

STREAM ECOLOGY IN AN URBANIZED LANDSCAPE

Understanding human impacts on streams helps prevent detrimental effects of development and agriculture and focus attention on important areas for restoration. Ecologists and resource managers are relying more and more on stream invertebrate sampling as a means of assessing water quality, an approach called *stream bioassessment*. Benthic (bottom-dwelling) macroinvertebrates can be used to rapidly assess stream quality because certain groups are highly sensitive to stream degradation, while others are relatively tolerant. Because these organisms develop and grow within the water, they integrate the environmental conditions over a long period of time. They are affected by changes in stream conditions, whether caused by infrequent spikes in pollutants or subtle yet chronic reductions in dissolved oxygen. The degree of stream impairment traditionally has been assessed through monthly or seasonal monitoring water chemistry parameters (temperature, nutrient levels, dissolved oxygen, etc.); however these abiotic measures may fail to detect occasional but strong changes in conditions, such as a pulse of pollutants following a storm event. These two approaches (biotic and abiotic) can be combined by calculating indices based on multiple metrics of stream quality using both analyses of benthic macroinvertebrate communities and direct analyses of water chemistry parameters.

In this lab, we will gather data on the water chemistry, habitat, and the community structure of benthic macroinvertebrates in three Bellingham creeks to compare stream quality at the three locations. **Whatcom Creek** originates at Lake Whatcom, passes through forested Whatcom Falls Park, and then flows through an industrial area of Bellingham parallel to Iowa Street, where the creek is channelized, lacks significant riparian vegetation, and receives pollution-laden runoff. **Padden Creek** flows from Lake Padden through a second-growth forest before entering the residential area of Happy Valley (see map on following page). Below its confluence with Connelly Creek, Padden Creek is channelized to control flooding and to minimize the creek's meander through the riparian area in protected Fairhaven Park. In contrast, **Chuckanut Creek** originates in the hills southeast of Bellingham and flows through a mostly forested landscape that features only minor agricultural and residential development, with essentially no structural modifications.

Over the course of the next four weeks, we will be conducting research to determine if Whatcom Creek, Padden Creek and Chuckanut Creek differ from one another, using both biotic and abiotic measures of stream quality. This study will take several steps:

- In the first week of lab, we will survey these sites and come up with hypotheses about how they might (or might not) differ from one another.
- In the second week of lab, we will sample for our main comparison between Padden Creek (within Fairhaven Park) and Chuckanut Creek (within Arroyo Park) by conducting field invertebrate sampling, habitat characterization, and water chemistry measurements at both sites.
- In the third week, you will identify and tally the invertebrates you collected, and calculate metrics commonly used in stream bioassessment.
- In the fourth week, you will do statistical analyses and create graphs of your data to test the hypotheses we initially derived. You will also compare these data to measurements from a site along Whatcom Creek, in industrial Bellingham. These comparisons will form the basis of the lab report that you will write.

Through this stream ecology project you will gain a comprehensive understanding of how to conduct a complete ecological research project, culminating in a formally written scientific report.

Objectives:

The objectives of this lab project are for you to:

1. Conduct an ecological research project, from question and hypothesis development through to analysis and interpretation of results.
2. Compare stream characteristics between three streams.
3. Develop an understanding of the integration of physiological, population, & community ecology.
4. Identify stream invertebrates using pictorial keys.
5. Participate in a long-term study of Bellingham stream invertebrates.
6. Gain experience using Excel and Systat to manage data, calculate basic statistics, and prepare figures.
7. Learn how to turn complex data, such as abundance data for many species in a community, into meaningful, easy to interpret metrics.
8. Write a scientific paper that draws from the published literature.

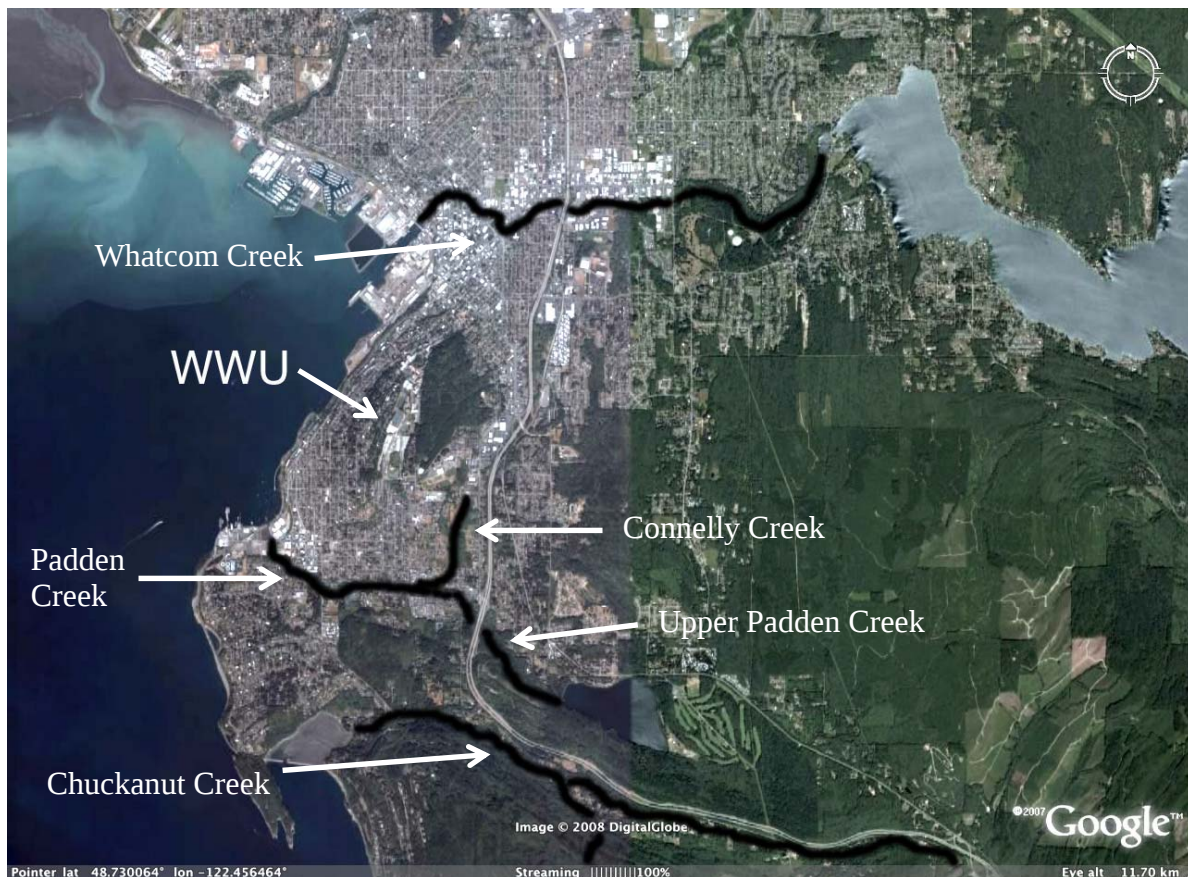


Figure 1. Aerial view of Bellingham showing the Western Washington University campus, and the streams that will be the focus of this study. Image from Google Earth®.

RELEVANT PADDEN CREEK LITERATURE:

- Hachmöller, B. 1989. The benthic macroinvertebrate community in Padden Creek, summer 1988. M.S. thesis, Western Washington University, Bellingham, WA
- Hachmöller, B., Matthews, R.A., and D.F. Brakke. 1991. Effects of riparian community structure, sediment size, and water quality on the macroinvertebrate communities in a small, suburban stream. Northwest

Science 65: 125-132.

Matthews, G.B., Matthews, R.A., and B. Hachmöller. 1991. Mathematical analysis of temporal and spatial trends in the benthic macroinvertebrate communities of a small stream. Canadian Journal of Fisheries and Aquatic Sciences 48: 2184-2190.

TO DO BEFORE NEXT LAB:

- 1) Complete the stream literature assignment (see separate handout)
- 2) Read this entire handout

WEEK 2 - SAMPLING PROCEDURE – TO BE COMPLETED FOR TWO SITES (Padden & Chuckanut):

Invertebrate Sampling

1. Mark off a 10m length of stream using a meter tape and flagging. Do not overlap with another group, and remember to collect the flagging when you are finished!
2. Within your length of stream, sample invertebrates from a riffle (cobble-bottomed portion) because that is the preferred habitat of many benthic macroinvertebrates.
 - ☞ Place your D-net firmly on the stream bottom, such that water cannot easily flow beneath it; have the top of the net above the stream surface, if possible.
 - ☞ Holding the net in place for **1 minute**, have group members disturb the streambed from the net to 1m upstream of the net.
 - Pick up rocks and rub them thoroughly, holding them in the water directly upstream of the net (so all debris flows into the net). If you can't pick up a rock, rub the surface thoroughly.
 - Vigorously kick the streambed with your heel to stir up any invertebrates you may have missed.
 - ☞ After sampling is completed, carefully lift the net up from the water (without losing your sample) by moving the D-net upstream as you lift.
3. Empty the contents of the D-net into the pan by inverting the net, and sort through it to find invertebrates.
 - ☞ Place the enamel sorting pan on level ground with enough room for several people to gather around it. Add a small amount of water in the pan
 - ☞ Rinse the net to remove any invertebrates that are stuck to inside walls or are caught in the mesh!
 - ☞ Place all invertebrates collected into a wide-mouth jar containing 70% ethanol – be sure the jar is also labeled with your names, date, and the site (labels should be in PENCIL on a small piece of paper inside the jar).

Stream Characterization

Any aspects of the stream characterization that require you to enter the stream (such as measuring stream velocity and depth, assessing particle size, and quantifying water chemistry) need to be done *after* you have collected your stream invertebrate sample.

1. Complete the SITE DESCRIPTION data sheet
2. For habitat characterization, make sure you have at least two people making the estimates, and both sites needs to be done by the same people.
3. We have two Eureka water chemistry probes, which simultaneous measure temperature, pH, specific conductivity, and dissolved oxygen. Either the instructor or TA will come by each group with the Eureka probe and provide instructions on use.

IMPORTANT: At the end of the day make sure that everyone in your group has a copy of the data.

WEEK 3 - IN-LAB INVERTEBRATE SORTING

After the field sampling is completed, a lab session will be dedicated to identifying the invertebrates you collected. To use time efficiently, you should divide the members of your group so that the two samples can be sorted simultaneously. There are two steps to the identification process: rough-sorting (placing like with like) and identifying (insects to the level of Family, and other invertebrates to the level of Class).

Rough-sorting

1. Fill the wells of the sorting tray half-full with 70% ethanol.
2. Carefully pour some of your sample into a Petri dish and examine the sample. Initially see if you can do any sorting without the microscope (it's faster if you can). Sort the invertebrates from a site into groups that look similar. Start with broad categories ('worm-like', 'worm-like with legs', 'insect-like', etc.).
3. Place the groups of invertebrates into the wells of your sorting tray and label. DO NOT combine samples from multiple sites.
4. When it is no longer effective to sort without the microscope, use the dissecting microscope which will make the task of sorting smaller invertebrates much easier.

Identification

1. Use the reference tools available, to help you identify each individual within your rough-sorted groups.
2. As you identify organisms from specific taxonomic groups, place them into a taxonomically labeled well in the sorting tray.
3. *If in doubt, check with your partners, the instructor or TA. We need to make sure that the class is consistently and accurately identifying the different taxonomic groups.*
 - ☞ You may find that identification is quicker if one of you specializes on identifying one group of organisms, another identifies another group, etc.
 - ☞ As part of class-wide quality control, you must confirm your identification with other lab groups.
 - ☞ If your group is unable to finish identifying your invertebrates during lab, you will need to take time outside of regular class hours to finish the job.
4. Each individual taxonomic group should be stored in its own capped vial that is labeled with a small, white piece of paper on which is the following information:
group members' names • sample location • date collected • taxonomic group
5. Once all invertebrates are sorted and identified, count all of the individuals in each taxonomic group, and complete the BENTHIC MACROINVERTEBRATES data sheet.
6. If you finish early, help groups that have more specimens than you – after all, you will be sharing data with them, and it'll help us finish sooner.

DATA ORGANIZATION

1. Using the information on your STREAM CHARACTERIZATION data sheet, complete the MULTIMETRIC HABITAT INDEX table. Make sure to properly identify the site at the top of the form to avoid mixing up data between the two sites.
2. Use the data on your BENTHIC MACROINVERTEBRATES data sheet to complete the MULTIMETRIC BIOTIC INDEX table.
3. Enter your group's data into the EXCEL Stream Ecology worksheet. **IMPORTANT:** Have a person from your group who did not enter the data go through the worksheet, and check the accuracy of the data entry.
4. Finally, **submit an electronic copy** of the Excel spreadsheet with the name "streamlab_" plus the last name of the student who makes the submission. Also **turn in one set of completed data sheets** to the TA. Only one set per group is needed (both sites). The entire group will receive the same grade for this assignment, and you will be assessed on the accuracy of your calculations, data entry, and the timeliness of your submission.

WEEK 4 - DATA ANALYSIS:

In the final week of the stream ecology lab, we will perform statistical analyses on the pooled class data, to determine if the sites differed in terms of: water chemistry, multimetric habitat index, and/or multimetric biotic index. To increase the statistical power of our analyses, we will combine the data from the two 326 sections and take advantage of the fact that we have independent data from multiple groups. In addition, we will use data collected previously from Whatcom Creek, to allow us to compare the same set of parameters for three streams. Means and standard deviations will be calculated from the data, and the statistical significance of any differences in means between sites will be evaluated using analysis of variance (ANOVA). *We will go through these analyses in class, but if you find yourself struggling with them, be sure to ask for help!*

LAB REPORT:

Using the results of your analyses, prepare an 8-10 page (not counting references, figures, or tables) scientific report. The guidelines for your written report are available in a separate handout – you will be evaluated on the completeness of the report, depth of analysis, quality of writing, and your ability to adhere to the report guidelines. Your scientific paper must include the following: 1) an introduction that includes a) background information that integrates the study within a broader scientific context using the scientific literature, and b) your hypotheses, 2) a methods section with an appropriately detailed description of how you tested your hypotheses, 3) a results section to present your data, and 4) a discussion section to integrate your findings with the broader ecological context, previous research, and your conclusions. Before writing this paper, be sure to **read the “Guidelines for Writing Lab Reports” handout**. The handout specifies what belongs in each section of the paper, how to cite your sources, the rubric we will use to grade your paper, and much more. Read this handout again before you turn in your paper, to be sure that you have followed the guidelines.

Although you will ultimately turn in a complete paper, we will get there through an iterative process:

1. **Introduction and Methods** (first draft) – You will first submit a draft of these sections. **DUE: 4/12.**
2. **Complete Paper** (including revised Intro & Methods) – After getting feedback on the Introduction and Methods, you will revise those sections and incorporate them into the remaining sections of a paper (Title, Abstract, Introduction, Methods, Results, Discussion, References, Figures, and Tables). **DUE: 4/26.**
3. **Final submission of complete paper** – After receiving feedback on the draft of your entire paper, you will revise it and submit a final draft. **DUE: 5/17.**

PLEASE NOTE: To be successful in this assignment, you have two important responsibilities. First, make your first drafts as good as you possibly can. You should write your drafts as if they are the final copies that you're turning in. Only if you do as well as you can will we be able to help you work on areas of difficulty. Otherwise, we'll waste our time and yours commenting on things you already knew how to do better. **If your first drafts reflect minimal effort, they will be returned to you without comments**, which will make it much more difficult for you in subsequent drafts. Second, you must respond to the feedback we give you. Not only will your writing improve, but you'll also get a better grade on your subsequent drafts. Later drafts are graded harder than initial drafts. If you still have the same problems in later drafts that were in earlier drafts, you will get marked off even more.

There is a reason we're going through this process – scientific writing is hard, and we want to give you the opportunity to improve your writing, a skill that will benefit you in other college courses as well as in your future career.

SITE DESCRIPTION					
Date:	Site:	Lab Group:			
Weather:	Now	Last 48 hours (Clear/Sunny, Overcast, Showers, Steady Rain, Heavy Rainstorm)			
STREAM CHARACTERISTICS					
STREAM HABITAT: (check if present)	Riffle ____ small surface waves	Glide ____ smooth moving water	Pool ____ still water		
# of riffles in 10m segment: ____		% of 10m total that is riffles: ____			
STREAM BOTTOM (estimate % in each category, according to particle size):					
_____ % bedrock	_____ % boulder > 10"	_____ % cobble rocks 1"-10"	_____ % gravel rocks <1"	_____ % sand (coarse sediment)	_____ % silt (fine sediment)
MID-CHANNEL FLOW VELOCITY (m/s) for a 4m stretch in your site (see below for directions):					
1: ____		2: ____		3: ____	
				Average: ____	
STREAM WIDTH – measure the width of the water at three points within your 10m stream length					
Top of reach: ____		Middle: ____		End: ____	
				Average: ____	
MID-CHANNEL DEPTH – measured at each position used for stream width measurements					
Top of reach: ____		Middle: ____		End: ____	
				Average: ____	
CHANNEL ALTERATION & EROSION					
Do the banks or channel appear altered? ____ (Y or N)					
% Left bank erosion (facing upstream) ____			% Right bank erosion ____		
RIPARIAN VEGETATION					
Characterized for the area within 5m of the high water line.					
% of banks covered by vegetation: ____ Left bank ____ Right bank					
VEGETATION COMPOSITION (estimate cover by each, total can be > 100%):					
Shrubs ____% Grass ____% Deciduous trees ____% Coniferous trees ____% Bare ____%					
STREAM SHADING (estimate):					
100% ____ 75-100% ____ 50-75% ____ 25-50% ____ 1-25% ____ 0% ____					

Mid-channel flow velocity

Find an unobstructed 4m length of stream in the middle of the stream channel. Drop a lemon in the water where it will not be affected by water moving around your legs. Time how long it takes the lemon to move 4m downstream, where it should be caught by another group member. Take 3 measurements at the same spot.

WATER CHEMISTRY	
pH: ____	Conductivity: ____ μ S/cm
Dissolved Oxygen: ____ mg/L	Water Temperature: ____ °C

MULTIMETRIC HABITAT INDEX				
Date:		Site:		Lab Group:
Habitat Metric	Excellent 5	Fair 3	Poor 1	Site Score
% Cobble	≥50%	25-49%	<25%	
Velocity	0.40-0.65 m/s	0.15-0.39 m/s or 0.66-0.93 m/s	< 0.15 m/s or > 0.93 m/s	
Riffle dominance	≥60% riffle	10-59% riffle	<10% riffle	
Bank erosion	0%	1-50%	>50%	
Bank vegetation	≥90%	50-89%	<50%	
Shading	≥75%	25-74%	<25%	
Total Score				

Qualitative Interpretation of Multimetric Habitat Assessment Score

Score Range

>23

17-23

<17

Stream Habitat Condition

High quality habitat

Moderate quality habitat

Impaired habitat

SITE DESCRIPTION					
Date:	Site:	Lab Group:			
Weather:	Now	Last 48 hours (Clear/Sunny, Overcast, Showers, Steady Rain, Heavy Rainstorm)			
STREAM CHARACTERISTICS					
STREAM HABITAT: (check if present)	Riffle ____ small surface waves	Glide ____ smooth moving water	Pool ____ still water		
# of riffles in 10m segment: ____		% of 10m total that is riffles: ____			
STREAM BOTTOM (estimate % in each category, according to particle size):					
_____ % bedrock	_____ % boulder > 10"	_____ % cobble rocks 1"-10"	_____ % gravel rocks <1"	_____ % sand (coarse sediment)	_____ % silt (fine sediment)
MID-CHANNEL FLOW VELOCITY (m/s) for a 4m stretch in your site (see below for directions):					
1: ____		2: ____		3: ____	
				Average: ____	
STREAM WIDTH – measure the width of the water at three points within your 10m stream length					
Top of reach: ____		Middle: ____		End: ____	
				Average: ____	
MID-CHANNEL DEPTH – measured at each position used for stream width measurements					
Top of reach: ____		Middle: ____		End: ____	
				Average: ____	
CHANNEL ALTERATION & EROSION					
Do the banks or channel appear altered? ____ (Y or N)					
% Left bank erosion (facing upstream) ____			% Right bank erosion ____		
RIPARIAN VEGETATION					
Characterized for the area within 5m of the high water line.					
% of banks covered by vegetation: ____ Left bank ____ Right bank					
VEGETATION COMPOSITION (estimate cover by each, total can be > 100%):					
Shrubs ____% Grass ____% Deciduous trees ____% Coniferous trees ____% Bare ____%					
STREAM SHADING (estimate):					
100% ____ 75-100% ____ 50-75% ____ 25-50% ____ 1-25% ____ 0% ____					

Mid-channel flow velocity

Find an unobstructed 4m length of stream in the middle of the stream channel. Drop a lemon in the water where it will not be affected by water moving around your legs. Time how long it takes the lemon to move 4m downstream, where it should be caught by another group member. Take 3 measurements at the same spot.

WATER CHEMISTRY	
pH: ____	Conductivity: ____ $\mu\text{S/cm}$
Dissolved Oxygen: ____ mg/L	Water Temperature: ____ $^{\circ}\text{C}$

MULTIMETRIC HABITAT INDEX				
Date:		Site:		Lab Group:
Habitat Metric	Excellent 5	Fair 3	Poor 1	Site Score
% Cobble	≥50%	25-49%	<25%	
Velocity	0.40-0.65 m/s	0.15-0.39 m/s or 0.66-0.93 m/s	< 0.15 m/s or > 0.93 m/s	
Riffle dominance	≥60% riffle	10-59% riffle	<10% riffle	
Bank erosion	0%	1-50%	>50%	
Bank vegetation	≥90%	50-89%	<50%	
Shading	≥75%	25-74%	<25%	
Total Score				

Qualitative Interpretation of Multimetric Habitat Assessment Score

Score Range

>23

17-23

<17

Stream Habitat Condition

High quality habitat

Moderate quality habitat

Impaired habitat

BENTHIC MACROINVERTEBRATES			
Date:		Site: Lab Group:	
Family	# Indivs.	Family	# Indivs.
EPHEMEROPTERA (Mayflies)			
Siphonuridae		Baetidae	
Heptageniidae		Ephemerellidae	
Leptophlebiidae		Other (list):	
Total Ephemeroptera Taxa		Total Ephemeroptera Indivs.	
PLECOPTERA (Stoneflies)			
Nemouridae		Perlidae	
Perlodidae		Chloroperlidae	
Other (list):			
Total Plecoptera Taxa		Total Plecoptera Individuals	
TRICHOPTERA (Caddisflies)			
Hydropsychidae		Rhyacophilidae	
Glossosomatidae		Limnephilidae	
Other (list):			
Total Trichoptera Taxa		Total Trichoptera Individuals	
DIPTERA (Flies)			
Blephariceridae		Tipulidae	
Dixidae		Chironomidae	
Simuliidae		Other (list):	
Total Diptera Taxa		Total Diptera Individuals	
COLEOPTERA (Beetles)			
Elmidae		Other (list):	
Total Coleoptera Taxa		Total Coleoptera Individuals	
OTHER INSECTS			
Total Other Insect Taxa		Total Other Insect Individuals	
NON-INSECT INVERTEBRATES			
Amphipods		Annelids	
Gastropods		Other (list):	
Total Non-Insect Taxa		Total Non-Insect Individuals	
TOTAL INVERTEBRATES			
Total Invertebrate Taxa		Total Invertebrate Individuals	
MULTIMETRIC BIOTIC INDEX			

Date:	Site:	Lab Group:		
Biotic Metric	Excellent 5	Fair 3	Poor 1	Site Score
Taxa Richness (total # of taxa)	>9	7-9	<7	
Ephemeroptera Families	>4	2-4	<2	
Plecoptera Families	>2	1-2	0	
Trichoptera Families	>2	1-2	0	
% chironomids (of total indivs.)	<15%	15-30%	>30%	
% dominance* (of total indivs.)	<50%	50-90%	>90%	
% EPT**	>50%	30-50%	<30%	
Sensitive Insect Taxa***	>3	2-3	0-1	
Total Score				

* To get this value, add the total individuals from the three most abundant taxa (for insects, look at the abundance of each family, not each order). Then, divide the combined total for the three most abundant taxa by the total number of invertebrates in your sample.

** %EPT is the percentage of total individuals that belong to the orders Ephemeroptera, Plecoptera, and Trichoptera. To calculate %EPT add up the number of individuals in the EPT orders and divide by the total number of individuals, then multiply by 100.

***Number of insect taxa with a tolerance index <4 (see p. 14).

Interpretation of Multimetric Biotic Index

Score Range

Stream Habitat Condition

>30

Good invertebrate diversity and stream conditions with little disturbance

23-30

Moderate invertebrate diversity and some evidence of disturbance to stream conditions (moderate impairment).

<23

Poor invertebrate diversity and strong evidence of disturbance to stream conditions (severe impairment).

BENTHIC MACROINVERTEBRATES			
Date:		Site:	
		Lab Group:	
Family	# Indivs.	Family	# Indivs.
EPHEMEROPTERA (Mayflies)			
Siphonuridae		Baetidae	
Heptageniidae		Ephemerellidae	
Leptophlebiidae		Other (list):	
Total Ephemeroptera Taxa		Total Ephemeroptera Indivs.	
PLECOPTERA (Stoneflies)			
Nemouridae		Perlidae	
Perlodidae		Chloroperlidae	
Other (list):			
Total Plecoptera Taxa		Total Plecoptera Individuals	
TRICHOPTERA (Caddisflies)			
Hydropsychidae		Rhyacophilidae	
Glossosomatidae		Limnephilidae	
Other (list):			
Total Trichoptera Taxa		Total Trichoptera Individuals	
DIPTERA (Flies)			
Blephariceridae		Tipulidae	
Dixidae		Chironomidae	
Simuliidae		Other (list):	
Total Diptera Taxa		Total Diptera Individuals	
COLEOPTERA (Beetles)			
Elmidae		Other (list):	
Total Coleoptera Taxa		Total Coleoptera Individuals	
OTHER INSECTS			
Total Other Insect Taxa		Total Other Insect Individuals	
NON-INSECT INVERTEBRATES			
Amphipods		Annelids	
Gastropods		Other (list):	
Total Non-Insect Taxa		Total Non-Insect Individuals	
TOTAL INVERTEBRATES			
Total Invertebrate Taxa		Total Invertebrate Individuals	
MULTIMETRIC BIOTIC INDEX			

Date:	Site:	Lab Group:		
Biotic Metric	Excellent 5	Fair 3	Poor 1	Site Score
Taxa Richness (total # of taxa)	>9	7-9	<7	
Ephemeroptera Families	>4	2-4	<2	
Plecoptera Families	>2	1-2	0	
Trichoptera Families	>2	1-2	0	
% chironomids (of total indivs.)	<15%	15-30%	>30%	
% dominance* (of total indivs.)	<50%	50-90%	>90%	
% EPT**	>50%	30-50%	<30%	
Sensitive Insect Taxa***	>3	2-3	0-1	
Total Score				

* To get this value, add the total individuals from the three most abundant taxa (for insects, look at the abundance of each family, not each order). Then, divide the combined total for the three most abundant taxa by the total number of invertebrates in your sample.

** %EPT is the percentage of total individuals that belong to the orders Ephemeroptera, Plecoptera, and Trichoptera. To calculate %EPT add up the number of individuals in the EPT orders and divide by the total number of individuals, then multiply by 100.

***Number of insect taxa with a tolerance index <4 (see p. 14).

Interpretation of Multimetric Biotic Index

Score Range	Stream Habitat Condition
>30	Good invertebrate diversity and stream conditions with little disturbance
23-30	Moderate invertebrate diversity and some evidence of disturbance to stream conditions (moderate impairment).
<23	Poor invertebrate diversity and strong evidence of disturbance to stream conditions (severe impairment).

INSECTS OF PADDEN CREEK*

Bold are taxa that represent greater than 0.5% of total density**

<u>Taxonomic group</u>	<u>Functional Feeding Group</u>	<u>Tolerance (0-10; 0 = most sensitive)</u>
Ephemeroptera (Mayflies)		
Siphonuridae	collector-gatherer	4
Baetidae	collector-gatherer	5
Heptageniidae	scraper, collector-gatherer	3
Ephemerellidae	predator, collector-gatherer	1
Leptophlebiidae	scraper, collector-gatherer	3
Plecoptera (Stoneflies)		
Pteronarcyidae	shredder	0
Taeniopterygidae	scraper	2
Nemouridae	shredder	2
Leuctridae	shredder	0
Perlidae	predator	2
Perlodidae	predator	2
Chloroperlidae	predator	0
Hemiptera (True Bugs)	predator	?
Megaloptera (Alderflies)		
Sialidae	predator	4
Trichoptera (Caddisflies)		
Polycentropodidae	predator, shredder	6
Hydropsychidae	collector-filterer	4
Rhyacophilidae	predator	1
Glossosomatidae	scraper	1
Brachycentridae	shredder	1
Lepidostomatidae	shredder	1
Limnephilidae	shredder, collector-gatherer, scraper	3
Coleoptera (Beetles)		
Halplidae	scraper, piercer-herbivore	5
Dytiscidae	predator	5
Hydrophilidae	shredder	5
Elmidae	scraper, shredder	4
Curculionidae	shredder	5
Diptera (Flies)		
Blephariceridae	scraper	0
Tipulidae	predator, shredder, collector-gatherer	3
Psychodidae	scraper, collector-gatherer	8
Ceratopogonidae	predator, collector-gatherer	6
Dixidae	collector-gatherer	1
Empididae	predator, collector-gatherer	6
Chironomidae	collector-gatherer, collector-filterer, predator	6
Simuliidae	collector-filterer	6

*Hachmöller, B. 1989

**Matthews et al. 1991