VOLUNTEER-BASED MONITORING PROGRAM

FOR THE SALMON RIVER BASIN: USING BENTHIC INDICATORS TO ASSESS STREAM ECOSYSTEM HEALTH

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EXECUTIVE SUMMARY

The traditional approach to environmental management in North America has been focused on the assessment of chemical concentratons within receiving environments, largely neglecting ecological structure and function within those environments (Reynoldson and Metcalfe-Smith, 1992). Recently, the utility of the ecosystem approach became widely recognized and the approach explicitly favoured by all levels of government in British Columbia (Marmorek et al., 1993).

Within the ecosystem approach, monitoring of benthic invertebrates has been shown to provide valuable information concerning the ecosystem health of aquatic ecosystem. Measuring ecosystem health using riverine invertebrate communities is not only effective but also involves sampling techniques that can be easily learned by individuals with little or no scientific training. In consultation with the Salmon River Watershed Roundtable, we developed a monitoring program for the Salmon River that incorporates local knowledge and assists in the development of environmental objectives and bioindicators.

This report is intended to serve as a methods manual for volunteer monitoring of small rivers such as the Salmon River. The contents will be most useful to coordinators of volunteer-based monitoring programs as a reference document and training tool. We recognize that the goals of volunteer monitoring groups are varied and range from a desire to increase environmental stewardship by volunteers to the more ambitious objective of providing data directly to regulatory agencies. These different goals require substantially different levels of monitoring effort. Because of these differences, we developed a bioassessment program which identifies three tiers of monitoring effort that span a range of monitoring efforts to be considered by volunteer groups.

Aspects of the program have been adapted from the highly successful, “Volunteer Stream Monitoring: A Methods Manual”, a program developed by the US EPA (1995) and modelled after the efforts of volunteer monitoring groups such as the Maryland Save Our Streams’ Project Heartbeat, the Izaak Walton League of America’s Save Our Streams program. We also incorporate methods from the Department of Fisheries and Oceans’ Streamkeepers program where appropriate. By modifying and

refining existing programs, and by considering in detail the specific ecology of the Salmon River, we have been able to tailor the Program to address the unique environments of mountain streams of British Columbia as well as the specific needs of the Roundtable. Our hope is that this model will serve as a template for the development of similar programs elsewhere in British Columbia and other provinces.

SOMMAIRE À L'INTENTION DE LA DIRECTION

L'approche classique en matière de gestion de l'environnement en Amérique du Nord était axée sur l'évaluation des concentrations de produits chimiques dans les milieux récepteurs, et ne tenait généralement pas compte de la structure et du rôle écologiques dans ces milieux (Reynoldson et Metcalfe-Smith, 1992). Depuis peu, on reconnaît l'utilité de l'approche écosystémique, qui est maintenant clairement privilégiée par tous les paliers de gouvernement en Colombie-Britannique (Marmorek *et al.*, 1993).

Dans le cadre de l'approche écosystémique, la surveillance des invertébrés benthiques fournit des données précieuses sur la santé de l'écosystème aquatique. L'évaluation de la santé de l'écosystème par l'étude des communautés d'invertébrés riverains est non seulement efficace, mais elle fait appel à des techniques d'échantillonnage que des personnes n'ayant qu'une formation scientifique limitée, voire aucune, peuvent apprendre facilement. En collaboration avec la table ronde sur le bassin hydrographique de la Salmon, nous avons élaboré un programme de surveillance de cette rivière qui intègre les connaissances locales et aide à l'établissement d'objectifs et de bioindicateurs environnementaux.

Le présent rapport servira de manuel pour la surveillance par des bénévoles de petites rivières comme la Salmon. Les informations qu'il contient seront très utiles aux coordonnateurs de programmes de surveillance volontaire tant comme document de référence et que comme outil de formation. Nous reconnaissons que les objectifs des groupes de surveillance volontaire sont variés et vont du désir de faire mieux participer des bénévoles à la gérance de l'environnement jusqu'à un objectif plus ambitieux qui est de fournir directement des données aux organismes de réglementation. Ces objectifs multiples exigent des niveaux de surveillance très différents, ce qui nous a amenés à élaborer un programme de bioévaluation qui comporte trois niveaux couvrant divers travaux de surveillance que peuvent envisager les groupes de bénévoles.

Certains aspects du programme ont été empruntés au document intitulé *Volunteer Stream Monitoring : A Methods Manual*, manuel à grand succès élaboré par l'EPA des États-Unis (1995) et conçu d'après les efforts de groupes de surveillance volontaire comme le projet Hearbeat, mené au Maryland dans le cadre du programme *Save Our Streams* de l'association *Izaak Walton League* des États-Unis. Nous avons également intégré au besoin certaines méthodes du programme des gardiens de cours d'eau du ministère des Pêches et des Océans. Grâce à la modification et au perfectionnement des programmes existants, et à la prise en compte détaillée de l'écologie particulière de la Salmon, nous avons pu construire le programme de manière à ce qu'il vise les milieux particuliers des cours d'eau de montagne de la Colombie-Britannique et les besoins spécifiques de la table ronde. Nous espérons que ce modèle servira de modèle pour l'élaboration de programmes semblables à d'autres endroits en Colombie-Britannique et dans d'autres provinces.

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1.1. Introduction to the Ecosystem Approach

The traditional approach to environmental management in North America has been based largely on the assessment of chemical concentrations within receiving environments. One drawback of this approach is that it has paid little attention to ecological structure and function within those environments (Reynoldson and Metcalfe-Smith 1992). The recent movement toward an ecosystem approach to environmental assessment and monitoring represents a major shift in emphasis away from a chemical/physical approach toward one that recognizes: (1) the complex nature of interactions that occur at a variety of levels within the environment; (2) the fact that human populations constitute an important component of that environment and cannot be viewed as being separate from it; and (3) the need for human populations to make use of natural resources in a sustainable fashion (Marmorek *et al*. 1993). Although specific definitions of the ecosystem approach may vary, most contain three key traits: (1) an emphasis on the collection and synthesis of integrated knowledge of ecosystem structure and function; (2) a holistic perspective, interrelating systems at different levels within the ecosystem; and (3) an attempt to develop management strategies that are ecological, anticipatory and ethical.

One of the most important benefits of an ecosystem approach is the explicit recognition that non-scientists, including land owners, representatives from industry, and recreational and subsistence users must be directly involved in the formulation of policy regarding the management of ecosystems. The role of these stakeholders is to provide valuable input in the establishment of general ecosystem goals and the refinement of these goals into more specific ecosystem objectives. Stakeholders also play a role in defining the "desired" state of the ecosystem and in balancing (and better measuring) the costs and benefits associated with future development and/or current remediation. The utility of the ecosystem approach is now widely recognized and is rapidly becoming the favoured approach for environmental management and ecosystem health assessment in both North America and Europe. It is also the approach explicitly favoured by all levels of government in British Columbia (Marmorek *et al*. 1993).

1.2. Benthic Macroinvertebrates in Volunteer-Based Monitoring

Within the ecosystem approach, monitoring of benthic invertebrates has been shown to provide valuable information concerning ecosystem health of aquatic ecosystems. The composition and structure of benthic invertebrate communities in flowing waters is closely linked to the surrounding terrestrial landscape and instream chemical, hydrological and geomorphological gradients (Culp and Davies 1982). Because of these qualities, riverine invertebrate communities are ideal candidates for use as ecosystem health indicators in mountain watersheds.

Benthic macroinvertebrates: Large invertebrates which live on the bottom of lakes and streams.

Measuring ecosystem health using benthic macroinvertebrates is not only effective but also involves sampling techniques that can be easily learned by individuals with little or no scientific training. Indeed, local citizens groups throughout North America have begun to monitor their local water quality using invertebrate community structure (e.g., the Save Our Streams Program in the United States). This assessment is based on a sound experimental design which relates benthic communities to key water quality and habitat variables. Recently, the history of biological water monitoring using macroinvertebrates has been reviewed from the perspectives of volunteer organizations (Firehock and West 1995) and the regulatory biologist (Penrose and Call 1995). Volunteer monitoring programs can be designed to address several different objectives. These can include (1) the development of baseline characterization data, (2) documenting changes in macroinvertebrates and water quality over time, (3) educating the local community to encourage pollution prevention and environmental stewardship, (4) screening for potential water quality problems from land use activities and point source discharges (i.e., municipal or industrial effluents), (5) providing a scientific basis for making decisions on the management of streams, and (6) demonstrating to public officials that local citizens care about the condition and management of their water resources (US EPA 1995).

Volunteer-based monitoring of macroinvertebrate indicators in the Salmon River will provide citizens with a means of tracking progress towards the attainment of ecosystem objectives set by the community. Perhaps the greatest benefit of volunteer-based monitoring will be a more highly educated public which understands and lobbies for improved environmental stewardship of the river watershed.

1.3. Development of a Volunteer Monitoring Program for the Salmon River

In consultation with the Salmon River Watershed Roundtable, we developed a monitoring program for the Salmon River that incorporates local knowledge and assists in the development of environmental objectives and bioindicators. This program includes the development of a multi-tier, rigorously designed, scientific monitoring program intended to be carried out by volunteers. Local stakeholders were involved in all aspects of the monitoring program from the setting of objectives, through field monitoring of the system and the interpretation of the collected data. A benefit of this process is that stakeholders become more aware of, and involved in, local water quality issues, while providing potentially useful monitoring information to provincial and federal governments (Firehock and West 1995; Penrose and Call 1995). Our hope is that this model will serve as a template for the development of similar programs elsewhere in British Columbia and other provinces.

This report is intended to serve as a methods manual for volunteer monitoring of small rivers such as the Salmon River. The contents will be most useful to coordinators of volunteer-based biomonitoring programs as a reference document and training tool. Aspects of the program have been adapted from the highly successful, "*Volunteer Stream Monitoring: A Methods Manual*", a program developed by the US EPA (1995) and modelled after the efforts of volunteer monitoring groups such as the Maryland Save Our Streams' Project Heartbeat, the Izaak Walton League of America's Save Our Streams program. We also incorporate methods from the Department of Fisheries and Oceans' Streamkeepers program where appropriate. By modifying and refining existing programs, and by considering in detail the specific ecology of the Salmon River, we have been able to tailor the Program to address the unique environments of mountain streams of British Columbia as well as the specific needs of the Roundtable. We expect the key to conducting a successful volunteer monitoring venture will be a dedicated core of volunteers who can maintain continuity of data collection and train new volunteers. In addition, the Roundtable must work in partnership with Government in order to monitor specific water quality variables (e.g., dissolved oxygen, algal biomass) and to facilitate the exchange of data with regulators.

1.4. Organization of Report

The document, *"Volunteer-based Monitoring Program for the Salmon River Basin: Using Benthic Indicators to Assess Stream Ecosystem Health"*, is organized into seven main chapters. All chapters will be useful to coordinators of volunteer-based monitoring programs. Volunteers will find that chapters 4, 5, and 6 provide the information necessary for sampling techniques and participating in sample collection. Chapter 1 introduces the ecosystem approach, provides a background for volunteer monitoring programs which use benthic indicators, and outlines the manual's organization. Chapter 2 summarizes information on the Salmon River Watershed such as basin hydrology, land use, impacts and remediation. Chapter 3 describes baseline information on river biota, and descriptions of sampling sites. Chapter 4 outlines our three-tiered approach to volunteer monitoring. Chapter 5 details how to sample benthic macroinvertebrates, illustrates key identification characteristics for the major benthic groups, and discusses the equipment and specific procedures that are to be used for monitoring. Chapter 6 describes the important physical and chemical variables that need to be measured; this description includes a detailed discussion of sampling equipment and methods. Chapter 7 provides information on volunteer training, quality assurance/ quality control (QA/QC) guidelines, and discusses data management and interpretation. A glossary of technical terms can be found in Appendix B. Data sheets for the sampling program, invertebrate taxonomic keys and reference material are listed in Appendices A and C.

2. The Salmon River Watershed

2.1. Location

The Salmon River is located in British Columbia's Interior Plateau southwest of Shuswap Lake and drains a land area of 1510 km^2 (Figure 2.1). The river originates near Bouleau Mountain in Monte Hills Provincial Forest and generally flows northeast for 120 km through a diverse landscape of forest, grasslands, rocky gullies, and fertile valleys, emptying into the southeast arm of Shuswap Lake at Salmon Arm. Water from the Salmon River eventually empties into the Fraser River via the Thompson River.

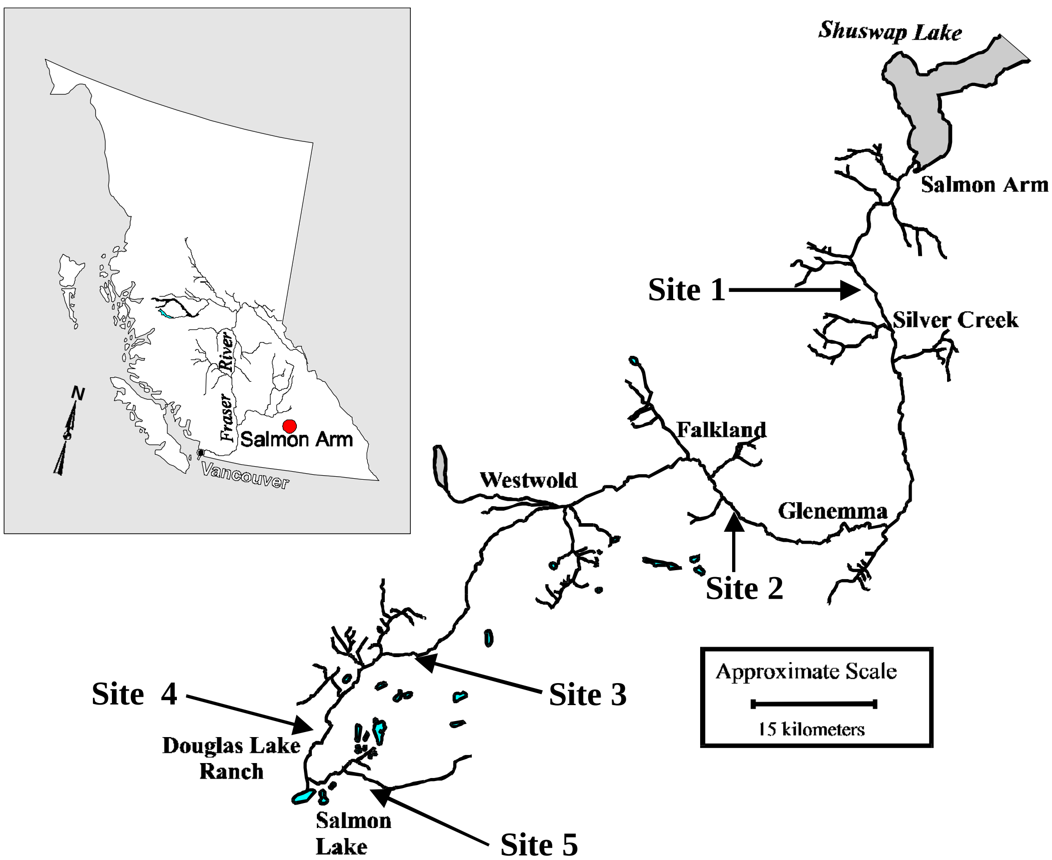


Figure 2.1. Salmon River Watershed. Approximate Location of Recommended Monitoring Sites is Indicated.

Bedrock geology of the Salmon River Watershed upstream of Westwold consists of volcanic (basalt lava) and sedimentary rock. Between Westwold and Glenemma, the bedrock is dominated by argillite, greenstone, limestone, conglomerate, and granitic intrusives. North of Glenemma the geology is that of metasediments and metavolcanics. Surficial geology of the upland areas consist of bare rock, clay-rich soils, and undifferentiated materials (likely till and colluvium). Small deposits of glacio-lacustrine deposits occur in the Westwold to Glenemma area, and a large deposit of pre-Fraser Glaciation unconsolidated sediments occur west of Westwold. In the lower Salmon River Valley, the extensive glacio-lacustrine deposits are a result of a considerably larger Glacial Shuswap Lake (Miles 1995).

2.2. Topography and Hydrology

Headwaters to Westwold

Headwaters of the Salmon River are located 1520 m above sea level (ASL) (Figure 2.2). The steeply sloped (17 m/km) upper portion of the river is bordered by spruce forests and differs greatly from the broad valley and meandering channels of the lower portion. Elevation drops rapidly to 600 m ASL just upstream of Westwold.

North of Salmon Lake, a significant amount of water (approximately 15-30% depending on the season) is diverted from the river into the lake. Water that is not diverted flows across the valley floor to the confluence with McInnis Creek, the outlet from the lake (Gormican *et al*. 1994). From this confluence, the Salmon River flows northeast through an open meadow, then down a rocky canyon toward Westwold. Beginning approximately 8 km upstream of Westwold, a 13 km reach of the river has no surface flow for as much as 9 months of the year. This reach serves as a physical division between the upper and lower watershed and can act as a barrier to fish migration. Subsurface flow in this reach occurs at all times of the year but it is not known to what extent groundwater is recharged along the reach. Outcrops of bedrock force water back to the surface downstream of Westwold (Gormican *et al*. 1994). It is only during the high flow periods (usually May-July) that the river flows above ground in this reach.

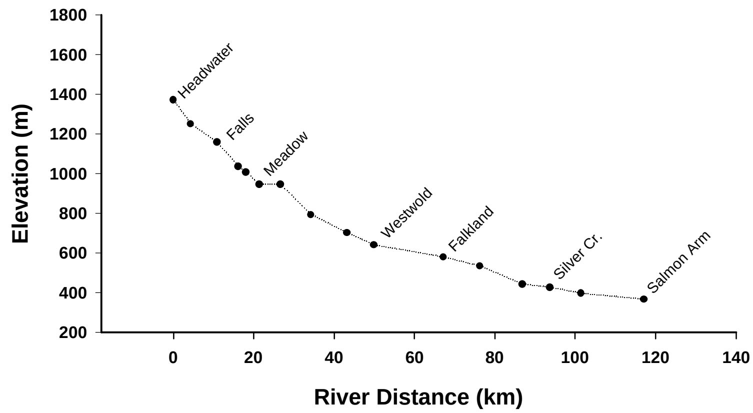


Figure 2.2. Longitudinal Profile of the Salmon River, B.C.

Westwold to Silver Creek

The 15 km from Westwold to the Bolean confluence at Falkland is that of a low gradient wetland (slope = 0.24 m/km) (Miles 1995). In this reach, the river reappears on the surface and flow gradually increases downstream, apparently from ground water contribution (Gormican *et al*. 1994). At the confluence with Bolean Creek, the only major tributary of the Salmon River, the river gradient increases to 5.9 m/km at Falkland, then gradually declines over the 35 km to Silver Creek. Agricultural activity is concentrated in this reach of the valley and has apparently reduced riparian vegetation and bank stability along the river.

Silver Creek to Shuswap Lake

In the 20 km reach from Silver Creek area to Salmon Arm, the slope is more gradual (2.1 m/km). The streambed consists of unstable sand and silts transported from upstream. It is likely that the greatest human impacts on the river occur in this region which is inhabited by more than 12,000 people.

A large marsh with an extensive mud flats area marks the river mouth (gradient 0.27 m/km). The formation of this marshy delta can be attributed to the deposition of sediments from upstream erosion sites within the valley (Miles 1995). Large sediment plumes are carried into the lake from the delta, and in combination with nutrient loading from the river, have the potential to affect Shuswap Lake water quality.

2.2.1 Discharge

Peak discharge in the Salmon River typically occurs in May (17 m^3/sec) and June (12 m^3/sec) as the snow melts at higher altitudes (Figure 2.3). From August to March, the average mean discharge at Salmon Arm remains low at 2.5 m^3/sec. An initial increase in discharge during March is due to low-altitude snowmelt in the valleys. During this time, a flushing of manure from livestock areas will occur, increasing nutrients and faecal coliform concentrations in the river. The rapid snowmelt at higher elevation in April contributes to the high flows of May and June. Low flows in the months of July, August, and September are exacerbated by increased irrigation demands (Gormican *et al*. 1994).

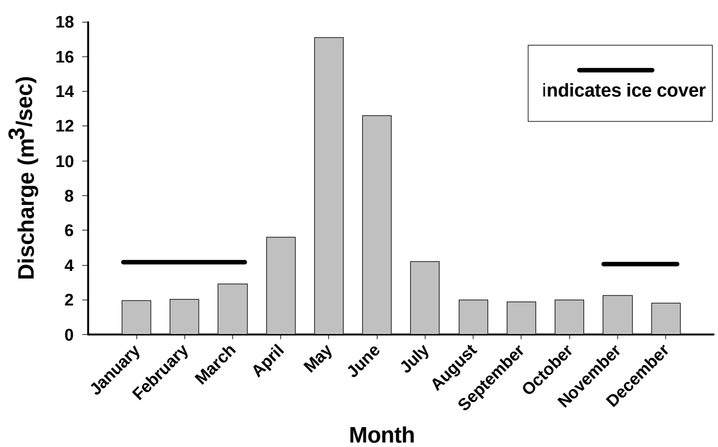


Figure 2.3. Average Discharge of the Salmon River at Salmon Arm, B.C. (1974-1990).

Bolean Creek is the major tributary of the Salmon River and contributes flow year round. Eight other tributaries in the watershed have significant inflow for part or all of the year. Kernaghan, Pringle, Silver, Weyman, Bolean, Fowler, Gordon, Spa, and Ingram Creeks all have recorded peak discharge (ranging from 0.5 to 4.0 m^3/sec) into the Salmon River (British Columbia Historical Flows). None are noted to contribute substantially to sediment loadings of the Salmon River (Miles 1995).

2.3. Land Use

Potentially harmful impacts to the river can result from many human activities occurring near streams. Removal of streamside vegetation (farming, logging, urban development) often results in increased runoff, erosion of stream banks, and increased sediment load in the stream. The Salmon River watershed is subject to a variety of land uses, primarily agriculture, recreation and forestry. Agriculture is the dominant activity throughout the watershed. Forestry is limited to the upper watershed and recreational activities are scattered throughout the Salmon River valley.

2.3.1. Agriculture (summarized from McPhee et al. 1996)

Ranching, dairy farming, and crop production are the major agricultural activities in the Salmon River watershed, with ranching dominating agricultural use (58% of farms in 1991). In 1991, there were 317 farms occupying ~32,000 Ha. Of the 10,117 Ha under cultivation, approximately 4,000 Ha were irrigated, more than 1,600 Ha received manure application and nearly 2,900 Ha received fertilizer applications. Limitations to agricultural expansion include a lack of agricultural land area and the water resources needed for irrigation.

2.3.2. Forestry (summarized from G. Wellburn, Riverside Forest Products Ltd. in Environment Canada, 1995)

The Salmon River watershed has an area of more than 200,000 Ha of which 185,000 Ha are forested. Forestry activities in the upper watershed are primarily conducted by Riverside Forest Products Ltd. operating primarily in Tree Farm Licence 49 (TFL 49). Riverside Forest Products Ltd. estimates 610 Ha are harvested yearly, producing a volume of 175,000 cubic metres of wood (5000 truck loads of logs). This harvest volume directly translates into 210 jobs (560 jobs including spinoff employment). Reforestation of harvested areas is the responsibility of Riverside, thereby requiring extensive ongoing silviculture programs. All cutting and silviculture plans are subject to review by Ministry of Forests, Ministry of Environment, and Department of Fisheries and Oceans. Riverside harvesting practices include leaving riparian buffer strips along waterways, deactivating roads that are no longer in use, and prior approval of stream crossings by a Professional Hydrologist.

2.3.3. Recreation (summarized from McPhee et al*. 1996)*

Recreation activities in the watershed are numerous. Most of the backcountry activities occur within Provincial Forests. Monte Hills, Martin Mountain, Okanogan, Shuswap, Salmon Arm, Fly Hills, and Mount Ida Provincial Forests all lie, at least partially, within the Salmon River watershed. As the population of the watershed increases, demand for recreational activities will surely increase. Logging roads provide much of the access to these recreation areas, however, they also allow greater access to potentially sensitive areas. Decommisioning some of these roads could be an issue in the future.

2.4. Impacts and Remediation

Upstream of Westwold, the Salmon River is less subject to the concentrated agricultural activity than downstream. Logging and ranching are the major land use activities upstream of Salmon Lake. Ranches first occur in the Salmon Lake region and are most concentrated near Westwold. Agricultural activities and population steadily increase in the valley as the river nears Salmon Arm.

The Salmon River is a major tributary stream of the South Thompson and is at risk from excessive water withdrawal during the low flow summer months (Gormican *et al*. 1994). In the highly agricultural area from Westwold to Salmon Arm there are 567 licenced surface water withdrawals and 649 licenced ground water well withdrawals (Gormican *et al*. 1994). Low summer flows have led to water volume concerns for irrigation users and a loss of quality fish habitat.

High flows during spring freshet are also of concern due to erosion of stream banks in agricultural areas where riparian vegetation has been removed. The increased sediment load enters the water column and is deposited in downstream pools and riffles as well as the delta at Shuswap Lake itself. Erosion of the river channel has prompted a variety of bank stabilization efforts (i.e., riparian zone enhancement). Fencing, planting, spiling, tree revetments, and rip-rap have all been used in attempts to stabilize river banks (Miles 1995). Currently, there are 26 ongoing habitat rehabilitation projects in the Salmon River watershed, all of which are being accomplished through landowner cooperation with the Roundtable (McPhee *et al*. 1996). Bank stabilization techniques have had varying degrees of success. The most effective means of stabilizing banks, though not the quickest, is to establish a riparian zone of erosion resistant vegetation. This technique requires the fencing of river banks to exclude or restrict cattle access so that vegetation can become established (Miles 1995).

3. Sampling Locations and Baseline Biomonitoring Data

3.1. Introduction

Having described the watershed and principal impacts acting on the Salmon River, we now provide a more detailed overview of the baseline sampling undertaken during the development of a monitoring program. This chapter consists of four sections which describe: (1) the original sampling sites and types of data collected at those sites, (2) our rational for a focus on macroinvertebrates in biomonitoring, (3) the macroinvertebrate community measured within the basin, and (4) the process by which the 18 original sampling sites were reduced to five monitoring sites. In subsequent chapters we provide a tiered approach to monitoring at these sites (Chapter 4), as well as more detailed information on the monitoring techniques to be employed (Chapters 5 and 6).

3.2. Sampling Locations

The initial biomonitoring survey of the Salmon River was conducted by Environment Canada in August and November, 1995. A series of seventeen sites on the Salmon River and one site on Bolean Creek were sampled for benthic macroinvertebrates invertebrates (density and biomass), pH, conductivity, dissolved oxygen, temperature, chlorophyll-*a*, ash-free dry mass (AFDM), and algal taxonomy (Table 3.1). In addition, a variety of water chemistry variables were measured including: TP, TDP, alkalinity, HCO_3, CO_3, NO_3 +NO_2, NH_4, TDN, particulate N, DOC, and particulate C. The sites are located at intervals from the headwaters to near Salmon Arm and were chosen to represent all biogeoclimatic zones, and to assess any effects of suspected point source and cumulative impacts.

3.3. Baseline Biomonitoring Using Benthic Macroinvertebrates

Macroinvertebrates lack a backbone (invertebrate), and include animals such as insects in their larval or adult forms, crayfish, clams, snails, and worms. **Aquatic macroinvertebrates** are known to be good indicators of water quality because they: (1) possess a sedentary mode of life making them representative of local conditions, (2) integrate the effects of short- and long-term environmental variations, (3) are relatively easy to identify to the taxonomic level of order and many "intolerant" taxa can be identified to lower taxonomic levels with ease, (4) are relatively easy to sample, (5) are a primary food source for many important fish, and (6) are abundant in most streams (Plafkin *et al.* 1989).

Table 3.1. Environment Canada Sampling Locations Along the Salmon River, B.C.

Site Distance From River Mouth (km)	Approximate Location
3	Salmon River Road bridge nearest Salmon Arm
7	Branchflower Road
13	Haines Road
17	Sallenbach Road
23	First bridge on Salmon River Road north of highway 97 intersection
31	Highway 97 bridge at Salmon River Road intersection
40	Cedar Hill Road
45	Shaw Road
50	Falkland downstream of Bolean Creek confluence
51	Falkland upstream of Bolean Creek confluence
50	Bolean Creek at Falkland
67	Bridge on Back Road near Westwold
76	7 km south (upstream)from Back Road turnoff on Douglas Lake Road
80	11.5 km south (upstream) from Back Road turnoff on Douglas Lake Road
85	Bridges on Douglas Lake Rd. south of site 13
93	In the meadow on Douglas Lake Road
100	Upstream of Salmon Lake at Mowing Machine Road and Salmon River Road intersection
107	Salmon River Road, 8 km upstream from site 16 (November 1995 only)

Macroinvertebrates are used in aquatic biomonitoring surveys to assess environmental conditions. This type of biosurvey involves collecting and processing benthic invertebrate samples, and determining invertebrate community structure. Because the presence and abundance of aquatic invertebrates are determined by a variety of environmental factors (Merritt & Cummins 1995), some macroinvertebrates are more sensitive to water pollution (or other habitat disturbances) than others. These invertebrates are recognized as indicator taxa (Table 3.2). Note that this indicator approach cannot tell us what the specific pollutant is or why certain types of fauna are present or absent. For this reason, a **macroinvertebrate biosurvey must be accompanied by an assessment of habitat and other water quality variables.** Monitoring water quality variables such as dissolved oxygen, temperature, pH, and nutrients will help to identify which pollutants are responsible for impacts to a stream (U.S. EPA 1995).

Table 3.2. Relative Pollution Tolerance of Macroinvertebrates of the Salmon River: The Scale Ranges From 10 (most tolerant) to 0 (least tolerant). Adapted from Resh *et al*. (1996).

Order	Tolerance Value	Order	Tolerance Value
Ephemeroptera		**Plecoptera**	
Baetidae	4	Capniidae	1
Ephemerellidae	1	Chloroperlidae	1
Heptageniidae	4	Leuctridae	0
Leptophlebidae	2	Nemouridae	2
Siphlonuridae	7	Perlidae	1
		Perlodidae	2
		Pteronarcyidae	0
		Taeniopterygidae	2
Trichoptera		**Diptera**	
Brachycentridae	1	Athericidae	2
Glossosomatidae	0	Ceratopogonidae	6
Hydropsychidae	4	Blood-red Chironomidae	8
Hydroptilidae	4	Other Chironomidae	6
Lepidostomatidae	1	Empididae	6
Leptoceridae	4	Ephydridae	6
Limnephilidae	4	Psychodidae	10
Philpotamidae	3	Simulidae	6
Polycentripodidae	6	Tabanidae	6
Rhyacophilidae	0	Tipulidae	3
Sericostomatidae	3		
Coleoptera		**Mollusca**	
Elmidae	4	Sphaeriidae	8
Dryopidae	5		
Oligochaeta	8	**Hirudinea** (leeches)	10
Amphipoda		**Turbellaria**	
Gammaridae	4	Platyhelminthidae	4

3.4. *Macroinvertebrate Community Structure in the Salmon River*

Five major taxonomic groups, the mayflies, caddisflies, dipterans, stoneflies, and coleopterans, constitute about 90% of all invertebrates collected in the Salmon River. Figure 3.1 shows the relative percentage of pollution intolerant taxa (Tolerance Value $\leq$ 4) at each of the sampling locations in August 1995. This figure illustrates that, while the makeup of the benthic community varied from site to site, pollution intolerant taxa were common at all sites and dominated the community at most (76%) sites (Table 3.2). What follows is a brief description of the ecology of each of the dominant taxa. Additional information and identification keys for each of these taxa are provided in Appendix A. Other insects are present in the river but are relatively uncommon and will not be discussed further. Reference and voucher collections of all invertebrates collected from the Salmon River have been supplied to the Royal British Columbia Museum and the Salmon River Watershed Roundtable.

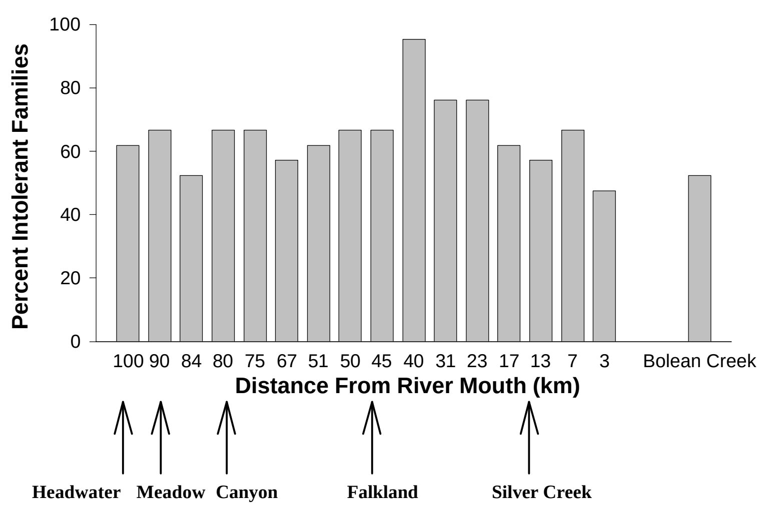


Figure 3.1. Presence of Pollution Intolerant Taxa in the Salmon River, August 1995.

Caddisflies (Order Trichoptera) (Appendix A- Figures A.4 and A.7) make up a significant portion of the benthic community in the Salmon River. Caddisfly larvae commonly occur in unpolluted water and occupy a diverse array of habitats. Their feeding mechanisms vary from highly specialized filter-feeders, that spin capture nets to collect food, to algae grazers and predators. Dominance by filter-feeders can

Caddisfly Families Present in Salmon River:

- Brachycentridae
- Glossosomatidae
- Hydropsychidae
- Hydroptilidae
- Lepidostomatidae
- Limnephilidae
- Polycentripodidae
- Rhyacophilidae

sometimes indicate moderate organic pollution. Some species are free living while others make case retreats out of silk and a variety of mineral particles or bits of plant matter. All caddisflies have hard-shelled head capsules. Often the first three segments behind the head also have hard-shelled plates on the top (dorsal) surface. Three pairs of jointed thoracic legs are always present. The rest of the body (abdominal segments) is soft and generally cylindrical. Larvae possess two characteristic small hooks and/or prolegs on the last abdominal segment for holding onto the substrate or their cases. Caddisflies undergo complete metamorphosis in the water to transform from larvae into winged adults. All species of caddisflies build cases for pupation, even those that are free-living in their larval form. Adults live for up to several months during which time they reproduce.

Stonefly Families Present in Salmon River:

- Capniidae
- Chloroperlidae
- Perlidae
- Perlodidae
- Pteronarcyidae

Stoneflies (Order Plecoptera) (Appendix A- Figures A.3 and A.6) are good indicators of high water quality because of the nymphs' (larvae) requirement for high oxygen levels. They tend to inhabit clear cool streams and are very intolerant of reduced water quality; their presence generally indicates satisfactory water quality. Most larvae are detritivorous, feeding primarily on dead plant material (ie. leaf litter). Perlidae and Perlodidae families are the only predaceous members of this order commonly found in the Salmon River. The heads and the top surface of the first three body segments (thorax) of stonefly larvae are hardened. Their antennae are moderately long, and all species have only two caudal filaments (cerci). Stonefly larvae may have gills around the base of their legs or no gills at all. Abdominal gills of the family Pteronarcyidae are limited to the first two or three abdominal segments. Small stonefly larvae may be easily mistaken for mayfly larvae due to similarities in body shape, but mayfly larvae usually have three tail filaments. Unlike mayflies, stoneflies can have gills on their thorax. Furthermore, stoneflies have three distinct thoracic segments, whereas mayflies often appear to have only two thoracic segments. Larval growth cycles in stoneflies range between 1-3 years depending on species and environmental conditions. Adult stoneflies generally live less than one month.

Mayfly Families Present in Salmon River:

- Baetidae
- Ephemerellidae
- Heptageniidae
- Leptophlebidae
- Siphlonuridae

Mayflies (Order Ephemeroptera) (Appendix A- Figure A.2 and A.5) are found in a wide variety of habitats and can tolerate warmer environments than many stoneflies. Mayflies eat substantial amounts of algae and detritus, although a few are carnivorous. Mayfly larvae are usually relatively easy to identify. General morphology is similar to that of stonefly larvae but differs enough that volunteers can learn to separate these with little taxonomic training. Larvae can be short and flattened, or long and slender. The three thoracic segments overlap such that there appear to be only two thoracic segments. Three pairs of segmented legs extend from the thorax; antennae are often visible on the head. Most larvae are easily identified by three (rarely two) tail filaments and by the seven pairs of abdominal gills found on most species. Gills may appear flat, spade-shaped or feathery in appearance, depending on the species. Mayfly life cycles of 3-12 months are common, depending on species and environmental conditions, and larvae undergo many molts during this development period. Once adults emerge, they are very short lived (hours to a few days).

Riffle Beetles (Order Coleoptera) (Appendix A- Figure A.9) represent a small portion of the order Coleoptera. Elmidae is the most common family of Coleoptera found in the Salmon River. Elmidae presence generally indicates good water quality because of their high oxygen requirement (Merritt & Cummins, 1995). These beetles are entirely aquatic but cannot swim, their movements being limited to crawling on the substrate where they primarily feed on detritus and algae. Other families of Coleoptera are expected to be extremely rare in the Salmon River. Elmidae adults and larvae have a distinctively compact, hard body with six visible thoracic legs. The adult's first pair of wings, called the elytra, is hardened and covers the second set of membranous wings which are used for short dispersal flights after pupation. Larvae differ significantly from adults but are still distinctive in appearance. The larval growth period is 6-8 months long, while the pupae stay in mud burrows for 2-3 weeks before becoming adults. The life history of adult Elmidae is relatively unknown other than its life span which may reach 2 years.

Coleoptera Families Present in Salmon River:

- Dryopidae
- Dytiscidae
- Elmidae

***True Flies* (Order *Diptera*)** (Appendix A- Figure A.8) make up a diverse taxonomic group and are found in many different aquatic habitats. Chironomidae are the most abundant invertebrate family found in the Salmon River. Some Dipteran larvae are extremely pollution tolerant, but their presence does not necessarily indicate poor water

Diptera Families Present in Salmon River:

- Athericidae
- Ceratopogonidae
- Chironomidae
- Empididae
- Simulidae
- Tabanidae
- Tipulidae

quality. Several Dipterans are notable pests of humans and animals; these include the adult forms of simulids (black flies), and ceratopogonids (biting midges). Dipteran larvae living exposed to flowing waters generally are filter-feeders, scrapers, or browsers of aquatic organisms, although some are predators (Merritt & Cummins, 1995). A common feature among families is the absence of jointed thoracic legs. Appendages on the body of larvae, called prolegs, may be found on one or more segments. Adult dipterans are terrestrial and are identified by a single set of functional wings. Larvae are entirely aquatic but pupation occurs on land or water. Adults usually live for a few days (and up to several weeks).

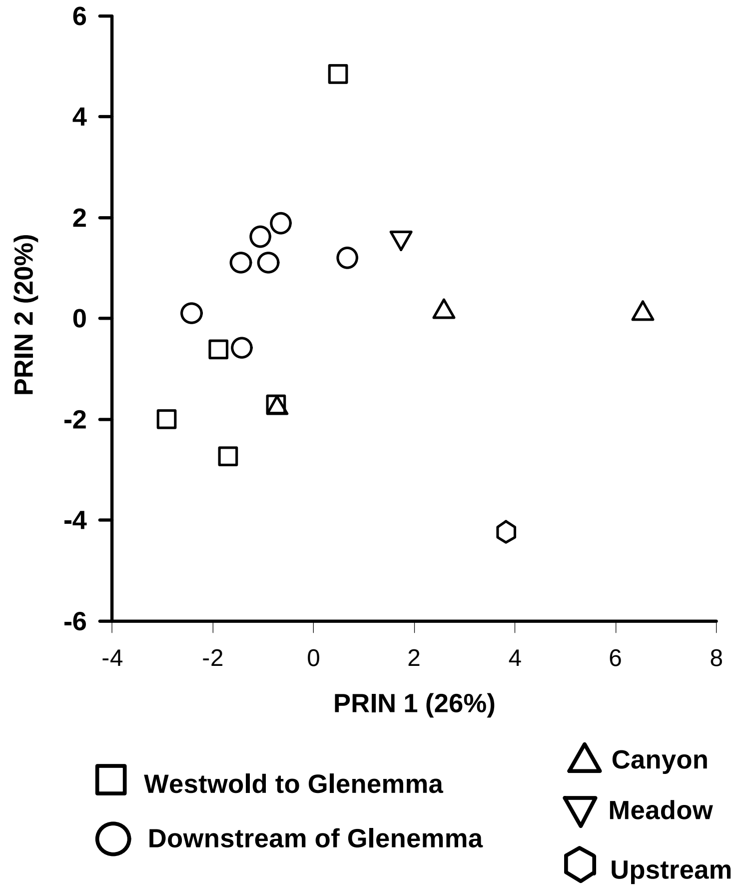


Figure 3.2. Principal Component Analysis of Invertebrate Communities in the Salmon River, August 1995.

3.5. Final Selection of Monitoring Sites

Following the sorting and identification of macroinvertebrates contained in the 17 different samples, multivariate statistical techniques (i.e., Principal Component Analysis, or PCA) were used to examine overall community structure within the basin for August 1995. This type of analysis is useful for identifying patterns of change in macroinvertebrate community composition along the river. In essence, we used this analysis to reduce the number of sites that would be sampled by volunteers. It is important to note that while pollution sensitive taxa dominated the community in all sampling sites, the details of community structure also varied from site to site as revealed by the PCA. The results of the

PCA are given in Figure 3.2 which plots each sampling site in ordination space. Within Figure 3.2, sites that are plotted close to one another in ordination space have macroinvertebrate community structures that are more similar to one another than are sites plotted further away from one another.

Taken together, the first two axes of the PCA account for almost 50% of the total variation in macroinvertebrate community structure. The first PCA axis (PRIN 1) accounts for the largest single component of variation (26%) and distinguishes sites largely as a function of increasing relative densities of several mayfly families. The second axis (PRIN2) accounts for 20% of the total variation and separates sites on the basis of the relative numbers of stoneflies and aquatic beetles (Elmidae).

It is clear from Figure 3.2 that sites located downstream of Glenemma tend to be quite similar to one another and cluster together in ordination space. Similarly, with one exception, sites between Glenemma and Westwold are also similar and cluster together. Sampling sites within the canyon were separated along PRIN 1 but not along PRIN 2, suggesting that the differences among these sites are related to changes in the number of mayflies rather than beetles or stoneflies. The Meadow sampling site contained a community somewhat similar to that measured downstream in the canyon while the furthest upstream site possessed a macroinvertebrate community dissimilar to that observed elsewhere in the basin.

This analysis of macroinvertebrate community structure along with a consideration of water chemistry and other environmental variables measured at each site allowed us to reduce the 17 sampling sites located throughout the basin to five sites that adequately represent the general habitat and community types observed within the Salmon River. The final five sampling sites are shown in Figure 2.1 and Table 3.3. To facilitate comparisons among these sites the results of macroinvertebrate sampling, periphyton analysis and several water quality measures are provided in Figures 3.3, 3.4, 3.5, and 3.6.

Table 3.3. Location and Description of Volunteer Sampling Sites.

Site	Site Distance from River Mouth (km)	Site Name and Description
1	17	Silver Creek: representative of the reach from Glenemma to Shuswap Lake
2	45	Falkland: representative of the reach from Falkland to Glenemma
3	80	Canyon: recovery area through a rocky canyon with a steeper gradient
4	93	Meadow: channelized reach in low gradient meadow, impacted by grazing and subject to nutrient loading
5	107	Headwater: undisturbed headwaters

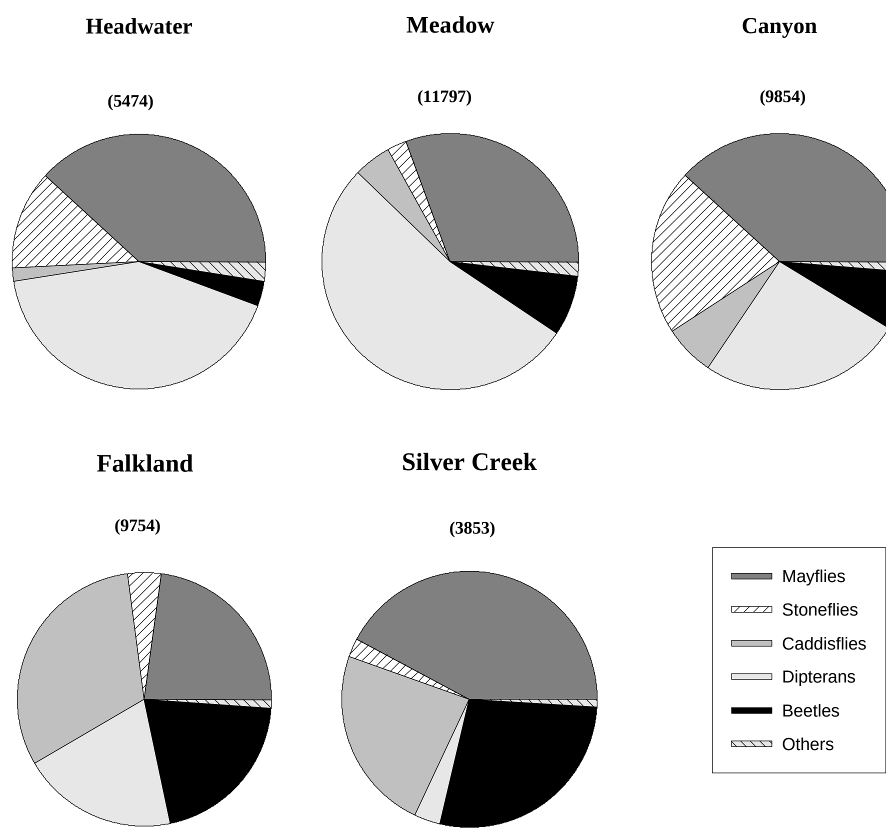


Figure 3.3. Relative Abundance of Major Taxa at Each of the Five Monitoring Sites Along the Salmon River, August 1995. The Number In Parenthesis Indicates the Total Number of Individuals.

Our recommendation to the Roundtable is that these five sites form the core of the sampling program for volunteers. Clearly, other sites could be added if desired. Because the composition of macroinvertebrate communities changes seasonally, it would be ideal to sample these five sites once during each of the seasons; summer (late July to mid-August), fall (late September to mid-October), and late winter (prior to spring discharge, late March to mid-April). If sampling occurs only once per year, then sampling should take place in summer when the stresses of low water, low dissolved oxygen, and high water temperature are the greatest (Norris and Georges 1993; Resh *et al*. 1995).

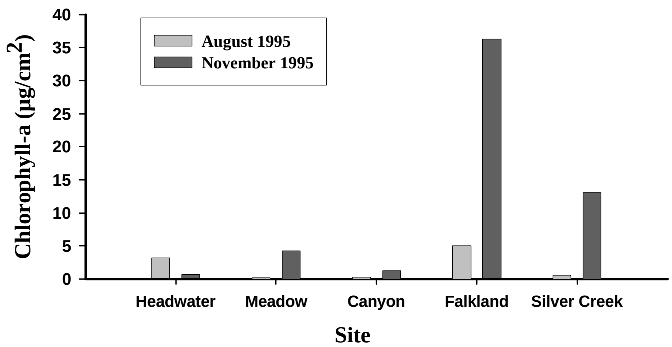


Figure 3.4. Periphyton biomass in the Salmon River, August and November, 1995

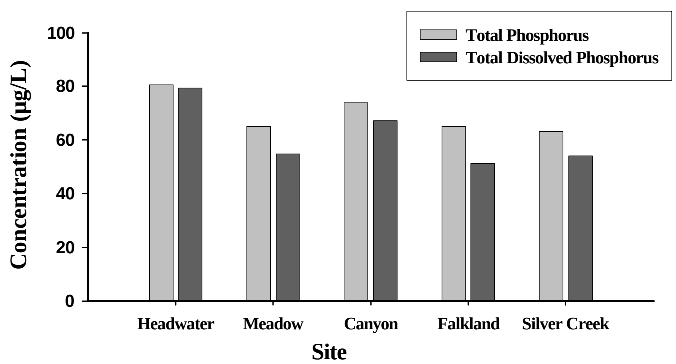


Figure 3.5. Phosphorus Concentration in the Salmon River, August 1995.

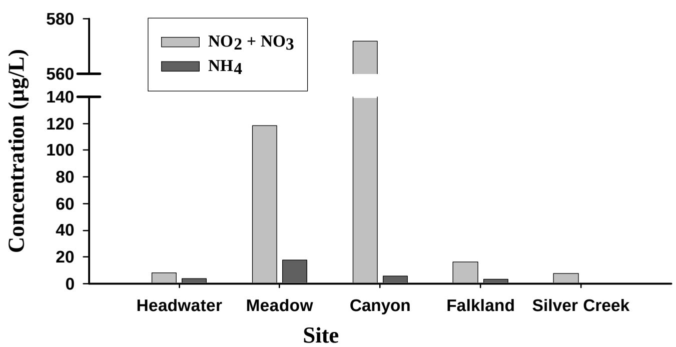


Figure 3.6. Nitrogen Concentration in the Salmon River, August, 1995.

4. Tiered Approach to Volunteer Monitoring Programs

4.1. Introduction

The goals of volunteer monitoring groups are varied and range from a desire to increase environmental stewardship by volunteers to the more ambitious objective of providing data directly to regulatory agencies. These different goals require substantially different levels of monitoring effort. For example, the number of sample replicates, sample processing methodology and data quality control will vary with different program needs. Because of these differences, we developed a bioassessment program which identifies three tiers of monitoring effort that span the range of monitoring objectives considered by the Roundtable.

4.2. Tier 1

Tier 1, which is designated Basic Stream Monitoring (BSM), is similar to streamside bioassessment monitoring developed by the US EPA (US EPA 1995). This monitoring strategy is based upon the collection of macroinvertebrate samples from the stream with immediate taxonomic identification to order in the field (Table 4.1). BSM also includes a basic survey of habitat variables such as substrate characteristics and pH (Table 4.1). The primary purpose of BSM is to provide a unique educational experience in which volunteers learn basic concepts of stream biology and water pollution assessment. Through the regular application of BSM methods, volunteers will be able to measure progress toward the Roundtables' goals, such as improved streambank stability and the preservation of a viable macroinvertebrate community.

Table 4.1. Characteristics of Basic (Tier 1), Extensive (Tier 2) and Intensive (Tier 3) Stream Monitoring Programs.

Level of Monitoring Program		Program Attributes
TIER 1	BASIC STREAM MONITORING (BSM)	Purpose: education, environmental stewardship, and tracking of advocate group goals Variables Measured: abundance of invertebrate orders and stream habitat characteristics Partnerships with Regulatory Agencies: beneficial but none required
TIER 2	EXTENSIVE STREAM MONITORING (ESM)	Purpose: early warning screening of potential pollution problems plus BSM attributes Variables Measured: algal biomass, key water quality variables plus variables of BSM Partnerships with Regulatory Agencies: beneficial but not required
TIER 3	INTENSIVE STREAM MONITORING (ISM)	Purpose: collection of high quality data for reporting to regulatory agencies plus ESM attributes Variables Measured: abundance of invertebrate families plus variables of ESM Partnerships with Regulatory Agencies: beneficial and required; direct reporting to agency possible

4.3. Tier 2

Our Tier 2, or Extensive Stream Monitoring (ESM), includes all of the components of the BSM survey, but extends the measurements to include key water quality variables and samples of algae (Table 4.1). Because samples of water chemistry and attached algae must be sent to professional laboratories for analysis, ESM surveys will likely require governmental partners. ESM produces identical benthic macroinvertebrate information as the Tier 1 program. However, the water quality and algal information would be of a quality that could be reported directly to regulatory agencies. Thus, ESM would provide early warning screening of potential pollution problems and/or changes in productivity that is not possible using the basic (BSM) program.

4.4. Tier 3

Tier 3 surveys, termed Intensive Stream Monitoring (ISM), include all of the field sampling and measurements of Tiers 1 and 2. In addition, they require all benthic invertebrate samples to be preserved and taken to the laboratory for taxonomic identification at least to the level of family (Table 4.1). This level of effort requires professional experience to verify the QA/QC of macroinvertebrate identification. Thus, ISM requires government partners to support and participate in the program. Although the effort and cost of ISM is high, relative to the lower tier programs, data collected for ISM can be directly reported to regulatory agencies.

Chapters 5 and 6 detail the specific methods to be used in each of the above monitoring tiers. As described in Chapter 5, BSM and ESM surveys use the same methods for gathering information on macroinvertebrate abundance, while ISM methods require benthic invertebrate samples to be preserved for later identification in the laboratory. Methods for measuring the standard stream habitat characteristics are the same for all three monitoring tiers (Chapter 6). However, ESM and ISM surveys collect additional information on water chemistry and algal biomass (Chapter 6).

5. SAMPLING MACROINVERTEBRATES (TIERS 1, 2, and 3)

Most of the equipment required for this volunteer biosurvey is supplied in the monitoring kit. Some items will have to be supplied by the individual. A list of equipment is compiled in Table 5.1. Note that sampling methods are identical for tiers 1 and 2. Methods for tier 3 require the preservation of invertebrate samples in the field and taxonomic identification in the laboratory. The tiered approach for volunteer monitoring is described in chapter 4.

Table 5.1. Required Equipment for All Tiers of Volunteer Monitoring.

Shared Equipment (all tiers)	Equipment for Each Group
• aquatic d-frame net with spare net • subsampling device with bucket • extra sieves and wash bottles • swirling buckets • scalpel blades and algal template • formalin or other preservative • sample jars, tape, labels, permanent pens • thermometer • tape measure • metre stick • flagging tape • rubber gloves	• white sorting trays and forceps • field data sheets • magnifying lens • pencils • set of instructions for monitoring • first aid kit • safety glasses • preservative (ethanol of formalin)
	Personal Equipment
	• waders or rubber boots • sunscreen, hat, insect repellent • drinking water, food (if desired)

5.1. Tier 1 and 2 Invertebrate Sampling

Macroinvertebrates are usually sampled from riffles (areas of faster flow, usually over cobble substrate) because this habitat is the most productive area of the river and, generally, has the most diverse biological communities. In areas lacking riffles a run section with a cobble bottom will be appropriate for sampling.

Each replicate sample requires that you collect invertebrates with an aquatic d-frame net from three spots within a designated riffle. This kind of sample is called a **composite sample**. (*A composite sample is a series of smaller samples, in this case three, combined into one larger sample that is more representative of the riffle than any one small sample would be.*) This composite sample will be divided into smaller portions called **subsamples**, and some of the subsamples will be picked for invertebrates. Once all invertebrates have been picked from the subsamples, they will be sorted into **taxonomic groups**, and the numbers of invertebrates in each group **counted**. **The collection procedure must be followed carefully and closely to ensure that data are collected correctly, consistently, and reliably.**

Steps for Collecting the Invertebrate Samples:

1) Identify the sampling location:

Find the site and riffle to be sampled by referring to the site description and location instructions provided. The site should be marked with flagging tape that indicates the upper and lower extent of the sample area. If the site is not flagged, do this now and record on the data sheets that you did so. A composite sample will be collected from the lower (downstream) third of the riffle (sample area) across a transect of the river at 1/4, 1/2, and 3/4 of the wetted width for 10 seconds at each spot. The complete composite sample will represent a 30 second collection. Often it is desirable to collect replicate samples. We recommend collecting 3-5 replicates, with each replicate obtained from a different riffle in the sampling reach. When sampling more than one riffle in a reach, sample the furthest downstream riffle first and then move upstream to subsequent riffles.

2) Get into position:

Always move upstream to the sample spot. Avoid walking in or upstream of the area to be sampled. Collect the first sample at 1/4 of the wetted width. Place the D-net on the downstream edge of the first sample spot, so the opening faces the flow. Be sure not to disturb the area in front of the net prior to sampling. Push the net frame into the substrate just enough to ensure that there are no gaps between the net and substrate through which invertebrates might escape.

3) Take the sample:

Keeping your body behind the net, hold the net firmly in place with one hand. Without obstructing the flow of water, carefully kneel down to the side of the net and, with the other hand, disturb the area immediately in front of the net (30cm x 30cm) for 10 seconds. Have a partner time you. Rub all rock surfaces (bottom, sides, top) and agitate the sediments to a depth of 5cm. The dislodged organisms will be carried into the net by the current. Pick up the net in a forward scooping motion to prevent the flow from washing invertebrates out of the net.

4) Repeat steps 2 & 3:

Step back from the area just sampled and move behind the next sample area (1/2 wetted width). Move up to the spot you want to sample and ***place the net down in a forward motion so that the flow keeps captured invertebrates in the net.*** Ensure the net is properly placed on the substrate and repeat the sampling process.

Repeat this sampling process again at 3/4 wetted stream width.

5) Empty the Net:

Once all three samples have been collected, wash all material to the bottom of the net by splashing streamwater onto the outside of the net. Move to the shore and carefully empty the net into a bucket half filled with cool stream water. Swish the net in the water to make sure that all invertebrates come off and, if necessary, use forceps to gently remove any remaining invertebrates from the net and place them in the bucket.

6) Subsampling:

Inspect the larger pieces of debris (sticks, twigs, large stones) in the bucket for invertebrates. Wash or pick any clinging invertebrates back into the bucket and then discard the debris. Gently swirl the contents of the bucket with your hand and pour the suspended organic material into the divided 400µm sieve. Leave all inorganic material (sand, silt, rocks) in the bucket. Add fresh stream water to the bucket and repeat the swirl and pour process until all invertebrates and organic material are in the sieve. Only sand and gravel will remain in the bucket. Discard the sand and gravel after visually checking for any remaining invertebrates (*i.e*. large caddisfly cases).

Attach the subsample collar to the inside of the sieve. Press firmly to ensure a snug fit. Fill the subsampler bucket with water and lower the subsampler into it. Insert the mixer/plunger in the subsampler and use it to suspend and mix the contents thoroughly (raise and lower the plunger 10 times with a slight twisting motion). Quickly remove the subsampler from the subsampler bucket. Water will drain out through the sieve and should distribute the invertebrates evenly in the four compartments of the sieve. Attach the retainer lid to cover all but one section of the sieve and wash all material from the exposed section into an enamel tray. Use forceps to remove any invertebrates adhering to the exposed section of the sieve. **Repeat the above process and wash the material from each of the other 3 sections into separate containers for later use.** Pour enough water into the tray so that the material from the first subsample is covered with about 1 cm of water. This fraction (1/4), or subsample of the whole sample is ready to be sorted.

7) Pick and Count the Subsample:

Have one or more partners help you pick the subsample in the tray or split the subsample among several trays so each person can search for invertebrates. Add size markers to limit your search to invertebrates larger than **3mm**. Size markers are most easily made by cutting color coated wire into 3mm lengths. Sort the invertebrates into compartments of an ice cube tray that have been filled with stream water. Use a separate compartment for each type of invertebrate. **When you think there are no more invertebrates remaining in the enamel tray, switch trays with a partner and have them look for invertebrates that**

may have been missed. **If less than 100 organisms have been found in the first subsample, a second, and possibly a third subsample from the divided sieve must be randomly selected and sorted completely.** Once you have started picking a subsample, it must be completely sorted even if you have counted 100 organisms, so that the amount of sample which has been picked is known.

Use the provided keys in Appendix A to identify the organisms to Order and **have other volunteers confirm your identifications**. Record on the data sheets the numbers of each group found. The chart identifies major taxonomic groups (order) that are most important for assessing this river system. Keep in mind that all invertebrates may not be on the invertebrate key sheets. Note that there are many suborders, families, and species within each group, so invertebrates within an order may look quite different. Use of a magnifying glass may help to identify features on some of the smaller invertebrates. If there is an abundance of a particular invertebrate that is not pictured in the key, record the number found and preserve several of the specimens in rubbing alcohol for later identification.

8) Replicate Sampling:

If replicate samples are needed, repeat steps 1-7 in an upstream riffle within the same reach until the appropriate number of replicates are collected.

5.2. Safety Considerations

Volunteers should be concerned with safety at all times. They must be trained in safety procedures and carry a set of safety instructions. Listed in Table 5.2 are some basic safety rules that should be followed at all times. **Remember: Safety is your primary concern**.

Table 5.2. Safety Precautions.

Before You Go
• Check weather reports. • Confirm that you have landowner permission for your site. • Note the location and phone number of the nearest medical centre. • Ensure that you have a first aid kit.
Instream Safety
• Always sample with a partner • Park in a safe location. • Never wade in deep or swift flowing water. Only sample in periods of low flow. • Be careful! Watch for slippery rocks, deep spots, and mucky areas.
Your Health
• Do not drink water out of the stream. Assume it is unsafe. • Wear a hat and sunscreen. Watch for signs of heat-stroke, sunstroke or hypothermia • Wear gloves and eye protection when handling any chemicals. • Dress in layers of clothing

5.3. Tier 3 Invertebrate Sampling

The procedures for Tier 3 are identical to those of tier 1 & 2 except that after subsampling, the subsamples will be placed in containers labelled and preserved for laboratory processing. Containers should be labelled on the outside with permanent ink, and a paper label written in pencil placed inside the container. The labels must clearly show the site, sample number, sample date, and individuals that collected the samples. Samples should be preserved in 10% formalin or 80% ethanol providing safety glasses and rubber gloves are used. Formalin is the better preservative, however, volunteer groups may prefer to use ethanol because it is easier to obtain and safer to use.

6. STREAM CHARACTERISTICS & WATER QUALITY

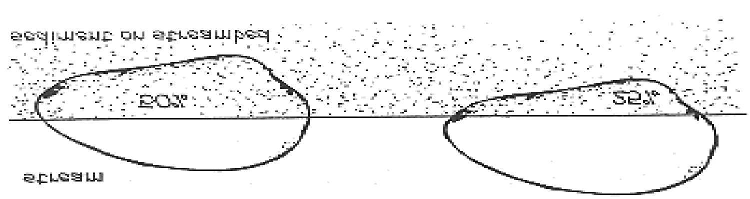
6.1. Standard Survey for All Tiers (1-3)

The standard survey described below is undertaken in all tiers of monitoring (*i.e*., BSM, ESM, ISM). Chapter 4 describes the tiered approach for volunteer monitoring.

6.1.1. Embeddedness

In undisturbed mountainous streams in British Columbia, fine sediments (< 2mm) generally do not accumulate in large quantities on gravel and cobble in riffles. If large amounts of sediments are found to bury or embed riffle substrates, it may indicate erosion problems in the watershed. Embedded riffle substrates provide less desirable habitat for invertebrates and fish, and reduce stream productivity.

- Measuring embeddedness: Wade into the middle of the riffle that you sampled for macroinvertebrates and pick up **at least 5** pieces of gravel and cobble. Estimate the



(Adapted from Streamkeepers Handbook, 1995)

percentage of rock surface buried in the fines (sand and silt).

A stain line on the rock may indicate the level of burial and aid in the estimation of embeddedness. Repeat this exercise in the lower and upper part of the riffle and record the average estimated percent embeddedness on the field data sheet.

6.1.2. Substrate Classification

The composition of the streambed surface material is important in identifying hydrological characteristics of the river and the types of habitat available to aquatic organisms. Insects need to attach themselves to the stream bottom, or live within the bed materials. The more attachment or living spaces available, the greater will be the variety and number of insects found. Optimally, the stream bed will be dominated by cobbles, gravel, and boulders. As the percentage of sand and silt increases, the suitability and availability of living space for invertebrates will decrease. Large substrate materials, like cobbles and boulders create roughness and offer more resistance to flow, therefore absorbing some of the hydraulic energy of the stream.

- Estimating substrate: The simplest technique for measuring substrate is to walk through the reach and stop every few steps to examine the streambed materials. The sampling path should run diagonal from one streambank to the other to ensure that all materials in the riffle are sampled. Use a ruler to measure the mean diameter of materials and estimate the overall composition of these materials on the bottom. Several (i.e., $\geq$ 4) volunteers should perform this task to prevent individual bias. Each volunteer should measure 25 stones. Record the relative % composition of sand, fine gravel, gravel, cobble and boulders that are present in the reach.

6.1.3. Stream Width

As flow decreases, water will cover less of the stream bottom which will limit the available habitat for aquatic organisms.

- Measuring stream width: Stretch a tape measure across the stream such that it is level, and perpendicular to the flow. Record the wetted width of the stream on the data sheets.

6.1.4. Streamside Vegetation

The riparian vegetation and the overhead canopy of branches and leaves bordering a stream serve to protect the stream. The riparian vegetation acts as a buffer to pollutants entering a stream and protects the banks from erosion. The overhead canopy provides shading for the stream, helping to keep it cool on hot, sunny days.

- Measuring riparian vegetation: Stretch a tape measure from the edge of the stream into the vegetation on the stream bank. Measure the depth of the undisturbed riparian habitat on both sides of the stream. Right and left banks are determined facing upstream. Record the presence and relative abundance (in %) of the types of vegetation in the riparian zone.

- Estimating overhead canopy: Stand in the middle of the stream and estimate the percent shading provided by overhanging vegetation. Have several members of your team provide estimates and record the average estimation.

6.1.5. Consolidation

Consolidation is a measure of compaction of the substrate materials on the streambed. Compaction of the stream bed may affect suitability for fish spawning and reduce habitat quality for other organisms. Sand, silt, and clay can "cement" the gravel and cobble making redd *(i.e.*, depressions in which salmon deposit eggs) excavation very difficult or impossible for salmon.

- Estimating consolidation: Use your heel to move the bottom materials in several locations on the streambed. Record on the field data sheet whether it was easy to move, difficult to move, or very difficult to move the bottom substrate.

6.1.6. Temperature

Temperature is a key physical parameter in aquatic ecosystems that directly affect many of the biological, physical, and chemical factors influencing aquatic organisms. Metabolic rates of plants and animals, dissolved oxygen, and sensitivity of organisms to stressors are all affected by temperature. If temperatures are outside the normal tolerance range of an organism for prolonged periods, they may become stressed and die (Table 6.1). This can result in a change in the types of organisms that inhabit a river.

Temperature in rivers and streams is affected by weather, removal of riverbank shading (riparian zones), turbidity from sediment carried in the water (turbid water absorbs more solar radiation), industrial discharges, urban storm water inputs, groundwater inputs (usually different temperature than surface water), and impoundment's such as dams. (APHA, 1985)(US EPA 1995).

Table 6.1. Water Temperature and Effects on Stream Life. (Adapted from Streamkeepers Handbook, 1995 and B.C. Ambient Criteria, 1994.

Temperature Range (^oC)	Effect on Stream life
20-25^{o}C (warm)	High plant and algal growth, high disease risk to fishes, lowered dissolved oxygen.
13-20^{o}C (cool)	Good plant and algal growth, moderate disease risk to fishes, upper limit for successful hatching of salmonid eggs.
5-13^{o}C (cold)	Controlled plant growth, low disease risk for fishes, optimal temperature for salmonids and trout

- Measuring temperature: Sample away from the riverbank in the main current. Place the thermometer at least 10 cm below the surface or halfway to the bottom if the stream is shallow. Allow the reading to stabilize for at least 1 minute before recording. If possible, try to read the temperature with the thermometer bulb below the water surface. If this is not possible, remove the thermometer and quickly read the temperature before it begins to respond to air temperature. Take temperature readings in two other places spaced 5 metres apart. Record the average temperature and the time of day on the field data sheets. Record the air temperature in a shaded area. Be sure to allow at least 2 minutes for the reading to stabilize.

6.1.7. Stream Discharge

Stream flow has a great impact on water quality and habitat within the stream. Rivers with high discharge are more resistant to pollution inputs, water withdrawals and thermal influences. Streams with low discharge have less capacity to dilute these kinds of impacts. Stream discharge is the volume of water that flows over a designated cross-section in a fixed period of time. The flow is a function of cross-sectional area and velocity and is expressed as cubic metres per second (m^3/sec). Velocity is the rate at which water passes a given point and is expressed as metres per second. Cross-sectional area can be estimated by multiplying the average depth by wetted width.

Water velocity strongly influences habitat and type and distribution of organisms within habitat. Each organism has specific current velocity requirements. Water velocity also affects the amount of silt and sediment carried by the stream. Sediment in fast moving water will be suspended longer in the water column and transported farther than in slow moving water. Fast moving streams generally have higher dissolved oxygen than slow streams due to increased aeration.

- Assessing stream flow: Consult Water Survey of Canada flow records or check with the Salmon River Watershed for flow monitoring data.

6.1.8. Dissolved Oxygen

The amount of oxygen dissolved in streamwater affects the kind of life found there. Water with higher concentrations of oxygen is generally considered to be of higher quality and capable of supporting many kinds of life. Depleted oxygen levels can create unfavourable conditions for many organisms and can change population structure. Under conditions of extremely low dissolved oxygen, organisms that require high oxygen levels (e.g., mayflies, stoneflies, fish) will emigrate, or die off, leaving other organisms that can tolerate low oxygen (e.g., dipteran larvae, tubificid worms) (Table 6.2).

Low dissolved oxygen (DO) concentration in streams may be caused by several factors. Temperature is a major influence because cold water holds more oxygen than warm water (Table 6.3). Streams with low flows in the summer when air temperatures are high are susceptible to decreased dissolved oxygen as water temperature increases. Slow-flowing water will also have less surface turbulence so aeration from atmospheric oxygen will be reduced. Organic waste inputs such as agricultural runoff and septic system seepage, can reduce dissolved oxygen when micro-organisms (e.g., bacteria) decompose these substances. This biochemical oxygen demand (BOD) results from the consumption of oxygen by micro-organisms as they break down organic waste. A high BOD in streams and rivers may significantly reduce dissolved oxygen.

Aquatic plants and algae replenish oxygen during daylight hours but actually consume oxygen from dusk to dawn. This can result in an extremely low oxygen concentration just before dawn, particularly near and within macrophyte (i.e., weed) beds. In a stream where oxygen levels are already depressed, the nocturnal consumption of dissolved oxygen by plants can prove to be disastrous for many types of organisms, including salmon fry. Events of low dissolved oxygen can be particularly damaging in mid-summer when water temperatures are high and macrophyte biomass is near its annual peak.

Table 6.2. Dissolved Oxygen (DO) Concentrations and Effects on Aquatic Life (B.C. Ambient Criteria: 1994).

Effect on Aquatic Organisms	DO Concentration (mg/L)
Invertebrates	
No production impairment	8.0
Some production impairment	5.0
Acute mortality limit	4.0
Salmonids	
Later Life Stages	
No production impairment	8.0
Slight production impairment	6.0
Severe production impairment	4.0
Limit to avoid acute mortality	3.0
Embryo & Larval Stages	
No production impairment	11.0
Slight production impairment	9.0
Severe production impairment	7.0
Limit to avoid acute mortality	6.0
Non-Salmonids	
Later Life Stages	
No production impairment	6.0
Slight production impairment	5.0
Severe production impairment	3.5
Limit to avoid acute mortality	3.0

Table 6.3. Maximum DO Concentrations (mg/l) at Specific Water Temperatures (°C). Adapted from US EPA (1995)

Temperature (°C)	DO (mg/L)	Temperature (°C)	DO (mg/L)
10	11.27	18	9.45
11	11.01	19	9.26
12	10.76	20	9.07
13	10.52	21	8.90
14	10.29	22	8.72
15	10.07	23	8.56
16	9.85	24	8.40
17	9.65	25	8.24

- Measuring dissolved oxygen: Dissolved oxygen may vary significantly along the length of a river. In riffle areas where re-aeration occurs, DO will be higher than in slow moving areas and pools. Therefore, it is important that DO readings be taken in similar habitat at each site. An alternative would be to take several readings (at least 3) in riffles and pools and record average values for each habitat type. Be sure to record the time of day when DO is measured because DO varies throughout a 24 hour period. Because brief excursions of DO to very low levels can have long term effects on the stream community, it is advisable to be opportunistic with DO sampling and measure at times other than the scheduled monitoring periods. For example, dissolved oxygen should always be monitored during periods of low flow and high temperature.

Make sure the DO metre has been calibrated according to manufacturer's instructions before each sampling trip. If it is not properly calibrated, the data will be unreliable.

6.1.9. pH

The relative acidity of water ranked on a pH scale of 0-14. A pH of 0 is strongly acidic while pH of 14 is strongly basic (alkaline). Pure water has a pH of 7 (neutral). The pH scale is logarithmic, which means that for every pH unit increase, there is a 10-fold increase in the acidity of the water. A river with pH= 6.5 is 100 times more acidic than a river with pH= 8.5 .

Water with pH of 6.5 to 8.5 is suitable for the greatest diversity of aquatic organisms. If pH changes too rapidly or moves outside the optimal range, some organisms will become stressed and other less desirable species may begin to dominate the habitat. Young fish and aquatic insects are especially sensitive to extreme pH values outside the optimum range. Stream pH is usually determined by the surrounding geological makeup. Acid rain, wastewater discharges, and drainage of coniferous forests (acidic) may decrease the pH of a stream.

- <u>Measuring pH</u>: Measurement of pH will be dependent upon the type of instrument used. For all types of meters, the unit must be calibrated following the manufacturer's instructions. A water sample from the main flow should be collected in a clean container, and the pH of this sample determined. Allow the reading to stabilize before recording the value on the field data sheet. Record the time of day during which the reading was observed.

6.2. Additional Survey Data for Tiers 2 and 3

These measurements of algal biomass and water chemistry are undertaken in ESM and ISM programs.

Table 6.4. Additional Equipment Needed for Tiers 2 and 3 Data Collection.

- Scalpel handles and spare blades
- algae scraping template
- plastic scintillation vials
- clean bottles for water chemistry analysis
- cooler with ice

6.2.1. Algae

Algal communities are also useful for water quality monitoring because algae show dramatic responses downstream of pollution sources. Algae will often indicate effects that are only indirectly observed in the benthic communities because of their different range of sensitivity. By monitoring biomass, chlorophyll-*a*, and taxonomic composition, effects of toxicants or nutrients may be observed. Some advantages of using algae as a monitoring tool are: (1) algae generally have rapid reproduction rates and very short life cycles, making them valuable indicators of short term impacts; (2) as primary producers, algae are most affected by physical and chemical factors; (3) sampling is easy, inexpensive, and creates minimal impact to resident biota; (4) standard methods exist for evaluation of non-taxonomic structural characteristics of algal communities (Plafkin *et al*. 1989). Factors affecting algae include water temperature, nutrients, contaminants, current velocity, light, and macroinvertebrate grazing. Macroinvertebrates are known for their ability to substantially affect periphyton biomass and may be the most important factor in controlling the algal mat in streams. Table 6.5 is a summary of B.C.water quality criteria for algae.

Two ways of estimating algae biomass are measuring the amount of chlorophyll-*a* and estimating the ash free dry mass (AFDM). Chlorophyll-*a* is distinguished from AFDM in that it only measures pigment contained within live algae cells. Large amounts of non-living organic matter will not affect chlorophyll-*a* values as it would for AFDM. Chlorophyll-*a* is extracted from the cells with a solvent (ethanol) and measured spectrophotometrically or fluorometrically (Standard Methods). AFDM is a measure of the amount of volatile organic matter, which is widely used to estimate the productivity of streams. Within the periphyton layer, a complex biota can exist including bacteria, attached protozoa, rotifers, and algae. It may also include free-living organisms that are creeping, swimming, or lodged within the attached forms. Algal samples from the Salmon River were collected in August and November 1995 and analysed for chlorophyll-a and AFDM. Chlorophyll-*a* results are displayed in Figure 3.4.

Table 6.5. Summary of Water Quality Criteria for Algae in Streams (B.C. Ambient Criteria, 1994).

Water Use	Chlorophyll-*a* (mg/m^2)
Aquatic Life:	100 maximum
Recreation:	50 maximum

- Sampling algae: Through the use of accepted sampling methods (Aloi 1990; Moore 1974) volunteers might easily collect periphyton samples for chlorophyll-*a* and ash-free dry mass analysis. By scraping a known area of a rock surface with a scalpel, collected periphyton samples can then be frozen for later analysis in a qualified laboratory. A small bottle cap (diameter ≅ 3 cm) or other object of known area, must be used as scraping template and the size of this template recorded and submitted with the samples. Other required equipment is listed in Table 6.4.

  From the riffle(s) sampled for invertebrates, randomly select three cobble size rocks (64-256 mm dia.) When picking up the rocks be sure to maintain their orientation and only handle the bottoms as you will want to scrape the undisturbed top side of each rock. Carry each rock to the stream bank for scraping. Place the template on the top of the rock to be scraped. While holding the template firmly in place, use the back of the scalpel to score around the outside edge of the template. Carefully remove the template from the rock. An outline of the template should be visible. Thoroughly scrape the rock only within the scored mark from the template and place all scraped material directly into a labelled plastic scintillation vial. Once all three rocks from the riffle have been scraped into the same vial, the vial must be capped, and placed in a closed cooler with ice (i.e., sunlight and heat will damage the samples). Repeat this procedure for each riffle sampled. Once sampling is complete, the chlorophyll samples must be kept frozen and in the dark until analysed. Good storage conditions will allow these samples to be stores for several months with no chlorophyll degradation. If analysis requires shipping the samples, arrangements must be made to ship the samples frozen with dry ice.

6.2.2. Water Chemistry

Water quality parameters are easily measured and provide a great amount of information about the types of pollutants impacting a stream. Specific activities produce specific pollutants. By identifying specific pollutants we can identify some activities that may be having an impact on the river. For example, nutrients are likely to come from animal feedlots and grazing land, but could also come from changes in land use such as forestry harvesting or construction sites. By monitoring many variables such as ecological indicators, physical parameters, and water chemistry, the volunteer monitoring group will have a better picture of ecosystem health than if just one or two variables are monitored.

6.2.2.1. Phosphorus (as PO_4)

Phosphorus is an essential element for both plant and animal life as aquatic plant growth is limited by the amount of phosphorus available. Usually phosphorus functions as a growth limiting factor in streams and rivers due to naturally low concentrations. Inputs from human activities can cause phosphorus levels to rise and thereby increasing the growth of aquatic plants and algae. Excessive algal growth (blooms) is a symptom of eutrophication (accelerated plant growth) often caused by excessive phosphorus (Table 6.6). Algal blooms can lead to low dissolved oxygen and the death of fish, invertebrates and other aquatic animals (U.S. EPA. 1995)(Mitchell & Stapp. 1995)

In natural waters, phosphorus is present as phosphate (PO_4), in both organic and inorganic forms. Organic phosphate consists of a phosphate molecule associated with a carbon molecule, as in plant or animal matter. Phosphate not associated with a carbon molecule is inorganic. Inorganic phosphate is the form rapidly taken up by plants. Organic and inorganic phosphate is available for use to animals, including bacteria which convert organic phosphates back into inorganic phosphates which can then be used by algae and other aquatic plants. Sources of phosphates in a river system are numerous and include sewage from wastewater treatment plants, septic field leakage, industrial wastes, waste runoff from animal feedlots, fertilizers, and soil erosion (Mitchell & Stapp. 1995).

6.2.2.2. *Nitrogen (as NH_3, NO_3, NO_2)*

Nitrogen, like phosphorus, is an essential element for all living things. Because NO_3 and NO_2 act as nutrients, much like PO_4, eutrophication (accelerated plant growth) can occur. In freshwater systems, nitrogen is usually available in amounts the are not limiting to the growth of aquatic plants. Therefore, aquatic systems are generally not as sensitive to increases in nitrogen as they are to phosphorus. However, in the Salmon River, background (i.e., natural) levels of phosphates are high, thus nitrogen may be a limiting factor for plant growth. In addition to nutrient effects, nitrites, nitrates, and ammonia can have toxic effects on organisms if concentrations are high enough (Table 6.6).

Common sources of nitrogen (in various forms) from human activities include sewage systems and improperly functioning septic systems. Fertilizers and runoff from cattle feedlots can also contribute to nitrogen loading of water. Water containing nitrates may be harmful to humans as well as aquatic organisms.

Table 6.6. Summary of Water Quality Criteria for Nitrogen and Phosphorus (B.C. Ambient Criteria: 1994).

Water use	**Total P (: g/L)**	**NO_3 (mg/L as N)**	**NO_2 (mg/L as N)**	**NH_3 (mg/L as N)**
Drinking	<10 (lakes only)	<10	<1	no standard
Aquatic life	<5-15 (lakes only)	<200	<0.06	<~20 @ pH 7
Livestock watering	none	100	10	no standard

7. Ensuring Data Quality

7.1. Volunteer Training

Training for volunteers is an essential component of citizen-based monitoring programs. This training includes explaining the goals of the monitoring program to all personnel as well as instruction in sampling methods to ensure that the collected data conform to established QA/QC protocol. Besides producing higher quality data, trained volunteers will better understand their role in protecting water quality and will require less supervision. A well organized training program will produce volunteers that feel part of the monitoring team (US EPA 1995).

A key to establishing a successful training program is the designation of a program coordinator with the responsibility of establishing and conducting training sessions. The coordinator must outline a detailed, written training schedule. This schedule must include times and locations of workshops and sampling dates so all participants can plan ahead. The coordinator, or an appropriate designate must teach training sessions to ensure continuity of monitoring techniques and principles covered. The training schedule should include regular training sessions for new volunteers and dates for regular “refresher” sessions as a check on volunteer performance. For the Salmon River benthic monitoring program, staff at the National Hydrology Research Institute (Environment Canada) conducted an inaugural workshop on March 3, 1997 in order to establish a curriculum for training sessions to be used in future sessions by the Roundtable (Table 7.1).

Table 7.1. Sample Agenda for Initial Training Workshop for Biomonitoring Volunteers.

AGENDA: VOLUNTEER TRAINING FOR SALMON RIVER BIOMONITORNG
Morning Session 9:00-12:00
WELCOME to the workshop **INTRODUCTION:** • Purpose of biomonitoring in the Salmon River Watershed • Measuring river health **INVERTEBRATES:** • Importance and role in stream ecosystems • Ecosystem indicators • Food webs **BACKGROUND INFORMATION FOR SALMON RIVER:** • Location of monitoring sites • Rationale of site selection for monitoring **COLLECTION OF DATA:** • What and how is information collected? • Invertebrate collection • Collection of pH, dissolved oxygen, and temperature data • Collection of data on stream characteristics: stream bed and riparian zones **INVERTEBRATE IDENTIFICATION:** • Identifying features of major orders • Use of taxonomic keys
LUNCH
Afternoon Session 1:00 - 5:00pm
FIELD ACTIVITIES: (Afternoon at Silver Creek site) • Collection and subsampling of macroinvertebrates • Macroinvertebrate identification, QA/QC, and data recording • Basic Survey: Measurements of Stream Characteristics ***Personal Equipment Required for Field Activities:*** • Waders or rubber boots • Sunscreen, hat, insect repellent • Drinking water, food (if desired)

Training for volunteers is the responsibility of the Roundtable. A program coordinator should establish dates for sessions, arrange for necessary equipment and handouts, and do the initial training and "follow up QA/QC' Some volunteer monitoring programs have developed job descriptions for volunteers so that expectations and obligations of volunteers are clearly stated (US EPA 19'95). Training sessions must be well planned with a clear agenda. The inclusion of interesting, hands-on demonstrations contribute greatly to the success of training sessions.

From experiences on the Salmon River, a 1 day training session work wel (for tiers 1 and 2) when the morning session covers the principles and techniques of the program, while the afternoon session focuses on hands-on demonstrations of monitoring techniques at one of the sampling sites. After this 1 day. session, volunteers can undertake sampling under supervision from the coordinator An additional 0.5 day is required for tier 3 training, -excluding invertebrate identification training beyond the level of order. Taxonomic identification to family level 'and beyond requires the supervision of one or more persons with extensive training in' invertebrate taxonomic identification. Upon completion of the biomonitoring training, volunteers receive a'certificate indicating date of course completion (Figure 7.1) and an expiry date after which continued certification would require a refresher short course.

The Salmon River Watershed

This Is To Certify That

-VOLUNTEER-

Has Successfully Completed

Tier 1, 2, and 3 Training For Biomonitoring

June **19, 1997**

Presented by: National Hydrology Research Institute
Environment Canada
Saskatoon, Saskatchewan

Instructor

Figure' 7.1. Example of Training Certificate.

Finally, volunteers should be encouraged to provide feedback after the sessions so that the effectiveness of the training program can be improved. A detailed summary of time estimates for initial training exercises, refresher courses, and frequency of training sessions is listed in Table 7.2.

Table 7.2. Summary of Recommended Training Time and Group Sizes.

Training Level	Maximum Group Size	Time Required
Tiers 1 & 2	15 persons	1 day (see table 7.1 for agenda)
Tier 3	10 persons	0.5 day (in addition to tier 1 & 2)
Yearly Refresher course (all Tiers)	15 persons	0.5 day

7.2. QA/QC Guidelines

Quality Assurance and Quality Control (QA/QC) is an ongoing process which has the goal of prevention, early detection, and correction of field and analytical data collection errors (U.S EPA 1995). Volunteers must ensure that <u>all</u> data sheets are filled in correctly and completely. They must ask themselves if the data are reasonable before they leave the field, and if not, the measurements need to be repeated before leaving. QA/QC procedures for field sorting of invertebrates and physical measurements are listed in Tables 7.3 and 7.4. Project coordinators need to screen all data sheets to identify unusual observations and confirm effectiveness of QA/QC procedures.

Table 7.3. Summary of Steps That Ensure Reliable Collection of Data.

QA/QC for Field Sorting of Invertebrates:
1. Sample sites are preselected to ensure adequate and consistent monitoring sites. 2. Work is done in groups of 4 to ensure proper data collection techniques and accurate data recording. 3. Subsampling (splitting) of collected invertebrate sample minimizes volunteer workload. 4. Search for invertebrates is size-standardized (>3mm) to ensure consistent results for different sorters. 5. Volunteers must check their partners picking efficiency. 6. Volunteers must confirm each other's invertebrate identifications before recording data. 7. Project coordinators should screen all data sheets to identify unusual observations and to confirm effectiveness of QA/QC procedures.

Table 7.4. QA/QC for Physical Measurements.

1. *Embeddedness*: Examine 5 or more stones from several locations within the sample area before estimating embeddedness. Others in the monitoring team must confirm the estimation.

2. *Consolidation*: Volunteers must sample several locations within the sample reach before estimating consolidation. Another team member should confirm the estimation.

3. *Water temperature*: Volunteers must sample away from the riverbank and check the temperature in several locations before recording an average value. If possible, the thermometer should be read while submerged 10 cm below the surface. Allow the reading to stabilize at least 1 minute. If the thermometer is an electronic type, it must be calibrated to the manufacturer's instructions before use.

4. *Substrate classification*: Visual estimates should be assessed by $\geq$ 4 members of the group before average values are recorded ($\geq$ 100 rocks sampled). Volunteers are encouraged to assess several areas within the sampling site before making an estimation. Substrate classification data must accompany embeddedness and consolidation estimates to complete the description of the stream bottom and to eliminate discrepancies.

5. *Dissolved oxygen*: The DO meter must be calibrated before each day of use according to the manufacturer's instructions. Several readings must be taken from a variety of habitats (pools & riffles) before recording the average value for each habitat. Time of day and water temperature must be recorded along with DO readings. Additional DO readings taken throughout the day can provide valuable information, and may detect brief, but biologically important, decreases in DO.

6. *pH measurements*: pH meters must be calibrated to the manufacturer's instructions before use. Time of day must also be recorded. A sample for pH measurement must be collected in a clean container from the main area of flow.

7.3. Data Management

Now that the data have been collected in an efficient and reliable method with QA/QC steps in place, what happens next? Because people are usually much more enthusiastic about collecting data than managing data, it is critical that a plan for managing data be established early in the program. A monitoring program's credibility may suffer if there is no data management plan to deal with collected data that can pile up quickly.

The task of ensuring the quality of the data before entering them into a computerized database is extremely important. This process begins, but does not end, with collecting data following established procedures and QA/QC guidelines. Once data have been collected they should be reviewed by the program coordinator or designated analyst, and examined for any outliers (i.e., findings that differ greatly from past data). This process requires that the results be compared to previously collected data to see if the two sets are "reasonably" close. Thus, the reviewer must be familiar with expected ranges in which the data should fall. Remember that parameters will vary throughout the day, seasons and years. If the results do appear unusual, it may require someone returning to the monitoring site to confirm the abnormal result. Once all raw data have been verified, they should be entered into a computerized spreadsheet package that can be customized for the volunteer group. Most spreadsheet software packages (e.g. Quattro Pro, Excel, Lotus 1-2-3) allow sufficient management of data, are not difficult to master, and have graphing capabilities.

7.4. Data Interpretation

Each data sheet represents a volunteer's time and commitment. Volunteers deserve to be rewarded for their efforts by an equal commitment to organize the data and display it in an easy to understand form such as site-specific results and graphical summaries of findings. When data need to be analysed and summarized for presentation to a volunteer group, graphical representation is usually the most efficient and interesting method. Data summaries can be tailored for the intended audience, making the graphs as simple or complex as required. For a detailed discussion of managing and presenting volunteer data, the U.S. EPA (1995) publication Volunteer Stream Monitoring: A Methods Manual should serve as a good reference source.

In the case of Tier 1 and Tier 2 monitoring, the data are probably best interpreted using simple graphics (e.g., histograms, line plots) of the type used in Chapter 3 of this report. Graphics of this type are easily interpreted and allow for data comparisons among years. Moreover, this level of interpretation is readily accomplished using widely available spreadsheet and presentation software.

Tier 3 monitoring represents a more rigorous approach to data collection and thus the data are amenable to a more sophisticated level of statistical analyses. Appropriate statistical analyses for Tier 3 monitoring could potentially involve multivariate analyses (e.g., Principal Component Analyses as discussed in Chapter 3), trend analysis and/or the application of a variety of biotic indices. Descriptions and reviews of various analyses are widely described in the available literature, but the specific techniques most appropriate to the questions being asked should be determined by the Roundtable in discussion with consultants or government agencies.

Regardless of how sophisticated a statistical technique might be, the results of the analyses should be presented clearly and simply. Even the most complicated of analyses can be readily interpreted by an audience unfamiliar with statistics if an effort is made to present the results properly. The Roundtable should ensure that, if they choose to take a Tier 3 approach, the results are readily interpretable by the volunteers. This is best accomplished by working closely with whomever is responsible for data analyses and establishing partnerships with regulatory agencies.

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Appendix A:

Data sheets
Invertebrate keys

SALMON RIVER

Site # _________ **Date:**______________
Location:__________________________ **Replicate #**__________
Investigators: _______________________ **Arrival time:**________ **Departure time:** _______

WEATHER IN LAST 24 HOURS
- Heavy Rain
- Steady Rain
- Showers
- Overcast
- Partly Cloudy
- Clear / Sunny

WEATHER NOW
- Heavy Rain
- Steady Rain
- Showers
- Overcast
- Partly Cloudy
- Clear / Sunny

PHYSICAL PARAMETERS:

Air temperature ____ ^{0}C
Water temperature ____ ^{0}C
Dissolved Oxygen**:**
Riffle average ____mg/L
Pool average ____mg/L
pH ____ units

STREAM CHARACTERISTICS

Present stream: width _____m.
Bank stability: intact banks_____ some erosion _____ extensive erosion ____

Substrate Classification (Estimate using a ruler as an aid)

%Silt/sand	_____	(<2mm)
%Fine Gravel	_____	(2-8mm)
%Gravel	_____	(8-64mm)
%Cobble	_____	(64-256mm)
%Boulders	_____	(>256mm)

Embeddedness of Substrate (see diagram on how to estimate)

_____<25%, _____<50%, _____<75%, ____>75%

Consolidation of Substrate

_____ Loose, easily moved
_____ Moderately difficult to move with boot heel
_____ Tightly cemented, difficult to move by kicking

Streamside vegetation:

Overhead canopy: ____<25% ____<50% ____<75% ____>75%

Riparian zone:

Left bank: none ____ <10m wide ____ 10-20m wide ____>20m

Right bank: none ____ <10m wide ____ 10-20m wide ____>20m

Types of streamside vegetation: Record presence and relative abundance.

Conifers:____

Deciduous:____

Small trees & shrubs:__________________________________

Grasses:____

SALMON RIVER INVERTEBRATE DATA

Site # ________ **Date:**________________
Location:_________________________ **Replicate #**___________
Investigators: ______________________

INVERTEBRATE COLLECTION (30 sec. composite)

Record portion of sample sorted: 1/4____, 1/2 ___, 3/4___,

Determine the subsample factor and circle:

Portion sorted	Subsample factor
1/4	4
2/4 (or 1/2)	2
3/4	1.33
4/4 (i.e. entire sample)	1

Count the numbers of each taxonomic group found and record in column 3:

Column 1 **Group**	*Column 2* **Subgroup**	*Column 3* **# of individuals in subsample**	*Column 4* **# of individuals in total sample***
Stoneflies	**Total**		
Mayflies	Heptageniidae		
	all others		
	Total		
Caddisflies	Hydropsychidae		
	all others		
	Total		
Dipterans	Tipulidae		
	Simulidae		
	Chironomidae		
	all others		
	Total		
Coleopterans	Elmidae larvae		
	all adults		
	all others		
	Total		
All Invertebrates	**Total**		

*Column 3 multiplied by subsample factor

Comments or Additional Information (use back of page)

____

Figure A.1. Key to Order

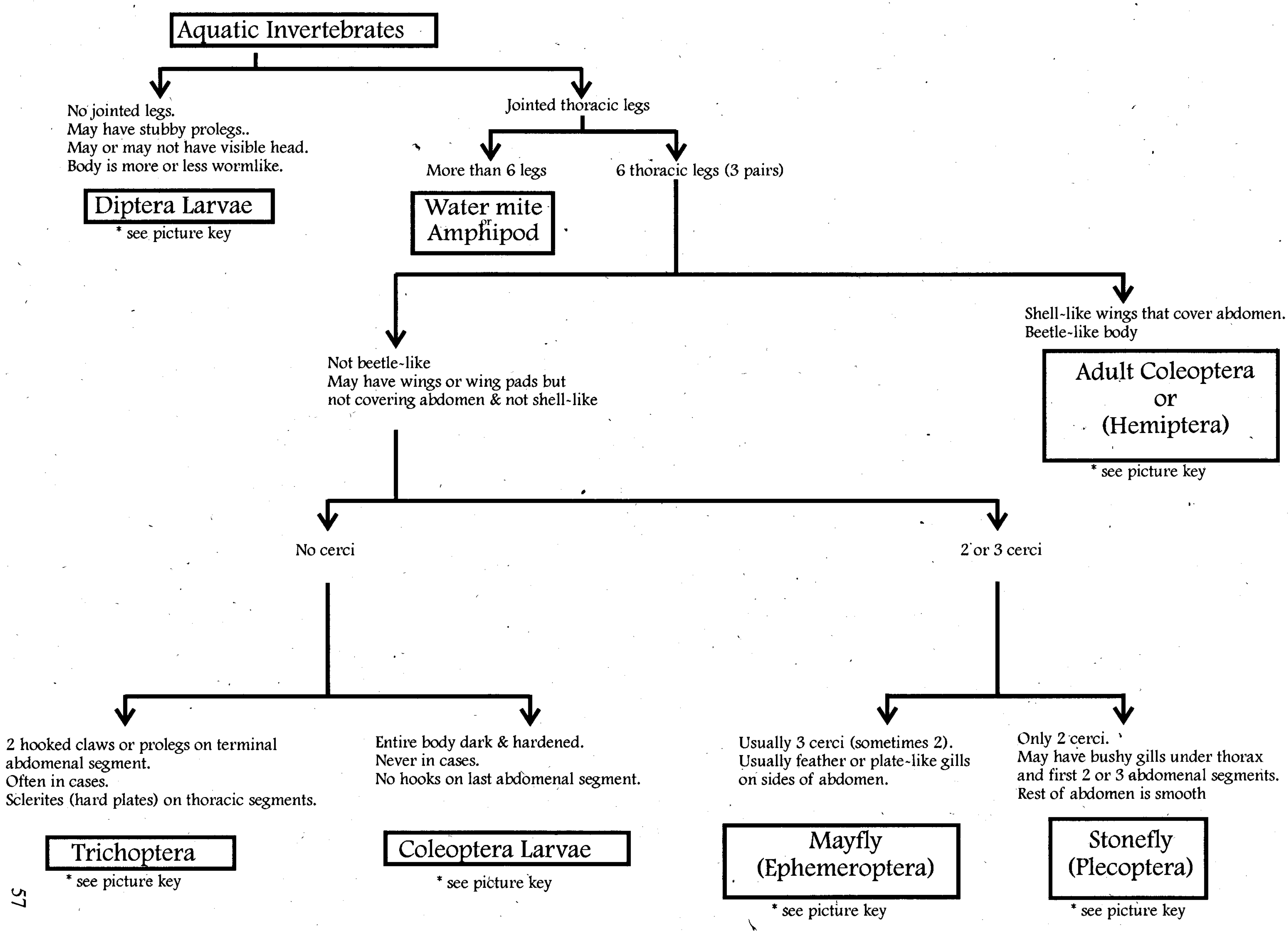


Figure A.2. Key Mayfly Features

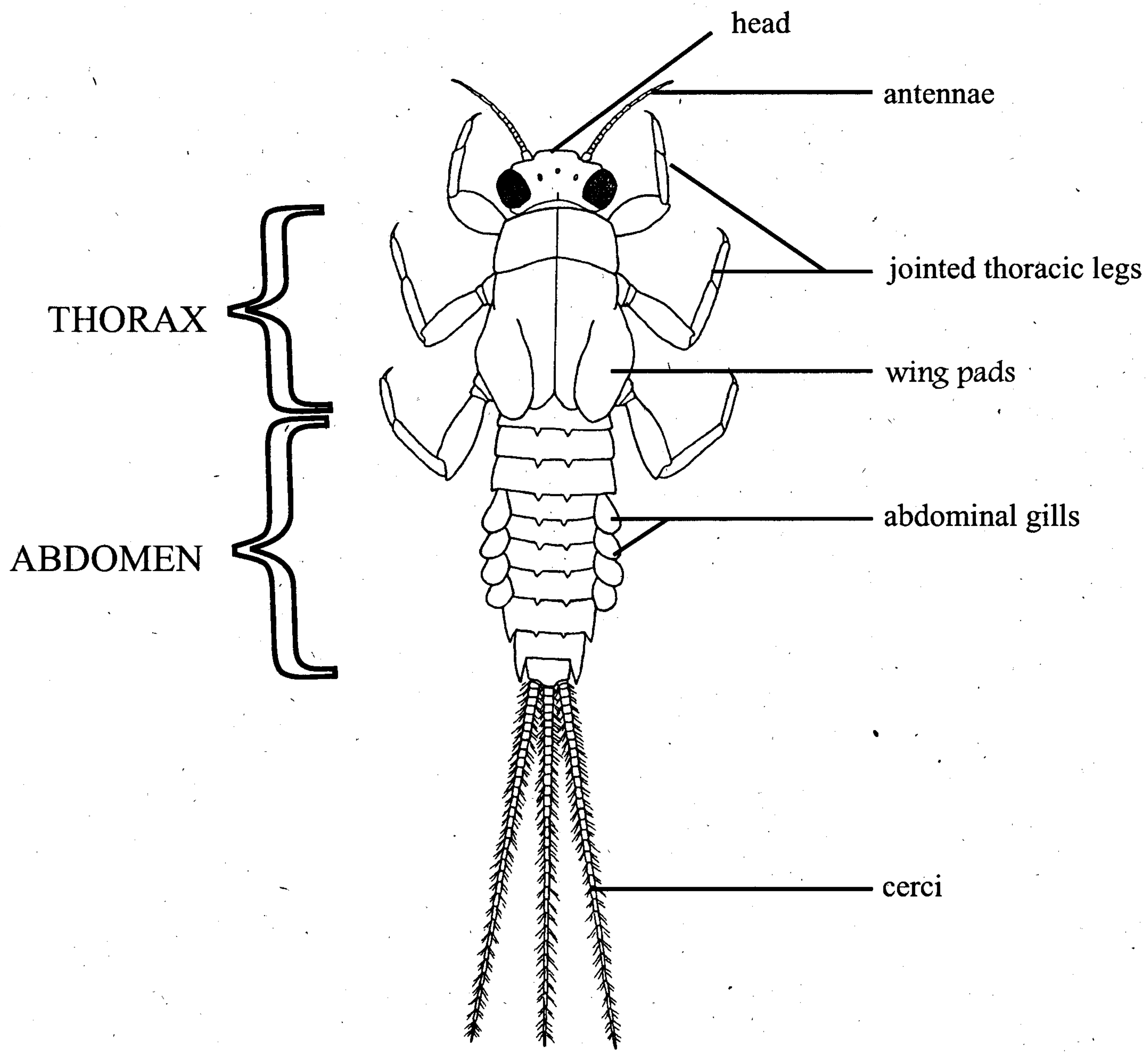


Figure adapted from Clifford, H.F.. 1991

Figure A.3. **Key Stonefly Features**

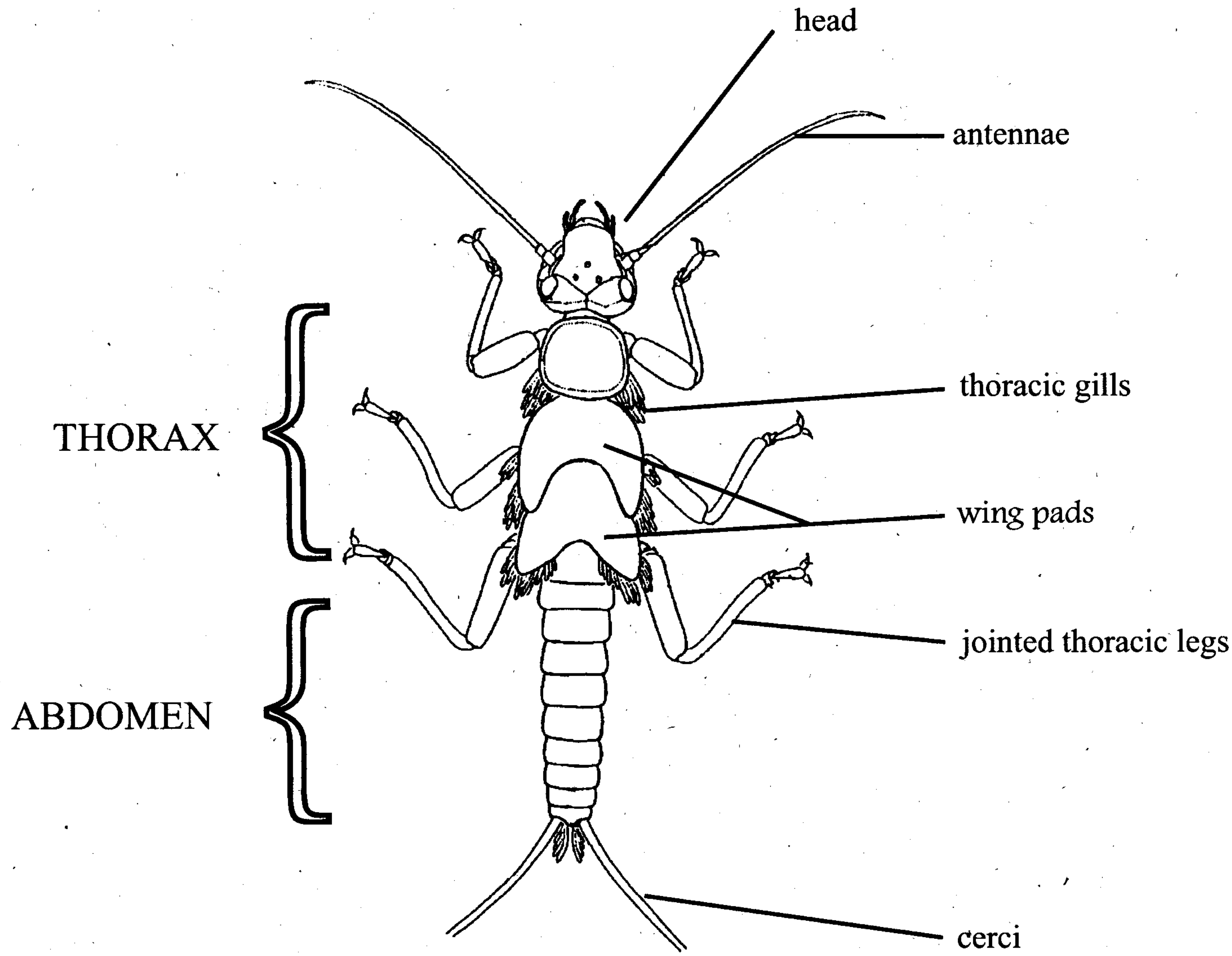


Figure adapted from Ward, J.V. 1992.

Figure A.4. Key Caddisfly Features

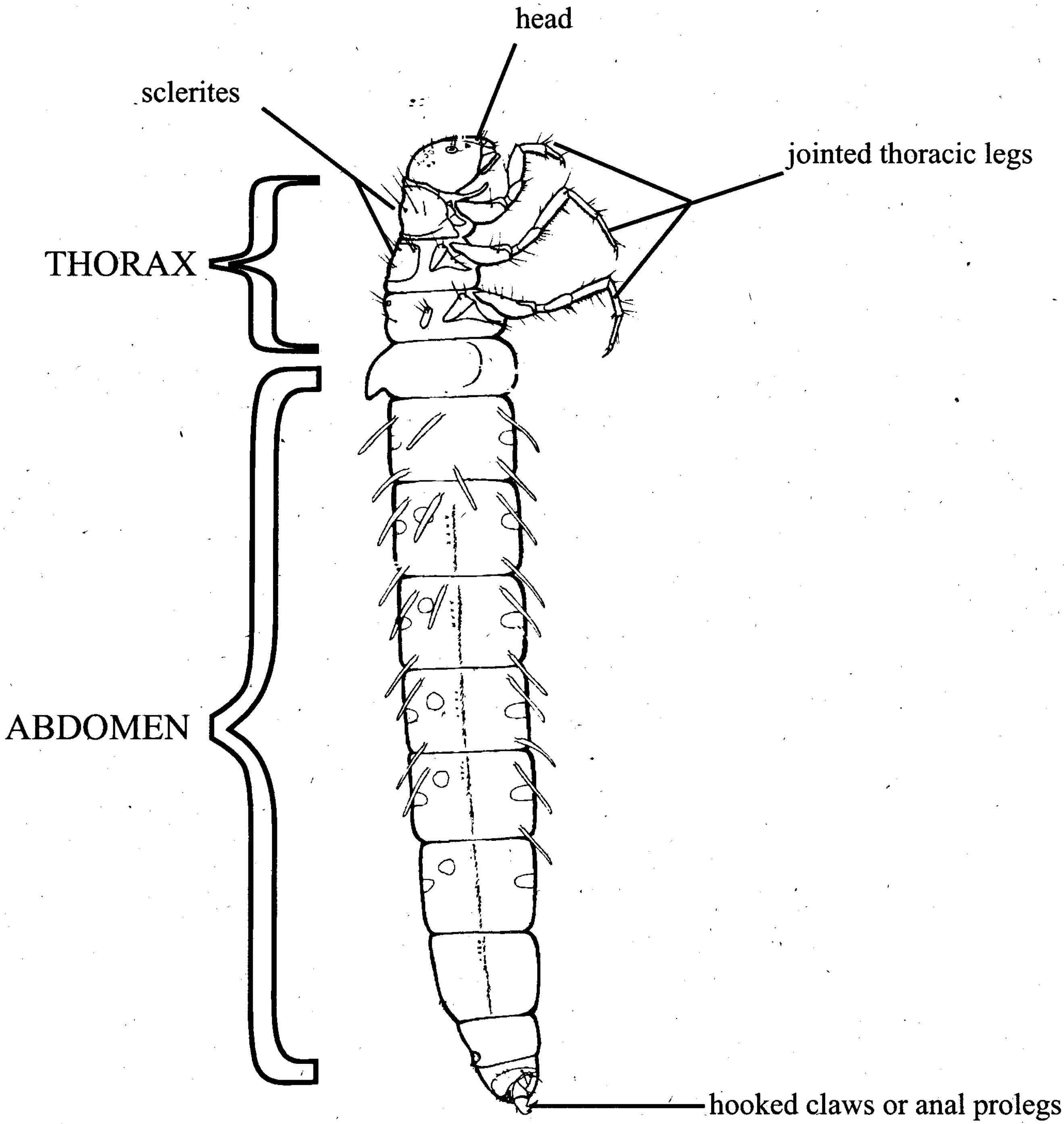
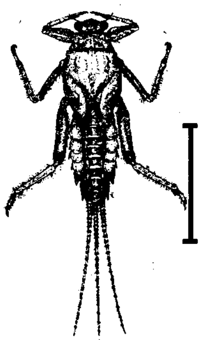
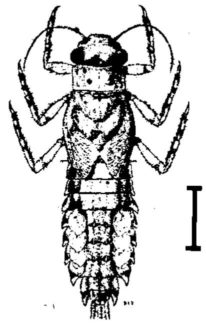


Figure adapted from Merritt, R.W., & K.W. Cummins. 1984

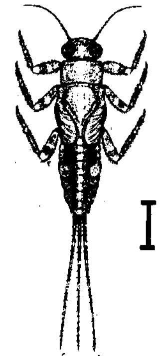
Figure A.5. # Mayfly Nymphs of the Salmon River (Order: Ephemeroptera)



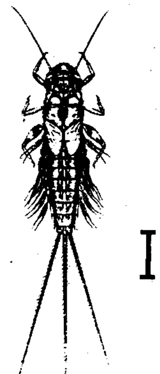
Ephemerellidae



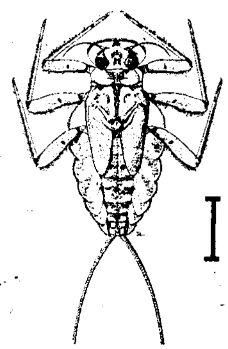
Ephemerellidae



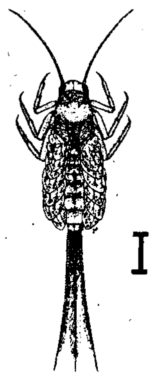
Ephemerellidae



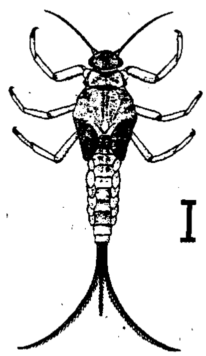
Leptophlebidae



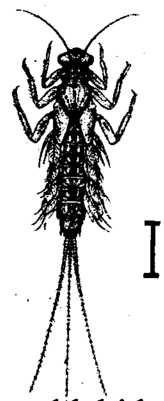
Heptageniidae



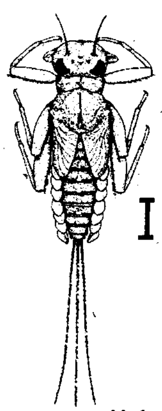
Baetidae



Baetidae



Leptophlebidae



Heptageniidae

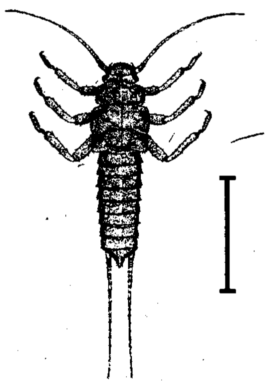
CHARACTERISTICS:

- 3-20mm in size
- 6 legs
- 3 cerci (occasionally 2)
- plate-like or feathery gill on abdomen
- body may be flattened or minnow-like
- good swimmers

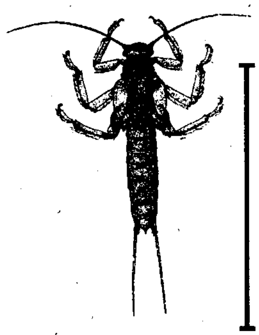
Bar indicates maximum size

Figures adapted from Clifford, H. F. 1991, Edmunds G. F.,1976, and Ward, J. V. 1992.

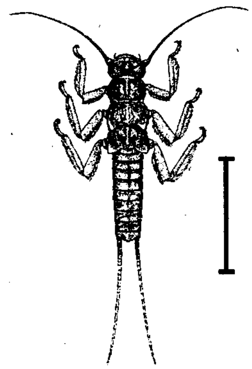
Figure A.6. **Stonefly Larvae of the Salmon River (Order: Plecoptera)**



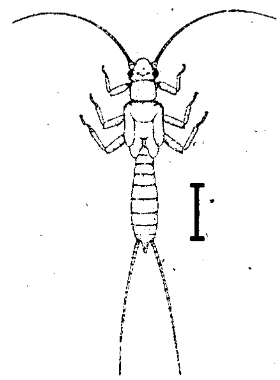
Pteronarcyidae



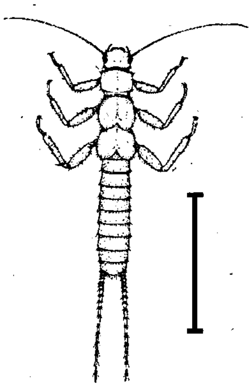
Pteronarcyidae



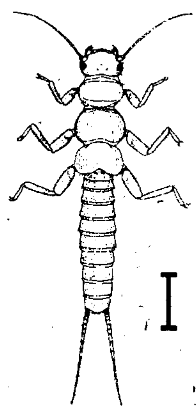
Perlodidae



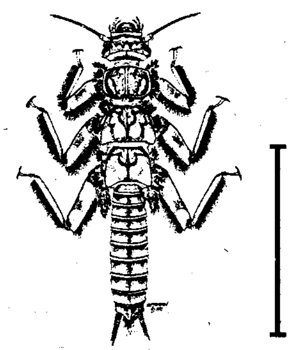
Capniidae



Chloroperlidae



Chloroperlidae



Perlidae

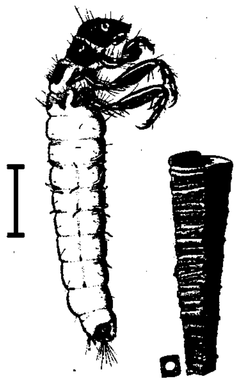
CHARACTERISTICS:

- 5-40mm in length
- only 2 cerci
- no gills on abdomen
- gills occasionally visible on thorax
- 6 legs
- usually crawls rather than swims

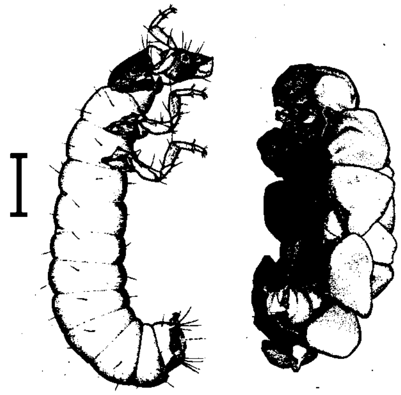
Bar indicates maximum size

Figures adapted from Clifford, H. F. 1991, Ward, J.V. 1992

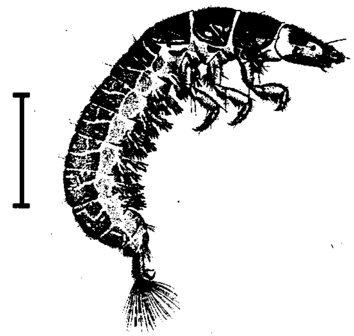
Figure A.7. Caddisfly Larvae of the Salmon River (Order: Trichoptera)



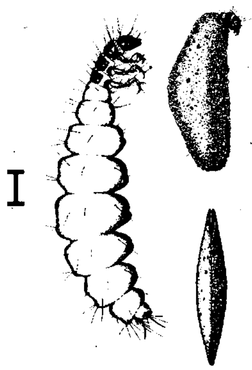
Brachycentridae



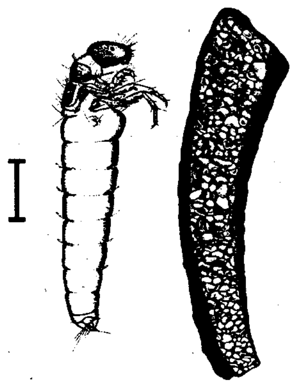
Glossosomatidae



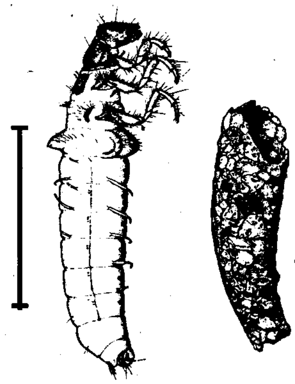
Hydropsychidae



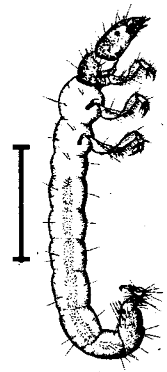
Hydroptilidae



Lepidostomatidae

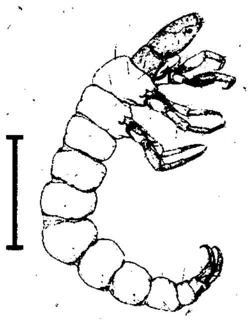


Limnephilidae



Polycentripodidae

Rhyacophilidae



Rhyacophilidae

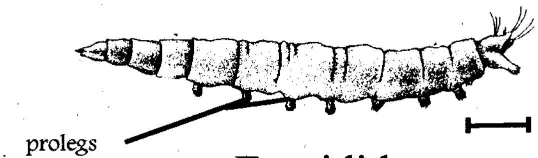
CHARACTERISTICS:

- Up to 30mm in length
- 6 jointed legs on thorax
- may be in a case or free living
- cases constructed of plant or mineral material
- may have fluffy gills on abdomen

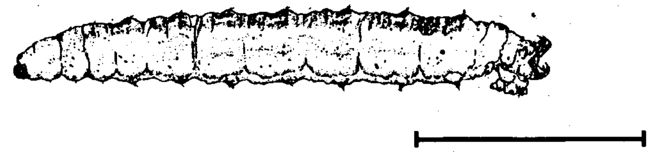
Bar indicates maximum size

Figures adapted from: Clifford, H.F. 1991., Wiggins, G.B. 1977. and Ward, J.V. 1992

Figure A.8. Dipteran Larvae of the Salmon River (Order: Diptera)

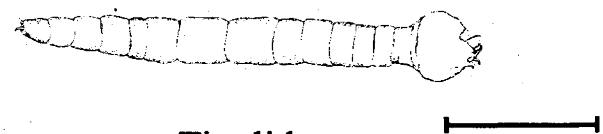


Empididae

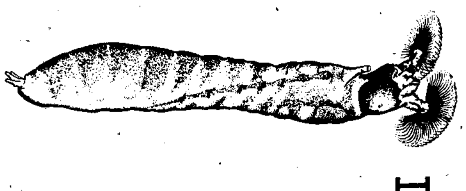


Tipulidae

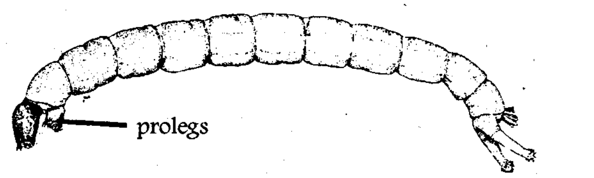
Psychodidae



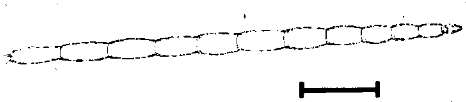
Tipulidae



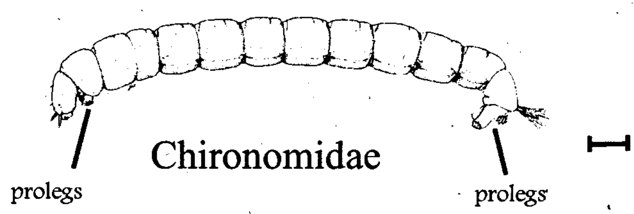
Simulidae



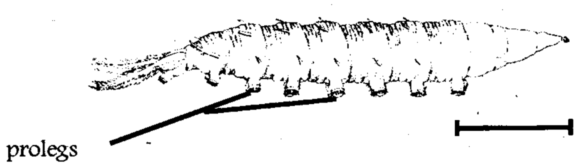
Chironomidae



Ceratopogoniidae



Chironomidae



Athericidae

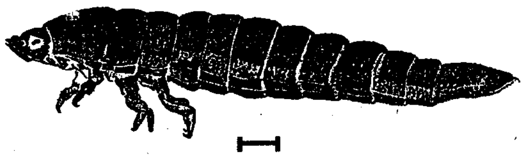
Bar indicates maximum size

CHARACTERISTICS

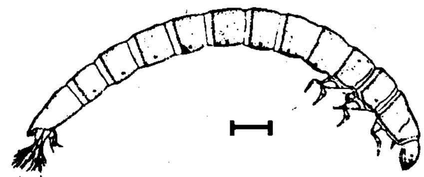
- Slender body shape
- no distinct thorax
- no jointed thoracic legs
- may or may not have an apparent head
- size range: 4-35mm long

Figures adapted from Clifford, H.F. 1991, Ward, J.V. 1992

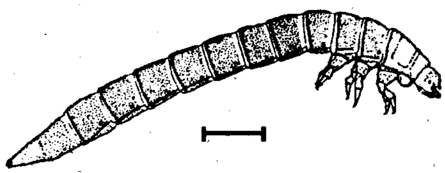
Figure A.9. Beetle Larva of the Salmon River (Order: Coleoptera)



Elmidae larva

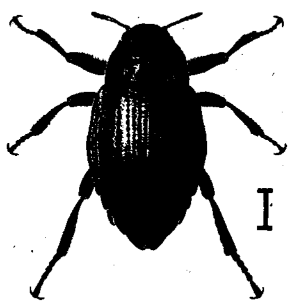


Elmidae larva

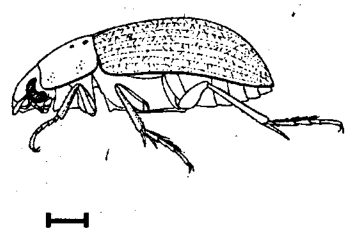


Elmidae larva

Adult Beetles of the Salmon River (Order: Coleoptera)



Elmidae adult

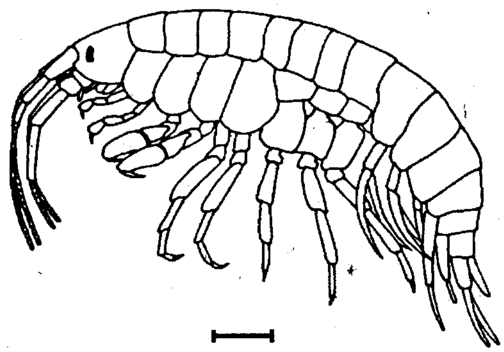


Adult Coleopteran

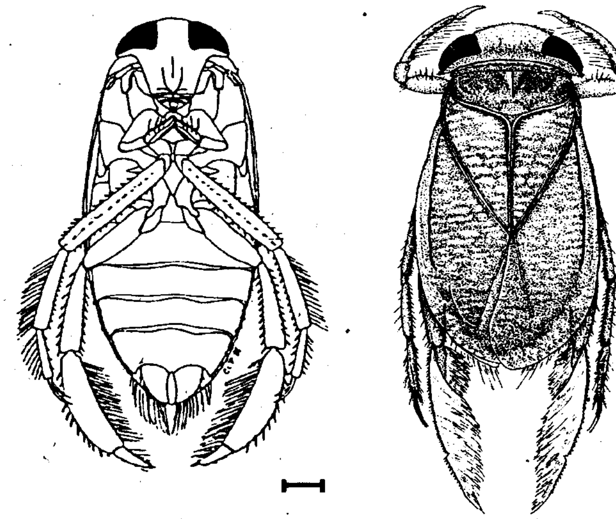
Bar indicates maximum size

Figures adapted from Ward, J.V. 1992.

Figure A.10. Other Invertebrates of the Salmon River



Amphipoda



Corixidae (Order: Hemiptera)

Characteristics

- more than 6 legs
- shrimp like appearance

Characteristics

- long swimming hairs on hind legs
- leathery wings covering abdomen
- mouth in shape of sucking beak

Bar indicates maximum size

Figures adapted from Clifford, H. F. 1991.

Appendix B:
Glossary

Algae:	• General name for single cell, aquatic plants. In streams these are usually attached to rocks.
Benthic:	• Living on or in the bottom environment of a water body.
Benthic Macroinvertebrates:	• Large invertebrates visible to the naked eye which live on or in the bottom of streams, rivers and lakes.
Biofilm:	• A term encompassing the entire organic layer on rocks and the stream bottom.
Channel:	• The section of the stream bed that contains the main flow.
Channelization:	• The straightening of a river or stream. Often, this involves the removal of riparian vegetation.
Chlorophyll:	• The general name for the green pigment (protein molecule) in plants which acts as a light receptor in photosynthesis. In stream ecology, chlorophyll-*a* is generally used as an indicator of total chlorophyll in algal tissue.
Cobble:	• Medium-size stones (64-256 mm diameter) (smaller than boulders, larger than pebbles) found on a stream bottom.
Community:	• The entire collection of organisms living within a defined area (e.g., microbes, plants, animals). Also known as an ecological community.
D-frame net:	• A metal frame in the shape of a "D" with a fine mesh net attached to a pole. It is used for sampling benthic environments.
Detritus:	• Loose organic material that is terrestrial or aquatic in origin, such as leaves, twigs, or dead aquatic plants found on the stream bottom.
Diatoms:	• A common name for algae having silica cell walls. Diatoms often are a major constituent in the algal biofilm of streams and rivers.
Discharge:	• The volume of water that flows past a point in a fixed period of time expressed as cubic metres per second (m^3/sec).

DO (dissolved oxygen):	• The amount of oxygen in water that is available for respiration by aquatic organisms.
Ecoregion:	• A geographic area that is defined by its similar ecological characteristics within the area.
Effluent:	• The liquid that is discharged from industrial, municipal, or agricultural processing into a river system.
Embeddedness:	• The degree to which rocks within the stream are surrounded or covered by fine sediments or sand.
Emergent plant:	• Plants that are associated with aquatic environments and that have roots underwater with leaves extending out of the water.
Ethyl alcohol:	• A colourless liquid used to store preserved aquatic samples.
Eutrophic:	• A body of water with high plant productivity resulting from high nutrient concentrations (usually nitrogen or phosphorus) often as a result from human activities.
Formaldehyde:	• A simple aldehyde that is a very effective preservative. However, it should be used with extreme caution by volunteers.
Formalin:	• An aqueous solution of formaldehyde, usually 37% formaldehyde by weight. 10% formalin is often used as a preservative for aquatic samples. It should be used with extreme caution by volunteers.
Headwaters:	• The foremost upstream source of a stream or river
Hypoxia:	• Severe oxygen deficiency in an aquatic environment usually causing mortality
Land use:	• Any human activities that have the potential to alter the landscape (e.g., farming, ranching, logging, etc.). Land uses that affect water quality are particularily important in aquatic monitoring.
Macroinvertebrate:	• Any animal that is large enough to be seen with the naked eye and lacking a backbone and internal skeleton.

Morphology:	• The structure and body form of an organism at any stage in its life history.
Nitrogen:	• A plant nutrient present in aquatic environments as ammonia (NH_3), nitrate (NO^-_3), or nitrite ($NO^-{}_2$). Not usually a limiting factor in plant growth.
Oligotrophic:	• Lakes or streams containing low nutrients and little or no apparent plant growth.
Outfall:	• The pipe through which industrial or municipal wastewater is discharged into a river or stream.
Periphyton:	• This usually refers to the mat of algae, bacteria, and fungi growing on stones of the stream bottom.
pH:	• A measure of hydrogen ion concentration (acidity) of a solution defined as $-\log_{10}[H^+]$. pH<7 is acidic, pH=7 is neutral, pH>7 is basic.
Phosphorus:	• A plant nutrient that often is the limiting factor for growth. Most common form is organic and inorganic phosphates (PO_4).
Photosynthesis:	• The reaction occurring in green plants that uses light energy to convert water and carbon dioxide to chemical energy with the release of oxygen.
Pigments:	• Any colouring matter in plants or animals.
Pools:	• Distinct habitats within the stream in which the velocity of the water is reduced and the depth of the water is greater than in most other areas of the stream.
Population:	• The entire group of interbreeding organisms belonging to a particular species occupying a specific geographic area.
QA/QC:	• An abbreviation for Quality Assurance / Quality Control. This refers generally to the steps taken to ensure reported data is consistent and reliable.
Riffle:	• An area of the stream in which the flow is faster and more turbulent, usually over a cobble bottom.

Riparian zone:	• Is the area of natural vegetation on, and extending out from the stream bank. The riparian zone is a buffer to pollutants entering a stream from runoff. It controls erosion by maintaining bank stability, and also provides some nutrient input into the stream (e.g., leaf-fall).
Runoff:	• Water that flows from land into streams and rivers.
Runs or glides:	• The sections of a stream with a relatively low velocity that flow gently with little or no turbulence at the water surface. These usually are located between riffles and pools.
Stream vegetation:	• Includes emergent, submergent, and floating plants in the stream.
Submergent plant:	• Aquatic plants that are rooted and grow entirely underwater.
Substrate:	• Material that makes up the streambed. These are materials such as clay, sediment, mud, cobbles or boulders.
Taxa (taxon):	• Usually refers to a specific level of classification within the scientific system of categorization (see taxonomy).
Taxonomy:	• The hierarchal system of classification of organisms that reflects their differences and similarities. The seven major categories are kingdom, phylum, class, order, family, genus, species.
Tolerance:	• The ability to endure the effects of particular conditions.
Tributaries:	• A stream or river that flows into a larger water body
Turbidity:	• A term that refers to the cloudiness, or murkiness of water.
Velocity:	• The rate that water flows past a point in a fixed period of time expressed as metres per second (m/sec).
Watershed:	• The drainage area or catchment of a stream.

Appendix C:
Suggested Reference Materials

Atlantic Coastal Action Plan. Volume I: Sharing the Challenge: A Guide for Community-Based Environmental Planning. Canada's Green Plan.

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