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A COMPARISON OF BENTHIC INVERTEBRATE COMMUNITIES IN THREE AQUATIC HABITATS OF THE HOH RIVER VALLEY, OLYMPIC NATIONAL PARK, WASHINGTON

by

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Abstract

Macroinvertebrate communities in three aquatic habitats of the Hoh River Valley, Jefferson County, Washington, were characterized and compared. Within-stream and between-stream habitat differences and similarities were analyzed in a valley-wall tributary (Twin Creek), river off-channel (side channel of the Hoh River) and terrace tributary (Taft Creek). Between-stream differences were found to be significant using a one-way ANOV. Twin Creek and the side channel were similar in most physical characteristics, dominance of benthic functional groups, and general dominance by taxa. The major variable between these two sites was the influence of silt in the side channel. The effects of a high silt load and the process of siltation appear to be responsible for much lower $\bar{x}$ benthic densities and the absence of scrapers in the side channel. Taft Creek differed from the other sites in physical characteristics and benthic community composition. Twin Creek and the side channel had rock-rubble substrate, higher current velocities and heavy canopy cover, while Taft Creek had homogeneous substrate, reduced current velocities, dense macrophytic growth, and little canopy cover. Mean benthic densities in Taft Creek (103,914 m^{-2}) were much higher than those found in Twin Creek (15,009 m^{-2}) or the side channel (2,983 m^{-2}). There was a predominance of Diptera (40%) and non-insects (51%) in Taft Creek and Diptera and Ephemeroptera in Twin Creek (42% and 24% respectively) and the side channel (30%

and 43% respectively). Collectors were the predominant functional group at all three sites. No significant differences between riffle, reach, and pool habitat types was found in either Twin Creek or the side channel using a one-way ANOV. When comparing taxonomic and functional group composition, however, reach and riffle habitats were more similar to each other than to pool habitats in both Twin Creek and the side channel.

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INTRODUCTION

Little is known about the benthic macroinvertebrate communities of Washington's Olympic Penninsula streams in general, and even less is known about its pristine, glacial-fed streams. The effects of increased siltation from logging on benthic macroinvertebrate communities in Olympic Penninsula streams has been studied by Wasserman et al. (in press), Martin (1976), Cedarholm and Lestelle (1974), and Deschamps (1971).

Martin (1976) examined the effects of sediment and organic detritus on benthic macroinvertebrate community structure, production, and standing crop in 4 tributary streams of the Clearwater River, Washington and found no significant differences in macrobenthic communities due to different logging intensities.

Wasserman et al. (1984) studied the effects of logging siltation on benthic macroinvertebrate standing crops in 25 western Olympic Penninsula streams and found no significant differences. They concluded that the hydrologic regimes of Olympic Penninsula streams ($\bar{x}$ annual preciptation of 32 m) may reduce the siltation effects of logging operations and minimize effects on stream benthos.

Although useful baseline information on macrobenthic communities was generated by Martin (1976) and Wasserman et al. (1984), their sampling was limited to riffle areas. It is not known what differences in macrobenthic community structure would have been found if reach and pool habitats had also been studied.

As part of an 11 day interdisciplinary "pulse" study, Ward et al. (1982) sampled benthic macroinvertebrates in river channel, river off-channel, terrace tributary, and valley-wall tributary habitats of the South Fork of the Hoh River to generate baseline data on macrobenthic communities of a pristine, glacial stream system. These stream systems are unique in that they carry a naturally high sediment load. Benthic macroinvertebrates were grouped according to their functional role (Cummins 1974) and habitats were compared using both insect densities and biomass.

Baseline data generated by Ward et al. (1982) and companion projects of the interdisciplinary "pulse" study provide a general groundwork of ecological information on the South Fork of the Hoh River Valley. This general groundwork provides a stepping stone from which other similar, but longer term and more intensive studies may be conducted.

The purpose of this study was to characterize and compare the macrobenthic communities of 3 aquatic habitats of the Hoh River Valley - valley wall tributary, terrace tributary and side channel (river off-channel). This type of baseline information on macrobenthic communities is needed for the following reasons: (1) the Hoh River and its tributaries provide important habitat for some of the last genetically pure strains of salmon; (2) the Hoh River carries a naturally high sediment load because it is glacial-fed, thus allowing for comparison of its benthic communities with those of similar streams in which logging has increased siltation rates; (3) within the National Park boundary the Hoh River and its tributaries are pristine and information generated about natural communities within such unaltered systems can be used as a baseline to monitor environmental change.

STUDY AREA

The Hoh River Valley is located on the western slopes of Washington's Olympic Mountains (fig. 1), an area of extremely high annual rainfall ($\bar{x}$ annual precipitation of 30 m) and mild temperatures ($\bar{x}$ = 10°C, min. = 1°C, and max. = 21°C). The Hoh River receives a large glacial silt load during spring, summer and fall months from the meltwaters of glaciers situated on the north slopes of Mount Tom, Mount Olympus and Mount Mathis. Adjacent mountain slopes are composed mainly of sandstones and shales (Franklin 1982).

Aquatic habitats in the Hoh River Valley are similar to those described for the South Fork of the Hoh River Valley (Swanson and Lienkaemper 1982, Ward et al. 1982). These descriptions were used as a general guideline for selecting study sites. Areas selected for study included a valley-wall tributary (W. Twin Creek), a terrace tributary (Taft Creek) and a river off-channel (side channel of the Hoh River). A site on the main channel was not chosen because of sampling difficulties due to unpredictably high discharges.

Twin Creek

The Twin Creek site (fig. 2) was located approximately 22 m upstream of the Park road and approximately 3.2 km east of the Park boundary. Average width of the stream during

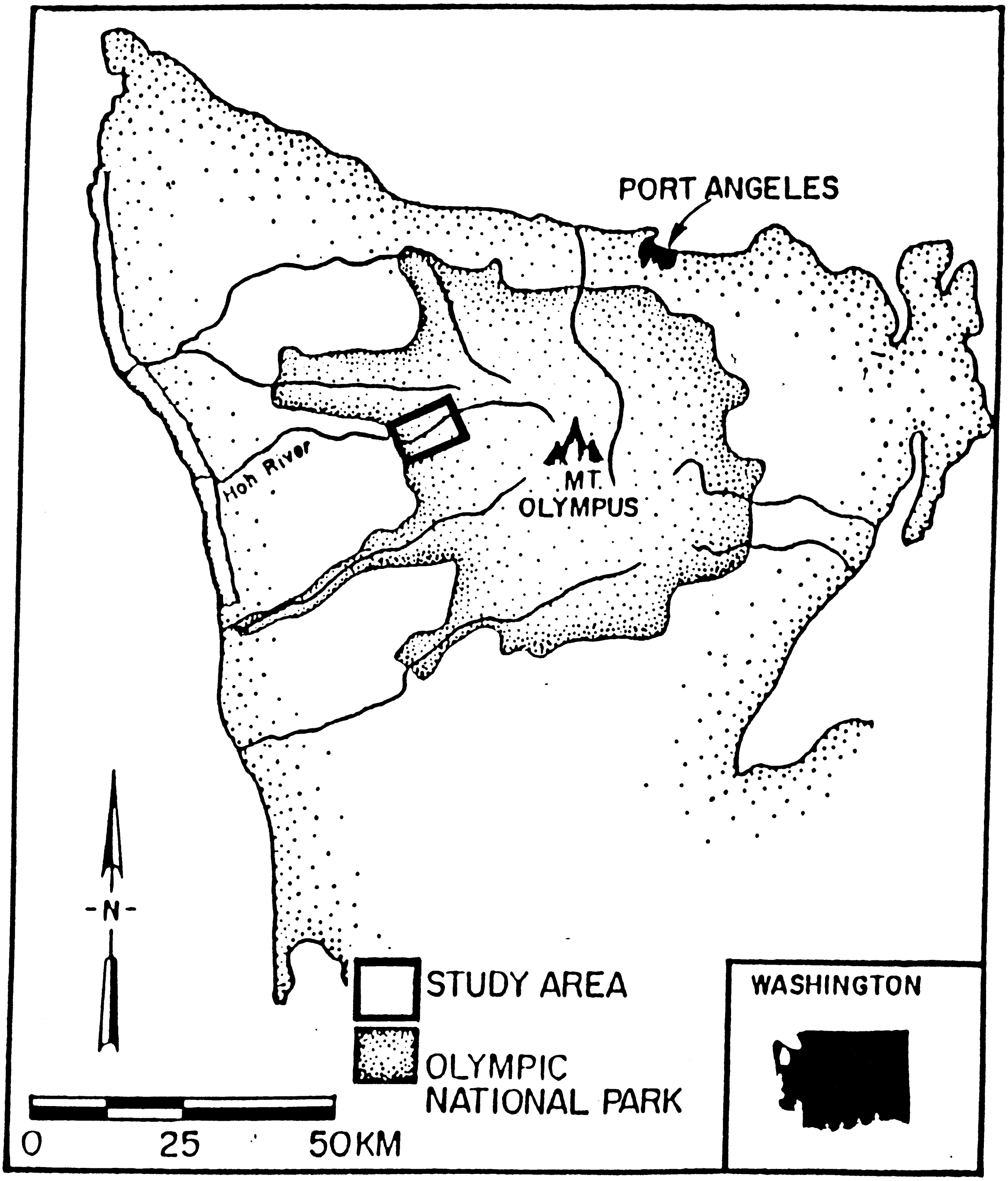


Figure 1.--Geographical location of Olympic National Park and the Hoh valley study area.

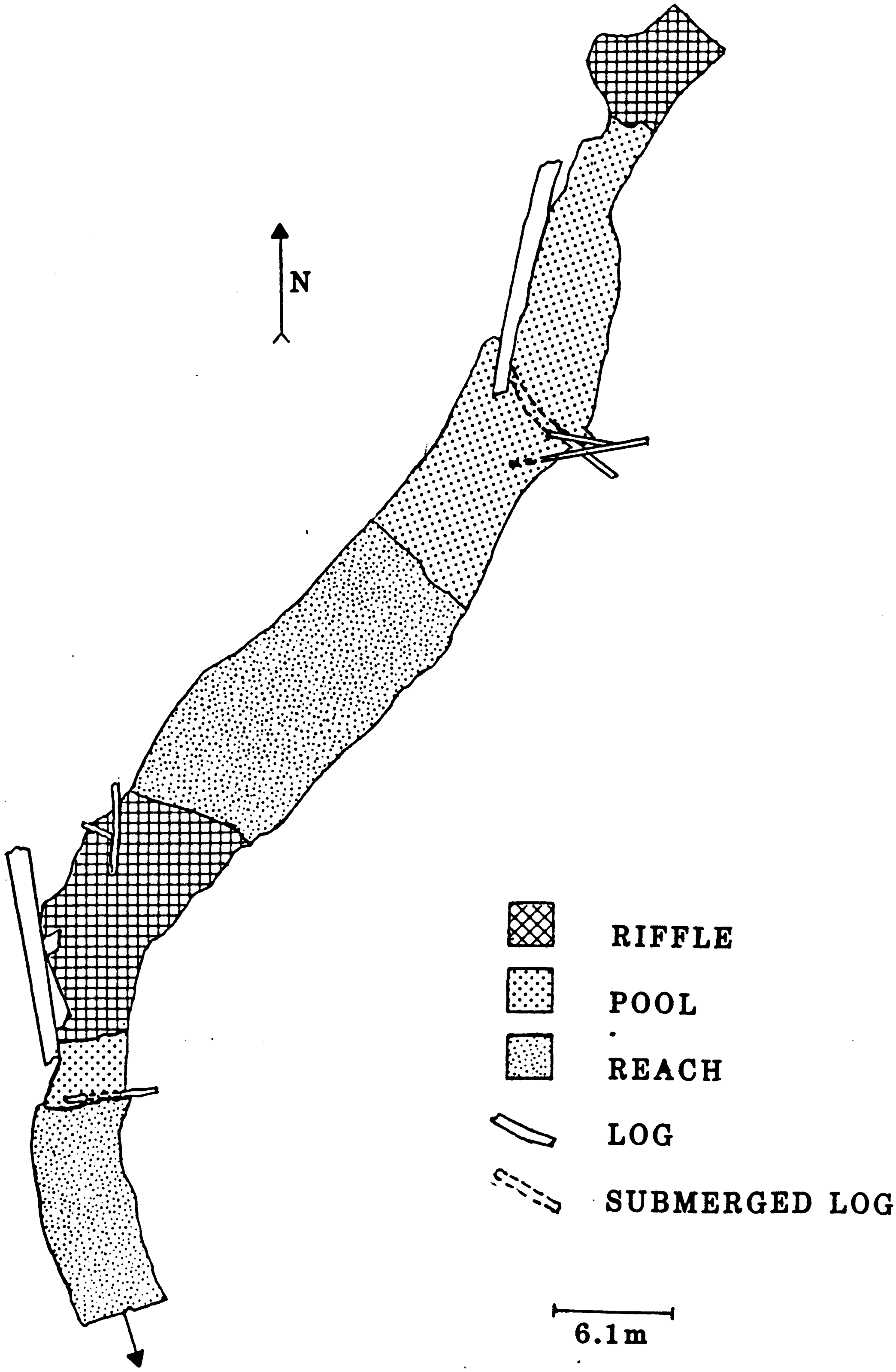


Fig. 2. Twin Creek study site.

moderate-low flow was 4.9 m and length of sampling area was 77 m. Canopy cover was dense, consisting primarily of red alder (Alnus rubra Bong.). Big leaf maple (Acer macrophyllum Pursh.), Sitka spruce (Picea sitchensis (Bong.)Carr.) and western hemlock (Tsuga heterophylla (Raf.)Sarg.)) also border the stream. Three habitat types were selected for benthic sampling, including riffles (rapid flow, shallow depth), reaches (moderate flow and depth) and pools (slow flow, greater depth).

Side Channel

The side channel sampling site (fig. 3) was located approximately 6.5 km east of the Park boundary (approximately 0.2 km east of the riverside loop c campground sites). Average width of the sampling site during moderate-low flow was 3.9 m and length was 73 m. This site was connected to a larger, more open and less stabilized side channel which forms part of the braided network of the Hoh River. Eight to 23 cm diameter red alder bordering the site indicated that the channel had been stabilized for a number of years. A dense canopy of red alder covered the site and Sitka spruce and western hemlock seedlings could be found near the site, primarily on nurse logs. A large number of fallen trees partially or fully crossed the channel, exerting a great influence on its physical characteristics. A large amount of glacial silt was present in the site because of its connection with the

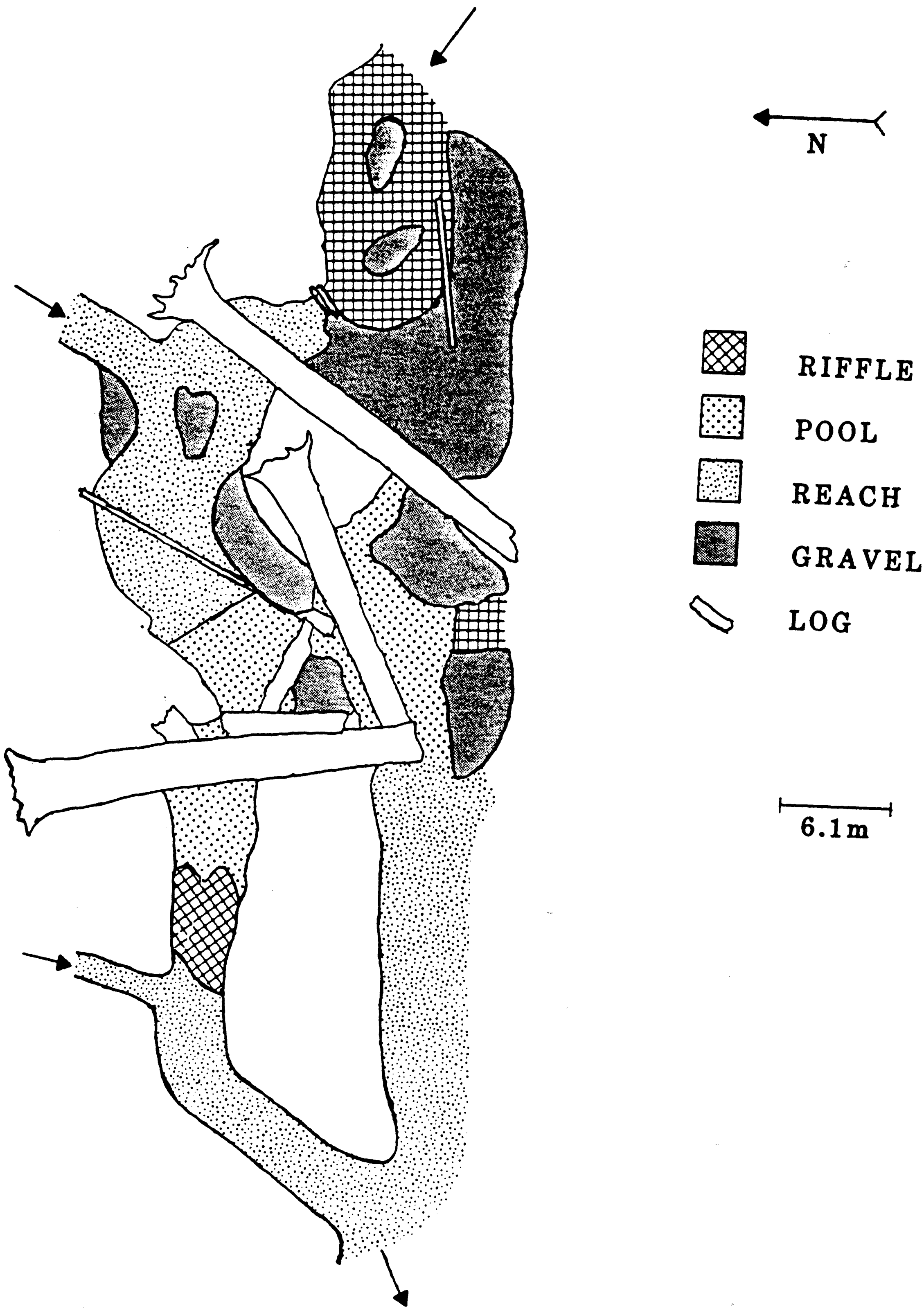


Fig. 3 Side channel of Hoh River study site.

main channel. During most of the sampling period the side channel was highly turbid and milky gray in coloration. When current was reduced, a thick coating of gray glacial silt could be seen blanketing and filling the interstices of the substrate. Riffles were the only areas which remained relatively clear, although the substrate was still partially imbedded in silt. As in Twin Creek, riffle, reach, and pool areas were selected for sampling.

Taft Creek

Taft Creek originates from a side channel of the Hoh River and is also spring-fed. It flows approximately parallel to the Hoh on a lower terrace for most of its length. Upstream of the sampling site it was narrow and shallow, there was a strip of gravel near its center, and approximately 40% of the stream was covered with emergent (primarily Oenanthe sarmentosa Presl.) and submergent (primarily Utricularia sp.) aquatic macrophytes. At the sampling site (fig. 4), the stream was significantly wider and deeper, macrophyte cover had increased to approximately 70%, the stream no longer had a strip of gravel near its center, and the substrate which consisted of clay, silt, sand, and a high percentage of organics had a more homogeneous spatial distribution. The stream width increased downstream of the sampling site and the channel was difficult to locate. Overall, Oenantha sarmentosa was the dominant emergent macrophyte and Utricularia sp. was the

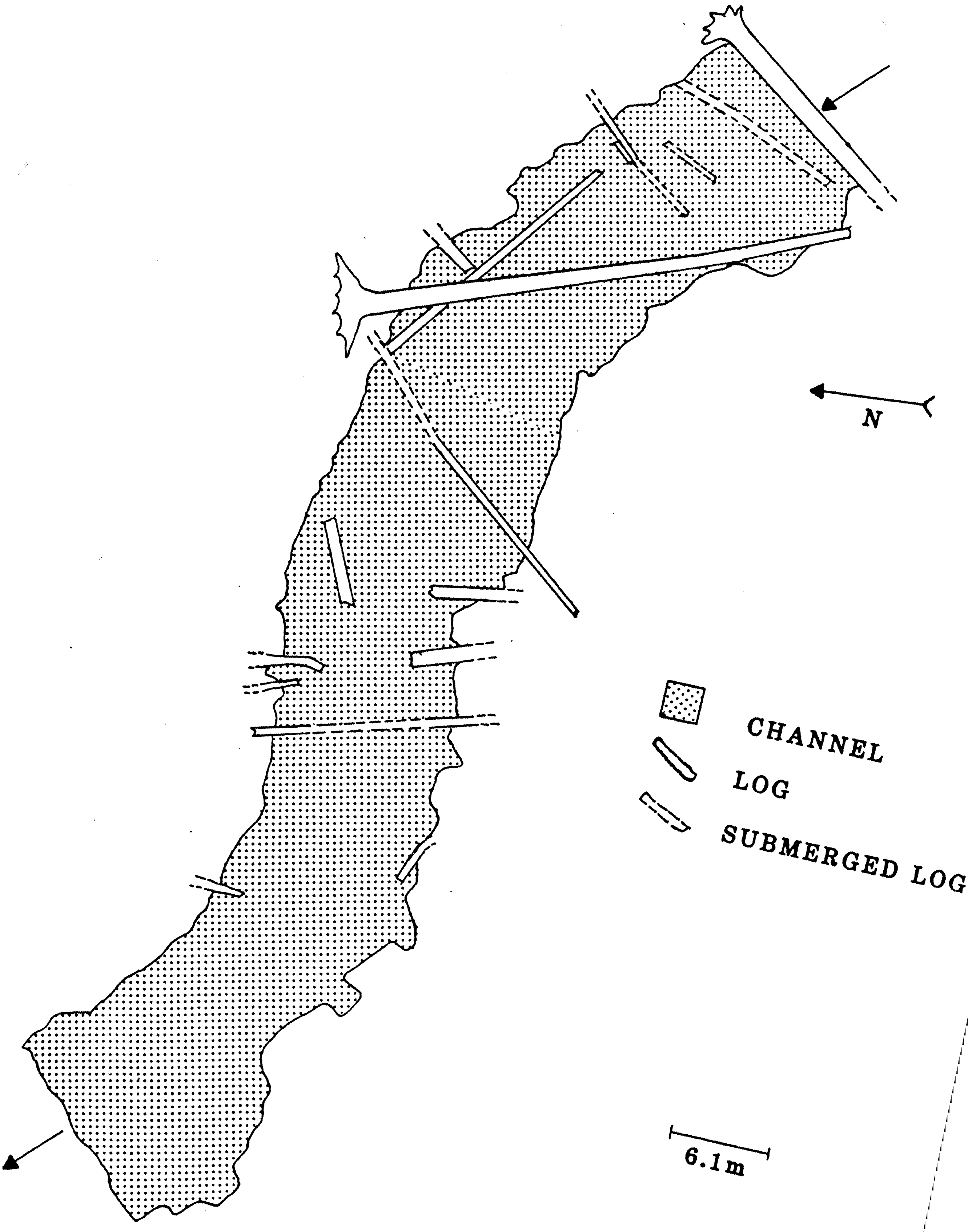


Fig. 4. Taft Creek study site.

most common submergent macrophyte in the stream. A wet area dominated by sedges borders the stream, extending to the Park road (approximately 100 m) to the south and to the foot of a near, older river terrace to the north. Sitka spruce, bigleaf maple and western hemlock were widely scattered throughout the area and a number of large fallen trees partially or fully crossed the stream (fig. 4).

METHODS AND MATERIALS

Study Period

Bottom fauna and environmental parameters were monitored for a 2 month period beginning 3 June 1983 and ending 10 August 1983. Samples were collected bi-weekly, except for a two week period during mid-July when high water conditions prohibited sampling (fig. 8).

Stream Physical and Chemical Measurements

Current velocity, depth and temperature measurements were taken with every quantitative benthic sample. Current velocities were measured 10 cm from the substrate surface, which was as close to the benthic environment as could be consistently measured in all three sites. A Marsh-McBirney model 201 electronic current meter was used for measuring current velocities. On alternate weeks, physical (temperature and width) and chemical (alkalinity, total hardness, dissolved oxygen and pH) measurements were made using a standard Hach kit.

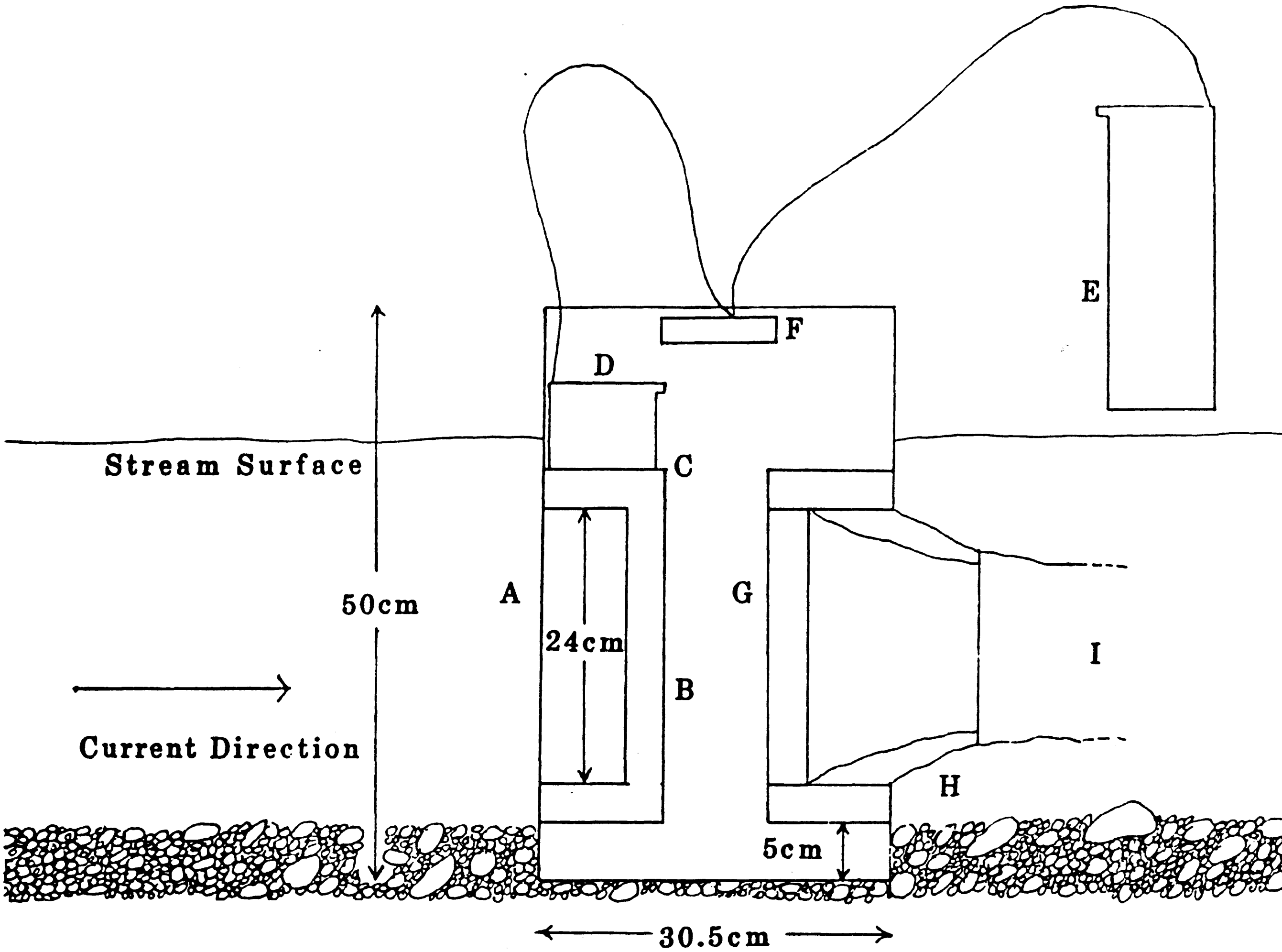
Mapping of the Study Sites

Study sites were field mapped on 4, 5, and 6 June with a transit, stadia rod, and tape (figs. 2, 3, 4).

Benthic Sampling Methods

Quantitative benthic samples were collected in the Twin Creek and side channel sites using a modified Hess sampler (fig. 5) which samples an area of 693 cm^2 and has a trailing net with a mesh size of 230 cm^{-4}. The trailing net consists of an upper non-removable portion which directly attaches to the cylinder and a lower removable collecting net which attaches to the upper portion with Velcro fasteners. The sampler was operated by simultaneously pushing and turning it into the substrate until a seal was obtained. Large rocks were rubbed free of organisms in front of the net opening and visually inspected to ensure removal of attached organisms before being discarded. Front and rear doors were closed and the remaining organisms and debris were dislodged from the substrate to a depth of approximately 10 cm by vigorously stirring the gravel with a large stick after which the doors were immediately opened, allowing the current to flush organisms and debris into the net. After the water was allowed to clear, the doors were shut and the procedure was repeated two more times. The sample was then emptied into a white enamel pan and the organic material separated from the non-organics by floatation. The organic material was poured into a 250 cm^{-4} sieve and then into a sampling bag. and preserved in 70% ethyl alchohol.

In Taft Creek, the modified Hess sampler was inadequate because of the muddy substrate, dense macrophytic vegetation



A Screen over perforated front opening.
B Canvas and metal strips bordering screen.
C Track for sliding door.
D Front sliding door with attached cord.
E Rear sliding door (hung outside for flushing).
F Handle for rotating cylinder.
G Canvas and metal strips fastening net to sampler.
H Canvas cowl.
I Trailing net (230 micron mesh).

Fig. 5. Modified Hess sampler.

and slow current. At this site, a 10 cm diameter core sampler (fig. 6) was used. The corer was pushed into the substrate to a depth of 14 cm and then removed with the sample remaining intact. After the sample was obtained, it was sieved free of clay and fine silt using a 250 cm^{-4} sieve and preserved in 70% ethyl alchohol.

Three sets of replicate samples (each replicate consisting of three samples) were collected bi-weekly at each study site. In Twin Creek and the side channel, one set of replicates was collected from each major habitat type which included riffles, reaches, and pools. Because the substrate of Taft Creek at the sampling site was relatively homogeneous, the three sets of replicate samples were taken at random selected locations throughout the site.

Qualitative samples were collected bi-weekly at each site with a rectangular kick net (630 cm^{-4} mesh). Samples were taken along stream margins in all sites and under large rocks in Twin Creek and the side channel.

All organisms were stained with rose bengal to aid in identification and separated from debris by handpicking under a dissecting microscope. When sample size was large, a sediment splitter was used to obtain reliable subsamples and a minimum of 200 organisms per sample were counted and identified to the lowest possible taxonomic level. Aquatic insects were usually identified to the generic or family level and non-insect identification ranged from phylum to species, depending on the group. Identification of all

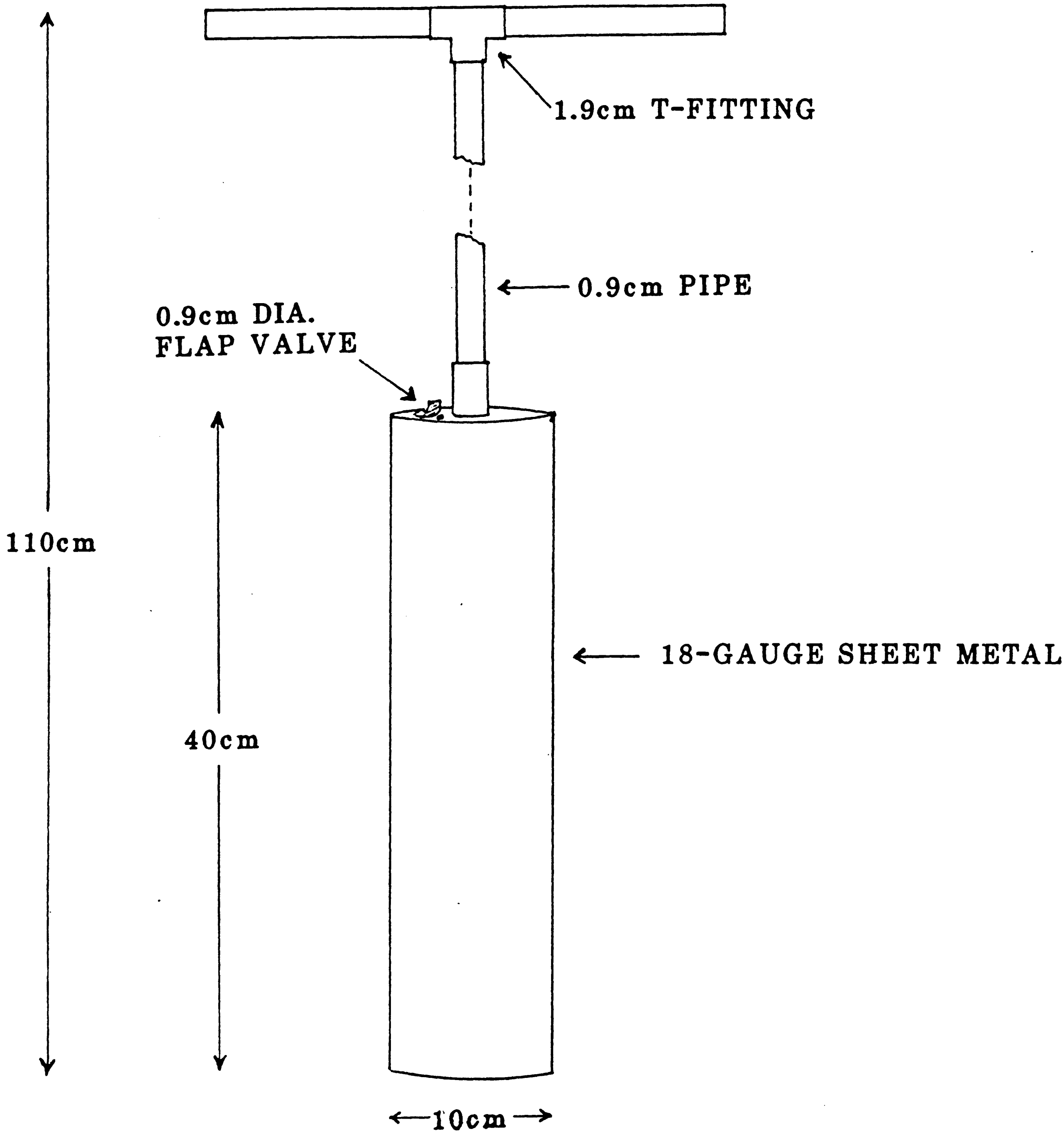


Fig. 6. Benthos core sampler.

aquatic insects to the generic or species level was not possible since most specimens were very small and immature with undeveloped body structures (fig. 10). Insects collected from Twin Creek and the side channel were measured with a metric ruler graduated in mm and placed in one of the following size classes - 0-2mm, 2-4mm, 4-6mm, 6-8mm, >8mm.

Methods of Analysis

To determine benthic distribution within the study streams, a chi-square test for "goodness of fit" with the Poisson series was used and variances were compared with corresponding mean numbers.

A one-way analysis of variance (Elliott 1977; Kachigan 1982) using a log transformation on $\bar{x}$ numbers of benthos was used to test for significant differences between sampling sites (fig. 15), between reach, riffle, and pool habitats in Twin Creek and the side channel (figs. 5, 9), or between sampling dates.

Kulczynski's similarity index (Kulczynski 1928) was used to test for between-stream and within-stream taxonomic similarities. Using reach, riffle, and pool habitats of Twin Creek and the side channel, and treating Taft Creek as a separate habitat, index values were calculated for all possible combinations. All taxa which were greater than or equal to 1% of the benthic composition in each habitat/site were included in the calculation. The following equation was used:

$$I = \frac{2c}{a+b}$$

a = total species/taxa in a
b = total species/taxa in b
c = total species/taxa in common in a and b

Index values can range from 0 (least similar) to 1 (most similar). For comparison purposes, the calculated index values were displayed in a similarity triangle (fig. 9).

As an index of precision, the D statistic (standard error/mean)(Elliott 1977) was calculated and the number of samples required for a 20% error was determined.

Benthic communities were also analyzed using taxonomic groupings, functional group composition, and abundance. Taxa were grouped into trophic categories according to Merritt and Cummins (1978). These categories include shredders (which feed on coarse particulate organic matter), collectors (that feed on fine particulate organic matter), scrapers (whose main diet consists of periphyton), and predators (which feed on organisms in other functional groups).

RESULTS AND DISCUSSION

Physical and Chemical Composition

Annual peak flows in the Hoh River generally occur during the winter months when precipitation is greatest and minimum flows usually occur in the autumn (fig. 7)(U.S.G.S. 1972-1983). During the sampling period, discharge was relatively stable except for a sharp increase in mid-July (fig. 8). Discharge within the study streams correspondingly increased during this period which prohibited benthic sampling.

Stream substrate in Twin Creek and the side channel was heterogeneous. However, there was a general decrease in particle size from riffles to reaches to pools. In Twin Creek there was also a general decrease in particle size with depth. During moderate-low flow, $\bar{x}$ current velocity at Twin Creek and the side channel (as measured 10 cm above the substrate) was 34 cm/s (Twin Creek) and 49 cm/s (side channel) in riffles, 18 cm/s (Twin Creek) and 30 cm/s (side channel) in reaches, and 9 cm/s (Twin Creek) and 6 cm/s (side channel) in pools. Similarly, $\bar{x}$ depth was 18 cm (Twin Creek) and 16 cm (side channel) in riffles, 25 cm (Twin Creek) and 30 cm (side channel) in reaches, and 40 cm (Twin Creek and the side channel) in pools. Both Twin Creek and the side channel were shaded by a dense canopy of red alder and were devoid of in-stream vegetation.

Fig. 7. Hoh River monthly discharge

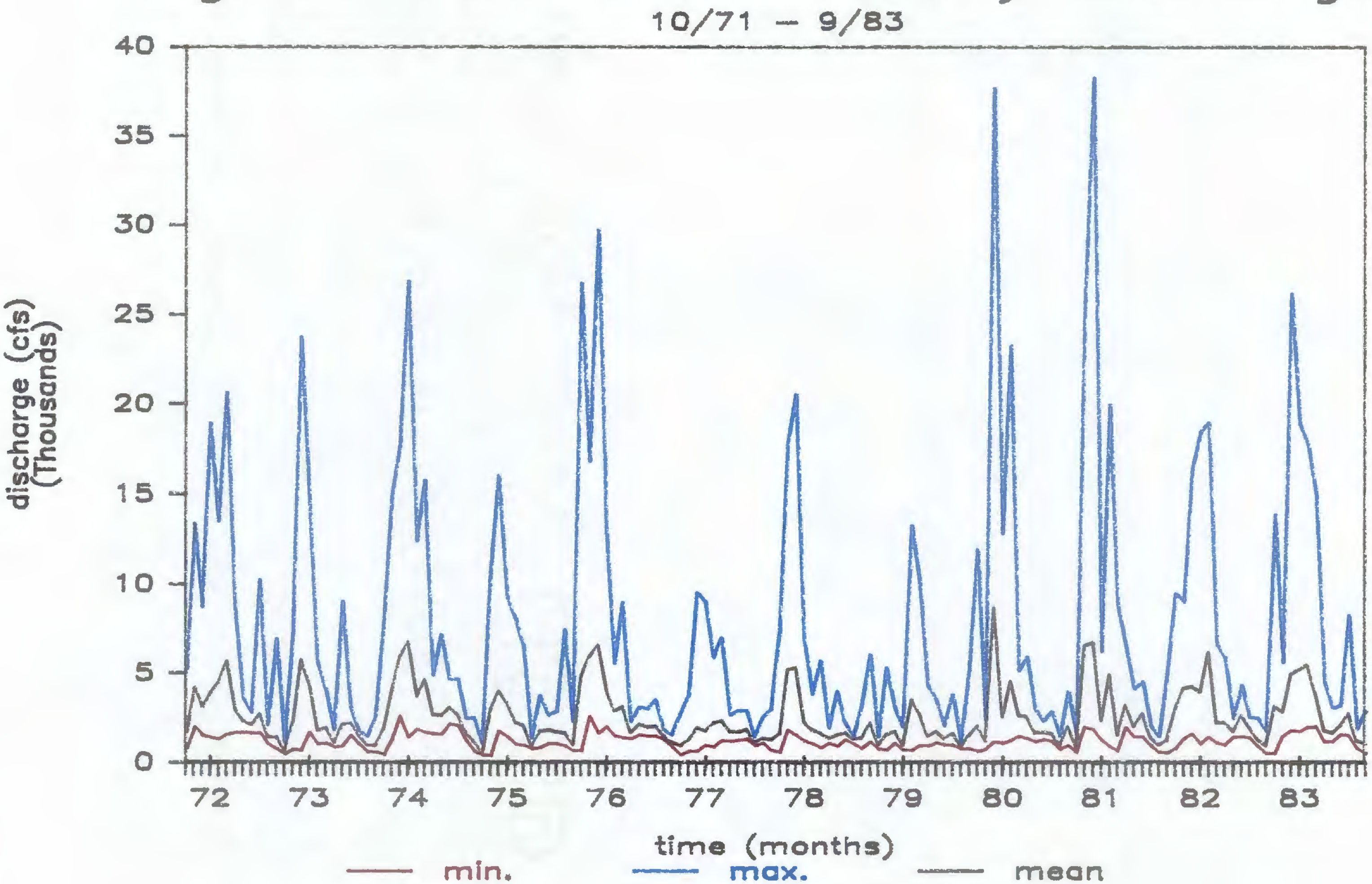
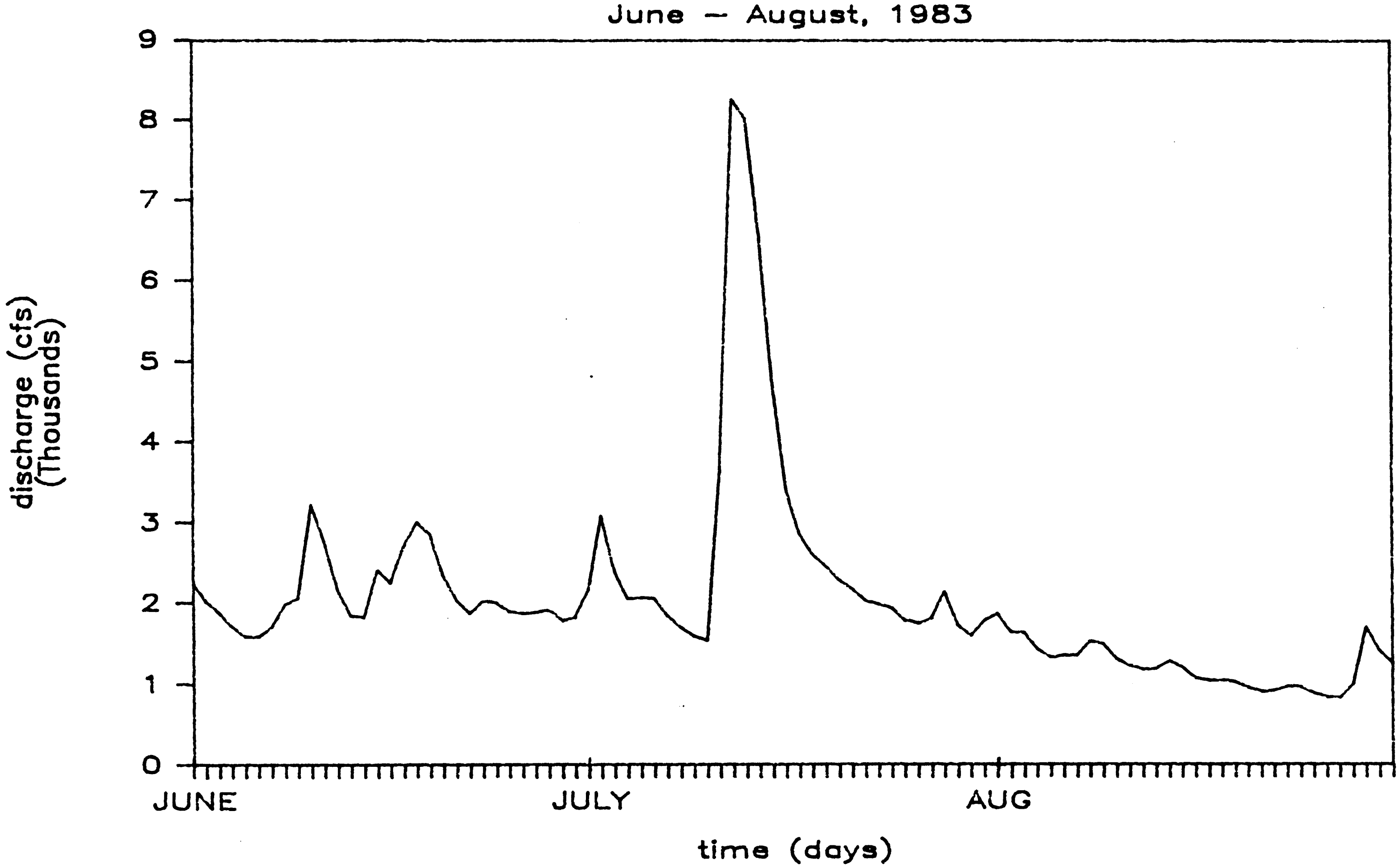


Fig. 8. Hoh River mean daily discharge



In contrast to Twin Creek and the side channel, Taft Creek had lower current velocities ($\bar{x}$ = 6 cm/s), homogeneous substrate, dense macrophytic growth, and little canopy cover.

Chemical parameters were constant throughout the sampling period for all sites (table 1). Total alkalinity and total hardness were low for all sites, reflecting the low carbonate composition of the surrounding bedrock. All sites had high dissolved oxygen values and near neutral pH. Throughout the sampling period, water temperature varied by only 1^{o}C in Twin Creek, 0^{o}C in Taft Creek and 4^{o}C in the side channel at the times of sampling.

Benthic Community Composition

Twin Creek

The predominant orders in Twin Creek were Diptera, Ephemeroptera, and Plecoptera (table 2). Chironomidae was the most abundant Diptera, *Ephemerella* sp. (especially *E. doddsi* Needham) and Heptegeniidae the predominant Ephemeroptera and Chloroperlidae the predominant Plecoptera (table 3). Non-insects comprised 15% of the benthic composition; Oligochaeta and Acarina were the most abundant groups (table 3).

Collectors were the predominant functional group, comprising 20% of the benthic fauna. Predators were second

Table 1. Physical and chemical parameters of Twin Creek, the side channel, and Taft Creek.

Physical and Chemical Parameters

	Twin Ck. ($\bar{x}$)	Side Channel ($\bar{x}$)	Taft Ck. ($\bar{x}$)
air temperature	17°C	18°C	17°C
water temperature	10°C	9°C	8°C
width	5.3 m	3.9 m	13 m
total alkalinity	20 mg $CaCO_3$/l	20 mg $CaCO_3$/l	27 mg $CaCO_3$/l
total hardness	34 mg $CaCO_3$/l	34 mg $CaCO_3$/l	40 mg $CaCO_3$/l
dissolved oxygen	9 mg O_2	9 mg O_2	8 mg O_2
pH	6.8	7.0	6.7

Table 2. Mean benthic invertebrate density (number m-2) with 95% confidence intervals and percent composition in Twin Creek Taft Creek, and the side channel.

	Twin Creek			Taft Creek			Side Channel		
		$\bar{X}$	CI		$\bar{X}$	CI		$\bar{X}$	CI
Ephemeroptera	24%	3540	720	6%	5942	4089	43%	1291	826
Plecoptera	13%	2002	228	1%	1152	780	11%	343	157
Trichoptera	5%	825	132	0%	266	136	0%	9	6
Coleoptera	1%	76	31	0%	27	47	0%	4	3
Megaloptera	0%	0	0	0%	21	25	0%	0	0
Diptera	42%	6280	4165	42%	43955	15168	30%	894	392
Bivalvia	0%	5	6	7%	7161	2173	0%	0	0
Gastropoda	0%	2	4	2%	1938	943	0%	0	1
Hirudinea	0%	0	0	0%	0	0	0%	1	1
Hydracarina	4%	561	162	2%	2012	1197	1%	33	15
Nematoda	0%	6	6	8%	8305	2426	1%	21	9
Oligochaeta	11%	1695	614	18%	18607	7622	13%	384	124
Ostracoda	0%	15	9	14%	14519	6615	0%	3	2
Totals	100%	15009	4918	100%	103914	27655	100%	2983	926

Table 3. Mean benthic invertebrate density (number m-2) with 95% confidence intervals and percent composition by dominant taxa in Twin Creek, Taft Creek, and the side channel.

	Twin Creek			Taft Creek			Side Channel		
Dominant Taxa		$\bar{X}$	CI		$\bar{X}$	CI		$\bar{X}$	CI
Baetidae	3%	378	189	3%	3546	2227	20%	608	384
Ephemerellidae	11%	1668	323	0%	0	0	4%	128	100
Heptageniidae	8%	1190	384	0%	69	52	18%	536	362
Chloroperlidae	8%	1126	142	0%	0	0	7%	201	113
Leuctridae	3%	462	164	0%	0	0	3%	91	46
Glossosomatidae	3%	389	128	0%	0	0	0%	1	1
Chironomidae	39%	5816	4117	40%	41371	14668	18%	537	333
Empididae	0%	25	9	0%	493	291	4%	105	55
Simuliidae	0%	22	13	0%	388	386	3%	91	98
Tipulidae	1%	95	47	0%	478	329	4%	126	42
Sphaeriidae	0%	0	0	7%	7161	2173	0%	0	0
Gastropoda	0%	2	4	2%	1938	943	0%	0	1
Acarina	4%	561	162	2%	2012	1197	1%	33	15
Nematoda	0%	6	6	8%	8305	2426	1%	21	9
Oligochaeta	11%	1695	614	18%	18607	7622	13%	384	124
Ostracoda	0%	15	9	14%	14519	6615	0%	3	2
Totals	90%	13450	6311	95%	98887	38930	96%	2865	1685

in abundance (15%), followed by shredders (5%), and scrapers (4%) (table 4). The high percentage of detrital processing organisms and low percentage of herbivores indicate that most benthos were obtaining food from allochthonous sources.

Significant differences between habitat types within Twin Creek could not be found using a one-way analysis of variance (table 5)(Elliott 1977; Kachigan 1982). Results from the Kulczynski similarity index (Kulczynski 1928) indicated that reaches and pools were the most similar habitats, riffles and reaches were intermediate in similarity, and riffles and pools were the least similar (fig. 10). However, differences between index values were small. Benthic density was highest in pools, intermediate in reaches, and lowest in riffles (table 6). Benthic composition and abundance was similar in reach and riffle areas for nearly all taxa, but differed from pool areas which had a greater abundance of Diptera (primarily Chironomidae) and a lower percentage of Ephemeroptera, Plecoptera, and Trichoptera (table 6, 7). Correspondingly, collectors, predators, and scrapers were less abundant in pools than in reaches or riffles (table 8).

Side Channel

Baetidae, Heptageniidae, and Chironomidae were the predominant families in the side channel (table 3). Ephemeroptera was the most abundant order, unlike in Twin Creek where Diptera were most abundant (table 2).

Table 4. Mean benthic invertebrate density (number m-2) with 95% confidence intervals and percent composition by functional group in Twin Creek, Taft Creek, and the side channel.

	Twin Creek			Taft Creek			Side Channel		
Functional Groups		$\bar{X}$	CI		$\bar{X}$	CI		$\bar{X}$	CI
collectors	20%	3047	608	6%	6558	4251	46%	1366	850
predators	15%	2240	378	1%	1544	687	14%	415	137
shredders	5%	815	221	1%	1323	863	6%	187	52
scrapers	4%	620	99	0%	0	0	0%	1	1
chironomidae	39%	5816	4117	40%	41371	14668	18%	537	333
non-insects	15%	2264	584	51%	52542	12625	15%	442	132
unassignable	1%	186	55	1%	576	255	1%	35	15
Totals	100%	15009	4918	100%	103914	27655	100%	2983	926

Table. 5. ANOV significance between sampling sites, between reach, riffle, and pool habitats in Twin Creek and the side channel, or between sampling dates.

	calculated F	F (P=0.05)[a]	ANOV significance
Twin Ck. reach vs. riffle	4.10	5.99[b]	NO
Twin Ck. riffle vs. pool	0.75	5.99[b]	NO
Twin Ck. pool vs. reach	0.005	5.99[b]	NO
Side channel reach vs. riffle	1.19	5.99[b]	NO
Side channel riffle vs. pool	2.77	5.99[b]	NO
Side channel pool vs. reach	0.74	5.99[b]	NO
Twin Ck. vs. side channel	54.23	4.30[b]	YES
Twin Ck. vs. Taft Ck.	74.16	4.30[b]	YES
Taft Ck. vs. side channel	196.92	4.30[b]	YES
Sampling periods	0.10	2.91[b]	NO

a. When the calculated F is < F (P=0.05) in published tables, the null hypothesis (H_o) is accepted, indicating that there are no significant differences between the populations being tested.

b. Values obtained from F tables in Kachigan, S.K. 1982. Multivariate statistical analysis. Radius Press. 297 pp.

Figure 10. Kulczynski's similarity triangle of index values which compare benthic communities of reach, riffle, and pool habitats of Twin Creek and the side channel with Taft Creek and with each other.

Twin Creek riffle	Twin Creek reach	Twin Creek pool	Side Channel riffle	Side Channel reach	Side Channel pool	
0.48	0.44	0.32	0.41	0.43	0.43	Taft Ck.
	0.85	0.84	0.57	0.67	0.67	Twin Ck. riffle
		0.87	0.61	0.67	0.53	Twin Ck. reach
			0.41	0.50	0.50	Twin Ck. pool
				0.62	0.50	Side Ch. riffle
					0.77	Side Ch. reach

$$I = \frac{2c}{a+b}$$

a = total species/taxa in a
b = total species/taxa in b
c = total species/taxa in common in a and b

Table 6. **Mean benthic invertebrate density (number m-2) and percent composition by habitat in Twin Creek, Taft Creek, and the side channel.**

	Twin Creek						**Side Channel**						Taft Creek	
	Reach		Riffle		Pool		Reach		Riffle		Pool			
		$\overline{X}$		$\overline{X}$		$\overline{X}$		$\overline{X}$		$\overline{X}$		$\overline{X}$		$\overline{X}$
Ephemeroptera	29%	4504	29%	3103	16%	3014	51%	1757	59%	2040	4%	77	6%	5949
Plecoptera	15%	2381	16%	1675	10%	1952	14%	478	13%	460	4%	90	1%	1152
Trichoptera	7%	1080	8%	833	3%	563	0%	5	1%	21	0%	1	0%	266
Coleoptera	1%	108	1%	76	0%	44	0%	4	0%	6	0%	1	0%	27
Megaloptera	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	21
Diptera	35%	5446	23%	2470	58%	10924	20%	693	15%	522	71%	1468	42%	43955
Bivalvia	0%	5	0%	0	0%	10	0%	0	0%	0	0%	0	7%	7161
Gastropoda	0%	0	0%	0	0%	6	0%	0	0%	0	0%	1	2%	1938
Hirudinea	0%	0	0%	0	0%	0	0%	0	0%	1	0%	1	0%	0
Acarina	5%	793	4%	396	3%	494	1%	43	1%	24	2%	31	2%	2012
Nematoda	0%	0	0%	5	0%	15	0%	17	1%	26	1%	20	8%	8305
Oligochaeta	9%	1336	19%	2061	9%	1687	12%	422	10%	363	18%	367	18%	18607
Ostracoda	0%	24	0%	11	0%	10	0%	1	0%	2	0%	5	14%	14519
Totals	100%	15678	100%	10630	100%	18719	100%	3419	100%	3466	100%	2063	100%	103914

Table 7. Mean benthic invertebrate density (number m-2) and percent composition by habitat and dominant taxa in Twin Creek, Taft Creek, and the side channel.

	Twin Creek						Side Channel						Taft Creek	
	Reach		Riffle		Pool		Reach		Riffle		Pool			
Dominant Taxa		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$
Baetidae	3%	508	5%	545	0%	81	22%	743	31%	1058	1%	23	3%	3546
Ephemerellidae	13%	2109	13%	1332	8%	1562	6%	212	4%	154	1%	17	0%	0
Heptageniidae	10%	1585	11%	1150	4%	836	23%	773	23%	802	2%	34	0%	69
Chloroperlidae	8%	1284	12%	1225	5%	869	9%	293	8%	287	1%	24	0%	0
Leuctridae	3%	523	1%	153	4%	710	5%	158	2%	65	2%	51	0%	0
Glossosomatidae	4%	574	4%	414	1%	179	0%	0	0%	2	0%	0	0%	0
Chironomidae	33%	5112	19%	2043	55%	10293	11%	385	5%	181	51%	1044	40%	41371
Empididae	0%	26	0%	28	0%	21	3%	104	0%	15	9%	195	0%	493
Simuliidae	0%	15	0%	36	0%	15	0%	16	7%	254	0%	5	0%	389
Tipulidae	1%	82	0%	35	1%	168	5%	162	1%	52	8%	166	0%	478
Sphaeriidae	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	7%	7161
Gastropoda	0%	0	0%	0	0%	6	0%	0	0%	0	0%	1	2%	1938
Acarina	5%	793	4%	396	3%	494	1%	43	1%	24	2%	31	2%	2012
Nematoda	0%	0	0%	5	0%	15	0%	17	1%	26	1%	20	8%	8305
Oligochaeta	9%	1336	19%	2061	9%	1687	12%	422	10%	363	18%	367	18%	18607
Ostracoda	0%	24	0%	11	0%	10	0%	1	0%	2	0%	5	14%	14519
Totals	89%	13970	89%	9434	91%	16946	97%	3327	95%	3285	96%	1983	95%	98887

Table 8. Mean benthic invertebrate density (number m-2) and percent composition by habitat and functional group in Twin Creek, Taft Creek, and the side channel.

	Twin Creek						Side Channel						Taft Creek	
	Reach		Riffle		Pool		Reach		Riffle		Pool			
Functional Groups		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$		$\bar{x}$
collectors	24%	3791	24%	2589	15%	2763	51%	1736	66%	2280	4%	83	6%	6558
predators	17%	2720	23%	2411	8%	1589	16%	547	12%	415	14%	281	1%	1544
shredders	6%	980	3%	351	6%	1114	7%	240	4%	148	8%	175	1%	1323
scrapers	5%	740	6%	586	3%	534	0%	0	0%	2	0%	0	0%	0
chironomidae	33%	5112	19%	2043	55%	10293	11%	385	5%	181	51%	1044	40%	41371
non-insects	14%	2158	23%	2473	12%	2221	14%	483	12%	417	21%	426	51%	52542
unassignable	1%	178	2%	177	1%	205	1%	28	1%	22	3%	55	1%	576
Totals	100%	15678	100%	10630	100%	18719	100%	3419	100%	3466	100%	2063	100%	103914

Chloroperlidae and Leuctridae were the predominant Plecoptera families, collectively composing 11% of the benthos and Trichoptera were nearly absent. Fifteen percent of the benthos were non-insects, most of which were Oligochaeta (13%).

Collectors were the predominant functional group in the side channel, comprising 46% of the benthic fauna (table 4). Predators composed 14% of the benthos and 6% were shredders, while scrapers were nearly absent (0.03%). The high percentage of detrital processors in the side channel indicate that most of the benthic fauna were obtaining food from heterotrophic sources.

Significant differences between habitats (reach, riffle, pool) could not be detected using a one-way analysis of variance (table 5)(Elliott 1977; Kachigan 1982). Results from Kulczynski's similarity index (Kulczynski 1928) indicated that reaches and pools were the most similar habitats, riffle and reach areas were intermediate in similarity, and riffle and pool areas were the least similar (fig. 10). Benthic density was similar in reach and riffle areas; pools had somewhat lower densities.

Percent composition of nearly all taxa were similar in reach and riffle areas (tables 6, 7). Ephemeroptera was the predominant order in both habitats, followed by Diptera and Plecoptera. Diptera composition differed for the two habitats, Simuliidae was the predominant family in riffles and Chironomidae in reaches. Benthic fauna within pools differed greatly from riffles and reaches, and was predominately composed of Diptera (71%) and non-insects (21%). Ephemeroptera and Plecoptera were much less abundant in pools than in reaches or riffles.

A comparison of trophic categories also indicated a greater similarity of reach and riffle areas to each other than with pools (table 8). Collectors were predominant in riffles and reaches, comprising 66% and 51% of the benthic fauna (respectively), while their percent composition in pool areas was only 4%. Predator composition was similar in all three habitats, and shredders were less abundant in riffles than in reaches or pools.

Taft Creek

Benthic composition of Taft Creek was predominately non-insects (51%) and Diptera (42%). The most abundant non-insect groups were Oligochaeta (18%) and Ostracoda (14%), followed by Nematoda (8%), Sphaeriidae clams (7%), Gastropoda (2%), and Acarina (2%) (table 2). Chironomidae was the predominant Diptera family (table 3).

Collectors were the predominant functional group, comprising 6% of the total benthic fauna, as compared to 1% for both predators and shredders, and 0% for scrapers (table 4).

Between-site analysis

Results from the chi-squared test for "goodness of fit" rejected agreement with the Poisson series and indicated a contagious or clumped distribution for Twin and Taft Creeks at the $\bar{x}$ numbers m^{-2} per sample level (table 9). Agreement with the Poisson series was not rejected at the $\bar{x}$ numbers m^{-2} per sample level but was rejected at the dominant taxon level for the side channel (table 9). At all sites, variances were greater than means, which also indicated a contagious distribution for benthos within these sites.

A standard error equal to 20% of the mean has been considered to be an acceptable error for benthic samples (Elliott 1977). The D statistic (standard error/arithmetic mean) was usually equal to or less than 20% for all three sites for the four sampling periods (table 10). The number of samples (9 per sampling period per site) collected were usually greater than or equal to the number needed for a 20% error, indicating that a sufficient number of samples were usually taken (table 10)(Elliot 1977).

The average size of benthos was extremely small at all sites. Most of the insects in Twin Creek and the side channel were <4 mm; 92% and 88%, respectively (fig. 10) Non-insects were not measured because Oligochaeta, the predominant non-insect, and Nematoda, constrict upon preservation, preventing accurate length measurements. The

Table 9. Summarization of results from the chi-squared test for "goodness of fit" with the Poisson series for Twin Creek, Taft Creek, the side channel, and Leuctridae and Ephemerellidae in the side channel.

	calculated chi-square	chi-square (P=0.05)
Twin Creek	23.7[a]	12.5
Taft Creek	33.1[a]	30.0
Side channel	19.4	22.3
Leuctridae	29.7[a]	15.5
Ephemerellidae	23.1[a]	16.9

a. $p \leq 0.05$, ie., reject hypothesis of agreement with a Poisson series, it should be concluded that benthic organisms were contagiously, not randomly distributed on the stream bottom.

Table 10. a) D statistic for Twin Creek, Taft Creek, and the side channel for each sampling period, b) number of sampling units required for D=20% in Twin Creek, Taft Creek, and the side channel for each sampling period.

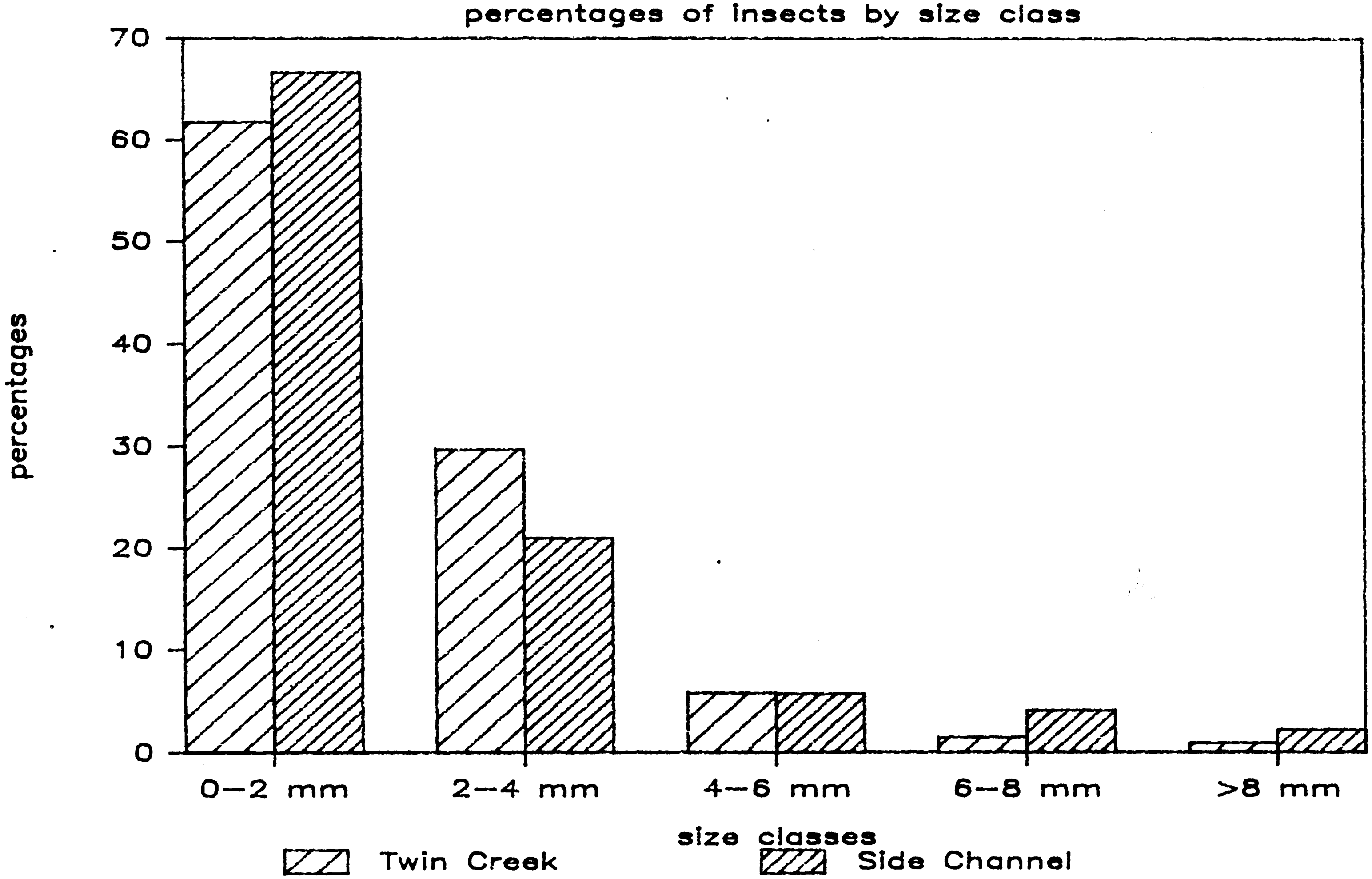
a) D statistic for Twin Creek, Taft Creek, and the side channel for each sampling period.

	Twin Creek	Taft Creek	Side Channel
June 12-15	21%	23%	12%
June 27-30	8%	22%	25%
July 24-26	12%	18%	27%
August 8-10	22%	13%	17%

b) number of sampling units required for D=20% in Twin Creek, Taft Creek, and the side channel for each sampling period.

	Twin Creek	Taft Creek	Side Channel
June 12-15	9	12	3
June 27-30	1	11	14
July 24-26	3	8	16
August 8-10	11	4	6

Fig. 10. Twin Creek and Side Channel



benthos of Taft Creek were not measured because of the great predominance of non-insects.

Significant differences in benthic fauna between sampling periods were not found using a one-way analysis of variance (Elliott 1977; Kachigan 1982)(table 5). There was, however, a considerable decrease in $\bar{x}$ numbers of benthos in both Twin Creek and the side channel shortly after the high flows in mid-July, while in Taft Creek numbers greatly increased (table 11).

Significant differences were found between the benthic fauna of Twin Creek, Taft Creek, and the side channel using a one-way analysis of variance (table 5). Results from the Kulczynski similarity index (Kulczynski 1928) indicate that the benthic fauna of Twin Creek and the side channel are most similar to each other and least similar to Taft Creek (fig. 10).

Total $\bar{x}$ benthic density in Twin Creek was approximately five times greater than that found in the side channel. A possible explanation for this difference may be the influence of glacial silt in the side channel, since these two sites are similar in most other characteristics (ie., substrate, flow regime, temperature, shading, chemical parameters and size). The detrimental effects of silt upon benthos has been well documented (Gebhardt 1970; Cordone and Kelly 1961; Hynes 1960; Tebo 1955). Silt was found to blanket and fill the interstices of the substrate within the side channel and only riffle areas remained relatively

Table 11. Mean benthic invertebrate density (number m-2) in Twin Creek, Taft Creek, and the side channel for each sampling period.

	Twin Creek	Taft Creek	Side Channel
June 12-15	25476	96601	2123
June 27-30	13040	57527	4713
July 24-26	9694	117371	1935
August 8-10	11824	144156	3159

clear. Side channel riffle habitats had the highest benthic standing crops of all habitat types, while in Twin Creek, these habitats had the lowest standing crops. Taft Creek had much higher benthic densities than either Twin Creek or the side channel ($\bar{x}$ = 103,914 numbers m^{-2} for Taft Creek, $\bar{x}$ = 15,009 numbers m^{-2} for Twin Creek, and $\bar{x}$ = 2,983 numbers m^{-2} for the side channel).

Ephemeroptera were the most abundant taxonomic group in the side channel, whereas Diptera (primarily Chironomidae) were most abundant in Twin Creek, and non-insects and Diptera were predominant in Taft Creek (table 2). Twin Creek was the only site in which Trichoptera (primarily Glossosomatidae) formed a significant portion of the benthic fauna and, correspondingly, in which scrapers were found. This may indicate a lack of periphyton in Taft Creek and the side channel. Ephemeroptera, Plecoptera, and Trichoptera in Twin Creek and the side channel collectively comprised 42% and 54% (respectively) of the benthic fauna, whereas their percent abundance in Taft Creek was only 7%. However, actual $\bar{x}$ numbers of these groups were greater in Taft Creek ($\bar{x}$ = 7,360 numbers m^{-2}) than in Twin Creek ($\bar{x}$ = 6,367 numbers m^{-2}) or the side channel ($\bar{x}$ = 1,643 numbers m^{-2})(table 2). The predominant Ephemeroptera in both Taft Creek and the side channel was Baetidae, whereas _Ephemerella_ _sp._ (especially _E. doddsi_) was most abundant in Twin Creek (table 3). Heptageniidae was abundant in both the side channel and Twin Creek. Percent abundances of Plecoptera were similar in Twin Creek and the side channel; Chloroperlidae and Leuctridae were the most abundant families. Chironomidae was the predominant Diptera family and formed a high percentage of the benthic fauna in all three sites. Empididae, Simuliidae and Tipulidae were abundant Diptera families in the side channel, but had relatively low percent abundances in Twin Creek and Taft Creek. Non-insects formed 51% of the benthic fauna in Taft Creek, whereas in Twin Creek and the side channel, non-insects were considerably less abundant (15% in both Twin Creek and the side channel)(table 4). At all three sites, Oligochaeta was the most abundant non-insect group.

A comparison of trophic categories using functional groups indicated a predominance by collectors at all sites (table 4). Scrapers were only significant in Twin Creek. Predators were approximately 3 times as abundant as shredders in Twin Creek and the side channel, but were approximately equally abundant in Taft Creek.

Confidence intervals (95% level) varied greatly for all groupings (±11% to ±172%) and no definite trends could be detected (tables 2, 3, 4). The confidence intervals for total mean numbers of benthos for the three sites were relatively similar (33% for Twin Creek, 31% for the side channel, and 27% for Taft Creek).

CONCLUSIONS

The predominance of detrital processing organisms (ie., collectors) in Twin Creek and the side channel indicate that the major energy source for these streams was probably allochthonous detritus. Both sites were heavily shaded and contained large amounts of woody debris and trapped leaf litter. Collectors were also the predominant functional group in river off-channel and valley wall tributary habitats of the South Fork of the Hoh River (Ward et al. 1982), and in Olympic Penninsula streams studied by Wasserman et al. (1984). However, scrapers were predominant in tributaries of the Clearwater River (Martin 1976).

It is more difficult to infer the primary energy source in Taft Creek, since the majority of benthos (91%) were non-insects and Chironomidae and could not be assigned a trophic category. Most of the benthos that were placed in functional groups were collectors, indicating that allochthonous detritus was probably an important food source. In addition, algae which coated macrophytes within the stream may have also provided an important source of energy for benthos in Taft Creek.

Within-stream habitat (reach, riffle, pool) relationships in Twin Creek were similar to respective habitats in the side channel when comparing taxa and percent abundances. At both sites, reach and riffle habitats were similar to each other, but considerably different from pools. However, benthic density relationships differed between the two sites. In Twin Creek, $\bar{x}$ benthic densities were lowest in riffles (10,630 m^{-2}), intermediate in reaches (15,678 m^{-2}) and highest in pools (18,719 m^{-2}); while in the side channel, $\bar{x}$ benthic densities were highest in riffles (3,466 m^{-2}), slightly lower in reaches (3,419 m^{-2}) and lowest in pools (2,063 m^{-2})(tables 6,7,8). These differences may reflect the influence of a high glacial silt load in the side channel. Silt tends to settle-out and cover areas where current velocity is reduced (pools), and to remain in suspension where velocity is greatest (riffles). The effects of a high silt load include decreased light penetration and scouring of algal cells from rock surfaces. Also, the process of siltation causes a decrease in available niche space for benthos and decreased autochthonous production through the elimination of appropriate substrate. These effects may also be reflected in the low $\bar{x}$ number of benthos in the side channel (2,983 m^{-2}) in comparison to Twin Creek (15,009 m^{-2}) and in the absence of scrapers in the side channel. Scrapers were also absent in off-channel habitats, but present in valley-wall tributaries in the South Fork Hoh River (Ward et al. 1982).

Differences in benthic community composition and abundance between Taft Creek and the other sites seems to reflect differences in available benthic habitat. Taft Creek is a slow moving stream with a large amount of macrophytic growth, muddy substrate, and little canopy cover. Twin Creek and the side channel have rock-rubble substrate, greater current velocities and are heavily shaded. The high $\bar{x}$ number of benthos found in Taft Creek indicate that it is an excellent habitat for benthic production. Taft Creek also appears to be less affected by freshets than the other sites, providing a more stable habitat for benthos. After the storm in mid-July produced great increases in discharge in the Hoh River and its tributary streams, $\bar{x}$ benthic densities in Taft Creek increased, but substantially decreased in the side channel and Twin Creek. During this storm, the sedge meadow through which Taft Creek flows was shallowly flooded. When the water level dropped, run-off may have provided additional allochthonous input and nutrients to the stream, increasing the benthic food base and stimulating autochthonous production. Drifting benthic organisms from upstream areas during high discharge may have also contributed to this increase. The side channel experienced the greatest decrease in $\bar{x}$ numbers of benthos after the storm. Because of its connection with the Hoh River, discharge and silt load in the side channel correspondingly increased and may have resulted in increased abrasive scouring and disruption of the benthic environment.

Benthic densities in similar habitats of the South Fork Hoh River (river off-channel - $\bar{x}$ = 228 m^{-2}, terrace tributary - $\bar{x}$ = 559 m^{-2}, valley wall tributary - $\bar{x}$ = 626 m^{-2}

(Ward et al. 1982) were much lower than those found in this study (side channel - $\bar{x}$ = 2,983 m^{-2}, Taft Creek - $\bar{x}$ = 103,914 m^{-2}, Twin Creek - $\bar{x}$ = 15,009 m^{-2}). In tributaries of the Clearwater River (Martin 1976), benthic densities in riffle areas ($\bar{x}$ = 3,079-4,573 m^{-2}) were similar to those found in riffle areas of the side channel ($\bar{x}$ = 3,466 m^{-2}), but much lower than those found in Twin Creek ($\bar{x}$ = 10,630 m^{2}) in this study. Mean benthic densities for riffle areas in Olympic Penninsula streams studied by Wasserman et al. (1984) varied greatly, ranging from less than those found in the side channel to greater than those found in Twin Creek in this study.

The high percentage of small benthos found in this study (fig. 11) seems to be typical for Olympic Penninsula streams (Wasserman et al. in press; personal communication Martin).

Possible sources of error related to this study are that only the upper 10 cm of the substrate was sampled and that two different types of samplers were used. Benthos have been found to occur as deep as 70 cm within the hyporheic zone of streams with suitable substrate (Williams and Hynes 1974); therefore, neglecting the hyporheos of streams in this study may have resulted in an underestimation of the actual benthic densities. Because a different sampler was used in Taft Creek, small differences in benthic densities between this site and the other sites may not be significant due to differential biases of the two samplers. I attempted to reduce additional biases by using a 250 cm^{-4} sieve and processing the benthos identically in all three sites.

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Appendix A. List of the benthic taxa recorded from all streams during the study.

EPHEMEROPTERA

Baetidae

Baetis sp.

Ephemerellidae

Ephemerella sp.

E. Drunella

E. doddsi

E. flavilinea

Heptageniidae

Cinygmula sp.

Epeorus sp.

Rhithrogena sp.

Leptophlebiidae

Paraleptophlebia sp.

Siphlonuridae

Ameletus sp.

PLECOPTERA

Capniidae

Chloroperlidae

Paraperla sp.

Perlinella sp.

Appendix A. (continued.) List of the benthic taxa recorded from all streams during the study.

Suwallia, Sweltza, Triznaka sp.

Leuctridae

Nemouridae

Amphinemura sp.

Zapada sp.

Peltoperlidae

Talloperla sp.

Perlidae

Doroneuria sp.

Hesperaperla sp.

Phasganophora sp.

Perlodidae

Kogotus sp.

Megarcys sp.

Pteronarcyidae

Pteronarcys sp.

TRICHOPTERA

Trichoptera pupae

Brachycentridae

Micrasema sp.

Glossosomatidae

Glossosoma sp.

Hydropsychidae

Arctopsyche sp.

Appendix A. (continued.) List of the benthic taxa recorded from all streams during the study.

Hydropsyche sp.

Parapsyche sp.

Lepidostomatidae

Lepidostoma sp.

Limnephilidae

Apatania sp.

Dicosmoecus sp.

Ecclisomyia sp.

Goeracia sp.

Onocosmoecus sp.

Psychoglypha sp.

Philopotamidae

Rhyacophilidae

Rhyacophila sp.

COLEOPTERA

Dytiscidae

Elmidae

Hydrophilidae

Staphilinidae

MEGALOPTERA

Sialidae

Sialis sp.

Appendix A. (continued.) List of the benthic taxa recorded from all streams during the study.

DIPTERA

Diptera pupae

Ceratopogonidae

Chironomidae

Deuterophlebiidae

Dixidae

Empididae

Ephydridae

Psychodidae

Ptychopteridae

Simuliidae

Tipulidae

Dicranota sp.

Hexatoma sp.

Prionocera sp.

Tipula sp.

BIVALVIA

Sphaeriidae

Pisidium sp.

GASTROPODA

HIRUDINEA

Piscicolidae

Piscicola salmositica

Appendix A. (continued.) List of the benthic taxa recorded from all streams during the study.

ACARINA

NEMATODA

OLIGOCHAETA

OSTRACODA

Appendix B. Benthic taxa by sampling period.

Taxa	Twin Creek ($\bar{x}$ numbers m^{-2}) 12 June	27 June	24 July	8 August
EPHEMEROPTERA				
Baetidae	138	137	247	723
Baetis sp.	187	39	6	35
Ephemerellidae				
Ephemerella sp.	935	827	846	1034
E. Drunella	248	292	94	29
E. doddsi	717	870	609	170
Heptageniidae	1198	1378	773	395
Cinygmula sp.	203	174	0	13
Epeorus sp.	372	213	35	0
Rhithrogena sp.	6	0	0	0
Leptophlebiidae	0	4	0	0
Paraleptophlebia sp.	139	90	53	125
Siphlonuridae	0	6	0	0
Ameletus sp.	548	140	51	60
PLECOPTERA				
Capniidae	43	30	152	210
Chloroperlidae	1016	1046	1099	977
Paraperla sp.	2	4	0	0
Suwallia, Sweltza, Triznaka sp.	296	45	20	0
Leuctridae	699	464	348	336
Nemouridae	134	230	108	258
Zapada sp.	13	0	0	0
Peltoperlidae	0	0	0	0
Perlidae	72	50	128	56
Hesperaperla sp.	0	0	0	3
Phasganophora sp.	2	0	0	0
Perlodidae	7	39	23	77
Kogotus sp.	19	4	0	0
Megarcys sp.	0	0	0	0
TRICHOPTERA				
Trichoptera pupae	0	13	0	0
Brachycentridae				
Micrasema sp.	13	0	0	0
Glossosomatidae				
Glossosoma sp.	225	380	383	567
Hydropsychidae	0	0	0	0
Arctopsyche sp.	0	7	0	0
Hydropsyche sp.	17	0	0	0
Lepidostomatidae				
Lepidostoma sp.	19	0	0	0

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Twin Creek ($\bar{x}$ numbers m^{-2}) 12 June	27 June	24 July	8 August
Limnephilidae	37	6	9	47
Apatania sp.	262	62	71	23
Dicosmoecus sp.	14	0	9	0
Goeracia sp.	0	0	6	0
Onocosmoecus sp.	0	0	2	0
Psychoglypha sp.	0	0	0	0
Philopotamidae	0	7	0	0
Rhyacophilidae				
Rhyacophila sp.	343	284	292	203
COLEOPTERA	0	6	37	0
Dytiscidae	0	0	0	9
Elmidae	78	32	49	93
Hydrophilidae	0	0	0	0
Staphilinidae	0	0	0	0
MEGALOPTERA				
Sialidae				
Sialis sp.	0	0	0	0
DIPTERA	39	4	6	0
Diptera pupae	159	230	126	125
Ceratopogonidae	21	6	34	39
Chironomidae	13574	2825	2260	4605
Deuterophlebiidae	13	101	148	214
Dixidae	7	11	0	4
Empididae	14	39	27	19
Ephydridae	0	0	0	0
Psychodidae	2	0	0	0
Ptychopteridae	0	0	0	0
Simuliidae	23	6	37	20
Tipulidae	34	26	4	36
Dicranota sp.	110	43	58	48
Hexatoma sp.	2	6	0	13
Tipula sp.	0	0	0	0
BIVALVIA	13	0	0	6
Sphaeriidae				
Pisidium sp.	0	0	0	0
GASTROPODA	0	0	9	0

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Twin Creek ($\bar{x}$ numbers m^{-2}) 12 June	27 June	24 July	8 August
HIRUDINEA				
Piscicolidae				
<u>Piscicola salmositica</u>	0	0	0	0
ACARINA	632	372	408	833
NEMATODA	13	0	0	13
OLIGOCHAETA	2818	2463	1112	385
OSTRACODA	0	28	14	18
total	25476	13040	9694	11824

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Taft Creek ($\bar{x}$ numbers m^{-2}) 15 June	30 June	26 July	9 August
EPHEMEROPTERA				
Baetidae	1527	1455	6319	4884
Baetis sp.	0	0	0	0
Ephemerellidae				
Ephemerella sp.	0	0	0	0
E. Drunella	0	0	0	0
E. doddsi	0	0	0	0
Heptageniidae	137	82	0	55
Cinygmula sp.	0	0	0	0
Epeorus sp.	0	0	0	0
Rhithrogena sp.	0	0	0	0
Leptophlebiidae	0	146	0	0
Paraleptophlebia sp.	412	1198	5478	2104
Siphlonuridae	0	0	0	0
Ameletus sp.	0	0	0	0
PLECOPTERA				
Capniidae	0	41	0	55
Chloroperlidae	0	0	0	0
Paraperla sp.	0	0	0	0
Suwallia, Sweltza, Triznaka sp.	0	0	0	0
Leuctridae	0	0	0	0
Nemouridae	1646	764	1591	512
Zapada sp.	0	0	0	0
Peltoperlidae	0	0	0	0
Perlidae	0	0	0	0
Hesperaperla sp.	0	0	0	0
Phasganophora sp.	0	0	0	0
Perlodidae	0	0	0	0
Kogotus sp.	0	0	0	0
Megarcys sp.	0	0	0	0
TRICHOPTERA				
Trichoptera pupae	0	0	0	0
Brachycentridae				
Micrasema sp.	0	0	0	0
Glossosomatidae				
Glossosoma sp.	0	0	0	0
Hydropsychidae	0	0	0	0
Arctopsyche sp.	0	0	0	0
Hydropsyche sp.	0	0	0	0
Lepidostomatidae	0	0	0	0
Lepidostoma sp.	55	0	55	146

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Taft Creek ($\bar{x}$ numbers m^{-2}) 15 June	30 June	26 July	9 August
Limnephilidae	82	0	0	0
Apatania sp.	0	0	0	0
Dicosmoecus sp.	0	0	0	0
Goeracia sp.	0	0	0	0
Onocosmoecus sp.	0	0	0	0
Psychoglypha sp.	329	87	0	55
Philopotamidae	27	0	0	0
Rhyacophilidae				
Rhyacophila sp.	82	37	55	55
COLEOPTERA	0	0	0	0
Dytiscidae	0	0	0	0
Elmidae	0	0	0	110
Hydrophilidae	0	0	0	0
Staphilinidae	0	0	0	0
MEGALOPTERA				
Sialidae				
Sialis sp.	0	27	55	0
DIPTERA	0	0	73	0
Diptera pupae	777	201	430	823
Ceratopogonidae	55	201	1536	531
Chironomidae	29134	17278	49748	69325
Deuterophlebiidae	0	0	0	0
Dixidae	0	183	0	0
Empididae	0	380	512	1079
Ephydridae	0	0	0	0
Psychodidae	0	0	0	0
Ptychopteridae	18	73	0	0
Simuliidae	768	233	549	0
Tipulidae	274	41	27	0
Dicranota sp.	750	243	82	494
Hexatoma sp.	0	0	0	0
Tipula sp.	0	0	0	0
BIVALVIA				
Sphaeriidae				
Pisidium sp.	8357	5306	8449	6530
GASTROPODA	887	1624	2295	2945

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Taft Creek ($\bar{x}$ numbers m^{-2})			
	15 June	30 June	26 July	9 August
HIRUDINEA				
Piscicolidae				
Piscicola salmositica	0	0	0	0
ACARINA	3768	1271	1619	1390
NEMATODA	9401	5796	9263	8762
OLIGOCHAETA	30590	15080	19541	9219
OSTRACODA	7523	5778	9693	35083
total	96601	57527	117371	144156

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Side Channel ($\bar{x}$ numbers m^{-2}) 13 June	28 June	25 July	10 August
EPHEMEROPTERA				
Baetidae	90	959	612	670
Baetis sp.	48	7	22	24
Ephemerellidae				
Ephemerella sp.	51	197	56	82
E. Drunella	19	18	10	5
E. doddsi	3	68	2	0
Heptageniidae	30	751	314	639
Cinygmula sp.	19	67	8	2
Epeorus sp.	55	74	40	6
Rhithrogena sp.	0	37	34	68
Leptophlebiidae	0	0	0	0
Paraleptophlebia sp.	43	11	2	10
Siphlonuridae	0	0	0	0
Ameletus sp.	0	5	8	0
PLECOPTERA				
Capniidae	0	2	0	27
Chloroperlidae	108	132	111	219
Paraperla sp.	0	0	0	0
Suwallia, Sweltza, Triznaka sp.	0	93	22	121
Leuctridae	63	122	45	135
Nemouridae	10	14	17	50
Zapada sp.	0	0	0	3
Peltoperlidae	0	0	0	2
Perlidae	2	7	2	3
Hesperaperla sp.	0	0	0	0
Phasganophora sp.	0	0	0	0
Perlodidae	3	25	13	8
Kogotus sp.	0	0	2	0
Megarcys sp.	0	4	6	2
TRICHOPTERA				
Trichoptera pupae	2	5	0	5
Brachycentridae				
Micrasema sp.	0	0	0	0
Glossosomatidae				
Glossosoma sp.	0	2	0	2
Hydropsychidae	0	2	0	0
Arctopsyche sp.	0	0	0	0
Hydropsyche sp.	0	0	0	0
Lepidostomatidae	0	0	0	0

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Side Channel ($\bar{x}$ numbers m^{-2}) 13 June	28 June	25 July	10 August
Lepidostoma sp.	2	0	0	2
Limnephilidae	0	0	0	0
Apatania sp.	0	0	0	0
Dicosmoecus sp.	0	0	0	0
Goeracia sp.	0	0	0	0
Onocosmoecus sp.	0	0	0	0
Psychoglypha sp.	0	0	0	0
Philopotamidae				
Rhyacophilidae				
Rhyacophila sp.	6	6	0	5
COLEOPTERA	0	0	2	0
Dytiscidae	0	2	0	0
Elmidae	0	0	3	0
Hydrophilidae	2	0	2	0
Staphilinidae	3	0	2	0
MEGALOPTERA				
Sialidae				
Sialis sp.	0	0	0	0
DIPTERA	11	8	2	11
Diptera pupae	50	28	11	8
Ceratopogonidae	5	3	0	2
Chironomidae	836	943	195	174
Deuterophlebiidae	0	0	0	0
Dixidae	0	0	0	0
Empididae	132	121	53	114
Ephydridae	2	0	0	0
Psychodidae	0	0	2	0
Ptychopteridae	0	0	0	0
Simuliidae	11	101	18	235
Tipulidae	72	26	34	79
Dicranota sp.	10	110	29	90
Hexatoma sp.	0	4	2	5
Tipula sp.	0	39	3	5
BIVALVIA				
Sphaeriidae				
Pisidium sp.	0	0	0	0
GASTROPODA	0	0	2	0

Appendix B. (continued.) Benthic taxa by sampling period.

Taxa	Side Channel ($\bar{x}$ numbers m^{-2})			
	13 June	28 June	25 July	10 August
HIRUDINEA				
Piscicolidae				
Piscicola salmositica	0	2	0	2
ACARINA	34	44	29	24
NEMATODA	26	42	3	14
OLIGOCHAETA	372	633	222	309
OSTRACODA	6	3	0	2
total	2123	4713	1935	3159