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Influence of Engineered Log Jam Placement on Habitat, Periphyton, Invertebrates and Fish in the South Fork Skokomish River

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Abstract

Millions of dollars have been spent restoring salmonid habitat in the Pacific Northwest. Unfortunately, the effectiveness of many restoration techniques is poorly understood due to inadequate monitoring. Engineered Log Jams (ELJs) are a relatively new technique for restoring habitat in large rivers. ELJs have not been sufficiently monitored due to the short time in which they have been used. The U.S. Forest Service installed 30 ELJs in the South Fork Skokomish River in 2010 to restore riparian vegetation, floodplain resiliency, resistance to flow, stream channel and bank stability, fish habitat, and fish production. This report summarizes results of initial monitoring efforts to assess the effectiveness of these ELJs in restoring habitat, primary and secondary production, and fish communities. This assessment was completed by measuring habitat, periphyton, invertebrates, invertebrate drift, salmonid diet, fish communities, and salmonid abundance in the restored reach (ELJ) and an adjacent control reach where no restoration work was completed (downstream of the ELJ treatment reach). Few substantial differences were observed between the ELJ and control reach. Overall channel length, sinuosity, and the ratio of total channel length to mainstem length were greater at the ELJ reach. At the habitat-unit scale, turbulent-water habitats were more common in the ELJ reach. There were no differences in periphyton, benthic invertebrate, or diatom metrics between the ELJ and control reach. Invertebrate drift in the control reach consisted of a greater proportion of Diptera, was more abundant, and had a greater biomass than that of the ELJ reach. No obvious differences were observed in fish abundance and the size or diet of trout fry or greater than 1+ *O. mykiss* in ELJ and control reaches. The lack of differences observed between the ELJ and control reaches may have been influenced by the relatively short time-period between restoration and this monitoring effort (~2 yrs). In addition, the lack of replication of restored and control reaches would make it difficult to draw strong generalized conclusions about the effectiveness of ELJs. A more rigorous and extensive assessment of ELJs should be completed to address this issue.

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Introduction

Habitat restoration has become a common practice the past few decades to restore degraded riverine habitat and threatened salmonids species, resulting in millions of dollars of expenditures each year (Roni et al. 2002). However, the effectiveness of many of these methods is poorly understood and/or has been inadequately monitored (Roni et al. 2002; Vehanen et al. 2010). Engineered Log Jams (ELJs) are becoming a common tool to restore rivers throughout the west coast of the United States (e.g., Nagayama and Nakamura 2010; Pess et al. 2012; Peters et al. 2012). However, the effectiveness of ELJs is poorly understood due to the short timeframe during which they have been used.

The few published reports suggest that ELJs have potential for restoring aquatic communities in riverine systems. Pess et al. (2012) reported that ELJs are potentially useful for restoring juvenile salmonid habitat. They observed increased juvenile salmonid densities at ELJ units relative to non-ELJ units; however, the results varied among years and species. Brooks et al. (2004) observed greater species richness and increased overall fish abundance at ELJs in the Williams River, Australia; however, the benefits appeared short-lived (Brooks et al. 2006). Greater periphyton biomass and invertebrate densities have also been observed on ELJs compared to non-ELJ substrates, with ELJs supporting a unique invertebrate community (Coe et al. 2009).

The South Fork (S.F.) Skokomish River, particularly the reach extending from river kilometer (RKM) 17.4 to 20.8 has been degraded by past upland logging, riparian logging, road construction, stream bank erosion, and removal of wood from the stream channel (Bair et al. 2008a). Based on a reach assessment, it was determined that habitat conditions within this reach would limit biological production (Bair et al. 2008a). ELJs and large wood debris (LWD) structures were proposed for floodplains, tributary fans, and the bankfull perimeter of this reach to restore physical processes and biological communities (Bair et al. 2008a). The restoration goals were to 1) restore riparian vegetation, 2) restore floodplain resiliency and resistance to flow, and stream channel and bank stability, and 3) restore fish habitat and fish production (Bair et al. 2008b).

The purpose of this report is to provide information regarding the influence of these ELJs and large wood structures on instream habitat and aquatic biological communities (i.e., restoration goal number 3 from above). The specific objectives were to assess the influence of ELJs on instream habitat diversity, primary and secondary production, fish species diversity, and fish populations in the restored reach (i.e., ELJs added – ELJ reach) and nearby control reaches (i.e., reach with no LW added – Control reach) of the S.F. Skokomish River.

Study Area

The Skokomish Basin, including the S.F. Skokomish River basin have been described in a number of reports (e.g., USFS 1995, ME2 1997, Skokomish Tribe and WDFW 2010, Peters et al. 2011). The S.F. Skokomish River is one of three major sub-basins of the Skokomish River and drains a basin area of 331 km^2. The S.F. Skokomish can be generally divided into four sections: the lower river from the confluence with the North Fork Skokomish River upstream to the canyon at RKM 8.0, the canyon reach from RKM 8 to RKM 16.1, a wide alluvial valley section from RKM 16.1 to RKM 37.8, and the final canyon reach from RKM 37.8 upstream to the headwaters. The study reach for this project, which extends from RKM 17.4 to 20.8, is within the large alluvial valley section (Figure 1). This reach is generally unconfined and has a moderate gradient of around 0.013 (ME2 1997).

The geology of the S.F. Skokomish watershed consists of submarine basalt flows dating from the Eocene Epoch (37-50 million years ago), which have been uplifted due to tectonic plate movement. The headwaters are underlain by marine sedimentary slates, mudstones, and sandstones, which originally formed part of the accretionary wedge associated with the subduction zone. These bedrocks are covered by sediments deposited during alpine glaciation originating in the Olympic Mountains. Soil depths in the watershed are generally less than one meter, except in the valleys where glaciation and fluvial deposition have accumulated sediment over 30 meters deep in some places (WDFW and PNPTT 2000).

The Skokomish basin lies within a temperate marine climate with wet winters and dry summers. There is a large precipitation gradient from the headwaters to the mouth of the Skokomish basin. The upper portions of the watershed receive over 300 cm of rain annually, while areas near the mouth at Hood Canal receive approximately 150 cm of rain annually. This rain results in peak flows during the winter-wet season for the S.F. Skokomish River (England 2007). Sections of the lower S.F. Skokomish go dry during summer low flow due to aggradation.

Land use in the S.F. Skokomish River is dominated by commercial timber harvest and associated road construction. The study reach has been described thoroughly by Bair et al (2008a). The area was logged and instream wood removed to facilitate the construction of a dam proposed at the downstream end of the reach in 1952. Other habitat alterations include riparian timber harvest, additional removal of instream wood, increased sedimentation from landslides associated with upslope timber harvest, surface erosion associated with road construction and stream bank erosion. This has resulted in more than a 50% reduction of vegetation coverage within the flood-prone area, a 29% increase in meander length, 30% increase in pool spacing, and a 68% increase in bankfull width. Large wood within the floodplain and the bankfull channel have decreased by about 67%.

Seven salmonid species are present in the S.F. Skokomish River including Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*),

cutthroat trout (*O. clarkii*), pink salmon (*O. gorbuscha*), steelhead and resident rainbow trout (*O. mykiss*), and bull trout (*Salvelinus confluentus*). However, pink salmon and chum salmon were not observed in the study area during fish surveys completed in 2008, while Chinook and coho salmon were extremely rare in the study reach (Peters et al. 2011).

Five species of sculpin (*Cottus* spp.) are found in the Skokomish River, including prickly sculpin (*C. asper*), coastrange sculpin (*C. alecticus*), riffle sculpin (*C gulosus*), reticulate sculpin (*C. perplexus*), and shorthead sculpin (*C. confusus*). River lamprey (*Lampetra ayrsi*), western brook lamprey (*L. richardsoni*),), and Pacific lamprey (*Entosphenus tridentate*) have been observed in the Skokomish Basin. Sculpin were observed throughout the Skokomish Basin including the upper S.F. Skokomish River during snorkel surveys (Peters et al. 2011). However, they were not actually captured and therefore could not be accurately identified to species (Peters et al. 2011). Sculpin likely inhabiting this area include riffle sculpin and shorthead sculpin. Shorthead sculpin were documented in the upper S.F. Skokomish River by Mongillo and Hallock (1997).

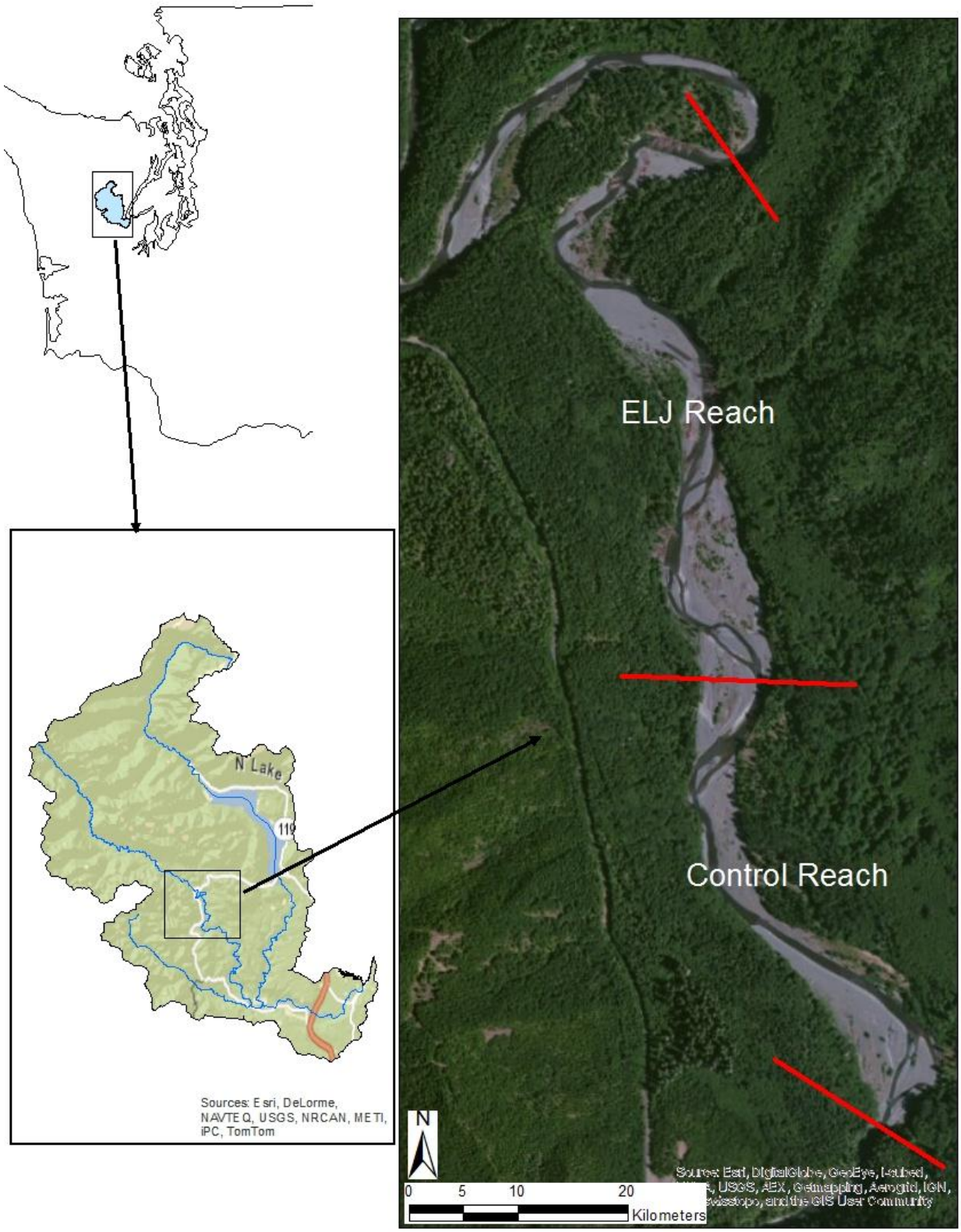

Figure 1. Engineered Log Jam (ELJ) and control reach of the S.F. Skokomish River. The red lines show the start and end of each reach. The photo was taken after ELJ placement.

Methods

Reach selection was determined primarily by the restoration project. The treatment reach (ELJ) was located in a wide alluvial valley that was bordered by upstream and downstream canyons, which defined the upper and lower extent of the reach available for assessment. The ELJ reach began just downstream of the upstream canyon and ended approximately 1.5 km downstream. There was approximately 1 km of the alluvial valley remaining downstream of the ELJ reach for the control reach before the channel entered the downstream canyon. The control began one habitat unit downstream of the ELJ reach, to provide at least some separation between the two reaches and ended about two habitat units above the downstream canyon. All mainstem, side channel, braided channel, and backwater habitats within this area were measured for habitat conditions. Data were summarized relative to available habitat area (channel lengths or area) for reach scale summaries or by sampling area for finer scale summaries (e.g., macroinvertebrate and periphyton sampling area).

Habitat

Habitat data was collected while walking downstream following modifications to methods described by Peters et al. (2011). This method is based on modifications of habitat classification systems described by Murphy et al. (1989), Hawkins et al. (1993), and Hirschi and Reed (1998). First, the channel type in which the habitat unit was located was classified as main channel, braided channel, side channel, or backwater channel. Main channels contained all or a majority of the river discharge. Braided channels contained a smaller proportion of the total discharge and were separated from the main channel by gravel bars containing immature riparian vegetation. Side channels were similar to braided channels except that they were separated from the main channel by islands with mature riparian vegetation. Backwater channels were abandoned channels formed when sediment and/or organic debris blocked the upstream end of a braid or branch of the main channel.

Levels 2 through 4 classify the main geomorphic units (pools, riffles) of the channel (Table 1). The habitat depth is simply classified as shallow, average depth or deep in level 2. Level 3 further divides these classes as turbulent or non-turbulent for shallow and average depth habitats, and scour pool or dammed pool for deep-water habitats. Level 4 further divides these groups to more specific traditional habitat classifications. For example, shallow, turbulent areas can be classified as falls, cascades, riffle, or chute, and scour pools can be classified as eddy, lateral, mid-channel, trench, convergence, or plunge.

The length and width of each habitat unit was measured using a laser rangefinder (TruPulse 200B). Wetted width was measured at 25%, 50%, and 75% of the distance from the upstream end of the unit to the downstream end of the unit. These measurements were used to

calculate the surface area of individual habitat units. The sum of the unit lengths and unit areas were used to calculate total reach length and surface area, respectively.

We used three different metrics to characterize the river channel banks, including riparian habitat, bank modifications, and bank stabilization. Riparian habitats were classified visually as bare ground, grass/shrub, immature/mature deciduous/confer, or mixed deciduous conifer. Banks were classified with regard to modifications as either natural or modified. Bank stability was classified as stable or eroding. Eroding banks were those with obvious signs of erosion (i.e., exposed substrate, slumping banks, etc.).

Cover for fish was characterized by measuring vegetation overhang and wood cover. Vegetation overhang was classified as present or absent and included any vegetation overhanging the wetted channel within 0.3 m of the water surface. The longitudinal length and average distance the vegetation overhung the water surface was measured using a laser rangefinder. Wood cover was classified as ELJs, natural large wood accumulations (LWD), small wood accumulations (SWD), single logs (SL), attached vegetation (AV), or logs with rootwads (LRW). The complexity of cover provided to juvenile salmonids was classified as complex or sparse. Complex cover provided substantial cover for juvenile salmonids trying to avoid predators (i.e., debris jams, complex branches, etc.), while sparse cover provided little protection (i.e., single logs). The length and width of each cover element was measured using the laser rangefinder.

Water depth (nearest 0.1 m) was measured at 9 to 11 locations in each habitat unit using a stadia rod. We measured water depth at 25%, 50%, and 75% of the distance across the channel at the three locations where we measured channel width. We also measured maximum depth and riffle crest depth for pool habitats (the riffle crest at the downstream end of the pool). These data were used to calculate the average depths for each unit, maximum depth for each pool, and overall reach average depth.

Substrate was classified using two methods. We estimated substrate size for each habitat unit visually as the percent of substrate present in five size categories, including fines (<2 mm), small gravel (2-16 mm), gravel (16-64 mm), cobble (64-256 mm), and boulder (>265 mm - includes riprap). In addition, individual pieces of substrate were collected at the base of the stadia rod at the nine to eleven locations where we measured average depth. We measured and recorded the b-axis of each of these pieces of substrate to provide information about the average grain size of the reach.

Table 1. Description of three-level hierarchical habitat classification system used in this study (modified from Murphy et al. (1989), Hawkins et al. (1993), and Hirschi and Reed (1998)).

Level 2	Level 3	Level 4	Description
Shallow Water			Riffles; rapid, shallow stream sections with steep water surface gradient (McMahon et al. 1996).
	Turbulent		Channel units having swift current, high channel roughness (large substrate), steep gradient, and non-laminar flow and characterized by surface turbulence.
		Riffle	Shallow, lower-gradient channel units with moderate current velocity and some partially exposed substrate (usually cobble).
	Non-Turbulent		Channel units having low channel roughness, moderate gradient, laminar flow, and lack of surface turbulence.
		Sheet	Shallow water flowing over smooth bedrock
		Glide	Shallow water flowing over a variety of substrates
Average Water Depth			
	Turbulent		
		Rapid	Deeper stream section with considerable surface agitation and swift current; large boulders and standing waves often present.
		Run	Fast flowing water that is relatively deep and mildly turbulent. Usually found at the head of pools or in areas that result in limited scour.
	Non-turbulent		
		Glide	Shallow water flowing over a variety of different substrates
Deep Water			
	Scour Pool		Formed by scouring action of current
		Eddy	Formed by circular current pattern created by bank obstruction, usually occur along the bank

Table 1.-Continued.

Level 2	Level 3	Level 4 & 5	Description
		Trench	Formed by scouring of bedrock. Usually located in the main channel
		Mid-Channel	Formed in the main channel by channel constriction at the head of the pool
Deep Water (cont.)		Convergence	Formed in the main channel by converging streams
		Lateral	Formed in the main channel where flow is deflected by a partial channel obstruction (stream bank, rootwad, log, or boulder); for example at the outside bends in the channel of meandering streams, deeper on one side than the other and formed as a result of a deflector at the head of the pool
		Plunge	Formed in the main channel, deeper upstream, and are formed by water dropping vertically over a channel obstruction
		Deposition	Depositional area within a scour pool. Usually along the point bar of a lateral scour pool.
	Dammed Pool		Water impounded by channel blockage
		Debris	Formed by rootwad and logs
		Beaver	Formed by beaver dam
		Landslide	Formed by large boulders
		Backwater	Formed by obstructions along banks
		Abandoned Channel	Formed alongside main channel, usually associated with gravel bars

Periphyton and Invertebrate Sampling

We collected periphyton and stream dwelling benthic macroinvertebrates from four randomly selected riffles in both the ELJ and control reach. Within the ELJ reach, two units downstream of ELJs and two units within the ELJ reach downstream of units lacking ELJs were selected (not every habitat unit within the ELJ reach contained an ELJ). Only riffles with sufficient flow, depth, and length to collect samples were selected based on protocols developed for other Olympic Peninsula rivers (Morley et al. 2008).

At each site, we sampled periphyton from randomly selected cobbles that ranged from baseball to softball size, one adjacent to each macroinvertebrate slack sample (see below). Periphyton growing on the surface of each cobble was scrubbed with a toothbrush and rinsed into a pooled sample for all five cobbles. This elutriate was homogenized by stirring with a hand-blender and subsamples were collected for taxonomy and Chlorophyll-*a* concentration. Chlorophyll-*a* samples were filtered through 47 mm glass-fiber filters (1 μm pore size), which were frozen until they were analyzed in the laboratory. Chlorophyll-*a*, which specifically estimates the major algal component of periphyton, was estimated following EPA Method 446 (Arar 1997). Chlorophyll-*a* was extracted with 90 % acetone and the concentration (biomass per unit area – mg/cm^2 – based on total rock area sampled) of the resulting supernatant measured using spectrophotometry (Hach DR/2000). To determine the pheopigment-corrected Chlorophyll-*a* concentration, the aliquot of the supernatant was measured at 750 nm and 665 nm before and after acidification with 0.1 N HCl, to assess turbidity in the sample, with the sample absorbance measured at 750 nm subtracted from the samples absorbance at 665 nm (Arar 1997). Taxonomy samples were preserved in Lugol's solution and held in dark containers until analysis in the laboratory.

We collected five benthic invertebrate samples from the riffle margin using a Slack sampler (500 μm mesh, 0.25 m^2 frame), a net developed for use in large, deep rivers (Moulton et al. 2002). Based on a power analysis from previous work in the Elwha River (Morley et al. 2008), we collected five invertebrate samples from each riffle that were subsequently pooled for taxonomic analysis. Samples were distributed evenly over the length of the riffle, with the first placement of the slack sampler determined using dice, which provided a random distance (1 – 6 m) from the downstream end of the riffle to locate the first slack sample. The other four samples were then evenly distributed throughout the remainder of the riffle based on total riffle length. The optimal depth for the slack sampler to operate, based on water depth < 30 cm and sufficient flow, determined the distance from the wetted edge.

Once the random sample location was determined, the 0.25 m^2 frame was placed on the bed and water depth, current velocity, and substrate composition were recorded. Invertebrates were hand-cleaned off large pieces of substrate, which dislodged individuals into the current and carried them into the net immediately downstream. Once all of the large pieces of substrate were cleaned and removed, a garden trowel was used to disturb the remaining substrate (largely sand and gravel) to a depth of ~5 cm for 60 seconds. Once this was completed, the next random location upstream was located and the procedures repeated. Once all five slack samples were collected, the net contents were placed into a bucket and the sample washed with filtered river water to remove large substrate and debris, and then the portion of the sample within the water was filtered through a 500 μm sieve to retain macroinvertebrates, which were transferred to a sample container and preserved in 70% ethanol. Invertebrates that remained on the net were hand-picked and placed in the sample container

Periphyton and Invertebrate Lab Processing

Preserved periphyton samples were shipped to Rhithron Associates laboratory in Missoula, MT, with sample control and transfer documentation. We briefly summarize a report detailing the procedures used for sample processing and QA/QC provided to the authors by Rhithron Associates. This document, which also contains data summaries, is provided as an appendix (Appendix A). After arrival at the laboratory, samples were unpacked, checked for leaks or damage, and topped off with Lugol's preservative. For diatom taxonomic analysis, permanent slides were prepared following standard techniques for diatoms. Following thorough mixing, a subsample was treated with concentrated H_2SO_4 and 30% H_2O_2. Then, samples were neutralized with distilled water and subsamples were adjusted to obtain sufficient densities of cells. Samples were placed on 22-mm square glass cover slips, dried, and mounted to laboratory glass slides using Naphrax diatom mount. This was repeated three times to ensure high quality mounts were available, to archive samples, and to provide replicate samples for QA/QC procedures. On each slide a diamond scribe mark was inscribed on the cover slip, which served as a transect line to guide the search for 600 different diatom valves (half of an individual diatom cell, 300 cells) for taxonomic identification, which is the standard protocol for assessing diatom community structure (Porter et al. 1993). A Leica DM 2500 compound microscope, Nomarski contrast, and 1000x magnification were used for making identifications. Diatoms were identified to the lowest practical taxonomic level, generally species, following standard taxonomic references.

For quality control purposes, three (10% of the total) randomly selected diatom slides were re-identified by a different taxonomist from Rhithron Associates. The two species lists and densities were compared using Bray-Curtis similarity, a common arithmetic metric used to evaluate the resemblance between two species assemblage lists (Clarke et al. 2006). Discrepancies in identifications, if present, were discussed and rectifications to the data were made if necessary. Taxa lists and counts for each diatom sample re-analyzed averaged 88.7% similarity, a level falling within acceptable industry standards (Loren Bahls, personal communication).

The precision of the spectrophotometer used for estimating Chlorophyll-*a* concentration was assured by running a serially diluted standard solution of 1.00 mg/l of pure Chlorophyll-*a* standard solution at the start of the analysis and a reagent blank of 90% acetone at the end of the analysis. Results from the Chlorophyll-*a* QA/QC procedure indicated that no drift of the spectrophotometer was observed during sample analysis and that minimal laboratory contamination occurred during processing.

The taxonomic composition of benthic macroinvertebrate samples was determined, following standard procedures, by Bob Wissman of Aquatic Biology Associates (ABA), Inc., Corvallis, OR. Invertebrate specimens were separated from mineral and organic debris and the

first 500 individuals were randomly chosen (if more than 500 were present) using standard sub-sampling procedures. Estimates for the total number of invertebrates in a sample that required subsampling was generated by multiplying the number of each taxa identified by the inverse of the sample fraction that was processed. All insect taxa were identified to species where possible. In some cases, due to a damaged specimen or for groups with difficult or unresolved taxonomy, such as those within the Dipteran family Chironomidae, resolution was to the lowest practical taxonomic level or that recommended by the NW Biological Assessment Taxonomy working group. Non-insect taxa were identified generally to order (e.g., crustaceans), class (e.g., annelid worms), or family (e.g., mollusks). All generic level identifications of aquatic insects follow Merritt and Cummins (1996). Various references, as outlined by Plotnikoff and White (1996), were used for species level identification.

ABA also applied strict QA/QC procedures for sorting, taxonomic identification, and data entry. These included requiring random sorting efficiency and taxonomic similarity checks performed by an independent observer on a portion of all samples (generally 10%), routine proofing of all data entry, and crosschecking of laboratory notes with electronic databases.

Habitat Conditions at Periphyton and Invertebrate Sampling Locations

We measured a suite of habitat characteristics at each slack sample location and of the entire riffle where invertebrate and periphyton samples were collected. We characterized the streambed particle size within the slack frame using a visual estimate of percent coverage of five substrate classes (silt, sand, gravel, cobble, and boulder) and classified embeddedness based on the level of sand or silt covering the substrate on a scale from one to five (1 - <5%; 2 – 6-25%; 3 – 26-50%; 4 51-75%; 5 – 76-100%) (Platts et al. 1983). Temperature and specific conductance were recorded using an YSI model 85 multimeter and water depth and velocity was recorded using a Marsh-McBirney Model 2000 portable flow meter and standard USGS flow meter rod. We averaged values across the five slack sample locations at each site. For riffle-scale measurements, we measured wetted width, gradient, and riffle length using a laser range finder. Particle size distribution across the entire sample riffle(s) was characterized by Wolman (1954) pebble counts, from which we calculated D_{50} (median particle size) and D_{85}:D_{15}. Both of these statistics are calculated from the cumulative frequency distribution of pebble count data. The former is the substrate size category that contains the 50th percentile and the latter is a unitless estimate of the variability in substrate class size that is obtained by dividing the substrate size category that contains the 85th percentile by the category containing the 15th percentile. We converted the 20-substrate categories into sizes in mm by taking the median size per category. Canopy above the riffle was measured using a modified spherical densiometer and averaged across 18 readings per sample site.

Invertebrate Drift

Invertebrate drift data were collected from the habitat units just upstream of the benthic invertebrates and periphyton sampling locations. The exact sampling site was selected by moving upstream from the downstream end of the unit until a location with depths and velocity as close as possible to 0.41 m and 5 cm/s, respectively was located. These physical parameters were selected to allow the drift net to be placed 0.1 m above the substrate and still sample the water surface and meet recommended water velocities for drift sampling (Lazorchak et al. 2000).

Drift samples were collected during a one-hour period beginning at least one hour after sunset. A drift net with a 25 cm by 45 cm (standard size available from selected manufacturers) opening and 500-micron mesh was secured in the desired location by pounding two pieces of rebar into the stream bed. Water velocity at the net opening was measured twice, once at the beginning and once at the end of the sampling period. Drift samples were processed as described above.

Fish Abundance and Diet

Fish abundance estimates were made for each reach using mark-recapture methods during the summer of 2012. Multiple habitat units were sampled within each reach. Seining was completed at night to take advantage of movements of fish to slower current areas at night (R.J. Peters, unpublished data). Seining was limited to areas where the seine could be fished without hanging up on debris or large boulders. These conditions were most common in pools, along point bars, in backwater units, and in lateral channels. Mark surveys (surveys when the fish were marked for the mark-recapture) were completed on one night and recapture surveys were completed the following night. It was assumed that the fish would move throughout the reach during the 24 hr period and therefore be adequately ‘mixed’ for the mark-recapture estimates. This assumption is supported by observations that fish use entire habitat units over a 24 hr period in rivers as large as the Hoh River (Peters et al. 2012).

During the mark survey, all fish were identified to species when possible, weighed (nearest 0.1 g), measured for fork length (nearest mm), and marked using Bismark brown. Steelhead and resident rainbow could not be distinguished and are referred to jointly as *O. mykiss*. In addition, steelhead and cutthroat trout fry could not be identified to species and are referred to collectively as trout fry. For each habitat unit, stomach samples were collected from up to 10 steelhead parr or trout fry (> 50 mm fork length) using gastric lavage (Foster 1977). Stomach samples from individual fish were placed in a vial and fixed with 70% ethanol. Stomach contents were identified in the laboratory by ABA using a dissecting scope to the family or the lowest major taxonomic group practical. Relatively fresh ingested invertebrates were measured (nearest 0.5 mm if <5 mm, nearest 1 mm if > 5 mm) to enable weight estimates to be calculated based on published length weight regression estimates. All fish were released back into the area from which they had been captured. During the recapture survey, all fish were

identified to species when possible, checked for marks, and released back to the units from which they were removed.

Population estimates and 95% confidence intervals were calculated for each site following the Chapman modification of the Petersen mark-recapture estimate (Ricker 1975) using:

Equation 1, $N = ((m+1)* (c+1))/(r+1)$

where, N is the estimated population size, m is the number of fish marked during the marking survey, c is the catch during the recapture survey, and r is the number of marked fish caught during the recapture survey. Confidence intervals (95%) were calculated as:

Equation 2, $CI = N \pm 1.96*SE$

Where SE equals the standard error of the variance ($V(N)$) which was calculated as:

Equation 3, $SE = V(N)^{1/2} = (((N^2(c-r))/((c+1)*(r+2)))^{1/2}$

Analysis

Rigorous statistical comparisons of data collected during this study were precluded since only a single ELJ and control reach were sampled. Thus, generalizations were made based on the apparent differences in the data. In cases where apparent differences were observed, we state they were apparent or substantial. Statements of 'significant' differences were reserved for cases where true statistical comparisons could be made (e.g., fish size).

Habitat data collected during this work was summarized at the reach and primary habitat unit scale. No pre-project data was available that could be easily used for comparisons to the data collected for this project. We calculated total length and area of different channel types in each reach by summing all the primary habitat unit lengths and area estimates. This information was used to compare the proportion of different channel types present in each reach. We also calculated the ratio of overall channel length to main channel length and sinuosity. The proportion of the reach composed of different primary habitat types was calculated. Reach scale summaries were prepared for the proportion of the channel composed of different riparian conditions, bank modifications and stability, overhead cover, and wood cover. Reach level mean depths and velocities were calculated using the depth and velocity data collected for each habitat unit.

Periphyton samples were summarized using three separate methods, including Chlorophyll-*a* concentration (ug/cm^2), Ash Free Dry Mass (AFDM) (mg/cm^2), and numeric bio-criteria based on periphyton species assemblages. Chlorophyll-*a* provides a measure of the algal

component of periphyton, while AFDM provides a measure of total periphyton biomass including algae, fungi, bacteria, and microzoans (Steinman and Lambert 1996).

Numeric bio-criteria based on Bahls (1993) and Tepley and Bahls (2005), and Shannon's H' were used to place the periphyton species assemblage data into a bio-assessment context. This procedure, like that of the macroinvertebrate Index of Biotic Integrity (IBI) approach (see Karr 1981, 1991), uses the composition and structure of the diatom community identified in each sample to assess the biological integrity and impairment level of the sites. The metrics used were developed for streams in Montana and is the most comprehensive analysis available in the northwestern United States. To the best of our knowledge, no such bio-criteria currently exist for streams in western Washington State. The Montana bio-assessment method examines multiple metrics, three of which we used herein – a siltation index, a pollution index, and a metals index. We also report scores for the Montana bio-index for mountain streams. These indices are based on the concept that certain taxa will increase or decrease in abundance in the presence of a particular disturbance. By examining a large number of stream stations (1,500) throughout Montana that vary along gradients of disturbance from different anthropogenic sources and comparing the community composition with relatively pristine reference samples, the authors identified groups of taxa that, "demonstrated a meaningful, measurable response to the observed stress" (Tepley and Bahls 2005, p. 24). Shannon's H was also calculated to provide a comparative index of species richness at the two study reaches following Kwak and Peterson (2007) as:

$H' = -\sum_{i=1}^{S} p_i(log_2 p_i)$, where

S = the number of species and p_i is the proportion of the overall sample represented by species i.

Five metrics were calculated to describe macroinvertebrate communities in the ELJ and control reach, including density, taxonomic richness, Ephemeroptera, Plecoptera, Tricoptera (EPT) taxa richness (total count of unique EPT taxa in the sample), EPT density, and percent of the top three dominant taxa. These metrics were developed using data obtained from a sub-sample of 600 macroinvertebrates per sample that were identified to the lowest taxonomic level practical. Abundance data was converted to density data based on the sample area and the proportion of the entire sample that was processed. Richness metrics were calculated using two different methods, cumulative totals for all replicate samples (i.e., the four samples collected in each reach) and averaged across all replicate samples.

Habitat data collected at the riffles where periphyton and macroinvertebrates were collected were summarized for each reach. These data summaries include wetted width (m), gradient (%), riffle length (m), depth (m), velocity (m/s), conductivity (uS), D_{50}, D_{85}:D_{50} ratio, dominant substrate, embeddedness, and riparian canopy.

Diets were pooled by size class (trout fry and >1+ *O. mykiss*) and reach (Control or ELJ). We calculated the weight of each forage item by family when possible, except for mayflies, caddis flies, and stoneflies, which were summarized by order. Weights of organisms consumed by individual fish were summarized for all size classes and reach types to estimate the total weight of each food item eaten. We calculated Horn's diet-overlap index (Horn 1966) to compare the diet of trout fry and >1+ *O. mykiss* between these size classes and reaches as:

$$C = 2\sum_{i=1}^{s} X_i Y_i \,/(\sum_{i=1}^{s} X_i^2 + \sum_{i=1}^{s} Y_i^2)$$

Where C is the index value, s is the number of food categories; X_i is the proportion of the total diet by age class or reach X contributed by food category i, and Y_i is the proportion of the total diet by age class or reach Y contributed by food category i. Index values range from 0 (no overlap) to 1 (complete overlap). An overlap index value of 0.6 or more indicates a significant overlap in diet (Zaret and Rand 1971; Johnson 1981).

Invasive Species

We reviewed all data sets for the presence of invasive species. Diatom summary data received from Rhithron Associates was queried for Didymo (*Didymosphenia geminate).* Macroinvertebrate summary data received from Aquatic Biology Associates was queried for New Zealand mudsnails (*Potamopyrgus antipodarum).* All fish species were identified to species and any invasive species collected were recorded. Invasive species were summarized by location in the ELJ and control reach.

Results

Habitat

Habitat conditions were similar in the ELJ and control reach with the exception of metrics involving channel lengths. The channels were generally characterized by low riparian cover with unstable banks. The overall mainstem reach length was greater in the ELJ reach (1,475 m) than in the control reach (864 m), because of the length of the channel restored by the USFS and the length of channel remaining to serve as a control. However, the total channel length and sinuosity in the ELJ reach was greater than that of the control reach. The ratio of total channel length to main channel length was 1.90 in the ELJ reach compared to 1.48 for the control reach. Sinuosity values were 1.86 and 1.10 for the ELJ and control reaches, respectively.

Although differences were observed in channel length metrics between the ELJ and control reach, very few differences were observed in other habitat metrics. A majority of the channel area in both ELJ and control reach was classified as main channel habitat (Figure 2). Braided channels were the next most common channel type. Little of the reaches were composed of backwater habitats and side channels were completely absent.

The proportions of the habitat classified as deep or shallow water varied by channel type (Figure 2). Braided channels were composed of predominantly shallow water habitats, while backwater channels were composed of predominantly deep-water habitats. No apparent differences existed among ELJ and control reach channels. Main channels in the control reach consisted of nearly equal proportions of deep and shallow water, while main channels in the ELJ reach consisted of a bit more shallow water than deep water.

Differences between the ELJ and control reaches became more apparent at fine habitat classification levels (Figure 2). Turbulent habitat was a bit more prevalent in mainstem channels of the ELJ reach than in the control reach, while the opposite was true for non-turbulent habitats. In addition, dammed pools were much more frequent in backwater channels located in the ELJ reach than in the control reach, where scour pools made up a greater proportion of the habitat units.

Differences in habitat conditions between the ELJ and control reaches were less apparent based on the most detailed level of habitat classification (Figure 2). Marginal differences existed in the proportion of glide habitats present in braided channels of the ELJ and control reaches. Backwater channels in the ELJ reach had a greater proportion of convergence pools than the control reach, which were composed primarily of lateral scour pools. The proportion of glide habitat present in ELJ and control reaches was the only difference observed in main channels. There was substantially more glides in the ELJ reach than the control reach.

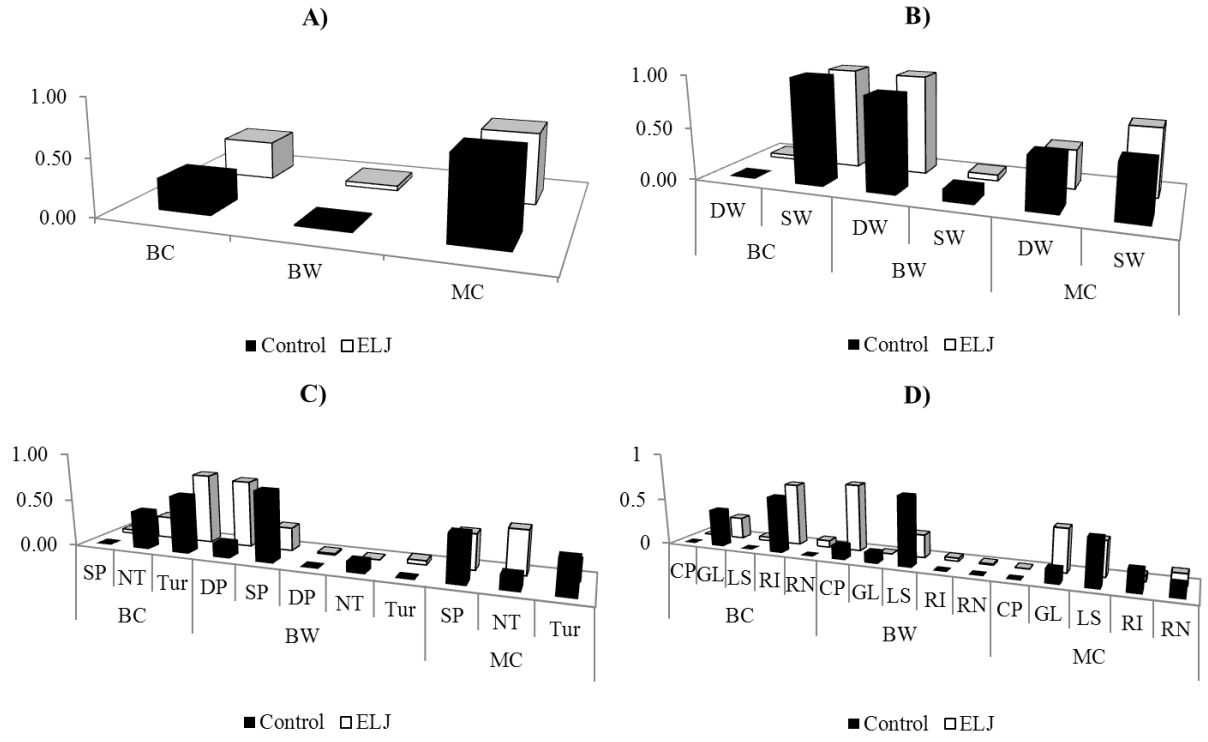

Figure 2. Proportion of habitat area in control and ELJ reaches composed of different A) primary habitat types (BC = Braided Channel; BW = Backwater Channel; MC = Main Channel), B) secondary habitats (DW = Deep Water; SW = Shallow Water), C) level 3 habitats (SP = Scour Pool; DP = Dammed Pool; NT = Non-Turbulent; Tur = Turbulent), and D) level 4 habitats (CP = Convergence Pool; GL = Glide; LS = Lateral Scour Pool; RI = Riffle; RN = Run).

Riparian vegetation in the ELJ and control reach was composed primarily of bare ground, regardless of channel type (Figure 3). There were no apparent differences in proportions of riparian vegetation present in ELJ and control reach. Grass and shrubs were slightly more common in backwater and main channel habitat than in braided channels.

The banks of both the ELJ and control reach can be generally described as being infrequently modified and unstable. There were no bank modifications in the control reach. Braided channels, backwater channels, and main channels in the ELJ reach had 7%, 1%, and 5% modified banks, respectively. All of these modifications were due to ELJ placement associated with the restoration project. The only difference in bank stability between the ELJ and control reach was the presence of more stable banks in control backwater channels (ELJ = 1%, control 16%). The percentage of stable banks present in the reaches ranged from zero in control reach braided channels to 16% in control backwater channels. The percent of stable banks in main channels was 10% and 11% for ELJ and control reaches, respectively.

Little overhanging vegetative cover was present in either the ELJ or the control reach and no differences existed between the reaches. Only three of 54 ELJ reach habitat units had overhanging cover and overhanging cover was 10% in all three cases. All the habitat units within the control reach lacked overhanging vegetation.

There were no obvious differences in average depth, maximum depth, residual depth, or width-depth ratios between the ELJ and control reach (Figure 4). Average depth for both reaches was approximately 0.5 m, while maximum depths were between 1.5 and 2.0 m. Residual depths were between 1.0 and 1.5 m. The average width to depth ratio was approximately 35.

Wood cover varied between the control and ELJ reach, but differences were dependent upon the metric examined (Figure 5). However, much of this difference was due to the ELJs in the ELJ reach. Natural LWD accumulations and single logs were a bit more common in the control than the ELJ reach based on numbers per channel length and numbers per habitat unit, but not based on cover area provided relative to overall habitat area. In contrast, rootwads not associated with ELJs were much more prevalent in the ELJ reach than the control reach based on numbers per habitat unit and channel length, but not based on cover area per overall habitat area.

Periphyton

Chlorophyll-*a* content values ranged from 0.41 to 3.03 mg/cm^2, while AFDM concentrations ranged from 0.0004 to 0.0018 mg/cm^2 (Figure 6). The Chlorophyll-*a* concentration of 3.03 mg/cm^2 from habitat unit 18 in the ELJ reach was an extreme outlier. Without this value, the greatest concentration observed was 1.64 mg/cm^2. There were no apparent differences in Chlorophyll-*a* or AFDM concentration between the ELJ and control reach. No apparent longitudinal pattern between Chlorophyll-*a* or AFDM concentrations existed.

No apparent differences existed between the ELJ and control reaches based on diatom community metrics (Table 2). Diatom species richness ranged from 30 to 48 taxa at the eight sample sites and did not differ substantially (Figure 7). Shannon's H values ranged from 3.5 to 4.3 and did not differ substantially between the ELJ and control reach. No longitudinal patterns in species richness or Shannon's H were apparent. The diatom quality ratings for all eight sites were excellent for the siltation index, pollution index, and metals index. The Montana bio-index rating was excellent at three of the four control sites and good at the fourth, while the four ELJ sites received two excellent and two good ratings.

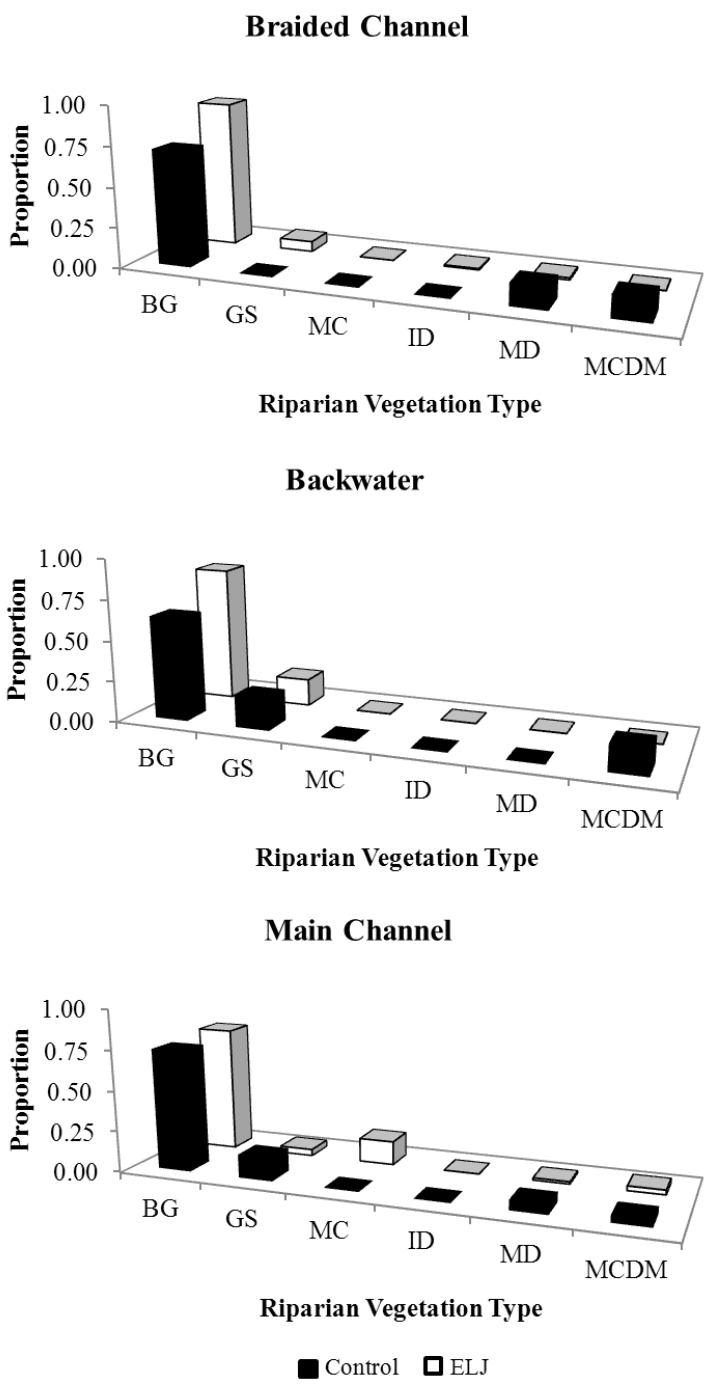

Figure 3. Proportion of riparian areas adjacent to braided channels, backwaters, and main channels composed of different vegetation types (BG = Bare Ground, GS = Grass/Shrub, MC = Mature Conifer, ID = Immature Deciduous, MD = Mature Deciduous, MCDM = Mixed Conifer Deciduous Mature)

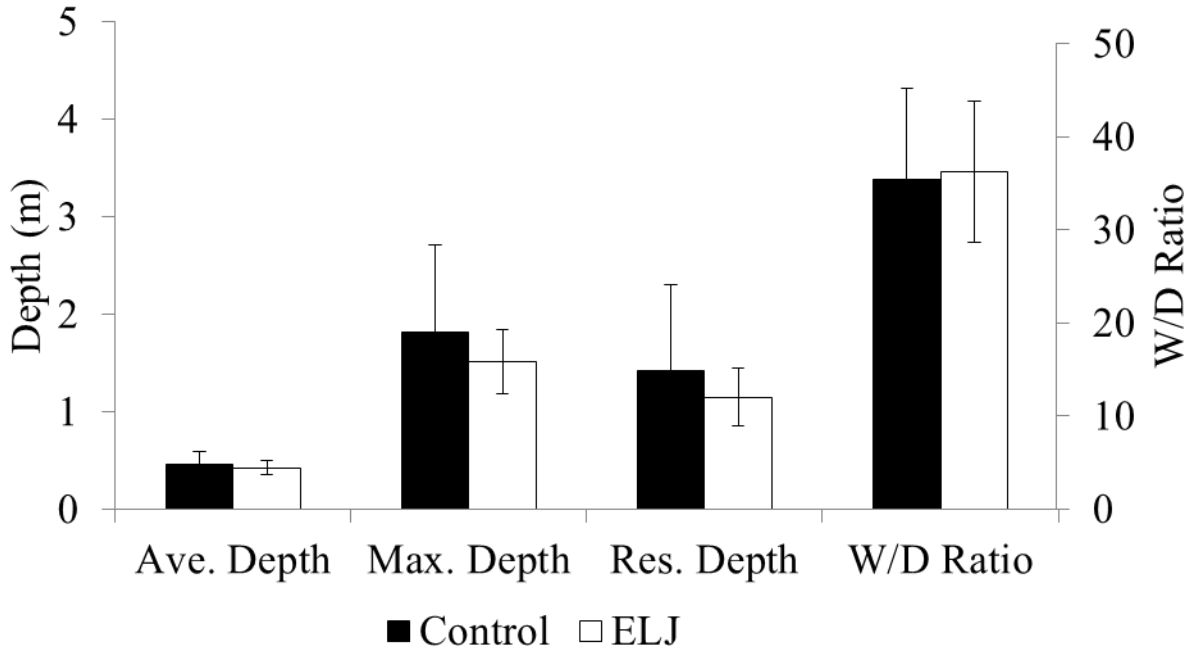

Figure 4. Mean (± 2 SE) average (Ave.) depth, maximum (Max.) pool depth, residual (Res.) pool depth, and wetted width/depth (W/D) ratio for habitat units within the ELJ and control reaches of the S.F. Skokomish River.

Invertebrates

There were no apparent differences between the ELJ and control reach for any of the benthic invertebrate metrics calculated (Table 3 and Table 4). Results were similar regardless of analysis method (i.e., cumulative based on replicate samples or means of replicate analyses). Total and EPT taxa richness was slightly greater in the ELJ reach than the control reach. EPT abundance was also greater in the ELJ than in the control reach. Total abundance and percent top three taxa were slightly greater in the control than ELJ reach. There were no apparent longitudinal patterns in any of the benthic invertebrates calculated.

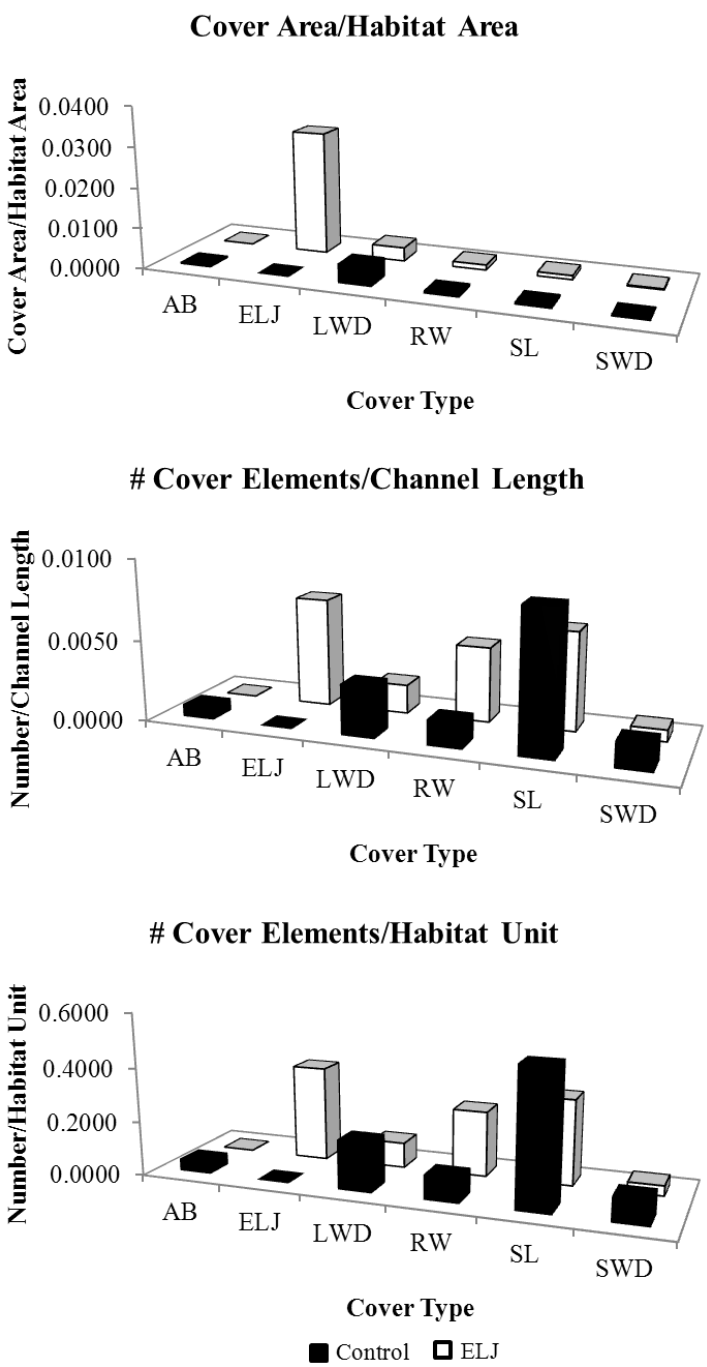

Figure 5. Cover area per habitat area (top), number of cover elements per channel length (middle), and number of cover elements per habitat unit in ELJ and control reaches of the S.F. Skokomish River. AB = Attached Branches, ELJ = Engineered Log Jam, LWD = Large Wood Debris Accumulation, RW = Rootwad, SL = Single Log, and SWD = Small Wood Debris Accumulation

Table 2. Ratings for the diatom siltation index, pollution index, metals index, and Montana bio-index (Bahls 1993) for the four habitat units sampled in the treatment (ELJ) and control reaches.

Unit#	Reach	Siltation Index	Pollution Index	Metals Index	Montana Bio-index
4	ELJ	Excellent	Excellent	Excellent	Good
18	ELJ	Excellent	Excellent	Excellent	Excellent
26	ELJ	Excellent	Excellent	Excellent	Excellent
43	ELJ	Excellent	Excellent	Excellent	Good
105	Control	Excellent	Excellent	Excellent	Excellent
113	Control	Excellent	Excellent	Excellent	Good
118	Control	Excellent	Excellent	Excellent	Excellent
121	Control	Excellent	Excellent	Excellent	Excellent

Habitat Conditions at Periphyton and Invertebrate Sampling Locations

With the exception of riffle length and substrate conditions, there were no obvious differences between the habitat conditions at the periphyton and invertebrate sampling locations in the ELJ and control reaches (Table 4). There was no riparian cover over any of the riffles sampled for periphyton and invertebrates. Riffle lengths in the control reach were about 50% longer than riffles in the ELJ reach. In addition, substrate size was generally larger in the control reach, based on several metrics. There were no boulders in the ELJ reach; however, the control reach contained 2.25% boulders. There were also more cobbles in the control reach and more gravel in the ELJ reach. The D_{15}, D_{50}, and D_{84}'s were also nearly twice as large in the control reach as the ELJ reach.

Substantial differences existed between invertebrate drift at the ELJ and control reach for a few of the metrics examined (Figure 8). Diptera made up a substantially greater proportion of the sample in the control reach than the ELJ reach. Total biomass and total abundance was much greater at the control reach than at the ELJ reach as well. In contrast, Acari (mites) were nearly four times more prevalent at the ELJ reach than at the control reach. There were no obvious longitudinal trends for any of the drift invertebrate metrics examined (Figure 9).

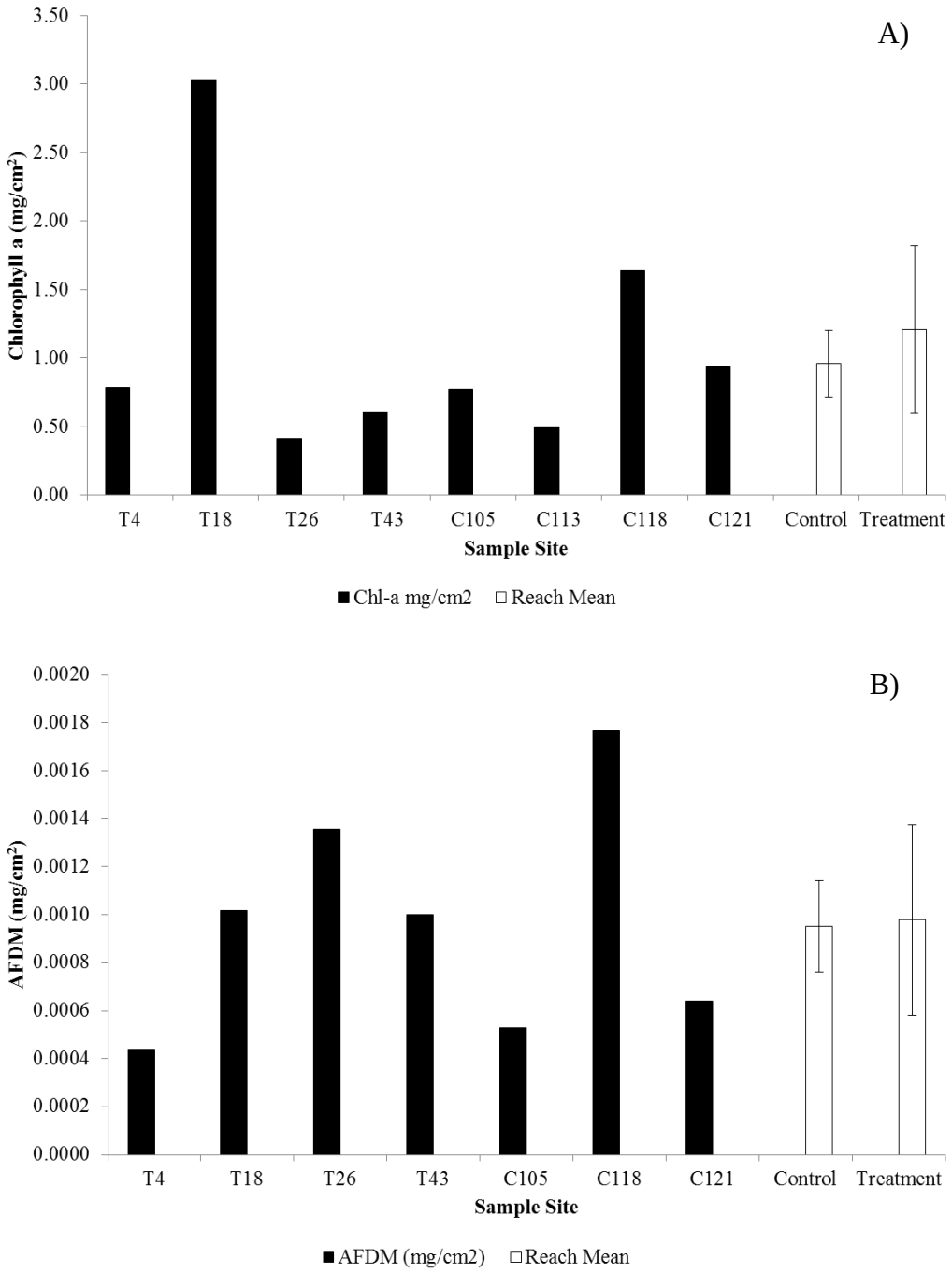

Figure 6. Longitudinal patterns (T4 is upstream to C121 downstream) of chlorophyll-*a* (A) and periphyton Ash-Free Dry Mass (AFDM) (mg/cm^2) (B) values observed at individual riffle habitat units and the mean values (error bars are standard error) for the ELJ and control reaches. The sample sites are designated as either control (C) or treatment (T) and the habitat unit number. For example, unit T4 is the fourth habitat unit from the upstream end of the study reach and is located in the treatment reach.

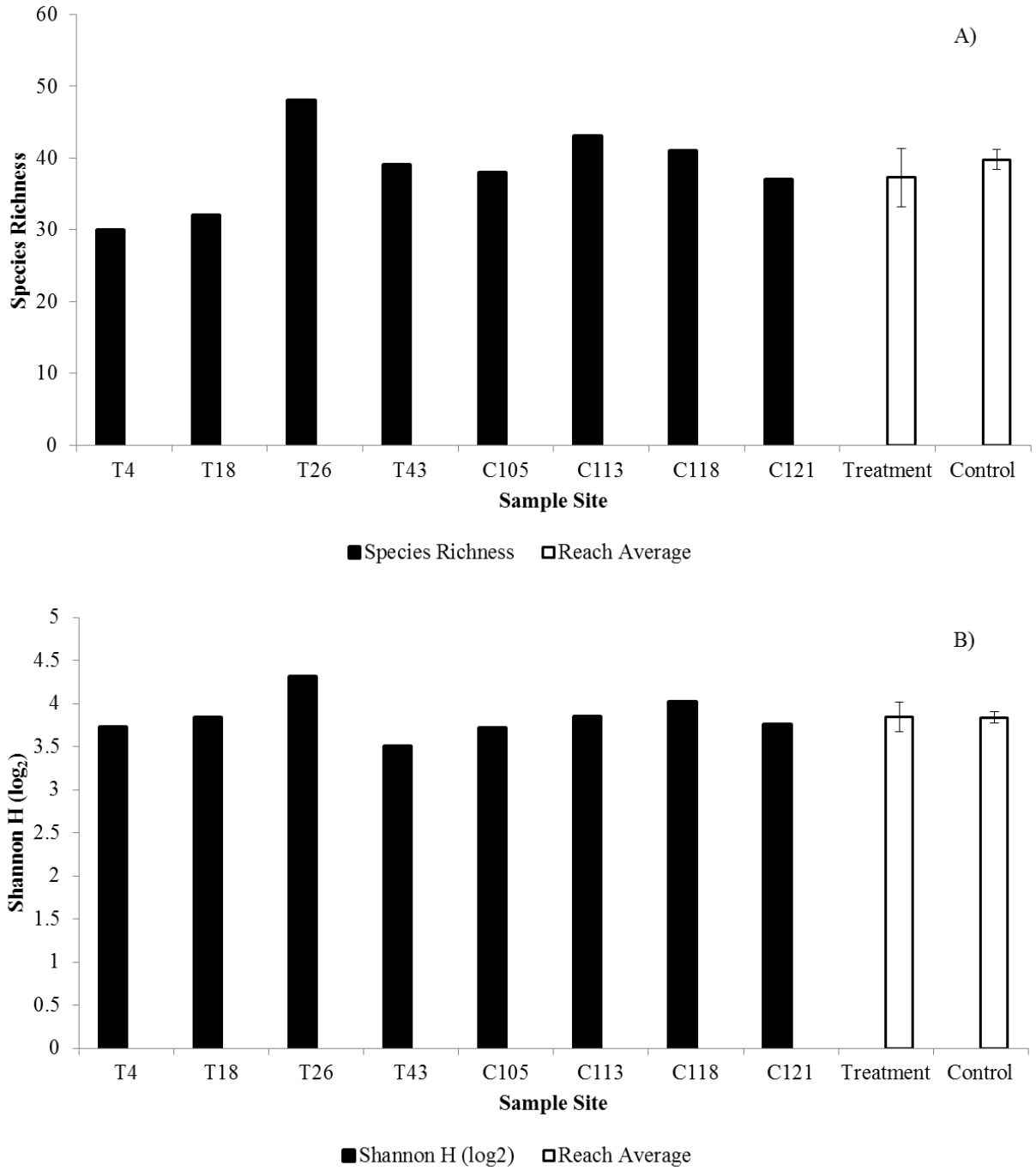

Figure 7. Longitudinal patterns (T4 is upstream to C121 downstream) of species richness (A) and Shannon's H ($\log_2$) (B) values observed at individual riffle habitat units and the mean values (error bars are standard error) for the ELJ and control reaches. The sample sites are designated as either control (C) or treatment (T) and the habitat unit number. For example, unit T4 is the fourth habitat unit from the upstream end of the study reach and is located in the treatment reach.

Table 3. Reach scale summaries of benthic macroinvertebrate metrics for the Engineered Log Jam (ELJ) and control reaches of the S.F. Skokomish River.

Treatment	ELJ	Control
Total taxa richness	55	51
Total abundance (number/m^2)	5,182	5,681
EPT taxa richness	37	33
EPT abundance	3,257	3,136
% Top 3 taxa	53.8	58.4

Table 4. Habitat unit benthic macroinvertebrate metrics along with means and twice the standard error (SE) for habitat units in the Engineered Log Jam (ELJ) and control reaches of the S.F. Skokomish River.

	Replicate Unit					
	1	2	3	4	Mean	2SE
			ELJ			
Habitat Unit #	4	18	26	43		
Total taxa richness	29	31	44	30	33.5	7.0
Total abundance	6,230	4,563	5,668	4,266	5,181	923
EPT taxa richness	21	20	31	21	23.3	5.2
EPT abundance	5,040	2,047	3,500	2,440	3,257	1,338
% Top 3 taxa	65.8	62.8	54.8	62.0	61.36	4.65
			Control			
Habitat Unit #	105	113	118	121		
Total taxa richness	35	31	34	36	34.0	2.2
Total abundance	11,364	5,321	1,482	4,555	5,681	4,136
EPT taxa richness	25	21	22	24	23.0	1.8
EPT abundance	6,244	2,865	540	2,896	3,136	2,347,
% Top 3 taxa	58.5	55.1	78.8	64.5	64.24	10.43

Fish

Few fish species were observed during our fish sampling. We observed three species/order groupings in the ELJ reach, including cottids (not identified to species), *O. mykiss*, and lamprey (not identified to species). In contrast, we observed only cottids and *O. mykiss* in the control reach. We also observed a greater diversity of age-classes of *O. mykiss* in the ELJ (4) reach than the control reach (2).

Sufficient numbers of marked fish were caught during the recapture survey to calculate population estimates for only three of the eight fish species/order – age class combinations, including trout fry, all salmonids, and all fish (Table 6). Population estimates and densities tended to be somewhat greater for all three groups in the ELJ reach than the control reach; however, the 95% confidence intervals overlapped for all three suggesting these differences were not statistically significant. Although population estimates could not be calculated, due to insufficient numbers of recaptures (zero), substantially more cottids were caught in the ELJ reach than the control reach. Twice as many 2+ *O. mykiss* were caught in the ELJ reach than the control reach. More than three times as many salmonids and total fish were also caught in the ELJ reach than in the control reach.

Length frequency data for salmonids caught during this study are shown in (Figure 10). Based on this we divided juvenile salmonids into two groups for the size and diet analysis, trout fry (<80 mm) and >1+ *O. mykiss* (>80 mm). There were no differences in the sizes of trout fry (t-test: P=0.089) or >1+ *O. mykiss* (t-test: P=0.3296) caught in the ELJ and control reach or trout fry (t-test: P=0.5923) and >1+ *O. mykiss* (t-test: P=0.1563) sampled for diet analysis (Figure 11).

Table 5. Average values for the habitat variables measured at the five locations where slack sampling was completed for benthic invertebrates and the average of all the sites for the treatment and control reaches. There was no canopy cover at any of the sites on either bank or in the center of the channel based on densiometer readings.

	Treatment Sites					Control Sites				
Variable	4	18	26	43	Mean	105	113	118	122	Mean
Bankfull width (m)	42.3	57.8	49.6	90	59.93	73	50.1	72	66	65.28
Gradient (%)	-0.3	-0.6	-0.7	-0.3	-0.48	-1.2	-0.1	-0.2	-0.4	-0.48
Total Riffle Length (m)	10.3	98	32	40	45.08	60	61	104	40	66.25
Distance from Left Bank	19.32	13.06	5.44	2.90	10.18	8.92	14.64	13.16	4.72	10.36
Distance from Right Bank	6.70	5.34	5.26	19.10	9.10	21.10	2.80	5.50	17.38	11.70
Wetted Width (m)	27.02	18.40	10.70	22.00	19.53	30.02	17.44	18.66	22.10	22.06
Depth (m)	0.09	0.08	0.20	0.25	0.16	0.18	0.19	0.20	0.22	0.20
Velocity (m/s)	0.60	0.40	0.32	NM	0.44	0.34	0.30	0.32	0.33	0.32
Water Temp. °C	13.98	15.48	14.80	13.88	14.54	16.64	15.78	14.66	12.56	14.91
Conductivity µs	73.22	59.40	60.00	56.64	62.32	57.58	65.18	75.40	65.26	65.86
% Boulder	0	0	0	0	0	0	0	5	4	2.25
% Cobble	5	54	58	54	42.75	34	59	53	61	51.75
% Gravel	86	44	34	38	50.5	64	41	36	29	42.5
% Sand	9	2	8	8	6.75	2	0	6	6	3.5
% Silt	0	0	0	0	0	0	0	0	0	0
Embeddedness	1	1	0	2	1	1	5	2	1.6	2.4
D_{15}	11.8	26.5	27.8	9.3	18.8	39.3	37.9	28.1	33.7	34.8
D_{50}	43.1	79.3	83.0	48.4	63.5	147.3	144.6	78.2	79.8	112.5
D_{84}	90.1	155.3	162.4	167.2	143.8	297.0	275.7	161.5	168.9	225.8

NM=Not measured due to flow meter malfunction.

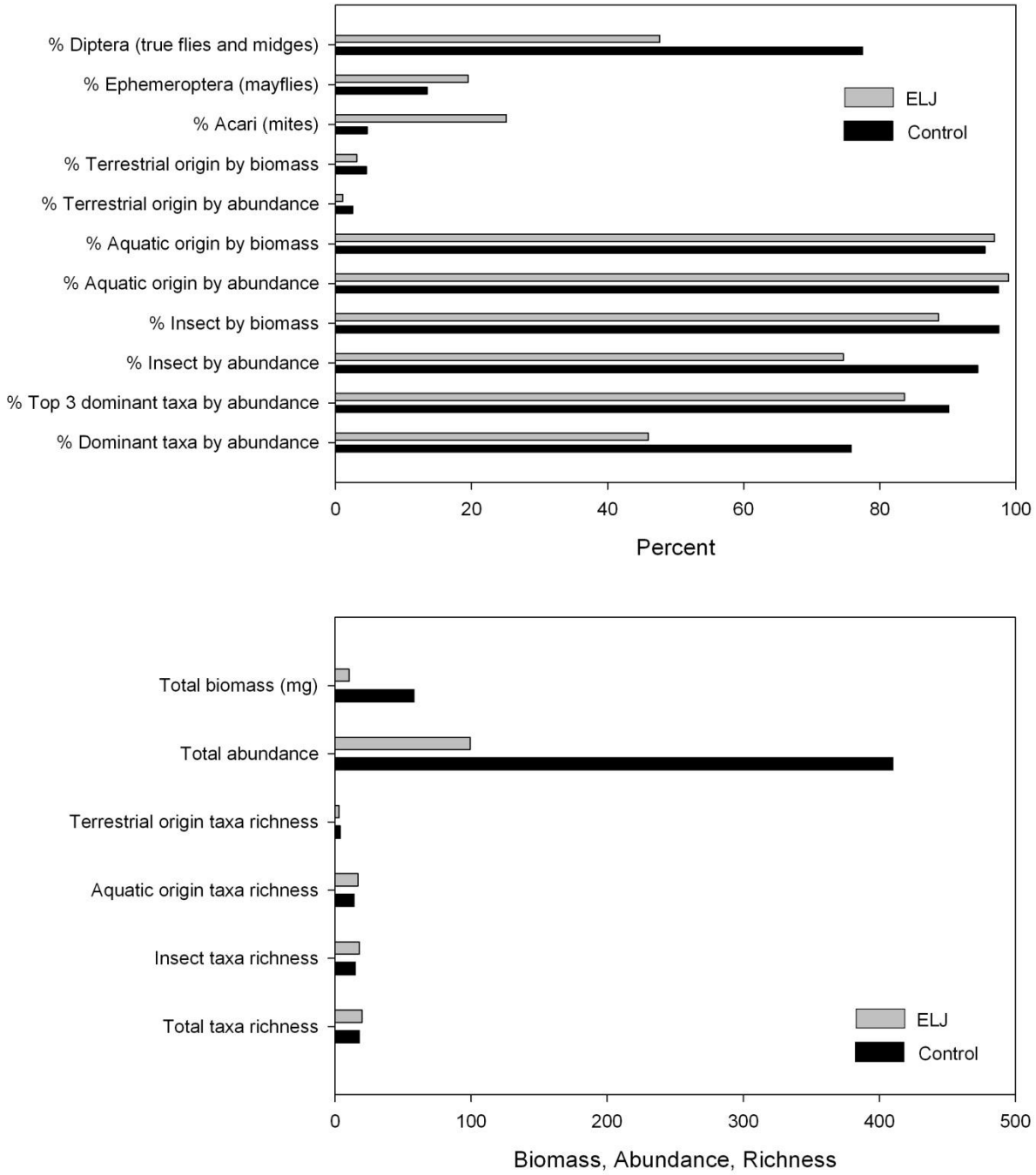

Figure 8. Summary of invertebrate drift metrics observed in the four control and treatment (ELJ) reach samples. Taxa richness values are the cumulative total for all four replicates, while the remaining data are the means. Biomass and abundance are expressed as values per 100 m^3 of filtered water.

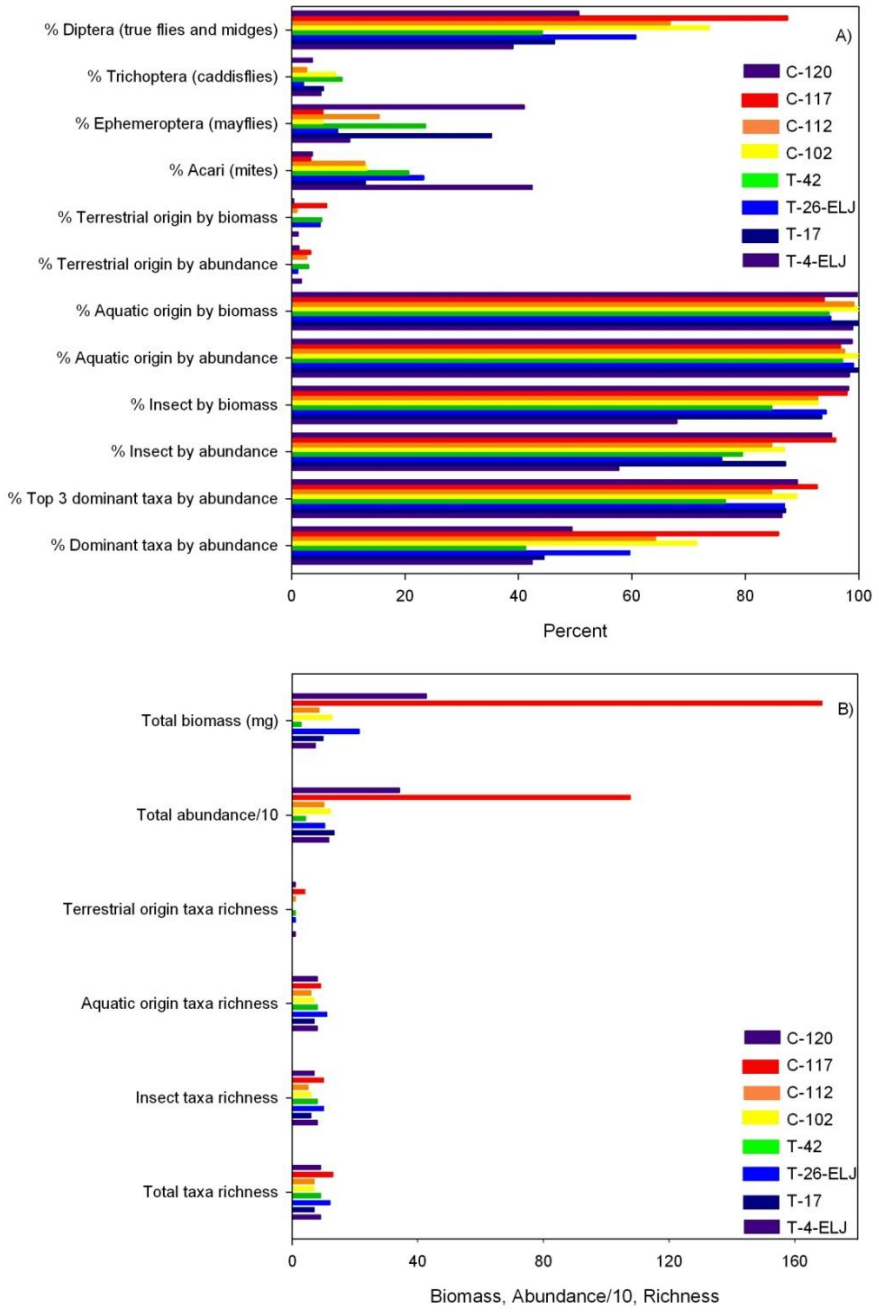

Figure 9. Summary metrics for invertebrate drift observed longitudinally from upstream (T4) to downstream (C120). Taxa richness values are the cumulative total for all four replicates, while the remaining data are the means. Biomass and abundance are expressed as values per 100 m^3 of filtered water. Abundance estimates were divided by 10 for scaling purposes.

Table 6. Number of fish of different species and age-classes marked, caught unmarked (Catch) or marked (Recap) during the recapture survey and the mark-recapture population estimate (N), standard error of that estimate (SE), upper and lower 95% confidence intervals (CI) of those population estimates for the ELJ and control reaches of the S.F. Skokomish River. Densities based on habitat surface area (fish/m^2) and river length (fish/m) and their associated upper and lower 95% confidence intervals are provided.

Species	Marked	Catch	Recap	N	SE	95% CI Lower	95% CI Upper	Density (Fish/m)	Fish/m 95% CI Lower	Fish/m 95% CI Upper	Density (fish/m^2)	Fish/m^2 95% CI Lower	Fish/m^2 95% CI Upper
						ELJ							
Sculpin	86	102	0										
Trout fry	81	137	12	870.5	221.41	436.5	1,304.4	0.311	0.156	0.466	0.019	0.010	0.019
1+ *O. mykiss*	9	28	1										
2+ *O. mykiss*	1	12	0										
<2+ *O. mykiss*	0	1	0										
Lamprey	0	1	0										
All Salmonids	91	178	13	1,176.3	291.60	604.8	1,747.8	0.420	0.216	0.624	0.026	0.013	0.026
All Fish	177	281	13	3,585.4	902.48	1,816.6	5,354.3	1.281	0.649	1.913	0.079	0.040	0.079
						Control							
Sculpin	36	47	0										
Trout fry	55	45	10	234.2	58.97	118.6	349.8	0.184	0.093	0.274	0.011	0.006	0.011
1+ *O. mykiss*	4	5	0										
2+ O. *mykiss*	0	0	0										
<2+ *O. mykiss*	0	0	0										
<2+ *O. mykiss*	0	0	0										
Lamprey	0	0	0										
All Salmonids	59	50	10	278.2	71.12	138.8	417.6	0.218	0.109	0.328	0.013	0.007	0.013
All Fish	95	97	10	855.3	232.63	399.3	1,311.2	0.671	0.313	1.028	0.041	0.019	0.041

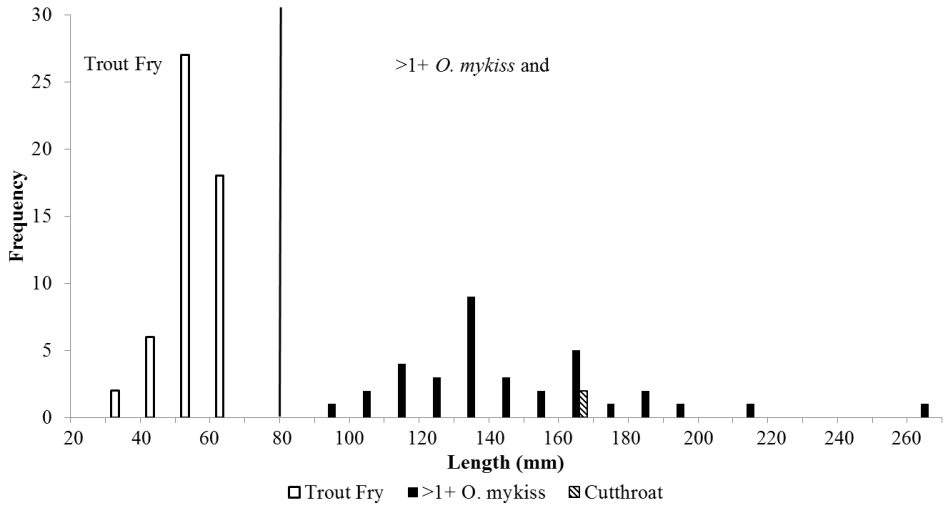

Figure 10. Length frequency (10-mm increments, e.g., 20-29, 30-39) for salmonids (n=88) caught in both the ELJ and control reaches during the mark-recapture and diet sampling.

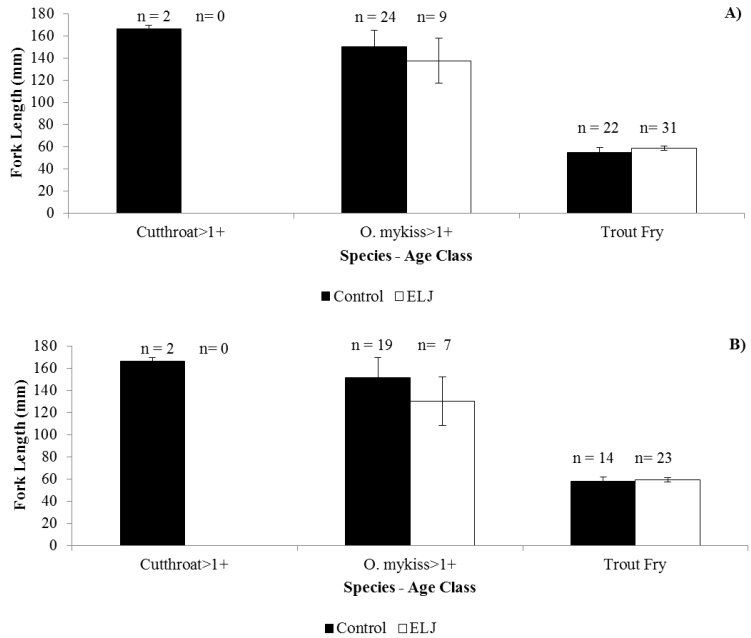

Figure 11. Mean fork length (± 2 SE) for age 1+ cutthroat, age 1+ or greater *O. mykiss*, and trout fry in ELJ and control reaches of the S.F. Skokomish River. Figure A is all fish captured and B is only those fish for which stomach samples were taken. Sample sizes for each group are listed above the bars (i.e., n = 2). No statistically significant differences existed (t-test: P = 0.09-0.59).

Diet

Sample sizes for the diet analysis varied among age-classes and reaches. We sampled 14 and 23 trout fry and 19 and 7 >1+ *O. mykiss* in the control and ELJ reach, respectively. We observed 70 different family or order groupings of organisms in the diet, 11 of which represented terrestrial groups. The diet of trout fry was predominantly Ephemeroptera and Diptera, while diets of >1+ *O. mykiss* was predominantly Ephemeroptera, Tricoptera, and Diptera. The one exception to this was a large crayfish eaten by one fish, which resulted in that being the major diet component when included. For this reason, the comparisons for >1+ *O. mykiss* were completed with this fish included and excluded from the analysis.

A general assessment of the diets of trout fry and >1+ *O. mykiss* based on the proportions of different invertebrate categories consumed implied differences between fish in the ELJ and control reach (Figure 12). However, these differences were only marginally supported by the Horn's overlap index values. The diet of trout fry consisted of more Ephemeroptera and less Plecoptera and Diptera in the control reach than in the ELJ reach. Larger *O. mykiss* consumed fewer terrestrial invertebrates, Ephemeroptera, Plecoptera, Tricoptera, and Diptera in the control reach than in the ELJ reach, and substantially more Astacidae (crayfish) when the fish that had eaten the large crayfish was included in the analysis. However, when the fish that had eaten the crayfish was excluded from the analysis, the only differences observed were that *O. mykiss* in the control reach consumed more Tricoptera but fewer Plecoptera than those in the ELJ reach. *O. mykiss* in the ELJ reach also appeared to consume more terrestrial insects than those in the control reach (O+: control 1.74% by weight, ELJ: 2.56%; >1+: control: 13.5% (not including the fish that consumed the large crayfish), ELJ: 18.9%).

Based on Horn's overlap index, the diets of only >1+ *O. mykiss* significantly overlapped (values >0.6) between the ELJ and control reach (Horn's overlap index 0.61). This overlap occurred when the fish that had eaten the large crayfish was excluded from the analysis; the diets did not overlap when this fish was included in the analysis (Horn's overlap index 0.03). The diets of trout fry (Horn's overlap index (0.59) nearly overlapped significantly between the ELJ and control reach.

Invasive Species

Didymo was the only aquatic invasive species found during this survey. It was found in four of the eight locations sampled for periphyton, including ELJ habitat unit 43 and control reach habitat units 105, 113, and 121. No New Zealand mudsnails were observed in any of the eight benthic or drift invertebrate samples. We did not observe any nonnative fish species during our surveys.

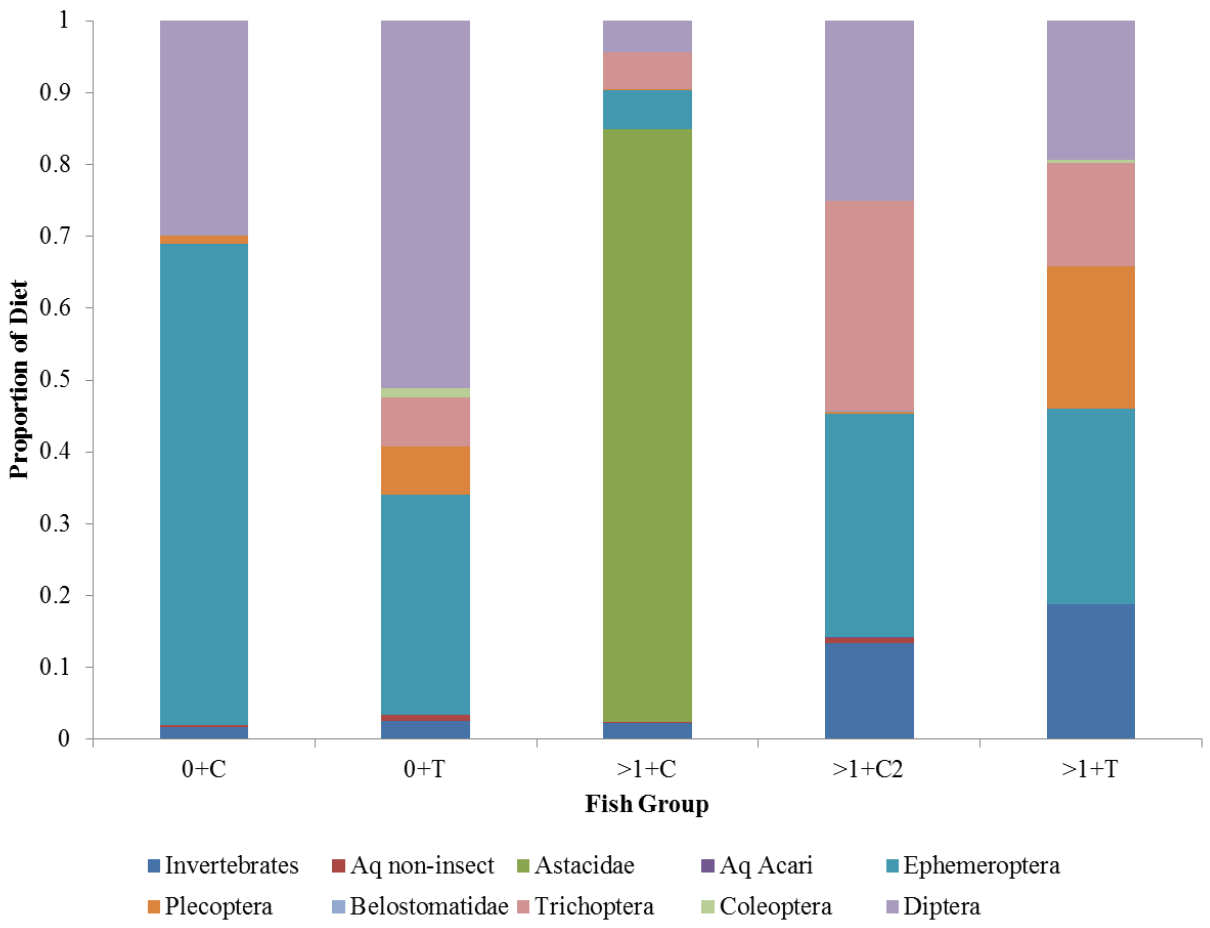

Figure 12. Proportion (by weight) of major taxonomic groups observed in the diet of trout fry and age 1+ or greater *O. mykiss* in the S.F. Skokomish River treatment and control reaches. The figure shows two sets of bars for 1+ or greater *O. mykiss* from the control reach, with and without one fish that ate a large crayfish (Astacidae) that swamped the analysis. The legend codes are as follows: 0+C = trout fry in the control reach; 0+T = trout fry in the treatment reach; >1+C = age 1+ or greater *O. mykiss* from the control reach (with large crayfish); >1+C2 = age 1+ or greater *O. mykiss* from the control reach (without the large crayfish); >1+T = age 1+ or greater *O. mykiss* from the treatment reach.

Discussion

Few substantial differences in physical and biological metrics were observed between the ELJ and control reach during this simple case study. This is not a surprising result given the short time period between the completion of the restoration project and this initial monitoring effort (2 years). In addition, no statistical comparisons between the treatment and control could be completed, since this assessment represents a case study with a single treatment and control reach. The data collected for this report will be useful for long-term evaluations of this restoration effort. In addition, this work provides a potential model for larger scale assessments of restoration using ELJs through Before-After-Control-Impact (BACI) or extensive control-impact designs.

The primary physical habitat differences between the ELJ and control reach was the overall length of the channel and sinuosity. Channel length, sinuosity, and the ratio of total channel length to main stem channel length were greater in the ELJ reach than the control reach. Differences in main channel length were because the ELJ reach was longer than the control reach, which was restricted due to the downstream canyon. The ELJ reach also had more total channel length relative to the main channel length, suggesting that more lateral habitats (i.e., braided channels) were present relative to the control reach. These findings are consistent with observations of increased side-channel habitat in the Elwha River (McHenry et al. 2007). Although, this is a desirable outcome of restoration using ELJs, it is unclear whether the differences observed in the S.F Skokomish existed prior to restoration, since comparable pre-project data is lacking. Continued investigation is required to determine if these differences are due to the ELJs or due to large-scale geomorphic controls.

In contrast to the reach scale observations, it appears the ELJs had little influence at the habitat-unit scale. The only apparent difference between the ELJ and control reach was the presence of more turbulent water in the ELJ reach. This contradicts the observations and goal of many ELJ restoration projects of increased pool area and depth. Scour pools have been observed near ELJs (McHenry et al. 2007) that generally result in increased pool area (Brooks et al. 2004, 2006) and depth (Brooks et al. 2006, Pess et al. 2005). The lack of pool formation near the S.F. Skokomish ELJs may be due to hydrology since project completion, location of the ELJs, and/or, high sediment loads in the S.F. Skokomish River.

Provisional data from U.S. Geological Survey (USGS) for gage 12060500 on the S.F. Skokomish River (http://nwis.waterdata.usgs.gov/wa/nwis/uv/?cb_00060=on&format=gif_default&period=&begin_date=2010-09-01&end_date=2012-07-01&site_no=12060500) shows that at least one flow event equaling the ten-year recurrence interval (> 11,600 ft^3/s – Bair et al. 2008a) occurred

between project completion and this assessment. However, this was the only event greater than the bankfull event (approximately 6,290 ft^3/s (Bair et al. 2008a)). It's possible that this single large event was not adequate to result in pool formation near the constructed ELJs or that pools may have been filled during smaller events (~3,500 cfs) occurring during this same time period.

Pool formation at the ELJs may also have been impacted by excessive sediments in the S.F. Skokomish River. An estimated 168,200 m^3 of sediment has been delivered to the S.F. Skokomish River between the late 1940's and the late 1990's due to landslides (ME2 1997). Excessive sediments and aggrading channels are common in the Skokomish River, which can fill pools and reduce pool scour (Lisle 1982; Buffington et al. 2002). ELJs have been found to store large quantities of sediment (Brooks et al. 2004, 2006), which in the long-term may result in increased pool scour at the S.F. Skokomish ELJs as excessive sediments are stored and stabilized in the floodplain.

The location and frequency of ELJs in the active channel may also have influenced the lack of pool formation in the S.F. Skokomish River. Restoration efforts were completed along a 1.6-km reach. Many of the structures were located in the floodplain to store and stabilize sediments and promote floodplain forest development (Bair et al. 2008a). Our study identified 54 habitat units in the restored reach, of which 12 had ELJs within the active channel and most of these had a relatively small portion of the ELJ in the active channel. The frequency and impact of ELJs may have been too small to detect at the reach scale assessed in the current study. Of the 12 habitat units with associated ELJs, six were classified as scour pools. Thus, at least half of the ELJs were resulting in pool scour.

Any of the three factors described above are plausible causes for the lack of pool formation observed in the S.F. Skokomish River. Unfortunately, it is unclear which factor or combination of factors influenced the lack of pool formation observed during this study. Long-term monitoring of the site will help identify the causal factor, or eliminate potential factors, especially if large freshets occur prior to the next monitoring effort. We recommend that an assessment of pool scour be completed after a major freshet (> 2 yr recurrence interval) to help identify the causal factor(s).

Few substantial differences were observed between primary and secondary producer communities at the ELJ and control reach. We observed no differences in periphyton biomass or diatom communities between the two reaches. Coe et al. (2006, 2009) reported that periphyton biomass and invertebrate densities were greater on ELJs than non-ELJ substrates. However, their sampling differed from ours in that they collected samples directly off the ELJ. By comparison, we collected our samples off substrate within the ELJ unit. Coe et al. (2006, 2009) did not observe a difference between periphyton biomass and invertebrate densities between non-ELJ

substrates (i.e., rocks) in ELJ units and non-ELJ units, which is more similar to the study design employed in the current study. Results reported in the current study, support the hypothesis presented by Coe et al. (2009) that the differences may be due to the substrate types (ELJ, Cobble) and therefore may be restricted to the ELJs themselves and do not occur at a larger spatial scale.

Chlorophyll-*a* concentrations were within the limit observed for western Washington Rivers. Concentrations observed during the current study were lower than those observed previously for S.F. Skokomish samples (Peters et al. 2012). However, concentrations observed in the current study were greater than those observed for other western Washington systems (Morley et al. 2008; Coe et al. 2009). Differences between the current samples and those from Peters et al. (2012) may be due to differences in discharge between the two years, which can result in differences of an order of magnitude (Morley et al. 2008).

We expected invertebrate drift to be greater in the ELJ reach because invertebrate communities are often more abundant on ELJs (Coe et al. 2009). Although, we observed some apparent differences in drift, few of these differences were consistent with predicted expectations of increased diversity and abundance of invertebrate drift caused by ELJs. We observed a greater proportion of Diptera and an apparent increase in invertebrate drift biomass and abundance in the control reach. Diptera are an important taxa because they are often a preferred taxa for foraging salmonids including listed Chinook salmon in a variety of habitats (e.g., Muir and Emmett 1988; Merz 2001) and can make up a substantial component (~77%) of the energy intake during certain times of the year (Tiffan et al. 2014). Thus, it appears that the expected increase in invertebrates resulting from placement of ELJs is not occurring downstream in the drift. It may be that invertebrates settle out or are collected by hydraulic conditions near the ELJs and therefore were not reflected in our samples, which were collected near the downstream end of the unit. It may also be due to the observation that riffles sampled in the control reach were longer than those sampled in the ELJ reach.

We observed slightly greater fish species and age-class diversity in the ELJ reach than the control reach. This was due to the observation of a single lamprey and a single *O. mykiss* classified as greater than 2+ in the ELJ reach. It is possible that we simply did not detect these groups in the control reach due to their apparent low abundance and because the control reach was shorter. The ELJ reach was nearly twice as long as the control reach, which would increase the probability of detecting a group present in low abundance. Thus, there is no substantial support that the ELJs resulted in increased fish diversity in the S.F. Skokomish River. This contradicts results of the Brooks et al. (2004) observation of increased fish diversity one year after ELJs were installed. However, they did not observe increased fish diversity four years post-restoration (Brooks et al. 2006). Peters et al. (2012) reported that differences in species richness

of fishes between an ELJ and riprap reach of the Hoh River varied among sampling events. Thus, it appears that ELJs have little or no effect on species richness of fishes or that the effect may be short-lived.

One stated goal of the S.F. Skokomish restoration project was to increase fish production. We did not observe a substantial difference in fish abundance between the ELJ and control reach of the S.F. Skokomish River. This is due in part to the inherent large variation in population estimates in streams and river channels. This variability makes it difficult to draw strong conclusions from restoration monitoring efforts, especially case studies such as this that lack replication. Similar results have been observed by others. Brooks et al. (2004) observed increases in fish abundance one-year post-restoration, but not four years post-restoration (Brooks et al. 2006). No differences in the abundance of juvenile Chinook salmon, juvenile coho salmon, or all fish combined were observed between an ELJ and a riprap reach in the Hoh River (Peters et al. 2012). Pess et al. (2012) observed a general increase in juvenile salmonids at ELJs in the Elwha River. However, Pess et al. (2012) collected data at a much finer spatial scale than that reported in this study (i.e. locations within individual habitat units). Differences in scale can significantly influence results of these types of investigations (Peters 1996). Thus, potential differences may be restricted to ELJ units or areas directly adjacent to ELJs within habitat.

Fish size has not consistently been shown to be influenced by wood or ELJs. No difference in size was observed between fish in the ELJ and control reach during the current study. Peters et al. (2012) observed inconsistent results for fish size comparisons, with fish from an ELJ reach being larger than those at a riprap reach during one survey and then smaller the next. There was no difference in size of *O. mykiss* in the control or treatment reach in the current study. Inconsistent findings have also been observed for growth rates, which obviously influence size. Giannico and Hinch (2003) reported that winter growth rates of coho salmon were greater in areas with wood. In contrast, Giannico and Hinch (2007) reported no influence of wood on the growth rates of coho salmon in side channels. Thus, further study is required to determine if wood, including ELJs, influence juvenile salmonid size.

There was no strong evidence that diets of trout differed between the ELJ and control reaches. Horn’s overlap index was just under 0.6 for trout fry, which is the stated value for diet overlap (Horn 1966). This small difference between overlap and non-overlap in the diet may have been influenced by our relatively small sample size. As observed for 1+ *O. mykiss*, this analysis can be influenced by a single fish eating a large mass of a single prey type (a large crayfish in this case). Replication of ELJ and control reaches would help address this issue and is recommended for future ELJ evaluations.

Aquatic invasive and/or nuisance species have become a concern throughout the world. We examined our periphyton and invertebrate samples for two invasive species common in Washington State, Didymo and New Zealand mudsnails. Didymo was observed in four of the eight samples. Didymo presence increased in the downstream direction, suggesting that its presence may have been influenced by the canyon at the upstream end of the reach. New Zealand mudsnails were not observed during our sampling; however, this does not provide strong evidence that they are not present in the system. It does imply; however, that they are likely not abundant if they are present.

This study has several limitations that may have resulted in few differences being observed between the ELJ and control reaches and the strength of conclusions drawn. This study represents a simple case study since a single restored and control reach were sampled. No comparable pre-treatment data was available to confirm similarity of the ELJ and control reach prior to the treatment and the treatment reach was nearly twice as long as the control reach. In addition, the monitoring occurred relatively quickly after the restoration project was completed. Much of the restoration work also focuses on floodplain restoration and the development of mature riparian conditions on the floodplain, which may take decades to show a significant response. Thus, it is not surprising that few changes were observed in the near-term. The data presented in this report will be useful for long-term monitoring efforts at this site, but will provide little information for applicability of this type of restoration across a larger landscape.

The effectiveness of many restoration techniques is poorly understood because they have not been adequately evaluated (Roni et al. 2002). Although case studies such as this are preferable to no monitoring, the information will provide little knowledge in the near-term unless multiple case studies are completed to allow for meta-analysis, or a more rigorous sampling design developed to allow potential detectable differences to be identified (Vehanen et al. 2010). There have been a number of case studies evaluating ELJ restoration throughout western Washington, which have provided valuable information (e.g., Pess et al. 2005; McHenry et al. 2007, Peters et al. 2012). However, there are now sufficient numbers of ELJ restoration projects that have been in place long enough to expect physical and biological changes to have occurred to allow for a more rigorous evaluation of ELJs. We recommend partnerships be developed to complete an extensive assessment of ELJs using a standard protocol. The methods used in the current study could be used for that assessment or would be a good starting point for developing a standardized protocol. Given the costs associated with ELJ construction, it is imperative that a more rigorous assessment be completed.

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Appendix A: Periphyton and Diatom Technical Summary

Analysis of biological samples:
Technical summary of methods and quality assurance procedures
Prepared for Western Washington Fish and Wildlife Service
Roger Peters, Project Manager
April 30, 2013

by
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METHODS

Sample processing

Eight samples for diatom and non-diatom algae identification, periphyton biomass and chlorophyll-a analyses were delivered to Rhithron's laboratory facility in Missoula, Montana on December 4, 2012. All samples arrived in good condition. An inventory document containing sample identification information was provided by the Western Washington Fish and Wildlife Service (WWFWS) Project Manager. Upon arrival, samples were unpacked and examined, and checked against the WWFWS inventory. Discrepancies were resolved by the WWFWS Project Manager.

Periphyton samples for identification

The periphyton samples, preserved with Lugol's solution, were topped-off upon arrival at the laboratory. The samples were thoroughly mixed by shaking. Permanent diatom slides were prepared: subsamples were taken and treated with concentrated H_2SO_4 and 30% H_2O_2. The samples were neutralized by rinses with distilled water, and subsample volumes were adjusted to obtain adequate densities. Small amounts of the samples were dried onto 22-mm square coverslips. Coverslips were mounted on slides using Naphrax diatom mount. To ensure a high quality mount for identification and to make replicates available for archives, 3 slide mounts were made from each sample. One of the replicates was selected from each sample batch for identification. A diamond scribe mark was made to define a transect line on the cover slip, and a minimum of 600 diatom valves were identified along the transect mark. A Leica DM 2500 compound microscope, Nomarski contrast, and 1000x magnification were used for identifications. Diatoms were identified to the lowest possible taxonomic level, generally species, following standard taxonomic references.

For the soft-bodied (non-diatom) algae samples, the raw periphyton sample was manually homogenized and emptied into a porcelain evaporating dish. A small, random sub-sample of algal material was pipetted onto a standard glass microscope slide using a disposable dropper or soda straw. Visible (macroscopic) algae were also sub-sampled, in proportion to their estimated importance relative to the total volume of algal material in the sample, and added to the liquid fraction on the slide. The wet mount was then covered with a 22X30 mm cover slip.

Soft-bodied (non-diatom) algae were identified to genus using an Olympus BHT compound microscope under 200X and 400X. The relative abundance of each algal genus (and of all diatom genera collectively) was estimated for comparative purposes, and abundances were expressed according to the following system:

- rare (r): represented by a single occurrence in the sub-sample
- occasional (o): multiple occurrences, but infrequently seen
- common (c): multiple occurrences, regularly seen
- frequent (f): present in nearly every field of view
- abundant (a): multiple occurrences in every field of view, but well within limits of enumeration

- dominant (d): multiple occurrences in every field of view, but generally beyond practical limits of enumeration

Soft-bodied genera (and the diatom component) were also ranked according to their estimated contribution to the total algal biovolume present in the sample.

Periphyton samples for biomass analysis

The volume of each periphyton biomass sample was measured to the nearest 0.5 milliliter. Periphyton biomass was determined following Britton and Greeson (1988). Filters (47mm glass, PALL Type A/E, 1micron pore size) were placed in numbered aluminum boats and pre-ashed by heating to 500º C for 20 minutes. Boats were then placed in desiccant, allowed to cool to room temperature and weighed to the nearest 0.0001 gram using a Denver Instruments A-250 precision balance. Each filter was placed in the filtration apparatus and moistened with 2 ml of de-ionized water before the sample was added. Each sample was thoroughly mixed and filtered. Each sample bottle was rinsed two times with 10 ml of de-ionized water and the filtering apparatus was given a final rinse with 10 ml de-ionized water. The filters were then placed back in their numbered boats and dried to a constant weight at 105° C. Constant dry weight was considered to be $\leq$ 0.2 % change in 24 hours. Filters were then ashed in a muffle furnace for 1½ hours at 500°C and placed in a desiccator to cool to room temperature. Samples were then moistened with de-ionized water and again dried to constant dry weight at 105°C. This final step of moistening and re-drying alleviates the bias of clays that would hold some water at 105°C but not at 500°C. The ash-free dry weight was reported as the final ashed constant dry weight minus the constant dry weight, measured to the nearest 0.0001 gram. Periphyton biomass analyses were performed by Rhithron technicians at the Rhithron laboratory.

Chlorophyll-α filters

Chlorophyll-a filters arrived frozen at the Rhithron laboratory, and were maintained at 0ºC until processed. Chlorophyll-a samples were analyzed following the EPA's Method 446.0 (Arar 1997). The pigments were extracted from the phytoplankton from glass fiber filter samples in 90% acetone with the aid of a mechanical tissue grinder. Samples were allowed to steep for a minimum of 2 hours, but not exceeding 24 hours, to ensure thorough extraction of the pigments. The filter slurry was centrifuged at 675 g for 15 minutes (or at 1000g for 5 min) to clarify the solution. To determine the pheopigment-corrected chlorophyll-a, an aliquot of the supernatant was transferred to a glass cell and absorbance was measured at 750 nm and 664 nm before acidification and at 750 nm and 665 nm after acidification with 0.1 N HCl. A multi-wavelength spectrophotometer (Hach DR/2000) was used for this analysis. Absorbance values were entered into a set of equations that utilize the extinction coefficients of the pure pigments in 90% acetone to simultaneously calculate the concentrations of the pigments in a mixed pigment solution. Chlorophyll density was determined using the proportion of the original sample that was assessed for chlorophyll and converted to biomass per unit area based upon the total rock surface area sampled at each site. Results were reported in mg/cm^2. Chlorophyll-a analyses were performed by Rhithron technicians at the Rhithron laboratory.

Quality assurance procedures

Periphyton identification

Quality control procedures for periphyton taxonomy involved the re-identification of diatoms and non-diatom algae from one randomly selected sample by independent taxonomists. Re-identifications of diatoms and non-diatom algae were made internally at Rhithron. Bray-Curtis similarity statistics were generated by comparing the original identifications with the re-identifications, and adjustments to taxonomy were made where appropriate. Discrepancies in identifications were discussed, and rectifications were made to the data.

Periphyton biomass

One Method Fortified Blank was prepared to assess cross-contamination and laboratory hygiene. Method Fortified Blanks were analyzed following the same methods used for periphyton biomass sample analysis.

Chlorophyll α

Precision of the spectrophotometer was assured by running a serially-diluted standard solution of 1.00 mg/l of pure chlorophyll-a (spinach: Sigma-Aldrich, Inc.) at the start of analysis. The standard was read at 664 nm. A laboratory reagent blank, which was an aliquot of 90% acetone, was analyzed at the end of analysis to quantify laboratory contamination during sample processing. These procedures were repeated at the beginning of each analysis session.

Data analysis

Taxa lists and counts for each diatom sample were constructed. Standard metric calculations for periphyton assemblages were made using Rhithron's customized database software. Non-diatom algae identifications, relative abundances and biovolume rankings were compiled in Microsoft Excel.

Periphyton identifications, chlorophyll-a totals for each filter, and periphyton biomass weights were compiled in Microsoft Excel spreadsheets and flat data files for electronic delivery to the WWFWS Project Manager.

RESULTS

Quality Control Procedures

Results of quality control procedures for periphyton taxonomy are given in Table 1. Taxonomic precision for identification and enumeration was 93.50% for the randomly selected periphyton QA sample. These similarity statistics fall within acceptable industry criteria (Bahls pers. comm.)

Results from periphyton biomass and chlorophyll-a analyses quality assurance procedures showed below detection values indicating minimal laboratory contamination during processing.

Data analysis

Taxa lists and counts, and values and scores for various standard bioassessment metrics and indices calculated by Rhithron are given in the Appendix.

Electronic spreadsheets were sent to the WWFWS Project Manager via email.

Diatom slides and un-processed periphyton sample portions were shipped to the WWFWS Project Manager.

Table 1. *Results of internal quality control procedures for periphyton taxonomy.*

RAI Sample ID	Station name	Site ID	Bray-Curtis similarity for taxonomy and enumeration
WWFWS12P001	SF Skok	Unit # 26	
WWFWS12P002	SF Skok	Unit # 18	
WWFWS12P003	SF Skok	Unit # 4	
WWFWS12P004	SF Skok	Unit # 43	
WWFWS12P005	SF Skok	Unit # 118	93.50%
WWFWS12P006	SF Skok	Unit # 121	
WWFWS12P007	SF Skok	Unit # 113	
WWFWS12P008	SF Skok	Unit # 105	

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APPENDIX
Diatom taxa lists and metric summaries
Non-diatom algae identifications
Periphyton biomass results
Chlorophyll-a results

Western Washington Fish and Wildlife Service
2012

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P001

RAI No.: WWFWS12P001 **Sta. Name:** SF Skok
Client ID: Unit # 26
Date Coll.: 8/31/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium deflexum	41	6.83%	0	
Achnanthidium minutissimum	88	14.67%	0	
Achnanthidium pyrenaicum	21	3.50%	0	
Achnanthidium rivulare	3	0.50%	0	
Amphipleura pellucida	3	0.50%	0	
Amphora inariensis	2	0.33%	0	
Chamaepinnularia soehrensis	2	0.33%	0	
Cocconeis placentula	3	0.50%	0	
Cocconeis placentula v. lineata	20	3.33%	0	
Cocconeis pseudolineata	1	0.17%	0	
Cymbella hustedtii	2	0.33%	0	
Cymbella neocistula	2	0.33%	0	
Cymbella subturgidula	75	12.50%	0	
Diatoma mesodon	10	1.67%	0	
Encyonema silesiacum	8	1.33%	0	
Fragilaria capucina v. gracilis	2	0.33%	0	
Fragilaria vaucheriae	2	0.33%	0	
Geissleria decussis	2	0.33%	0	
Gomphoneis geitleri	62	10.33%	0	
Gomphoneis minuta	16	2.67%	0	
Gomphonema sp.	83	13.83%	0	
Gomphonema kobayasii	22	3.67%	0	
Gomphonema minusculum	7	1.17%	0	
Gomphonema minutum	1	0.17%	0	
Gomphonema pumilum	2	0.33%	0	
Gomphonema rhombicum	3	0.50%	0	
Hannaea arcus	11	1.83%	0	
Karayevia suchlandtii	4	0.67%	0	
Navicula caterva	3	0.50%	0	
Navicula concentrica	1	0.17%	0	
Navicula cryptotenella	1	0.17%	0	
Navicula cryptotenelloides	2	0.33%	0	
Navicula gregaria	2	0.33%	0	
Nitzschia sp.	2	0.33%	0	
Nitzschia acidoclinata	2	0.33%	0	
Nitzschia dissipata	8	1.33%	0	
Nitzschia inconspicua	2	0.33%	0	
Nitzschia lacuum	2	0.33%	0	
Nitzschia linearis	3	0.50%	0	
Nitzschia palea	13	2.17%	0	
Nitzschia pumila	2	0.33%	0	

Taxa Listing

Project ID: **WWFWS12P**
RAI No.: **WWFWS12P001**

RAI No.: WWFWS12P001 **Sta. Name:** SF Skok
Client ID: Unit # 26
Date Coll.: 8/31/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Nitzschia supralitorea	1	0.17%	0	
Planothidium frequentissimum	6	1.00%	0	
Planothidium lanceolatum	13	2.17%	0	
Reimeria sinuata	6	1.00%	0	
Rhoicosphenia abbreviata	18	3.00%	0	
Synedra ulna	6	1.00%	0	
Synedra ulna v. contracta	9	1.50%	0	

Sample Count **600**

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P002

RAI No.: WWFWS12P002 **Sta. Name:** SF Skok
Client ID: Unit # 18
Date Coll.: 8/31/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium minutissimum	36	6.00%	0	
Achnanthidium rivulare	4	0.67%	0	
Amphipleura pellucida	3	0.50%	0	
Cocconeis placentula	9	1.50%	0	
Cocconeis placentula v. lineata	30	5.00%	0	
Cocconeis pseudolineata	2	0.33%	0	
Cymbella subturgidula	87	14.50%	0	
Diatoma hiemalis	1	0.17%	0	
Diatoma mesodon	10	1.67%	0	
Encyonema silesiacum	3	0.50%	0	
Fragilaria capucina v. gracilis	7	1.17%	0	
Gomphoneis geitleri	133	22.17%	0	
Gomphoneis minuta	10	1.67%	0	
Gomphonema sp.	89	14.83%	0	
Gomphonema kobayasii	21	3.50%	0	
Gomphonema minusculum	3	0.50%	0	
Gomphonema minutum	5	0.83%	0	
Gomphonema olivaceoides	1	0.17%	0	
Gomphonema rhombicum	1	0.17%	0	
Hannaea arcus	21	3.50%	0	
Karayevia suchlandtii	4	0.67%	0	
Navicula cryptotenella	4	0.67%	0	
Navicula tenelloides	3	0.50%	0	
Nitzschia dissipata	19	3.17%	0	
Nitzschia fonticola	1	0.17%	0	
Nitzschia inconspicua	1	0.17%	0	
Planothidium frequentissimum	3	0.50%	0	
Planothidium lanceolatum	11	1.83%	0	
Reimeria sinuata	13	2.17%	0	
Rhoicosphenia abbreviata	30	5.00%	0	
Synedra ulna	10	1.67%	0	
Synedra ulna v. contracta	25	4.17%	0	
Sample Count	**600**			

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P003

RAI No.: WWFWS12P003 **Sta. Name:** SF Skok
Client ID: Unit # 4
Date Coll.: 8/30/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium minutissimum	23	3.83%	0	
Cocconeis placentula	56	9.33%	0	
Cocconeis placentula v. lineata	81	13.50%	0	
Cocconeis pseudolineata	5	0.83%	0	
Cymbella subturgidula	24	4.00%	0	
Diatoma hiemalis	1	0.17%	0	
Diatoma mesodon	2	0.33%	0	
Encyonema silesiacum	4	0.67%	0	
Fragilaria capucina v. gracilis	3	0.50%	0	
Gomphoneis geitleri	26	4.33%	0	
Gomphoneis minuta	3	0.50%	0	
Gomphonema sp.	161	26.83%	0	
Gomphonema kobayasii	41	6.83%	0	
Gomphonema minusculum	2	0.33%	0	
Gomphonema minutum	8	1.33%	0	
Gomphonema olivaceoides	2	0.33%	0	
Gomphonema rhombicum	6	1.00%	0	
Hannaea arcus	16	2.67%	0	
Karayevia suchlandtii	3	0.50%	0	
Navicula concentrica	1	0.17%	0	
Navicula cryptotenella	7	1.17%	0	
Navicula cryptotenelloides	2	0.33%	0	
Nitzschia dissipata	6	1.00%	0	
Planothidium dubium	2	0.33%	0	
Planothidium frequentissimum	3	0.50%	0	
Planothidium lanceolatum	17	2.83%	0	
Reimeria sinuata	52	8.67%	0	
Rhoicosphenia abbreviata	8	1.33%	0	
Synedra ulna	12	2.00%	0	
Synedra ulna v. contracta	23	3.83%	0	
Sample Count	**600**			

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P004

RAI No.: WWFWS12P004 **Sta. Name:** SF Skok
Client ID: Unit # 43
Date Coll.: 8/31/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium deflexum	2	0.33%	0	
Achnanthidium minutissimum	18	3.00%	0	
Amphipleura pellucida	2	0.33%	0	
Cocconeis placentula	3	0.50%	0	
Cocconeis placentula v. lineata	10	1.67%	0	
Cocconeis pseudolineata	1	0.17%	0	
Cymbella subturgidula	151	25.17%	0	
Diatoma mesodon	5	0.83%	0	
Didymosphenia geminata	1	0.17%	0	
Encyonema silesiacum	4	0.67%	0	
Epithemia turgida	3	0.50%	0	
Fragilaria capucina v. gracilis	7	1.17%	0	
Fragilaria vaucheriae	3	0.50%	0	
Gomphoneis geitleri	174	29.00%	0	
Gomphoneis minuta	14	2.33%	0	
Gomphonema sp.	58	9.67%	0	
Gomphonema kobayasii	16	2.67%	0	
Gomphonema minutum	2	0.33%	0	
Hannaea arcus	22	3.67%	0	
Navicula caterva	1	0.17%	0	
Navicula concentrica	2	0.33%	0	
Navicula cryptotenella	2	0.33%	0	
Navicula cryptotenelloides	1	0.17%	0	
Navicula gregaria	6	1.00%	0	
Navicula radiosa	1	0.17%	0	
Navicula tenelloides	2	0.33%	0	
Nitzschia sp.	4	0.67%	0	
Nitzschia dissipata	12	2.00%	0	
Nitzschia liebetruthii	3	0.50%	0	
Nitzschia linearis	1	0.17%	0	
Nitzschia palea	3	0.50%	0	
Nitzschia supralitorea	2	0.33%	0	
Planothidium lanceolatum	12	2.00%	0	
Reimeria sinuata	5	0.83%	0	
Rhoicosphenia abbreviata	3	0.50%	0	
Rhopalodia gibba	2	0.33%	0	
Synedra mazamaensis	2	0.33%	0	
Synedra ulna	13	2.17%	0	
Synedra ulna v. contracta	27	4.50%	0	

Sample Count **600**

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P005

RAI No.: WWFWS12P005 **Sta. Name:** SF Skok
Client ID: Unit # 118
Date Coll.: 9/4/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium minutissimum	93	15.50%	0	
Achnanthidium rivulare	2	0.33%	0	
Amphipleura pellucida	11	1.83%	0	
Cocconeis placentula	3	0.50%	0	
Cocconeis placentula v. lineata	15	2.50%	0	
Cocconeis pseudolineata	1	0.17%	0	
Cymbella neocistula	2	0.33%	0	
Cymbella percymbiformis	10	1.67%	0	
Cymbella subturgidula	106	17.67%	0	
Diatoma mesodon	6	1.00%	0	
Encyonema silesiacum	5	0.83%	0	
Eolimna minima	1	0.17%	0	
Fragilaria capucina v. gracilis	12	2.00%	0	
Fragilaria vaucheriae	4	0.67%	0	
Gomphoneis geitleri	86	14.33%	0	
Gomphoneis minuta	12	2.00%	0	
Gomphonema sp.	71	11.83%	0	
Gomphonema kobayasii	20	3.33%	0	
Gomphonema minutum	3	0.50%	0	
Gomphonema olivaceoides	2	0.33%	0	
Gomphonema rhombicum	6	1.00%	0	
Gomphonema subclavatum	6	1.00%	0	
Hannaea arcus	18	3.00%	0	
Karayevia suchlandtii	1	0.17%	0	
Melosira varians	1	0.17%	0	
Navicula cryptotenella	6	1.00%	0	
Navicula gregaria	2	0.33%	0	
Nitzschia sp.	4	0.67%	0	
Nitzschia dissipata	10	1.67%	0	
Nitzschia fonticola	1	0.17%	0	
Nitzschia heufleriana	2	0.33%	0	
Nitzschia linearis	1	0.17%	0	
Nitzschia recta	1	0.17%	0	
Nitzschia sublinearis	1	0.17%	0	
Nitzschia tropica	4	0.67%	0	
Nitzschia tubicola	2	0.33%	0	
Planothidium lanceolatum	4	0.67%	0	
Reimeria sinuata	9	1.50%	0	
Rhoicosphenia abbreviata	8	1.33%	0	
Synedra ulna	18	3.00%	0	
Synedra ulna v. contracta	30	5.00%	0	

Taxa Listing

Project ID: **WWFWS12P**
RAI No.: **WWFWS12P005**

RAI No.: WWFWS12P005 **Sta. Name:** SF Skok
Client ID: Unit # 118
Date Coll.: 9/4/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment

Sample Count **600**

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P006

RAI No.: WWFWS12P006 **Sta. Name:** SF Skok
Client ID: Unit # 121
Date Coll.: 9/4/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium minutissimum	32	5.33%	0	
Achnanthidium rivulare	1	0.17%	0	
Amphora inariensis	1	0.17%	0	
Aulacoseira sp.	1	0.17%	0	
Cocconeis placentula	36	6.00%	0	
Cocconeis placentula v. lineata	38	6.33%	0	
Cocconeis pseudolineata	1	0.17%	0	
Cymbella neocistula	2	0.33%	0	
Cymbella subturgidula	75	12.50%	0	
Diatoma mesodon	1	0.17%	0	
Didymosphenia geminata	2	0.33%	0	
Encyonema silesiacum	7	1.17%	0	
Epithemia turgida	1	0.17%	0	
Fragilaria capucina v. gracilis	6	1.00%	0	
Fragilaria vaucheriae	3	0.50%	0	
Gomphoneis geitleri	62	10.33%	0	
Gomphoneis minuta	4	0.67%	0	
Gomphonema sp.	138	23.00%	0	
Gomphonema kobayasii	44	7.33%	0	
Gomphonema olivaceoides	2	0.33%	0	
Gomphonema pumilum	1	0.17%	0	
Gomphonema rhombicum	4	0.67%	0	
Gomphonema subclavatum	2	0.33%	0	
Hannaea arcus	6	1.00%	0	
Karayevia suchlandtii	1	0.17%	0	
Navicula cryptotenella	6	1.00%	0	
Navicula gregaria	2	0.33%	0	
Nitzschia archibaldii	2	0.33%	0	
Nitzschia dissipata	2	0.33%	0	
Nitzschia inconspicua	2	0.33%	0	
Planothidium dubium	1	0.17%	0	
Planothidium lanceolatum	16	2.67%	0	
Psammothidium bioretii	1	0.17%	0	
Reimeria sinuata	68	11.33%	0	
Rhoicosphenia abbreviata	9	1.50%	0	
Synedra ulna	12	2.00%	0	
Synedra ulna v. contracta	8	1.33%	0	

Sample Count **600**

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P007

RAI No.: WWFWS12P007 **Sta. Name:** SF Skok
Client ID: Unit # 113
Date Coll.: 9/4/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium minutissimum	42	7.00%	0	
Amphipleura pellucida	4	0.67%	0	
Cocconeis pediculus	1	0.17%	0	
Cocconeis placentula	16	2.67%	0	
Cocconeis placentula v. lineata	26	4.33%	0	
Cocconeis pseudolineata	2	0.33%	0	
Cymbella excisa	1	0.17%	0	
Cymbella neocistula	2	0.33%	0	
Cymbella subturgidula	86	14.33%	0	
Diatoma mesodon	4	0.67%	0	
Didymosphenia geminata	1	0.17%	0	
Encyonema silesiacum	2	0.33%	0	
Epithemia turgida	5	0.83%	0	
Fragilaria capucina v. gracilis	6	1.00%	0	
Fragilaria vaucheriae	8	1.33%	0	
Gomphoneis geitleri	88	14.67%	0	
Gomphoneis minuta	14	2.33%	0	
Gomphonema sp.	158	26.33%	0	
Gomphonema kobayasii	19	3.17%	0	
Gomphonema minusculum	3	0.50%	0	
Gomphonema olivaceoides	2	0.33%	0	
Gomphonema pumilum	2	0.33%	0	
Gomphonema rhombicum	2	0.33%	0	
Hannaea arcus	17	2.83%	0	
Karayevia suchlandtii	2	0.33%	0	
Meridion circulare v. constrictum	2	0.33%	0	
Navicula concentrica	1	0.17%	0	
Navicula cryptotenella	8	1.33%	0	
Navicula cryptotenelloides	3	0.50%	0	
Navicula gregaria	1	0.17%	0	
Navicula seibigiana	1	0.17%	0	
Navicula tenelloides	4	0.67%	0	
Nitzschia sp.	2	0.33%	0	
Nitzschia dissipata	7	1.17%	0	
Nitzschia inconspicua	2	0.33%	0	
Nitzschia lacuum	1	0.17%	0	
Nitzschia tropica	1	0.17%	0	
Planothidium dubium	2	0.33%	0	
Planothidium frequentissimum	1	0.17%	0	
Planothidium lanceolatum	5	0.83%	0	
Reimeria sinuata	5	0.83%	0	

Taxa Listing

Project ID: **WWFWS12P**
RAI No.: **WWFWS12P007**

RAI No.: WWFWS12P007 **Sta. Name:** SF Skok
Client ID: Unit # 113
Date Coll.: 9/4/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Rhoicosphenia abbreviata	10	1.67%	0	
Synedra ulna	19	3.17%	0	
Synedra ulna v. contracta	12	2.00%	0	

Sample Count **600**

Taxa Listing

Project ID: WWFWS12P
RAI No.: WWFWS12P008

RAI No.: WWFWS12P008 **Sta. Name:** SF Skok
Client ID: Unit # 105
Date Coll.: 9/4/2012 **No Jars:** 1 **STORET ID:**
Sample Notes:

Taxonomic Name	Count	PRA	Abnorm.	Comment
Diatoms				
Bacillariophyta				
Achnanthidium minutissimum	116	19.33%	0	
Achnanthidium pyrenaicum	2	0.33%	0	
Achnanthidium rivulare	2	0.33%	0	
Amphipleura pellucida	4	0.67%	0	
Cocconeis placentula	9	1.50%	0	
Cocconeis placentula v. lineata	3	0.50%	0	
Cymbella neocistula	2	0.33%	0	
Cymbella subturgidula	101	16.83%	0	
Diatoma mesodon	1	0.17%	0	
Didymosphenia geminata	3	0.50%	0	
Encyonema silesiacum	4	0.67%	0	
Epithemia adnata	2	0.33%	0	
Epithemia turgida	1	0.17%	0	
Fragilaria capucina v. gracilis	2	0.33%	0	
Fragilaria vaucheriae	12	2.00%	0	
Gomphoneis geitleri	54	9.00%	0	
Gomphoneis minuta	6	1.00%	0	
Gomphonema sp.	123	20.50%	0	
Gomphonema kobayasii	16	2.67%	0	
Gomphonema minusculum	2	0.33%	0	
Gomphonema olivaceoides	2	0.33%	0	
Gomphonema rhombicum	4	0.67%	0	
Hannaea arcus	11	1.83%	0	
Karayevia suchlandtii	2	0.33%	0	
Navicula concentrica	2	0.33%	0	
Navicula cryptotenella	7	1.17%	0	
Nitzschia sp.	2	0.33%	0	
Nitzschia dissipata	9	1.50%	0	
Nitzschia inconspicua	1	0.17%	0	
Nitzschia linearis	1	0.17%	0	
Nitzschia recta	1	0.17%	0	
Nitzschia tropica	2	0.33%	0	
Planothidium lanceolatum	8	1.33%	0	
Reimeria sinuata	22	3.67%	0	
Reimeria uniseriata	2	0.33%	0	
Rhoicosphenia abbreviata	16	2.67%	0	
Synedra ulna	26	4.33%	0	
Synedra ulna v. contracta	17	2.83%	0	

Sample Count **600**

Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P001
Station Name: SF Skok
Client ID: Unit # 26
STORET ID:
Date Collected: 8/31/2012
Count Of Taxon: 48
Sum Of Count: 600

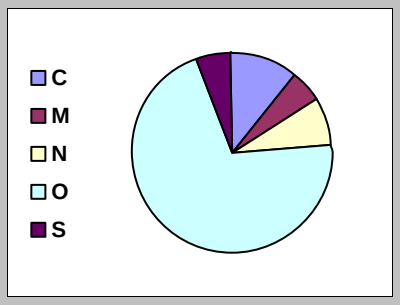
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	4.319	Excellent	Excellent
Species Richness	48	Excellent	Excellent
Native Taxa Percent	23.83%		
Cosmopolitan Taxa Percent	42.83%		
Mountains Rare Taxa Percent	13.00%		
Plains Rare Taxa Percent	13.17%		
Dominant Taxon Percent	14.67%	Excellent	Excellent
Sediment			
Siltation Taxa Percent	8.00%	Excellent	Excellent
Motile Taxa Percent	9.83%		
Mountains Brackish Taxa Percent	53.83%		
Plains Brackish Taxa Percent	3.17%		
Organic Nutrients			
Pollution Index	2.840	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	2.67%		
Polysaprobous Taxa Percent	10.83%		
Low DO Taxa Percent	2.50%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	38.83%		
Eutraphentic Taxa Percent	12.67%		
Rhopalodiales Percent	0.00%		
Metals			
Disturbance Taxa Percent	10.33%	Excellent	Excellent
Acidophilous Taxa Percent	0.33%		
Metals Tolerant Taxa Percent	7.83%		
Abnormal Cells Percent	0.00%	Excellent	

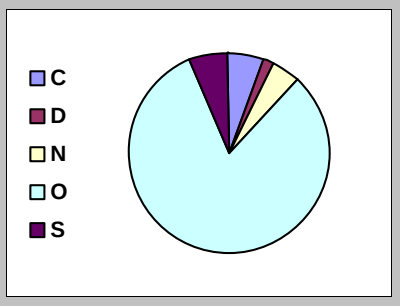
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Excellent
MTP	Montana DEQ Plains (Bahls 1992)	Excellent

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	14.00%	29.12%
Mountains Metals Increasers Taxa Percent	6.00%	6.94%
Mountains Nutrient Increasers Taxa Percent	9.83%	13.79%
Mountains Sediment Increasers Taxa Percent	6.83%	16.85%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	2.00%	86.65%
Plains General Increasers Taxa Percent	6.83%	2.87%



Tuesday, April 23, 2013

Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P002
Station Name: SF Skok
Client ID: Unit # 18
STORET ID:
Date Collected: 8/31/2012
Count Of Taxon: 32
Sum Of Count: 600

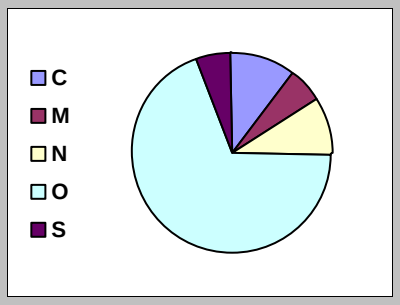
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	3.841	Excellent	Good
Species Richness	32	Excellent	Good
Native Taxa Percent	20.50%		
Cosmopolitan Taxa Percent	32.67%		
Mountains Rare Taxa Percent	15.17%		
Plains Rare Taxa Percent	5.17%		
Dominant Taxon Percent	22.17%	Excellent	Excellent
Sediment			
Siltation Taxa Percent	4.67%	Excellent	Excellent
Motile Taxa Percent	7.33%		
Mountains Brackish Taxa Percent	44.83%		
Plains Brackish Taxa Percent	2.67%		
Organic Nutrients			
Pollution Index	2.878	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	0.17%		
Polysaprobous Taxa Percent	9.33%		
Low DO Taxa Percent	0.00%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	40.33%		
Eutraphentic Taxa Percent	15.17%		
Rhopalodiales Percent	0.00%		
Metals			
Disturbance Taxa Percent	0.00%	Excellent	Excellent
Acidophilous Taxa Percent	0.00%		
Metals Tolerant Taxa Percent	7.67%		
Abnormal Cells Percent	0.00%	Excellent	

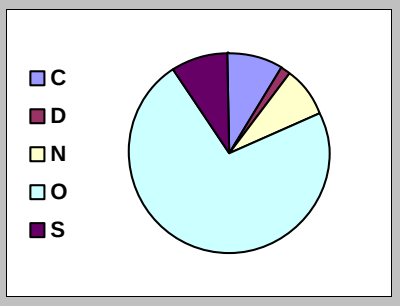
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Excellent
MTP	Montana DEQ Plains (Bahls 1992)	Good

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	13.67%	28.43%
Mountains Metals Increasers Taxa Percent	6.83%	7.78%
Mountains Nutrient Increasers Taxa Percent	11.67%	16.60%
Mountains Sediment Increasers Taxa Percent	6.83%	16.85%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	2.00%	86.65%
Plains General Increasers Taxa Percent	11.00%	5.48%



Tuesday, April 23, 2013

Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P003
Station Name: SF Skok
Client ID: Unit # 4
STORET ID:
Date Collected: 8/30/2012
Count Of Taxon: 30
Sum Of Count: 600

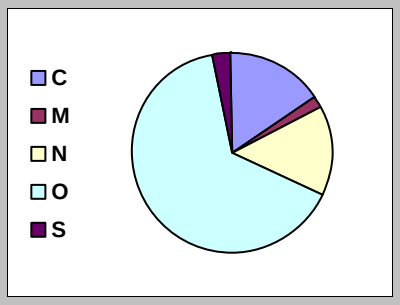
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	3.730	Excellent	Good
Species Richness	30	Excellent	Good
Native Taxa Percent	12.33%		
Cosmopolitan Taxa Percent	49.17%		
Mountains Rare Taxa Percent	4.00%		
Plains Rare Taxa Percent	7.33%		
Dominant Taxon Percent	26.83%	Good	Good
Sediment			
Siltation Taxa Percent	2.67%	Excellent	Excellent
Motile Taxa Percent	11.33%		
Mountains Brackish Taxa Percent	62.33%		
Plains Brackish Taxa Percent	1.50%		
Organic Nutrients			
Pollution Index	2.877	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	0.00%		
Polysaprobous Taxa Percent	9.83%		
Low DO Taxa Percent	0.00%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	52.83%		
Eutraphentic Taxa Percent	29.17%		
Rhopalodiales Percent	0.00%		
Metals			
Disturbance Taxa Percent	0.00%	Excellent	Excellent
Acidophilous Taxa Percent	0.00%		
Metals Tolerant Taxa Percent	8.17%		
Abnormal Cells Percent	0.00%	Excellent	

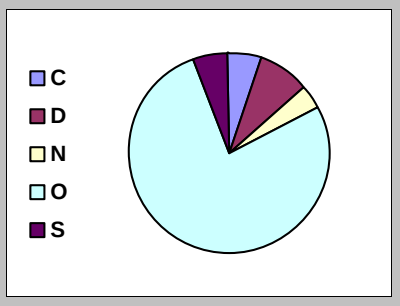
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Good
MTP	Montana DEQ Plains (Bahls 1992)	Good

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	20.00%	40.13%
Mountains Metals Increasers Taxa Percent	1.83%	3.92%
Mountains Nutrient Increasers Taxa Percent	18.00%	28.77%
Mountains Sediment Increasers Taxa Percent	3.33%	11.51%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	9.33%	73.89%
Plains General Increasers Taxa Percent	6.17%	2.56%



Tuesday, April 23, 2013

Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P004
Station Name: SF Skok
Client ID: Unit # 43
STORET ID:
Date Collected: 8/31/2012
Count Of Taxon: 39
Sum Of Count: 600

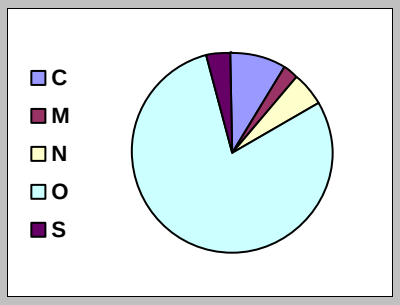
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	3.504	Excellent	Good
Species Richness	39	Excellent	Good
Native Taxa Percent	30.67%		
Cosmopolitan Taxa Percent	20.83%		
Mountains Rare Taxa Percent	25.17%		
Plains Rare Taxa Percent	5.67%		
Dominant Taxon Percent	29.00%	Good	Good
Sediment			
Siltation Taxa Percent	6.67%	Excellent	Excellent
Motile Taxa Percent	8.67%		
Mountains Brackish Taxa Percent	30.00%		
Plains Brackish Taxa Percent	1.17%		
Organic Nutrients			
Pollution Index	2.830	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	0.83%		
Polysaprobous Taxa Percent	12.00%		
Low DO Taxa Percent	1.50%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	27.00%		
Eutraphentic Taxa Percent	8.17%		
Rhopalodiales Percent	0.83%		
Metals			
Disturbance Taxa Percent	0.33%	Excellent	Excellent
Acidophilous Taxa Percent	0.00%		
Metals Tolerant Taxa Percent	9.33%		
Abnormal Cells Percent	0.00%	Excellent	

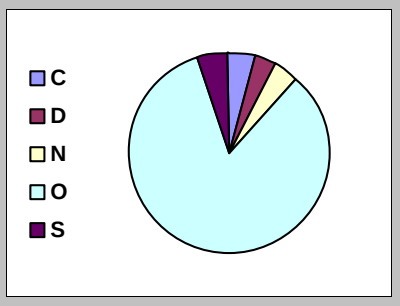
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Good
MTP	Montana DEQ Plains (Bahls 1992)	Good

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	10.33%	22.97%
Mountains Metals Increasers Taxa Percent	3.17%	4.75%
Mountains Nutrient Increasers Taxa Percent	6.00%	9.18%
Mountains Sediment Increasers Taxa Percent	4.50%	13.14%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	3.17%	85.08%
Plains General Increasers Taxa Percent	5.67%	2.33%



Tuesday, April 23, 2013

Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P005
Station Name: SF Skok
Client ID: Unit # 118
STORET ID:
Date Collected: 9/4/2012
Count Of Taxon: 41
Sum Of Count: 600

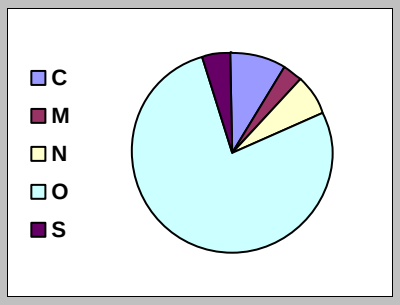
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	4.024	Excellent	Excellent
Species Richness	41	Excellent	Excellent
Native Taxa Percent	24.33%		
Cosmopolitan Taxa Percent	34.17%		
Mountains Rare Taxa Percent	18.00%		
Plains Rare Taxa Percent	5.33%		
Dominant Taxon Percent	17.67%	Excellent	Excellent
Sediment			
Siltation Taxa Percent	5.83%	Excellent	Excellent
Motile Taxa Percent	9.17%		
Mountains Brackish Taxa Percent	48.67%		
Plains Brackish Taxa Percent	1.50%		
Organic Nutrients			
Pollution Index	2.808	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	0.33%		
Polysaprobous Taxa Percent	12.67%		
Low DO Taxa Percent	0.50%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	43.50%		
Eutraphentic Taxa Percent	7.00%		
Rhopalodiales Percent	0.00%		
Metals			
Disturbance Taxa Percent	0.00%	Excellent	Excellent
Acidophilous Taxa Percent	0.00%		
Metals Tolerant Taxa Percent	9.33%		
Abnormal Cells Percent	0.00%	Excellent	

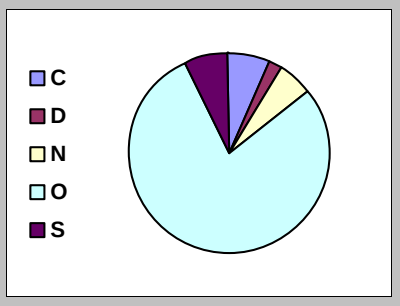
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Excellent
MTP	Montana DEQ Plains (Bahls 1992)	Excellent

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	10.83%	23.58%
Mountains Metals Increasers Taxa Percent	3.67%	5.05%
Mountains Nutrient Increasers Taxa Percent	7.17%	10.38%
Mountains Sediment Increasers Taxa Percent	4.67%	13.35%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	2.83%	85.54%
Plains General Increasers Taxa Percent	7.83%	3.36%



Tuesday, April 23, 2013

Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P006
Station Name: SF Skok
Client ID: Unit # 121
STORET ID:
Date Collected: 9/4/2012
Count Of Taxon: 37
Sum Of Count: 600

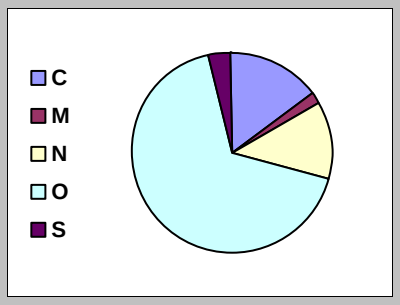
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	3.763	Excellent	Good
Species Richness	37	Excellent	Good
Native Taxa Percent	21.33%		
Cosmopolitan Taxa Percent	39.83%		
Mountains Rare Taxa Percent	12.67%		
Plains Rare Taxa Percent	8.00%		
Dominant Taxon Percent	23.00%	Excellent	Excellent
Sediment			
Siltation Taxa Percent	2.33%	Excellent	Excellent
Motile Taxa Percent	14.00%		
Mountains Brackish Taxa Percent	51.00%		
Plains Brackish Taxa Percent	0.67%		
Organic Nutrients			
Pollution Index	2.888	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	0.33%		
Polysaprobous Taxa Percent	8.33%		
Low DO Taxa Percent	0.33%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	42.67%		
Eutraphentic Taxa Percent	18.17%		
Rhopalodiales Percent	0.17%		
Metals			
Disturbance Taxa Percent	0.00%	Excellent	Excellent
Acidophilous Taxa Percent	0.00%		
Metals Tolerant Taxa Percent	6.83%		
Abnormal Cells Percent	0.00%	Excellent	

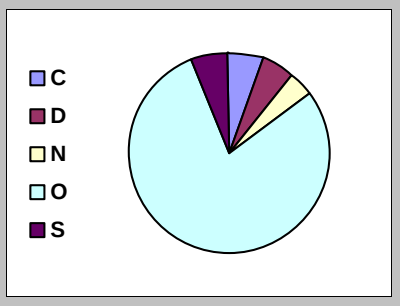
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Excellent
MTP	Montana DEQ Plains (Bahls 1992)	Good

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	18.67%	37.83%
Mountains Metals Increasers Taxa Percent	2.33%	4.27%
Mountains Nutrient Increasers Taxa Percent	15.50%	23.27%
Mountains Sediment Increasers Taxa Percent	4.50%	13.14%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	6.33%	79.96%
Plains General Increasers Taxa Percent	6.33%	2.62%



Tuesday, April 23, 2013

Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P007
Station Name: SF Skok
Client ID: Unit # 113
STORET ID:
Date Collected: 9/4/2012
Count Of Taxon: 44
Sum Of Count: 600

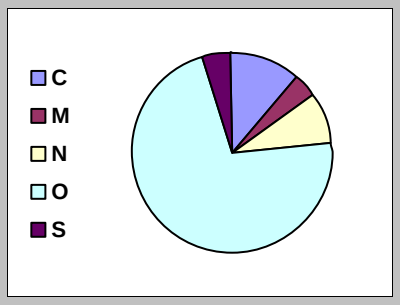
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	3.853	Excellent	Good
Species Richness	43	Excellent	Excellent
Native Taxa Percent	20.17%		
Cosmopolitan Taxa Percent	29.33%		
Mountains Rare Taxa Percent	14.33%		
Plains Rare Taxa Percent	5.50%		
Dominant Taxon Percent	26.33%	Good	Good
Sediment			
Siltation Taxa Percent	5.17%	Excellent	Excellent
Motile Taxa Percent	7.50%		
Mountains Brackish Taxa Percent	38.33%		
Plains Brackish Taxa Percent	1.50%		
Organic Nutrients			
Pollution Index	2.855	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	0.33%		
Polysaprobous Taxa Percent	9.00%		
Low DO Taxa Percent	0.17%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	34.33%		
Eutraphentic Taxa Percent	12.83%		
Rhopalodiales Percent	0.83%		
Metals			
Disturbance Taxa Percent	0.00%	Excellent	Excellent
Acidophilous Taxa Percent	0.00%		
Metals Tolerant Taxa Percent	5.83%		
Abnormal Cells Percent	0.00%	Excellent	

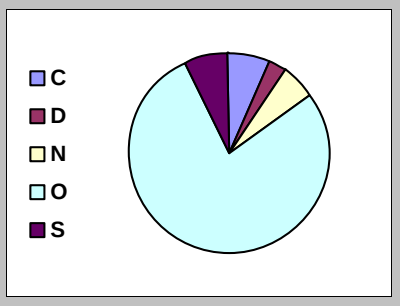
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Good
MTP	Montana DEQ Plains (Bahls 1992)	Good

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	14.17%	29.46%
Mountains Metals Increasers Taxa Percent	4.67%	5.82%
Mountains Nutrient Increasers Taxa Percent	10.00%	14.01%
Mountains Sediment Increasers Taxa Percent	5.50%	14.69%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	3.50%	84.61%
Plains General Increasers Taxa Percent	8.00%	3.44%



Metrics Report

Project ID: WWFWS12P
Sample ID: WWFWS12P008
Station Name: SF Skok
Client ID: Unit # 105
STORET ID:
Date Collected: 9/4/2012
Count Of Taxon: 38
Sum Of Count: 600

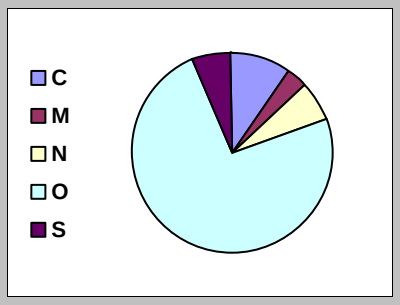
Table 1 Metrics

Metric	Value	MTM	MTP
Community Structure			
Shannon H (log2)	3.720	Excellent	Good
Species Richness	38	Excellent	Good
Native Taxa Percent	21.83%		
Cosmopolitan Taxa Percent	41.67%		
Mountains Rare Taxa Percent	17.17%		
Plains Rare Taxa Percent	3.67%		
Dominant Taxon Percent	20.50%	Excellent	Excellent
Sediment			
Siltation Taxa Percent	4.17%	Excellent	Excellent
Motile Taxa Percent	9.33%		
Mountains Brackish Taxa Percent	49.67%		
Plains Brackish Taxa Percent	1.17%		
Organic Nutrients			
Pollution Index	2.850	Excellent	Excellent
Nitrogen Heterotroph Taxa Percent	0.17%		
Polysaprobous Taxa Percent	12.00%		
Low DO Taxa Percent	0.00%		
Inorganic Nutrients			
Nitrogen Autotroph Taxa Percent	45.17%		
Eutraphentic Taxa Percent	8.17%		
Rhopalodiales Percent	0.50%		
Metals			
Disturbance Taxa Percent	0.33%	Excellent	Excellent
Acidophilous Taxa Percent	0.00%		
Metals Tolerant Taxa Percent	7.17%		
Abnormal Cells Percent	0.00%	Excellent	

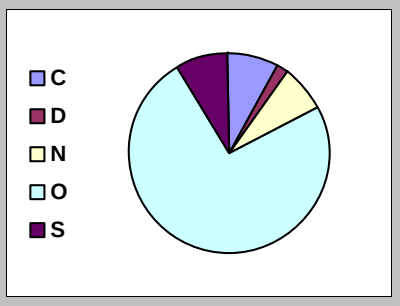
BioIndex	Description	Rating
MTM	Montana DEQ Mountains (Bahls 1992)	Excellent
MTP	Montana DEQ Plains (Bahls 1992)	Good

Increaser/Decreaser Taxa

Metric	Value	Prob.
Mountains General Increasers Taxa Percent	12.33%	26.11%
Mountains Metals Increasers Taxa Percent	3.67%	5.05%
Mountains Nutrient Increasers Taxa Percent	7.83%	11.12%
Mountains Sediment Increasers Taxa Percent	7.17%	17.62%



Metric	Value	Prob.
Plains General Decreasers Taxa Percent	2.33%	86.21%
Plains General Increasers Taxa Percent	10.33%	4.95%



Non-diatom algae study: Western Washington Fish & Wildlife Service 2012					Determinations by Rhithron Associates, Inc.	
RAI Sample ID	**Client ID**	**Sample Date**	**Taxon**	**Division**	**Relative Abundance**	**Biovolume Rank**
WWFWS12P001	Unit # 26	8/31/2012	Diatoms	Bacillariophyta	F	1
WWFWS12P001	Unit # 26	8/31/2012	*Spirogyra*	Chlorophyta	O	2
WWFWS12P001	Unit # 26	8/31/2012	*Phormidium*	Cyanophyta	C	3
WWFWS12P001	Unit # 26	8/31/2012	*Komvophoron*	Cyanophyta	C	4
WWFWS12P001	Unit # 26	8/31/2012	*Leptolyngbya*	Cyanophyta	C	5
WWFWS12P001	Unit # 26	8/31/2012	*Oscillatoria*	Cyanophyta	O	6
WWFWS12P001	Unit # 26	8/31/2012	*Homeothrix*	Cyanophyta	O	7
WWFWS12P001	Unit # 26	8/31/2012	*Pseudanabaena*	Cyanophyta	O	8
WWFWS12P001	Unit # 26	8/31/2012	*Calothrix*	Cyanophyta	R	9
WWFWS12P001	Unit # 26	8/31/2012	*Staurastrum*	Chlorophyta	R	10
WWFWS12P001	Unit # 26	8/31/2012	*Cosmarium*	Chlorophyta	R	11
WWFWS12P001	Unit # 26	8/31/2012	*Ankistrodesmus*	Chlorophyta	R	12
WWFWS12P002	Unit # 18	8/31/2012	Diatoms	Bacillariophyta	F	1
WWFWS12P002	Unit # 18	8/31/2012	*Audouinella*	Rhodophyta	O	2
WWFWS12P002	Unit # 18	8/31/2012	*Zygnema*	Chlorophyta	O	3
WWFWS12P002	Unit # 18	8/31/2012	*Phormidium*	Cyanophyta	O	4
WWFWS12P002	Unit # 18	8/31/2012	*Spirogyra*	Chlorophyta	O	5
WWFWS12P002	Unit # 18	8/31/2012	*Leptolyngbya*	Cyanophyta	O	6
WWFWS12P002	Unit # 18	8/31/2012	*Homeothrix*	Cyanophyta	C	7
WWFWS12P002	Unit # 18	8/31/2012	*Pseudanabaena*	Cyanophyta	R	8
WWFWS12P002	Unit # 18	8/31/2012	*Calothrix*	Cyanophyta	R	9
WWFWS12P002	Unit # 18	8/31/2012	*Anabaena*	Cyanophyta	R	10
WWFWS12P003	Unit # 4	8/30/2012	Diatoms	Bacillariophyta	C	1
WWFWS12P003	Unit # 4	8/30/2012	*Leptolyngbya*	Cyanophyta	R	2
WWFWS12P004	Unit # 43	8/31/2012	Diatoms	Bacillariophyta	F	1
WWFWS12P004	Unit # 43	8/31/2012	*Phormidium*	Cyanophyta	C	2
WWFWS12P004	Unit # 43	8/31/2012	*Homeothrix*	Cyanophyta	O	3
WWFWS12P004	Unit # 43	8/31/2012	*Spirogyra*	Chlorophyta	O	4
WWFWS12P004	Unit # 43	8/31/2012	*Pseudanabaena*	Cyanophyta	O	5
WWFWS12P004	Unit # 43	8/31/2012	*Leptolyngbya*	Cyanophyta	O	6
WWFWS12P004	Unit # 43	8/31/2012	*Heteroleibleinia*	Cyanophyta	O	7
WWFWS12P005	Unit # 118	9/4/2012	Diatoms	Bacillariophyta	F	1
WWFWS12P005	Unit # 118	9/4/2012	*Phormidium*	Cyanophyta	O	2
WWFWS12P005	Unit # 118	9/4/2012	*Homeothrix*	Cyanophyta	O	3
WWFWS12P005	Unit # 118	9/4/2012	*Leptolyngbya*	Cyanophyta	O	4
WWFWS12P005	Unit # 118	9/4/2012	*Komvophoron*	Cyanophyta	R	5
WWFWS12P005	Unit # 118	9/4/2012	*Spirogyra*	Chlorophyta	R	6
WWFWS12P006	Unit # 121	9/4/2012	*Phormidium*	Cyanophyta	C	1
WWFWS12P006	Unit # 121	9/4/2012	Diatoms	Bacillariophyta	C	2
WWFWS12P006	Unit # 121	9/4/2012	*Staurastrum*	Chlorophyta	R	3
WWFWS12P007	Unit # 113	9/4/2012	Diatoms	Bacillariophyta	F	1
WWFWS12P007	Unit # 113	9/4/2012	*Phormidium*	Cyanophyta	O	2
WWFWS12P007	Unit # 113	9/4/2012	*Homeothrix*	Cyanophyta	O	3
WWFWS12P007	Unit # 113	9/4/2012	*Spirogyra*	Chlorophyta	R	4
WWFWS12P007	Unit # 113	9/4/2012	*Audouinella*	Rhodophyta	R	5
WWFWS12P007	Unit # 113	9/4/2012	*Leptolyngbya*	Cyanophyta	O	6
WWFWS12P007	Unit # 113	9/4/2012	*Pseudanabaena*	Cyanophyta	R	7
WWFWS12P007	Unit # 113	9/4/2012	*Oscillatoria*	Cyanophyta	R	8
WWFWS12P008	Unit # 105	9/4/2012	Diatoms	Bacillariophyta	F	1
WWFWS12P008	Unit # 105	9/4/2012	*Phormidium*	Cyanophyta	C	2
WWFWS12P008	Unit # 105	9/4/2012	*Zygnema*	Chlorophyta	R	3

RAI Sample ID	Client ID	Sample Date	Taxon	Division	Relative Abundance	Biovolume Rank
WWFWS12P008	Unit # 105	9/4/2012	*Audouinella*	Rhodophyta	R	4
WWFWS12P008	Unit # 105	9/4/2012	*Homeothrix*	Cyanophyta	O	5
WWFWS12P008	Unit # 105	9/4/2012	*Leptolyngbya*	Cyanophyta	R	6
WWFWS12P008	Unit # 105	9/4/2012	*Pseudanabaena*	Cyanophyta	R	7
WWFWS12P008	Unit # 105	9/4/2012	*Komvophoron*	Cyanophyta	R	8

R = rare = only one cell/fragment in scan; O = occasional = >1 cell/fragment in scan; C = common = 1 to 5 cells per field-of-view, F = frequent = 5 to 25 cells per field-of-view, A = abundant = >25 cells per field-of-view, D = dominant = too numerous to count

Periphyton biomass study: Western Washington Fish and Wildlife Service						Determinations by Rhithron Associates, Inc.		
RAI Sample ID	**Client ID**	**Pre-Ashed Wt. (g)**	**Ashed Wt. (g)**	**AFDM (g)**	**AFDM/v (mass per unit volume) (g/mL)**	**AFDM/a (mass per unit area) (g/cm2)**	**AFDM (mg/m2)**	**AFDM (mg/cm2)**
WWFWS12A001	S.F. Skok ELJ 4	1.4171	1.4113	0.0058	0.0002	0.0004	4.3699	0.0004
WWFWS12A002	Skok ELJ 113	1.4112	1.4061	0.0051	no volume	no area	n.a.	n.a.
WWFWS12A003	Skok ELJ 118	1.4286	1.4219	0.0067	0.0008	0.0018	17.6975	0.0018
WWFWS12A004	Skok ELJ 121	1.4272	1.4212	0.0060	0.0003	0.0006	6.3957	0.0006
WWFWS12A005	Skok ELJ 105	1.4326	1.4271	0.0055	0.0006	0.0005	5.2749	0.0005
WWFWS12A006	Skok ELJ 18	1.4263	1.4211	0.0052	0.0005	0.0010	10.1750	0.0010
WWFWS12A007	S.F. Skok ELJ 26	1.4372	1.4319	0.0053	0.0005	0.0014	13.5649	0.0014
WWFWS12A008	S.F. Skok ELJ 43	1.4181	1.4137	0.0044	0.0004	0.0010	10.0168	0.0010

Chlorophyll-a study: Western Washington Fish and Wildlife Service 2012												Determinations by Rhithron Associates, Inc.		
RAI Sample ID	Client ID	750nm	664nm	665nm	750nm	C_e	DF	Sample Area per filter (cm^2)	cell length (cm)	Volume Extract (mL)	C_E	[Chl-a] mg/cm^2	proportion filtered	[Chl-a] mg/cm^2 (Whole Sample)
WWFWS12C001	S.F. Skok ELJ 4	0.003	0.044	0.031	0.003	0.35	1	4.4242	1	10.00	0.35	0.78	0.01	74.53
WWFWS12C002	Skok ELJ 113	0.002	0.055	0.034	0.002	0.56	1	11.2542	1	10.00	0.56	0.50	0.03	17.99
WWFWS12C003	Skok ELJ 118	0.003	0.078	0.049	0.003	0.77	1	4.7323	1	10.00	0.77	1.64	0.02	106.35
WWFWS12C004	Skok ELJ 121	0.004	0.047	0.032	0.004	0.40	1	4.2642	1	10.00	0.40	0.94	0.01	89.23
WWFWS12C005	Skok ELJ 105	0.002	0.079	0.049	0.002	0.80	1	10.4267	1	10.00	0.80	0.77	0.02	34.57
WWFWS12C006	Skok ELJ 18	0.003	0.079	0.049	0.002	0.77	1	2.5553	1	10.00	0.77	3.03	0.01	515.13
WWFWS12C007	S.F. Skok ELJ 26	0.005	0.063	0.041	0.004	0.56	1	13.6750	1	10.00	0.56	0.41	0.04	9.84
WWFWS12C008	S.F. Skok ELJ 43	0.002	0.045	0.030	0.002	0.40	1	6.5889	1	10.00	0.40	0.61	0.02	38.50

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