TOLERANCE VALUES AND EFFECTS OF SELECTED ENVIRONMENTAL DETERMINANTS ON CADDISFLY (TRICHOPTERA) DISTRIBUTION IN NORTHWEST AND NORTH CENTRAL WASHINGTON, USA

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ABSTRACT.—Caddisflies were collected at 181 wall seep, stream, river, and lake habitats in 7 counties in northwest and north central Washington over a 6-year period. From 17,405 specimens, we identified 164 adult caddisfly species within 62 genera and 16 families. Twenty taxa were new state records, bringing the number of species currently reported from Washington to 230. Species assemblages were compared to altitude, physicochemical factors, aquatic habitats, and land use (urban, agriculture, and forest) on the west and east sides of the North Cascade Range. Species richness showed significant positive correlations to altitude and pH and showed significant negative correlations to total phosphorus, total nitrogen, and specific conductivity, as well as especially to channel embeddedness. A multilevel hierarchical clustering model separated wall seeps, streams, and rivers into geographic and land-use regions based on adult caddisfly assemblages. We used a multimetric index (caddisfly tolerance index [CTI]) to determine environmental tolerance levels for adult caddisfly species. The index performed well in distinguishing among the effects of total phosphorus, total nitrogen, specific conductance, and channel embeddedness on the distribution of caddisfly species. These CTI values provide baseline information for monitoring changes in ecosystem health in drainages throughout Washington landscapes.

RESUMEN.—Se colectaron frigáneas en 181 hábitats que incluyen filtraciones en paredes, arroyos, ríos y lagos, en siete condados ubicados en el noroeste y la parte norte-central de Washington, en un período de seis años. Identificamos 164 especies adultas de frigáneas de 62 géneros y 16 familias de 17,405 especímenes. Se registraron veinte nuevos taxones en el estado, 230 especies ya reportadas en Washington. Se compararon distintos ensambles de especies en relación con la altitud, los factores fisicoquímicos, los hábitats acuáticos y la explotación del suelo (urbano, agrícola y bosque) en el lado oeste y este de North Cascade Range. La riqueza de especies mostró correlaciones positivas significativas en relación con la altitud y el pH, y correlaciones negativas significativas con el fósforo total, el nitrógeno, la conductividad específica y, en especial, con la superposición de los cauces de agua. Un modelo de agrupamiento jerárquico multinivel separó las filtraciones en paredes, los arroyos y los ríos, en regiones geográficas y de explotación del suelo, según los grupos de adultos de frigáneas. Utilizamos un índice multimétrico (Índice de tolerancia de frigáneas [CTI, por sus siglas en inglés]) para determinar los niveles de tolerancia ambiental para adultos de las especies de frigáneas. El índice funcionó correctamente para distinguir entre el efecto del fósforo total, el nitrógeno total, la conductancia específica y la superposición de los cauces de agua en la distribución de las especies de frigáneas. Estos valores del CTI proporcionan información de referencia para monitorear los cambios de estado del ecosistema en los desagües de los paisajes de Washington.

Few studies have been published on the distribution of caddisflies in Washington, even though the state includes parts of 13 terrestrial (Ricketts et al. 1999) and 3 freshwater ecoregions (Abell et al. 2000). The terrestrial ecoregions range from central Pacific coastal forests to Palouse grasslands. In the USA, only California is as diverse in its terrestrial ecoregions as Washington (Ricketts et al. 1999). We propose that the high diversity of ecoregions in Washington should yield equally high diversity in caddisfly assemblages.

One of the earliest published collections of caddisflies in Washington was by Davis (1948),

who reported 102 species from 17 counties throughout the state. Six of these counties are included in this study. In addition, Ruiter et al. (2005) reported 117 species from Mt. Rainier National Park, while Zack et al. (2006) collected 40 caddisfly species in a spring-stream system in the semiarid southeastern region at the Hanford Reach National Monument. Betts and Wisseman (1995) reported on the geographic range and habitat characteristics of *Cryptochia neosa* in the Blue Mountains of Washington.

Distributions of caddisflies have been published for nearby regions. Anderson (1976)

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reported 282 caddisfly species in Oregon, while Cannings (2007) published an updated list of 275 species in British Columbia, Canada. In addition, there have been 156 species of caddisflies reported in Idaho (J. Pappani, Idaho Department of Environmental Quality, personal communication; Newell and Minshall 1977).

Many of the aquatic habitats (urban, agricultural, forest) included in this study are considered vulnerable and endangered, with a high to medium likelihood of future threats (Abell et al. 2000). The threats to these freshwater ecoregions include increased agriculture and urbanization, loss of floodplain and riparian habitats from forest clearing, and increased turbidity and channel embeddedness in streams. These conditions may increase the potential of losing existing fauna, as well as potentially undescribed endemic species.

Caddisflies play important roles in food webs (Couceiro et al. 2007) and ecological processes such as leaf breakdown (Vannote et al. 1980). Also, Céréghino et al. (2003) reported that caddisflies were good predictors of environmental conditions along stream orders because various species occupy the full spectrum of altitudinal gradients. In addition, Houghton (2006) determined that adult caddisflies were an important group for biomonitoring farmland streams in Minnesota because of their high species richness, ecological diversity, and abundance in all types of freshwater ecosystems. Finally, Cuffney et al. (2011) found invertebrate responses to land-cover disturbances more sensitive than algal responses in urban environments.

Paulsen et al. (2008) examined the ecological conditions of wadeable, perennial streams and small rivers in 3 major ecoregions in the United States, which included the western USA. Nationally, 42% of the stream length was in poor condition. The most widespread stressors observed were nitrogen, phosphorus, riparian disturbance, and streambed sediments.

We provide an updated list of adult caddisfly species for Washington and discuss the role of total nitrogen (TN), total phosphorus (TP), specific conductance, channel embeddedness, maximum water temperature, canopy cover, altitude, land use, and habitat type on the distribution of these species.

Ecologists have recommended indices based on the most robust and finest taxonomic resolution over family or generic resolution for

the bioassessment of habitats and landscapes (Hawkins and Norris 2000, Whittier and Van Sickle 2010). Also, Barbour et al. (1995) recommended a multimetric approach for measuring biological conditions.

We developed tolerance values for adult caddisfly species based on nutrients (TN, TP), specific conductance, and channel embeddedness. These tolerance values provide a baseline for monitoring changes in ecosystem health for aquatic ecosystems in Washington State. To date, no tolerance rankings have been developed for adult caddisflies in the varied landscapes of Washington.

STUDY AREA

The study area encompasses about 48,000 km² and 7 counties in northwest and central Washington (Fig. 1A–1C). The region includes the North Pacific Coastal and Columbia Glaciated freshwater ecoregions with a variety of temperate coastal seeps, streams, rivers, and lakes (Abell et al. 2000). The North Pacific Coastal Region includes mesic landscapes on the west side of the North Cascade Range and a drier Columbia Glaciated Region east of the Cascade Range.

Landscapes contain a number of urban communities with a combined total of over 250,000 residents (<http://quickfacts.census.gov>; cited 6 January 2013). Bellingham is the largest urban center, with about 82,000 residents; most other urban centers have <5000 residents. Dairy, corn, and berry farming make up a large portion of the agricultural landscapes on the west side of the Cascade Range, whereas dryland crops and rangelands are common on the east side of the Cascade Range (personal observations). The urban and agricultural landscapes are typically <300 m in altitude, and most forest landscapes range from 300 to >2000 m.

Riparian vegetation in urban landscapes includes *Acer macrophyllum*, *Alnus rubra*, and *Pseudotsuga menziesii*, whereas agricultural landscapes include grasses, sedges, and *Alnus rubra*. Riparian vegetation along lowland forest sites contains *Acer macrophyllum*, *Alnus rubra*, *Salix scouleriana*, *Salix sitchensis*, *Pseudotsuga menziesii*, and *Populus balsamifera* ssp. *trichocarpa*, which is replaced by *Tsuga heterophylla* in upland riparian systems (Pojar and MacKinnon 1994). Riparian

Fig. 1. Location of collection sites in northwest and north central Washington. Site numbers are taken from Appendix 1: 1A, sites in Whatcom and Skagit counties; 1B (facing page), sites in Chelan, King, Kittitas, Skagit, and Snohomish counties; 1C (facing page), sites in Chelan and Okanogan counties.

vegetation in drier eastern Washington includes *Pseudotsuga menziesii*, *Pinus ponderosa*, and dry grassland vegetation (personal observation).

METHODS

Adult and immature caddisflies were collected from 12 wall seeps (water draining down rock faces), 107 streams, 35 rivers, and 27 lakes and ponds from 2006 through 2011 in northwest and north central Washington (Appendix 1). Adult caddisflies were collected between early April and mid-November by using a 12-cm, 4-W ultraviolet light placed over a 14 × 21-cm plastic tray containing 70% isopropyl alcohol. Two trays were placed at different locations near the site 1 h before sunset and retrieved after 5–6 h. Species abundance was determined as the percentage of captured adults and averaged for each site over the 6-year period. Caddisfly larvae and pupae were handpicked from submerged vegetation, rocks, and woody debris during most visits in order to compare them with adult collections. Seventy percent of the sites were sampled in 2 different years, 16% were sampled in 3 different years, and 80% were sampled at least twice during a one-year period. Specimens were identified to the lowest feasible taxon using the available taxonomic literature, and they are deposited in the David E. Ruiter Personal Collection (DERPC) located in Grants Pass, Oregon.

Land use (urban, agriculture, forest) was noted based on observations, and physico-chemical information was collected at each site. Air temperatures and maximum water temperatures for every collection were measured with a handheld thermometer on-site when trays were placed and retrieved. Specific conductance of water (at 25 °C) was determined with a conductance meter (Radiometer, Copenhagen, Denmark; Model CDM2e) in the laboratory, and pH was measured with an Oakton pH 6 meter on-site. Channel embeddedness was determined to the nearest 5% interval at each site following methods of Platts et al. (1983). Suspended sediments were determined according to MacDonald et al. (1991), and canopy cover was determined with a spherical densiometer (Forest Densiometer Model A) to the nearest 5% interval.

Water collections for TN and TP were immediately placed on dry ice and analyzed

within 14 days by the persulfate digestion and flow injection method on an FS3000 Flow Injection Analyzer made by OI Corporation (APHA 2005). The digestion method was an alkaline oxidation (APHA 4500-PJ) using sodium hydroxide and potassium persulfate. Following the digestion, total phosphorus was measured using the ascorbic acid method (APHA 4500-PH), and total nitrogen was measured using the cadmium reduction method on the FS3000 (APHA 4500 NO3-I).

Kendall's tau (τ) rank correlation coefficients were calculated between species richness and TN, TP, specific conductance, channel embeddedness, altitude, maximum water temperature, pH, suspended solids, and percent canopy. We also used principal components analysis based on singular value decomposition of the centered, scaled data matrix to extract the important relationships among the water quality and caddisfly variables (Jongman et al. 1995, Ben-Hur and Guyon 2003, R Development Core Team 2011). The principal components were used as new variables to identify stable clusters using hierarchical clustering with Euclidean distance and Ward's minimum variance cluster method, following the methods outlined by Ben-Hur and Guyon (2003).

A tolerance index was developed for TN, TP, specific conductance, and channel embeddedness to compare the distribution of adult caddisfly species along each of these environmental gradients. The following equation was developed by Blinn (1993) for specific conductance (SCI) and used by Blinn and Bailey (2001) for diatoms and Blinn and Ruiter (2006) for caddisflies:

$$SCI_x = \frac{\sum_{i=1}^{N_x} [\log_{10} (RA_i \cdot 100)] (\text{Specific Conductance, } \mu\text{S/cm})}{N_x},$$

where RA = relative abundance (%) of species x at a given stream site and N = number of streams in which species x occurred. The Caddisfly Tolerance Index (CTI) is a summation of the adjusted combined numeric values of TNI, TPI, SCI, and EMBI. Elevated nutrients, salinization of water, and siltation of cobbles are 3 of the most influential stressors for stream biota (Laws 2000, Enger and Smith 2009). We adjusted the CTI numeric scores to a 0–10 scale in order to compare with values

Fig. 2. Mean caddisfly species richness for land use and habitats in northwest and north central Washington.

from the U.S. Environmental Protection Agency (Barbour et al. 1999).

RESULTS

Caddisfly Distribution and Physicochemical Features

We identified 164 caddisfly species within 62 genera and 16 families from 17,405 specimens, which resulted in 20 new records for the state (Morse 2009; Appendix 2). Ruiter et al. (2005) summarized the literature on the distribution of caddisfly species and reported at least 210 species from Washington. The addition of 20 species in this study resulted in at least 230 caddisfly species recorded for the state.

Forty-six species were collected in wall seeps, 140 in streams and rivers, and 38 in lakes (Appendix 2). All families were represented in stream habitats. Members of Phryganeidae and Rhyacophilidae were common in wall seeps, and Leptoceridae, Limnephilidae, Phryganeidae, and Polycentropodidae were common in lakes. Forest landscapes and streams had the highest mean number of species per site, and urban landscapes and lakes had the lowest mean number of species (Fig. 2). Overall average species richness per site was 9.6 (SE 0.6) on the west side and 9.8 (SE 0.9) on the east side of the North Cascade Range.

One hundred fifty-one taxa were collected on the west side of the North Cascade Range and 71 taxa on the east side (Appendix 2). Hydropsychidae, Hydroptilidae, Lepidostomatidae, Limnephilidae, Philopotamidae, and Rhyacophilidae composed 76% of the caddisfly assemblages collected on the west side. In contrast, Glossosomatidae, Hydropsychidae, Hydroptilidae, Leptoceridae, Limnephilidae, and Rhyacophilidae made up 79% of the caddisfly assemblage on the east side. No species in Goeridae, Odontoceridae, or Phryganeidae were collected on the east side of the Cascade Range.

Caddisfly species richness showed significant positive correlations to altitude and pH and showed significant negative correlations to TN, TP, specific conductivity, and especially channel embeddedness (Table 1). No significant correlations were determined between species richness and suspended solids, maximum water temperature, or canopy cover.

Two limnephilids, *Ecclisomyia conspersa* and *Onocosmoecus unicolor*, were the most common species collected from both west and east sides of the Cascade Range (Appendix 2). These species were collected in nearly one-third of all the sites examined at altitudes ranging from 4 m to >1300 m. *Ecclisomyia conspersa* was collected in all habitats, whereas *Onocosmoecus unicolor* was collected only in streams. *Hydropsyche oslari* (29.1%), *Parapsyche elsis* (27.9%), *Polycentropus variegatus*

TABLE 1. Kendall's τ rank-based correlations between caddisfly species richness and environmental determinants. An asterisk (*) indicates statistical significance.

	Kendall's τ	P value
Altitude*	0.233	0.0002
Specific conductivity*	-0.157	0.0125
Maximum water temperature	-0.091	0.1590
Total phosphorus*	-0.152	0.0149
Total nitrogen*	-0.158	0.0103
pH*	0.197	0.0027
Suspended solids	-0.041	0.5580
% Canopy cover	-0.033	0.6260
Channel embeddedness*	-0.198	0.0030

(27.1%), *Rhyacophila vao* (26.7%), and *Arcopsyche grandis* (26%) were the next most common species throughout the study area. These species were collected primarily in streams and wall seeps from west and east sites of the Cascade Range. Limnephilidae and Rhyacophilidae had the most species, with 40 and 35 species, respectively. Eight species (*Sisko* sp., *Tinodes cascadia*, *Rhyacophila chilsia*, *Rhyacophila fenderi*, *Rhyacophila norcuta*, *Rhyacophila rotunda*, *Rhyacophila viquaea*, and *Rhyacophila visor*) were collected only in wall seep habitats on the west side of the Cascade Range (Appendix 2).

Limnephilids, including *Chyranda centralis*, *Ecclisocosmoecus scylla*, *Ecclisocosmoecus conspersa*, *Eocosmoecus frontalis*, *Lenarcus vastus*, and *Psychoglypha alascensis*, and one uenoidid, *Neothremma didactyla*, were common in high-altitude lakes (>1200 m; Appendix 2). Hydroptilidae (*Agraylea multipunctata*, *Stactobiella delira*), Leptoceridae (*Mystacides alafimbriata*, *Oecetis inconspicua*, *Triaenodes tardus*), and Polycentropidae (*Polycentropus cinereus*, *Polycentropus variegatus*) were common in lakes at altitudes <400 m. No members of the Apataniidae, Brachycentridae, Glossosomatidae, Goeridae, Hydropsychidae, Odontoceridae, Philopotamidae, and Psychomyiidae were collected in lakes. *Chyranda centralis*, *Ecclisocosmoecus conspersa*, and *Neophylax splendens* were common in wall seep habitats.

Specific conductance ranged from 0.004 to 26.2 mS $\cdot$ cm⁻¹, TP from 4 to 787 μ g $\cdot$ L⁻¹, TN from 0.8 to 5615 μ g $\cdot$ L⁻¹, and channel embeddedness from 5% to 99% throughout the study area (Appendix 1, Table 1). Average TN concentrations were 7 times higher in agricultural landscapes on the west side of the Cascade Range compared to the east side (Table 1).

Other relationships between environmental parameters on the west and east sides of the Cascade Range can be found in Table 2.

Hierarchical clustering produced 5 stable cluster groups using the first 5 principal components as clustering variables (Fig. 3). These cluster groups appeared to match natural groups formed by geographic location and land-use type. A simple chi-square contingency table showed a significant association between the 5 "blind" hierarchical cluster groups and the following location/land-use groups (Crawley 2007). Clusters A, B¹, and B² contained wall seeps and streams primarily on the west side of the North Cascade mountain range, whereas cluster C contained both streams and rivers mostly on the west side, and D included streams and rivers mostly on the east side of the Cascades.

Cluster A included high-altitude habitats (≥ 350 m) in the Mount Baker region on the west side of the Cascade Range. Average concentrations for TP and TN were 7 μ g $\cdot$ L⁻¹ (SE 1.1) and 81.5 μ g $\cdot$ L⁻¹ (SE 15), respectively. Varden and Jack creeks, also high-altitude sites, were the only sites included in Cluster A from the east side of the North Cascades. Cluster B¹ included shallow streams in regions with low altitudes (<35 m) and heavy agriculture including dairy, berry, and corn farms with high average TP (48.3 μ g $\cdot$ L⁻¹, SE 11.1) and TN (2509 μ g $\cdot$ L⁻¹, SE 651) concentrations.

B² included streams at altitudes ≤ 165 m with limited agriculture (ranching and horses) and small urban areas with TP and TN concentrations of 9.8 μ g $\cdot$ L⁻¹ (SE 1.3) and 488 μ g $\cdot$ L⁻¹ (SE 77), respectively. Cluster C included streams/rivers at altitudes <400 m primarily on the west side of the Cascades with TP and TN concentrations of 18 μ g $\cdot$ L⁻¹ (SE 2.9) and 137 μ g $\cdot$ L⁻¹ (SE 27), respectively. And Cluster D included streams/rivers at altitudes >400 m primarily on the east side of the Cascades with similar low concentrations of TP (15.8 μ g $\cdot$ L⁻¹, SE 3.6) and TN (119 μ g $\cdot$ L⁻¹, SE 26).

Caddisfly assemblages in Cluster A with limited landscape disturbance included *Chyranda centralis*, *Dolophilodes pallidipes*, *Ecclisocosmoecus scylla*, *Ecclisocosmoecus conspersa*, *Homophylax andax*, *Oligophiloides sierra*, *Rhyacophila vaccua*, *Rhyacophila vaefes*, and *Rhyacophila vocala*. Common assemblages associated with heavy agricultural land use in Cluster B¹ included *Agraylea multipunctata*,

Fig. 3. Multilevel hierachial clustering using 6 environmental factors for seeps, streams, and rivers in northwest and north central Washington. Site numbers in Appendix 1 are listed on the x-axis. A = seeps and streams at altitudes ≥ 350 m, primarily in the Mount Baker area (31 sites); B¹ = streams at altitudes ≤ 35 m in landscapes with heavy agriculture (dairy, berry, and corn) on the west side of the Cascades (7 sites); B² = streams at altitudes ≤ 165 m in moderate agricultural (alfalfa and ranching) and urban landscapes on the west side of the Cascades (21 sites); C = streams and rivers at altitudes < 400 m, primarily on the west side of the Cascades (25 sites); D = streams and rivers at altitudes > 400 m, primarily on the east side of the Cascades (21 sites).

TABLE 3. Caddisfly tolerance index (CTI) for species collected in Washington. Lower tolerance values indicate that species are sensitive to the environmental parameter: EMBI = channel embeddedness; TPI = total phosphorus; TNI = total nitrogen; SCI = specific conductance. CTI = combined tolerance value. Combined tolerance values for collections (WADJUS) were adjusted to a scale of 0 to 10 according to Barbour et al. (1999) and compared with U.S. Environmental Protection Agency (USEPA) tolerance values for other regions when available. Species are arranged from most sensitive to most tolerant according to the adjusted (WADJUS) tolerance value. NA = not available.

Caddisfly species	EMBI	TPI	TNI	SCI	CTI	WADJUS	USEPA
<i>Banksiola crotchi</i>	1	1	5	5	12	0.1	NA
<i>Rhyacophila grandis</i>	1	1	14	4	20	0.1	1
<i>Pedomoeus sierra</i>	2	2	10	10	24	0.2	0
<i>Alloosmoecus partitus</i>	4	1	32	10	47	0.5	0
<i>Lepidostoma hoodi</i>	3	2	19	27	51	0.5	NA
<i>Rhyacophila tucula</i>	3	1	24	32	60	0.6	NA
<i>Ecclisocsmoeus scylla</i>	6	3	30	22	61	0.6	1
<i>Wormaldia occidea</i>	2	6	20	45	73	0.7	NA
<i>Glossosoma wenatchee</i>	5	4	33	34	76	0.8	NA
<i>Rhyacophila vaefes</i>	4	3	48	22	77	0.8	1
<i>Rhyacophila bifila</i>	5	4	32	42	83	0.8	NA
<i>Agapetus taho</i>	5	3	42	43	93	0.9	NA
<i>Glossosoma penitum</i>	7	5	40	43	95	1.0	NA
<i>Ecclisomyia maculosa</i>	5	3	48	42	98	1.0	NA
<i>Hesperophylax alaskensis</i>	25	5	41	28	99	1.0	NA
<i>Himalopsyche phryganea</i>	9	6	40	44	99	1.0	NA
<i>Dolophiloides pallidipes</i>	6	5	29	62	102	1.0	NA
<i>Parapsyche almota</i>	3	7	37	56	103	1.0	3
<i>Amiocentrus aspilus</i>	7	13	59	24	103	1.0	2
<i>Rhyacophila vocala</i>	12	5	52	46	115	1.2	NA
<i>Dicosmoecus atripes</i>	6	11	55	45	117	1.2	1
<i>Chyranda centralis</i>	14	7	58	39	118	1.2	1
<i>Neothremma didactyla</i>	12	6	70	31	119	1.2	NA
<i>Neophylax occidentis</i>	4	8	40	72	124	1.2	3
<i>Ecclisomyia conspersa</i>	13	6	72	42	133	1.3	NA
<i>Polycentropus denningi</i>	5	7	63	58	133	1.3	NA
<i>Rhyacophila hyalinata</i>	6	6	26	95	133	1.3	NA
<i>Goeracea genota</i>	4	18	13	107	142	1.4	0
<i>Oligophlebodes sierra</i>	12	5	89	54	160	1.6	NA
<i>Parapsyche elsis</i>	19	9	64	70	162	1.6	1
<i>Homophylax andax</i>	30	7	65	60	162	1.6	NA
<i>Hydroptila rono</i>	3	3	111	46	163	1.6	NA
<i>Rhyacophila narvae</i>	2	4	131	27	164	1.6	NA
<i>Neophylax splendens</i>	4	22	26	137	189	2.0	3
<i>Arctopsyche grandis</i>	33	15	85	65	198	2.0	2
<i>Neophylax rickeri</i>	5	3	150	52	210	2.1	3
<i>Mystacides alafimbriata</i>	33	2	158	24	217	2.1	NA
<i>Rhyacophila angelita</i>	13	8	136	68	224	2.2	NA
<i>Stactobiella delira</i>	38	8	112	71	229	2.3	NA
<i>Rhyacophila brunnea</i>	22	5	148	56	231	2.3	NA
<i>Hesperophylax designatus</i>	7	19	128	78	232	2.3	NA
<i>Rhyacophila vao</i>	7	6	172	55	240	2.3	NA
<i>Rhyacophila vaccua</i>	9	5	171	57	242	2.4	NA
<i>Dolophilodes dorcus</i>	9	9	148	78	244	2.4	NA
<i>Dicosmoecus gilvipes</i>	4	3	224	50	281	2.8	2
<i>Dolophiloides novusamericanus</i>	4	11	192	80	287	2.9	NA
<i>Hydatophylax hesperus</i>	13	6	223	69	311	3.1	NA
<i>Micrasema bacro</i>	9	8	211	83	311	3.1	1
<i>Brachycentrus americanus</i>	36	13	179	92	320	3.2	1
<i>Hydropsyche osleri</i>	35	16	200	98	349	3.5	4
<i>Rhyacophila vuzana</i>	21	7	261	70	359	3.5	NA
<i>Wormaldia gabriella</i>	7	11	294	95	407	4.0	NA
<i>Lepidostoma unicolor</i>	14	19	288	87	408	4.0	NA
<i>Lepidostoma rayneri</i>	21	13	290	88	412	4.1	NA
<i>Polycentropus variegatus</i>	22	16	301	75	414	4.1	NA
<i>Hydropsyche occidentalis</i>	25	35	210	161	431	4.3	4
<i>Ptilostomis ocellifera</i>	26	5	365	58	454	4.5	NA
<i>Lepidostoma roafi</i>	28	9	297	127	461	4.6	NA

TABLE 3. Continued.

Caddisfly species	EMBI	TPI	TNI	SCI	CTI	WADJUS	USEPA
<i>Lenarchus vastus</i>	39	15	363	60	477	4.8	NA
<i>Limnephilus fumosus</i>	20	4	390	67	481	4.8	NA
<i>Psychoglypha alascensis</i>	35	23	347	131	536	5.3	NA
<i>Lepidostoma rayneri</i>	23	20	429	99	571	5.6	NA
<i>Onocosmoecus unicolor</i>	29	18	436	105	588	5.6	2
<i>Cheumatopsyche analis</i>	25	14	432	121	592	6.0	NA
<i>Lepidostoma cascadenae</i>	7	7	468	178	660	6.6	NA
<i>Hydroptila hamata</i>	82	15	451	115	663	6.7	NA
<i>Hydropsyche amblis</i>	10	10	572	131	723	7.2	NA
<i>Oecetis inconspicua</i>	50	21	629	101	801	8.0	8
<i>Oxyethira serrata</i>	99	104	475	212	890	8.9	NA
<i>Hydroptila arctica</i>	32	11	694	160	897	9.0	NA
<i>Agraylea multipunctata</i>	73	49	630	153	905	9.0	8
<i>Trianodes tardus</i>	41	32	709	128	910	9.0	6
<i>Polycentropus cinereus</i>	118	15	680	100	913	9.1	NA
<i>Hydroptila xera</i>	146	95	510	346	1097	10.0	NA

Cheumatopsyche analis, *Hydroptila* spp., *Lepidostoma unicolor*, *Oxyethira* spp., *Polycentropus variegatus*, and *Ptilostomis ocellifera*.

Arctopsyche grandis, *Brachycentrus americanus*, *Ecclisomyia conspersa*, *Hydroptila arctica*, *Hydropsyche oslari*, *Onocosmoecus unicolor*, *Polycentropus variegatus*, and *Stactobiella delira* were common species in each of the rivers on both west and east sides of the Cascade Range. These 8 species in clusters C and D composed at least 46% of the caddisfly assemblage in each of the 19 rivers on both sides of the Cascades.

Caddis Tolerance Values

Caddis tolerance values for nutrients (TPI, TNI), specific conductance (SCI), channel embeddedness (EMBI), and a combined Caddisfly Tolerance Index (CTI) are provided in Table 3 for 74 of the more common species in the region. The CTI values ranged from 0 to 10, with tolerance values ≤ 2.0 considered more sensitive to the combined measured environmental metrics and tolerance values ≥ 4.0 considered more tolerant to the measured environmental parameters.

Species in Rhyacophilidae, Hydropsychidae, and Limnephilidae had the widest range of CTI values throughout the region (Table 3). Rhyacophilidae species, including *Rhyacophila grandis*, *R. bifila*, *R. tucula*, and *R. vaefes* were found to be highly sensitive (CTI ≤ 1.0), whereas *R. vedra* and *R. vuzana* were more tolerant (CTI ≥ 3.5). Species in Glossosomatidae, Philopotamidae, and Uenoidae commonly had the lowest CTI values (CTI <

1.5), whereas species in Hydropsychidae, Hydroptilidae, and Leptoceridae had the highest values (CTI > 3.0).

Caddisfly assemblages in agricultural and urban landscapes had CTI values ranging from 3.5 to 10 and were common in lower-elevation streams and lakes with fine sediments. These landscapes commonly included *Arctopsyche grandis*, *Hydropsyche oslari*, *Lepidostoma cascadenae*, *Lepidostoma unicolor*, *Onocosmoecus unicolor*, and *Polycentropus variegatus*. Ninety-six percent of the caddisfly species with a CTI ranking ≥ 3.5 were collected on the west side compared to 64% on the east side of the Cascade Range (Appendix 2, Table 3).

In contrast, caddisfly assemblages in forest landscapes had CTI values ranging from 0.2 to 1.6 and were commonly associated with small, cool mountain streams (Table 3). Some of the more common species in forest landscapes included *Chyranda centralis*, *Ecclisocosmoecus scylla*, *Ecclisomyia conspersa*, *Glossosoma penitum*, *Oligophlebodes sierra*, *Parapsyche elsis*, and *R. vocala*.

DISCUSSION

Caddisfly species richness declined as channel conditions deteriorated throughout the study area. Crghino et al. (2003) determined species richness to be a valuable tool for assessing disturbance when a limited number of environmental variables are examined. Also, Martel et al. (2007) reported that caddisfly species richness had the greatest decline in areas after clear-cutting of forests.

Recently, Landeiro et al. (2012) tested the importance of dispersal processes versus in situ environmental factors on the composition of caddisfly species in Amazonian streams. They found that caddisflies were more dependent on environmental gradients within streams than on dispersal processes; therefore, caddisflies were good indicators of site properties and disturbance in monitoring programs. Miller et al. (2002) also found similar results for *Helicopsyche mexicana* and *Gumaga griseola* in the White Mountains of eastern Arizona.

The hierarchical multilevel dendrogram indicated that adult caddisflies were useful environmental indicators for both landscape and habitat conditions in Washington (Fig. 3). Caddisfly assemblages were separated into distinct clusters that included habitats associated with high-altitude landscapes, limited land use, agricultural and urban landscapes, and low-altitude streams and rivers on the west side of the Cascade Range and high-altitude streams and rivers on the east side (Fig. 3).

Pauls et al. (2006) reported a high level of genetic differentiation among mountain range populations of the caddisfly species *Drusus discolor*, which suggested limited adult dispersal capabilities between and over mountain ranges. Therefore, it is likely that a combination of both altitude and dispersal properties may be operating.

Several investigators have employed tolerance values or rankings for caddisflies under a variety of land-use conditions, but none have been developed for the state of Washington. Many of these rankings operate at the generic level (Black et al. 2004, Couceiro et al. 2007, Silalom et al. 2006), with only a few at the species level (Barbour et al. 1999, Blinn and Ruiter 2006, Houghton et al. 2011). Smith et al. (2007) used TP and nitrate to establish nutrient tolerance values in New York for stream macroinvertebrates and they determined TP and nitrate optima values for assorted caddisfly taxa.

Our Caddisfly Tolerance Index (CTI) rankings at the species level showed close agreement with published tolerance values for caddisfly species in Idaho (Northwest) listed by the United States Environmental Protection Agency (Barbour et al. 1999). Twenty-eight of the 56 caddisfly species listed from the Northwest were collected in this study, 17 of which were within one unit, and all but 4 within 2

units of the tolerance values. Also, our CTI results were generally within 1–2 units of the nutrient tolerance values for similar caddisfly genera and species reported by Smith et al. (2007). The large number and variety of sites, the multiple physicochemical parameters (TN, TP, specific conductance, and embeddedness), and the high level of taxonomic resolution increased the sensitivity of our tolerance index. Also, repeated collections at many sites over several years enhanced the utility of the tolerance index.

Though CTI values in Table 3 provide a cumulative evaluation of 4 environmental parameters, numeric values of each determinant can also be informative. For example, *Allocosmoecus paritus* had a low CTI value and low values for TP, specific conductivity, and embeddedness, but a relatively high value for TN (Table 3). *Allocosmoecus partitus* was exclusively collected in small, low-elevation (≤ 500 m) streams in forested areas with limited agricultural/recreational activities. This suggests that these habitats are at the initial stages of stream modification. Therefore, the disappearance of *A. partitus* might serve as an early indicator of disturbance in the surrounding landscape.

TPI values were relatively low throughout the caddisfly assemblages, which may suggest that TP is less of a disturbance factor than TN in Washington landscapes. However, the high TPI values for *Hydroptila xera* and *Oxyethira serrata* suggest a tolerance to TP (Table 3). These 2 species were collected in agricultural landscapes in Whatcom County, including California Creek, Fish Trap Creek, Terrell Creek, Lake Padden, Scudder Pond, Silver Lake, and Sumas River. TP levels were generally at least an order of magnitude higher in all of these systems compared to other aquatic habitats throughout the study area (Appendix 1).

Both TNI and SCI, however, had a much higher and wider range of values across the caddisfly assemblages (Table 3). Law et al. (2004) reported how human activities in urban areas can increase inputs of nitrogen. Also, elevated specific conductance values result from water running off impervious streets and parking lots that contain higher levels of inorganic dissolved solids such as chloride, sulfate, sodium, and calcium (Roy and Shuster 2009).

Black et al. (2004) ranked 45 stream sites in the Puget Sound Basin based on the level of

urban and agricultural disturbance. Fourteen of these streams were in the Nooksack River watershed and were included in our study. Six of these sites had watersheds with <1% disturbance, whereas 8 sites had watersheds with 22% to 86% disturbance. The average altitude for sites with high disturbance was 69 m (SE 25), which suggests that most of these streams were influenced by agricultural and urban activities.

In a comparison of CTI rankings to the disturbance rankings of Black et al. (2004), the average CTI value for caddisfly assemblages in sites in the Nooksack River watershed with low disturbance was 385 (SE 46) compared to 671 (SE 51) for sites with high disturbance. Therefore, caddisfly tolerance metrics can be a useful approach for monitoring changes in lotic ecosystems.

Disparities in CTI values for individual species may result from several factors. One species may have a relatively high tolerance value for 1 of the 4 measured variables, especially TN, and yield an overall high CTI value. Also, species from a nearby disturbed site may fly to a less disturbed site and influence the CTI value of the latter site. Therefore, species assemblages provide a more realistic evaluation of environmental conditions than individual species.

Abell et al. (2000) reported greater threats to aquatic ecosystems on the west side of the North Cascade Range compared to those on the east. The overall higher CTI values for caddisfly assemblages on the west side also suggest greater threats to this area.

Also, average TN in habitats west of the Cascades was 7 times higher than TN of habitats on the east side (Table 2). Crop, dairy, and livestock farming are common west of the Cascades, especially in Whatcom County, whereas dry-land farming and ranching are prominent east of the Cascades (personal observation). Farms on the west side frequently use manure as a nutrient source for crop production. If manure applications exceed the capacity of the crop to incorporate the nutrients, a surplus will remain in the soil and eventually move into streams and rivers on the watershed (Cogger et al. 1999). The higher levels of TN in streams on the west side compared to the east side suggest this may be occurring.

In addition, average specific conductance was 25% higher in streams on the west side,

which may be due in part to regions of poorly drained soils in Whatcom County (Goldin 1992). There were significant negative correlations between TN and specific conductivity with species richness in the study area (Table 1).

Several other factors were important in determining caddisfly distributions. No adult caddisflies were collected in light traps at air temperatures $\leq 9^{\circ}\text{C}$. Blinn and Ruiter (2006) also reported no adult caddisfly captures at temperatures $<12^{\circ}\text{C}$ throughout Arizona, and Kimura et al. (2008) found no adults in light traps at temperatures $<10.7^{\circ}\text{C}$ in the Shinano River in central Japan. Abundance, diversity of adult caddisflies, and proportion of males were also reduced at dusk temperatures $<10^{\circ}\text{C}$ in the northern regions of Minnesota (Houghton 2004). Furthermore, Waringer (1991) reported that dusk temperature greater than 7°C was necessary to obtain a representative sample.

No larval or adult caddisflies were collected in California Creek (Site 2; Appendix 1). This is a 1st-order tidal stream in an agricultural region with limited hard surfaces and fluctuating specific conductance readings as high as $50\text{ mS} \cdot \text{cm}^{-1}$. To date, there are only a few reports of caddisfly larvae inhabiting marine and/or inland saline systems in North America (Colburn 1983, Flint and Giberson 2005), and none reported from coastal regions in Washington. Colburn (1983) reported *Limnephilus assimilis* from inland saltwater habitats in Death Valley, California, with salinities from 11 to 25 ppt, and Flint and Giberson (2005) reported *Limnephilus ademus* in salt marshes with salinities from 5 to 25 ppt in Prince Edward Island, Canada.

In addition, no larval or adult caddisflies were collected at the 2 lower sites of Nooksack River in Lynden and Slater Bridge (Sites 1 and 17; Appendix 1). These 2 sites are 4th- to 5th-order river sites with limited hard surfaces for larval attachment in a heavy dairy and crop farming region.

Future studies are needed in the Columbia Unglaciated freshwater ecoregion that runs along the southern border of Washington and into Oregon and Idaho in the Blue Mountains of the Umatilla National Forest (Abell et al. 2000). This region escaped glaciation during the Pleistocene and may yield endemic invertebrates not yet described (Scudder 1996). This may be especially true for seeps and springs in the region.

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APPENDIX 1. Site, location, altitude (ALTI), maximum water temperature (MTEM), total phosphorus (TP), total nitrogen (TN), specific conductance (SPCO), canopy cover (CAN), embeddedness (EMBE), suspended sediment (SUSE), and caddisfly richness (RICH) for 181 streams, rivers, seeps, and lakes in northwestern Washington, USA, including North Cascades National Park and Mt. Baker-Snoqualmie, Okanogan, and Wenatchee national forests. Sites are listed in order of increasing elevation. Counties include the following: CH = Chelan, KIN = King, KIT = Kittitas, OK = Okanogan, SK = Skagit, SN = Snohomish, and WH = Whatcom. NA = not available; NCNP = North Cascades National Park. Lakes and ponds are in boldface type. Information and collections by National Park Service and North Cascades National Park Service Complex, Sedro Woolley, WA. * sampled 2 different years; ** sampled 3 or more years.

Site	Location	ALTI (m)	MTEM (°C)	TP ($\mu\text{g}\cdot\text{L}^{-1}$)	TN ($\mu\text{g}\cdot\text{L}^{-1}$)	SPCO ($\text{mS}\cdot\text{cm}^{-1}$)	CAN (%)	EMBE (%)	SUSE ($\text{mg}\cdot\text{L}^{-1}$)	RICH
1	Nooksack River at bridge on Slater Rd. (WH)**	3	20	58	190	0.110	5	99	16	0
2	California Cr.; Knickerville Rd. (WH)**	4	27	30	2359	26.200	5	99	4	0
3	Squalicum Cr.; Bellingham (WH)*	5	19	25	578	0.247	30	55	5	2
4	California Cr.; Valley View Rd. (WH)*	7	19	181	3238	0.381	95	95	2	8
5	Terrell Cr. on Jackson Rd. (WH)*	10	20	9	1209	0.490	95	95	1	5
6	Johnson Cr. in Sumas, WA (WH)*	13	20	84	5615	0.264	85	85	5	8
7	Oyster Cr.; Chuckanut Drive (SK)*	13	17	4	1420	1.187	85	10	2	17
8	Chuckanut Cr.; Fairhaven (WH)*	15	19	11	951	0.243	90	15	2	11
9	Tennile Cr. on Tennile Rd. (WH)*	22	19	52	817	0.340	5	95	3	2
10	Fourmile Cr. on Tennile Rd. (WH)*	22	21	85	3157	0.386	5	95	5	2
11	Dakota Cr. on Valley View Rd. (WH)	23	20	NA	NA	0.298	90	75	1	6
12	Fever Cr.; Bellingham (WH)*	24	18	19	527	0.262	60	40	1	2
13	Scudder Pond, Bellingham (WH)*	25	22	787	99	0.182	0	95	1	5
14	Breckenridge Cr., Goodwin Rd. (WH)*	25	19	19	401	0.244	90	15	3	6
15	Whatcom Cr.; Bellingham (WH)*	25	22	8	440	0.226	20	20	4	13
16	Unknown stream to Dakota Cr. (WH)*	27	19	30	1021	0.180	85	20	2	6
17	Nooksack R. in Lynden, WA (WH*)	30	19	57	197	0.093	5	99	10	0
18	Fish Trap Cr. (Hwy. 546) (WH)*	33	20	24	3429	0.303	45	85	5	5
19	Sumas River on Lindsay Rd. (SK)*	33	25	NA	NA	0.088	70	50	5	6
20	Nooksack River on Lindsay Rd. (WH)*	33	20	54	974	0.360	5	95	12	12
21	Nooksack River at Cedarville (WH)**	33	17	20	105	0.080	5	80	156	2
22	Stillquamish River on Strotz Rd. (SN)*	34	16	6	188	0.045	5	25	1	3
23	Bear Cr. on 136th Street, Redmond, WA (KIN)	38	20	NA	NA	0.060	75	35	2	4
24	Bear Cr.; Cain Lk. Rd. (SK)**	40	18	4	609	0.102	80	25	2	10
25	Baker River in Concrete (SK)	48	19	25	110	0.045	5	85	15	8
26	Swift Cr. bridge on Goodwin Rd. (WH)*	50	21	10	390	0.230	595	5	5	5
27	Grandy Cr. (Mi 82.7), Hwy. 20 (SK)*	53	16	11	217	0.200	70	45	5	14
28	Smith Cr. (Mi 11.4), Hwy. 542 (WH)*	54	16	7	275	0.084	85	35	1	11
29	Jackman Cr. (Mi 91), Hwy. 20 (SK)*	55	21	5	158	0.060	60	40	5	9
30	Lake Terrell (WH)	65	27	36	1149	0.098	0	99	2	9
31	Nooksack River (bridge on Hwy. 9) (WH)**	69	16	20	105	0.080	5	95	15	7
32	Bacon Cr. (Mi 110.8), Hwy. 20 (SK)	70	13	4	68	0.040	50	20	1	8
33	Lake Padden, Bellingham (WH)*	74	19	11	471	0.055	5	99	1	3
34	Padden Cr.; Padden Cr. Park (WH)*	75	18	10	638	0.183	95	10	1	4

APPENDIX 1. Continued.

Site	Location	ALTI (m)	MTEM (°C)	TP (µg·L ⁻¹)	TN (µg·L ⁻¹)	SPCO (mS·cm ⁻¹)	CAN (%)	EMBE (%)	SUSE (mg·L ⁻¹)	RICH
35	Sammish Lake, Bellingham, WA (WH)*	75	21	19	370	0.068	10	40	2	1
36	Skagit River at Rockport (SK)*	76	16	16	35	0.088	50	10	10	10
37	Samish River (old Hwy. 99) (SK)*	82	16	9	757	0.128	60	40	4	13
38	N. Fork Stillquamish (Mi 38.2), Hwy. 530 (SN)*	83	16	NA	NA	0.068	5	15	5	9
39	Anderson Cr. on Martin Rd. bridge (WH)	84	21	19	425	0.208	80	80	5	6
40	S. Fork Nooksack River; Hwy. 9 bridge (WH)*	84	17	7	131	0.120	30	25	5	9
41	Friday Cr.; Friday Cr. Rd. (SK)**	90	19	8	572	0.135	80	15	2	2
42	Lake Whatcom; Agate Bay (WH)	93	19	4	455	0.063	5	80	5	8
43	Sauk River (Mi 59.6), Hwy. 530 (SK)*	93	19	28	31	0.050	5	20	150	7
44	Lake Whatcom, Agate Bay (WH)**	96	19	4	455	0.063	5	80	5	5
45	Jordan Cr., Marblemount, WA (SK)	96	14	NA	NA	0.023	75	10	1	9
46	Skagit River at Marblemount, WA (SK)	96	14	7	71	0.040	10	90	5	3
47	Carpenter Cr.; Bellingham (WH)*	96	15	22	660	0.119	95	25	1	6
48	Wall Seep at Mi 71.3, Hwy. 9 (WH)*	98	16	31	363	0.085	75	20	1	4
49	N. Fork Nooksack on Mosquito Rd. (WH)*	98	15	7	64	0.095	10	65	14	9
50	White Cr. (Mi 60.6), Hwy. 530 (SK)*	99	18	5	66	0.060	80	15	1	24
51	Anderson Cr. bridge on Hwy. 542 (WH)**	103	18	18	400	0.126	85	20	1	14
52	Canyon Cr. on Mosquito Lk. Rd. (WH)**	105	17	4	73	0.100	70	15	1	37
53	Bell Cr. (Mi 17.4), Hwy. 542 (WH)	107	16	NA	NA	0.076	80	10	2	12
54	S. Fork Nooksack on Saxon Rd. (WH)*	108	16	5	120	0.073	20	20	5	10
55	Olsen Cr.; N. Shore Dr., Bellingham (WH)*	114	16	16	460	0.137	75	20	2	7
56	Kendell Cr., Nooksack Fish Hatchery (WH)*	124	16	7	586	0.203	25	80	2	7
57	Coal Cr. (Mi 22.7), Hwy. 542 (WH)**	124	16	NA	NA	0.098	80	5	2	20
58	Rocky Cr. (Mi 102.6), Hwy. 20 (SK)*	133	18	4	79	0.100	75	35	1	12
59	Squalicum Lk. on Squalicum Lk. Rd. (WH)	133	25	NA	NA	0.070	5	95	1	3
60	Squire Cr. at Squire Cr. campground (SN)*	134	16	NA	NA	0.032	85	15	1	8
61	Proctor Cr. (Mi 31.2), Hwy. 2 (SN)*	134	16	15	145	0.016	90	5	8	8
62	Mirror Lake (WH)*	135	22	12	343	0.055	10	95	1	7
63	Fir Cr.; Sudden Valley (WH)*	138	15	18	956	0.069	85	55	1	3
64	Smith Cr.; Rd. 3263 at bridge (WH)*	139	16	7	272	0.085	85	20	1	9
65	Brannian Cr.; Sudden Valley (WH)*	139	15	14	1016	0.050	90	55	1	4
66	Austin Cr.; Sudden Valley (WH)*	147	17	12	444	0.149	90	10	1	9
67	Porter Cr. on Mosquito Lk. Rd. (WH)**	149	17	4	188	0.050	15	10	1	16
68	Middle F Nooksack on Mosquito Rd. (WH)*	152	15	7	89	0.100	10	30	50	9
69	Dannation Cr. (Mi 115), Hwy. 20 (SK)	157	14	4	94	0.040	20	20	5	7
70	Silver Lake (WH)*	157	25	9	225	0.144	5	80	1	6
71	Bog pond (Mi 6.1) on Mosquito Rd. (WH)*	161	17	48	551	0.127	15	95	5	17
72	Maple Cr. (Mi 26.1), Hwy. 542 (WH)**	165	16	4	855	0.192	10	10	7	18
73	N. Fork Nooksack (Mi 27), Hwy. 542 (WH)**	168	14	11	48	0.060	5	20	18	6

APPENDIX 1. Continued.

Site	Location	ALTI (m)	MTEM (°C)	TP ($\mu\text{g}\cdot\text{L}^{-1}$)	TN ($\mu\text{g}\cdot\text{L}^{-1}$)	SPCO ($\text{mS}\cdot\text{cm}^{-1}$)	CAN (%)	EMBE (%)	SUSE ($\text{mg}\cdot\text{L}^{-1}$)	RICH
74	Hutchinson Cr. bridge on Mosquito Rd. (WH)*	174	15	11	268	0.092	95	10	1	13
75	Saar Cr. on South Pass Rd. (WH)*	183	18	6	605	0.152	85	20	1	23
76	Bog pond off Mosquito Lk. Rd. (WH)	184	16	NA	NA	0.103	35	95	1	11
77	Boulder Cr. (Mi 26.6), Hwy. 542 (WH)**	194	14	7	160	0.110	5	5	15	16
78	Stream near Boulder Cr. (Mi 28.5) (WH)*	195	14	NA	NA	0.171	20	5	1	12
79	Stream 5.5 mi on Mosquito Lk. Rd. (WH)	197	16	NA	NA	0.114	95	5	1	8
80	Stream at Mi 9.2 on Mosquito Lk. Rd. (WH)**	201	15	12	437	0.085	85	25	1	14
81	Mosquito Lake on Mosquito Lk. Rd. (WH)*	203	16	48	551	0.128	5	95	1	4
82	Toad Lake, Bellingham, WA (WH)	217	22	9	934	0.114	10	80	2	5
83	Cornell Cr. (Mi 32.5), Hwy. 542 (WH)**	263	14	4	113	0.050	60	5	2	27
84	Trib. into Colony Cr.; Blanchard Mt. (WH)	265	12	NA	NA	0.030	75	15	1	7
85	Sulphur Cr. (Mi 13.3), Baker Lk. Rd. (WH)*	269	15	NA	NA	0.036	90	15	1	10
86	Glacier Cr. on Hwy. 542 (WH)**	272	12	38	61	0.065	5	15	325	17
87	Galloper Cr. on Hwy. 542 (WH)**	274	14	11	301	0.060	45	15	1	37
88	Bear Cr. (Mi 9.5), Baker Lk. Rd. (SK)*	287	16	NA	NA	0.070	75	25	2	15
89	N. Fork Nooksack (Mi 35.3), Hwy. 542 (WH)**	292	13	22	89	0.070	40	20	16	12
90	Wall seep (Mi 125.3), Hwy. 20 (WH)	310	12	5	8	0.051	50	20	1	5
91	Thompson Cr. on FS 39 (WH)*	324	13	29	408	0.080	95	10	1	5
92	Wall seep (Mi 125.1), Hwy. 20 (WH)*	337	13	4	9	0.066	50	5	1	14
93	Stream (Mi 123.5), Hwy. 20 (WH)*	341	13	4	46	0.050	50	20	1	2
94	Stream/falls (Mi 123.6), Hwy. 20 (WH)	351	14	4	56	0.050	50	20	1	2
95	Stream/falls (Mi 124.4), Hwy. 20 (WH)*	353	12	4	75	0.062	20	10	1	9
96	Falls Cr. on FS 38 (WH)*	369	13	9	231	0.070	95	5	1	11
97	Clearwater Cr. on FS 38 (WH)*	373	13	7	68	0.064	5	5	5	3
98	Cascade River, 0.9 mi on FS 1550 (SK)*	377	12	41	63	0.027	20	10	5	5
99	Wall seep on FS Rd. 1550 (SK)	377	16	25	14	0.169	90	25	1	7
100	Stream at Mi 38.9 bridge; Hwy. 542 (WH)	385	15	NA	NA	0.127	15	5	1	3
101	Skykomish River (Mi 54.8), Hwy. 2 (KIN)	385	15	16	35	0.025	5	10	8	5
102	Tye River (Mi 55.6), Hwy. 2 (KIN)	416	14	NA	NA	0.026	95	5	1	22
103	Wenatchee River (Mi 96.5), Hwy. 2 (CH)*	422	15	19	94	0.026	5	10	16	14
104	Monogram Cr. on Cascade Rd. (SK)	429	18	5	273	0.030	80	5	1	7
105	Methow River at Carlton (OK)	430	18	NA	NA	0.102	65	25	1	3
106	N. Fork Nooksack River at Falls (WH)**	458	14	22	64	0.036	20	65	5	12
107	Wall seep near Nooksack Falls (FS 33) (WH)*	467	16	NA	NA	0.060	80	10	1	8
108	Trib. near Nooksack Falls (FS 33) (WH)**	469	12	20	40	0.080	85	20	11	9
109	Stream (Mi 40.1), Hwy. 542 (WH)*	474	12	7	67	0.130	80	20	1	15
110	Stream on Paradise Valley Rd. (WH)	478	13	NA	NA	0.065	70	20	1	3
111	Yakima River at Ellensburg (KIT)	495	20	NA	NA	0.105	5	25	16	8
112	Twisp River near Twisp (OK)*	500	18	8	173	0.144	40	40	5	17

APPENDIX 1. Continued.

Site	Location	ALTI (m)	MTEM (°C)	TP (µg·L ⁻¹)	TN (µg·L ⁻¹)	SPCO (mS·cm ⁻¹)	CAN (%)	EMBE (%)	SUSE (mg·L ⁻¹)	RICH
113	Wenatchee River (Mi 90.5), Hwy. 2 (CH)*	506	15	18	90	0.027	5	10	20	14
114	Stream (Mi 40.9), Hwy. 542 (WH)**	521	13	5	51	0.074	90	15	1	19
115	Chewuch River in Windrop, WA (OK)*	537	16	7	98	0.120	25	15	1	13
116	Beaver Cr. (Mi 205.9), Hwy. 20 (OK)	541	18	53	240	0.133	35	30	8	15
117	Irrigation ditch in Windrop, WA (OK)*	541	14	NA	NA	0.120	50	20	1	10
118	Stream/falls (Mi 41.6), Hwy. 542 (WH)*	558	12	4	22	0.060	15	10	1	12
119	Stream (Mi 42.8), Hwy. 542 (WH)*	574	15	4	8	0.131	10	5	1	6
120	Chiwaukum Cr. (Mi 89.9), Hwy. 2 (CH)*	574	14	29	157	0.029	45	5	1	17
121	Skinny Cr. (Mi 88.5), Hwy. 2 (CH)*	574	15	5	101	0.208	0	35	16	11
122	N. Fork Nooksack (Mi 45.2), Hwy. 542 (WH)*	592	12	29	67	0.033	10	15	15	12
123	Cle Elum River 1-90 (KIT)	599	17	10	61	0.051	5	10	5	14
124	N. Fork Nooksack; Hanneegan Pass (WH)*	608	12	20	53	0.029	5	5	1	6
125	Swamp Cr.; Hanneegan Pass Rd. (WH)*	609	13	4	55	0.076	10	35	5	7
126	Stream (Mi 46.2), Hwy 542 (WH)*	610	13	10	6	0.141	5	5	1	19
127	Teenaway River (Mi 6.3), Hwy. 970 (KIT)	614	23	51	207	0.162	5	20	5	15
128	Big Cr. on Nelson Siding Rd. (KIT)	618	15	16	35	0.090	90	20	1	7
129	Little Cr. on Nelson Siding Rd. (KIT)	619	15	18	45	0.125	90	25	1	11
130	Yakima River (Mi 79.1) I-90 (KIT)	620	17	16	108	0.065	35	10	10	8
131	Stream/falls 1.2 mi on Hanneegan Pass (WH)*	634	14	4	46	0.062	5	5	1	9
132	Nason Cr. (Mi 81.4), Hwy. 2 (CH)*	644	12	15	35	0.038	25	10	5	19
133	Lower Goat Cr., Goat Cr. Rd. (OK)*	660	16	5	25	0.099	10	5	5	9
134	Methow River at Mazama, WA (OK)*	664	15	4	28	0.090	25	5	5	14
135	Loup Loup Cr. (Mi 222.2), Hwy. 20 (OK)	664	14	61	166	0.188	30	15	1	8
136	Early Winter Cr. campground Hwy. 20 (OK)	669	14	4	29	0.070	10	5	5	11
137	Varden Cr. (Mi 173.1), Hwy. 20 (OK)	675	13	4	17	0.042	5	5	1	7
138	Wall seep 1.5 Mi on FS 33 (WH)**	676	15	NA	NA	0.061	90	5	1	13
139	Upper Goat Cr., FS 52 (OK)*	686	15	5	20	0.061	5	5	1	9
140	Boulder Cr. on FS 37 near Windthrop (OK)*	694	16	6	78	0.080	10	5	1	20
141	Stream (Mi 48.1), Hwy. 542 (WH)*	712	11	4	19	0.066	75	5	1	8
142	Barr Cr. (Mi 4.4) FS 33 (WH)*	715	11	12	83	0.147	0	15	785	5
143	Wells Cr. (Mi 4.4) FS 33 (WH)*	718	12	8	44	0.060	5	10	1	8
144	Wall seep at Wells Cr. (Mi 4.4) FS 33 (WH)*	729	11	4	42	0.205	75	20	1	12
145	Wall seep (Mi 47.6), Hwy. 542 (WH)*	734	15	8	32	0.104	5	5	1	5
146	Wall seep (Mi 48.6), Hwy. 542 (WH)*	741	15	4	38	0.168	20	10	1	19
147	Stream/falls (Mi 144.3), Hwy. 20 (WH)	763	12	4	51	0.034	20	5	1	8
148	Stream/falls (Mi 60.8), Hwy. 2 (KIN)	792	11	NA	NA	0.046	25	10	1	2
149	Bagley Cr. (Mi 49.1), Hwy. 542 (WH)**	822	12	8	106	0.033	95	5	1	30
150	Frazer Cr. (Mi 210.3), Hwy. 20 (OK)	848	15	51	180	0.161	95	15	3	13
151	Lower Galena Cr. (Mi 50.4), Hwy. 542 (WH)**	902	14	4	56	0.062	90	5	1	16

APPENDIX I. Continued.

Site	Location	ALTI (m)	MTEM (°C)	TP ($\mu\text{g}\cdot\text{L}^{-1}$)	TN ($\mu\text{g}\cdot\text{L}^{-1}$)	SPCO ($\text{mS}\cdot\text{cm}^{-1}$)	CAN (%)	EMBE (%)	SUSE ($\text{mg}\cdot\text{L}^{-1}$)	RICH
152	Ruth Cr. at Ruth Cr. campground (WH)	934	12	4	91	0.022	75	5	1	6
153	Swank Cr. (Mi 159.7), Hwy. 97 (KIT)	944	16	38	28	0.246	95	25	5	3
154	Whiteface Cr., FS 52 (OK)	967	14	NA	NA	0.086	90	10	1	10
155	Stream at bridge (Mi 51.4), Hwy. 542 (WH)	1051	14	NA	NA	0.031	80	10	1	12
156	Wall seep (Mi 52.1), Hwy. 542 (WH)*	1051	14	NA	NA	0.034	50	75	1	13
157	Unknown stream at (Mi 52.3), Hwy. 542 (WH)	1052	12	NA	NA	0.013	95	10	1	10
158	Long Cr. on FS 52 (OK)	1080	13	NA	NA	0.095	90	10	1	5
159	Jack Cr. (Mi 213.9), Hwy. 20 (OK)	1117	12	30	194	0.108	95	5	1	4
160	Upper Galena Cr. (Mi 53.8), Hwy. 542 (WH)*	1192	12	4	43	0.021	90	5	1	15
161	Wall seep (Mi 54), Hwy. 542 (WH)**	1229	16	5	117	0.016	25	5	1	16
162	Highwood Lake, Mt. Baker (WH)*	1238	19	15	163	0.037	0	95	1	7
163	Lower Diobsud Lake, NCNP (WH)	1286	14	NA	NA	0.040	0	NA	1	3
164	Picture Lake, Mt. Baker (WH)**	1317	19	8	164	0.062	0	90	1	10
165	Stream on Fire & Ice trail (WH)**	1329	12	11	30	0.025	0	5	1	24
166	Stream near Heather Info Center (WH)*	1343	16	4	0.8	0.006	0	5	1	10
167	Unknown Lake, Mt. Baker (WH)*	1344	18	13	130	0.013	0	75	1	9
168	Wall seep at Artist Point Hwy (WH)*	1381	13	4	57	0.004	0	5	0	1
169	Easy Ridge Lake, NCNP (WH)	1382	18	NA	NA	0.006	0	NA	NA	3
170	Sourdough Lake, NCNP (WH)	1407	16	NA	NA	0.014	6	NA	NA	4
171	Bridge Cr. (Mi 158.7), Hwy. 20 (CH)*	1414	10	4	42	0.030	10	5	4	4
172	Jeanita Lake, NCNP (WH)	1495	14	NA	NA	0.032	0	NA	NA	4
173	Lower Berdeen Lake, NCNP (WH)	1524	25	NA	NA	0.040	0	NA	NA	2
174	Upper Wilcox Lake, NCNP (SK)	1565	15	NA	NA	0.030	0	NA	NA	1
175	Early Winter Headwaters (OK)*	1570	13	NA	NA	0.009	0	10	1	2
176	Sweet Pea Lake, NCNP (SK)	1692	8	NA	NA	0.034	0	NA	NA	4
177	Kettling Lake, NCNP (CH)	1693	12	NA	NA	0.028	60	NA	NA	5
178	Stream/lake, Wenatchee campground (CH)	1860	17	NA	NA	0.024	0	90	1	9
179	Middle Blum Lake, NCNP (WH)*	1997	12	NA	NA	0.015	0	NA	NA	4
180	Upper Triplet Lake, NCNP (CH)	1997	14	NA	NA	0.039	0	NA	NA	6
181	Lower Lake Silent, NCNP (SK)	2042	11	NA	NA	0.100	0	NA	NA	3

APPENDIX 2. Mean frequency (%), percentage of habitats where taxa occurred (%), range in altitude (m), maximum water temperature (°C), mean embeddedness (%), habitat (LK = lake, SE = wall seep, ST = stream and river); location (W = west of Cascade Range, E = east of Cascade Range) for 164 caddisfly species collected in 181 sites in northwestern and central Washington. Asterisks (*) indicate new Washington State records. Standard errors are given in parentheses.

Species	Mean frequency (%)	% of habitats	Altitude (m)	Maximum water temp (°C)	Mean embed-dedness (%)	Habitat	Location
Apataniidae							
<i>Allomyia cascadiis</i> (Ross)	11.7 (7.4)	1.7	1329–1344	16	49.7 (24.7)	ST	W
<i>Apatania sorex</i> (Ross)	100.0	0.6	1181	14	5.0	ST	W
<i>Pedlmoecus sierra</i> Ross	3.1 (2.3)	4.4	105–848	18	19.4 (2.0)	ST	W, E
Brachycentridae							
<i>Amiocentrus aspius</i> (Ross)	4.5 (2.9)	2.8	108–422	17	5.0	ST	W, E
<i>Brachycentrus americanus</i> (Banks)	9.5 (1.9)	19.9	33–837	22	25.2 (3.7)	ST	W, E
<i>Micrasema bactro</i> Ross	7.7 (3.4)	9.9	52–644	19	19.3 (2.8)	ST	W, E
Glossomatidae							
<i>Agapetus taho</i> Ross*	7.3 (5.0)	4.4	90–694	19	15.0 (3.9)	ST	W, E
<i>Anagapetus bernea</i> Ross	6.5 (3.5)	2.8	263–741	16	13.8 (4.3)	ST, SE	W, E
<i>Anagapetus debilis</i> (Ross)	14.3	0.6	1080	14	5.0	ST	E
<i>Anagapetus hoodi</i> Ross	1.2	0.6	469	14	10.0	ST	W
<i>Glossosoma penitum</i> Banks	7.3 (1.4)	12.7	13–848	18	14.3 (3.2)	ST	W, E
<i>Glossosoma plerna</i> Ross*	6.1	0.6	432	18	14.0	ST	E
<i>Glossosoma pyroxum</i> Ross	11.3 (4.5)	1.1	82–90	14	25.0 (10)	ST	W
<i>Glossosoma traviatum</i> Banks	0.6	0.6	614	22	20.0	ST	E
<i>Glossosoma uenatchee</i> Ross & Spencer	2.9 (0.6)	5.5	99–967	18	9.5 (2.3)	ST	W, E
<i>Protophila coloma</i> Ross	3.9 (3.6)	1.1	495–537	15	30.0 (10.0)	ST	W, E
Goeridae							
<i>Goeracea genota</i> (Ross)	5.9 (1.4)	2.8	377–1023	16	12.5 (2.5)	ST, SE	W
Hydropsychidae							
<i>Arctopsycha grandis</i> (Banks)	17.4 (3.4)	26.0	53–712	16	17.4 (3.4)	ST, SE	W, E
<i>Cheumatopsycha andis</i> (Banks)	13.9 (11.8)	2.8	13–33	18	65.0 (20.2)	ST	W
<i>Cheumatopsycha mollala</i> Ross*	23.4	0.6	611	22	20.0	ST	E
<i>Hydropsycha ambilis</i> Ross	14.7 (3.7)	9.4	13–660	18	13.2 (1.7)	ST	W, E
<i>Hydropsycha californica</i> Banks	7.1	0.6	495	18	15.0	ST	E
<i>Hydropsycha centra</i> Ross	5.7	0.6	69	17	15.0	ST	W
<i>Hydropsycha cockerelli</i> Banks	10.3 (9.4)	1.7	25–664	22	16.7 (1.7)	ST	W, E
<i>Hydropsycha occidentalis</i> Banks	12.4 (3.7)	7.0	465–848	18	20.7 (2)	ST	E
<i>Hydropsycha oslari</i> Banks	9.5 (2.7)	29.1	45–1329	22	11.8 (1.3)	ST	W, E
<i>Parapsycha alnota</i> Ross	16.4 (9.8)	5.0	13–858	16	18.3 (8.4)	ST, SE	W, E
<i>Parapsycha elsis</i> Milne	17.2 (2.6)	27.9	49–1692	16	15.0 (2.6)	ST, SE	W, E
Hydroptilidae							
<i>Agraylea multipunctata</i> Curtis	4.0 (1.2)	5.0	10–664	22	57.1 (13.2)	ST, LK	W, E
<i>Agraylea saltesea</i> Ross	1.0 (0.6)	1.7	274–967	17	16.7 (9.3)	ST	E

APPENDIX 2. Continued.

Species	Mean frequency (%)	% of habitats	Altitude (m)	Maximum water temp (°C)	Mean embed-dedness (%)	Habitat	Location
<i>Hydropila gjar</i> Ross	4.5	0.6	90	17	15.0	ST	W
<i>Hydropila arctica</i> Ross*	13.1 (5.5)	6.1	15-665	20	38.0 (6.0)	ST	W, E
<i>Hydropila argosa</i> Ross	13.5 (5.7)	1.1	53-495	16	40.0 (5.0)	ST	W, E
<i>Hydropila consimilis</i> Morton	12.3 (2.3)	1.1	33-48	20	85.0 (5.0)	ST	W
<i>Hydropila hamata</i> Morton	19.4 (6.9)	4.3	25-1860	22	50.0 (13.8)	ST, LK	W, E
<i>Hydropila modica</i> Mosely	0.3 (0.1)	1.1	25-609	22	20.0 (5.0)	ST	W, E
<i>Hydropila rono</i> Ross	19.8 (10.7)	2.8	90-632	19	13.8 (1.3)	ST	W
<i>Hydropila xera</i> Ross	12.4 (4.6)	2.8	13-495	20	77.5 (14.2)	ST	W, E
<i>Leuctrichia</i> sp.	21.4	0.6	495	20	15.0	ST	E
<i>Ochrotrichia alsea</i> Denning & Bickle	3.3	0.6	84	18	15.0	ST	W
<i>Ochrotrichia tarsalis</i> (Hagen)	1.8	0.6	157	25	95.0	LK	W
<i>Ochrotrichia cristata</i> Morton*	0.8	0.6	33	20	90.0	ST	W
<i>Orthotrichia aegorfaciella</i> (Chambers)	1.4	0.6	83	18	15.0	ST	W
<i>Oxyethira dualis</i> Morton*	12.1 (43.7)	1.1	13-23	20	82.5 (2.5)	ST	W
<i>Oxyethira serrata</i> Ross*	47.5 (21.7)	2.8	4-75	23	93.8 (1.3)	ST, LK	W
<i>Oxyethira zeronia</i> Ross*	5.3	0.6	4	20	95.0	ST	W
<i>Stactobiella delira</i> (Ross)	14.2 (3.4)	17.1	48-676	24	22.8 (4.5)	ST, SE, LK	W, E
Lepidostomatidae							
<i>Lepidostoma cascadenae</i> (Milne)	8.7 (3.3)	12.7	13-1495	15	11.4 (2.0)	ST, SE, LK	W, E
<i>Lepidostoma cinereum</i> (Banks)	2.0	0.6	135	15	5.0	LK	W
<i>Lepidostoma hoodi</i> Ross	5.0 (2.6)	4.4	194-902	15	8.6 (1.4)	ST, SE	W
<i>Lepidostoma jewetti</i> Ross	2.8 (1.6)	1.7	337-619	16	8.3 (1.7)	ST, SE	W, E
<i>Lepidostoma rayneri</i> Ross	6.0 (1.4)	8.3	25-664	18	16.7 (1.9)	ST	W, E
<i>Lepidostoma reclinum</i> Denning	0.6	0.6	469	14	20.0	ST	W
<i>Lepidostoma roafi</i> Milne	28.0 (19.5)	3.3	351-1192	14	15.0 (5.8)	ST	W
<i>Lepidostoma unicolor</i> (Banks)	5.8 (1.7)	13.8	40-1695	18	26.7 (4.8)	ST	W, E
Leptoceridae							
<i>Ceraclea alagna</i> Ross	2.8 (1.1)	1.1	65-93	18	90.0 (5.6)	LK	W
<i>Ceraclea annulicornis</i> (Stephens)	1.1	0.6	422	16	15.0	ST, LK	E
<i>Ceraclea tarsipunctatus</i> (Vorbies)*	2.1	0.6	495	20	25.0	ST	E
<i>Mystacides alafimbriata</i> Hill-Griffin	6.0 (5.0)	5.0	13-157	20	36.0 (11.0)	ST, LK	W
<i>Oecetis atara</i> (Banks)	1.7 (1.3)	1.1	500-537	18	27.5 (7.5)	ST	E
<i>Oecetis inconspicua</i> (Walker)	8.9 (3.7)	7.7	7-669	24	42.7 (11.0)	ST, LK	W, E
<i>Trienodes baris</i> Ross*	0.8 (0.6)	1.1	25-65	22	50.0 (35)	ST, LK	W
<i>Trienodes tardus</i> Milne	6.8 (2.8)	8.8	7-620	24	36.2 (8.0)	ST, LK	W, E
Limnephilidae							
<i>Alloctenocercus paritatus</i> Banks	3.8 (2.7)	5.0	183-944	16	9.4 (1.8)	ST	W, E
<i>Amphictenocercus canax</i> (Ross)*	1.5	0.6	353	12	10.0	ST	W
<i>Chyandra centralis</i> (Banks)	11.9 (2.5)	19.3	99-1997	16	10.7 (1.3)	ST, SE, LK	W, E

APPENDIX 2. Continued.

Species	Mean frequency (%)	% of habitats	Altitude (m)	Maximum water temp (°C)	Mean embed-dedness (%)	Habitat	Location
<i>Clistronia magnifica</i> (Banks)	3.7 (1.8)	1.1	82–184	17	32.5 (2.5)	LK	W
<i>Cryptochia pilosa</i> (Banks)	0.8	0.6	263	14	20.0	ST	W
<i>Dicosmoecus atripes</i> (Hagen)	7.8 (2.9)	10.5	195–1693	17	11.5 (2.1)	ST, SE	W, E
<i>Dicosmoecus gilvipes</i> (Hagen)	5.4 (4.2)	12.7	13–694	19	13.0 (3.4)	ST	W, E
<i>Ecclosocmoecus scylla</i> (Milne)	5.4 (1.2)	3.3	274–1329	17	7.7 (1.0)	ST, SE	W, E
<i>Ecclosomyia conspersa</i> Banks	19.2 (3.2)	30.9	107–1180	17	12.2 (1.2)	ST, SE, LK	W, E
<i>Ecclosomyia maculosa</i> Banks	8.9 (2.9)	5.0	99–1692	16	9.0 (2.1)	ST, SE	W, E
<i>Ecclosomyia simulata</i> Bank	2.8 (2.0)	2.8	385–1052	16	5.0	ST	W, E
<i>Eocosmoecus frontalis</i> (Banks)	10.5 (10.0)	1.7	474–1382	15	15.0 (10.0)	ST	W
<i>Glyptopsyche irrorata</i> (Fabricius)	0.2	0.6	274	16	15.0	ST	W
<i>Halesochila taylora</i> (Banks)	66.7 (33.4)	1.1	1382–1565	15	15.0	LK	W
<i>Hesperophylax alaskensis</i> (Banks)	6.7 (2.7)	2.8	25–1344	18	12.0 (2.5)	ST, LK	W
<i>Hesperophylax designatus</i> (Walker)	17.9 (16.3)	2.8	337–1329	14	13.8 (5.5)	ST, SE	W, E
<i>Homophylax andax</i> Ross	9.9 (1.8)	10.5	469–2042	15	10.2 (1.5)	ST, SE	W
<i>Homophylax crotchii</i> Banks	5.0	0.6	1192	12	5.0	ST	W
<i>Hydatophylax argus</i> (Harris)	0.2	0.6	105	15	15.0	ST	W
<i>Hydatophylax hesperus</i> (Banks)	5.1 (1.8)	8.3	23–310	18	16.8 (3.6)	ST	W
<i>Lenarchus rho</i> (Milne)	6.2	0.6	43	17	45.0	LK	W
<i>Lenarchus castus</i> (Hagen)	10.2 (2.8)	7.9	13–1407	17	12.3 (1.3)	LK	W
<i>Limnephilus concolor</i> Banks	4.1 (0.3)	1.1	124–135	24	10.0 (5.0)	ST	W
<i>Limnephilus externus</i> Hagen	0.2	0.6	500	18	30.0	ST	E
<i>Limnephilus fagus</i> Ross	2.8 (2.1)	1.1	135–430	22	17.5 (2.5)	ST, LK	W, E
<i>Limnephilus frijole</i> Ross	0.7	0.6	10	18	80.0	ST	W
<i>Limnephilus fumosus</i> (Banks)	4.2 (0.7)	2.8	13–135	22	20.0 (4.6)	ST, LK	W
<i>Limnephilus harrinani</i> Banks	6.7 (2.4)	1.1	610–1229	16	15.0 (5.0)	SE, LK	W
<i>Limnephilus kalama</i> Denning	7.7	0.6	1997	20	20.0	LK	W
<i>Limnephilus lopho</i> Ross	2.4 (1.0)	2.8	574–1329	15	8.8 (2.4)	ST, LK	W
<i>Limnephilus moestus</i> Banks	9.3 (4.8)	2.8	634–1693	16	10.0 (3.5)	ST, LK	W
<i>Limnephilus nogus</i> Ross	2.6 (2.0)	1.7	474–712	15	6.7 (1.7)	ST	W
<i>Limnephilus ornatus</i> Banks*	1.0 (0.8)	1.1	822–1192	15	5.0	ST	W
<i>Limnephilus sericeus</i> (Say)	0.5	0.6	13	17	10.0	ST	W
<i>Limnephilus sitchensis</i> (Kolenati)	2.3	0.6	287	16	25.0	ST	W
<i>Limnephilus spinatus</i> Banks	1.1 (0.8)	1.1	134–599	16	10.0	ST	W, E
<i>Onocosmoecus unicolor</i> (Banks)	6.8 (1.6)	33.7	4–1343	20	23.4 (3.1)	ST	W, E
<i>Philoscasia antennata</i> (Banks)	2.0 (1.0)	1.1	1329–1438	15	22.5 (7.5)	LK	W
<i>Psychoglypha alascensis</i> (Banks)	4.9 (2.2)	2.8	105–1997	17	20.0 (4.2)	ST, LK	W
<i>Psychoglypha subborealis</i> (Banks)	2.9 (2.7)	1.1	96–274	15	15.0 (0.8)	ST	W
Odontoceridae							
<i>Parthina linea</i> Denning	4.4 (4.2)	1.1	201–337	15	5.0	ST, SE	W

APPENDIX 2. Continued.

Species	Mean frequency (%)	% of habitats	Altitude (m)	Maximum water temp (°C)	Mean embed-dedness (%)	Habitat	Location
Philopotamidae							
<i>Dolophilodes aequalis</i> (Banks)	0.7	0.6	686	15	5.0	ST	W
<i>Dolophilodes dorus</i> (Ross)	11.0 (1.9)	19.3	13-967	19	9.5 (1.0)	ST, SE	W, E
<i>Dolophilodes norusamericanus</i> (Ling)	10.8 (6.9)	3.9	310-741	14	12.1 (1.8)	ST, SE	W
<i>Dolophilodes pallidipes</i> (Banks)	11.9 (6.2)	6.6	377-1329	14	10.0 (1.7)	ST, SE	W
<i>Sisko</i> , sp.*	13.5 (5.5)	1.1	377-467	16	13.3 (1.7)	SE	W
<i>Wormaldia anilla</i> (Ross)	9.2 (8.1)	2.3	90-469	18	11.3 (1.3)	ST, SE	W
<i>Wormaldia gabriella</i> (Banks)	4.4 (1.4)	2.8	114-1023	16	15.0 (4.2)	ST, SE	W, E
<i>Wormaldia occidea</i> (Ross)	13.4 (6.3)	4.4	70-1052	18	14.2 (1.5)	ST, SE	W
Phryganeidae							
<i>Banksiola crotchi</i> Banks	2.9 (2.7)	2.8	65-274	18	36.7 (14.8)	ST, LK	W
<i>Phryganea cinerea</i> Walker	3.9	0.6	65	19	80.0	LK	W
<i>Phlostomis ocellifera</i> (Walker)	4.0 (1.9)	2.8	27-217	22	20.0 (7.4)	LK	W
Polycentropodidae							
<i>Nyctiophylax affinis</i> (Banks)*	1.8	0.6	157	24	80.0	LK	W
<i>Polycentropus cinereus</i> Hagen	34.9 (21.8)	2.8	93-96	19	57.5 (8.5)	LK	W
<i>Polycentropus denningi</i> Smith	6.5 (0.9)	10.5	114-1023	15	6.4 (0.9)	ST, SE	W
<i>Polycentropus flavus</i> (Banks)*	5.6 (4.1)	1.1	15	15	5.0	ST, LK	W
<i>Polycentropus interruptus</i> (Banks)*	7.1	0.6	65	19	80.0	LK	W
<i>Polycentropus variegatus</i> Banks	9.0 (1.6)	27.1	13-1997	21	24.4 (3.0)	ST	W, E
Psychomyiidae							
<i>Psychomyia flavida</i> Hagen	1.5	0.6	614	23	20.0	ST	E
<i>Tinodes cascadia</i> Denning*	1.2	0.6	337	14	5.0	SE	W
Rhyacophilidae							
<i>Himalopsyche phryganea</i> (Ross)	5.9 (3.1)	6.6	269-902	15	7.8 (1.2)	ST	W
<i>Rhyacophila angelita</i> Banks	10.7 (4.3)	19.9	90-1329	18	13.2 (1.7)	ST	W, E
<i>Rhyacophila bifila</i> Banks	4.2 (2.3)	9.0	272-669	16	14.4 (2.9)	ST	W, E
<i>Rhyacophila brunnea</i> Banks	5.2 (1.3)	13.3	5-619	19	17.4 (3.1)	ST	W, E
<i>Rhyacophila chilsia</i> Denning	4.2	0.6	676	14	15.0	SE	W
<i>Rhyacophila coloradenensis</i> Banks	0.7 (0.3)	1.1	53-541	18	27.5 (3.9)	ST	W, E
<i>Rhyacophila fenderi</i> Ross	9.9 (7.6)	1.7	377	16	5.0	SE	W
<i>Rhyacophila grandis</i> Banks	2.3 (0.9)	5.0	124-1229	18	7.5 (1.1)	ST, SE	W
<i>Rhyacophila hyalinata</i> Banks*	9.6 (3.2)	5.5	660-1080	16	12.1 (3.8)	ST, SE	W, E
<i>Rhyacophila inculta</i> Ross & Spencer	8.9 (3.8)	2.8	90-184	19	13.3 (4.4)	ST, LK	W
<i>Rhyacophila traida</i> Ross	1.0	0.6	1329	14	10.0	ST	W
<i>Rhyacophila jenniferiae</i> Peck	0.7	0.6	53	16	40.0	ST	W
<i>Rhyacophila kincaldi</i> Schmid	1.9 (0.5)	3.3	469-1192	15	5.8 (0.8)	ST, SE	W
<i>Rhyacophila latitergum</i> Davis	18.7 (14.4)	1.1	1229-1382	16	10.0 (0.1)	SE, LK	W

APPENDIX 2. Continued.

Species	Mean frequency (%)	% of habitats	Altitude (m)	Maximum water temp (°C)	Mean embed-dedness (%)	Habitat	Location
<i>Rhyacophila narvae</i> Navas	10.2 (5.7)	2.8	201–712	15	6.7 (1.1)	ST, SE	W, E
<i>Rhyacophila norcuta</i> Ross	4.3	0.6	1229	16	10.0	SE	W
<i>Rhyacophila oreta</i> Ross	7.8 (5.2)	1.7	147–377	17	7.5 (1.1)	ST, SE	W
<i>Rhyacophila pellisa</i> Ross	1.5 (0.4)	1.1	99–194	18	7.5 (2.5)	ST	W
<i>Rhyacophila perda</i> Ross	1.1 (0.7)	1.7	105–474	17	10.0 (5.0)	ST	W
<i>Rhyacophila perlana</i> Ross & Spencer	1.9 (1.2)	1.7	90–124	19	1.7 (3.3)	ST	W
<i>Rhyacophila rickeri</i> Ross	1.0	0.6	1329	12	10.0	ST	W
<i>Rhyacophila rotunda</i> Banks	1.2	0.6	337	14	5.0	SE	W
<i>Rhyacophila tralala</i> Schmid	1.1 (0.02)	0.6	194–1329	14	10.0	ST	W
<i>Rhyacophila tucula</i> Ross	4.2 (2.6)	3.6	105–822	18	11.4 (3.0)	ST	W, E
<i>Rhyacophila vaccua</i> Milne	6.9 (2.1)	11.6	75–1997	18	13.9 (2.1)	ST	W, E
<i>Rhyacophila vaeefes</i> Milne	2.2 (0.8)	8.1	53–902	17	16.5 (2.9)	ST	W, E
<i>Rhyacophila vagrita</i> Milne	0.6 (0.2)	1.7	105–274	17	20.0 (5.0)	ST	W
<i>Rhyacophila valama</i> Milne	1.4	1.7	183–263	18	5.0	ST	W
<i>Rhyacophila vao</i> Milne	8.8 (1.9)	26.7	13–1997	19	13.4 (1.8)	ST, SE	W, E
<i>Rhyacophila vedra</i> Milne	10.9 (4.3)	7.0	40–1997	19	20.0 (3.1)	ST	W, E
<i>Rhyacophila verrula</i> Milne	3.3 (0.7)	5.8	337–1329	15	6.4 (0.9)	ST, SE	W
<i>Rhyacophila viquaia</i> Milne	3.5 (0.8)	2.3	377–734	15	6.7 (1.7)	SE	W
<i>Rhyacophila visor</i> Milne	11.1	0.6	337	14	5.0	SE	W
<i>Rhyacophila vocala</i> Milne	7.1 (1.7)	13.4	194–1329	14	12.9 (2.4)	ST, SE	W, E
<i>Rhyacophila vuzana</i> Milne*	7.4 (1.5)	4.7	53–1238	16	22.1 (4.6)	ST, SE	W
Uenoidae							
<i>Farula</i> sp.	4.6 (1.5)	1.1	740–868	14	7.5 (2.5)	ST, SE	W
<i>Neophylax occidentis</i> Banks*	6.1 (1.8)	6.4	96–1997	18	10.0 (2.8)	ST	W, E
<i>Neophylax rickeri</i> Milne	1.8 (0.6)	2.8	90–537	19	13.8 (2.4)	ST	W, E
<i>Neophylax splendens</i> Denning	13.3 (2.2)	4.1	105–923	17	14.0 (1.3)	ST, SE	W
<i>Nothremma didactyla</i> Ross	11.5 (5.7)	5.8	474–2042	17	24.4 (5.6)	ST, LK	W
<i>Oligophlebodes sierra</i> Ross	14.3 (3.9)	11.6	292–1317	16	11.0 (1.7)	ST, SE	W, E