best explained variation of community occurrence on axis 3 for plot scale community patterns, the correlation between pH and EC and community occurrence was relatively low compared to other variables. Neither communities (reach and plot scale) nor stream types differed significantly in pH or EC and the total variance was quite low showing neutral values (6.5-8.1) for pH and diluted water (8.0-118.2 µS) for EC. At the reach scale, pH and EC had the lowest relative correlation values compared to other variables, providing further evidence that EC and pH may explain variation in site rather than plant community or stream types and are not particularly important for structuring the occurrence of riparian communities at high elevations. Soil pH and EC are important for riparian areas and water pH and EC are important determinates of wetland vegetation patterns (Merritt and Cooper 2000, Cooper et al. 2010, Lemly and Cooper 2011, Kuglerova et al. 2014), however water pH and EC were unimportant in explaining variation in plant community occurrence in this study .

6. CONCLUSION

The hydrogeomorphic processes of streams fed by glacier meltwater support abundant *Salix* dominated communities. Poole (2012) outlined research that has advanced the fields of aquatic and riparian ecology by incorporating hydrogeomorphic conditions in ecological frameworks. My study provides new insight into riparian ecology by identifying water sources as the key driver of hydrogeomorphic conditions. When glaciers disappear from GNP, changes in stream hydrogeomorphic conditions could significantly alter willow communities that could become less common. *Salix* species play critical roles in channel geomorphic conditions and the decline of willow communities could decrease stream bank stabilization and increase soil erosion (Corenblit et al. 2009). Additionally, riparian vegetation is crucial for aquatic ecosystem function and changes in riparian community types could impact food sources and habitat for alpine aquatic and terrestrial fauna (Flory and Milner 1999, Baxter et al. 2005).

Future studies of high elevation riparian areas should include measures of channel form and structures as variables derived from these measurements were highly correlated with plant community patterns. Vegetation patterns are strongly connected to hydrogeomorphic conditions connected to shifting water sources. Vegetation has been reported to take 10 years to respond to stream hydrologic changes (Ström et al. 2011) and large shifts in vegetation could be caused by the significant changes in hydrologic characteristics in GNP in the near future (Hall and Fagre 2003). My research provides a framework for future scenarios of riparian vegetation composition by considering water sources in future climate scenarios. When glaciers disappear and transition into permanent or intermittent snowfields shifts in vegetation structure from willows (shrubs) to herbaceous vegetation can lead to the loss of riparian vegetation in high elevation environments and result in decreased biodiversity across the landscape.

7. TABLES AND FIGURES

Table 1: Permanova p-values for pairwise comparisons of stream types with hydrogeomorphic variables. PermDisp procedure shows equal dispersion between stream types (p = 0.616). Global Permanova p-value = 0.001

Stream Types	Glacier (steep)	Glacier (flat)	Snow	Spring
Glacier (steep)	-----	-----	-----	-----
Glacier (flat)	0.001	-----	-----	-----
Snow	0.435	0.002	-----	-----
Spring	0.008	0.001	0.018	-----

Table 2: Pearson correlations (r) with a cut off r = 0.80 for each hydrogeomorphic variable along NMS axis 1 and 2 where +/- signifies the direction of the correlation. Cumulative r^2 values are also shown.

Hydrogeomorphic Variables	Axis 1	Axis 2	Cumulative r^2
Discharge	0.92(+)	0.23(+)	0.90
Roughness	0.54(+)	0.58(-)	0.63
Shear Stress	0.84(+)	0.36(-)	0.84
Width/(max)Depth	0.12(-)	0.90(-)	0.82

Table 3: Indicator species for reach level communities in Glacier National Park first order alpine streams, with up to 3 species shown per community. Communities are named by the top two indicator species. “Indic” refers to the indicator value (p<0.05) for the species listed. Mean cover value and constancy class values shown in bold represent the community for which the species is an indicator. Species with low constancy (class I) were omitted from this table for readability. Constancy classes: I, 0%-20%; II, 20%-40%; III 40%-60%; IV, 60%-80%; V, 80%-100%.

		Mean cover and constancy class by plant community			
Scientific name	Indic	A	B	C	D
(A) Mimulus lewisii, Veratrum viride **(n=3)**					
Mimulus lewisii	82.3	**29.06,V**	0.71,III	2.26,IV	-----
Veratrum viride	65.9	**1.19,IV**	-----	-----	-----
Chamerion angustifolium	64.2	**1.86,IV**	-----	-----	-----
(B) Oxyria digyna, Ranunculus karelinii **(n=20)**					
Oxyria digyna	64.3	0.8,V	**2.05,V**	0.48,V	0.13,II
Ranunculus karelinii	59.9	0.05,II	**0.32,IV**	0.01,III	-----
(C) Salix commutata, Castilleja occidentalis **(n=5)**					
Salix commutata	88.7	-----	-----	**17,V**	1.61,II
Castilleja occidentalis	40.6	-----	-----	**0.23,V**	0.24,II
(D) Salix drummondiana, Hedysarum sulphurescens **(n=8)**					
Salix drummondiana	81.5	-----	-----	1.39,II	**22.24,V**
Hedysarum sulphurescens	50	-----	-----	-----	**0.34,III**
Abies lasiocarpa	37.5	-----	-----	-----	**0.03,II**

Table 4: Indicator species for plot level communities in Glacier National Park first order alpine streams, with up to 5 species shown per community. Communities are named by the top two indicator species. “Indic” refers to the indicator value (p<0.05) for the species listed. Mean cover value and constancy class values shown in bold represent the community for which the species is an indicator. Species with low constancy (class I) were omitted from this table for readability. Constancy classes: I, 0%-20%; II, 20%-40%; III 40%-60%; IV, 60%-80%; V, 80%-100%.

		Mean cover and constancy class by plant community						
Scientific name	Indic	A	B	C	D	E	F	G
(A) *Chamerion latifolium, Epilobium anagallidifolium* (n=37)								
Chamerion latifolium	41.6	**5.6,III**	-----	-----	-----	-----	-----	-----
Epilobium anagallidifolium	29.9	**1.2,III**	1,II	-----	0.9,II	0.3,II	0.8,III	1.2,II
Poa alpine	28.4	**1.1,III**	0.5,III	0.3,II	0.3,II	0.6,III	0.8,III	-----
Oxyria digyna	27.1	**3,IV**	1.1,II	0.6,III	0.4,II	-----	1.1,III	2,II
Packera cymbalaria	17	**0.6,II**	-----	-----	-----	-----	0.2,II	-----
(B) *Hypericum formosum, Erigeron peregrinus* (n=65)								
Hypericum formosum	18.3	-----	**2.4,II**	-----	1.1,II	-----	-----	0.8,II
Erigeron peregrinus	17.2	-----	**1.8,II**	-----	1.4,II	-----	-----	1.1,II
Salix arctica	14.6	-----	**8,II**	-----	0.3,II	-----	-----	-----
(C) *Mimulus tilingii, Epilobium clavatum* (n=19)								
Mimulus tilingii	72.8	0.8,II	0.7,II	**8.6,V**	-----	-----	0.4,II	0.7,III
Epilobium clavatum	35.8	-----	0.5,II	**1.8,IV**	-----	-----	0.9,II	0.5,III
Romanzoffia sitchensis	15.7	-----	-----	**0.2,II**	-----	-----	-----	-----
Trisetum spicatum	15.3	-----	-----	**0.2,II**	-----	-----	-----	-----
(D) *Salix commutata, Carex podocarpa* (n=18)								
Salix commutata	93.7	-----	-----	-----	**51.9,V**	-----	-----	-----
Carex podocarpa	21	-----	4.5,II	-----	**3.5,IV**	-----	0.9,III	1.6,III
Triantha occidentalis	20.7	-----	-----	-----	**0.5,II**	-----	-----	-----
Parnassia fimbriata	14.2	-----	0.4,II	-----	**1.1,III**	-----	0.8,II	-----
Pedicularis groenlandica	11.5	-----	-----	-----	**1,II**	-----	-----	-----
(E) *Salix drummondiana, Symphyotrichum foliaceum* (n=37)								
Salix drummondiana	86	-----	-----	-----	2.4,II	**32.2,V**	-----	-----
Symphyotrichum foliaceum var. foliaceum	13.5	-----	-----	-----	0.8,II	**1.5,III**	-----	-----
(F) *Saxifraga lyallii, Veronica wormskjoldii* (n=27)								
Saxifraga lyallii	76.6	0.5,II	1,II	0.7,II	0.7,II	-----	**20.8,V**	0.9,II
Veronica wormskjoldii	14.9	-----	0.7,II	-----	-----	-----	**0.5,II**	-----
(G) *Senecio triangularis, Mimulus lewisii* (n=51)								
Senecio triangularis	53.5	-----	2.4,III	0.9,III	0.5,II	-----	3.5,III	**14.8,V**
Mimulus lewisii	32.1	-----	-----	0.9,II	-----	-----	0.9,II	**13,III**
Carex paysonis	17.9	-----	-----	-----	-----	-----	-----	**1.7,II**

Table 5: Permanova p-values for pairwise comparisons of reach scale community composition at each stream type. PermDisp, p-value = 0.099. Global Permanova, p-value = 0.003

Stream Types	Glacier (steep)	Glacier (flat)	Snow	Spring
Glacier (steep)	-----	-----	-----	-----
Glacier (flat)	0.028	-----	-----	-----
Snow	0.056	0.06	-----	-----
Spring	0.001	0.001	0.228	-----

Table 6: Permanova p-values for pairwise comparisons for occurrence of plot scale plant communities at each stream type. PermDisp, p-value = 0.121.
Global Permanova, p-value = 0.001

Stream Types	Glacier (steep)	Glacier (flat)	Snow	Spring
Glacier (steep)	-----	-----	-----	-----
Glacier (flat)	0.335	-----	-----	-----
Snow	0.014	0.026	-----	-----
Spring	0.001	0.001	0.026	-----

Table 7: Abiotic variables and Spearman rank correlation values (ρ) for abiotic variables along NMS axes 1, 2, and 3 of reach scale and plot scale community matrix where +/- signifies the direction of the correlation. Cutoff , ρ = 0.3 for both reach and plot scales.

REACH SCALE			
Abiotic variables	Axis 1	Axis 2	Axis 3
Topographic variables			
Aspect HI	0.19 (+)	0.04 (+)	0.17 (-)
Channel Slope	0.27 (-)	0.26 (+)	0.33 (-)
Elevation	0.47 (-)	0.46 (-)	0.02 (+)
Hydrogeomorphic variables			
Discharge	0.37 (+)	0.12 (-)	0.15 (-)
Roughness	0.17 (+)	0.48 (+)	0.28 (-)
Shear Stress	0.05 (+)	0.28 (+)	0.33 (-)
Width/(max) Depth	0.11 (+)	0.37 (-)	0.22 (+)
Water Chemistry variables			
EC	0.2 (+)	0.24 (-)	0.07 (+)
pH	0.06 (+)	0.02 (-)	0.03 (-)
PLOT SCALE			
Abiotic variables	Axis 1	Axis 2	Axis 3
Topographic variables			
Aspect HI	0.11 (-)	0.05 (+)	0.19 (-)
Channel Slope	0.36 (+)	0.01 (+)	0.02 (-)
Elevation	0.41 (+)	0.17 (-)	0.20 (-)
Hydrogeomorphic variables			
Discharge	0.45 (-)	0.33(-)	0.06 (-)
Roughness	0.07 (-)	0.42(+)	0.17 (-)
Shear Stress	0.04 (-)	0.05(-)	0.08 (-)
Width/(max) Depth	0.30 (-)	0.41(-)	0.07 (+)
Water Chemistry variables			
EC	0.16 (-)	0.12 (-)	0.20 (-)
pH	0.10 (-)	0.03 (-)	0.28 (-)

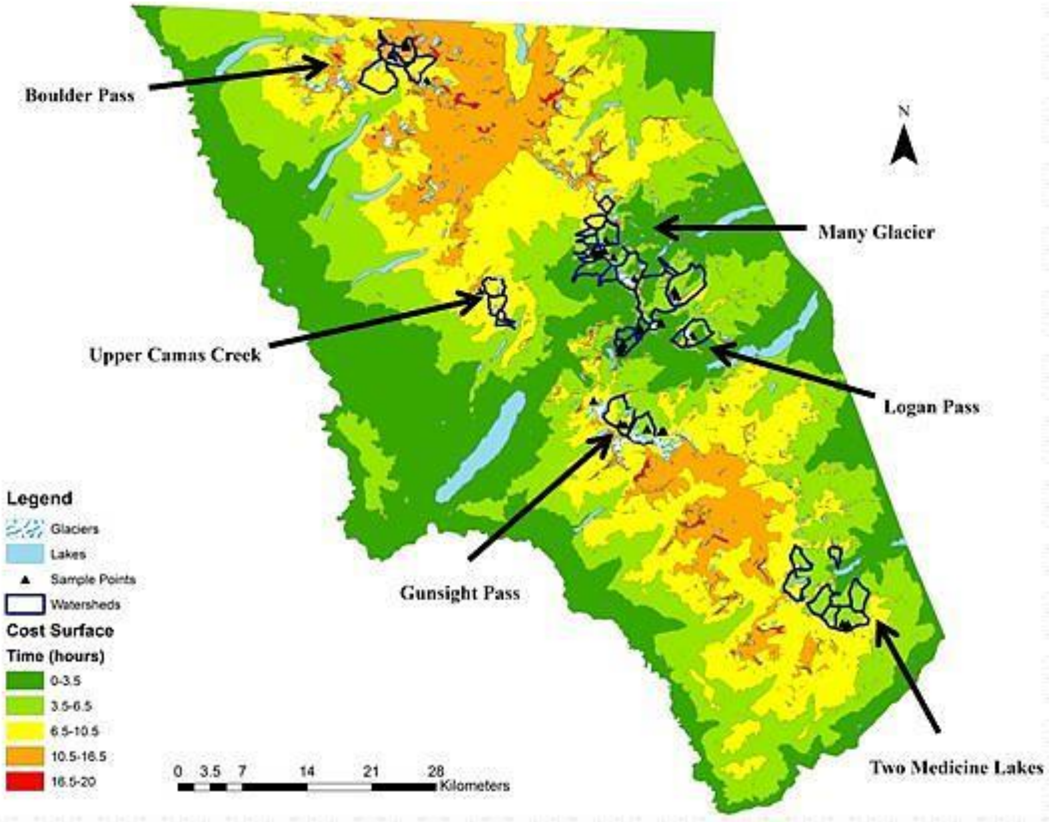

Figure 1: Map of GNP with cost surface, clusters of suitable watersheds, and sample locations. Categories of time were determined using natural breaks (Jenks) classification method in ArcGIS 10.1.

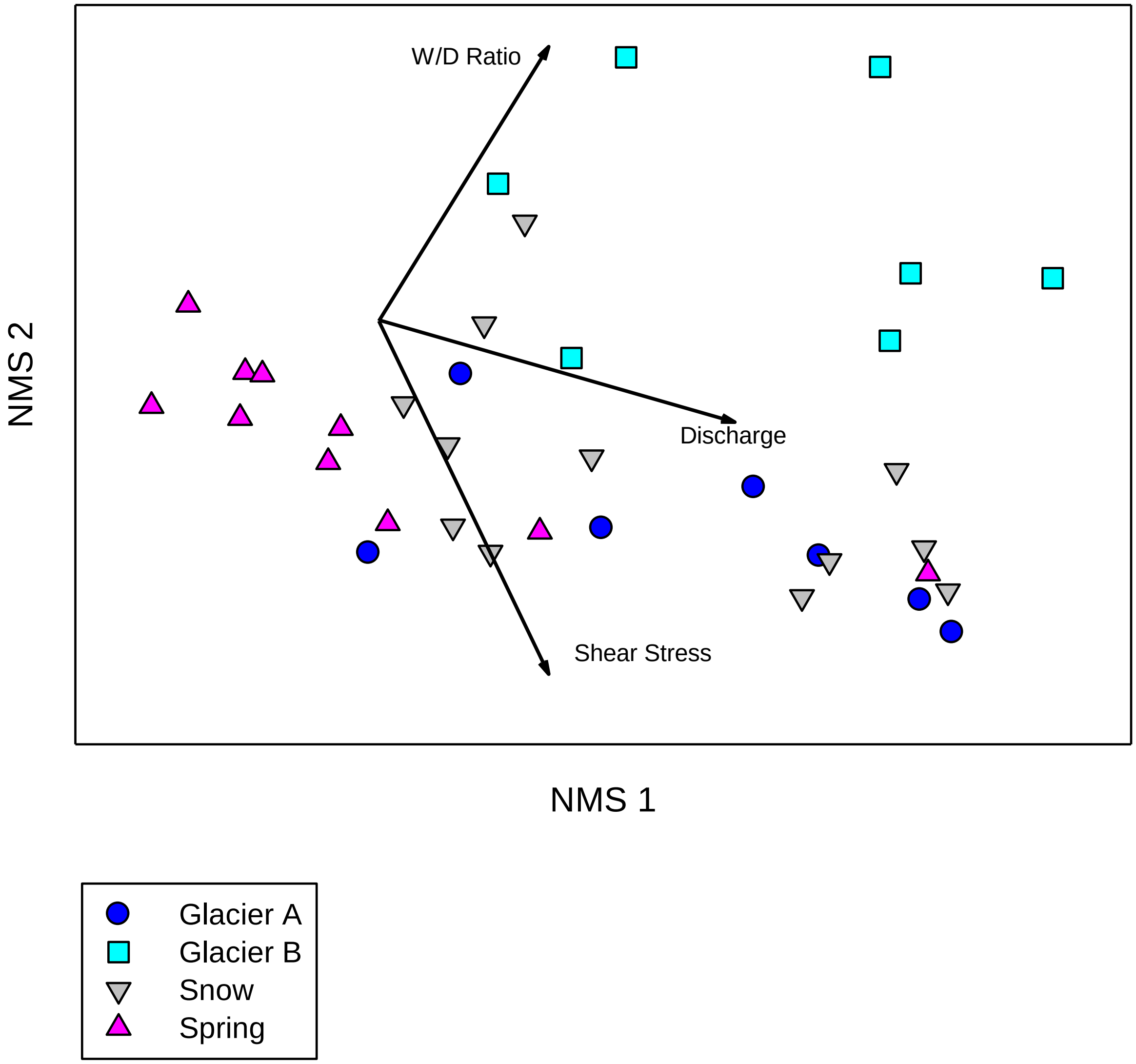

Figure 2: NMS ordination of 2-dimensional solution for disturbance variables (labeled on vectors) and stream types using Bray-Curtis similarity matrix. Glacier A = glacier (steep). Glacier B = glacier (flat). Stress for 2 dimensional NMS analysis was 0.08. Vectors of variables with Pearson correlation values ≥ 0.8 (±) are shown on the ordination.

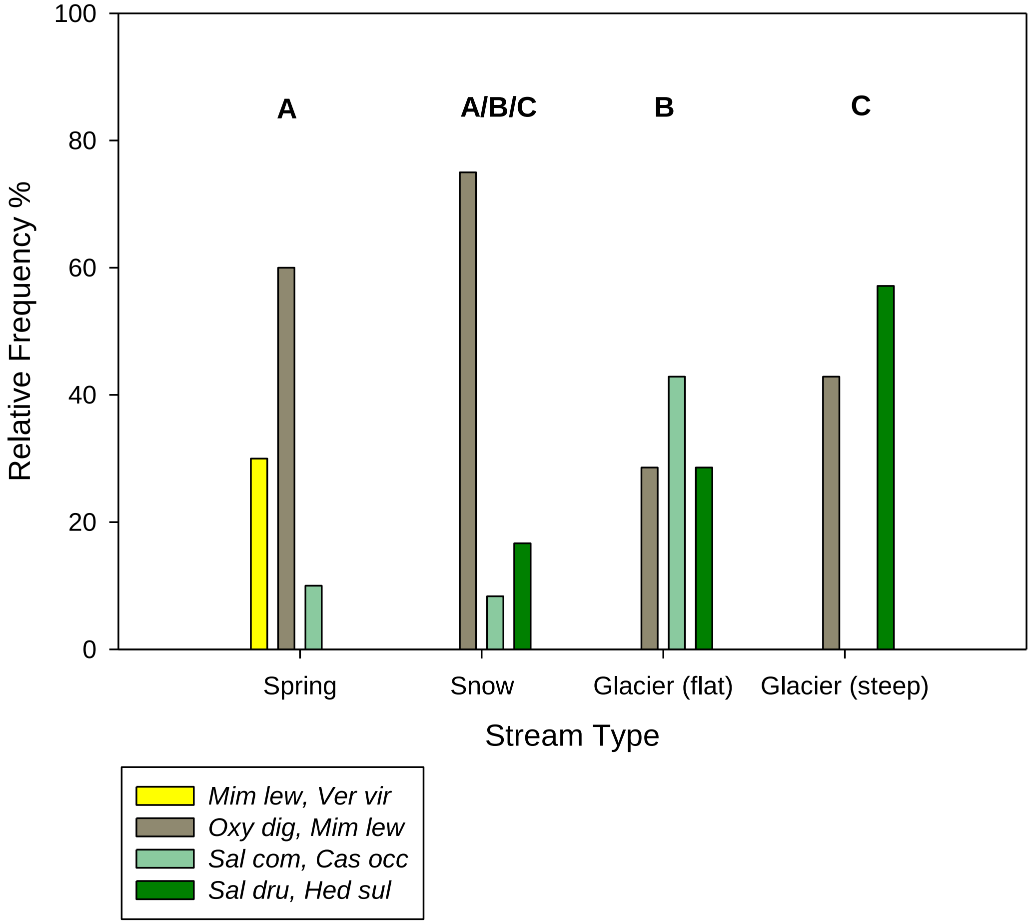

Figure 3: Frequency of occurrence of reach scale communities at stream types. Permanova analysis of vegetation composition was different for stream types ($p<0.05$) with significant overlap in vegetation represented by communities between snow and glacier (steep) sites, snow and glacier (flat) sites, and snow and spring sites. *Mim lew, Ver vir = Mimulus lewisii- Veratrum viride. Oxy dig, Ran kar = Oxyria digyna- Ranunculus karelinii. Sal com, Cas occ = Salix commutata – Castilleja occidentalis. Sal dru, Hed sul = Salix drummondiana – Hedysarum sulphurescens*

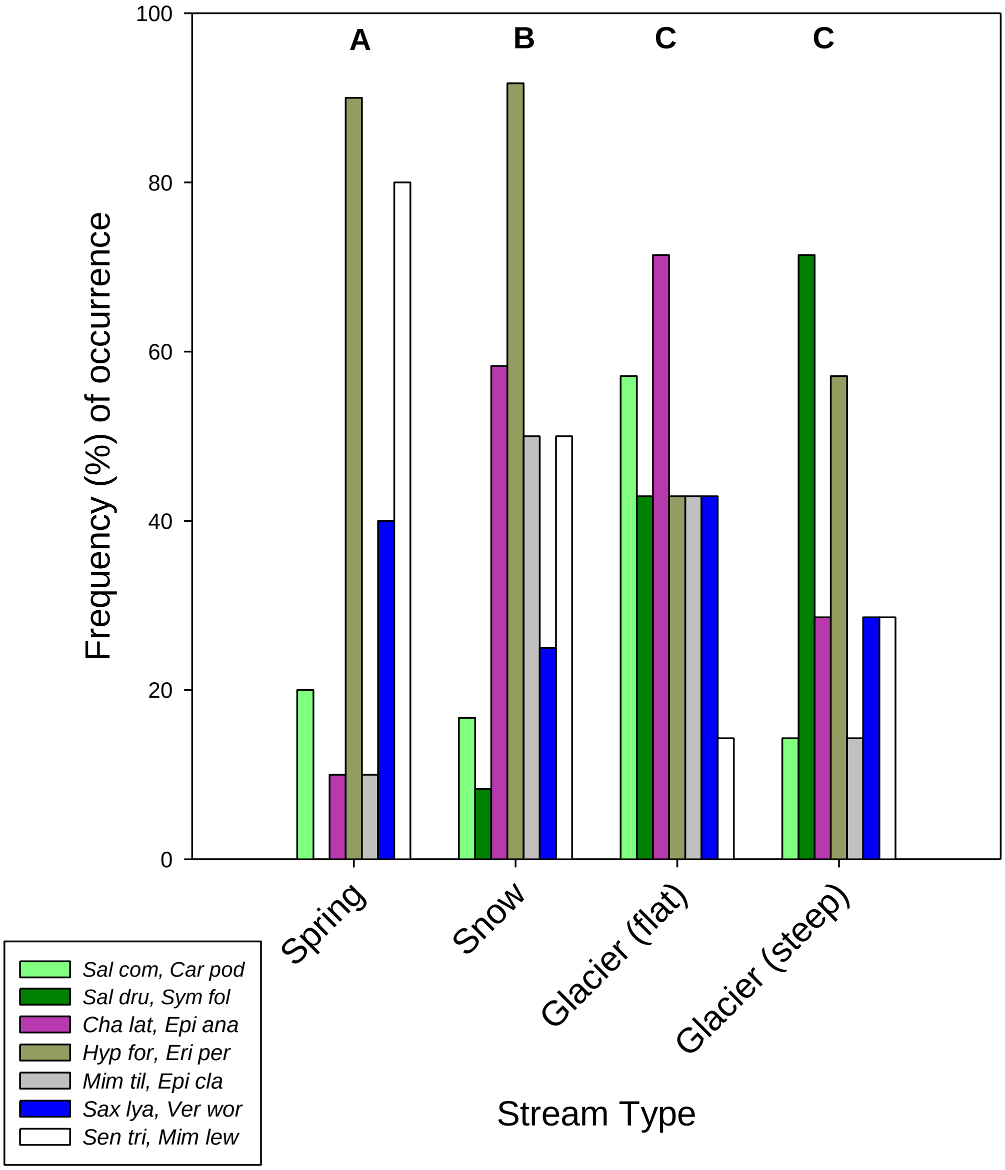

Figure 4: Relative frequency of plant community occurrence for each stream type. Multiple communities can be present at any given site. *Cha lat, Epi ana = Chamerion latifolium, Epilobium anagallidifolium. Hyp for, Eri per = Hypericum formosum, Erigeron peregrinus. Mim til, Epi cal = Mimulus tilingii, Epilobium clavatum. Sal com, Car pod = Salix commutata, Carex podocarpa. Sal dru, Sym fol = Salix drummondiana, Symphyotrichum foliaceum. Sax lya, Ver wor = Saxifraga lyallii, Veronica wormskjoldii. Sen tri, Mim lew = Senecio triangularis, Mimulus lewisii.*

Permanova analysis indicated no difference in occurrence of plant communities at glacier (steep) and glacier (flat), however occurrence of plant communities at both snow and spring fed streams were distinct.

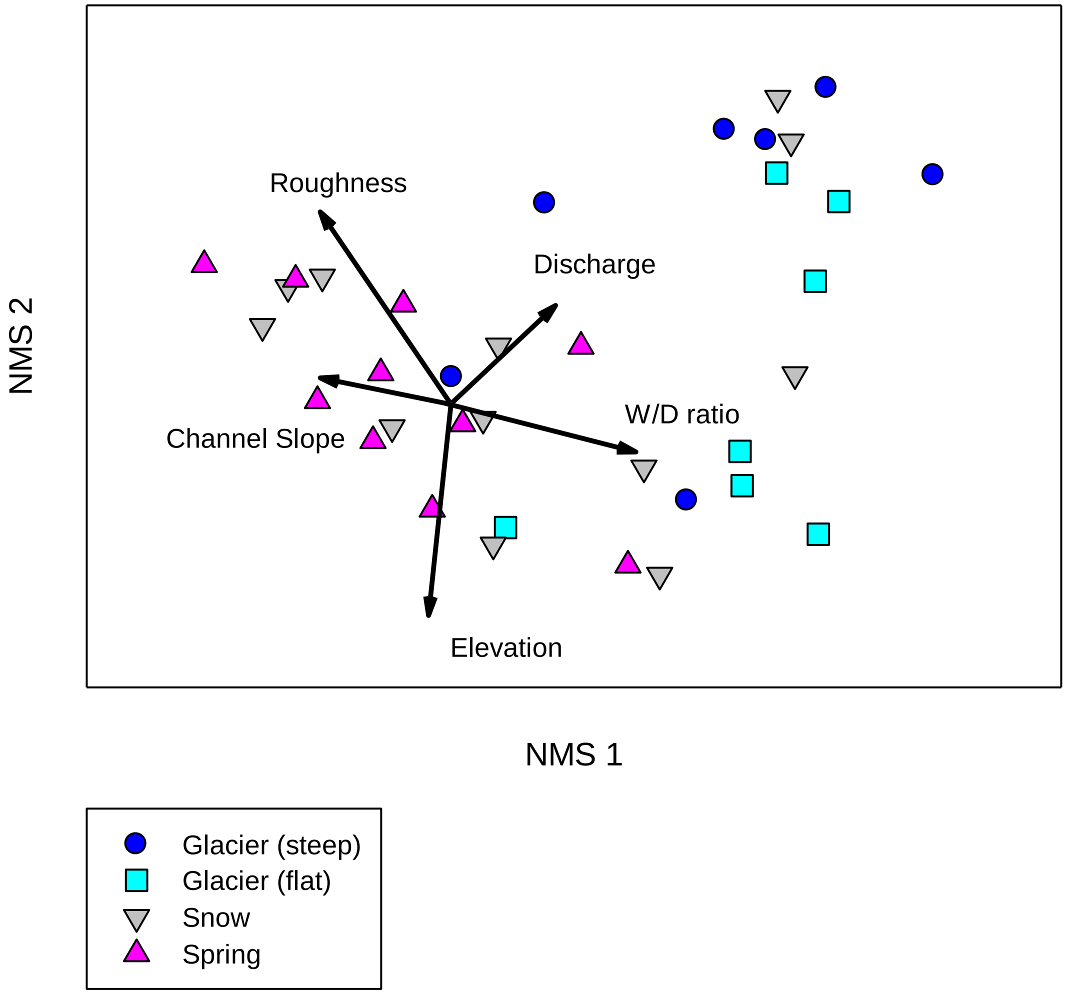

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Figure 5: NMS ordination of axis 1 and 2 of the three dimensional solution from reach scale vegetation matrix grouped by stream type (stress = 0.10). Vectors represent the relative strength of environmental variables that explain variation in vegetation composition. Variables with Spearman correlation values ≥ 0.30 (±) are shown on vectors. Bray-Curtis similarity matrix was used as the resemblance matrix

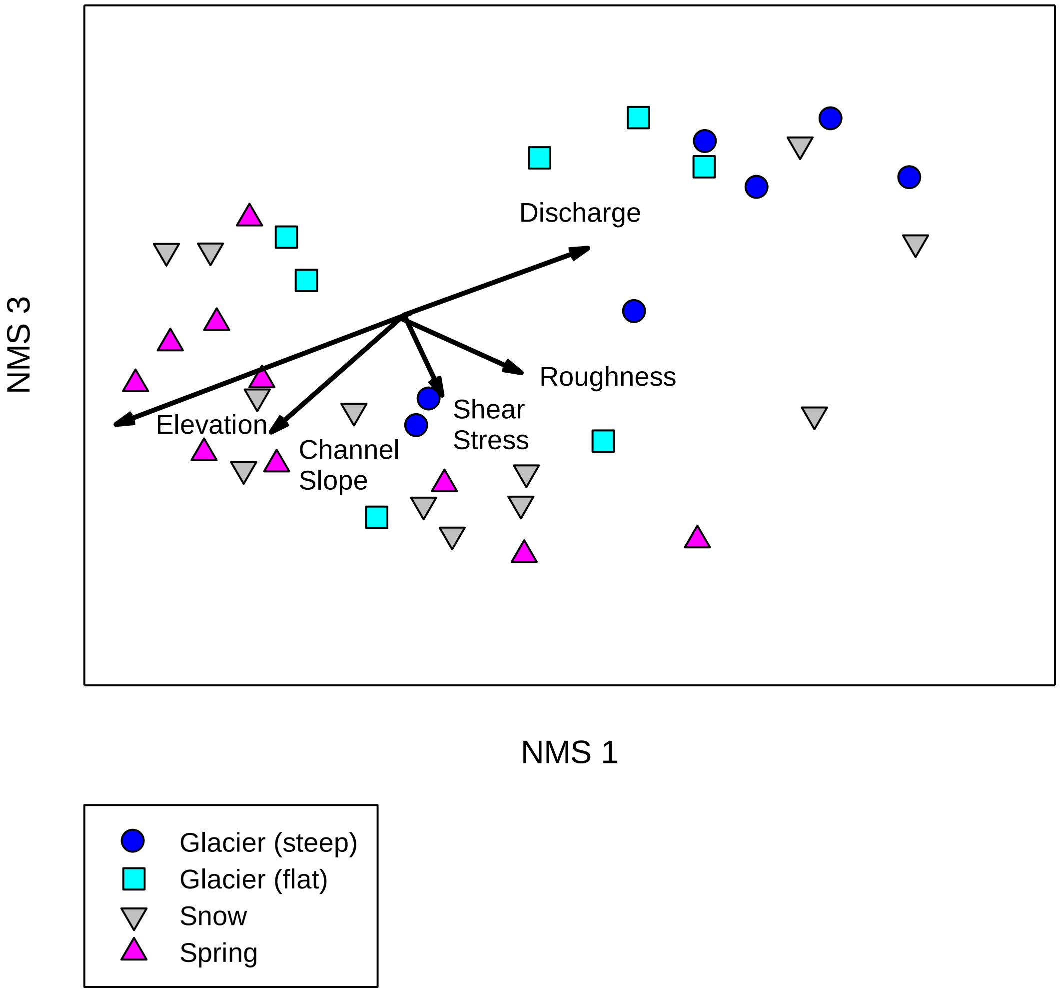

Figure 6: NMS ordination of axis 1 and 3 of the three dimensional solution from reach scale vegetation matrix grouped by stream type (stress = 0.10). Vectors represent the relative strength of environmental variables that explain variation in vegetation composition. Variables with Spearman correlation values ≥ 0.30 (±) are shown on vectors. Bray-Curtis similarity matrix was used as the resemblance matrix

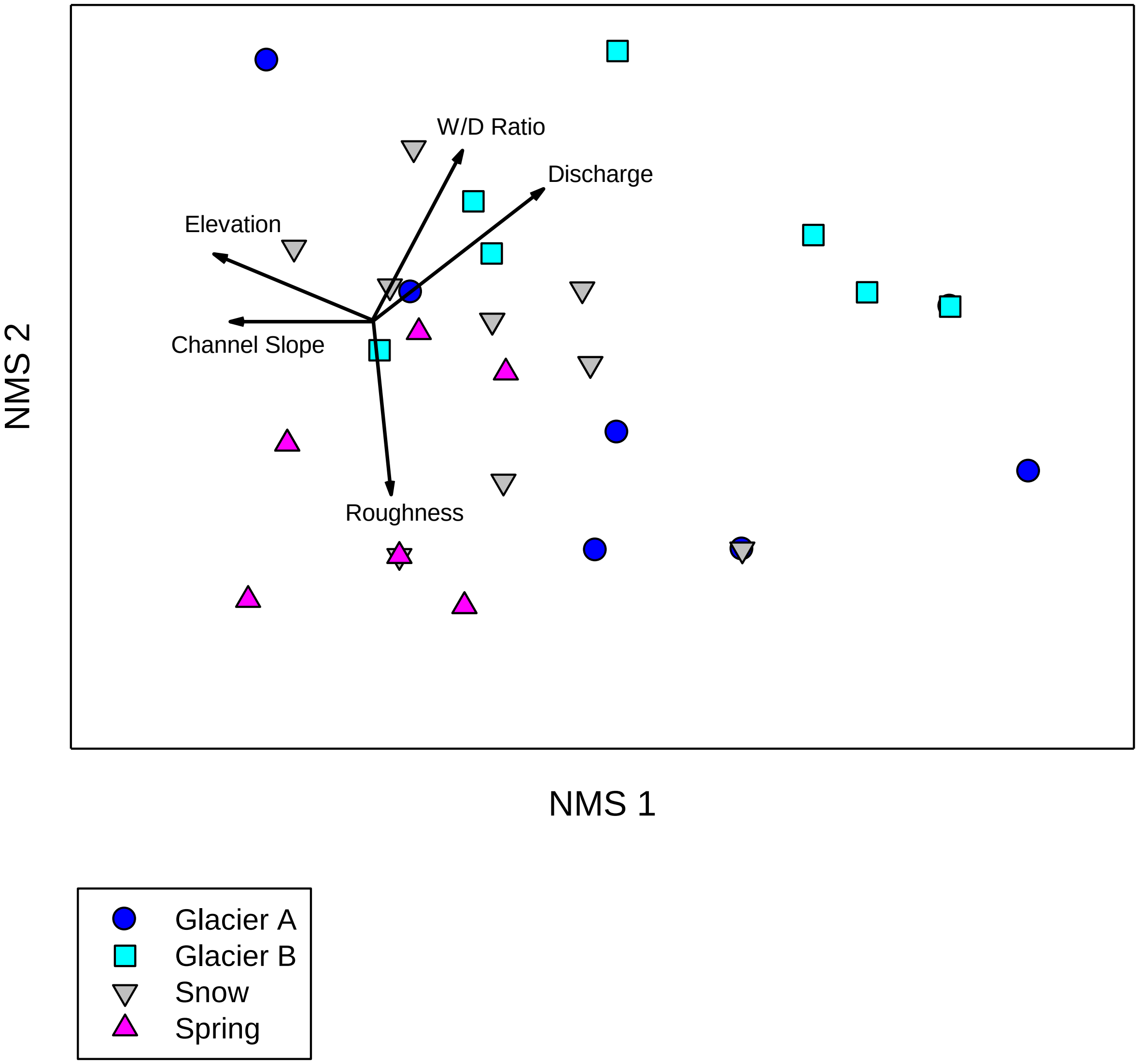

Figure 7: NMS ordination of axis 1 and 2 of the three dimensional solution from plant community (plot scale) occurrence matrix grouped by stream type (stress = 0.08). Some points on this graph overlap, indicating that some sample sites have the same communities present. Vectors represent the relative strength of environmental variables that explain variation in plant community occurrence. Variables with Spearman correlation values ≥ 0.30 (±) are shown on vectors. Axis 3 was correlated with variables below Spearman correlation coefficient cutoff. Bray-Curtis similarity matrix was used as the resemblance matrix. Glacier A = glacier (steep). Glacier B = glacier (flat).

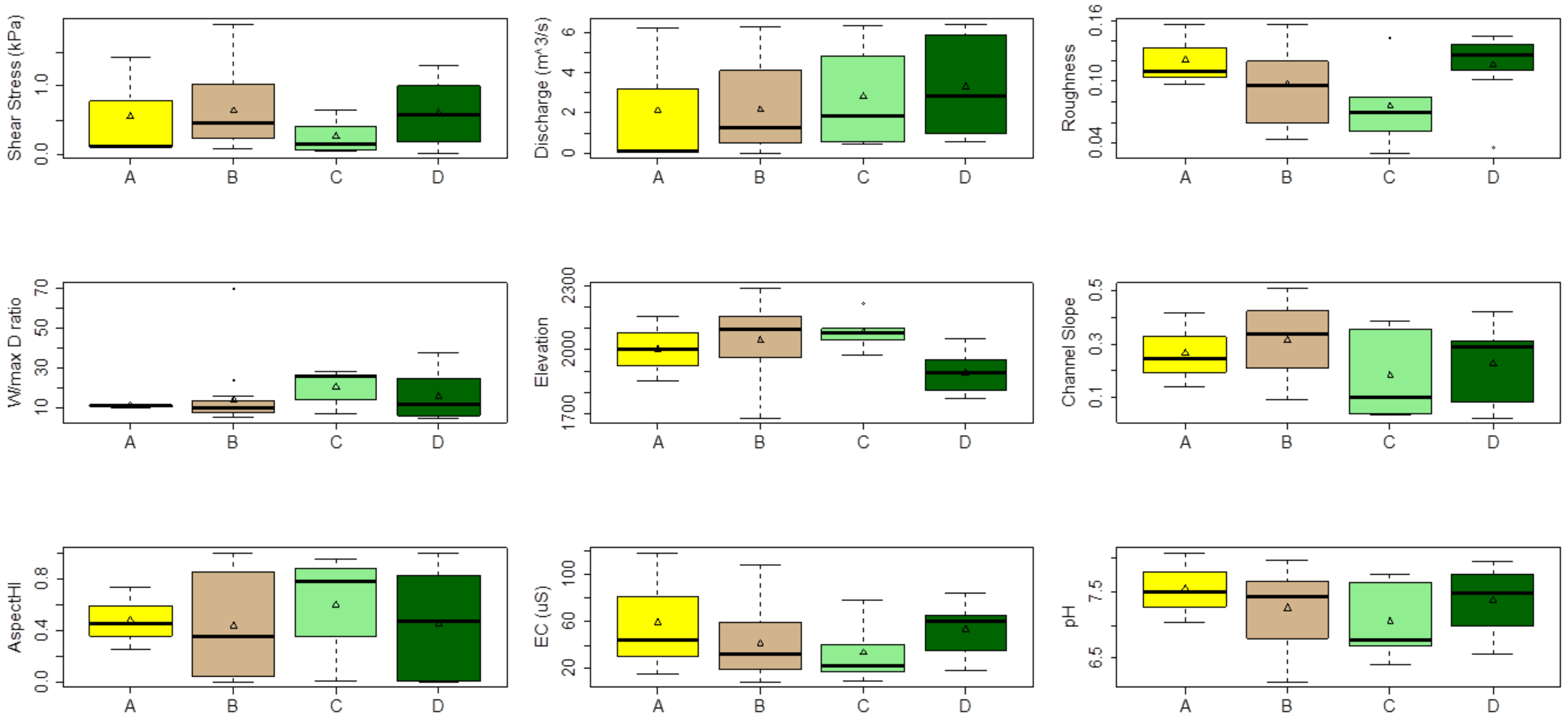

Figure 8: Box plots of abiotic variables and reach scale communities. No variables were significantly different at the $p < 0.05$ level across communities. A = *Mimulus lewisii- Veratrum viride.* B = *Oxyria digyna- Ranunculus karelinii.* C = *Salix commutata – Castilleja occidentalis.* D = *Salix drummondiana – Hedysarum sulphurescens*

△ = mean of abiotic variables

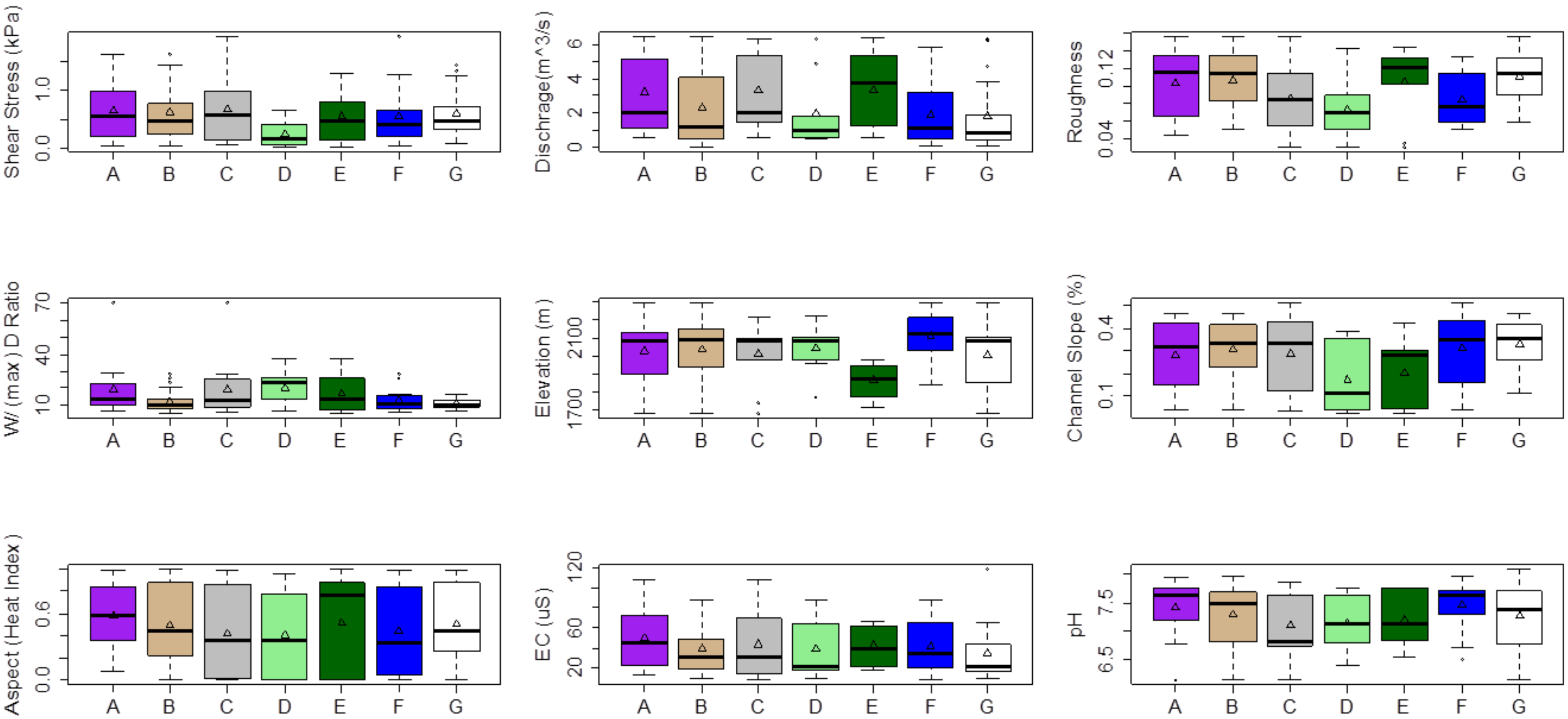

Figure 9: Box plots for abiotic variables at each plant community. Only elevation differed significantly across plant communities (Kruskal- Wallis, $p<0.05$) with no pairs of communities significantly different.
A = Chamerion latifolium, Epilobium anagallidifolium. B = Hypericum formosum, Erigeron peregrinus. C = Mimulus tilingii, Epilobium clavatum. D = Salix commutata, Carex podocarpa. E = Salix drummondiana, Symphyotrichum foliaceum. F = Saxifraga lyallii, Veronica wormskjoldii. G = Senecio triangularis, Mimulus lewisii.

△ = mean of abiotic variables

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APPENDIX A: VEGETATION DATA

Table 8: Vascular plant species found at sample sites. *= species removed in reach scale community analysis. ** = species removed in plot scale community analysis. ***=species removed in both reach and plot scale community analysis.

Family	Scientific Name	Binomial Author
Apiaceae	Heracleum maximum	W. Bartram
Apiaceae	Osmorhiza depauperata	Phil.
Asteraceae	Achillea millefolium	L.
Asteraceae	Agoseris aurantiaca***	(Hook.) Greene
Asteraceae	Antennaria alpina***	(L.) Gaertn.
Asteraceae	Antennaria media**	Greene
Asteraceae	Antennaria umbrinella***	Rydb.
Asteraceae	Arnica ×diversifolia	Greene (pro sp.)
Asteraceae	Arnica cordifolia	Hook.
Asteraceae	Arnica latifolia**	Bong.
Asteraceae	Arnica longifolia	D.C. Eaton
Asteraceae	Arnica mollis	Hook.
Asteraceae	Crepis nana***	Richardson
Asteraceae	Erigeron compositus**	Pursh
Asteraceae	Erigeron peregrinus	(Banks ex Pursh) Greene
Asteraceae	Eurybia sibirica**	(L.) G.L. Nesom
Asteraceae	Packera cymbalaria	(Pursh) W.A. Weber & Á. Löve
Asteraceae	Packera subnuda**	(DC.) D.K. Trock & T.M. Barkley
Asteraceae	Senecio fremontii**	Torr. & A. Gray
Asteraceae	Senecio triangularis	Hook.
Asteraceae	Solidago multiradiata	Aiton
Asteraceae	Symphyotrichum foliaceum	(Lindl. ex DC.) G.L. Nesom
Asteraceae	Taraxacum officinale ssp. Ceratophorum	F.H. Wigg.
Brassicaceae	Arabis drummondii**	A. Gray
Brassicaceae	Arabis lemmonii***	S. Watson
Brassicaceae	Arabis lyallii	S. Watson
Brassicaceae	Draba crassifolia**	Graham
Brassicaceae	Smelowskia calycina***	(Stephan ex Willd.) C.A. Mey.
Caprifoliaceae	Lonicera involucrate***	(Richardson) Banks ex Spreng.
Caryophyllaceae	Cerastium arvense**	L.
Caryophyllaceae	Sagina saginoides	(L.) Karst.

Caryophyllaceae	Silene acaulis	(L.) Jacq.
Caryophyllaceae	Silene parryi***	(S. Watson) C.L. Hitchc. & Maguire
Caryophyllaceae	Stellaria americana***	(Porter ex B.L. Rob.) Standl.
Caryophyllaceae	Stellaria crispa	Cham. & Schltdl.
Caryophyllaceae	Stellaria longipes	Goldie
Clusiaceae	Hypericum scouleri var. scouleri	Hook.
Crassulaceae	Sedum lanceolatum***	Torr.
Cyperaceae	Carex albonigra***	Mack.
Cyperaceae	Carex haydeniana	Olney
Cyperaceae	Carex lachenalii	Schkuhr
Cyperaceae	Carex lenticularis var. lipocarpa***	Michx.
Cyperaceae	Carex microptera***	Mack.
Cyperaceae	Carex nigricans	C.A. Mey.
Cyperaceae	Carex paysonis	Clokey
Cyperaceae	Carex phaeocephala***	Piper
Cyperaceae	Carex podocarpa	R. Br.
Cyperaceae	Carex praeceptorum	Mack.
Cyperaceae	Carex scirpoidea ssp. Pseudoscirpoidea***	Michx.
Cyperaceae	Carex spectabilis	Dewey
Dryopteridaceae	Cystopteris fragilis**	(L.) Bernh.
Ericaceae	Cassiope mertensiana***	(Bong.) G. Don
Ericaceae	Phyllodoce empetriformis***	(Sm.) D. Don
Ericaceae	Phyllodoce glanduliflora***	(Hook.) Coville
Fabaceae	Astragalus alpinus**	L.
Fabaceae	Hedysarum sulphurescens	Rydb.
Gentianaceae	Gentiana calycosa	Griseb.
Grossulariaceae	Ribes lacustre	(Pers.) Poir.
Hydrophyllaceae	Phacelia hastatq**	Douglas ex Lehm.
Hydrophyllaceae	Phacelia lyallii	(A. Gray) Rydb.
Hydrophyllaceae	Romanzoffia sitchensis	Bong.
Juncaceae	Juncus albescens***	(Lange) Fernald
Juncaceae	Juncus biglumis**	L.
Juncaceae	Juncus drummondii	E. Mey.
Juncaceae	Juncus mertensianus	Bong.
Juncaceae	Juncus nevadensis***	S. Watson
Juncaceae	Luzula parviflora	(Ehrh.) Desv.
Juncaceae	Luzula piperi**	(Coville) M.E. Jones
Juncaceae	Luzula spicata***	(L.) DC.

Liliaceae	Allium schoenoprasum**	L.
Liliaceae	Erythronium grandiflorum	Pursh
Liliaceae	Stenanthium occidentale	A. Gray
Liliaceae	Triantha occidentalis ssp. Montana	(S. Watson) Gates
Liliaceae	Veratrum viride	Aiton
Liliaceae	Zigadenus elegans***	Pursh
Onagraceae	Chamerion angustifolium ssp. Angustifolium	(L.) Holub
Onagraceae	Chamerion latifolium	(L.) Holub
Onagraceae	Epilobium anagallidifolium	Lam.
Onagraceae	Epilobium clavatum	Trel.
Onagraceae	Epilobium glaberrimum*	Barbey
Onagraceae	Epilobium halleanum	Hausskn.
Onagraceae	Epilobium hornemannii***	Rchb.
Onagraceae	Epilobium lactiflorum	Hausskn.
Ophioglossaceae	Botrychium minganense	Victorin
Papaveraceae	Papaver pygmaeum*	Rydb.
Pinaceae	Abies lasiocarpa**	(Hook.) Nutt.
Poaceae	Agrostis humilis**	Vasey
Poaceae	Bromus carinatus*	Hook. & Arn.
Poaceae	Bromus ciliatus***	L.
Poaceae	Calamagrostis canadensis***	(Michx.) P. Beauv.
Poaceae	Deschampsia cespitosa	(L.) P. Beauv.
Poaceae	Elymus trachycaulus	(Link) Gould ex Shinners
Poaceae	Festuca idahoensis	Elmer
Poaceae	Phleum alpinum	L.
Poaceae	Poa abbreviata ssp. pattersonii	R. Br.
Poaceae	Poa alpine	L.
Poaceae	Poa arctica	R. Br.
Poaceae	Poa fendleriana	(Steud.) Vasey
Poaceae	Poa leptocoma**	Trin.
Poaceae	Trisetum spicatum	(L.) K. Richt.
Poaceae	Vahlodea atropurpurea**	(Wahlenb.) Fr. ex Hartm.
Polygonaceae	Oxyria digyna	(L.) Hill
Polygonaceae	Polygonum bistortoides**	Pursh
Polygonaceae	Polygonum viviparum	L.
Portulacaceae	Claytonia lanceolata***	Pall. ex Pursh
Primulaceae	Dodecatheon pulchellum***	(Raf.) Merr.
Ranunculaceae	Aquilegia flavescens	S. Watson
Ranunculaceae	Ranunculus eschscholtzii	Schltdl.
Ranunculaceae	Ranunculus karelinii	Czern.
Ranunculaceae	Thalictrum occidentale	A. Gray

Rosaceae	Dasiphora fruticosa ssp. floribunda**	(L.) Rydb.
Rosaceae	Fragaria virginiana ssp. glauca	Duchesne
Rosaceae	Potentilla sp.***	
Rosaceae	Potentilla diversifolia	Lehm.
Rosaceae	Potentilla ovina var. ovina***	Macoun ex J.M. Macoun
Rosaceae	Sibbaldia procumbens	L.
Rubiaceae	Galium boreale***	L.
Rubiaceae	Galium trifidum***	L.
Salicaceae	Salix arctica	Pall.
Salicaceae	Salix boothii	Dorn
Salicaceae	Salix commutata	Bebb
Salicaceae	Salix drummondiana	Barratt ex Hook.
Salicaceae	Salix farriae	C.R. Ball
Salicaceae	Salix glauca ssp. glauca var. villosa***	L.
Salicaceae	Salix vestita	Pursh
Saxifragaceae	Leptarrhena pyrolifolia	(D. Don) R. Br. ex Ser.
Saxifragaceae	Mitella breweri	A. Gray
Saxifragaceae	Mitella pentandra	Hook.
Saxifragaceae	Parnassia fimbriata	K.D. Koenig
Saxifragaceae	Saxifraga adscendens***	L.
Saxifragaceae	Saxifraga ferruginea**	Graham
Saxifragaceae	Saxifraga lyallii	Engl.
Saxifragaceae	Saxifraga mertensiana**	Bong.
Saxifragaceae	Saxifraga occidentalis***	S. Watson
Saxifragaceae	Saxifraga rivularis***	L.
Scrophulariaceae	Castilleja miniata	Douglas ex Hook.
Scrophulariaceae	Castilleja occidentalis	Torr.
Scrophulariaceae	Castilleja rhexiifolia	Rydb.
Scrophulariaceae	Mimulus guttatus	DC.
Scrophulariaceae	Mimulus lewisii	Pursh
Scrophulariaceae	Mimulus tilingii	Regel
Scrophulariaceae	Pedicularis bracteosa***	Benth.
Scrophulariaceae	Pedicularis groenlandica	Retz.
Scrophulariaceae	Pedicularis parryi***	A. Gray
Scrophulariaceae	Penstemon ellipticus**	J.M. Coult. & Fisher
Scrophulariaceae	Veronica wormskjoldii	Roem. & Schult.
Valerianaceae	Valeriana sitchensis	Bong.

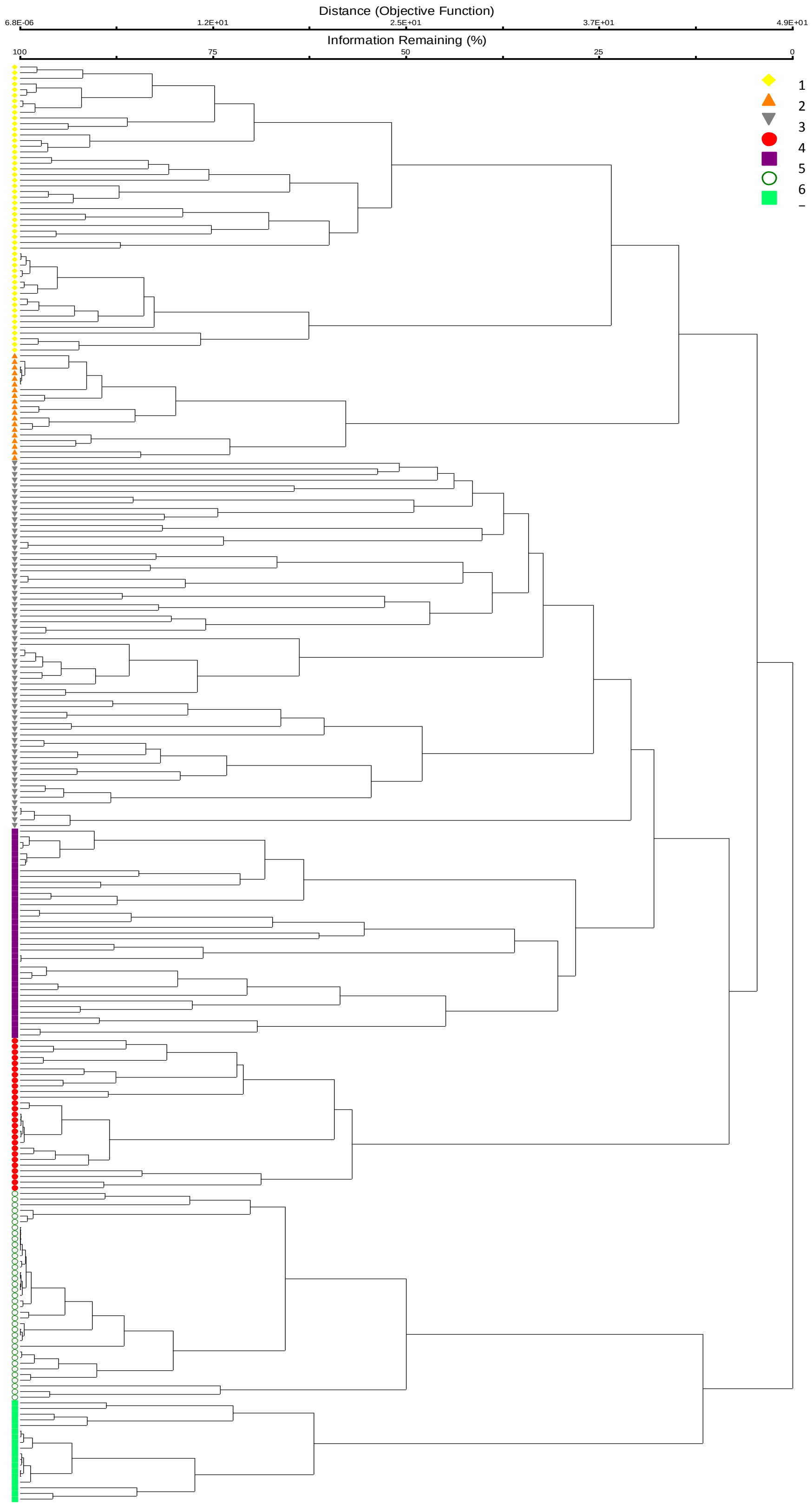

Figure 10: Dendrogram of cluster analysis. The colors along the left vertical axis represent the seven different communities identified. Data was relativized by maximum and cluster analysis was performed on Sorensen matrix with flexible beta (-0.25) for group linkage method. Percent chaining = 1.32

APPENDIX B: ABIOTIC VARIABLES

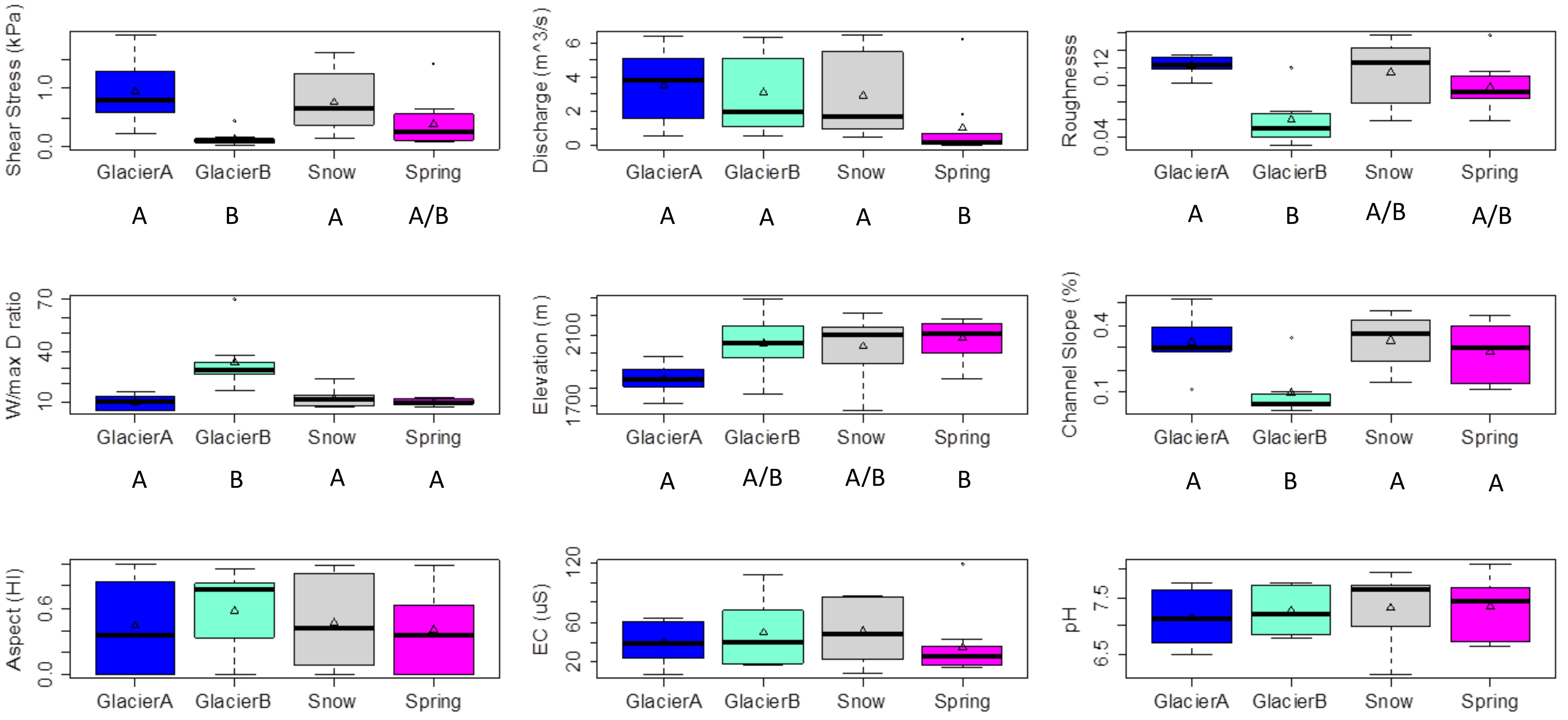

Figure 11: Box plots of abiotic variables used in statistical analyses grouped by stream type. Significant global comparisons from Kruskal-Wallis one way anova ($p \leq 0.05$) were present for shear stress, discharge, roughness, w/d ratio, elevation, and channel slope. Stream types that differ significantly (Nemenyi, $p \leq 0.05$) are noted as A and B. Glacier A = glacier (steep). Glacier B = glacier (flat).

Table 9: Equations used to calculate hydrogeomorphic variables

ABIOTIC VARIABLE	EQUATION
Shear Stress = τ Weight Density of Water =γ Hydraulic Radius = R Channel Slope = S	$\tau = \gamma \times R \times S$
Unit Stream Power = Ω_ω Weight Density of Water = γ Discharge= Q Channel slope = S Channel Width = W	$\Omega_\omega = \frac{\gamma \times Q \times S}{W}$
Discharge = Q Velocity = V Channel Area = A	$Q = A \times V$
Velocity = V Roughness (Manning's n) = n Hydraulic Radius = R Channel Slope = S	$V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$

APPENDIX C: FIELD SURVEYS

Table 10: Substrate categories for long term comparisons

Substrate Size Class Codes
RS = bedrock smooth (larger than car)
RR = Bedrock rough (larger than car)
RC = Concrete/Asphalt
XB = Large Boulder (1000 - 4000mm) - meter stick to car)
SB = Small Boulder (250-1000mm) - basketball to meter stick
CB = Cobble (64 - 250 mm) Tennis ball to basketball
GC = Coarse Gravel (16- 64 mm) - marble to tennis ball
GF = Fine Gravel (2 - 16 mm) lady bug to marble
SA = Sand (0.06 to 2 mm) - gritty up to lady bug size
FN = Silt/Clay/Muck (not gritty)
HP = hard pan (firm, unconsolidated fine substrate)
WD = Wood (any size)
OT = Other (comment below)

Table 11: Montgomery Buffington stream classification table. Glacier (flat) streams were all classified as bedrock. All other streams were colluvial/step-pool.

	Braided	Regime	Pool-Riffle	Plane Bed	Step-Pool	Cascade	Bedrock	Colluvial
Typical Bed Material	Variable	Sand	Gravel	Gravel, cobble	Cobble, boulder	Boulder	Not applicable	Variable
Bedform Pattern	Laterally oscillary	Multi-layered	Laterally oscillary	None	Vertically oscillary	None	*	Variable
Reach Type	Response	Response	Response	Response	Transport	Transport	Transport	Source
Dominant Roughness Elements	Bedforms (bars, pools)	Sinuosity, bedforms (dunes, ripples, bars, banks)	Bedforms (bars, pools), grains, LWD, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, LWD, banks)	Grains, banks	Boundaries (bed and banks)	Grains, LWD
Dominant Sediment Sources	Fluvial bank failure, debris flow	Fluvial bank failure, inactive channel	Fluvial bank failure, inactive channel, debris flows	Fluvial bank failure, debris flows	Fluvial hillslope, debris flow	Fluvial hillslope, debris flow	Fluvial hillslope, debris flow	Hillslope, debris flow
Sediment Storage Elements	Overbank, bedforms	Overbank, bedforms, inactive channel	Overbank, bedforms, inactive channel	Overbank, inactive channel	Bedforms	Lee and Stross sides of flow obstructions	*	Bed
Typical Slope	S<0.03	S<0.01	0.001<S and S<0.002	0.01<S and S<0.03	0.03<S and S <0.08	0.08<S and S<0.30	Variable	S>0.20
Typical Confinement	Unconfined	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Pool Spacing (Channel Widths)	Variable	5-7	5-7	none	1-4	<1	Variable	Variable

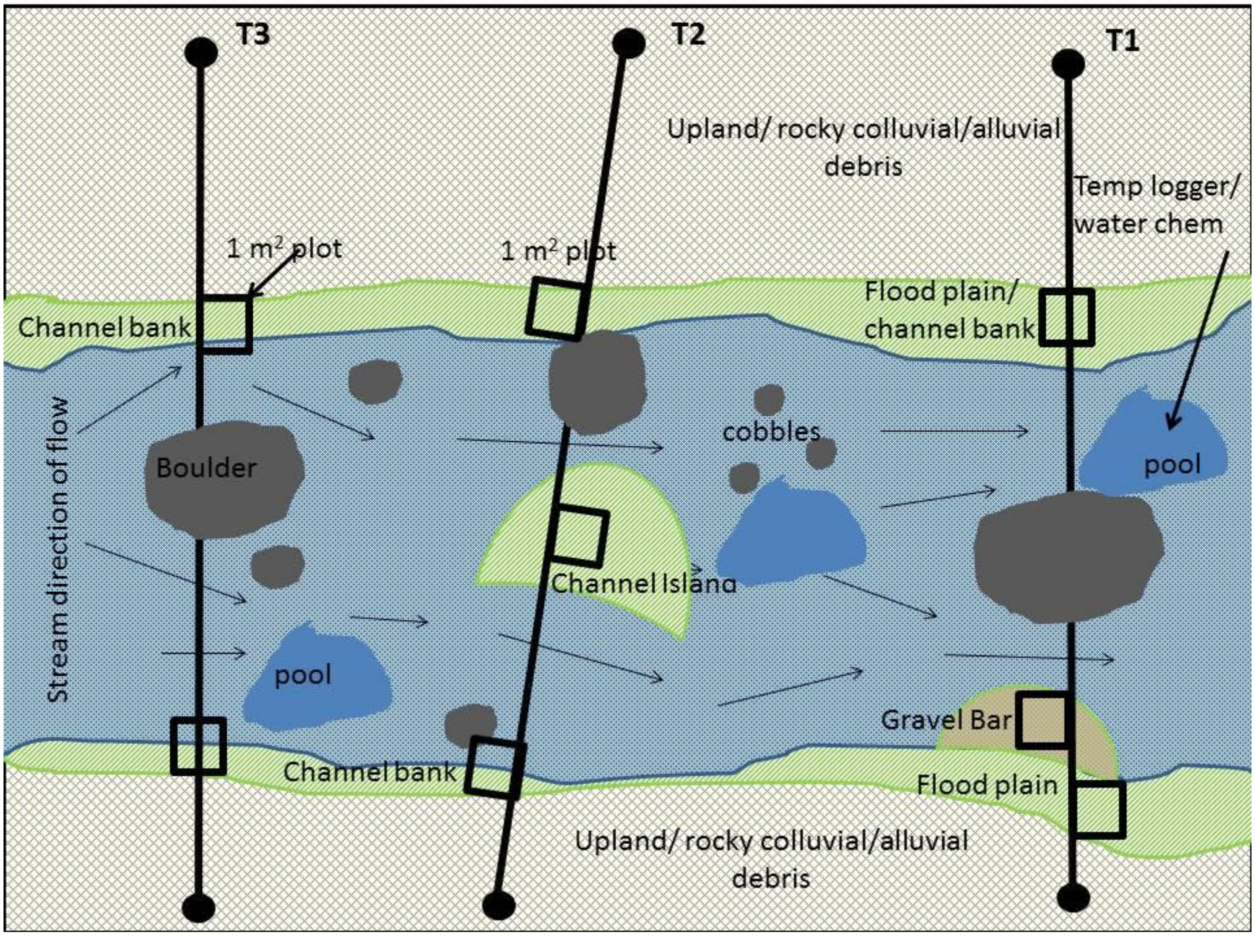

Figure 12: Plot layout of typical stream site

APPENDIX D: PICTURES OF STREAM TYPES

Figure 13: Glacier (steep) stream type, Siyeh Glacier

Figure 14: Glacier (flat) stream type, Blackfoot Glacier

Figure 15: Snow-fed stream, Reynold's Creek

Figure 16: Spring-fed stream, Reynold's Creek

APPENDIX E: STREAM TEMPERATURE DATA

Table 12: Average daily stream temperature (ºC) data for stream types. Data from this table is from 13 reaches. Loggers from 28 sites are still in streams in GNP. Loggers were placed in streams in 2012, 2013, and 2014 field seasons but no channel surveys were completed in 2012. Vegetation was surveyed at 2012 locations under a different protocol and resurveyed in 2013 and 2014 using the protocol described in this document.
NA= not applicable, and no data is available for those dates. Columns are greyed for readability.

DATE	Spring	Snow	Glacier (steep)	Glacier (flat)
8/3/2012	NA	3.05	NA	NA
8/4/2012	NA	4.78	NA	NA
8/5/2012	NA	5.53	NA	NA
8/6/2012	NA	6.03	NA	NA
8/7/2012	NA	6.20	NA	NA
8/8/2012	NA	6.37	NA	NA
8/9/2012	NA	6.15	NA	NA
8/10/2012	NA	6.51	NA	NA
8/11/2012	NA	7.12	NA	NA
8/12/2012	NA	7.28	NA	NA
8/13/2012	NA	7.30	7.55	NA
8/14/2012	NA	7.08	8.13	NA
8/15/2012	NA	3.82	4.31	NA
8/16/2012	NA	5.36	4.79	NA
8/17/2012	NA	7.20	7.58	NA
8/18/2012	NA	7.52	8.20	NA
8/19/2012	NA	7.42	8.28	NA
8/20/2012	NA	7.90	9.54	NA
8/21/2012	NA	6.72	9.08	NA
8/22/2012	NA	6.75	7.55	NA
8/23/2012	NA	6.19	6.69	NA
8/24/2012	NA	3.25	4.03	NA
8/25/2012	NA	5.76	5.21	NA
8/26/2012	NA	7.55	6.61	NA
8/27/2012	NA	8.83	9.17	NA
8/28/2012	15.02	7.94	8.16	NA
8/29/2012	9.32	5.97	5.91	NA
8/30/2012	8.62	6.25	5.28	NA
8/31/2012	10.64	7.40	6.40	NA
9/1/2012	10.04	6.62	5.50	NA
9/2/2012	8.38	5.32	4.93	NA
9/3/2012	7.31	5.90	5.38	NA

9/4/2012	8.03	6.37	5.83	NA
9/5/2012	7.83	6.96	6.04	NA
9/6/2012	4.51	4.29	5.07	NA
9/7/2012	6.79	6.75	5.79	NA
9/8/2012	8.79	7.54	6.13	NA
9/9/2012	9.42	7.19	7.16	NA
9/10/2012	4.32	3.14	4.64	NA
9/11/2012	2.57	1.08	3.10	NA
9/12/2012	4.07	3.34	3.20	NA
9/13/2012	7.66	8.06	4.50	NA
9/14/2012	9.42	8.63	6.35	NA
9/15/2012	8.46	6.96	6.30	NA
9/16/2012	7.50	7.08	5.29	NA
9/17/2012	8.38	7.68	5.73	NA
9/18/2012	9.35	7.87	6.25	NA
9/19/2012	9.00	7.75	6.21	NA
9/20/2012	9.84	8.55	6.89	NA
9/21/2012	11.10	9.61	7.41	NA
9/22/2012	10.26	8.92	7.49	NA
9/23/2012	9.69	9.12	7.48	NA
9/24/2012	10.22	9.21	7.19	NA
9/25/2012	8.71	8.33	7.46	NA
9/26/2012	7.22	7.26	6.71	NA
9/27/2012	8.37	8.46	5.67	NA
9/28/2012	9.91	9.67	5.88	NA
9/29/2012	8.51	7.55	6.18	NA
9/30/2012	8.14	7.53	6.00	NA
10/1/2012	8.15	7.68	5.39	NA
10/2/2012	5.75	4.81	4.59	NA
10/3/2012	2.35	0.75	1.27	NA
10/4/2012	2.41	0.82	1.14	NA
10/5/2012	2.09	0.80	1.20	NA
10/6/2012	1.78	0.67	1.09	NA
10/7/2012	1.79	0.83	1.26	NA
10/8/2012	1.61	0.84	1.36	NA
10/9/2012	2.09	1.00	1.14	NA
10/10/2012	2.68	1.28	1.37	NA
10/11/2012	2.53	1.79	1.01	NA
10/12/2012	4.65	2.91	2.13	NA
10/13/2012	3.18	2.45	2.18	NA
10/14/2012	3.42	3.18	3.44	NA
10/15/2012	3.40	3.15	3.77	NA
10/16/2012	2.13	1.66	1.87	NA

10/17/2012	1.18	0.13	0.50	NA
10/18/2012	1.56	0.46	0.57	NA
10/19/2012	1.69	0.89	0.99	NA
10/20/2012	0.91	0.25	0.40	NA
10/21/2012	1.25	0.15	0.66	NA
10/22/2012	1.38	0.19	0.64	NA
10/23/2012	1.39	0.22	0.50	NA
10/24/2012	1.35	0.25	-0.18	NA
10/25/2012	1.35	0.24	-0.26	NA
10/26/2012	1.36	0.22	0.01	NA
10/27/2012	1.37	0.29	0.16	NA
10/28/2012	1.34	0.28	0.33	NA
10/29/2012	1.35	0.32	0.34	NA
10/30/2012	1.41	0.51	0.37	NA
10/31/2012	1.57	0.94	1.25	NA
11/1/2012	1.76	0.98	1.56	NA
11/2/2012	1.65	0.57	0.88	NA
11/3/2012	1.53	0.44	1.17	NA
11/4/2012	1.74	0.83	2.26	NA
11/5/2012	1.84	1.26	2.54	NA
11/6/2012	2.10	1.91	2.16	NA
11/7/2012	1.56	0.95	1.57	NA
11/8/2012	1.05	0.11	0.40	NA
11/9/2012	1.05	0.09	0.48	NA
11/10/2012	1.18	0.17	0.34	NA
11/11/2012	1.35	0.20	-0.82	NA
11/12/2012	1.52	0.25	-0.19	NA
11/13/2012	1.49	0.24	-0.04	NA
11/14/2012	1.28	0.21	0.01	NA
11/15/2012	1.24	0.20	0.07	NA
11/16/2012	1.21	0.05	0.06	NA
11/17/2012	1.21	0.12	0.09	NA
11/18/2012	1.21	0.17	0.12	NA
11/19/2012	1.20	0.13	0.14	NA
11/20/2012	1.16	0.20	0.33	NA
11/21/2012	1.16	0.23	0.39	NA
11/22/2012	1.14	0.21	0.27	NA
11/23/2012	1.10	0.21	0.18	NA
11/24/2012	1.10	0.21	0.20	NA
11/25/2012	1.10	0.22	0.20	NA
11/26/2012	1.10	0.22	0.17	NA
11/27/2012	1.09	0.22	0.17	NA
11/28/2012	1.05	0.21	0.18	NA

11/29/2012	1.05	0.20	0.18	NA
11/30/2012	1.05	0.22	0.20	NA
12/1/2012	1.05	0.22	0.24	NA
12/2/2012	1.01	0.22	0.19	NA
12/3/2012	1.00	0.21	0.19	NA
12/4/2012	1.00	0.22	0.18	NA
12/5/2012	1.00	0.22	0.35	NA
12/6/2012	1.00	0.20	0.34	NA
12/7/2012	0.99	0.21	0.20	NA
12/8/2012	0.96	0.21	0.18	NA
12/9/2012	0.94	0.22	0.17	NA
12/10/2012	0.94	0.21	0.18	NA
12/11/2012	0.94	0.20	0.17	NA
12/12/2012	0.94	0.22	0.17	NA
12/13/2012	0.92	0.22	0.17	NA
12/14/2012	0.89	0.23	0.17	NA
12/15/2012	0.89	0.23	0.17	NA
12/16/2012	0.88	0.21	0.17	NA
12/17/2012	0.85	0.20	0.18	NA
12/18/2012	0.83	0.18	0.16	NA
12/19/2012	0.83	0.19	0.15	NA
12/20/2012	0.82	0.19	0.15	NA
12/21/2012	0.79	0.19	0.14	NA
12/22/2012	0.78	0.20	0.13	NA
12/23/2012	0.77	0.20	0.14	NA
12/24/2012	0.72	0.20	0.13	NA
12/25/2012	0.72	0.19	0.14	NA
12/26/2012	0.69	0.20	0.14	NA
12/27/2012	0.67	0.20	0.14	NA
12/28/2012	0.67	0.20	0.14	NA
12/29/2012	0.63	0.20	0.14	NA
12/30/2012	0.62	0.20	0.14	NA
12/31/2012	0.62	0.20	0.14	NA
1/1/2013	0.60	0.19	0.14	NA
1/2/2013	0.57	0.19	0.15	NA
1/3/2013	0.56	0.19	0.15	NA
1/4/2013	0.56	0.19	0.15	NA
1/5/2013	0.56	0.19	0.14	NA
1/6/2013	0.54	0.19	0.15	NA
1/7/2013	0.51	0.18	0.15	NA
1/8/2013	0.51	0.18	0.14	NA
1/9/2013	0.51	0.17	0.15	NA
1/10/2013	0.51	0.18	0.14	NA

1/11/2013	0.51	0.17	0.14	NA
1/12/2013	0.51	0.17	0.14	NA
1/13/2013	0.50	0.16	0.14	NA
1/14/2013	0.47	0.16	0.14	NA
1/15/2013	0.45	0.16	0.14	NA
1/16/2013	0.45	0.16	0.14	NA
1/17/2013	0.45	0.16	0.13	NA
1/18/2013	0.45	0.16	0.12	NA
1/19/2013	0.45	0.16	0.11	NA
1/20/2013	0.45	0.15	0.12	NA
1/21/2013	0.45	0.16	0.11	NA
1/22/2013	0.45	0.16	0.11	NA
1/23/2013	0.45	0.15	0.11	NA
1/24/2013	0.45	0.15	0.12	NA
1/25/2013	0.45	0.14	0.12	NA
1/26/2013	0.43	0.14	0.12	NA
1/27/2013	0.41	0.13	0.12	NA
1/28/2013	0.40	0.13	0.12	NA
1/29/2013	0.40	0.12	0.13	NA
1/30/2013	0.40	0.13	0.14	NA
1/31/2013	0.40	0.13	0.15	NA
2/1/2013	0.40	0.14	0.15	NA
2/2/2013	0.40	0.13	0.15	NA
2/3/2013	0.40	0.13	0.15	NA
2/4/2013	0.40	0.11	0.15	NA
2/5/2013	0.40	0.11	0.15	NA
2/6/2013	0.40	0.10	0.15	NA
2/7/2013	0.40	0.10	0.15	NA
2/8/2013	0.40	0.10	0.15	NA
2/9/2013	0.40	0.09	0.15	NA
2/10/2013	0.40	0.09	0.15	NA
2/11/2013	0.39	0.09	0.15	NA
2/12/2013	0.39	0.08	0.15	NA
2/13/2013	0.37	0.08	0.15	NA
2/14/2013	0.35	0.08	0.15	NA
2/15/2013	0.35	0.08	0.15	NA
2/16/2013	0.34	0.08	0.15	NA
2/17/2013	0.34	0.08	0.15	NA
2/18/2013	0.34	0.08	0.15	NA
2/19/2013	0.34	0.08	0.15	NA
2/20/2013	0.34	0.08	0.15	NA
2/21/2013	0.34	0.08	0.15	NA
2/22/2013	0.34	0.08	0.15	NA

2/23/2013	0.34	0.08	0.15	NA
2/24/2013	0.34	0.08	0.15	NA
2/25/2013	0.34	0.08	0.15	NA
2/26/2013	0.34	0.08	0.15	NA
2/27/2013	0.34	0.08	0.15	NA
2/28/2013	0.34	0.08	0.15	NA
3/1/2013	0.34	0.07	0.15	NA
3/2/2013	0.34	0.07	0.15	NA
3/3/2013	0.34	0.06	0.15	NA
3/4/2013	0.34	0.06	0.15	NA
3/5/2013	0.34	0.07	0.15	NA
3/6/2013	0.34	0.06	0.15	NA
3/7/2013	0.34	0.06	0.15	NA
3/8/2013	0.34	0.07	0.15	NA
3/9/2013	0.34	0.06	0.15	NA
3/10/2013	0.34	0.06	0.15	NA
3/11/2013	0.34	0.07	0.15	NA
3/12/2013	0.34	0.06	0.15	NA
3/13/2013	0.33	0.06	0.15	NA
3/14/2013	0.33	0.07	0.15	NA
3/15/2013	0.32	0.07	0.15	NA
3/16/2013	0.31	0.07	0.15	NA
3/17/2013	0.29	0.07	0.15	NA
3/18/2013	0.29	0.07	0.15	NA
3/19/2013	0.29	0.06	0.15	NA
3/20/2013	0.29	0.07	0.15	NA
3/21/2013	0.29	0.06	0.15	NA
3/22/2013	0.29	0.07	0.15	NA
3/23/2013	0.29	0.06	0.14	NA
3/24/2013	0.29	0.06	0.15	NA
3/25/2013	0.29	0.06	0.15	NA
3/26/2013	0.29	0.07	0.14	NA
3/27/2013	0.29	0.07	0.14	NA
3/28/2013	0.29	0.07	0.14	NA
3/29/2013	0.29	0.07	0.14	NA
3/30/2013	0.29	0.07	0.14	NA
3/31/2013	0.29	0.07	0.14	NA
4/1/2013	0.29	0.08	0.14	NA
4/2/2013	0.29	0.11	0.13	NA
4/3/2013	0.29	0.10	0.12	NA
4/4/2013	0.29	0.10	0.12	NA
4/5/2013	0.29	0.12	0.21	NA
4/6/2013	0.29	0.11	0.27	NA

4/7/2013	0.29	0.11	0.27	NA
4/8/2013	0.29	0.11	0.21	NA
4/9/2013	0.29	0.10	0.17	NA
4/10/2013	0.29	0.11	0.16	NA
4/11/2013	0.29	0.11	0.17	NA
4/12/2013	0.29	0.11	0.15	NA
4/13/2013	0.29	0.11	0.15	NA
4/14/2013	0.29	0.11	0.14	NA
4/15/2013	0.29	0.09	0.13	NA
4/16/2013	0.29	0.09	0.14	NA
4/17/2013	0.29	0.09	0.14	NA
4/18/2013	0.29	0.09	0.14	NA
4/19/2013	0.29	0.10	0.14	NA
4/20/2013	0.29	0.11	0.14	NA
4/21/2013	0.29	0.09	0.14	NA
4/22/2013	0.29	0.09	0.14	NA
4/23/2013	0.29	0.09	0.14	NA
4/24/2013	0.29	0.10	0.13	NA
4/25/2013	0.29	0.11	0.14	NA
4/26/2013	0.29	0.12	0.14	NA
4/27/2013	0.29	0.11	0.19	NA
4/28/2013	0.29	0.12	0.35	NA
4/29/2013	0.29	0.13	0.28	NA
4/30/2013	0.29	0.14	0.18	NA
5/1/2013	0.29	0.14	0.16	NA
5/2/2013	0.29	0.14	0.14	NA
5/3/2013	0.29	0.14	0.14	NA
5/4/2013	0.29	0.14	0.14	NA
5/5/2013	0.29	0.14	0.15	NA
5/6/2013	0.36	0.12	0.21	NA
5/7/2013	0.43	0.09	0.31	NA
5/8/2013	0.45	0.14	0.34	NA
5/9/2013	0.61	0.18	0.31	NA
5/10/2013	0.75	0.32	0.53	NA
5/11/2013	0.85	0.41	0.70	NA
5/12/2013	0.79	0.54	0.87	NA
5/13/2013	0.81	0.66	0.78	NA
5/14/2013	0.91	0.55	0.32	NA
5/15/2013	1.05	0.74	0.52	NA
5/16/2013	1.09	0.79	0.83	NA
5/17/2013	1.09	0.92	1.08	NA
5/18/2013	1.07	0.90	1.10	NA
5/19/2013	1.06	0.95	1.08	NA

5/20/2013	1.08	1.17	1.23	NA
5/21/2013	1.05	1.14	1.14	NA
5/22/2013	1.07	0.95	0.90	NA
5/23/2013	1.00	0.76	0.55	NA
5/24/2013	1.04	0.70	0.47	NA
5/25/2013	0.99	0.65	0.46	NA
5/26/2013	1.16	1.03	0.73	NA
5/27/2013	1.17	1.26	0.90	NA
5/28/2013	1.15	1.24	1.04	NA
5/29/2013	1.17	1.17	0.95	NA
5/30/2013	1.11	0.93	0.84	NA
5/31/2013	1.17	0.80	0.92	NA
6/1/2013	1.22	1.10	1.10	NA
6/2/2013	1.22	1.21	1.25	NA
6/3/2013	1.14	1.02	1.11	NA
6/4/2013	1.16	1.13	0.95	NA
6/5/2013	1.34	1.51	1.59	NA
6/6/2013	1.44	1.52	1.70	NA
6/7/2013	1.40	1.38	1.64	NA
6/8/2013	1.41	1.32	1.63	NA
6/9/2013	1.40	1.34	1.61	NA
6/10/2013	1.40	1.32	1.48	NA
6/11/2013	1.45	1.36	1.67	NA
6/12/2013	1.45	1.34	1.52	NA
6/13/2013	1.37	1.24	1.52	NA
6/14/2013	1.17	0.99	1.18	NA
6/15/2013	1.48	1.55	1.87	NA
6/16/2013	1.54	1.69	2.23	NA
6/17/2013	1.66	1.86	2.48	NA
6/18/2013	1.80	2.01	2.93	NA
6/19/2013	1.55	1.60	2.35	NA
6/20/2013	1.00	0.88	1.17	NA
6/21/2013	1.24	1.10	1.37	NA
6/22/2013	1.55	1.61	2.16	NA
6/23/2013	1.53	1.79	2.62	NA
6/24/2013	1.51	1.64	2.64	NA
6/25/2013	1.49	1.64	2.53	NA
6/26/2013	1.43	1.56	2.58	NA
6/27/2013	1.72	1.97	3.36	NA
6/28/2013	1.92	2.19	4.06	NA
6/29/2013	1.97	2.17	4.13	NA
6/30/2013	2.17	2.38	4.66	NA
7/1/2013	2.36	2.77	4.97	NA

7/2/2013	2.58	3.20	5.15	NA
7/3/2013	2.73	3.19	5.12	NA
7/4/2013	2.74	3.14	4.59	NA
7/5/2013	2.81	3.19	4.46	NA
7/6/2013	2.76	3.18	4.09	NA
7/7/2013	3.01	3.82	4.49	NA
7/8/2013	3.08	3.54	4.36	NA
7/9/2013	3.27	4.21	4.44	NA
7/10/2013	3.75	4.67	4.99	NA
7/11/2013	3.81	4.09	4.49	NA
7/12/2013	3.15	3.62	3.81	NA
7/13/2013	3.34	3.92	3.93	NA
7/14/2013	3.90	4.64	4.82	NA
7/15/2013	4.11	4.83	5.00	NA
7/16/2013	4.19	4.71	4.94	NA
7/17/2013	5.01	5.44	6.01	NA
7/18/2013	5.06	5.48	5.60	NA
7/19/2013	5.09	5.50	5.79	NA
7/20/2013	5.16	5.65	5.93	NA
7/21/2013	5.15	5.65	5.83	NA
7/22/2013	5.38	6.44	6.09	NA
7/23/2013	5.13	5.13	6.45	NA
7/24/2013	6.25	6.39	6.75	NA
7/25/2013	8.10	6.36	6.96	NA
7/26/2013	7.42	5.90	6.70	NA
7/27/2013	7.18	5.87	6.41	NA
7/28/2013	6.87	5.63	6.30	NA
7/29/2013	5.27	4.32	5.31	NA
7/30/2013	6.02	5.40	6.10	NA
7/31/2013	7.08	6.64	6.94	NA
8/1/2013	6.09	5.53	6.35	NA
8/2/2013	4.95	4.28	5.33	NA
8/3/2013	5.20	4.74	5.51	NA
8/4/2013	6.95	6.72	6.72	NA
8/5/2013	6.57	6.70	6.73	NA
8/6/2013	6.74	7.00	6.76	NA
8/7/2013	7.31	7.78	7.55	NA
8/8/2013	6.95	7.48	7.74	NA
8/9/2013	7.49	8.20	8.27	NA
8/10/2013	7.65	8.73	8.38	NA
8/11/2013	7.51	8.28	8.20	NA
8/12/2013	7.91	8.99	8.52	NA
8/13/2013	7.70	8.74	10.00	NA

8/14/2013	8.08	8.95	11.13	NA
8/15/2013	8.08	8.73	9.36	NA
8/16/2013	8.63	9.36	8.85	NA
8/17/2013	8.67	9.41	8.80	NA
8/18/2013	8.26	8.89	8.67	NA
8/19/2013	8.51	9.07	8.89	NA
8/20/2013	8.21	8.63	8.47	NA
8/21/2013	7.81	8.27	7.61	NA
8/22/2013	9.26	9.44	8.23	NA
8/23/2013	9.66	10.19	9.55	NA
8/24/2013	9.88	10.55	9.58	NA
8/25/2013	9.85	10.16	9.32	NA
8/26/2013	9.36	9.85	8.96	NA
8/27/2013	10.13	10.16	9.12	NA
8/28/2013	8.87	9.25	9.24	NA
8/29/2013	9.88	10.76	9.96	NA
8/30/2013	7.75	8.43	8.65	NA
8/31/2013	9.19	9.71	8.43	NA
9/1/2013	10.61	10.63	9.20	NA
9/2/2013	10.50	10.74	10.12	NA
9/3/2013	8.22	9.55	9.74	NA
9/4/2013	11.11	13.25	10.21	NA
9/5/2013	9.82	11.36	10.30	NA
9/6/2013	8.85	10.34	10.07	NA
9/7/2013	8.08	9.18	9.67	5.34
9/8/2013	6.95	7.33	8.11	5.23
9/9/2013	8.32	8.65	10.41	6.84
9/10/2013	9.95	10.40	11.07	7.16
9/11/2013	9.89	10.46	11.32	7.21
9/12/2013	10.41	11.14	12.14	7.29
9/13/2013	10.77	11.73	10.92	6.97
9/14/2013	9.93	10.76	9.30	7.14
9/15/2013	10.16	11.23	8.95	6.89
9/16/2013	9.46	10.43	9.22	6.92
9/17/2013	7.77	8.52	7.51	5.67
9/18/2013	3.97	4.59	5.32	4.57
9/19/2013	4.89	5.67	5.91	4.26
9/20/2013	5.92	8.38	6.49	5.91
9/21/2013	6.77	9.21	7.16	6.50
9/22/2013	4.78	5.74	5.40	4.35
9/23/2013	1.45	1.46	2.77	1.40
9/24/2013	1.61	2.31	3.70	3.21
9/25/2013	1.33	1.16	1.92	1.46

9/26/2013	1.08	0.55	1.79	1.29
9/27/2013	1.06	0.58	1.52	0.83
9/28/2013	0.92	0.25	1.33	0.40
9/29/2013	0.87	0.47	1.25	0.64
9/30/2013	0.75	0.21	0.67	0.23
10/1/2013	0.74	0.18	0.77	0.19
10/2/2013	0.84	0.49	0.94	0.18
10/3/2013	0.91	0.55	0.99	0.18
10/4/2013	0.94	0.56	0.63	0.20
10/5/2013	0.91	0.51	1.10	0.21
10/6/2013	1.04	0.72	0.49	0.20
10/7/2013	1.05	0.56	0.78	0.28
10/8/2013	0.89	0.19	0.83	0.19
10/9/2013	1.04	0.50	0.84	0.22
10/10/2013	0.98	0.30	0.83	0.25
10/11/2013	1.00	0.40	0.78	0.31
10/12/2013	1.03	0.41	0.46	0.44
10/13/2013	1.02	0.47	0.14	0.52
10/14/2013	1.02	0.46	0.52	0.55
10/15/2013	1.04	0.36	0.23	0.29
10/16/2013	1.04	0.39	0.51	0.28
10/17/2013	1.03	0.43	0.72	0.29
10/18/2013	0.99	0.39	0.40	0.26
10/19/2013	0.98	0.38	1.04	0.27
10/20/2013	1.03	0.41	0.97	0.30
10/21/2013	1.08	0.48	1.16	0.31
10/22/2013	1.12	0.79	1.24	0.36
10/23/2013	1.27	1.03	1.00	0.56
10/24/2013	1.32	1.38	1.36	0.62
10/25/2013	1.39	1.70	1.21	0.86
10/26/2013	1.32	1.38	1.14	0.88
10/27/2013	0.93	0.29	0.35	0.41
10/28/2013	0.75	0.15	-0.18	0.31
10/29/2013	0.94	0.22	-0.08	0.30
10/30/2013	0.89	0.22	-0.05	0.27
10/31/2013	0.86	0.21	0.14	0.27
11/1/2013	0.90	0.21	0.35	0.27
11/2/2013	0.88	0.19	0.40	0.28
11/3/2013	0.91	0.20	0.42	0.28
11/4/2013	0.90	0.21	0.42	0.26
11/5/2013	0.86	0.22	0.42	0.25
11/6/2013	0.86	0.23	0.42	0.25
11/7/2013	0.86	0.23	0.41	0.26

11/8/2013	0.87	0.22	0.41	0.24
11/9/2013	0.85	0.24	0.39	0.23
11/10/2013	0.86	0.26	0.38	0.23
11/11/2013	0.85	0.27	0.37	0.23
11/12/2013	0.84	0.27	0.39	0.23
11/13/2013	0.83	0.26	0.51	0.16
11/14/2013	0.82	0.26	0.41	0.16
11/15/2013	0.83	0.28	0.40	0.18
11/16/2013	0.84	0.28	0.39	0.18
11/17/2013	0.84	0.29	0.38	0.18
11/18/2013	0.82	0.29	0.37	0.17
11/19/2013	0.82	0.29	0.37	0.16
11/20/2013	0.76	0.26	0.35	0.17
11/21/2013	0.70	0.27	0.36	0.16
11/22/2013	0.69	0.28	0.35	0.15
11/23/2013	0.69	0.29	0.34	0.16
11/24/2013	0.69	0.31	0.34	0.16
11/25/2013	0.69	0.30	0.34	0.17
11/26/2013	0.68	0.32	0.37	0.17
11/27/2013	0.67	0.31	0.35	0.18
11/28/2013	0.66	0.30	0.35	0.18
11/29/2013	0.64	0.31	0.36	0.17
11/30/2013	0.65	0.31	0.37	0.18
12/1/2013	0.63	0.31	0.35	0.17
12/2/2013	0.63	0.31	0.38	0.17
12/3/2013	0.61	0.31	0.34	0.17
12/4/2013	0.60	0.30	0.34	0.17
12/5/2013	0.60	0.29	0.34	0.17
12/6/2013	0.58	0.28	0.32	0.17
12/7/2013	0.57	0.28	0.33	0.18
12/8/2013	0.57	0.28	0.34	0.18
12/9/2013	0.55	0.28	0.34	0.18
12/10/2013	0.55	0.29	0.34	0.18
12/11/2013	0.54	0.29	0.34	0.18
12/12/2013	0.52	0.29	0.37	0.17
12/13/2013	0.52	0.29	0.34	0.18
12/14/2013	0.48	0.30	0.35	0.18
12/15/2013	0.47	0.29	0.36	0.18
12/16/2013	0.47	0.28	0.35	0.18
12/17/2013	0.48	0.27	0.34	0.18
12/18/2013	0.48	0.26	0.33	0.18
12/19/2013	0.47	0.25	0.30	0.19
12/20/2013	0.47	0.25	0.31	0.20

12/21/2013	0.46	0.25	0.32	0.20
12/22/2013	0.45	0.25	0.34	0.20
12/23/2013	0.45	0.25	0.34	0.20
12/24/2013	0.46	0.25	0.34	0.20
12/25/2013	0.46	0.25	0.34	0.20
12/26/2013	0.46	0.26	0.34	0.20
12/27/2013	0.46	0.26	0.34	0.20
12/28/2013	0.44	0.26	0.34	0.20
12/29/2013	0.44	0.26	0.34	0.20
12/30/2013	0.44	0.26	0.35	0.20
12/31/2013	0.44	0.26	0.35	0.21
1/1/2014	0.44	0.26	0.35	0.22
1/2/2014	0.44	0.26	0.34	0.22
1/3/2014	0.44	0.26	0.34	0.22
1/4/2014	0.44	0.27	0.32	0.22
1/5/2014	0.42	0.27	0.29	0.22
1/6/2014	0.43	0.27	0.33	0.22
1/7/2014	0.42	0.27	0.34	0.21
1/8/2014	0.41	0.27	0.34	0.21
1/9/2014	0.41	0.27	0.34	0.22
1/10/2014	0.40	0.27	0.34	0.22
1/11/2014	0.40	0.28	0.34	0.22
1/12/2014	0.40	0.28	0.34	0.21
1/13/2014	0.40	0.28	0.34	0.20
1/14/2014	0.40	0.27	0.34	0.20
1/15/2014	0.40	0.28	0.34	0.20
1/16/2014	0.40	0.27	0.34	0.20
1/17/2014	0.40	0.28	0.34	0.20
1/18/2014	0.40	0.27	0.34	0.20
1/19/2014	0.39	0.27	0.34	0.19
1/20/2014	0.39	0.27	0.34	0.20
1/21/2014	0.38	0.26	0.33	0.20
1/22/2014	0.38	0.26	0.32	0.20
1/23/2014	0.38	0.26	0.32	0.20
1/24/2014	0.38	0.26	0.32	0.19
1/25/2014	0.38	0.26	0.31	0.19
1/26/2014	0.38	0.26	0.31	0.19
1/27/2014	0.38	0.26	0.29	0.19
1/28/2014	0.38	0.26	0.29	0.19
1/29/2014	0.38	0.26	0.29	0.19
1/30/2014	0.38	0.25	0.29	0.19
1/31/2014	0.38	0.26	0.29	0.19
2/1/2014	0.38	0.26	0.29	0.19

2/2/2014	0.37	0.26	0.29	0.19
2/3/2014	0.37	0.25	0.29	0.18
2/4/2014	0.36	0.23	0.29	0.17
2/5/2014	0.36	0.22	0.29	0.17
2/6/2014	0.36	0.23	0.29	0.17
2/7/2014	0.36	0.24	0.29	0.17
2/8/2014	0.36	0.23	0.29	0.17
2/9/2014	0.36	0.24	0.29	0.17
2/10/2014	0.36	0.24	0.29	0.16
2/11/2014	0.36	0.25	0.29	0.17
2/12/2014	0.36	0.24	0.29	0.17
2/13/2014	0.36	0.25	0.29	0.17
2/14/2014	0.36	0.25	0.29	0.17
2/15/2014	0.36	0.24	0.29	0.16
2/16/2014	0.35	0.24	0.29	0.15
2/17/2014	0.36	0.23	0.29	0.15
2/18/2014	0.36	0.23	0.29	0.15
2/19/2014	0.35	0.22	0.29	0.15
2/20/2014	0.35	0.21	0.29	0.15
2/21/2014	0.35	0.20	0.29	0.15
2/22/2014	0.35	0.20	0.29	0.15
2/23/2014	0.35	0.20	0.29	0.14
2/24/2014	0.34	0.20	0.29	0.14
2/25/2014	0.34	0.20	0.29	0.14
2/26/2014	0.34	0.21	0.29	0.15
2/27/2014	0.34	0.21	0.29	0.14
2/28/2014	0.33	0.21	0.29	0.14
3/1/2014	0.31	0.21	0.29	0.14
3/2/2014	0.32	0.21	0.29	0.13
3/3/2014	0.33	0.21	0.29	0.13
3/4/2014	0.32	0.21	0.29	0.14
3/5/2014	0.32	0.21	0.29	0.13
3/6/2014	0.32	0.21	0.28	0.13
3/7/2014	0.31	0.21	0.28	0.13
3/8/2014	0.31	0.21	0.28	0.13
3/9/2014	0.31	0.20	0.29	0.12
3/10/2014	0.30	0.20	0.29	0.13
3/11/2014	0.30	0.19	0.29	0.13
3/12/2014	0.30	0.20	0.29	0.13
3/13/2014	0.29	0.19	0.29	0.12
3/14/2014	0.29	0.20	0.29	0.12
3/15/2014	0.29	0.19	0.29	0.12
3/16/2014	0.29	0.19	0.29	0.12

3/17/2014	0.29	0.19	0.29	0.13
3/18/2014	0.29	0.19	0.29	0.12
3/19/2014	0.29	0.19	0.29	0.12
3/20/2014	0.29	0.19	0.29	0.12
3/21/2014	0.29	0.19	0.28	0.12
3/22/2014	0.29	0.19	0.28	0.12
3/23/2014	0.29	0.19	0.29	0.12
3/24/2014	0.29	0.19	0.29	0.12
3/25/2014	0.29	0.19	0.29	0.12
3/26/2014	0.29	0.19	0.29	0.12
3/27/2014	0.29	0.19	0.28	0.12
3/28/2014	0.29	0.19	0.29	0.12
3/29/2014	0.29	0.19	0.29	0.12
3/30/2014	0.29	0.19	0.28	0.12
3/31/2014	0.29	0.19	0.28	0.12
4/1/2014	0.29	0.19	0.28	0.12
4/2/2014	0.29	0.19	0.28	0.12
4/3/2014	0.29	0.19	0.28	0.12
4/4/2014	0.29	0.19	0.28	0.12
4/5/2014	0.29	0.19	0.28	0.12
4/6/2014	0.29	0.19	0.28	0.12
4/7/2014	0.29	0.19	0.28	0.12
4/8/2014	0.29	0.19	0.28	0.12
4/9/2014	0.28	0.19	0.28	0.12
4/10/2014	0.27	0.19	0.29	0.12
4/11/2014	0.27	0.19	0.28	0.12
4/12/2014	0.26	0.19	0.26	0.12
4/13/2014	0.26	0.19	0.26	0.12
4/14/2014	0.26	0.19	0.26	0.12
4/15/2014	0.25	0.19	0.26	0.12
4/16/2014	0.26	0.19	0.26	0.12
4/17/2014	0.27	0.19	0.26	0.12
4/18/2014	0.27	0.19	0.26	0.12
4/19/2014	0.27	0.19	0.26	0.12
4/20/2014	0.27	0.19	0.26	0.12
4/21/2014	0.27	0.19	0.26	0.12
4/22/2014	0.26	0.19	0.26	0.12
4/23/2014	0.27	0.19	0.25	0.12
4/24/2014	0.27	0.19	0.26	0.12
4/25/2014	0.27	0.19	0.26	0.12
4/26/2014	0.27	0.19	0.26	0.11
4/27/2014	0.25	0.19	0.25	0.12
4/28/2014	0.25	0.19	0.26	0.12

4/29/2014	0.26	0.19	0.26	0.11
4/30/2014	0.26	0.19	0.26	0.11
5/1/2014	0.25	0.19	0.24	0.11
5/2/2014	0.24	0.18	0.23	0.10
5/3/2014	0.26	0.17	0.37	0.09
5/4/2014	0.31	0.17	0.35	0.09
5/5/2014	0.31	0.17	0.33	0.09
5/6/2014	0.30	0.17	0.32	0.09
5/7/2014	0.30	0.17	0.29	0.09
5/8/2014	0.31	0.17	0.30	0.09
5/9/2014	0.30	0.18	0.27	0.09
5/10/2014	0.29	0.18	0.25	0.09
5/11/2014	0.29	0.18	0.24	0.09
5/12/2014	0.30	0.18	0.27	0.09
5/13/2014	0.31	0.18	0.26	0.09
5/14/2014	0.31	0.17	0.23	0.09
5/15/2014	0.28	0.16	0.42	0.09
5/16/2014	0.25	0.14	0.40	0.09
5/17/2014	0.29	0.15	0.57	0.09
5/18/2014	0.33	0.15	0.49	0.09
5/19/2014	0.37	0.19	0.60	0.09
5/20/2014	0.39	0.20	0.58	0.09
5/21/2014	0.38	0.22	0.66	0.09
5/22/2014	0.35	0.37	0.66	0.09
5/23/2014	0.34	0.50	0.91	0.09
5/24/2014	0.35	0.59	0.84	0.09
5/25/2014	0.36	0.71	0.95	0.09
5/26/2014	0.38	0.73	0.91	0.09
5/27/2014	0.39	0.77	0.92	0.09
5/28/2014	0.38	0.79	1.09	0.09
5/29/2014	0.38	0.62	0.52	0.09
5/30/2014	0.41	0.77	0.84	0.09
5/31/2014	0.41	0.85	1.14	0.12
6/1/2014	0.41	0.86	1.23	0.12
6/2/2014	0.42	0.88	1.27	0.12
6/3/2014	0.41	0.85	1.19	0.12
6/4/2014	0.41	0.87	1.26	0.12
6/5/2014	0.42	0.76	0.86	0.14
6/6/2014	0.43	0.82	0.80	0.21
6/7/2014	0.43	0.85	0.99	0.23
6/8/2014	0.44	0.93	1.31	0.23
6/9/2014	NA	0.93	1.40	0.21
6/10/2014	NA	0.80	1.02	0.22

6/11/2014	0.30	0.88	1.07	0.25
6/12/2014	0.31	0.93	1.39	0.27
6/13/2014	0.29	0.82	1.10	0.21
6/14/2014	0.32	0.80	1.11	0.30
6/15/2014	0.34	0.83	1.18	0.34
6/16/2014	0.36	0.91	1.05	0.34
6/17/2014	0.25	0.54	0.85	0.28
6/18/2014	0.25	0.52	0.45	0.36
6/19/2014	0.32	0.66	1.02	0.37
6/20/2014	0.34	0.88	1.48	0.33
6/21/2014	0.36	0.82	1.25	0.35
6/22/2014	0.44	0.95	1.68	0.40
6/23/2014	0.45	1.02	1.82	0.42
6/24/2014	0.48	1.05	2.08	0.40
6/25/2014	0.51	0.97	1.91	0.41
6/26/2014	0.46	0.91	1.86	0.46
6/27/2014	0.52	1.01	1.97	0.50
6/28/2014	0.46	0.90	1.65	0.42
6/29/2014	0.50	0.93	1.66	0.49
6/30/2014	0.64	1.04	1.95	0.58
7/1/2014	0.78	1.17	2.60	0.66
7/2/2014	0.89	1.30	3.07	0.73
7/3/2014	0.98	1.38	3.38	0.93
7/4/2014	0.98	1.35	2.77	0.98
7/5/2014	1.09	1.46	2.93	1.07
7/6/2014	1.22	1.64	3.54	1.15
7/7/2014	1.32	1.60	3.40	1.20
7/8/2014	1.43	1.72	3.66	1.31
7/9/2014	1.65	2.03	4.14	1.47
7/10/2014	1.68	1.90	3.62	1.56
7/11/2014	1.77	1.92	3.58	1.68
7/12/2014	1.96	2.02	3.78	1.84
7/13/2014	2.42	2.29	4.42	2.11
7/14/2014	3.05	2.21	4.48	1.86
7/15/2014	3.40	2.07	4.00	1.87
7/16/2014	4.95	2.75	4.52	2.57
7/17/2014	5.53	2.89	4.72	2.68
7/18/2014	4.99	2.77	4.27	2.31
7/19/2014	4.62	3.05	4.80	2.37
7/20/2014	4.47	2.82	4.41	2.29
7/21/2014	5.52	3.10	4.08	2.81
7/22/2014	4.77	2.91	3.88	2.69
7/23/2014	6.73	3.99	5.08	3.66

7/24/2014	3.25	2.31	3.24	2.14
7/25/2014	3.71	2.67	3.58	2.50
7/26/2014	5.11	3.76	5.05	3.56
7/27/2014	5.25	4.19	5.23	4.31
7/28/2014	5.51	4.39	5.30	4.51
7/29/2014	6.02	4.96	6.10	4.56
7/30/2014	6.17	4.92	6.22	4.18
7/31/2014	6.64	5.18	6.28	4.21
8/1/2014	6.97	5.34	6.84	4.18
8/2/2014	7.12	5.43	6.60	4.81
8/3/2014	6.61	5.12	6.12	4.52
8/4/2014	7.31	5.91	7.10	5.10
8/5/2014	7.49	6.07	6.93	5.29
8/6/2014	7.77	6.27	6.98	5.34
8/7/2014	7.59	6.29	6.64	5.49
8/8/2014	7.80	6.56	6.82	5.62
8/9/2014	7.66	6.55	6.66	5.55
8/10/2014	7.92	6.85	7.00	5.98
8/11/2014	8.47	10.62	7.53	6.29
8/12/2014	7.92	15.39	8.01	6.05
8/13/2014	16.59	16.54	8.08	6.32
8/14/2014	NA	11.79	8.20	5.70
8/15/2014	NA	5.60	8.49	5.98
8/16/2014	NA	5.71	7.94	5.04
8/17/2014	NA	6.72	9.11	5.33
8/18/2014	NA	8.57	10.72	6.14
8/19/2014	NA	8.63	10.40	6.00
8/20/2014	NA	8.32	8.95	5.40
8/21/2014	NA	6.22	6.26	4.41
8/22/2014	NA	5.31	5.61	4.24
8/23/2014	NA	4.07	6.12	3.65
8/24/2014	NA	6.80	12.31	4.29
8/25/2014	NA	11.33	NA	5.83
8/26/2014	NA	13.49	NA	10.83

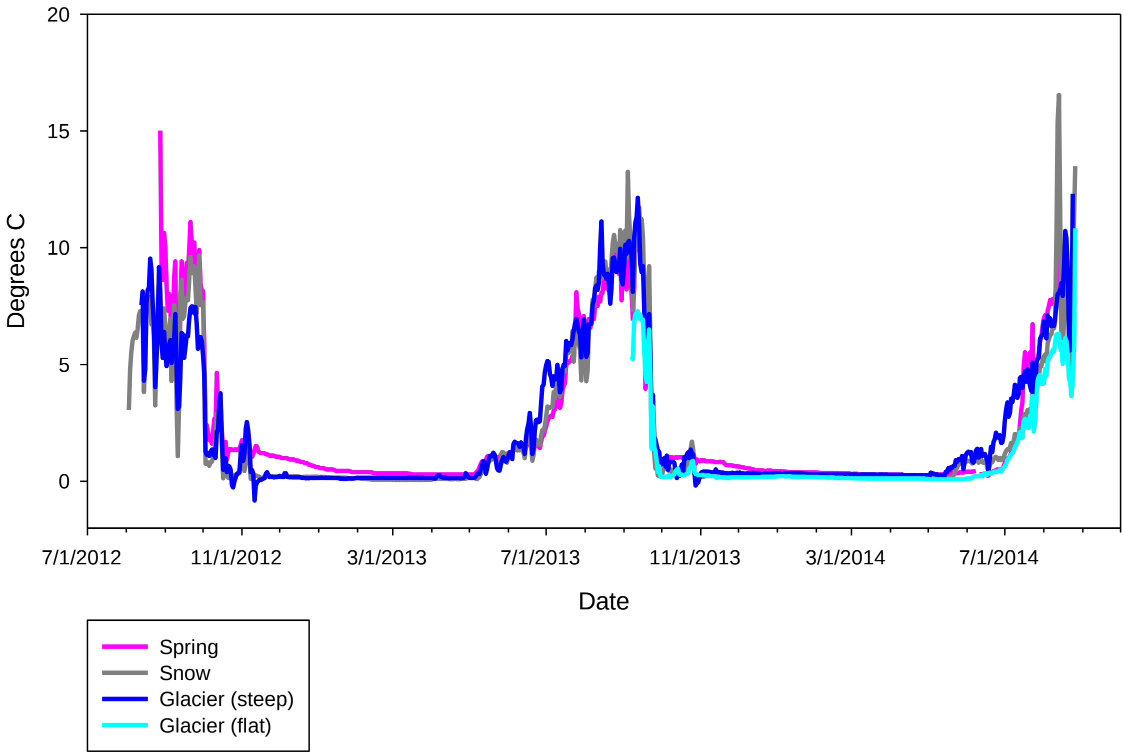

Figure 17: Graph of average daily stream type grouped by stream types. This graph shows data from 13 reaches (Spring – 4, Snow – 4, Glacier (steep) – 3, and Glacier (flat) – 2). Loggers from 28 sites are still in streams in GNP contributing to long term monitoring.