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Stream Macroinvertebrate Surveys in the Cle Elum and Bumping River Watersheds

Storage Dam Fish Passage Study
Yakima Project, Washington

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Prepared by:

S. Mark Nelson
Ecological Research and Investigations Group
Technical Service Center
Bureau of Reclamation
Denver Colorado 80225

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Introduction

Anadromous salmonids are being considered for reintroduction above Cle Elum and Bumping reservoirs in the Yakima Basin in Washington State. Fish passage at the dams is proposed to develop self-sustaining populations of anadromous salmonids, and permanent passage features will be designed after interim passage facilities are evaluated. The abundance and types of aquatic macroinvertebrates associated with these watersheds will have some bearing on the capability of anadromous salmonids to develop self-sustaining populations above the dams. Macroinvertebrate data will provide information on habitat qualities and information on the potential for survival and growth of juvenile anadromous salmonids.

Resource availability and basic productivity of rivers and streams have been recognized as major controlling factors in regulating fish populations (McFadden and Cooper, 1962). In large part, food resources for juvenile salmonids in lotic systems consist of benthos and invertebrates in the drift. Drift can be composed of benthic invertebrates that are moving, emerging invertebrates, and terrestrial invertebrates; but is often positively related to the amount of benthos present on the stream bottom (e.g., Perrin and Richardson, 1997; Siler et al., 2001). A variety of invertebrates are important as food items for fishes, and changes in invertebrate communities may result in changes in condition of fish communities (e.g., Ellis and Gowing, 1957; Waters, 1982; Bowlby and Roff, 1986; Wilzbach et al., 1986). Binns and Eiserman (1979) considered benthic macroinvertebrates as a limiting factor for salmonid standing crop in some streams in Wyoming. Juvenile salmon may be sensitive to many of the same parameters that have negative impacts on aquatic invertebrates. Conditions that limit stream invertebrate populations may affect fish populations as well (Cada et al., 1987; Deegan and Peterson, 1992; Plotnikoff and Polayes, 1999; Boss and Richardson, 2002). Growth rates of salmonids are often linked to food availability (Ensign et al., 1990) and increased food may lead to increased growth rates and ultimately higher survival. Juvenile salmon are both gape-limited predators and subject to gape-limited predation, therefore faster growth can improve their ability as predators and decrease their vulnerability to predation (e.g., Sommer et al., 2001). Higher densities of juvenile salmon (i.e., smaller territory size) have been found with increased food abundance (Dill et al., 1981). Differences in the ability of streams to produce salmonids are often related to food availability rather than physical habitat (Bisson and Bilby, 1998). Observational scales are critical in determining characteristics important in salmonid production, and overall maximum production may be related to geology and associated water quality, while other physical factors control fish carrying capacity on a local scale (e.g., Kwak and Waters, 1997).

Information on stream invertebrate characteristics may be critical in supporting salmonid reintroduction into watersheds above Reclamation reservoirs. This paper documents macroinvertebrate assemblages (including functional-feeding groups) and biomass associated with tributaries flowing into Cle Elum and Bumping reservoirs. Environmental parameters that may control macroinvertebrate assemblages were also measured and analyzed as part of this study. Because of the importance of organic matter as a resource (e.g., Vannote et al., 1980) for macroinvertebrate production (Richardson, 1993) and food web support, the amount of organic matter in the system was also quantified.

Methods

Sampling of biological, chemical, and physical parameters

Sampling at 21 sites took place in September of 2003 and 2004 and March/April of 2004. Sampling occurred above the Cle Elum and Bumping reservoirs in the Cle Elum and Bumping watersheds within the Cascades ecoregion (e.g., Cuffney et al., 1997). Sampling focused on riffle/run types of lotic habitat; however, a small number of in-stream pools were also sampled.

A 3-minute kick method with a D-frame net (700-800 µm mesh) was used for sampling benthic invertebrates along a ca. 25-m wadeable portion of the streams. Kick-net sampling is useful when a variety of habitat types are present that preclude sampling with more quantitative gear. Kick-net sampling is a widely used technique in the United States (Carter and Resh, 2001). The net was placed on the stream bottom and upstream substrate disturbed by vigorous kicking. As substrate was disturbed, the operator and net moved upstream for the required time. In a subsample of these sites, benthic samples were also collected with a 560-µm-mesh Surber sampler in order to develop a relationship between kick-net samples and a per unit estimate of biomass. Benthic samples were preserved in 70 percent propanol. In the laboratory, samples were washed in a 600-µm mesh sieve to remove alcohol, macroinvertebrates were then picked from the substrate with the aid of an illuminated 10X magnifier. Kick-net samples were then enumerated and identified to lowest practical taxon under a binocular dissecting scope. Organisms from Surber and kick-net samples were dried at 105˚C for 48 hrs and dry weight determined on an analytical balance.

Drift samples were collected using stationary nets (363 µm mesh) for ca. 30 minutes around dusk. Drift typically increases during the period just after sunset (Brittain and Eikeland, 1988). Samples were collected from riffle/run areas in the Cle Elum River in March and September of 2004. Flow velocities were measured in front of the nets using a digital flowmeter mounted in the mouth of the net, to calculate the volume of water sampled. Samples were preserved in 70 percent propanol. Invertebrates were removed from the samples under 10X magnification, counted and identified to Order, dried (105˚C for 48 hr), and weighed on an analytical balance. Values were converted to number/m^3 of water volume. Drift net organism abundance and biomass were presented as means ± standard error. All biomass data is reported as dry weight.

Coarse-particulate-organic-matter (CPOM) was picked from the kick-net samples during processing for benthic invertebrates. Material was dried (60˚C for 48 hrs) and weighed.

Periphyton samples were collected from rocks or other solid, flat surfaces with a sampling device made from a modified 30-mL syringe with an inside diameter of 2.06 cm (Porter et al., 1993). Samples from three different substrates from the area where invertebrates were to be collected were composited into a single sample. The composite sample was then filtered onto ash-free glass-fiber filters (1-µm pore size). Ash-free-dry-mass was determined using standard methods (Eaton et al., 1995). Filters were dried for 48 hrs at 105^{o}C, dry weight determined on an analytical balance, filters ashed at 500˚C for 1 hr, and the mass of the residue (ash weight) determined. Ash-free-dry-mass (AFDM) (g/m^2) was calculated by subtracting the ash weight from the dry weight of the sample and dividing by the periphyton sample area (9.99 cm^2).

Dissolved oxygen (D.O.), conductivity, pH, and water temperature were measured with a portable meter. Water samples for alkalinity and hardness were analyzed with titration methods (Hach test kit).

Size composition of the substrate was visually estimated at each site in the area where macroinvertebrates were collected. Categories were expressed as percent bedrock, boulders (30-91 cm diameter), cobble (8-30 cm diameter), coarse gravel (2.5-8 cm diameter), fine gravel (0.25-2.5 cm diameter), and sand/fines. Percentage categories were converted to a single substrate index (S.I.) value (e.g., Jowett and Richardson, 1990) using the formula S.I. = 0.08 (percent bedrock) + 0.07 (percent boulder) + 0.06 (percent cobble) +0.05 (percent gravel) + 0.04 (percent fine gravel) + 0.03 (percent sand and fines). Wet width of the stream was measured with a measuring tape or a range finder. Depth was measured with a calibrated rod.

Water velocity at 10 cm above the substrate was measured post-invertebrate sampling at three discrete points in the invertebrate collection area. The average of these three measurements was used in analysis.

Habitat disturbance was estimated with Pfankuch's Index (Pfankuch, 1975). This subjective, composite index involves scoring 15 stream channel variables along the upper bank, lower bank, and stream bottom. High scores represent unstable channels at the reach scale. This index has been found to measure disturbance in streams in other studies (Townsend et al., 1997).

Data analysis

Multivariate analysis (CANOCO 4.0), taxa richness and abundance, and biomass (dry weight) were used to compare macroinvertebrate assemblages. Ordination techniques were used to examine patterns in the macroinvertebrate data and to identify physical and chemical parameters that were most closely associated with invertebrate distributions. Because of seasonal differences in species, only data from September samplings were included in the analysis. Initial analysis of the macroinvertebrate data set used detrended correspondence analysis (DCA), and revealed that the data set had a gradient length > 3, suggesting that a unimodal model [canonical correspondence analysis (CCA)] rather than a linear model was appropriate for analysis of species response along the ordination axis. Infrequent taxa (taxa contributing < 0.05 percent of total number counted) were deleted and faunal data transformed [ln (X+1)] before analysis. Wilk-Shapiro rankit plots were used to test for normality of environmental variables. If needed, variables were transformed with ln (X+1) for numerical data or square-root/Arcsin transformed for percentage data. If environmental variables were strongly positively correlated ($r \geq$

0.60), only a single variable was selected for use in the CCA to avoid problems with multicollinearity. Forward selection of environmental variables and Monte Carlo permutations (1000 permutations) were used to determine whether variables exerted a significant effect ($P < 0.05$) on invertebrate distributions. In the ordination diagram, taxa and sites are represented by points and the environmental variables by arrows. The arrows roughly orient in the direction of maximum variation in value of the given variable. Pearson correlation was used to examine relationships between specific biotic and abiotic characteristics. Simple regression was used to relate macroinvertebrate biomass (standing crop) from quantitative collections (Surber samples) with kick-net invertebrate biomass. Standing crop categories promulgated by Mangum (1989) were used to relate biomass data collected in this study to other stream values. Repeated measures ANOVA was used to test for differences in benthic biomass between collection dates.

Functional feeding groups were assigned to benthos based on the primary feeding mechanism of the group, with categories defined as predators, scrapers, shredders, collector-filterers, and collector-gatherers. Most of this information was derived from Merritt and Cummins (1984).

Results

Difficulties in site access in March/April 2004 precluded sample collection from the Bumping drainage, therefore, in most cases only September collections were used for comparisons between watersheds and habitats.

Environmental parameters

Values for environmental variables collected during the study are presented in Table 1. Conductivity was highly correlated with alkalinity and hardness, while S.I. was correlated with percent sand. Therefore, only a single variable from these correlated pairs were used in CCA. Initial environmental variables used in the CCA model included conductivity, D.O., water temperature, stream width, pH, Pfankuch index, S.I., velocity, periphyton biomass, CPOM biomass, and depth. Water quality parameters such as pH, alkalinity, and hardness were grossly similar among sites.

It appeared that there were some distinct differences in variables among groups of sites found in Bumping and Cle Elum drainages and pools. Pool sites were only sampled in the Cle Elum drainage. Macroinvertebrate food resources differed among the groups of sites. Sites above the dam in the Bumping drainage had the greatest amounts of CPOM (dry weight in g/kick-net) (Figure 1a). Conversely, periphyton biomass (ash-free-dry weight in g/m^2) was lowest in the Bumping drainage (Figure 1b). Substrate also varied among groups with the percent of substrate containing boulders much higher at Cle Elum sites, while the percent of substrate that was sand was higher in pool sites (Figure 2a and b). Velocity was similar at lotic sites, and was much lower in pools (Figure 3a). Stream width was smallest at sites above the Bumping reservoir (Figure 3b). Bumping drainage sites were relatively shallow and deepest sites were those associated with pool habitat in the Cle Elum (Figure 4a). Average water temperatures were lowest at sites sampled in the Bumping drainage (Figure 4b).

Benthic invertebrate distributions and relationship with environmental parameters

Aquatic macroinvertebrates found at all sampling locations are listed in Appendix A. A total of 126 taxa were found in the study area.

CCA with all September samples (Figures 5 and 6) suggested differences among aquatic invertebrate communities. Divisions along Axis I separated the Cle Elum and Bumping sites. Width and water temperature were significant variables along Axis I. Many of the invertebrates (*Drunella coloradensis*, *Doroneuria*, *Yoraperla*, and *Zapada*) associated with the negative portion of Axis I (Bumping drainage) (Figure 6) are considered sensitive, coldwater obligates by Cole et al. (2003). The caddisfly, *Glossosoma*, which was associated with these sites, is sometimes indicative of hyporheic exchange (Pepin and Hauer, 2002). Some rare taxa that were present at Bumping drainage sites such as *Paraperla* and *Kathroperla* have hyporheic affinities (Pepin and Hauer, 2002) suggesting that cold groundwater is upwelling at these sites. Deep Creek was deeply incised at the upstream station and this may allow for intersection of groundwater. Axis II appeared to be influenced by substrate, with coarser substrate sites associated with the negative portion of Axis II (Figure 5) which corresponded mostly with lotic Cle Elum sites. It appeared that higher dissolved oxygen also occurred at these sites. Invertebrates along the positive portion of Axis II and towards the positive portion of Axis I were associated with finer sediments, increased depth, and higher Pfankuch (disturbance) values. Invertebrates associated with pools (Figure 6) were those such as *Paraleptophlebia* and *Ephemerella* that are tolerant of fine sediment (Relyea et al., 2000) and associated with increased water depths (Reece and Richardson, 2000), along with more lentic taxa such as *Hyalella*. The wider river sites associated with the Cle Elum were numerically dominated by collector-filterer functional feeding groups (Figure 6) and included organisms such as *Hydropsyche*. Collector-filterers are animals with anatomical structures (setae or fans) or secretions that sieve particulate matter from suspension. Bumping River sites contained more shredders (organisms that process large pieces of decomposing plant tissue) and scrapers (adapted to remove periphyton from substrates) (Figure 6) than did the lotic Cle Elum sites. Collector-gatherers (animals that feed primarily on deposited fine particulate organic matter) were also common at Bumping River sites. Differences in functional-feeding group abundance were obvious between watersheds and habitats (Figures 7 and 8) and Wallace and Webster (1996) have found that these differences are often associated with hydraulic conditions. An abundance of collector-filterers (Cle Elum lotic sites) suggests high-flow, low-retention habitats, while an abundance of collector-gatherers and shredders often dominate low-flow, high-retention areas (Bumping lotic sites) (e.g., Wallace and Webster, 1996). The high abundance of shredders associated with pool habitat was the result of a large number of *Hyalella* present at Cle Elum R+7. This is an anomalous site that consists of a long stretch of marsh-like, slow-velocity habitat.

Standing crop/ drift biomass

Surber samples (0.09 m^2) were used to relate kick-net dry weight biomass to g/m^2 using the regression equation:

grams of invertebrates/m^2 = 0.0569 + 1.3551 X grams of invertebrates/kick-net ($R^2 = 0.8433$, $P = 0.0005$, $n = 9$). Table 2 presents kick-net biomass and the corresponding dry weight standing crop derived from the regression equation. The majority of these sites would be described by Mangum's criteria for standing crop (Mangum, 1989) as poor. Several sites in the Bumping drainage, however, would be placed in the fair category, at least on single occasions. Kick-net invertebrate biomass at lotic sites upstream from the reservoirs appeared to be positively correlated with CPOM and negatively correlated with boulders (Figure 9a and b). Mean kick-net biomass at sites in the Bumping drainage was higher than that found at pool sites or lotic Cle Elum sites (Figure 10). Invertebrate biomass varied seasonally. A repeated measures ANOVA with 10 in-common sites for the three collection periods indicated that mean invertebrate biomass differed ($p = 0.0014$), with March/April collections statistically different (Tukey's test) and greater than September collections (which were not statistically different). Mean dry weight values in March/April were 0.1858 ± 0.0398 g/kick-net, while in September 2003 values were 0.0990 ± 0.0367 g/kick-net and in September 2004 values were 0.0518 ± 0.0133 g/kick-net.

Particular invertebrates such as midges (Diptera) and baetid mayflies (Ephemeroptera), perhaps because of their strong presence in the drift, may be especially important in the diet of juvenile salmonids (Rondorf et al., 1990; Bilby and Bisson, 1992; Sommer et al., 2001). Abundance of these invertebrates in the benthos varied with types of locations, with mean values highest (although not significantly so) in the Bumping drainage (Figure 11a and b).

Drift net sampling ($n = 5$) in the Cle Elum at sites Cle Elum R+2, Cle Elum R+3, and Cle Elum R+5 indicated that organisms in the drift were low during sampling in March and September 2004. Values were 0.2836 ± 0.1644 individual organisms/m^3 and 0.0000698 ± 0.0000426 g/m^3 (dry weight). Diptera (33.8 percent) and Ephemeroptera (26.5 percent) made up most of the drift organisms, with the rest made up of Plecoptera (19.1 percent), Coleoptera (16.2 percent), and Trichoptera (4.4 percent).

Organic matter

CPOM biomass (dry weight) was highest at sites in the Bumping drainage (Figure 1a). Lotic sites had low amounts of periphyton biomass (AFDM) (Figure 1b) relative to pools. CPOM biomass was significantly correlated with important biological parameters such as macroinvertebrate biomass ($r = 0.4406$, $p = 0.0072$) and baetid abundance ($r = 0.3780$, $p = 0.0230$). Periphyton biomass (ash-free-dry-mass) was negatively correlated with scraper abundance ($r = -0.3366$, $p = 0.0447$).

Discussion

Benthos distribution

Benthic macroinvertebrates in this study showed some of the same patterns associated with the River Continuum Concept (RCC) as described by Vannote et al. (1980), where a gradient of physical variables exists from upstream (smaller headwater streams) to downstream (larger rivers) and results in a continuum of biotic changes. In the present analysis, pools were not considered part of this gradient and contained invertebrates that were tolerant of depth, low velocity, and fine sediment. The broad constraints of the RCC suggest that heterotrophy in the lower order streams is replaced by autotrophy downstream, and processing of CPOM by upstream shredders results in fine particles that are then used by collector-filterers downstream. This pattern was found at sites associated with the Bumping and Cle Elum drainages and is typical of the northwest (Reece and Richardson, 2000). Although some of these observations may be associated with the RCC, it is possible that unique characteristics such as substrate size are also responsible for a portion of the watershed differences. The larger substrate size found at Cle Elum sites likely explains the lower amounts of CPOM, shredder abundance, and invertebrate biomass. The abundance of collector-filterers and the limited numbers of shredders and collector-gatherers in the Cle Elum also suggests that the Cle Elum does not retain substantial amounts of CPOM (Wallace and Webster, 1996).

The presence of specific hyporheic taxa at some of the Bumping sites suggests the presence of groundwater close to the surface. Some salmonids may selectively use such areas as spawning habitat (Baxter and Hauer, 2000).

Organic matter

Often there is a link between the amount of organic matter and productivity of a stream’s food-web. According to Bisson and Bilby (1998), food availability is often overlooked by fishery managers as a factor affecting the production of fishes. Litter exclusion has resulted in some of the lowest secondary production estimates reported for stream ecosystems (Johnson et al., 2003). Invertebrate biomass was positively correlated with CPOM in the present study. The decreased CPOM in the upper Cle Elum drainage may be related to the larger substrate size found there. Larrañaga et al. (2003) found that cobble-size material retained more CPOM than boulder-size material. Other factors that decrease CPOM standing crop (e.g., Brookshire and Dwire, 2003) include hydrology, riparian characteristics, stream size and depth (Webster et al., 1994), and past history of timber harvest (Webster et al., 1994). The importance of CPOM in stream ecology is demonstrated by studies that have attempted to enhance stream retention of detrital material (Laitung et al., 2002).

Absent from both of these above reservoir drainages at this time are salmon carcasses. These could be very important in enhancing the food web (e.g., Bisson and Bilby, 1998). Wipfli et al. (1998) found that biofilm and macroinvertebrate abundance increased in natural streams where salmon carcasses were introduced, suggesting an increase in stream productivity. The transfer of ocean nutrients to fresh waters via spawning salmon is considered an important ecosystem subsidy and is mostly uni-directional, although smolts do return a portion of the nutrients to the ocean (Moore and Schindler, 2004). Long-term paleolimnological records have also demonstrated a freshwater nutrient feedback loop where salmon carcasses "nourish" the next generation through nutrient releases which promote primary and secondary production (Gregory-Eaves et al., 2003), and even contribute nutrients to terrestrial habitats (Bilby et al., 2003). Carcass retention is critical to production increases, and a lack of response in primary production in a study by Ambrose et al. (2004) may have been from high flows removing carcasses from the system. Cederholm et al. (1989) suggests that the capacity for streams and rivers to retain carcasses is dependent upon high channel complexity and the presence of in-stream log jams.

Seasonally, resources may vary, with autochthonous sources more important to secondary production in the spring and summer, while allochthonous sources may be critical in the fall and winter (Bisson and Bilby, 1998). Production increases from salmon carcasses may be limited to periods around the time of salmon runs and have little impact at other times of the year (Lessard et al., 2003). Even temporary increased growth rates (e.g., Bilby et al., 1996) associated with spawning salmon, however, may have positive effects for salmonids because larger sizes are associated with increased juvenile salmon survival (Sommer et al., 2000).

Linkages with fish

In addition to food availability, salmonid productivity is also likely controlled by geology and resultant water quality characteristics, such as alkalinity, which are considered general indices of fertility (Kwak and Waters, 1997). Softwater streams such as those in the Bumping and Cle Elum drainages where alkalinity is less than 50 mg/L often have relatively low fish productivity (e.g., Kwak and Waters, 1997). In geographic areas with relatively uniform water quality, other proximate physical factors account for variation in fish production (Kwak and Waters, 1997). In these cases, macroinvertebrate production, which is linked to other physical characteristics, may control fish production within the larger framework of water quality. Richardson (1993) suggests that productivity of salmonids is controlled by lower trophic level production, resulting in "bottom-up" regulation of salmonid production. Mangum (1989) suggests that invertebrate biomass levels below 0.5 g/m^2 (dry weight) result in poor fisheries. Weng et al. (2001) found that juvenile salmonids experienced higher growth rates when streams were enriched to the point where benthic invertebrate dry weight biomass was in the range of 0.6 to 0.8 g/m^2. This is similar to Hetrick et al. (1998) who found that salmon streams contained 0.5 to 1.0 g/m^2 of invertebrate biomass. Sites that had the highest biomass in the present study were mostly found in the Bumping River drainage and on occasion had biomass that Mangum (1989) would describe as fair for fish production. CPOM likely contributes to a large portion of invertebrate biomass and CPOM was responsible for 59-100 percent of the energy provided to growth of juvenile salmon in tributaries to the Yukon River (Perry et al., 2003). Autochthonous sources may also be significant, and Bilby and Bisson (1992) found autotrophically based food to be very important to salmonid populations during the summer.

Low abundance and dry weight biomass in drift net samples from this study support the results of low invertebrate biomass in benthic samples from the Cle Elum River. The mean drift value of 0.28 individuals/m^3 is on the low end of the scale of 0.5 to 5.0 individuals/m^3 from summaries in Armitage, 1977; O'Hop and Wallace, 1983; and Cellot, 1989. Other studies have found higher numbers of drift, with Esteban and Marchetti (2004) reporting 1.4 to 11.2 individuals/m^3 (from Table 5) in a salmon river in California and Hieber et al. (2003) reporting values near 100 individuals/m^3 in high altitude streams in Switzerland.

It should be noted that hyporheic invertebrates (not specifically sampled in this study) from deep within the substrate may make up a large portion of stream productivity (Waters, 1988) that is available to fish predation (such as during emergence). Also, while standing crop is often related to production (Benke, 1993), short-lived species can have low standing crop but high turnover and yearly production (Waters, 1988) that could provide for increased fish food. These issues could modify conclusions drawn from a simple analysis of standing crop.

Conclusions

Macroinvertebrate standing crops in the Bumping and Cle Elum watersheds above the reservoirs were low and likely related to regional geology and water quality (e.g., low alkalinity). Macroinvertebrate standing crop was highest in the Bumping watershed with functional-feeding groups and physical attributes indicating high CPOM retention. Data suggested low retention of CPOM in the Cle Elum. Literature suggests that organic matter, such as CPOM, and the resulting invertebrate standing crop, may be very important to salmonid production. To take full advantage of fish passage in the Cle Elum above the reservoir, it may be necessary to increase retentiveness of organic matter in this watershed. Increased retentiveness would also allow for full utilization of salmon carcasses in the system. Goals for the Cle Elum system of increased CPOM and macroinvertebrate standing crop of ≥ 0.6 g/m^2 are achievable (see example of Laitung et al., 2002) and would likely play a large role in the success of an anadromous fish passage program.

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Table 1. Environmental variables associated with sites in the Cle Elum (CE) and Bumping River (B) drainages from September 2003/2004 and March/April 2004. Numbers represent increasing distances above the reservoirs. W corresponds with the Waptus River, C with the Cooper River, and D with Deep Creek. Riffles/runs are designated with the letter R and pools are designated with the letter P.

Variables	CER+1 (n=3)	CER+2 (n=3)	CER+3 (n=3)	CER+3.5 (n=1)	CER+4 (n=3)	CER+5 (n=3)	CEP+5 (n=3)	CER+6 (n=3)	CEP+6 (n=3)	CER+7 (n=2)	CER+8 (n=8)
pH	7.79 (0.12)	7.73 (0.11)	7.81 (0.12)	7.75	8.03 (0.16)	8.04 (0.15)	8.01 (0.08)	7.65 (0.22)	7.42 (0.14)	7.56 (0.39)	7.24 (0.16)
D.O. (mg/L)	10.16 (0.23)	11.04 (0.71)	11.04 (0.74)	10.73	12.31 (2.69)	10.98 (1.53)	12.41 (1.96)	8.93 (0.33)	8.83 (0.56)	6.99 (0.68)	7.59 (0.8)
Conductivity (µS/cm)	45 (5)	50 (5)	51 (5)	65	72 (6)	81 (8)	72 (6)	59 (13)	48 (10)	31 (1)	20 (1)
Temp (celsius)	9.3 (2.8)	8.8 (2.7)	8.9 (2.7)	9.4	7.7 (2.6)	8.0 (2.0)	7.8 (2.4)	8.3 (2.9)	8.9 (2.9)	12.5 (0.3)	12.8 (1.3)
Alkalinity (mg/L)	22 (3)	30 (5)	21 (0.0)	32	36 (4)	40 (4)	37 (5)	23 (5)	22 (6)	16 (2)	11 (1)
Hardness(mg/L)	22 (4)	22 (4)	25 (7)	27	36 (4)	39 (5)	38 (5)	21 (7)	23 (7)	13 (2)	7 (2)
Velocity (m/S)	0.79 (0.05)	0.52 (0.08)	0.82 (0.09)	.62	0.76 (0.21)	0.60 (0.04)	0.32 (0.05)	0.84 (0.04)	0.34 (0.10)	0 (0)	0.62 (0.09)
Pfankuch index	64 (5)	49 (4)	64 (8)	56	45 (1)	39 (4)	51 (5)	70 (12)	80 (6)	66 (11)	41 (4)
Width (m)	25 (5)	41 (3)	32 (6)	14	17 (2)	22 (2)	8 (0)	8 (2)	10 (2)	29 (1)	9 (2)
Substrate index	6.3 (0.2)	5.6 (0.2)	6.6 (0.2)	6.3	6.1 (0.3)	6.5 (0.1)	5.3 (0.4)	5.1 (0.1)	4.9 (0.4)	3.0 (0.0)	4.7 (0.0)
Percent sand	2 (2)	3 (3)	0 (0)	0	2 (2)	2 (2)	27 (16)	8 (4)	15 (8)	100 (0)	22 (2)
Periphyton biomass(g/m^2)	5.9 (0.7)	3.8 (1.8)	4.0 (1.1)	2.7	3.5 (0.6)	8.8 (3.7)	23.6 (7.7)	6.7 (4.5)	1.9 (0.2)	14.9 (1.8)	9.3 (1.6)
CPOM (g)	3.49 (0.62)	10.70 (2.86)	4.00 (1.11)	0.89	16.59 (7.11)	9.06 (8.01)	7.54 (5.75)	25.50 (10.68)	9.25 (4.16)	6.41 (3.63)	2.80 (1.12)
Depth (m)	0.5 (0.0)	0.3 (0.1)	0.6 (0.1)	0.4	0.4 (0.0)	0.4 (0.0)	0.7 (0.0)	0.4 (0.1)	0.9 (0.0)	0.6 (0.1)	0.5 (0.2)
GPS-west	642682	643677	643524	644265	645837	646316	646313	645920	645956	644703	642329
GPS-north	5247554	5251336	5251759	5253565	5254967	5255688	5255686	5263387	5263373	5265302	5268181

Table 1. Continued.

Variables	WR+1 (n=3)	WP+1 (n=3)	WR+2 (n=1)	CR+0.5 (n=1)	CR+1 (n=1)	CR+2 (n=2)	BR+1 (n=1)	BR+2 (n=1)	DR+1 (n=2)	DR+2 (n=2)
pH	7.48 (0.07)	7.43 (0.14)	7.45	7.22	7.51	7.59 (0.18)	7.20	7.52	7.11 (0.06)	7.36 (0.04)
D.O. (mg/L)	10.75 (0.42)	10.04 (0.48)	8.10	5.79	7.71	6.82 (1.66)	7.78	6.58	9.14 (2.19)	9.48 (2.47)
Conductivity (µS/cm)	28 (1)	28 (2)	29	20	26	53 (33)	47	30	56 (1)	54 (0.0)
Temp (celsius)	8.9 (2.6)	8.7 (2.8)	12.5	11.5	15.7	11.7 (0.6)	10.0	7.5	7.0 (0.5)	6.9 (0.7)
Alkalinity (mg/L)	10 (1)	13 (3)	24	10	18	22 (13)	23	14	18 (1)	17 (0)
Hardness(mg/L)	10 (0)	11 (2)	7	4	21	18 (11)	19	10	19 (1)	15 (1)
Velocity (m/S)	1.10 (0.29)	0.19 (0.05)	0.71	0.65	0.49	0.56 (0.06)	0.62	0.98	0.82 (0.12)	0.77 (0.19)
Pfankuch index	58 (8)	79 (12)	39	37	45	37 (0)	55	44	56 (17)	70 (13)
Width (m)	12 (2)	12 (2)	17	40	13	23 (0)	8	25	5 (1)	6 (0)
Substrate index	6.6 (0.1)	4.4 (0.2)	6.6	5.6	6.4	5.2 (0.2)	5.6	8.0	4.9 (0.4)	4.8 (0.0)
Percent sand	0 (0)	40 (15)	0	10	0	10 (0)	10	0	10 (5)	17 (2)
Periphyton biomass(g/m^2)	2.5 (0.2)	6.4 (1.6)	2.7	21.0	3.2	21.6 (9.2)	8.7	3.0	2.0 (0.2)	2.0 (0.2)
CPOM (g)	1.19 (0.50)	1.87 (0.73)	2.16	2.85	33.53	4.08 (2.83)	33.61	4.67	10.64 (2.51)	7.13 (1.52)
Depth (m)	0.6 (0.0)	1.0 (0.1)	0.4	0.6	0.3	0.4 (0.1)	0.2	0.2	0.4 (0.0)	0.3 (0.1)
GPS-west	644174	644205	642220	642886	642564	638668	624627	623767	628806	629063
GPS-north	5253673	5253669	5255430	5252332	5252438	5253582	5188640	5187633	5187992	5185842

Table 2. Dry weight biomass (standing crop) of macroinvertebrates associated with Cle Elum and Bumping River drainages. Potential for supporting fishery is based on the estimated value. Standard errors of predicted values are in parentheses.

Site	Biomass (g/m^2)[a]			Potential for supporting fishery[b]
	September-2003	March/April-2004	September-2004	
Cle Elum R+1	0.1162 (0.2015)	0.2574 (0.1975)	0.1241 (0.2012)	Poor
Cle Elum R+2	0.5161 (0.1972)	0.4299 (0.1963)	0.1373 (0.2007)	Poor
Cle Elum R+3	0.2036 (0.1987)	0.1178 (0.2014)	0.0834 (0.2028)	Poor
Cle Elum R+3.5	--	--	0.1028 (0.2020)	Poor
Cle Elum R+4	0.4149 (0.1962)	0.5417 (0.1976)	0.1951 (0.1989)	Poor
Cle Elum R+5	0.1070 (0.2018)	0.3253 (0.1966)	0.1569 (0.2001)	Poor
Cle Elum P+5	0.0800 (0.2029)	0.1712 (0.1996)	0.0704 (0.2033)	Poor
Cle Elum R+6	0.1356 (0.1979)	0.5882 (0.1987)	0.2218 (0.1983)	Poor
Cle Elum P+6	0.0937 (0.2023)	0.3551 (0.1963)	0.1577 (0.2000)	Poor
Cle Elum R+7	0.4271 (0.1963)	--	0.3040 (0.1968)	Poor
Cle Elum R+8	0.4330 (0.1963)	--	0.1642 (0.1998)	Poor
Waptus R+1	0.0648 (0.2035)	0.1037 (0.2019)	0.0590 (0.2038)	Poor
Waptus P+1	0.0735 (0.2032)	0.1963 (0.1989)	0.0654 (0.2035)	Poor
Waptus R+2	0.0883 (0.2026)	--	--	Poor
Cooper R+0.5	--	--	0.0826 (0.2028)	Poor
Cooper R+1	0.1714 (0.1996)	--	--	Poor
Cooper R+2	0.3448 (0.1964)	--	0.0873 (0.2026)	Poor
Bumping R+1	0.6431 (0.2003)	--	--	Fair
Bumping R+2	--	--	0.1623 (0.1999)	Poor
Deep R+1	0.7495 (0.2045)	--	0.4473 (0.1964)	Poor-Fair
Deep R+2	0.6646 (0.2010)	--	0.4414 (0.1964)	Poor-Fair

[a] Predicted values from regression equation, grams of invertebrates/m^2 = 0.0569 + 1.3551 x grams of invertebrates/kick-net.

[b] Mangum, F.A. 1989. Aquatic Ecosystem Inventory, Macroinvertebrate Analysis. In: Fisheries Habitat Surveys Handbook (R-4 FSH 2609.23) Chpt. 5. [Standing crop (g/m^2) categories are: Poor-0.0-0.5, Fair-0.6-1.5, Good-1.6-4.0, Excellent-4.1-12.0]

Figure 1. Macroinvertebrate food resources [(a) CPOM (dry weight in g/kick-net) and (b) periphyton (ash-free-dry-mass)] associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004.

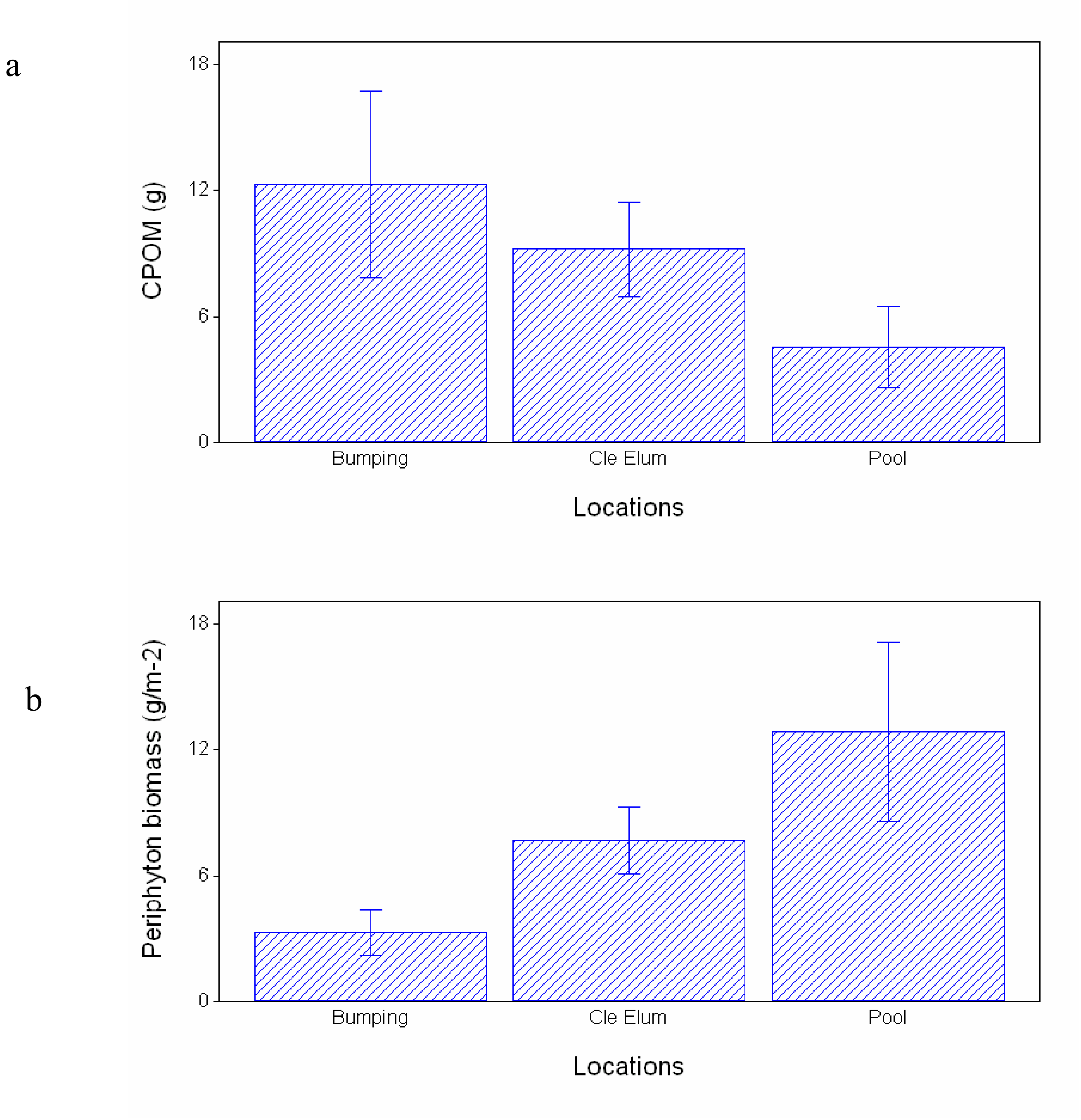


Figure 2. Substrate features [(a) boulders, (b) sand] associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004.

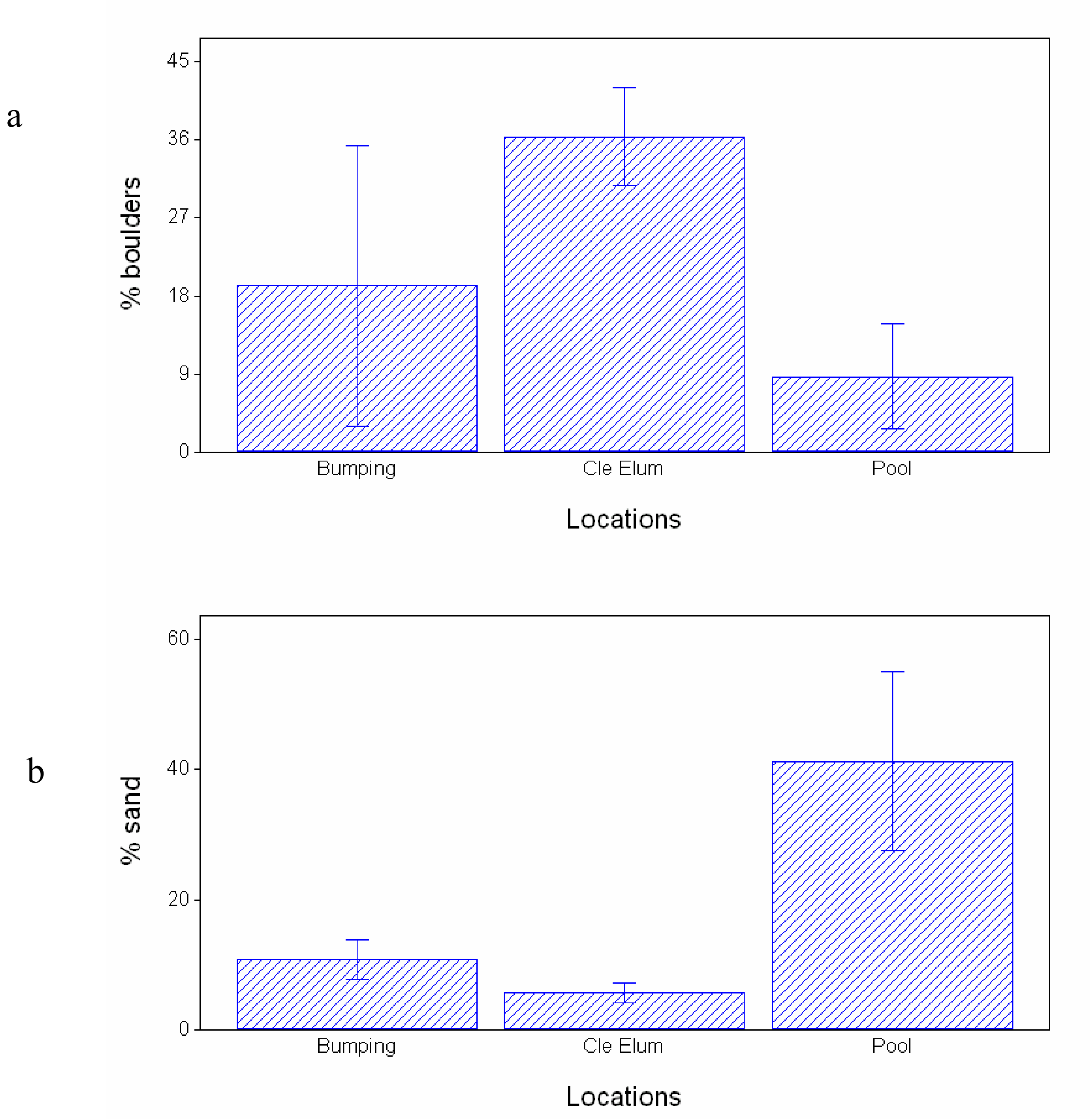


Figure 3. Velocity (a) and width (b) associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004.

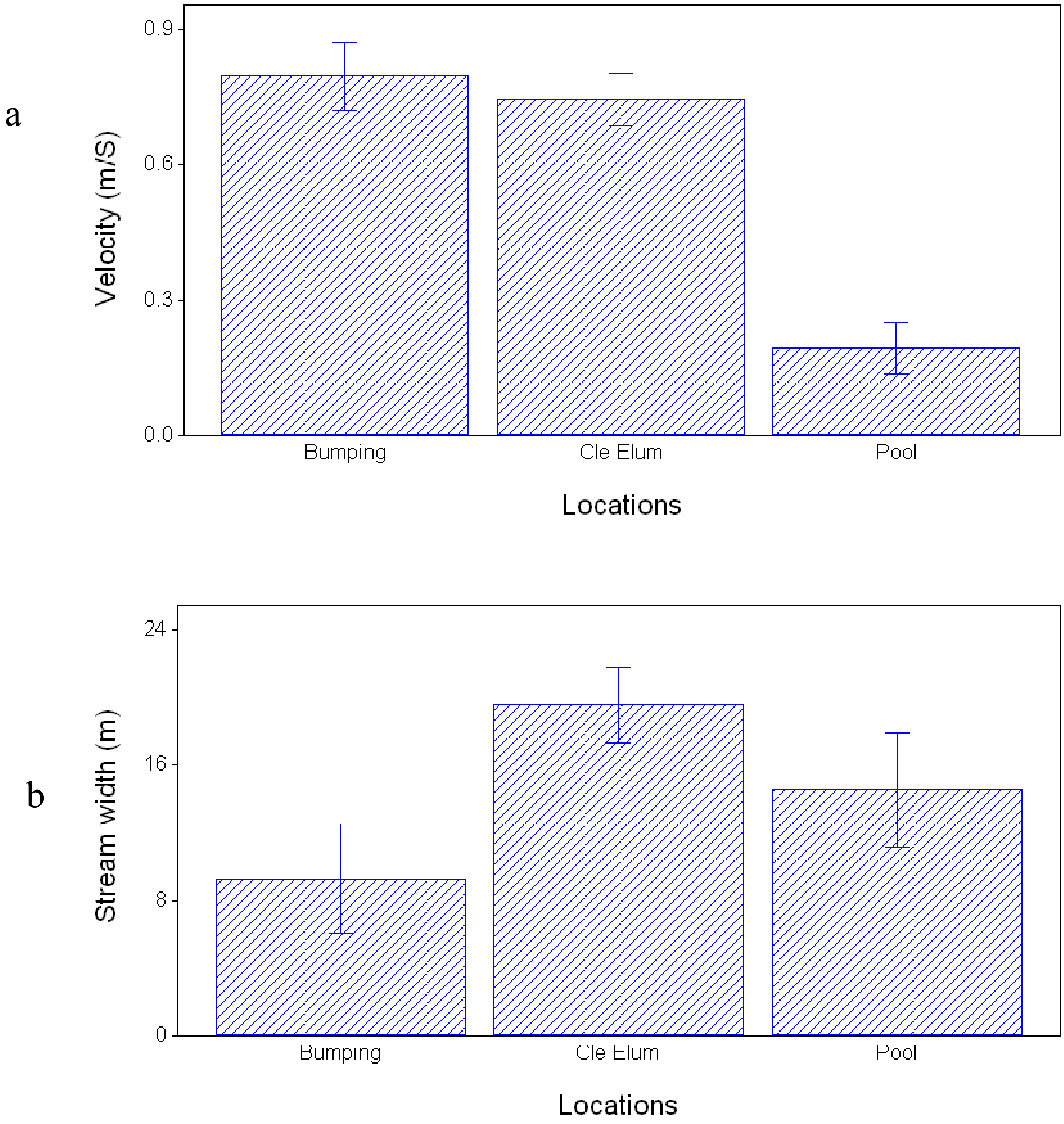


Figure 4. Depth (a) and temperature (b) associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004.

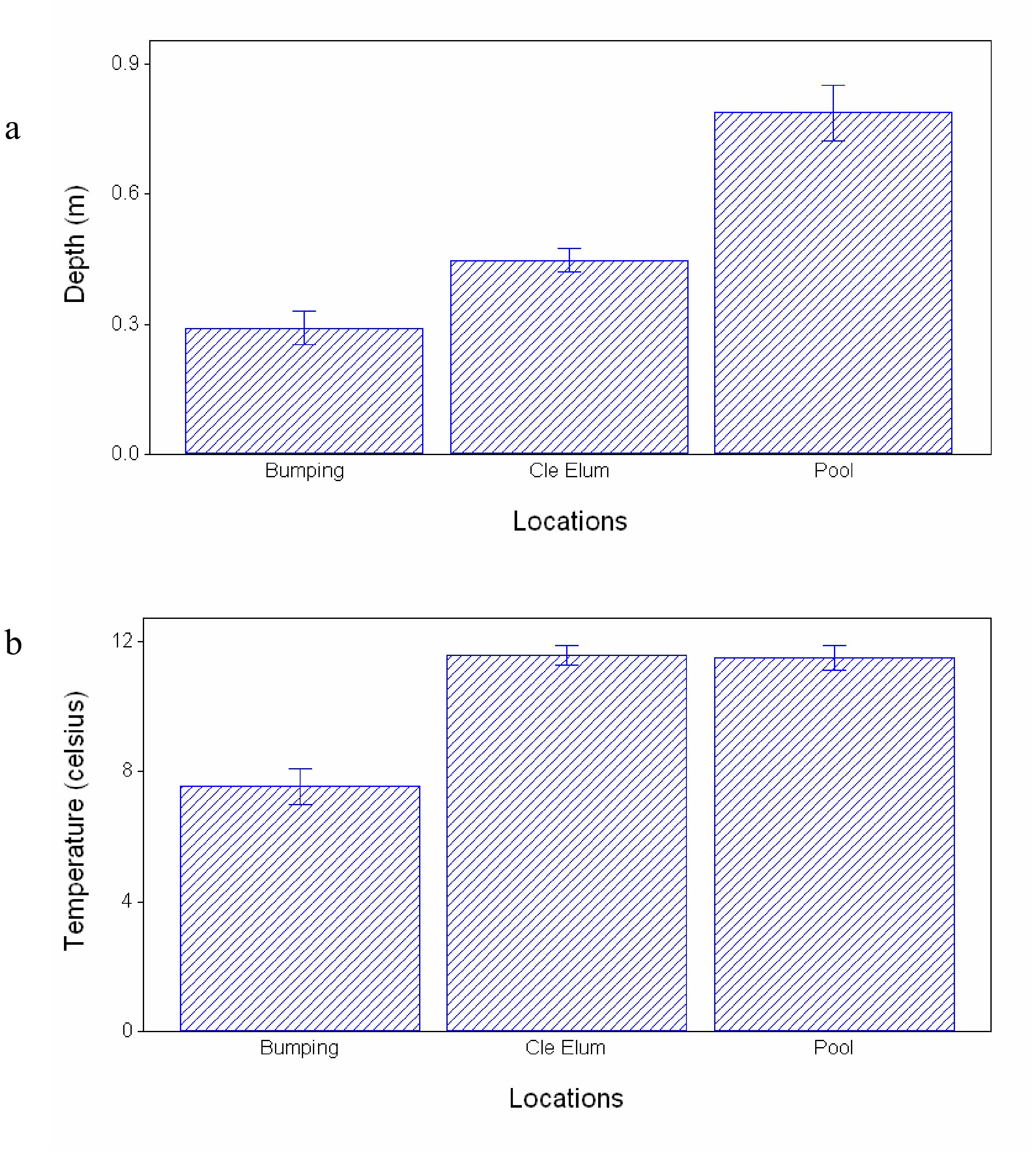


Figure 5. Biplot based on CCA of benthic macroinvertebrate data with respect to significant (P<0.05) environmental variables. Cle Elum sites are represented by open circles, pools by filled triangles, and Bumping River sites by filled circles. Open squares are associated with a slow-moving, marsh-like portion of Cle Elum that has pool-like attributes. The arrows roughly orient in the direction of maximum variation in value, with values increasing in the direction of the arrow.

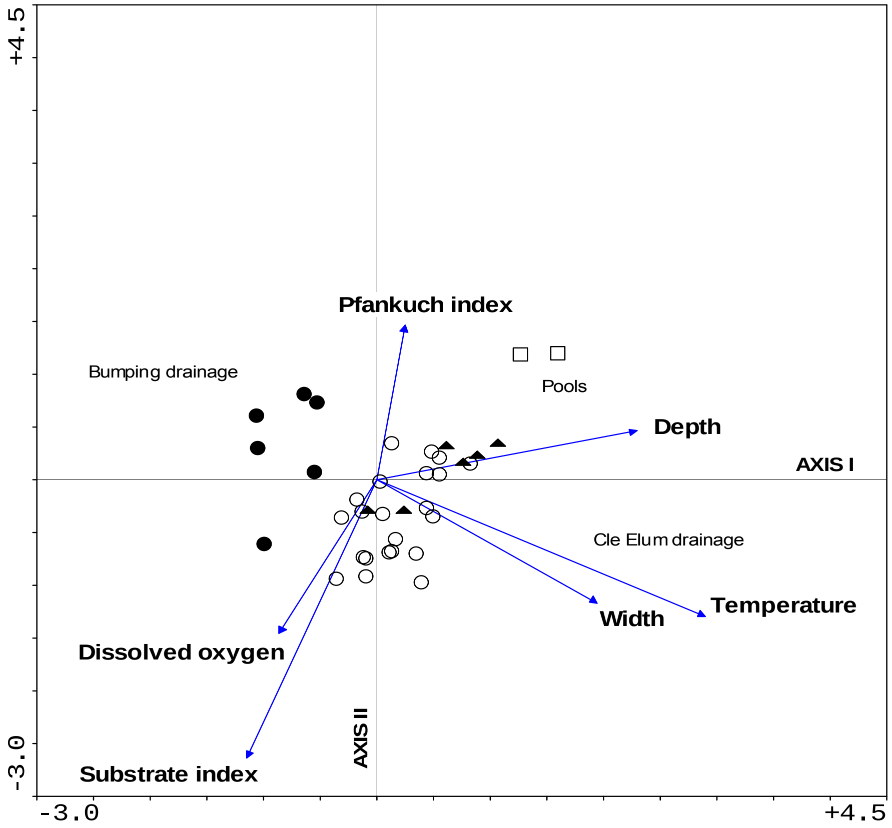


Figure 6. Biplot based on CCA of benthic macroinvertebrate data with respect to significant (P<0.05) environmental variables. Shown are taxa associated with sites and variables. The arrows roughly orient in the direction of maximum variation in value, with values increasing in the direction of the arrow. Taxa in the upper left quadrate were associated with the Bumping River and contained shredders such as *Doddsia occidentalis*, *Yoraperla*, and *Zapada* along with the scrapers *Cinygmula*, *Drunella* spp., and *Rhithrogena*. The upper right quadrate tended towards pool habitat and contained other shredders including *Hyalella*, *Limnephilus*, and *Paraleptophlebia*. Collector-filterers such as *Arctopsyche*, *Hydropsyche*, *Simulium*, and Tanytarsini were most common towards the bottom of the diagram which contained Cle Elum lotic sites.

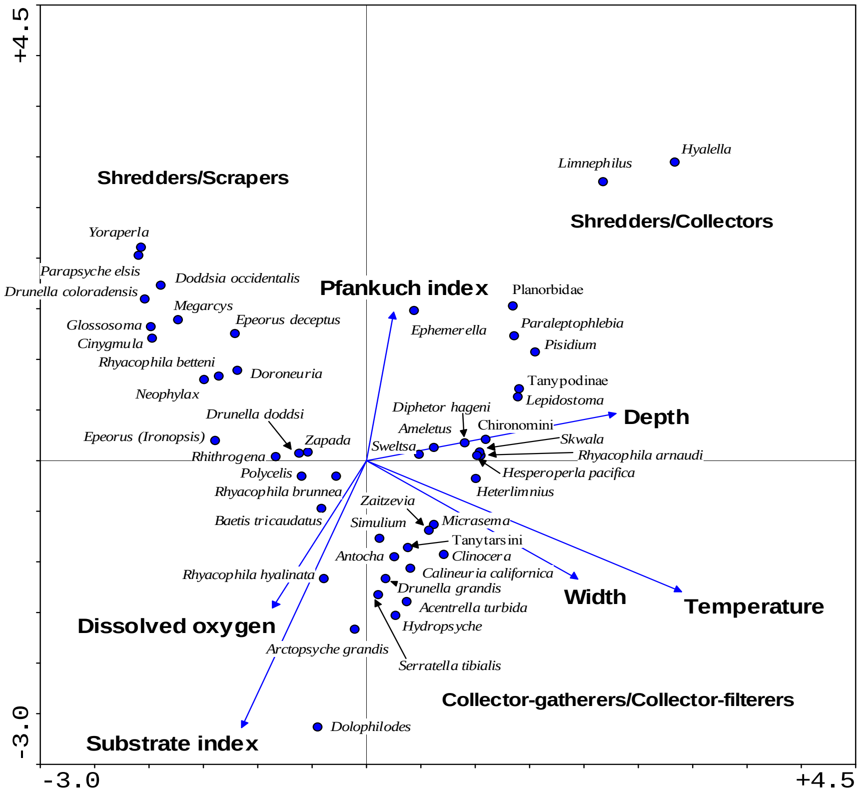


Figure 7. Functional feeding groups associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004. Shredders are shown in (a), while scrapers are presented in (b).

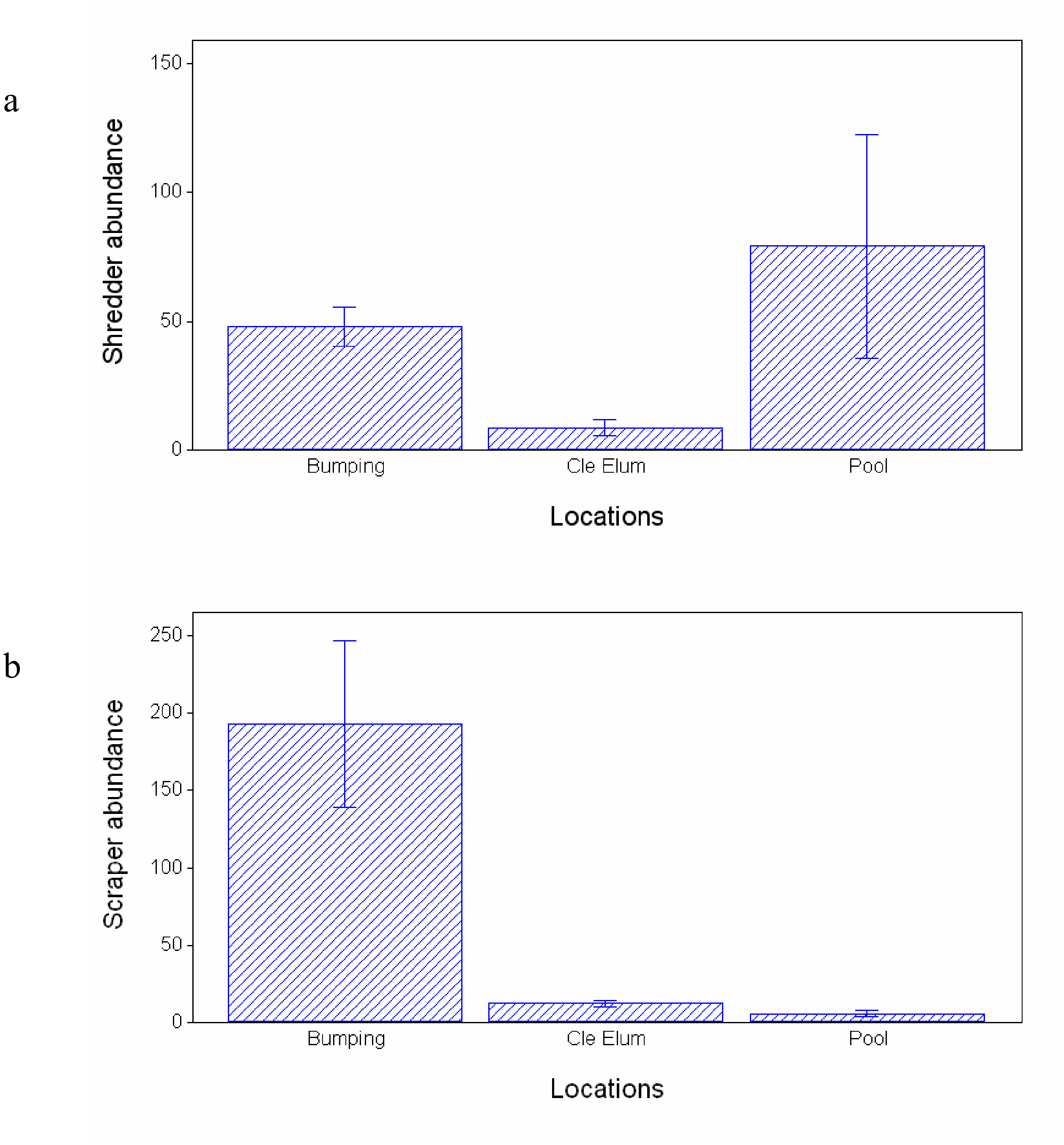


Figure 8. Functional feeding groups associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004. Collector-gatherers are shown in (a), while collector-filterers are presented in (b).

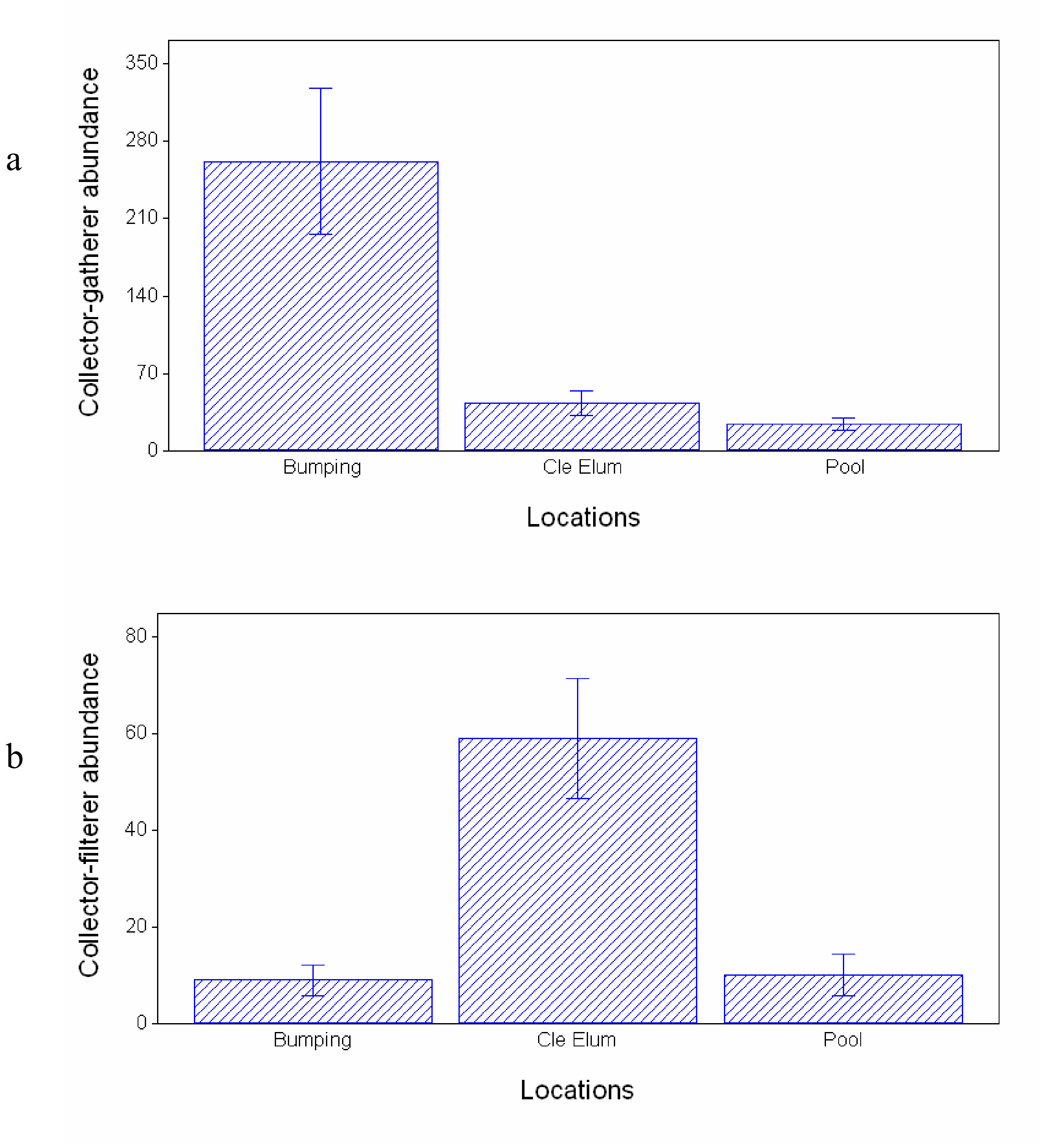


Figure 9. Association of kick-net biomass with CPOM (a) (*r* = 0.4406, p = 0.0072) and boulders (b) (*r* = -0.4130, p = 0.0123) .

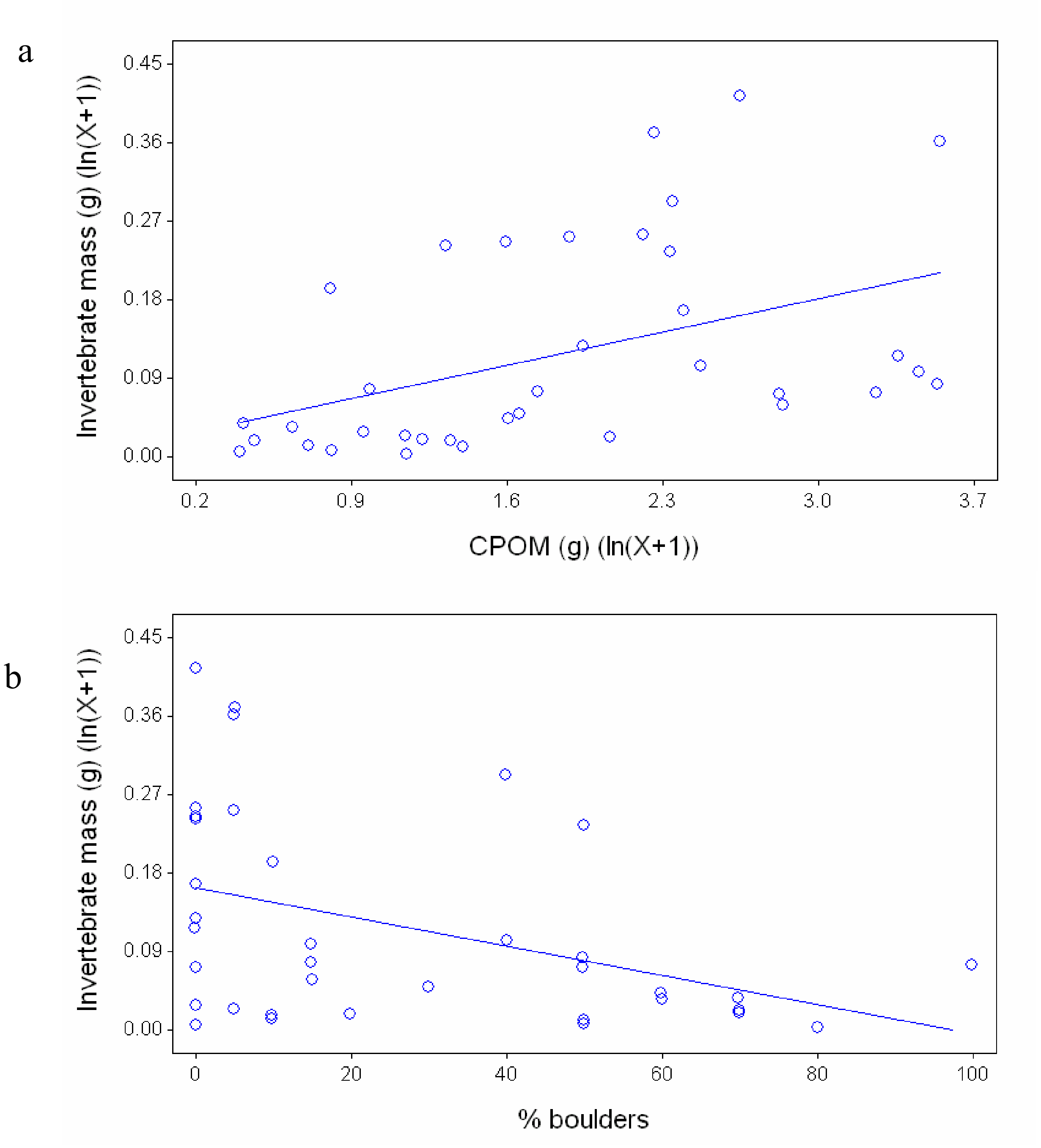


Figure 10. Comparison of macroinvertebrate biomass (dry weight) associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004.

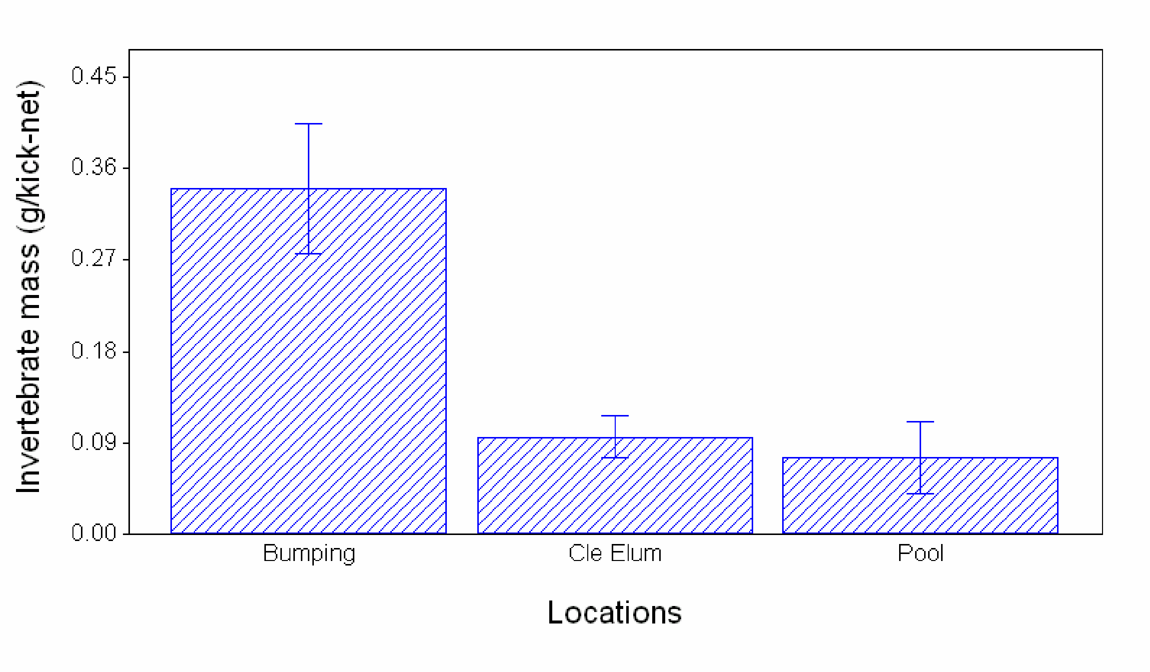
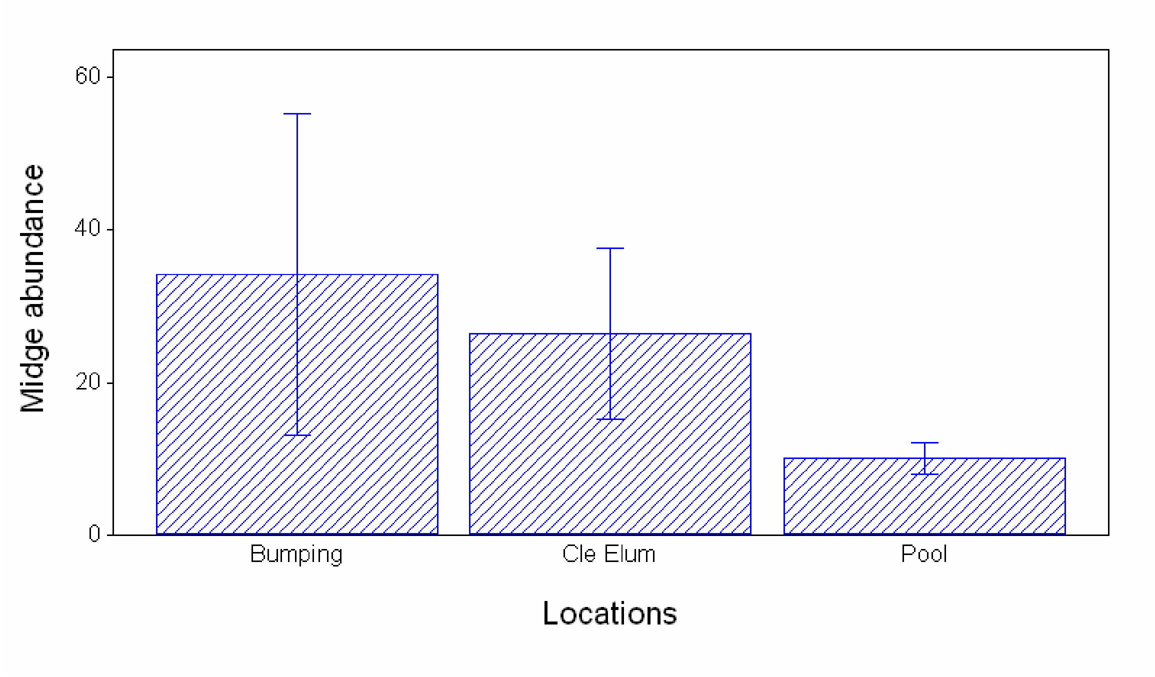
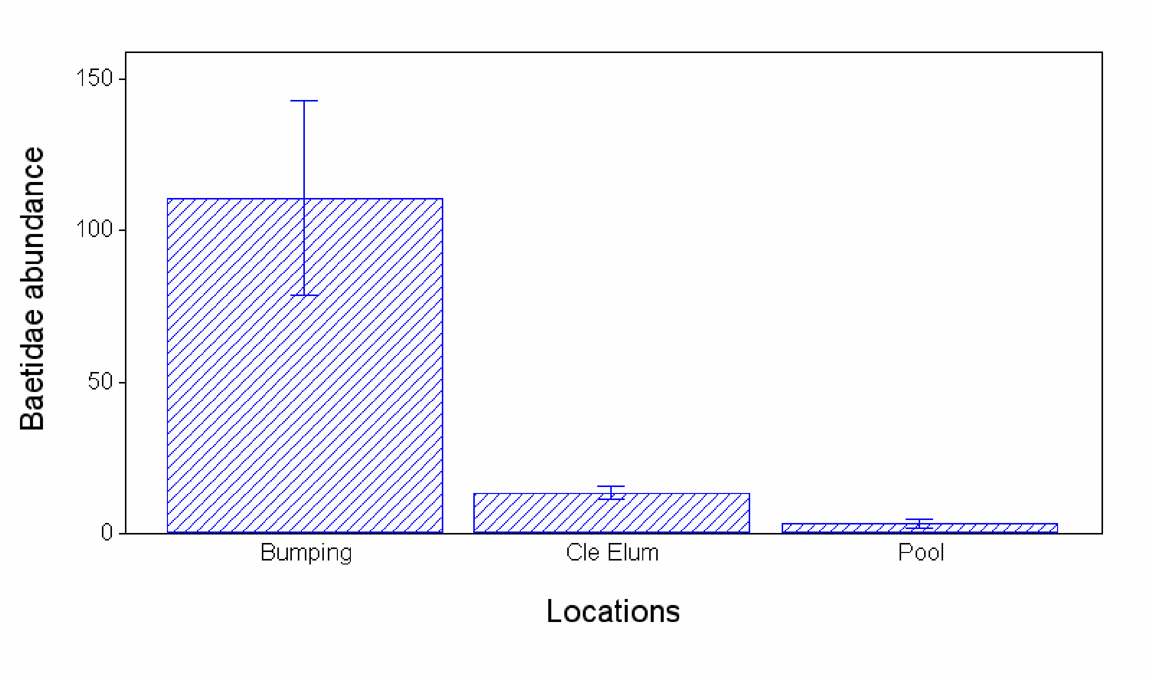


Figure 11. Abundance (number per kick-net) of specific juvenile salmonid food items associated with lotic habitat in the two watersheds and Cle Elum pool habitat. Data shown are combined from September 2003 and 2004. Midge abundance is shown in (a) and baetid abundance in (b).

a



b



Appendix A

Benthic macroinvertebrates associated with sites in the Cle Elum (CE) and Bumping (B) drainages from September 2003, March/April 2004, and September 2004.

- Numbers represent increasing distances above the reservoirs.
- Month and year of collection are presented after the backslash in the site code.
- W corresponds with the Waptus River, C with the Cooper River, and D with Deep Creek.
- Riffles/runs are designated with the letter R and pools are designated with the letter P.

	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1			Functional-feeding											
2			group	CER+1/9-03	CER+2/9-03	CER+3/9-03	CER+4/9-03	CER+5/9-03	CEP+5/9-03	CER+6/9-03	CEP+6/9-03	CER+7/9-03	CER+8/9-03	WR+1/9-03
3	ODONOTA													
4		*Aeshna*	prd (predator)											
5	EPHEMEROPTERA													
6		*Acentrella turbida*	c-g (collector-gatherer)	4	13	5								
7		*Ameletus*	c-g	1						4	4		1	
8		*Attenella margarita*	c-g											
9		*Baetis alius*	c-g											1
10		*Baetis bicaudatus*	c-g											
11		*Baetes tricaudatus*	c-g	2	36	12	26	22	8	14			30	5
12		*Caudatella hystrix*	c-g										2	
13		*Centroptilum/Procloeon*	c-g											
14		*Cinygmula*	scr (scraper)											
15		*Diphetor hageni*	c-g	1	1					4	2			
16		*Drunella coloradensis*	scr											
17		*Drunella doddsi*	scr		16	7	3	6	3				15	
18		*Drunella flavilinea*	scr											
19		*Drunella grandis ingens*	scr			2								1
20		*Drunella pelosa*	scr						1					
21		*Drunella spinifera*	scr								1			
22		*Epeorus deceptus*	scr											
23		*Epeorus longimanus*	scr											
24		*Epeorus (Ironopsis)*	scr		1	1	30	15						
25		*Ephemerella*	c-g						2	2	4	3	1	
26		*Heptagenia*	scr											
27		*Nixe criddlei*	scr	3										
28		*Paraleptophlebia*	shr (shredder)						1	2	59	4		
29		*Rhithrogena*	c-g	6	21	16	8	4	1	3			4	1
30		*Serratella tibialis*	c-g	2	25	10	2	2	1	3				
31		*Siphlonurus*	c-g									10		
32	PLECOPTERA													
33		*Calineuria californica*	prd	1	9	2	6	1	1				2	
34		Capniidae	shr											
35		Chloroperlidae	prd		1									
36		*Classsenia sabulosa*	prd	1	2					4				
37		*Cultus*	prd											
38		*Doddsia occidentalis*	shr											
39		*Doroneuria*	prd		2					1				
40		*Eucapnopsis*	shr											
41		*Hesperoperla pacifica*	prd	1		1				7	2		31	
42		*Isoperla*	prd											
43		*Kathroperla*	c-g											
44		*Kogotus*	prd											
45		*Malenka*	shr											
46		*Megarcys*	prd		1								1	
47		*Paraleuctra*	shr											
48		*Paraperla*												
49		*Plumiperla*												
50		*Podmosta/Prostoia*	shr											
51		*Pteronarcys*	shr											
52		*Skwala*	prd	2	5	1	2		1	1	5	39		
53		*Sweltsa*	prd		3	1	1			3	3			
54		*Taenionema*	shr											
55		*Visoka cataractae*	shr											
56		*Yoraperla*	shr											
57		*Zapada*	shr	1		5	2	1		1	1		10	
58	TRICHOPTERA													
59		*Agraylea*	c-g				1	2					2	
60		*Anagapetus*	scr											

	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1			Functional-feeding											
2			group	CER+1/9-03	CER+2/9-03	CER+3/9-03	CER+4/9-03	CER+5/9-03	CEP+5/9-03	CER+6/9-03	CEP+6/9-03	CER+7/9-03	CER+8/9-03	WR+1/9-03
61		*Apatania*												
62		*Arctopsyche grandis*	c-f (collector-filterer)		7	3	11			1				1
63		*Brachycentrus americanus*	c-f											
64		*Brachycentrus occidentalis*	c-f											
65		*Dolophilodes*	c-f				77	2	1					1
66		*Ecclisocosmoecus scylla*	scr											
67		*Glossosoma*	scr											
68		*Hydropsyche*	c-f	8	35	69	37	14		5		1		1
69		*Hydroptila*	scr											
70		*Lepidostoma*	shr								2			
71		*Limnephilus*	shr									35		
72		*Micrasema*	shr							2			54	
73		*Mystacides*												
74		*Neophylax*	scr			1			5					
75		*Neothremma*												
76		*Oligophlebodes*												
77		*Parapsyche elsis*	c-f											
78		*Pedocosmoecus sierra*												
79		*Polycentropus*	prd								1			
80		*Psychoglypha subborealis*	c-g											
81		*Rhyacophila arnaudi*	prd						1					
82		*Rhyacophila betteni*	prd	1	2	1							2	
83		*Rhyacophila brunnea*	prd	3	3	2	10	1		3		1	12	
84		*Rhyacophila hyalinata*	prd			1	16	5	1	1	1		1	1
85		*Rhyacohila narvae*	prd											
86		*Rhyacophila pellisa*	prd											
87		*Rhyacophila valuma*	prd											
88		*Rhyacophila vofixa*	prd											
89	HEMIPTERA													
90		*Cenocorixa*										1		
91		*Gerris*	prd									4		
92	MEGALOPTERA													
93		*Sialis*	prd									1		
94	COLEOPTERA													
95		*Heterlimnius*	c-g			1			3	5	1		6	
96		*Hydraena*	scr									1		
97		*Lara avara*	shr			1								
98		*Narpus concolor*	scr											
99		*Optioservus*	scr											
100		*Zaitzevia*	scr	4	13	1	1	2	1	9				
101	DIPTERA													
102		Tanypodinae	prd			1					4	2	2	
103		Chironomini	c-g		3	5						3		
104		Tanytarsini	c-f	11	39	56	12	2		12			14	
105		Orthocladiinae	c-g	3	6	3	18	4	17	5	11	1	14	1
106		Diamesinae	c-g					1	1					
107		*Antocha*	c-g	1					1					
108		*Bezzia/Palpomyia*	prd					1						
109		*Bittacomorpha*	c-g									22		
110		Ceratopogonidae	prd						1					
111		*Chelifera*	prd											
112		*Clinocera*	prd		1	1			3					
113		*Dicranota*	prd		2									
114		*Dixella*												
115		*Glutops*												
116		*Hesperoconopa*			1									
117		*Hexatoma*	prd		1				1	7			1	
118		*Oreogeton*												

	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1			Functional-feeding											
2			group	CER+1/9-03	CER+2/9-03	CER+3/9-03	CER+4/9-03	CER+5/9-03	CEP+5/9-03	CER+6/9-03	CEP+6/9-03	CER+7/9-03	CER+8/9-03	WR+1/9-03
119		*Philorus*												
120		*Prosimulium*	c-f											
121		*Simulium*	c-f	1	2	24	4	6		4			25	1
122		Tabanidae	prd									1		
123	TURBELLARIA													
124		*Polycelis*	prd		3	6	1						3	
125	NEMATODA													
126	OLIGOCHAETA													
127		Enchytraeidae	c-g		1	2				1			1	
128		Lumbricidae	c-g										2	
129		Lumbriculidae	c-g											
130		Naididae	c-g							1				
131		Tubificidae	c-g									15		
132	HIRUDINEA													
133		*Helobdella stagnalis*	prd									1		
134	CRUSTACEA													
135		*Hyalella*	shr								6	297		
136		Cambaridae	c-g											
137	ACARI													
138		*Sperchon*	prd						1					
139	GASTROPODA													
140		Lymnaeidae	scr											
141		Physidae	scr											
142		Planorbidae	scr							3				
143	BIVALVIA													
144		*Pisidium*	c-f							11		19	137	

	F	G	H	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1			Functional-feeding											
2			group	WP+1/9-03	WR+2/9-03	CR+1/9-03	CR+2/9-03	BR+1/9-03	DR+1/9-03	DR+2/9-03	CER+1/3-04	CER+2/3-04	CER+3/3-04	CER+4/3-04
3	ODONOTA													
4		*Aeshna*	prd (predator)											
5	EPHEMEROPTERA													
6		*Acentrella turbida*	c-g (collector-gatherer)		1	1		9						
7		*Ameletus*	c-g		1	3	3		1		1			
8		*Attenella margarita*	c-g											
9		*Baetis alius*	c-g											
10		*Baetis bicaudatus*	c-g							28				1
11		*Baetes tricaudatus*	c-g		6	9	14	248	130	101	85	83	42	74
12		*Caudatella hystrix*	c-g					29			2		2	18
13		*Centroptilum/Procloeon*	c-g											
14		*Cinygmula*	scr (scraper)					3	56	10	36	191	9	9
15		*Diphetor hageni*	c-g				3							
16		*Drunella coloradensis*	scr					6	6	9				
17		*Drunella doddsi*	scr		3			1	16	27	2	8		1
18		*Drunella flavilinea*	scr								3	2		1
19		*Drunella grandis ingens*	scr		7			5					1	
20		*Drunella pelosa*	scr								2			
21		*Drunella spinifera*	scr					4						
22		*Epeorus deceptus*	scr											
23		*Epeorus longimanus*	scr								6	33	4	13
24		*Epeorus (Ironopsis)*	scr		2	1		70	158	277	1	1	1	26
25		*Ephemerella*	c-g				9	1	6	2	38	113	17	41
26		*Heptagenia*	scr											
27		*Nixe criddlei*	scr											
28		*Paraleptophlebia*	shr (shredder)				2	2	1		2	2		
29		*Rhithrogena*	c-g		2			24	188	242		17		2
30		*Serratella tibialis*	c-g			2		3						
31		*Siphlonurus*	c-g											
32	PLECOPTERA													
33		*Calineuria californica*	prd		1	9	2			1				1
34		Capniidae	shr						2	1				
35		Chloroperlidae	prd											
36		*Classsenia sabulosa*	prd											
37		*Cultus*	prd											
38		*Doddsia occidentalis*	shr					3	5	1				
39		*Doroneuria*	prd				1	13	4					
40		*Eucapnopsis*	shr									2		
41		*Hesperoperla pacifica*	prd				10							
42		*Isoperla*	prd						2					
43		*Kathroperla*	c-g							1				
44		*Kogotus*	prd											
45		*Malenka*	shr				7							
46		*Megarcys*	prd					35	29	22				
47		*Paraleuctra*	shr											
48		*Paraperla*								1				
49		*Plumiperla*										3		
50		*Podmosta/Prostoia*	shr								25	73	33	22
51		*Pteronarcys*	shr											1
52		*Skwala*	prd	1			1	7						
53		*Sweltsa*	prd					5			3	9		2
54		*Taenionema*	shr									1		1
55		*Visoka cataractae*	shr					2	1					
56		*Yoraperla*	shr						15	54				
57		*Zapada*	shr		3	1	5	43	21	25	5	3		2
58	TRICHOPTERA													
59		*Agraylea*	c-g		3		28	8						
60		*Anagapetus*	scr							1				

	F	G	H	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1			Functional-feeding											
2			group	WP+1/9-03	WR+2/9-03	CR+1/9-03	CR+2/9-03	BR+1/9-03	DR+1/9-03	DR+2/9-03	CER+1/3-04	CER+2/3-04	CER+3/3-04	CER+4/3-04
61		*Apatania*												
62		*Arctopsyche grandis*	c-f (collector-filterer)		3	10		5						1
63		*Brachycentrus americanus*	c-f					5						
64		*Brachycentrus occidentalis*	c-f											
65		*Dolophilodes*	c-f		1									
66		*Ecclisocosmoecus scylla*	scr							1				
67		*Glossosoma*	scr					3	19	3		1		
68		*Hydropsyche*	c-f			13					10	2	1	8
69		*Hydroptila*	scr				12						1	
70		*Lepidostoma*	shr								4	5		
71		*Limnephilus*	shr											
72		*Micrasema*	shr		11	1	3				2		1	1
73		*Mystacides*												
74		*Neophylax*	scr					1	38	28				1
75		*Neothremma*												
76		*Oligophlebodes*												
77		*Parapsyche elsis*	c-f						4	5				
78		*Pedocosmoecus sierra*												
79		*Polycentropus*	prd											
80		*Psychoglypha subborealis*	c-g	1										
81		*Rhyacophila arnaudi*	prd		1		2							
82		*Rhyacophila betteni*	prd					9	31	29				
83		*Rhyacophila brunnea*	prd		3	4		31	6	8	1	1		2
84		*Rhyacophila hyalinata*	prd	1	3	3		2	2	7		1		1
85		*Rhyacohila narvae*	prd											
86		*Rhyacophila pellisa*	prd						1	1				
87		*Rhyacophila valuma*	prd									1		
88		*Rhyacophila vofixa*	prd						3	2			1	
89	HEMIPTERA													
90		*Cenocorixa*												
91		*Gerris*	prd											
92	MEGALOPTERA													
93		*Sialis*	prd											
94	COLEOPTERA													
95		*Heterlimnius*	c-g			1								
96		*Hydraena*	scr											
97		*Lara avara*	shr											
98		*Narpus concolor*	scr											
99		*Optioservus*	scr											
100		*Zaitzevia*	scr	2	1	5	4			1				
101	DIPTERA													
102		Tanypodinae	prd	1			9	1						
103		Chironomini	c-g	4			5						1	1
104		Tanytarsini	c-f	1	22	1	45	1	2		2	7		1
105		Orthocladiinae	c-g		3	1	173	131	18	14	12	4	1	14
106		Diamesinae	c-g				18	6		3				
107		*Antocha*	c-g				1	2						
108		*Bezzia/Palpomyia*	prd											
109		*Bittacomorpha*	c-g											
110		Ceratopogonidae	prd											
111		*Chelifera*	prd								1			
112		*Clinocera*	prd				2							1
113		*Dicranota*	prd	3		1		2		1				
114		*Dixella*												
115		*Glutops*												
116		*Hesperoconopa*												
117		*Hexatoma*	prd					7			1	2		1
118		*Oreogeton*							1	1				

	F	G	H	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1			Functional-feeding											
2			group	WP+1/9-03	WR+2/9-03	CR+1/9-03	CR+2/9-03	BR+1/9-03	DR+1/9-03	DR+2/9-03	CER+1/3-04	CER+2/3-04	CER+3/3-04	CER+4/3-04
119		*Philorus*												1
120		*Prosimulium*	c-f					1	2	1	7	17		7
121		*Simulium*	c-f	5	11	2	32	12	2	1	2	1		
122		Tabanidae	prd											
123	TURBELLARIA													
124		*Polycelis*	prd						2	2				
125	NEMATODA													
126	OLIGOCHAETA													
127		Enchytraeidae	c-g					3			1			
128		Lumbricidae	c-g											
129		Lumbriculidae	c-g			4	1							
130		Naididae	c-g				2							
131		Tubificidae	c-g											
132	HIRUDINEA													
133		*Helobdella stagnalis*	prd											
134	CRUSTACEA													
135		*Hyalella*	shr											
136		Cambaridae	c-g											
137	ACARI													
138		*Sperchon*	prd											
139	GASTROPODA													
140		Lymnaeidae	scr											
141		Physidae	scr											
142		Planorbidae	scr				1							
143	BIVALVIA													
144		*Pisidium*	c-f			1	77							

	F	G	H	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1			Functional-feeding											
2			group	CER+5/3-04	CEP+5/4-04	CER+6/4-04	CEP+6/4-04	WR+1/3-04	WP+1/3-04	CER+1/9-04	CER+2/9-04	CER+3/9-04	CER+3.5/9-04	CER+4/9-04
3	ODONOTA													
4		*Aeshna*	prd (predator)											
5	EPHEMEROPTERA													
6		*Acentrella turbida*	c-g (collector-gatherer)							6	10	3		
7		*Ameletus*	c-g	1		7	5		17	1	2			1
8		*Attenella margarita*	c-g							1				
9		*Baetis alius*	c-g											
10		*Baetis bicaudatus*	c-g	1	1	51	1							
11		*Baetes tricaudatus*	c-g	124	40	9	14	54	57		14	8	27	29
12		*Caudatella hystrix*	c-g	1	1			1						
13		*Centroptilum/Procloeon*	c-g											
14		*Cinygmula*	scr (scraper)	3	5	66	36	3	32		1			
15		*Diphetor hageni*	c-g							2				
16		*Drunella coloradensis*	scr											
17		*Drunella doddsi*	scr		3	1	2				2		1	6
18		*Drunella flavilinea*	scr	1										
19		*Drunella grandis ingens*	scr						3	1	2	1	1	
20		*Drunella pelosa*	scr	14	4			2						
21		*Drunella spinifera*	scr											
22		*Epeorus deceptus*	scr										3	6
23		*Epeorus longimanus*	scr	12	2	8		4	3					
24		*Epeorus (Ironopsis)*	scr	24	8	2		3						5
25		*Ephemerella*	c-g	26	21	17	13	6	43					
26		*Heptagenia*	scr											
27		*Nixe criddlei*	scr							1				
28		*Paraleptophlebia*	shr (shredder)			7		1	2					
29		*Rhithrogena*	c-g			15	1			2	7	2	3	5
30		*Serratella tibialis*	c-g							1	11	2	3	3
31		*Siphlonurus*	c-g											
32	PLECOPTERA													
33		*Calineuria californica*	prd	1	1		1		1	2				2
34		Capniidae	shr			2								
35		Chloroperlidae	prd			3								
36		*Classsenia sabulosa*	prd			3	3			4				
37		*Cultus*	prd		1						2			
38		*Doddsia occidentalis*	shr			14								
39		*Doroneuria*	prd			5	4							
40		*Eucapnopsis*	shr											
41		*Hesperoperla pacifica*	prd				5							
42		*Isoperla*	prd											
43		*Kathroperla*	c-g											
44		*Kogotus*	prd											
45		*Malenka*	shr											
46		*Megarcys*	prd											
47		*Paraleuctra*	shr											
48		*Paraperla*												
49		*Plumiperla*												
50		*Podmosta/Prostoia*	shr	26	12	2			1					
51		*Pteronarcys*	shr											
52		*Skwala*	prd							8	28	1	4	10
53		*Sweltsa*	prd			15	5	1		3	1			
54		*Taenionema*	shr											
55		*Visoka cataractae*	shr											
56		*Yoraperla*	shr			1	2							
57		*Zapada*	shr	2		12				2	1			
58	TRICHOPTERA													
59		*Agraylea*	c-g											
60		*Anagapetus*	scr											

	F	G	H	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1			Functional-feeding											
2			group	CER+5/3-04	CEP+5/4-04	CER+6/4-04	CEP+6/4-04	WR+1/3-04	WP+1/3-04	CER+1/9-04	CER+2/9-04	CER+3/9-04	CER+3.5/9-04	CER+4/9-04
61		*Apatania*												
62		*Arctopsyche grandis*	c-f (collector-filterer)							1	1		3	2
63		*Brachycentrus americanus*	c-f											
64		*Brachycentrus occidentalis*	c-f							1				
65		*Dolophilodes*	c-f											1
66		*Ecclisocosmoecus scylla*	scr											
67		*Glossosoma*	scr		2									
68		*Hydropsyche*	c-f	6	1			2	1	12	37	15	12	28
69		*Hydroptila*	scr						5					
70		*Lepidostoma*	shr	1	1	5			12	1	1			
71		*Limnephilus*	shr			1								
72		*Micrasema*	shr	1					2	1		1		
73		*Mystacides*												
74		*Neophylax*	scr										3	1
75		*Neothremma*					1							1
76		*Oligophlebodes*				1								
77		*Parapsyche elsis*	c-f											
78		*Pedocosmoecus sierra*												
79		*Polycentropus*	prd											
80		*Psychoglypha subborealis*	c-g											
81		*Rhyacophila arnaudi*	prd											
82		*Rhyacophila betteni*	prd									1	1	
83		*Rhyacophila brunnea*	prd	1						2				4
84		*Rhyacophila hyalinata*	prd		1	3	1					1		3
85		*Rhyacohila narvae*	prd											
86		*Rhyacophila pellisa*	prd											
87		*Rhyacophila valuma*	prd											
88		*Rhyacophila vofixa*	prd											
89	HEMIPTERA													
90		*Cenocorixa*												
91		*Gerris*	prd											
92	MEGALOPTERA													
93		*Sialis*	prd											
94	COLEOPTERA													
95		*Heterlimnius*	c-g		1	1	2			1			1	
96		*Hydraena*	scr											
97		*Lara avara*	shr											1
98		*Narpus concolor*	scr											1
99		*Optioservus*	scr								1			
100		*Zaitzevia*	scr							23	4		1	1
101	DIPTERA													
102		Tanypodinae	prd							1				
103		Chironomini	c-g			1				1	2	1		5
104		Tanytarsini	c-f	3		3	3	1	2	2	3			1
105		Orthocladiinae	c-g	17	8	30	8	2	1	3	8	1		1
106		Diamesinae	c-g	1			1			1	2	1	3	1
107		*Antocha*	c-g		1					5	1	2	1	1
108		*Bezzia/Palpomyia*	prd											
109		*Bittacomorpha*	c-g											
110		Ceratopogonidae	prd											
111		*Chelifera*	prd											
112		*Clinocera*	prd	1						1				
113		*Dicranota*	prd							1				
114		*Dixella*												
115		*Glutops*					1							
116		*Hesperoconopa*												
117		*Hexatoma*	prd			10	2		1					1
118		*Oreogeton*				1	1							

	F	G	H	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1			Functional-feeding											
2			group	CER+5/3-04	CEP+5/4-04	CER+6/4-04	CEP+6/4-04	WR+1/3-04	WP+1/3-04	CER+1/9-04	CER+2/9-04	CER+3/9-04	CER+3.5/9-04	CER+4/9-04
119		*Philorus*						2						
120		*Prosimulium*	c-f	3		9		1	1					
121		*Simulium*	c-f			2		1			1			11
122		Tabanidae	prd											
123	TURBELLARIA													
124		*Polycelis*	prd				1							
125	NEMATODA													
126	OLIGOCHAETA													
127		Enchytraeidae	c-g											
128		Lumbricidae	c-g			1	2							
129		Lumbriculidae	c-g											
130		Naididae	c-g											
131		Tubificidae	c-g											
132	HIRUDINEA													
133		*Helobdella stagnalis*	prd											
134	CRUSTACEA													
135		*Hyalella*	shr			7	10							
136		Cambaridae	c-g											
137	ACARI													
138		*Sperchon*	prd											
139	GASTROPODA													
140		Lymnaeidae	scr											
141		Physidae	scr											
142		Planorbidae	scr			5	3							
143	BIVALVIA													
144		*Pisidium*	c-f											

	F	G	H	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ
1			Functional-feeding											
2			group	CER+5/9-04	CEP+5/9-04	CER+6/9-04	CEP+6/9-04	CER+7/9-04	CER+8/9-04	WR+1/9-04	WP+1/9-04	CR+0.5/9-04	CR+2/9-04	BR+2/9-04
3	ODONOTA													
4		*Aeshna*	prd (predator)					4						
5	EPHEMEROPTERA													
6		*Acentrella turbida*	c-g (collector-gatherer)											
7		*Ameletus*	c-g			2	8				2	3	3	1
8		*Attenella margarita*	c-g											
9		*Baetis alius*	c-g										1	
10		*Baetis bicaudatus*	c-g											
11		*Baetes tricaudatus*	c-g	5	3	2	1		4	1	3	7		60
12		*Caudatella hystrix*	c-g											
13		*Centroptilum/Procloeon*	c-g								2	1		
14		*Cinygmula*	scr (scraper)											1
15		*Diphetor hageni*	c-g			8	8		1					
16		*Drunella coloradensis*	scr											
17		*Drunella doddsi*	scr						1					
18		*Drunella flavilinea*	scr											
19		*Drunella grandis ingens*	scr	2								9		2
20		*Drunella pelosa*	scr											
21		*Drunella spinifera*	scr	1										
22		*Epeorus deceptus*	scr											2
23		*Epeorus longimanus*	scr											
24		*Epeorus (Ironopsis)*	scr											
25		*Ephemerella*	c-g			1	3	5	1					
26		*Heptagenia*	scr						1				2	
27		*Nixe criddlei*	scr				1					1		
28		*Paraleptophlebia*	shr (shredder)			7	2	7	1				15	1
29		*Rhithrogena*	c-g											
30		*Serratella tibialis*	c-g											
31		*Siphlonurus*	c-g											
32	PLECOPTERA													
33		*Calineuria californica*	prd	1		3	4		1					
34		Capniidae	shr											
35		Chloroperlidae	prd											
36		*Classsenia sabulosa*	prd			2	1							
37		*Cultus*	prd											
38		*Doddsia occidentalis*	shr											
39		*Doroneuria*	prd											
40		*Eucapnopsis*	shr											
41		*Hesperoperla pacifica*	prd			1	1		5					
42		*Isoperla*	prd											
43		*Kathroperla*	c-g											
44		*Kogotus*	prd											2
45		*Malenka*	shr											
46		*Megarcys*	prd											1
47		*Paraleuctra*	shr											
48		*Paraperla*												
49		*Plumiperla*												
50		*Podmosta/Prostoia*	shr											
51		*Pteronarcys*	shr											
52		*Skwala*	prd	2		5	5				2	7	1	
53		*Sweltsa*	prd			5	10						2	
54		*Taenionema*	shr											
55		*Visoka cataractae*	shr			1							1	
56		*Yoraperla*	shr											
57		*Zapada*	shr	6			1		10				3	14
58	TRICHOPTERA													
59		*Agraylea*	c-g	1							1			
60		*Anagapetus*	scr											

	F	G	H	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ
1			Functional-feeding											
2			group	CER+5/9-04	CEP+5/9-04	CER+6/9-04	CEP+6/9-04	CER+7/9-04	CER+8/9-04	WR+1/9-04	WP+1/9-04	CR+0.5/9-04	CR+2/9-04	BR+2/9-04
61		*Apatania*			2		1				1			
62		*Arctopsyche grandis*	c-f (collector-filterer)	2					1					1
63		*Brachycentrus americanus*	c-f											
64		*Brachycentrus occidentalis*	c-f											
65		*Dolophilodes*	c-f											
66		*Ecclisocosmoecus scylla*	scr											
67		*Glossosoma*	scr											6
68		*Hydropsyche*	c-f	120	1		2							
69		*Hydroptila*	scr											
70		*Lepidostoma*	shr			3	16							
71		*Limnephilus*	shr			1	1	80			1			3
72		*Micrasema*	shr	2					9		2	3	2	10
73		*Mystacides*						1						
74		*Neophylax*	scr	11										12
75		*Neothremma*					1							
76		*Oligophlebodes*												
77		*Parapsyche elsis*	c-f											
78		*Pedocosmoecus sierra*												
79		*Polycentropus*	prd				1							
80		*Psychoglypha subborealis*	c-g											
81		*Rhyacophila arnaudi*	prd				2						3	
82		*Rhyacophila betteni*	prd	2										1
83		*Rhyacophila brunnea*	prd	6		1	3					2		
84		*Rhyacophila hyalinata*	prd	2										1
85		*Rhyacohila narvae*	prd											
86		*Rhyacophila pellisa*	prd											
87		*Rhyacophila valuma*	prd											
88		*Rhyacophila vofixa*	prd											
89	HEMIPTERA													
90		*Cenocorixa*												
91		*Gerris*	prd					2						
92	MEGALOPTERA													
93		*Sialis*	prd					4						
94	COLEOPTERA													
95		*Heterlimnius*	c-g			1	5		3		1	2		
96		*Hydraena*	scr					1						
97		*Lara avara*	shr	1					1					
98		*Narpus concolor*	scr			1	3							
99		*Optioservus*	scr			1								
100		*Zaitzevia*	scr			8	3				6	1		
101	DIPTERA													
102		Tanypodinae	prd	3		1	2	1	1				3	
103		Chironomini	c-g		2	1	1		1		17	1		
104		Tanytarsini	c-f	2		1	4		3				5	
105		Orthocladiinae	c-g	7	6	2	1		4			12	3	10
106		Diamesinae	c-g	1			1	1				3		
107		*Antocha*	c-g	3								3		2
108		*Bezzia/Palpomyia*	prd											
109		*Bittacomorpha*	c-g											
110		Ceratopogonidae	prd		1							1		
111		*Chelifera*	prd	1										
112		*Clinocera*	prd											
113		*Dicranota*	prd											
114		*Dixella*						48						
115		*Glutops*												
116		*Hesperoconopa*												
117		*Hexatoma*	prd			4	1						1	
118		*Oreogeton*				3	2							

	F	G	H	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ
1			Functional-feeding											
2			group	CER+5/9-04	CEP+5/9-04	CER+6/9-04	CEP+6/9-04	CER+7/9-04	CER+8/9-04	WR+1/9-04	WP+1/9-04	CR+0.5/9-04	CR+2/9-04	BR+2/9-04
119		*Philorus*												
120		*Prosimulium*	c-f											
121		*Simulium*	c-f			1			6	3				2
122		Tabanidae	prd											
123	TURBELLARIA													
124		*Polycelis*	prd	3										
125	NEMATODA					1								
126	OLIGOCHAETA													
127		Enchytraeidae	c-g			1								
128		Lumbricidae	c-g											
129		Lumbriculidae	c-g									2	1	
130		Naididae	c-g											
131		Tubificidae	c-g					5						
132	HIRUDINEA													
133		*Helobdella stagnalis*	prd											
134	CRUSTACEA													
135		*Hyalella*	shr			5	13	106						
136		Cambaridae	c-g									1		
137	ACARI													
138		*Sperchon*	prd											
139	GASTROPODA													
140		Lymnaeidae	scr					4						
141		Physidae	scr					6						
142		Planorbidae	scr			2	2	6						
143	BIVALVIA													
144		*Pisidium*	c-f			21	22	25	126			6	20	

	F	G	H	BA	BB
1			Functional-feeding		
2			group	DR+1/9-04	DR+2/9-04
3	ODONOTA				
4		*Aeshna*	prd (predator)		
5	EPHEMEROPTERA				
6		*Acentrella turbida*	c-g (collector-gatherer)		
7		*Ameletus*	c-g	4	1
8		*Attenella margarita*	c-g		
9		*Baetis alius*	c-g		
10		*Baetis bicaudatus*	c-g		15
11		*Baetes tricaudatus*	c-g	26	57
12		*Caudatella hystrix*	c-g		
13		*Centroptilum/Procloeon*	c-g		
14		*Cinygmula*	scr (scraper)	1	7
15		*Diphetor hageni*	c-g		
16		*Drunella coloradensis*	scr	4	1
17		*Drunella doddsi*	scr	8	32
18		*Drunella flavilinea*	scr		
19		*Drunella grandis ingens*	scr		
20		*Drunella pelosa*	scr		
21		*Drunella spinifera*	scr		
22		*Epeorus deceptus*	scr	24	44
23		*Epeorus longimanus*	scr		
24		*Epeorus (Ironopsis)*	scr	5	31
25		*Ephemerella*	c-g	3	6
26		*Heptagenia*	scr		
27		*Nixe criddlei*	scr		
28		*Paraleptophlebia*	shr (shredder)		
29		*Rhithrogena*	c-g	57	111
30		*Serratella tibialis*	c-g		1
31		*Siphlonurus*	c-g		
32	PLECOPTERA				
33		*Calineuria californica*	prd		
34		Capniidae	shr		1
35		Chloroperlidae	prd	3	
36		*Classsenia sabulosa*	prd		
37		*Cultus*	prd		
38		*Doddsia occidentalis*	shr	10	1
39		*Doroneuria*	prd	3	4
40		*Eucapnopsis*	shr		
41		*Hesperoperla pacifica*	prd		
42		*Isoperla*	prd		
43		*Kathroperla*	c-g		
44		*Kogotus*	prd	1	
45		*Malenka*	shr		
46		*Megarcys*	prd	24	24
47		*Paraleuctra*	shr	1	
48		*Paraperla*		1	
49		*Plumiperla*			
50		*Podmosta/Prostoia*	shr		
51		*Pteronarcys*	shr		
52		*Skwala*	prd		
53		*Sweltsa*	prd	1	
54		*Taenionema*	shr		
55		*Visoka cataractae*	shr	1	
56		*Yoraperla*	shr	9	35
57		*Zapada*	shr	10	14
58	TRICHOPTERA				
59		*Agraylea*	c-g		
60		*Anagapetus*	scr		24

	F	G	H	BA	BB
1			Functional-feeding		
2			group	DR+1/9-04	DR+2/9-04
61		*Apatania*		4	1
62		*Arctopsyche grandis*	c-f (collector-filterer)		
63		*Brachycentrus americanus*	c-f		
64		*Brachycentrus occidentalis*	c-f		
65		*Dolophilodes*	c-f		
66		*Ecclisocosmoecus scylla*	scr	1	2
67		*Glossosoma*	scr	25	14
68		*Hydropsyche*	c-f		
69		*Hydroptila*	scr		
70		*Lepidostoma*	shr		
71		*Limnephilus*	shr	1	
72		*Micrasema*	shr		
73		*Mystacides*			
74		*Neophylax*	scr	55	115
75		*Neothremma*			
76		*Oligophlebodes*			
77		*Parapsyche elsis*	c-f	1	6
78		*Pedocosmoecus sierra*		1	1
79		*Polycentropus*	prd		
80		*Psychoglypha subborealis*	c-g		
81		*Rhyacophila arnaudi*	prd		
82		*Rhyacophila betteni*	prd	23	19
83		*Rhyacophila brunnea*	prd	8	6
84		*Rhyacophila hyalinata*	prd		
85		*Rhyacohila narvae*	prd	1	2
86		*Rhyacophila pellisa*	prd		
87		*Rhyacophila valuma*	prd	1	
88		*Rhyacophila vofixa*	prd		
89	HEMIPTERA				
90		*Cenocorixa*			
91		*Gerris*	prd		
92	MEGALOPTERA				
93		*Sialis*	prd		
94	COLEOPTERA				
95		*Heterlimnius*	c-g		
96		*Hydraena*	scr		
97		*Lara avara*	shr		
98		*Narpus concolor*	scr		
99		*Optioservus*	scr		
100		*Zaitzevia*	scr		1
101	DIPTERA				
102		Tanypodinae	prd		
103		Chironomini	c-g	2	
104		Tanytarsini	c-f	1	
105		Orthocladiinae	c-g	8	4
106		Diamesinae	c-g	1	3
107		*Antocha*	c-g		
108		*Bezzia/Palpomyia*	prd		
109		*Bittacomorpha*	c-g		
110		Ceratopogonidae	prd		
111		*Chelifera*	prd	1	
112		*Clinocera*	prd		
113		*Dicranota*	prd		
114		*Dixella*			
115		*Glutops*		1	
116		*Hesperoconopa*			
117		*Hexatoma*	prd	1	
118		*Oreogeton*			

	F	G	H	BA	BB
1			Functional-feeding		
2			group	DR+1/9-04	DR+2/9-04
119		*Philorus*			
120		*Prosimulium*	c-f		
121		*Simulium*	c-f		2
122		Tabanidae	prd		
123	TURBELLARIA				
124		*Polycelis*	prd	3	
125	NEMATODA				
126	OLIGOCHAETA				
127		Enchytraeidae	c-g	1	
128		Lumbricidae	c-g		
129		Lumbriculidae	c-g		
130		Naididae	c-g		
131		Tubificidae	c-g		
132	HIRUDINEA				
133		*Helobdella stagnalis*	prd		
134	CRUSTACEA				
135		*Hyalella*	shr		
136		Cambaridae	c-g		
137	ACARI				
138		*Sperchon*	prd		
139	GASTROPODA				
140		Lymnaeidae	scr		
141		Physidae	scr		
142		Planorbidae	scr		
143	BIVALVIA				
144		*Pisidium*	c-f		