

Draft

Macroinvertebrate Study Report

**Energy Northwest
Packwood Lake Hydroelectric Project
FERC No. 2244
Lewis County, Washington**

Submitted to



**P.O. Box 968
Richland, Washington 99352-0968**

Submitted by



**1155 North State Street, Suite 700
Bellingham, Washington 98225
360.734.5915 phone, 360.734.5918 fax**

August 2006

TABLE OF CONTENTS

Section	Title	Page
1.0	INTRODUCTION	1
1.1	Study Goal and Objectives.....	2
2.0	STUDY AREA	3
3.0	METHODS	4
3.1	Metrics of Interest.....	4
3.2	Sampling Sites	5
3.3	Sampling Protocol for Shallow, Cobble-Riffle Habitat.....	7
3.4	Rare, ROD, Sensitive, and Species of Concern	7
3.5	Quality Control/Quality Assurance.....	9
3.6	Laboratory Protocols.....	9
3.6.1	<i>Taxonomic Resolution</i>	9
3.7	Data Analysis.....	10
3.7.1	<i>Individual Parameters</i>	10
3.7.2	<i>Taxonomic and Ecological Attributes</i>	10
4.0	RESULTS	12
4.1	Sample Site Characterization.....	12
4.2	Replicate Sample Results.....	15
4.2.1	<i>Duplicate Samples</i>	15
4.2.2	<i>Sorting Efficiency</i>	17
4.3	Macroinvertebrate Sampling Results Summary	17
4.3.1	<i>Total Invertebrate Abundance</i>	20
4.3.2	<i>Total Taxa Richness</i>	21
4.3.3	<i>EPT Taxa Richness</i>	22
4.3.4	<i>Percent Dominant (3 Taxa)</i>	23
4.3.5	<i>Major Invertebrate Groups</i>	24
4.3.6	<i>Feeding Groups</i>	27
4.3.7	<i>Tolerant Taxa</i>	32
4.3.8	<i>Intolerant Taxa</i>	33
4.3.9	<i>Semi-Voltine Species</i>	34
4.4	Rare, ROD, Sensitive, and Species of Concern	35
5.0	DISCUSSION.....	35
6.0	LITERATURE CITED.....	39

APPENDICES

Appendix A – Taxa List

Appendix B – Invertebrate Groups – Percent Contribution

LIST OF FIGURES

Figure	Title	Page
Figure 1-1.	Energy Northwest’s Packwood Lake Hydroelectric Project Located near Packwood, Washington (source Energy Northwest 2004).....	1
Figure 2-1.	Packwood Lake Hydroelectric Project Macroinvertebrate Study Reaches.....	3
Figure 3-1.	Packwood Lake Hydroelectric Project Macroinvertebrate Study Sample Sites.	6
Figure 4-1.	Invertebrate Abundance (Density) in October 2005 at 14 Sample Sites on Lake Creek	20
Figure 4-2.	Total Taxa Richness in October 2005 at 14 Sample Sites on Lake Creek.....	21
Figure 4-3.	EPT Taxa Richness in October 2005 at 14 Sample Sites on Lake Creek	23
Figure 4-4.	Percent Dominant (3 Taxa) in October 2005 at 14 Sample Sites on Lake Creek	24
Figure 4-5.	Major Invertebrate Group Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek.....	26
Figure 4-6.	Major Feeding Group Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek.....	27
Figure 4-7.	Shredder Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	28
Figure 4-8.	Collector-Filterer Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	29
Figure 4-9.	Collector-Gatherer Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	30
Figure 4-10.	Predator Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	31
Figure 4-11.	Scraper Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	32
Figure 4-12.	Tolerant Taxa Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	33
Figure 4-13.	Intolerant Taxa Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	34
Figure 4-14.	Semi-Voltine Species Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek	35

LIST OF TABLES

Table	Title	Page
Table 4-1.	General Characteristics of the Packwood Lake Hydroelectric Project Macroinvertebrate Sample Sites Located Along Lake Creek, Washington.....	14
Table 4-2.	Results from Duplicate Samples at Site 1-L Collected in October 2005	16
Table 4-3.	Benthic Macroinvertebrate Results Summary	19

1.0 INTRODUCTION

The Packwood Lake Hydroelectric Project (Project), licensed by the Federal Energy Regulatory Commission (FERC), is located east of the community of Packwood in the Cascade Mountains (Figure 1-1). Packwood Lake lies within the Gifford Pinchot National Forest. The Project includes: an intake canal; a concrete drop structure and an intake building on Lake Creek located about 424 feet downstream from the outlet to Packwood Lake; a 21,691-foot system of concrete pipe and tunnels; a 5,621 foot-long penstock; a surge tank; a powerhouse with a 26,126 kW turbine generator; and a 6,690 foot-long lined tailrace channel. The powerhouse is located at the base of the mountain adjacent to the community of Packwood. The powerhouse discharges into a constructed stilling basin and then travels through a lined tailrace channel about 6,690 feet to the confluence with the Cowlitz River. The tailrace includes a 200-foot highway culvert and 360-foot flume over Hall Creek.

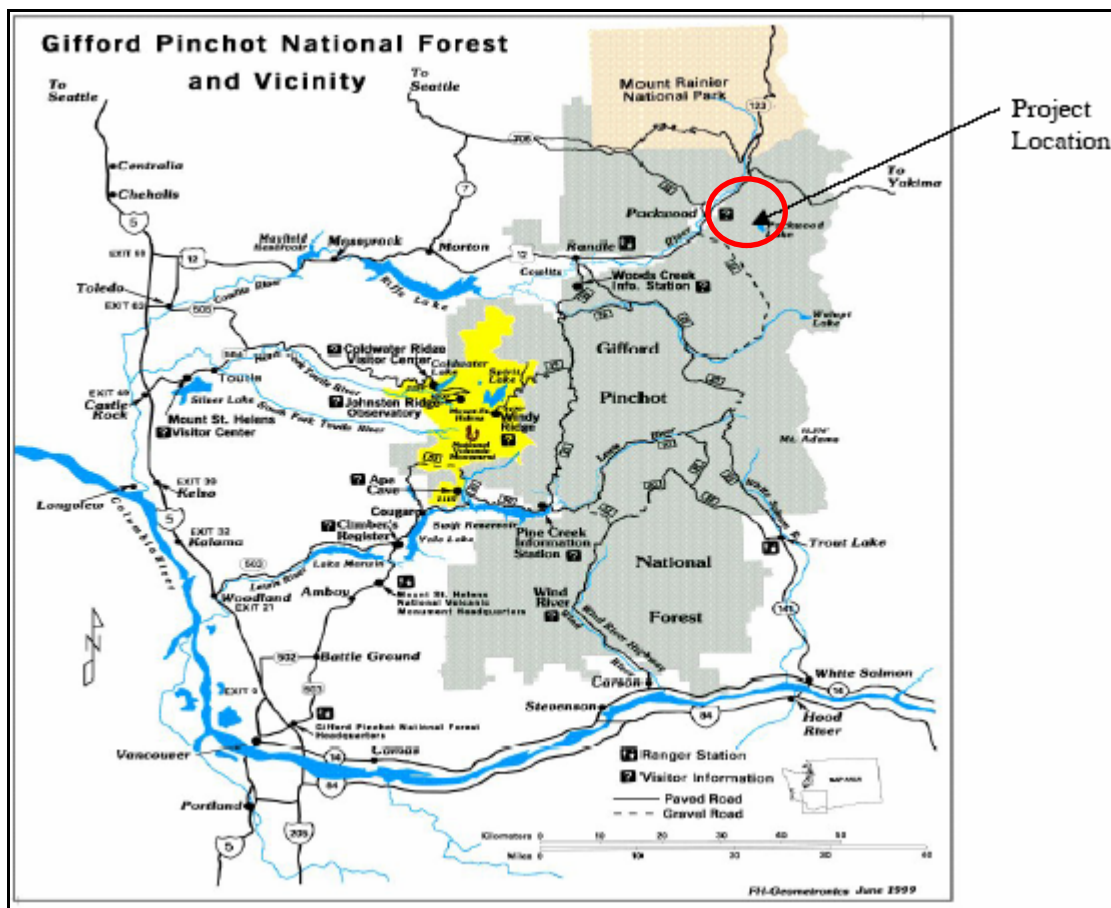


Figure 1-1. Energy Northwest's Packwood Lake Hydroelectric Project Located near Packwood, Washington (source Energy Northwest 2004)

The total area drained by Lake Creek and Packwood Lake is approximately 19.2 square miles at the drop structure. The total surface area of the lake is 452 acres. The natural lake elevation (El.) is 2,857 ft MSL, which is approximately 1,800 ft above the powerhouse. The Project seasonally regulates the lake level so that it is at El 2,857 ft \pm 0.5 ft in summer recreation months

and drawn down to no lower than El 2,849 ft MSL during winter months. This provides 8 feet of vertical storage usable by the Project. The Project is operated to achieve a lake elevation of 2,857 ft \pm 0.5 ft by May 1st of each year. This level is maintained until mid-September when draw down may begin. When lake level rises above the drop structure crest elevation (El. 2858.5 ft), the flow passes over the drop structure into Lake Creek. Currently, the FERC license for the Project requires a minimum instream flow of 3 cfs at the drop structure immediately downstream of the outlet of Packwood Lake. There is also an instream flow requirement of 15 cfs at the confluence of Lake Creek with the Cowlitz River. Energy Northwest is not currently required to measure streamflow in Lake Creek at its confluence with the Cowlitz River. The Project is operated in a baseload manner depending upon water availability and power contracts. The Project has a water right for 260 cfs, but the Project does not operate at capacity at all times. Average power production is 10 MW relative to a turbine generator rated at 27,500 kVA (26.5 MW). During the summer months, Project generation flow matches lake inflow to hold the lake elevation relatively constant. During dry periods with low inflows, the Project may be shut down. Instream flow releases to Lake Creek continue regardless of Project operation.

1.1 Study Goal and Objectives

The goal of this study is to provide sufficient information to support the application for 401 water quality certification by the Washington Department of Ecology (Ecology), pursuant to Section 401 of the Clean Water Act, for operation of the Project under a new FERC license. Specific water quality criteria relevant to benthic invertebrates and subject to 401 reviews include maintaining the biological integrity of the aquatic ecosystem affected by the Project. The objectives focus on Project waters, with emphasis on Lake Creek. The study area; however, includes waters upstream of the Project in order to provide a characterization of watershed level trends in benthic communities. Longitudinal trends form the basis for identifying Project related responses of the benthic invertebrate community. Deviations in basin level community trends that spatially coincide with Project altered hydrology, sediment transport, altered temperature regimes, or nutrient transport suggest a cause and effect relationship.

The objectives for this study are:

1. Characterize the relative abundance, composition and distribution of aquatic macroinvertebrates within the Lake Creek bypass reach.
2. Evaluate the Project impact to aquatic macroinvertebrate communities within the Lake Creek bypass reach.
3. Characterize the aquatic macroinvertebrate community where the tailrace waters are discharged into a side channel of the Cowlitz River

2.0 STUDY AREA

The study area includes Lake Creek from its confluence with the Cowlitz River to approximately one half mile upstream of Packwood Lake (Figure 2-1). Benthic invertebrate sample sites were established in the bypass reach below Packwood Lake. Sample sites were located within each of the five reaches of lower Lake Creek, characterized by the already completed habitat survey (EES Consulting, 2005). Reaches 1, 2, 3, and 4 each had two sample sites, and Reach 5 had three sample sites for a total of eleven sample sites below Packwood Lake. Three additional comparison sample sites were established in Upper Lake Creek above Packwood Lake. Thus, a total of 14 sample sites were established along Lake Creek above and below the lake in a total of six (6) study reaches.

A reconnaissance assessment of the side channel of the Cowlitz River that the Project tailrace flows into was also in the study area. The side flow in the side channel was insufficient to collect macroinvertebrate samples using the methods employed in this study at the time of the October survey when the Project was shut down. The highly mobile substrate and variable flow in the side channel makes it poor macroinvertebrate habitat based on best professional judgement. Sampling would not likely provide substantive findings as any macroinvertebrates would be opportunistic species inhabiting the area for short durations.

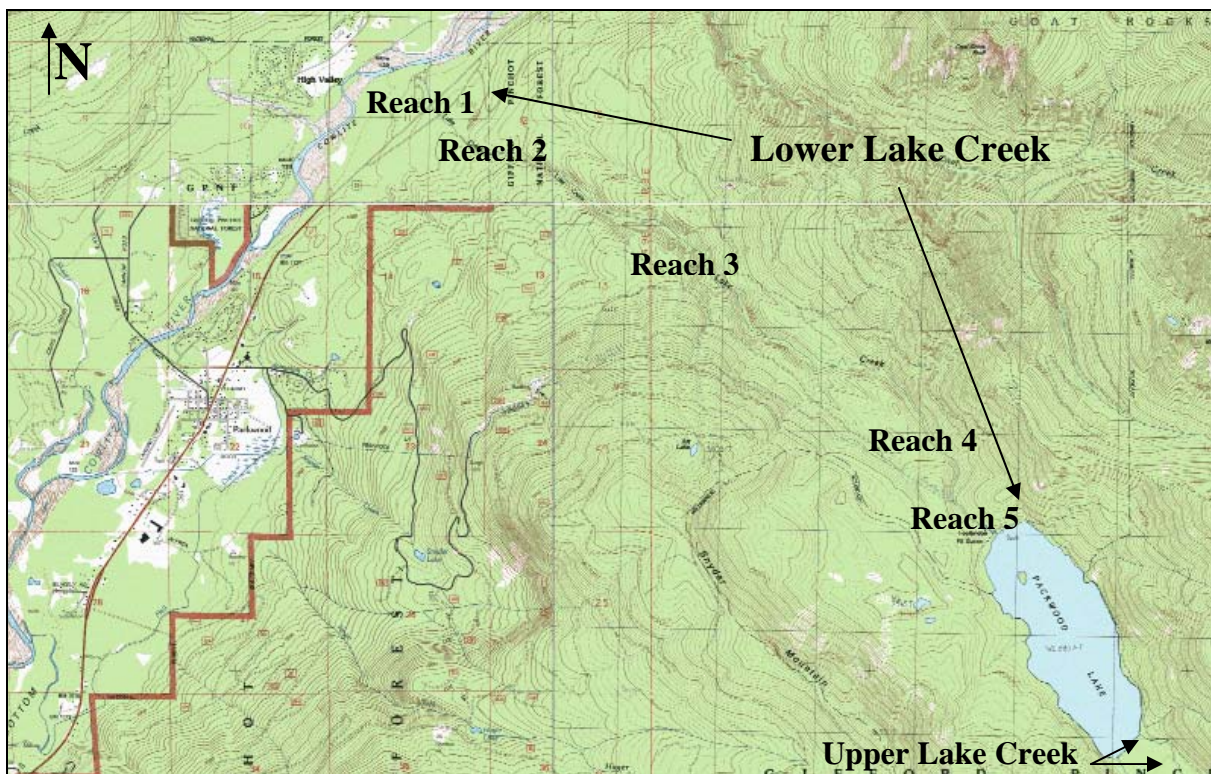


Figure 2-1. Packwood Lake Hydroelectric Project Macroinvertebrate Study Reaches

3.0 METHODS

Fall benthic samples from Lake Creek were collected using the Ecology protocol (Ecology 2001). This protocol uses a D-frame net or Surber sampler with a 500 micron mesh net. A device fastened to the base of the D-frame encloses an area approximately 30 cm (1 ft) by 61 cm (2 ft) in front of the sampler. This defines the 0.19 m² (2 ft²) sample area at each point. Macroinvertebrate samples are collected from 4 points in riffle habitats for each composite sample site. The total area sampled for a sample is 0.75 m² (8 ft²).

At each of the fourteen Lake Creek profile sample sites, an additional qualitative sample was collected. A D-frame net was used to sample non-riffle habitats (stream margin, pools, pockets, debris jams, etc.). This sample type was used primarily to assess for the presence RTE aquatic invertebrate species.

A primary focus of the macroinvertebrate study was to obtain a detailed assessment of changes in benthic invertebrate abundance, species composition and community structure along a longitudinal and altitudinal profile from headwater tributaries of the Lake Creek basin above all hydroelectric power development, downstream through Project affected waters.

October was chosen for the primary seasonal index period for sampling. Sampling occurred when the autumn base flow in Lake Creek was low. The analysis reports on longitudinal basin trends in the distribution, relative abundance and composition of benthic communities.

Alterations and impacts to benthic macroinvertebrate community structure in Lake Creek due to the Project were evaluated by plotting the response curve of selected community metrics along the longitudinal profile of Lake Creek. Metrics selected are generally responsive to declines in water and habitat quality.

3.1 Metrics of Interest

A total of nine metrics were sampled at each sample site:

1. Total invertebrate abundance (number of organisms per square meter of riffle substrate);
2. Total invertebrate taxa richness (number of distinct taxa identified);
3. EPT taxa richness (the number of taxa identified in the insect orders Ephemeroptera, Plecoptera, and Trichoptera). EPT taxa are typically dominant taxa in Pacific Northwest montane streams and are some of the most sensitive to human disturbance;
4. Percent Dominant (3 Taxa);
5. Major invertebrate groups abundance (number of organisms per square meter of riffle substrate) and percent contribution;
6. Feeding group composition;
7. Warm-water biota or tolerant taxa richness and percent contribution;
8. Cold-water biota or intolerant taxa richness and percent contribution; and,
9. Long-lived (semi-voltine) invertebrate taxa richness and percent contribution.

Abundance values were converted into percent composition metrics when doing so improved diagnostic and analytical capabilities. All procedures used for the purpose of collecting, preserving, and analyzing samples follow established protocol (Ecology 2001).

3.2 Sampling Sites

Site selection is designed to evaluate change in macroinvertebrate characteristics along the Lake Creek longitudinal profile, and the potential influence of project operations at Packwood Lake on Lake Creek macroinvertebrate populations. The sampling design is structured to evaluate the effects of Project operations and structures on macroinvertebrates.

The following considerations guided the selection of sampling stations and stratification of habitat types to be sampled:

- Data from riffle habitats have become the common currency for benthic invertebrate bio-monitoring studies throughout montane regions of North America.
- An analysis of longitudinal trends within the Lake Creek system demands that comparisons be made between similar habitat types.
- It is also desirable that the Lake Creek data be comparable with data collected from other riverine systems in western North America.
- Study objectives highlight potential impacts of flow regulation and other Project operations on macroinvertebrate habitats.
- Sampling protocols needed to be practical, cost effective, and replicable.
- Safety of field personnel was a consideration.

Although erosional habitat types (riffles, cascades and glides) are common in the mid- and upper reaches of lower Lake Creek, this is not necessarily the case as the creek approaches the Cowlitz River. Depositional habitats and slow glides become more dominant in the lower reaches. The experimental design of this study emphasizes comparability of samples along the entire longitudinal profile of Lake Creek by sampling only certain types of erosional habitats at each station.

An early fall seasonal index period was selected for several reasons. The benthic invertebrate community is believed to be more predictable at this time of year than in spring or summer for between station and year comparisons. Impacts to the benthic communities should be more discernable at the tail end of the lowest flow and highest temperature period of the year (late summer-early fall). The fall window allows the overlap of the summer and winter benthic communities to be viewed; the most tolerant and intolerant organisms that are present in the system can be sampled at this time. The period of lowest flow is also the most practical time to sample erosional habitats.

Figure 3-1 illustrates the location of sample sites.

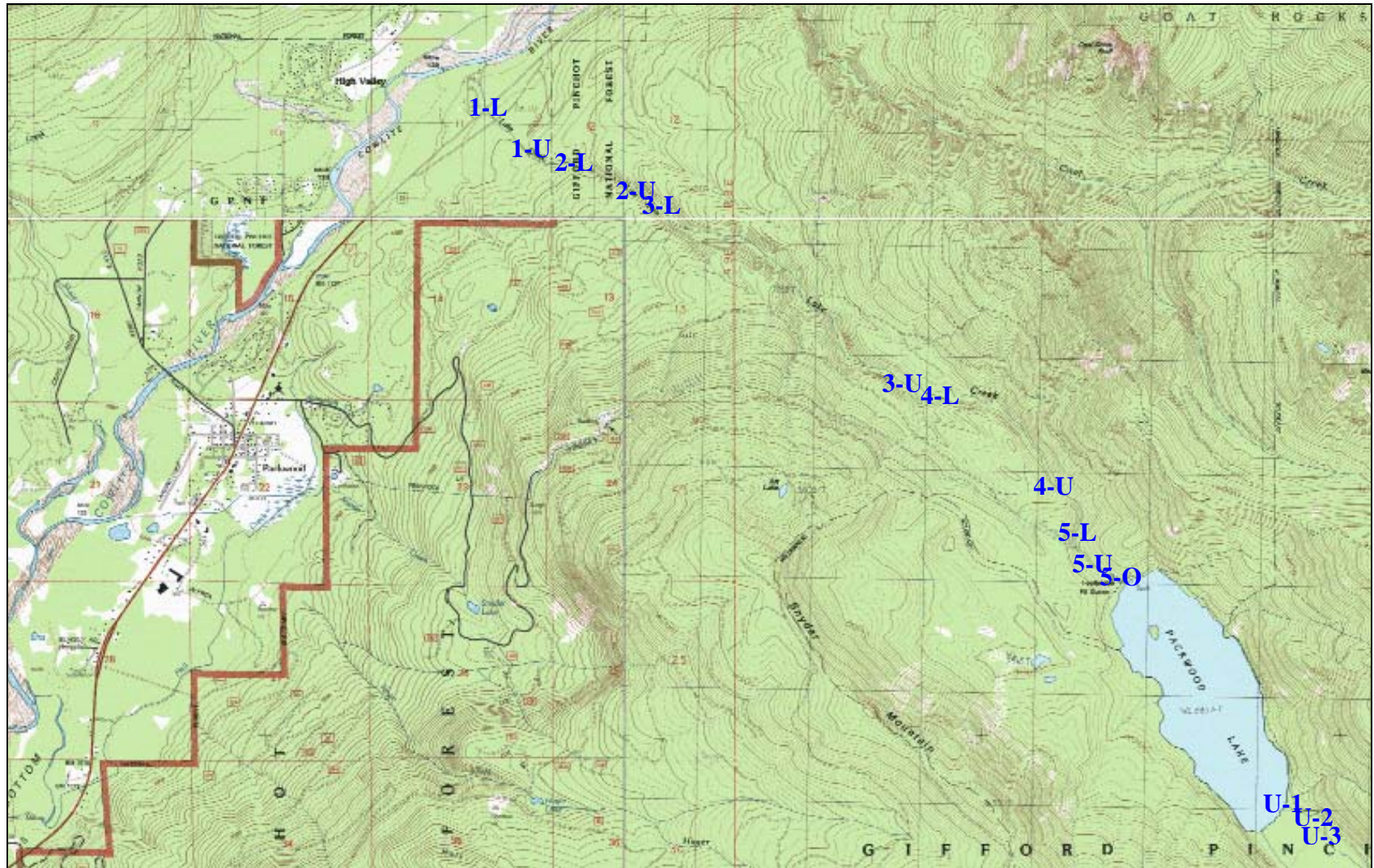


Figure 3-1. Packwood Lake Hydroelectric Project Macroinvertebrate Study Sample Sites.

3.3 Sampling Protocol for Shallow, Cobble-Riffle Habitat

Benthic community sampling in shallow, cobble-riffle habitat focused on water depths of 5-30 centimeters. Shallow depth and moderate water velocity in this zone allows field personnel to kneel in the creek and employ a quantitative sampling protocol. This protocol uses a D-frame net or Surber sampler (500 micron mesh) to collect macroinvertebrates from 4-8 points in riffle habitats for each composite sample. The total sample area was 0.75 m^2 (8 ft^2) for each composite sample.

At each of the four points within a riffle, the D-frame net is firmly planted on the creek bottom with the net opening facing upstream. The operator kneels behind the net; the operator's lower legs create wing dams on either side of the net opening. This position ensures most of the material dislodged from in front of the net is carried into the bag. Armor layer cobbles from a 0.19 m^2 (2 ft^2) rectangular area in front of the net are then lifted from the creek bed, placed in front of the net opening, and scrubbed thoroughly of all attached invertebrates and biofilm with short-handled, stiff nylon brush. Scrubbed cobbles are then tossed aside.

After the armor layer cobbles in the 0.19 m^2 (2 ft^2) quadrat above the net are removed and scrubbed, the operator uses his/her hands and the handle of the brush to thoroughly stir the finer sediment beneath the armor layer to a depth of 2-4 inches. Once the current has carried the last of the dislodged debris and invertebrates into the net, it is removed from the creek bottom. The net contents are washed into the bottom of the net. Sampling continues at additional points in the study riffle in an upstream direction until a total of four, 0.19 m^2 (2 ft^2) quadrats have been sampled. Unless the net begins to clog, the invertebrates and debris dislodged from each quadrat are kept in the net until all four points have been acquired for a total area sampled of 0.75 m^2 (8 ft^2).

The net containing the sample from all four quadrats is then emptied into a tub of clean creek water. Large rocks and organic debris are washed and discarded before concentrating the sample on a 500 micron sieve, transferring to the sieve contents to a sample bottle, and preserving the sample in a final concentration of 80-90% alcohol.

3.4 Rare, ROD, Sensitive, and Species of Concern

Surveys for the presence/absence of listed aquatic invertebrate taxa during macroinvertebrate studies were limited to Project affected waters in the Lake Creek drainage. Terminology describing listed aquatic invertebrate taxa is confusing because different federal agencies and private organizations use different terms, categories and definitions.

- **Endangered** (listed, proposed for listing, or candidate for listing) are species listed by the U.S. Fish and Wildlife Service or National Marine Fisheries Service under the Endangered Species Act as being in danger of becoming extinct within the foreseeable future. Based on professional judgment after site reviewing the Project waters and published information, no aquatic invertebrate taxa likely to occur in the Lake Creek basin are currently considered to be Endangered.

- **Threatened** (listed, proposed for listing, or candidate for listing) are species listed by the U.S. Fish and Wildlife Service or National Marine Fisheries Service under the Endangered Species Act as likely to become endangered within the foreseeable future. No aquatic invertebrate taxa likely to occur in the Lake Creek basin are currently considered to be Threatened.
- **Species of Concern** are species designated by the U.S. Fish and Wildlife Service or National Marine Fisheries Service for which additional information is needed to support a proposal for listing them as Threatened or Endangered under the Endangered Species Act. There are no required management plans attached to this designation by the Endangered Species Act. Agencies are encouraged to acquire additional information on the viability of the species through surveys.
- **Sensitive** is a term used by the USDA Forest Service and U.S. Bureau of Land Management that appears to be equivalent to the Species of Concern designation. Surveys for these taxa on federal lands are encouraged, but in application has not been mandatory. Theoretically, survey information would be incorporated into environmental assessments of proposed management activities on federal lands (e.g. timber harvest, roading, grazing plans, etc.). There are no sensitive aquatic invertebrate species (caddisflies, Order Trichoptera) that are likely to occur in the Lake Creek basin.
- **ROD (Record of Decision), Survey and Manage** taxa (ROD 1994) is an additional layer of listing that applies to federal lands within the range of the northern spotted owl. ROD taxa listed in the 1994 President's plan specifically require federal agencies to survey for these species on lands and waters within their jurisdiction that may potentially harbor populations prior to any significant management activities. There are no ROD species that are known to or likely to occur in the Lake Creek basin.
- **Rare** refers here to species that are not currently on any state, federal or private organization lists, but are thought to be rare by the specialists involved with the macroinvertebrate studies. These rare taxa are not expected to occur in the Lake Creek basin.
- **Watch List** refers to species that the U.S. Fish and Wildlife Service are interested in acquiring more information on because anecdotal information suggests their populations may be in decline. The freshwater mussel, *Anodonta californiensis* (Mollusca, Unionidae) is on the watch list for western North America, but is not expected to occur in the Lake Creek drainage due to lack of suitable habitat.

In addition to the above terms and categories, the State of Washington maintains its own lists, categories and terminology. The State of Washington maintains a list of state Threatened, Endangered and Species of Concern (WDFW 2006). Washington State also maintains a Washington State Monitor List, identifying additional species not yet listed as Threatened, Endangered or Species of Concern but warranting attention. These lists were reviewed prior to any field sampling.

Macroinvertebrate surveys for the ROD, Species of Concern and Sensitive aquatic invertebrate taxa included the following tasks.

- Presence/absence was documented by the analysis of the October 2005 benthic bio-monitoring samples collected along the longitudinal profile of Lake Creek. No ROD species of concerns were found. The type of benthic invertebrate sampling was not specifically designed to survey for Species of Concern and ROD taxa. The survey does; however, represent a relatively intensive survey of Project-affected waters for this purpose. Stations were located along the entire longitudinal profile of Lake Creek from its confluence with the Cowlitz River to points above the Project.
- A site review of the tailrace documented that the habitat in the tailrace and tailrace side channel is not suitable for any of the sensitive species of concern.
- Presence/absence of genera containing Species of Concern in all historical benthic invertebrate bio-monitoring data sets incorporated into this study was evaluated.
- Records of all adult caddisfly Species of Concern that potentially occur in the Lake Creek basin were reviewed (Wisseman, 1996b. Unpublished records).

3.5 Quality Control/Quality Assurance

Duplicate samples were collected in October 2005 for all sample types at 5% of the stations to test the repeatability of the sampling protocols. Duplicate samples were processed independently to test the variability of the sampling and analysis process. Sorting efficacy is determined by a second sorting technician after the first technician is finished. The check is performed routinely at the laboratory for 10% of the sample “remainders”.

3.6 Laboratory Protocols

Sub-sampling of the composite samples is accomplished using a Caton Tray. For composite samples with greater than 500 organisms, a minimum of 500 organisms is sorted from each sample using dissecting scopes. Once the 500-organism target count is achieved, a large/rare organism search is conducted on the remainder of the unsorted sample.

3.6.1 Taxonomic Resolution

The level of taxonomic resolution used for the Project samples and data analysis was in general accordance with the **Level 3** effort suggested by the Northwest Biological Assessment Working Group (NBAWG 2002) for use in benthic bio-monitoring studies in western North America. Most insect taxa were identified to the genus or species level, including the chironomid midges. Non-insect taxa were taken to a variable level of taxonomic resolution. A complete list of all aquatic invertebrate taxa encountered during the macroinvertebrate studies is provided in Appendix B, along with the level of taxonomic resolution achieved.

Taxonomic resolution in the Lake Creek macroinvertebrate studies met or exceeded the Level 3 standards in some invertebrate groups. A finer level of taxonomic resolution is conducted on some invertebrate groups when an increase in diagnostic capabilities may result.

A complete synoptic collection of all aquatic invertebrate taxa collected and identified from the Lake Creek basin during the macroinvertebrate studies will be maintained for QA/QC verification of taxonomic efficacy.

3.7 Data Analysis

The goal of this study is to extract relevant ecological information from the benthic invertebrate sampling program outlined above and relate it to patterns of Project induced changes in the Lake Creek watershed. River continuum theory predicts that energy flow and benthic invertebrate community structure will shift in a gradual fashion along a gradient of increasing stream size (and decreasing elevation) in a watershed (Vannote et al. 1980). Structural response may occur either in a relatively linear or non-linear fashion.

Comparative data derived from reference conditions in space or time are not available; e.g. baseline data on the Lake Creek system before Project development, or data from near-by, similar and minimally disturbed watersheds not subject to Project development. Therefore, it will remain unknown how Project operations specifically affect benthic invertebrate community structure along the longitudinal profile of Lake Creek. Probable impacts to biotic integrity from the Project can be tentatively inferred for localized creek reaches from evaluating departures in metric values or index scores from the general trend of the longitudinal profile. In actuality, the longitudinal profile also is likely to exhibit inherent variability.

Various approaches to analyzing the impacts of hydroelectric development to benthic invertebrate communities have been used elsewhere.

3.7.1 Individual Parameters

Presenting and discussing differences in individual community parameters above and below hydro-development has been the typical approach (Armitage 1984, Brusven 1984, Zimmermann & Ward 1984). Individual parameters may involve a focus on particular taxa, or ecological traits derived from community level analysis, e.g. functional feeding groups, tolerant/intolerant taxa, or other grouping.

3.7.2 Taxonomic and Ecological Attributes

Multimetric aquatic macroinvertebrate indices in western North America were developed following actions of the U.S. Environmental Protection Agency (Plafkin et al. 1989). Analysis of benthic community structure and the computation of metrics describing biological attributes of a community have largely relied on a standard taxonomic effort for the identification of benthic invertebrates. Ecological attributes (e.g. tolerance and functional feeding groups) attached to taxa, were developed by Aquatic Biology Associates, Inc., Corvallis, Oregon in the early 1990's and summarized by Wisseman (1996).

Functional Feeding Groups (Merritt & Cummins 1996)

- The updated coding system allows the functional feeding group designation for each taxon to be partitioned between several groups when appropriate. Functional feeding group designations were made for all Lake Creek samples.
- The % contribution and number of taxa in each functional feeding group for each sample were calculated.

Tolerance Attributes

The Community Tolerance Index CTI is a revision of the Modified Hilsenhoff Biotic Index (MHBI) widely used in multimetric benthic indices of biological integrity to assess human impacts (Barbour et al. 1995 & 1999, Hilsenhoff 1987). Tolerance values were assigned to all taxa occurring in the Lake Creek basin (Appendix B). The index assigns a tolerance value to each taxon, which is scaled from 0 (highly intolerant) to 10 (highly tolerant). The equation for the index is derived from Chutter's (1972) index:

$$CTI = \frac{\text{Sum } TV_i N_i}{\text{Total } N}$$

Where TV_i is the tolerance value assigned to the i th taxa, N_i is the total abundance of the i th taxa in the sample, and Total N is the total number of individuals in a sample. It is basically an average tolerance value for the benthic invertebrate community represented in a sample. The following steps describe this analytical process.

- Creating the Community Tolerance Index (CTI).
- Assign CTI tolerance values to all taxa encountered in the Lake Creek drainage (scaling is 0-10).
- Assign taxa to the following tolerance categories based on known biology and CTI tolerance value: highly intolerant (CTI 0-1), intolerant (2-3), intermediate (4-6), tolerant (7-8), and highly tolerant (9-10).
- Calculate the number of taxa and %contribution in the tolerant (CTI 0-3) and intolerant categories (7-10) for each sample.

Length of Life Cycle (Voltinism) Analysis

- Assign each taxon to one of ten class intervals that describes the length of the life cycle, from 1 (>10 generations per year) to 10 (>10 year life cycle).
- Calculate the % contribution and number of taxa in each sample that are multi-voltine 1-4 (2 or more generations per year), uni-voltine 5 (1 generation per year), and semi-voltine 6-10 (> 1 year per generation).

4.0 RESULTS

4.1 Sample Site Characterization

Samples were collected from shallow, riffle habitat at all sites with water depth between 5 and 30 cm. No sites associated with the tailrace side channel had flowing water of sufficient depth to sample. This section of the Cowlitz River is prone to shift, and was dry when sampling occurred in October 2005. Habitat in the side channel was not suitable for sampling and is not favorable to stable macroinvertebrate populations. All sites on Lake Creek had suitable depths for macroinvertebrate sampling.

Sampling in Upper and lower Lake Creek occurred between October 10 and October 12, 2005. Upper and lower Lake Creek are mid-order streams in the western Cascade ecoregion (see Ecology 2001). Upper Lake Creek is a glacial fed stream with a seasonally high suspended sediment load. Packwood Lake acts as a natural settling basin. Flow in lower Lake Creek downstream of Packwood Lake is dominated by groundwater accretion and precipitation runoff, except at flood flows when the drop structure is overtopped.

The 14 sample sites were stratified along the longitudinal profile of the Lake Creek drainage, with elevations ranging from 1150 ft to 2875 ft above mean sea level (AMSL). Maximum depth at base flow at the 14 sites varied between 0.1 m at the confluence of Upper Lake Creek and Packwood Lake to a maximum baseflow depth of approximately 1.0 m in the canyon section of lower Lake Creek. Upper Lake Creek showed signs of being entrenched throughout the reach sampled. Lower Lake Creek also showed signs of being entrenched, but only in Reach 1, the lowermost sampled.

Gradient was variable in the Lake Creek drainage. Gradient was low to medium in Upper Lake Creek. Lake Creek at the Packwood Lake outlet is initially medium gradient (Reach 5) that increases to medium-high through the canyon section to Reach 2. Reach 1 gradually reduces from the medium-high level in Reach 2 to a medium gradient as it approaches the confluence with the Cowlitz River. Macroinvertebrate study field notes indicated that Reaches 1, 4, 5, the Upper Lake Creek reach and site 2-L have a large percentage of run/riffle habitat types. Sites 2-U, 3-L, and 3-U were described in field notes as highly complex habitats, largely made up of complex step-pool, pocket water and chutes. These findings are generally consistent with more intensive habitat surveys of Lake Creek (EESC 2005).

Upper Lake Creek and lower Lake Creek exhibited very different substrate types. Upper Lake Creek was primarily sand, silt and gravel. Lower Lake Creek was variable along its longitudinal profile, but exhibited a high percentage of cobble and boulder substrate types.

Upper and lower Lake Creek also exhibited very different channel types. Upper Lake Creek was found to have low habitat complexity, high annual disturbance, very high seasonal disturbance, and very low stream bank stability. In contrast, lower Lake Creek had variable habitat complexity (low to high depending on reach), low to medium annual disturbance, low to medium seasonal disturbance, and high to very high stream bank stability (Table 4-1).

Differences in channel types and hydrology suggest that Upper Lake Creek may not serve as a very useful reference reach. Therefore, populations need to be considered on a reach by reach basis rather than comparing the upstream reach to the diversion reach.

Table 4-1. General Characteristics of the Packwood Lake Hydroelectric Project Macroinvertebrate Sample Sites Located Along Lake Creek, Washington

Reach	Lower Lake Creek Regulated downstream of Packwood Lake										Packwood Lake	Upper Lake Creek Unregulated		
	1		2		3		4		5			Upper Lake Creek		
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper		Lower	Middle	Upper
Site Location in Reach	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U		U-1	U-2	U-3
Site Name														
Direction of Flow	←													
General Site Characteristics														
Elevation (feet)	1150	1200	1250	1450	1500	2300	2400	2600	2700	2825	2856	2856	2865	2875
River Mile	0.1	0.7	0.8	1.3	1.4	3.4	3.7	4.7	5.0	5.2	n.a.	0.0	0.3	0.6
Maximum depth (m)	0.4	0.8	0.6	1.0	1.0	1.0	1.0	0.5	0.5	0.4	n.a.	0.1	0.5	1.0
Entrenchment (m)	2.0	2.0-3.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	1.0-2.0	1.0
Gradient	M	M-H	M-H	M-H	M-H	M-H	M-H	M	M	M	n.a.	L-M	L-M	M
Habitat Composition														
% Cascade/Chute	5	10	20	*	*	*	20	5	5	30	n.a.			
% Run/Riffle	90	60	60	*	*	*	40	75	60	35	n.a.	80	80	80
% Pool	5	30	20	*	*	*	40	20	30	35	n.a.	20	20	20
% Other									5		n.a.			
Substrate Composition														
% Silt/Sand		n.a.									n.a.	40	40	40
% Gravel	25	n.a.	30	20	25	25	25	30	30	15	n.a.	50	50	50
% Cobble	25	n.a.	30	20	25	25	25	35	35	20	n.a.	10	10	10
% Boulder	50	n.a.	40	60	50	50	50	35	35	65	n.a.			
Habitat Complexity	L-M	M	M	H	H	H	M-H	L	M	M	n.a.	L	L	L
Annual Disturbance	L	M	L	L	L-M	L	L	L-M	L	L	n.a.	H	H	H
Seasonal Disturbance	M	M	L	L-M	M	M	L-M	M	M	L-M	n.a.	VH	VH	VH
Streambank Stability	H	H	H	H-VH	VH	H	H	H	H	VH	n.a.	VL	VL	VL

*Macrohabitat composition was not recorded during the October 2005 macroinvertebrate study at Sites 2-U, 3-L and 3-U. Rather these sites were identified as having high habitat complexity with a combination of steps, pockets, pools and chutes.

VH = Very High, M = Moderate, L = Low, VL = Very Low

4.2 Replicate Sample Results

4.2.1 Duplicate Samples

Duplicate samples were collected in October 2005 at site 1-L to test the repeatability of the sampling protocols. Duplicate samples collected at site 1-L were similar in overall estimated abundance and percent contribution of warm water (tolerant) and cold water (intolerant) biota. Other metrics were not as comparable as was expected, as discussed below.

Major invertebrate group abundance and percent contribution were different between the two samples. Ephemeroptera (mayflies) and Tricoptera (caddisflies) were the first and second most abundant major invertebrate groups in both samples. The third most abundant major invertebrate group in sample 1 at site 1-L was the Plecoptera (stonefly), whereas Diptera (true flies) was found to be the third most abundant major invertebrate group in the duplicate sample.

Duplicate samples at site 1-L were found to have different feeding group percent contribution. Sample 1 had gatherer, filterer, and scraper feeding groups as the first, second, and third highest percent contribution in the sample, respectively. The duplicate sample, had gatherer, scraper, and filterer feeding groups as the first, second, and third highest percent contribution in the sample, respectively.

Long-lived (semivoltine) taxa abundance and percent contribution was different between the two samples. The first sample at site 1-L an estimated semivoltine abundance to be 29 organisms/m² per meter squared, which represents a percent contribution of 6.5%. The duplicate sample had an estimated abundance of 6 organisms per meter squared and a percent contribution of 1.5%. A similar number of semivoltine taxa were identified. Sample 1 had 5 semivoltine taxa. The duplicate sample had 4 semivoltine taxa.

Table 4-2 illustrates results from the first and duplicate sample at site 1-L, as well as the composite values used to with all other sites sampled on Lake Creek.

Table 4-2. Results from Duplicate Samples at Site 1-L Collected in October 2005			
Metrics	Sample Site 1L		
	Sample 1	Sample 2	Composite
Invertebrate abundance (m2)	458	456	457
Total taxa richness	51	34	43
EPT taxa richness	32	22	27
% Dominant (3 taxa)	43.4	62.7	53.0
Major invertebrate groups: abundance/m²			
Non insects	26	7	17
Odonata- dragonflies	0	0	0
Ephemeroptera- mayflies	140	217	179
Plecoptera- stoneflies	72	16	44
Trichoptera- caddisflies	112	153	133
Coleoptera- beetles	38	18	28
Misc. Diptera- true flies	24	28	26
Diptera: Chironomidae- midges	46	18	32
Major invertebrate groups- percent contribution			
Non insects	5.6	1.5	3.5
Odonata- dragonflies	0	0	0.0
Ephemeroptera- mayflies	30.7	47.6	39.2
Plecoptera- stoneflies	15.6	3.6	9.6
Trichoptera- caddisflies	24.5	33.4	29.0
Coleoptera- beetles	8.3	3.9	6.1
Misc. Diptera- true flies	5.3	6.2	5.8
Diptera: Chironomidae- midges	10	3.9	6.9
Feeding groups- percent contribution			
Predator	9.7	2.4	6.0
Gatherer	34.8	45.9	40.3
Filterer	16.5	13.9	15.2
Scraper	15.6	19.8	17.7
Shredder	15.0	2.4	8.7
Warm water biota (tolerant taxa)			
Abundance per square meter	0	0	0
Percent	0	0	0
Number of taxa	0	0	0
Cold water biota (intolerant taxa)			
Abundance per square meter	64	45	55
Percent	14.1	10.1	12.1
Number of taxa	11	10	14
Long-lived taxa (semivoltine, >1 year life cycle)			
Abundance per square meter	138	84	18
Percent	6.5	1.5	4.0
Number of taxa	5	4	6
<i>* Values represent cumulative rather than the average number of taxa for these metrics</i>			

Sorting Efficiency

Laboratory protocols identified 500 organisms as the target count for sample size. This minimum count was not achieved for a number of Lake Creek sample sites. As a result, it was unnecessary to sub-sample from composite samples for all sites except site 3-U. Sorting of the composite sample for site 3-U was completed using a $\frac{3}{4}$ sub-sample.

Sorting efficacy was determined by having a second sorting technician sort the same sample as the first technician. This check was performed at the laboratory for 10% of the samples. Sorting efficiency exceeded 95 % for all samples. This efficiency exceeds measurement quality objectives (MQO) of 10% total error for the identification and enumeration of extracted fauna (Strobel et al. 1995).

4.3 Macroinvertebrate Sampling Results Summary

A total of 116 benthic invertebrate taxa were identified from lotic habitats in the Lake Creek basin macroinvertebrate study (Tables A.1 through A.8, Appendix A). Results are based on a level 3 & 4 taxonomic effort, where the final level of identification varies from species to phylum, depending on the group.

Wiseman (1996) summarized ranges of invertebrate abundance, total taxa richness, EPT taxa richness, and % dominant (3 taxa) typical of mid-order, forested, montane, west-Cascade mountainous streams. The average macroinvertebrate abundance per Lake Creek sample site, 619 organisms, falls into the low range (500 – 1000). The average total taxa richness (37) was in the low range (30-40) of that expected for these types of streams. The average EPT taxa richness (23) is in the low range for streams similar to Lake Creek. The average percent dominant (3 taxa) index (55%) is in the fair range (50-74%) as described by Karr and Chu (1999).

Of the 116 taxa encountered in the basin, 64 taxa (approximately 55%) were rare or uncommon with no apparent trend or association with any of the sample sites or reaches. Although common elsewhere in the Pacific Northwest, it is not surprising that Hemiptera (true bugs) were not found and Odonata (dragonflies/damselflies) were not common in samples from the Lake Creek basin. Most Hemiptera and Odonata species are not stream-bottom dwelling species; they prefer lentic habitats. Hemipterans are typically found swimming in the water column (e.g. Corixidae, Notonectidae) or skating on the water surface (e.g. Gerridae) of stream pools and backwaters. Most Odonata also prefer lentic habitats or backwaters and pools in streams and rivers. Dragonflies of the genus *Cordulegaster*, however, have flattened bodies and long legs for sprawling on sandy and silty substrates in lotic habitats (Merritt and Cummins 1996).

Seven taxa (approximately 6%) were rare or absent downstream from Packwood Lake, but were more common in unstable or scoured substrates in Upper Lake Creek. Eight taxa (approximately 7%) tended to be restricted to areas above the lake. These species were predominantly in the “shredder” feeding group (see Section 4.2.6 for details). Shredders feed on leaf litter and other live and dead plant matter found along the stream bottom. One might expect to find more shredders in Upper Lake Creek above Packwood Lake where leaf litter is common as compared

with areas downstream of the lake. Vegetative matter tends to accumulate in the lake bottom rather than pass downstream.

Eleven taxa (approximately 9.5%) were restricted to or preferred Reach 5, which was influenced by lake-water outflow. These species tended to be those of the “filterer” feeding group (see section 4.2.6), and included a significant percentage of “tolerant” taxa (see Figure 4-12, Section 4.2.7). It is not unusual for lakes to have large numbers of filterer-type taxa and “tolerant” taxa immediately downstream from the lake outlet. Both natural and artificial lakes tend to elevate downstream water temperatures and pass suspended, fine particulate matter making this habitat most favorable to these feeding group and tolerant taxa types.

Four taxa (approximately 3.5%) were restricted to or in greatest abundance in sample site 3-U and somewhat in sample site 4-L. These taxa included members of the “intolerant” taxa (see Section 4.2.8) and semi-voltine (long-lived, Section 4.2.9) species. In addition, this section of Lake Creek was the only section with significant numbers of predator species (See Figure 4-10, Section 4.2.6), suggesting that this portion of Lake Creek provides complex habitat and supports a healthy biota.

Four taxa (approximately 3.5%) were restricted to the lowermost reaches of Lake Creek. Two of the four taxa, *Skwala* and *Arctopsyche grandis* were most abundant at Site 1-L, the lowest site sampled in the drainage. It is not surprising that these were found in greatest numbers at low elevations. *Skwala* and *Arctopsyche grandis* tend to favor larger rivers and streams; these species are likely to be found in large numbers in large stream like the Cowlitz River. Populations from the Cowlitz River may colonize the lower reach of Lake Creek.

The remaining taxa were either common in all reaches (13 taxa, approximately 11%) or were common in all reaches below the lake (5 taxa, approximately 4%). In the Lake Creek drainage, the most common taxa include those generally categorized as “gatherer” feeding group (see section 4.2.6). Some of these taxa that are common to Lake Creek are widespread, occurring in temperate regions throughout the world (e.g. Hydropsychidae caddisflies).

Table 4-3 summarizes 34 metrics across the longitudinal profile of sample sites in the Lake Creek drainage.

Table 4-3. Benthic Macroinvertebrate Results Summary

Reach	Lower Lake Creek Regulated downstream of Packwood Lake											Packwood Lake	Upper Lake Creek Unregulated			
	1		2		3		4		5				Outlet	Lower	Middle	Upper
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	5-O			U-1	U-2	U-3
Site Location in Reach	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3	
Site Name																
Direction of Flow	←															
Invertebrate abundance (m2)	457	698	344	591	479	990	431	506	655	437	1352		602	668	460	
Total taxa richness	43	48	33	43	40	57	41	35	30	39	21		15	47	19	
EPT taxa richness	27	34	25	33	22	38	24	20	18	15	12		13	29	16	
% Dominant (3 taxa)	53	47	48	45	48	34	38	52	69	49	85		87	46	79	
Major invertebrate groups- abundance per square meter																
Non insects	17	20	12	27	24	84	88	27	19	93	576		0	14	7	
Odonata- dragonflies	0	0	0	0	0	0	0	0	0	11	0		0	0	0	
Ephemeroptera- mayflies	179	320	155	266	211	243	142	147	236	47	123		185	76	169	
Plecoptera- stoneflies	44	49	12	62	42	354	23	19	8	16	70		390	269	282	
Trichoptera- caddisflies	133	234	138	176	116	174	105	208	348	163	516		1	27	1	
Coleoptera- beetles	28	32	18	8	15	48	41	38	3	3	0		0	0	0	
Misc. Diptera- true flies	26	16	7	36	54	47	18	31	34	42	33		12	43	0	
Diptera: Chironomidae- midges	32	27	3	16	18	39	15	36	7	62	33		14	240	1	
Major invertebrate groups- percent contribution																
Non insects	3.5	2.9	3.5	4.6	5.1	8.5	20.4	5.3	2.9	21.3	42.6		0.0	2.0	1.5	
Odonata- dragonflies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0		0.0	0.0	0.0	
Ephemeroptera- mayflies	39.2	45.8	45.1	45.0	43.9	24.6	32.9	29.1	36.1	10.8	9.1		30.7	11.3	36.7	
Plecoptera- stoneflies	9.6	7.0	3.5	10.5	8.7	35.8	5.3	3.7	1.2	3.7	5.2		64.8	40.2	61.3	
Trichoptera- caddisflies	29.0	33.5	40.0	29.7	24.2	17.5	24.5	41.1	53.2	37.4	38.2		0.2	4.0	0.3	
Coleoptera- beetles	6.1	4.6	5.1	1.4	3.1	4.9	9.4	7.5	0.4	0.6	0.0		0.0	0.0	0.0	
Misc. Diptera- true flies	5.8	2.3	2.0	6.2	11.3	4.7	4.1	6.1	5.2	9.6	2.5		2.0	6.5	0.0	
Diptera: Chironomidae- midges	6.9	3.9	0.8	2.7	3.7	4.0	3.5	7.2	1.0	14.2	2.5		2.2	36.0	0.3	
Feeding groups- percent contribution																
Predator	6	8	6	8	5	21	8	4	6	6	3		1	9	4	
Gatherer	40	38	33	46	49	30	29	26	28	26	50		24	15	12	
Filterer	15	9	6	10	7	2	16	38	46	42	40		2	5	0	
Scraper	18	25	37	19	16	14	33	21	9	10	1		7	3	23	
Shredder	9	6	3	7	7	19	3	3	1	9	4		64	41	60	
Warm water biota (tolerant taxa)																
Abundance per square meter	0	1	0	7	0	4	41	10	9	55	30		0	1	0	
Percent	0.0	0.2	0.0	1.1	0.0	0.4	9.4	2.1	1.4	13.0	2.2		0.0	0.2	0.0	
Number of taxa	0	1	0	1	0	2	1	2	3	8	3		0	1	0	
Cold water biota (intolerant taxa)																
Abundance per square meter	55	125	86	108	114	418	110	92	113	4	10		5	54	40	
Percent	12.1	18.0	25.1	18.0	23.9	42.1	25.7	18.1	17.3	0.9	0.7		0.9	8.3	8.8	
Number of taxa	14	13	7	11	9	17	11	10	8	2	2		3	10	6	
Long-lived taxa (semivoltine, >1 year life cycle)																
Abundance per square meter	18	13	3	29	14	303	25	13	30	16	7		2	15	3	
Percent	4	2	1	5	3	31	6	3	5	4	0		0	2	1	
Number of taxa	6	5	3	4	4	7	7	4	3	4	1		3	4	1	

4.3.1 Total Invertebrate Abundance

The total number of macroinvertebrates found in shallow riffle habitats of Upper and lower Lake Creek varied from 344 to 1352 organisms per square meter in lower Reach 2 (2-L) and Reach 5 (5-O), respectively. Most values were between 400 and 800 organisms per square meter. Wisseman (1996) found that the typical total benthic invertebrate densities in shallow riffle habitats of forested, montane, mid-order streams in western Oregon are as follows:

<u>Numbers per square meter</u>	<u>Rating</u>
>5000	High
1000-4000	Typical
500-999	Low
<500	Very Low

Both upstream and downstream of Packwood Lake, invertebrate densities in shallow riffle habitats were generally in the low range (Figure 4-1). Only at the outlet of Packwood Lake (site 5-O), were invertebrate numbers typical of a forested, mountainous, mid-order stream. The elevated abundance at this site is most likely the result of elevated water temperature and nutrient levels from the lake.

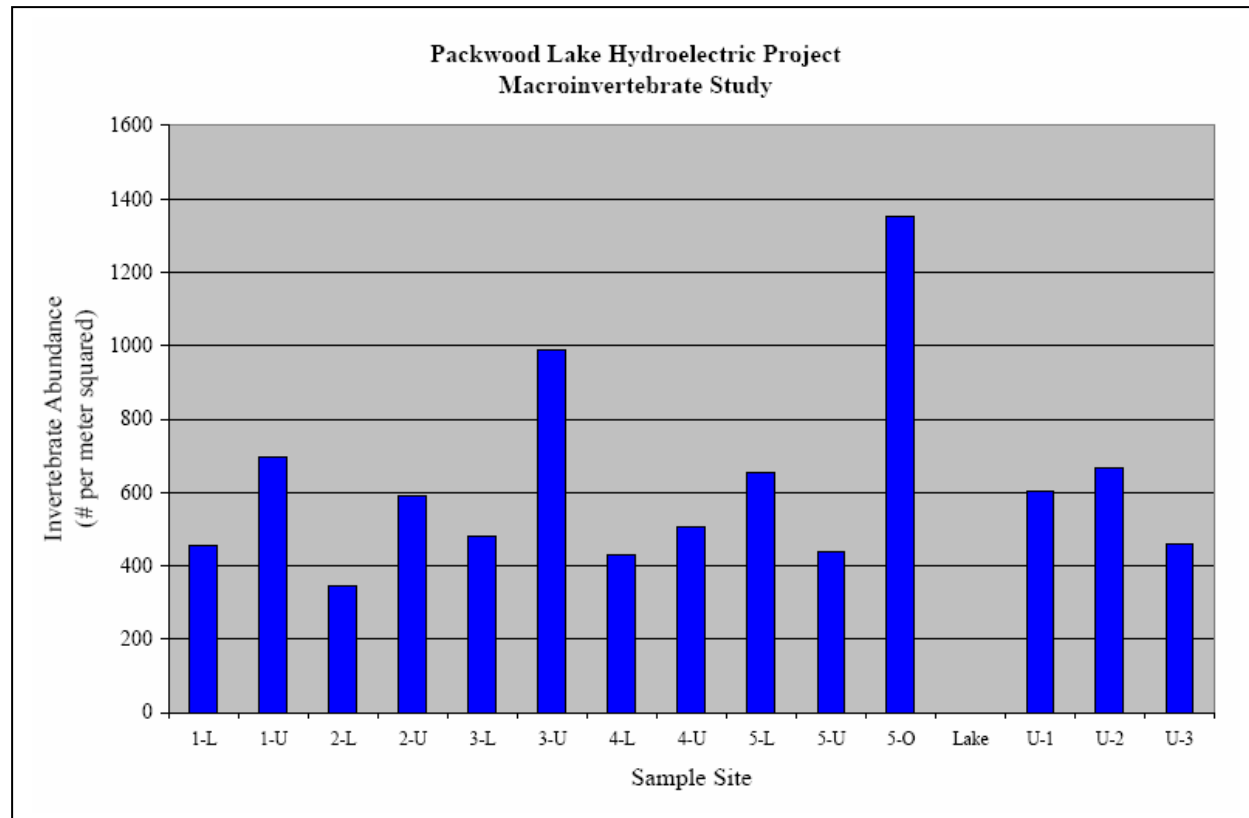


Figure 4-1. Invertebrate Abundance (Density) in October 2005 at 14 Sample Sites on Lake Creek

4.3.2 Total Taxa Richness

The total taxa richness found in riffle habitat in Upper and lower Lake Creek varied between 15 and 57 at site 1-L and site 3-U, respectively (Figure 4-2). Wisseman (1996) found that shallow riffle habitat of forested, montane, mid-order streams in eastern Oregon tend to have a total taxa richness as follows:

<u>Numbers per square meter</u>	<u>Rating</u>
>60	High
40-59	Medium
30-39	Low
<30	Very Low

Total taxa richness was generally very low in Upper Lake Creek and immediately downstream of Packwood Lake. Total taxa richness generally increased in a downstream direction to medium levels in Reach 3. Downstream of Reach 3, taxa richness was relatively similar to medium levels found at site 3-L.

Benthic invertebrate communities achieving only moderate richness in cold, spring-fed streams is typical (Stanford & Ward 1983, Williams & Williams 1998).

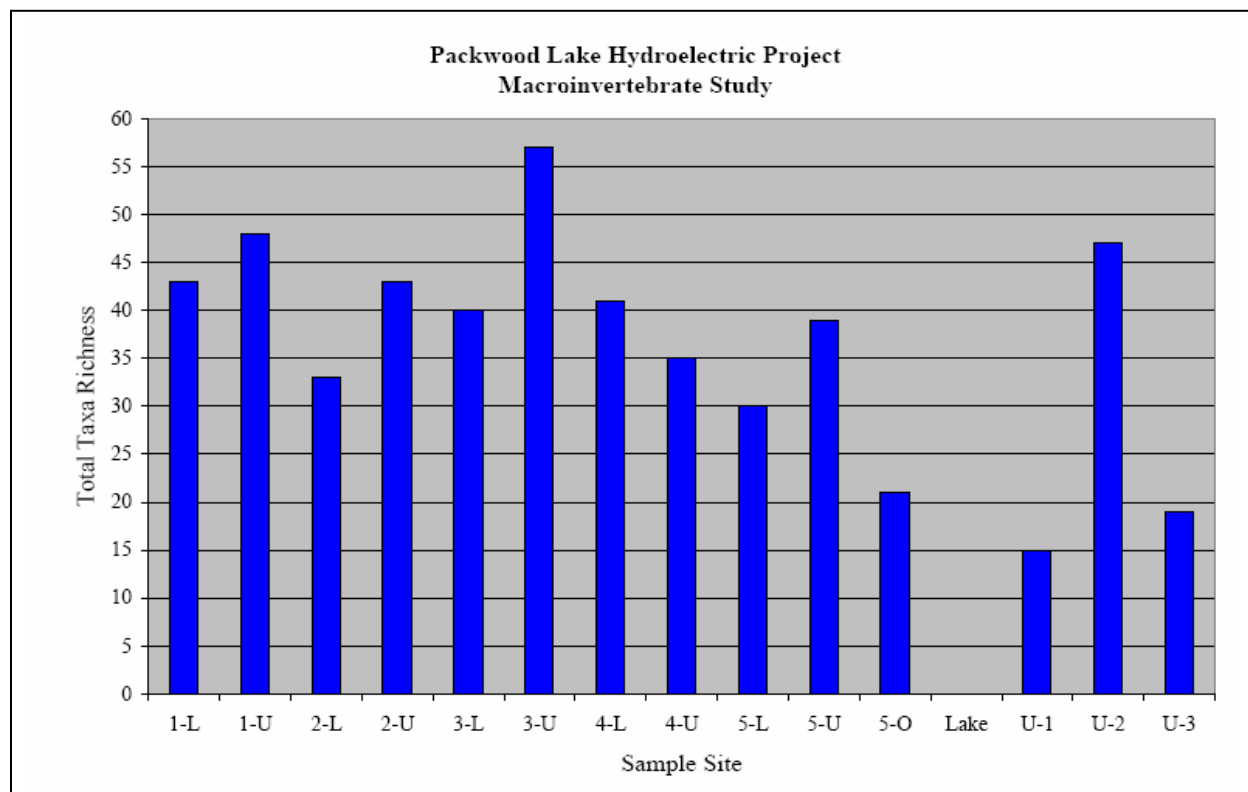


Figure 4-2. Total Taxa Richness in October 2005 at 14 Sample Sites on Lake Creek

4.3.3 EPT Taxa Richness

The EPT taxa richness metric represents the total number of taxa encountered in the insect orders Ephemeroptera (E - mayflies), Plecoptera (P - stoneflies), and Trichoptera (T- caddisflies). These three orders often dominate benthic invertebrate communities in montane streams. Many of the common “intolerant” taxa (see section 4.2.8) are in these orders. The EPT metric has been widely used to assess biological integrity of streams. It has been repeatedly demonstrated that this metric is highly correlated with habitat integrity and environmental impact levels. EPT taxa richness has been found to decrease with increasing levels of environmental disturbance and loss of habitat integrity (Barbour et al. 1999).

Wisseman (1996) found that typical shallow riffle habitat of forested, montane, mid-order streams in western Oregon tend to have the following EPT taxa richness values:

<u>EPT Taxa Richness</u>	<u>Rating</u>
>35	High
25-34	Medium
20-24	Low
<20	Very Low

EPT taxa richness in Lake Creek was rather variable (Figure 4-3). EPT values varied between 12 at site 5-O and 38 at site 3-U. These correspond with very low and high EPT values, respectively.

Upper Lake Creek had very low EPT scores. Sites U-1 and U-3 had EPT taxa richness scores of 15 and 19, respectively, corresponding with a very low rating. Site U-2 had a high EPT taxa richness score (47). It is difficult to associate such differences to environmental or habitat characteristics within the Upper Lake Creek reach, because general site characteristics were very similar across sites (see Table 4-1).

Reach 5 of lower Lake Creek had very low EPT taxa richness scores across all three sample sites. Sites 5-L, 5-U, and 5-O had EPT taxa richness scores of 18, 15, and 12, respectively. Streams immediately below both natural and artificial lakes typically have low EPT scores because of elevated water temperatures and nutrient levels.

EPT scores in Reach 4 illustrate a transition from low scores associated with the outlet of Packwood Lake to high scores associated with high habitat integrity in the canyon section of lower Lake Creek. Sites 4-L and 4-U both had EPT scores that would rate as low. Site 4-L had a score of 24 while site 4-U, the site closest to reach 5, had a score of 20, which suggests that there is improvement in habitat integrity in a downstream direction.

Reaches 1, 2, and 3 generally reflected greater habitat integrity. Site 3-U had an EPT score of 38, achieving a high rating. Scores downstream of site 3-U fluctuated between a low of 22 at site 3-L to a high of 34 at site 1-U. These score seem to reflect the variable habitat quality of the downstream reaches.

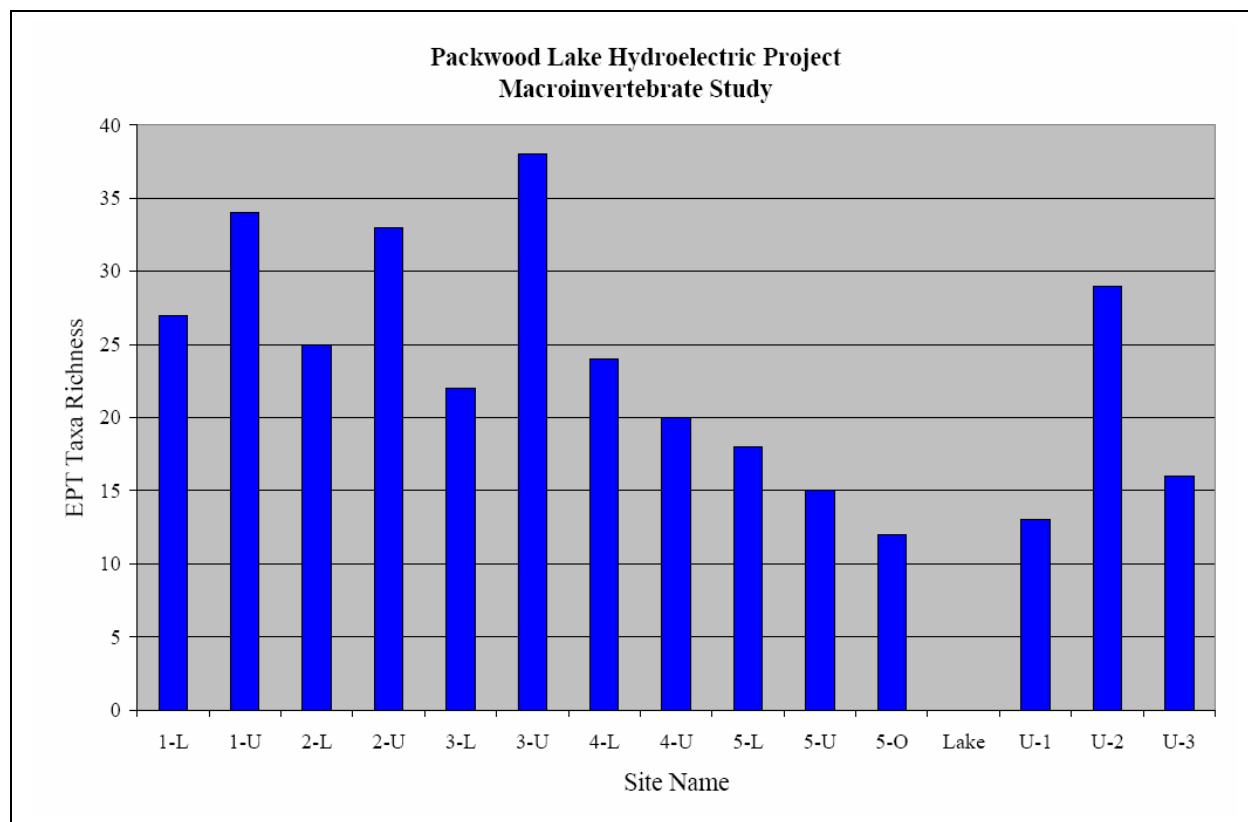


Figure 4-3. EPT Taxa Richness in October 2005 at 14 Sample Sites on Lake Creek

4.3.4 *Percent Dominant (3 Taxa)*

The percent dominant metric adds together the percent contribution of the three most dominant taxa in a sample, and is a simple measure of diversity and evenness for a benthic community. Most multimetric indices incorporate some measure of evenness and diversity since stressed communities in areas with low habitat integrity tend to be super dominated by several taxa. Karr’s benthic index of biological integrity (BIBI) for stream benthic invertebrate communities rates the percent three dominant taxa metric as follows:

<u>BIBI Score</u>	<u>Rating</u>	
0-49%	Good	
50-74%	Fair	
>74%	Poor	(Karr & Chu 1999).

Dominance in Upper and lower Lake Creek ranged between a low of 34 at site 3-U to a high of 87 at site U-1 in upper Lake Creek (Figure 4-4). These correspond with BIBI ratings of “good” and “poor” respectively. BIBI ratings were generally “poor” in Upper Lake Creek and at the outlet of Packwood Lake. BIBI scores improved to “good” at site 5-U, less than 0.1 miles downstream from the outlet of Packwood Lake. BIBI scores were only fair at sites 5-L and 4-U, but improved to “good” for the remainder of lower Lake Creek (Figure 4-4).

Lower habitat complexity often allows a few taxa to become super dominant (Stanford & Ward 1988). This may have been the case in Upper Lake Creek, where there is low habitat diversity, streambanks are highly unstable and entrenched, and the glacial hydrology results in a high annual disturbance and very high seasonal disturbance (see Table 4-1).

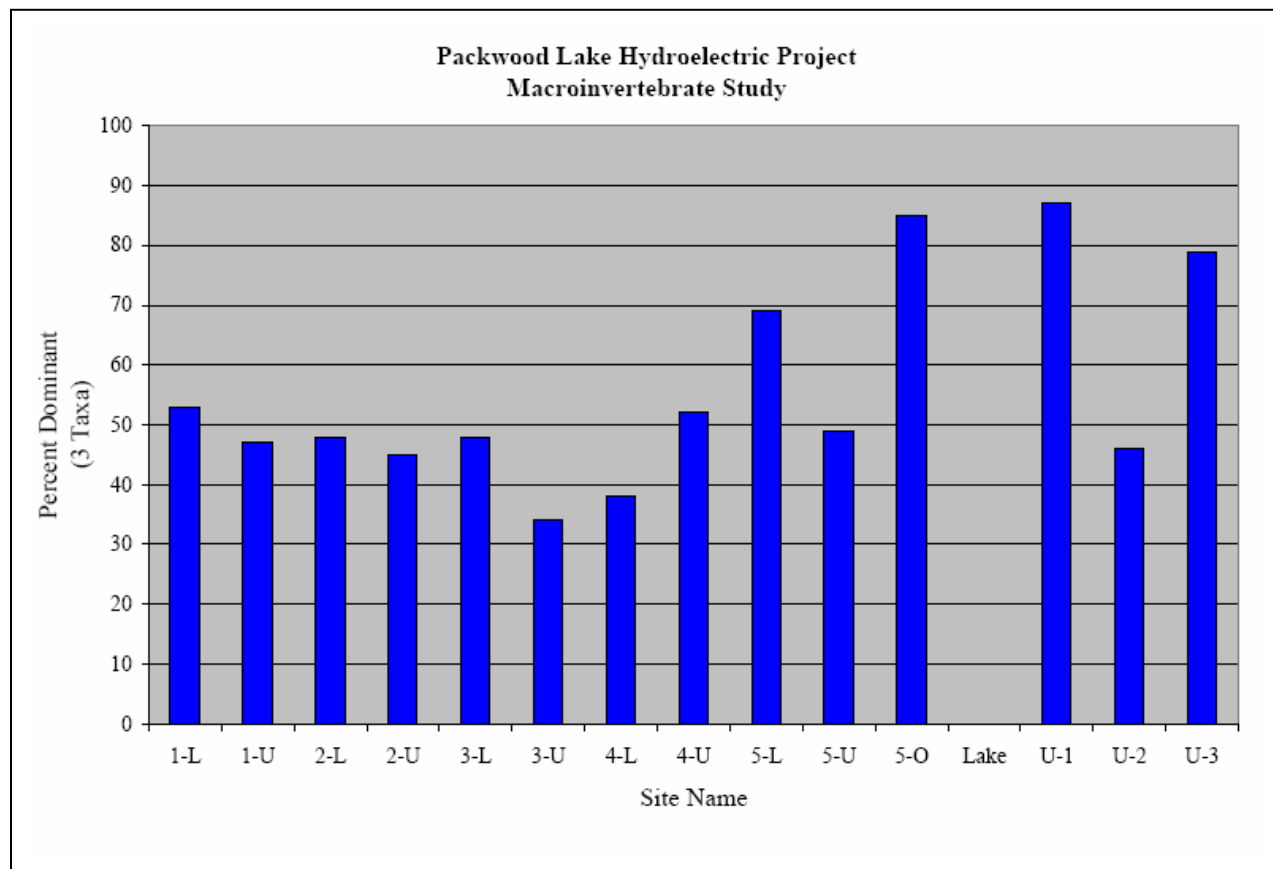


Figure 4-4. Percent Dominant (3 Taxa) in October 2005 at 14 Sample Sites on Lake Creek

4.3.5 Major Invertebrate Groups

The percent contribution of major invertebrate groups illustrates shifts in community composition along the longitudinal stream profile of the Lake Creek drainage (Figure 4-5; illustration for individual invertebrate groups can be found in Appendix B). Mayflies (Ephemeroptera) were a substantial portion of the community composition in all reaches and at most sites. The next most prevalent invertebrate group was caddisflies (Trichoptera). Although less than 5% percent of the community composition in Upper Lake Creek, caddisflies represented between 18% and 53% of the community composition in lower Lake Creek. Other invertebrate groups represented a large portion of the community composition at some sites, but not others. The following describes these changes from reach to reach.

Stoneflies (Plecoptera) were the most prevalent invertebrate group in Upper Lake Creek. The percent contribution of stoneflies was over 60% of the community at sites U-1 and U-3, and was 40% of the community at site U-2. Mayflies (Ephemeroptera) were also prevalent in Upper Lake Creek, with percent contribution of 31%, 11%, and 37 % at sites U-1, U-2, and U-3 respectively. At site U-2 true flies (Diptera) had a high percent contribution (36%), due to the capture of a large number of midges (Chironomidae).

In Reach 5 of lower Lake Creek, caddisflies had the highest percent contribution at sites 5-L and 5-U, and were well represented at site 5-O. Mayflies increased in occurrence, in a downstream direction, with percent contribution of 9%, 11%, and 36% at site 5-O, 5-U, and 5-L respectively. The highest percent contribution at site 5-O, however, was the non insect invertebrate group (43%), due to the large number of *Pisidium* (bivalve mollusks) collected. *Pisidium* were also prevalent at site 5-U with a percent contribution of 21%. True flies were common at site 5-U with percent contribution values of 14% and 10% for midges and other true flies, respectively.

Reach 4 had a mixed community composition. At site 4-U, caddisflies had a percent contribution of 41% and mayflies had a percent contribution of 29%. At site 4-L, caddisflies and mayflies were prevalent with percent contribution values of 25% and 33% respectively. Non insects, however, represented 20% of the percent contribution at site 4-L, driven up by the large percentage of freshwater snails (*Menetus*) found in the sample.

Reach 3 also had a mixed community composition. Site 3-U, like other upstream sites, had a large percentage of caddisflies (18%) and mayflies (25%). Unlike other sites in lower Lake Creek, however, site 3-U had a large percentage of stoneflies (36%). It is not surprising that this site would have the healthiest EPT taxa richness score (see Section 4.2.3). Site 3-L had a large percentage of caddisflies and mayflies, with percent contribution values of 24% and 44%, respectively. Rather than stoneflies, site 3-L had true flies (Diptera) as its next most prevalent invertebrate group with a percent composition of 11%.

Reaches 1 and 2 had similar community composition and percent contribution values. Throughout Reaches 1 and 2, mayflies and caddisflies were the most prevalent. Mayflies had a percent composition of 45%, 45%, 46%, and 39% for sites 2-U, 2-L, 1-U, and 1-L respectively. Caddisflies had a percent composition of 30%, 40%, 34%, and 29% for sites 2-U, 2-L, 1-U, and 1-L respectively. Stoneflies had a percent contribution of 11% and 10% at sites 2-U and 1-L, respectively. All other invertebrate groups represented less than 10% of the percent contribution for any site in Reaches 1 and 2.

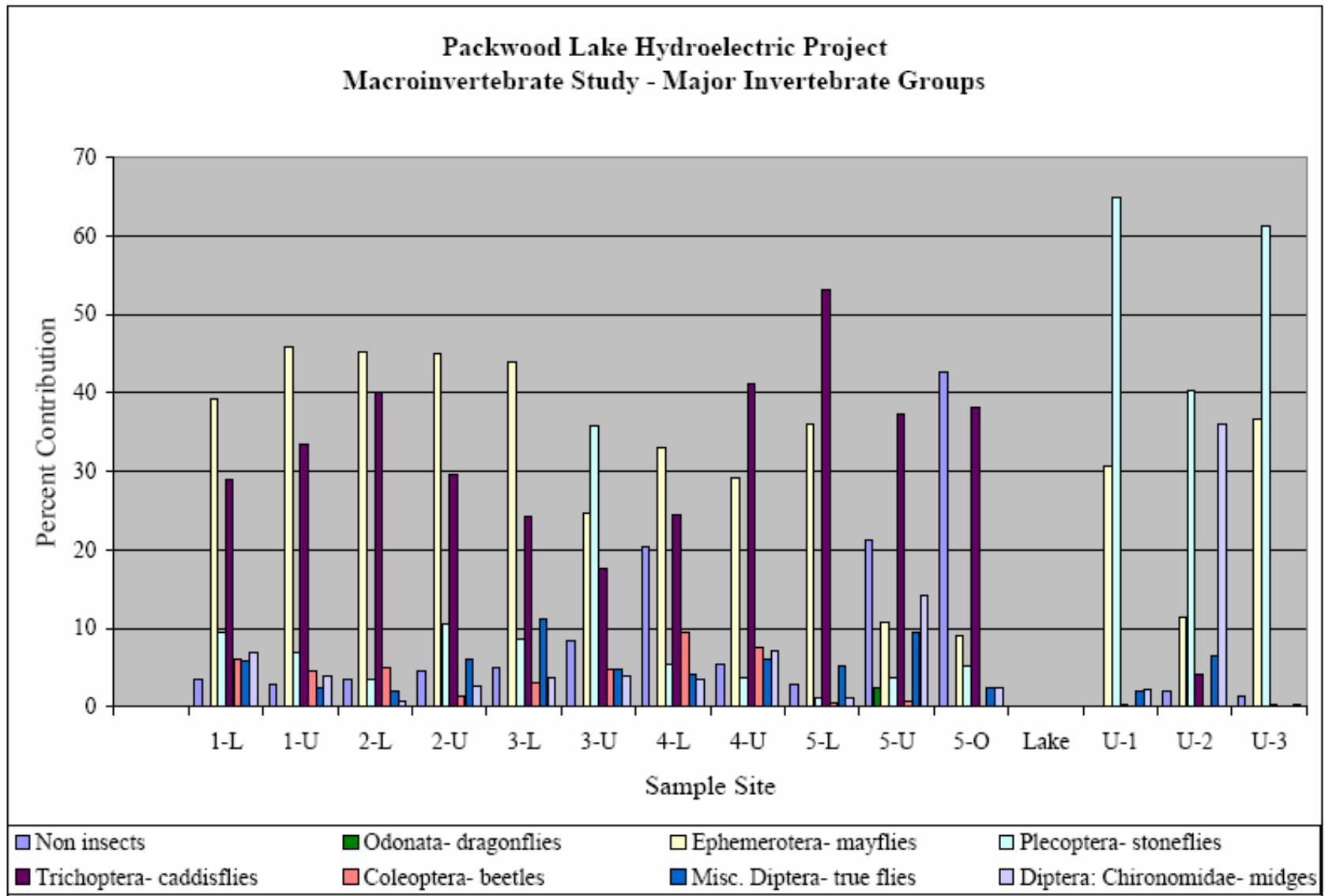


Figure 4-5. Major Invertebrate Group Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

4.3.6 Feeding Groups

Functional feeding group classification was used to distinguish taxa based on the different functions performed within the aquatic ecosystem. Groups of taxa, analogous to feeding guilds, were used to evaluate the relative availability of food resources (Merritt and Cummins 1996). The relative availability of different food resources is determined by the condition of the environment. Figure 4-6 illustrates the percent contribution of all feeding groups in Upper and lower Lake Creek during the October 2005 sample period.

The three feeding groups most prevalent in Lake Creek were shredders, filterers, and gatherers (Figure 4-6). Shredders were most prevalent in Upper Lake Creek, filterers were most prevalent in reaches 4 and 5 in lower Lake Creek, and gatherers were generally the most prevalent feeding group in reaches 1, 2, and 3. The following sub-sections further describe longitudinal trends in the shredder, filterer, gatherer, predator, and scraper feeding group percent contribution and dominance in the Lake Creek drainage.

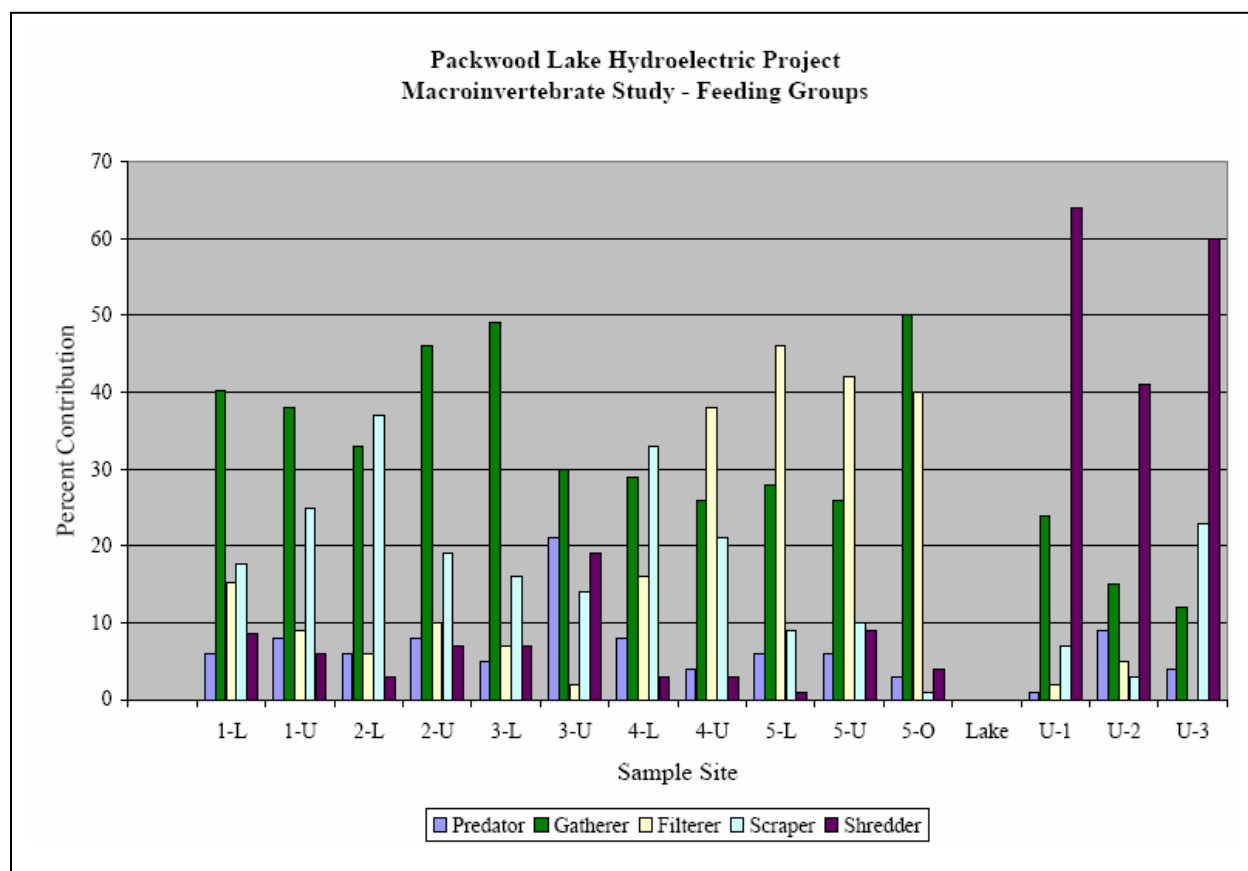


Figure 4-6. Major Feeding Group Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

Detritus shredders feed on coarse particulate organic matter (CPOM) carried into the stream, such as leaves from deciduous trees and shrubs and needles from coniferous trees. In forested, montane streams shredder densities and dominance are typically highest in headwater reaches of a stream where nutrients and sunlight are limited, and where the channel is in close proximity with adjacent riparian vegetation. Shredder populations are often limited where leaf litter and other CPOM are not available.

Shredders were the most dominant feeding group in Upper Lake Creek, and were relatively uncommon in lower Lake Creek (Figure 4-7). The percent contribution of shredders in Upper Lake Creek was 64 %, 41% and 60% at sites U-1, U-2, and U-3 respectively. In lower Lake Creek, percent contribution varied between 1% at site 5-L to 19% at site 3-U. Except for site 3-U, no sites in lower Lake Creek exceeded 10% contribution of the shredder feeding group.

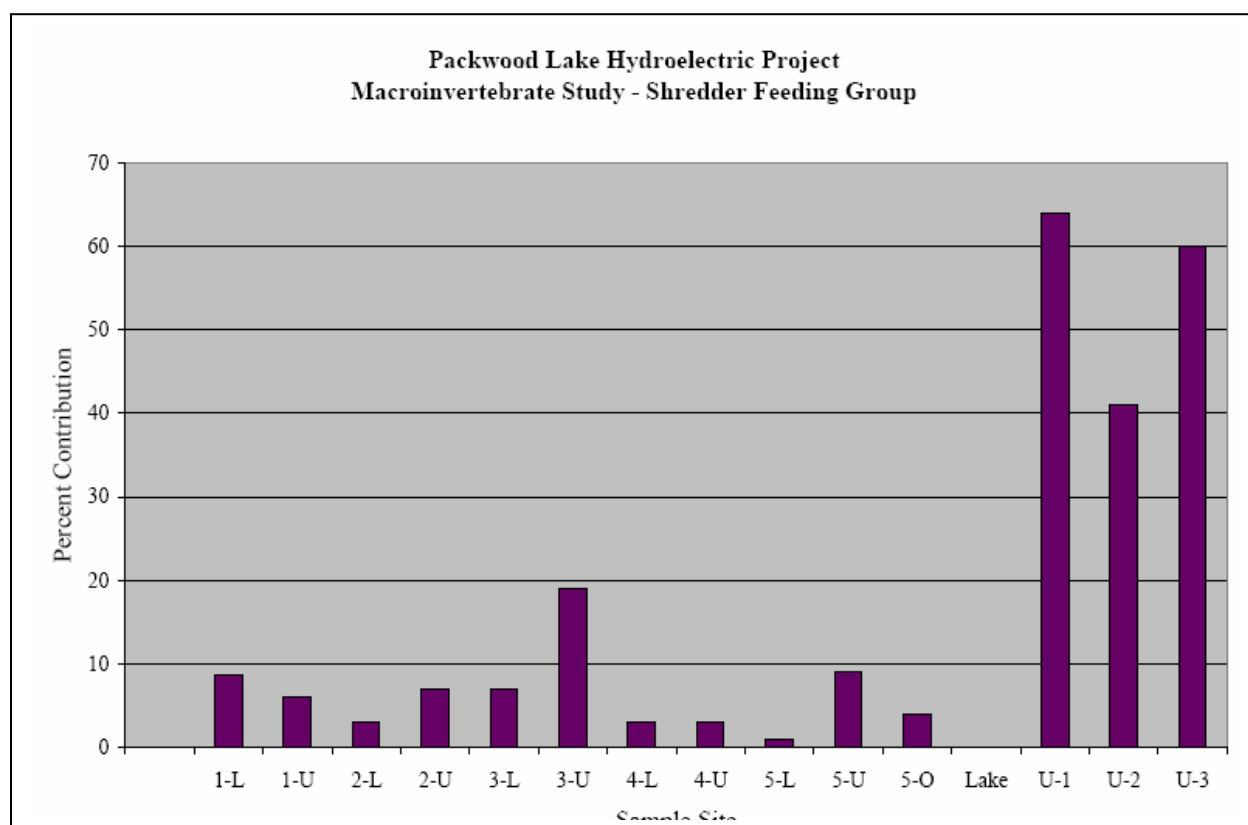


Figure 4-7. Shredder Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

Collector-filterers strain food particles from flowing water with the benefit of spun silk nets or through the use of specialized body appendages. Collector-filterer abundance and percent dominance of benthic invertebrate communities tends to occur in stream segments with high nutrient content. This often coincides with areas of high human use and nutrient enrichment. Warm surface water released from mesotrophic or eutrophic reservoirs often have enriched phytoplankton and zooplankton content that tends to support collector-filterers in tailrace reaches below dams. Conversely, bottom or hypolimnion release of cold, nutrient- and particle-poor water from oligotrophic reservoirs typically depresses both overall benthic invertebrate density,

and collector-filterers in particular (Lillehammer & Saltveit 1984, Ward 1992, Ward & Stanford 1979).

Collector-filterers were most prevalent in reaches 4 and 5 of lower Lake Creek and were much less common in Upper Lake Creek and the lower reaches of lower Lake Creek (Figure 4-8). Collector-filterer percent contribution in Upper and lower Lake Creek varied between zero and 46%. Upper Lake Creek had collector-filterer percent composition of 2%, 5%, and 0% at sites U-1, U-2, and U-3, respectively. This suggests that this reach is low in fine particulate organic matter (FPOM) and likely is low in nutrients.

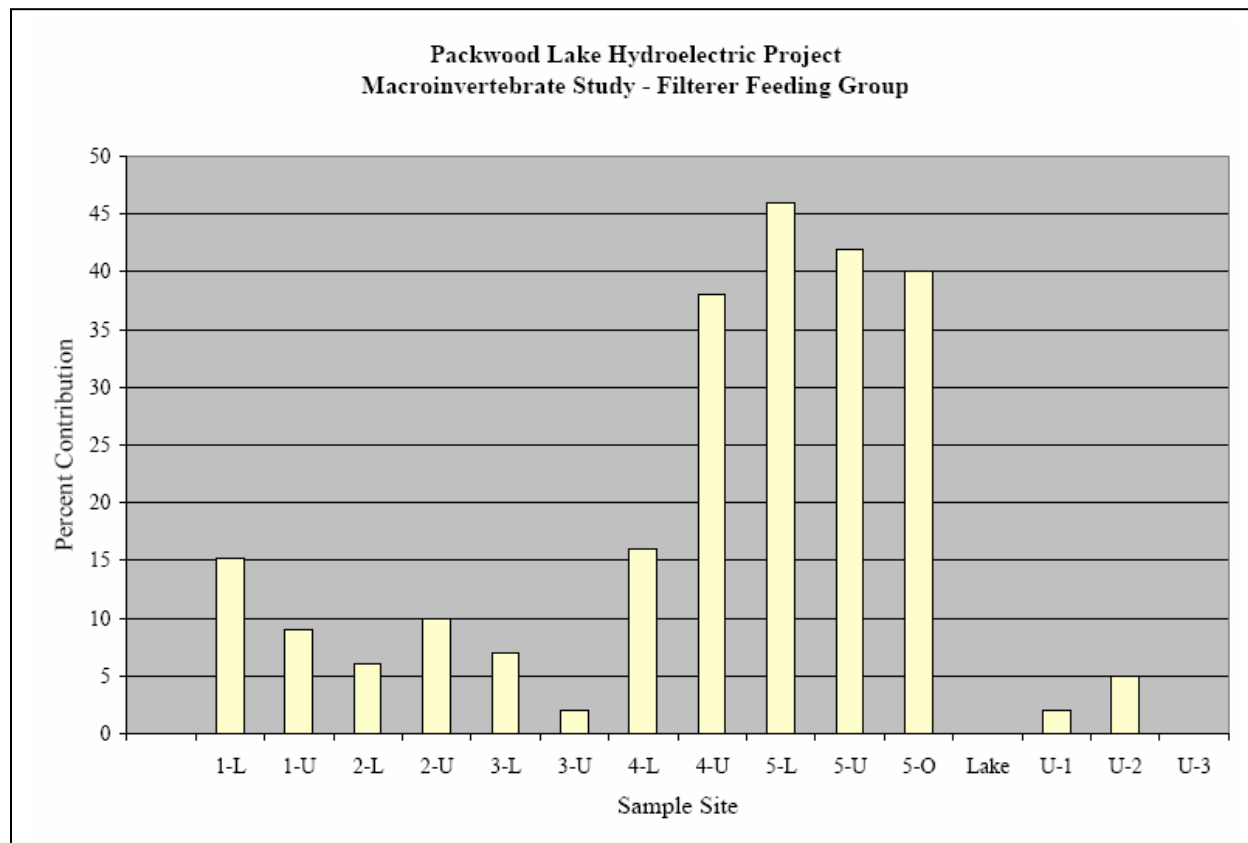


Figure 4-8. Collector-Filterer Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

The highest collector-filterer percent contribution occurred in reaches 4 and 5. Sites 5-L, 5-U, and 5-O had filterer abundances of 46, 42, and 40% respectively. Sites 4-L and 4-U had collector-filterer abundances of 16% and 38%, respectively. Higher collector-filterer levels in these reaches are not surprising as they are immediately downstream from Packwood Lake. The percent contribution of filterers decreased significantly below Reach 4 where other feeding groups were favored. Site 3-U had a percent contribution of 2%, but values gradually increased to a percent contribution of 15% at site 1-L.

Collector-gatherers use bodily appendages to feed on FPOM, live or senescent algal cells, small metazoans living in the sediment, or inorganic silt. Collector-gatherers tend to have higher

abundance in lower gradient reaches where fine sediment and food particles settle out onto the substrate. Results of the Lake Creek macro-invertebrate analysis generally agree with this tendency (Figure 4-9).

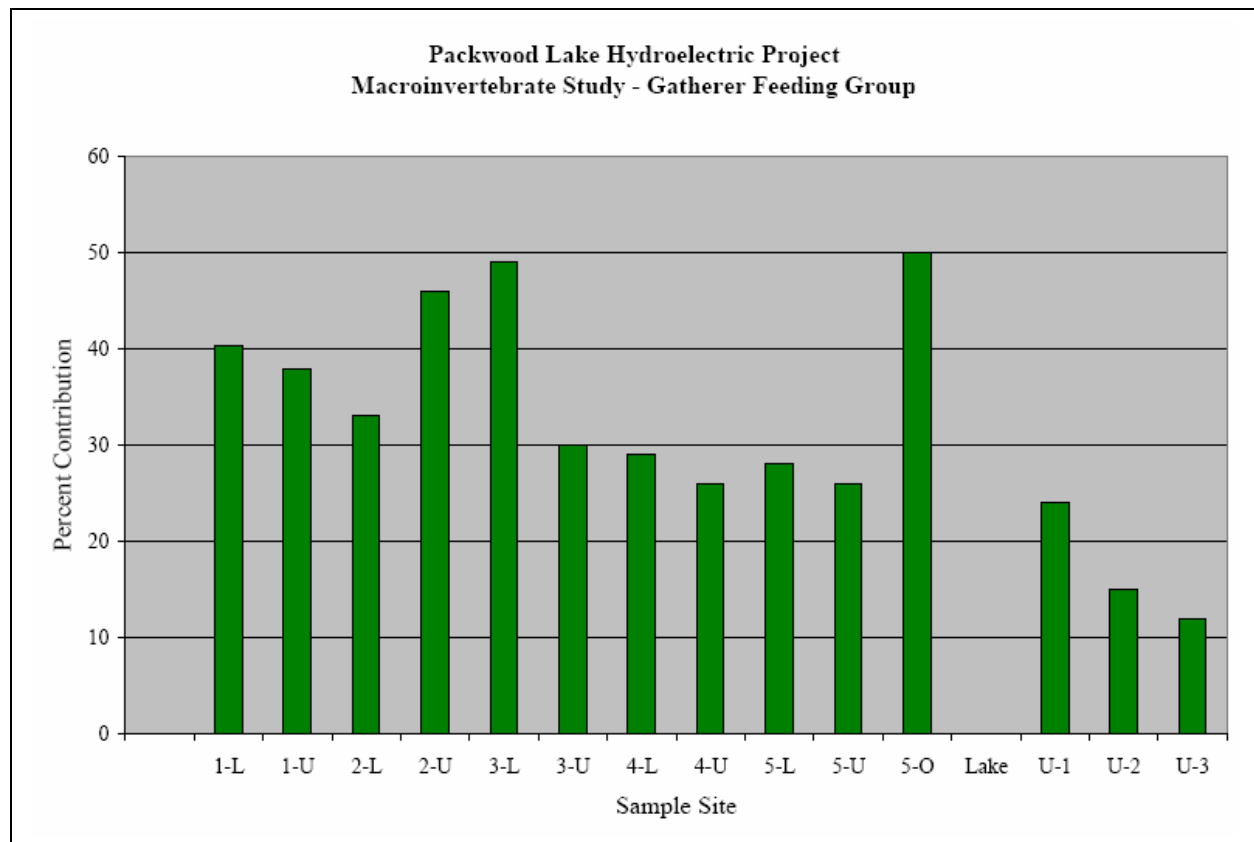


Figure 4-9. Collector-Gatherer Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

The collector-gatherer feeding group was fairly common throughout the Lake Creek drainage. The percent contribution of collector-gatherers in Upper Lake Creek varied between 24% and 12%. Percent contribution in lower Lake Creek varied between 26% and 50%. Except for site 5-O where collector-gatherers were half of the community composition, percent contribution was generally lower in the higher elevation reaches and increased in a downstream direction.

Predators eat other benthic invertebrates, and at times may eat juvenile fish, fish eggs or amphibians. Invertebrate predator dominance (% contribution) and taxa richness tend to be highest where there is the highest habitat complexity and environmental quality. Predatory macroinvertebrates are often large, long-lived taxa sensitive to loss of habitat integrity and stability (Karr & Chu 1999). As a result, they are useful as indicators of environmental quality.

Predators were present at all sites on Upper and lower Lake Creek (Figure 4-10). Percent contribution varied between 1% at site U-1 in Upper Lake Creek and 29% at site 3-U in lower

Lake Creek. Except at site 3-U, predators comprised less than 10% of the community composition at all sites in Upper and lower Lake Creek.

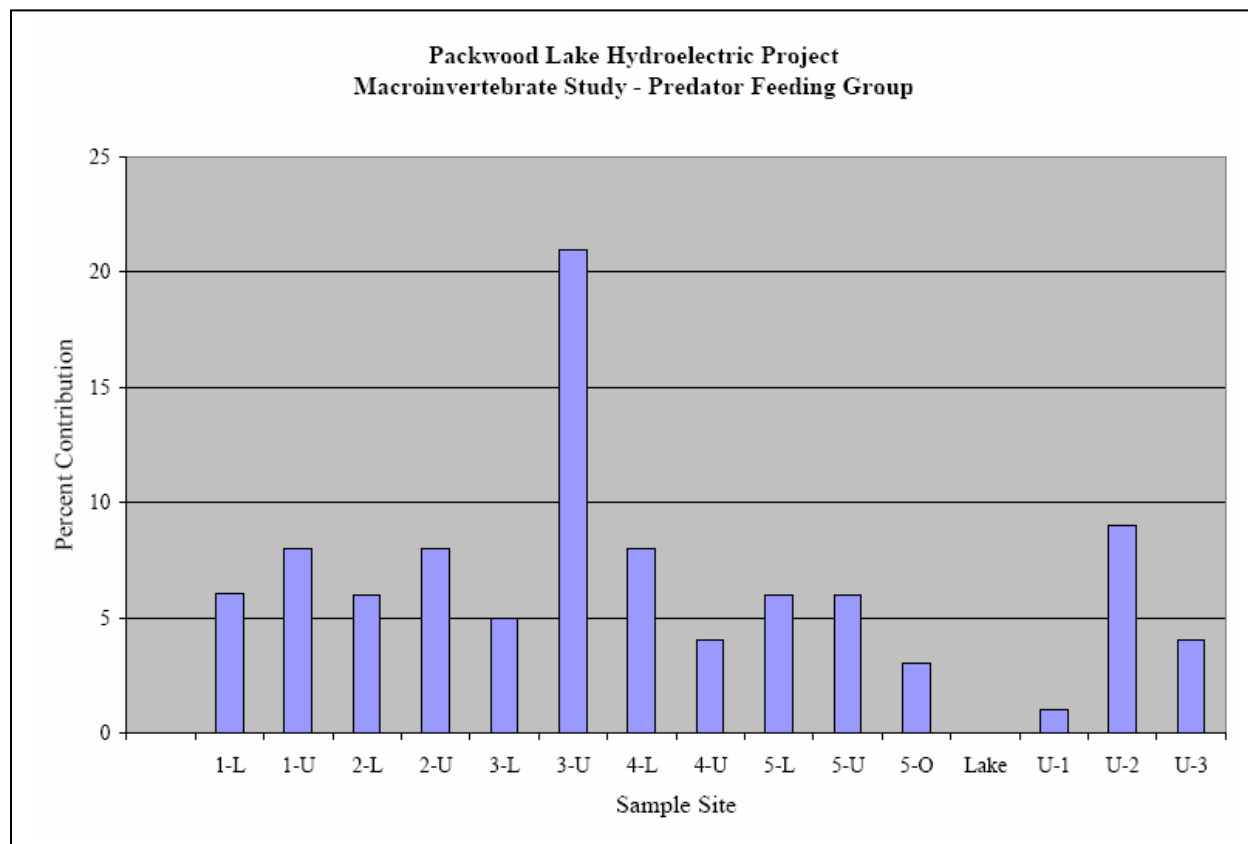


Figure 4-10. Predator Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

Scrapers use specialized mouthparts to “scrape” the film covering hard sediment surfaces. A film with a high proportion of live diatoms is the preferred food source of scrapers, although films may also contain FPOM, senescent algae, metazoans, bacteria, and inorganic silt. Scrapers are sensitive to warm temperatures, nutrient enrichment that fosters the growth of filamentous algae and bacteria, and elevated level of fine sediment that embed hard surfaces. Scrapers tend to be most prevalent in higher gradient, cool, oligotrophic, montane streams.

Scrapers were present at all sites. Percent contribution varied between 1% at site 5-O in lower Lake Creek and 37% at site 2-L in lower Lake Creek (Figure 4-11). Scrapers were relatively common in reaches 1 through 4 in lower Lake Creek, and at site U-3 in Upper Lake Creek. Scrapers were the most prevalent feeding group at site 2-L, closely followed by the grazing feeding group. A reason for the comparatively low scraper levels in Reach 5 may be due to the presence of fine sediments and filamentous algae.

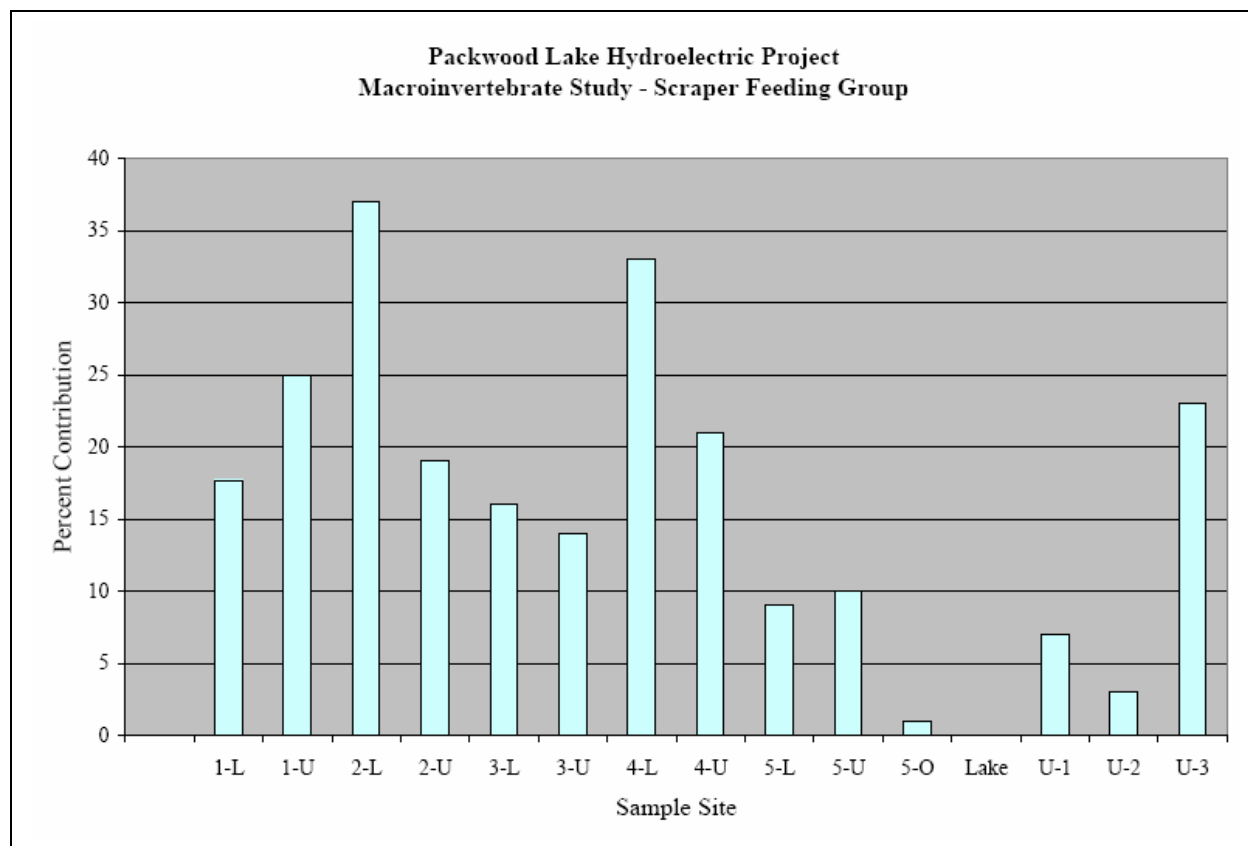


Figure 4-11. Scraper Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

4.3.7 *Tolerant Taxa*

Tolerant taxa are species that can tolerate warmer water, lower dissolved oxygen, and higher levels of sand, silt, and filamentous algae as part of the substrate. Tolerant taxa percent contribution represents the percentage of taxa in a sample that have been assigned CTI tolerance values from 7-10. Along an idealized longitudinal stream profile, one might expect to find the highest number of tolerant taxa at the lowest elevations where gradient is the lowest, water temperature is the highest, and nutrient enrichment is the greatest. One might also expect to observe a gradual increase, in a downstream direction, in the presence of tolerant taxa as gradient decreases, water temperatures increases, and nutrient enrichment accelerates.

The Lake Creek drainage did not follow such an idealized longitudinal profile (Figure 4-12). Throughout the Lake Creek drainage, the percent contribution of tolerant taxa was very low. With the exception of site 5-U, tolerant taxa were less than 10% of the overall community structure. Tolerant taxa were only 13% of the community composition at site 5-U, were less than 10 % of the community composition at site 4-L, were less than 5% of the community composition at 7 of the 14 sites, and were not even found at 5 of the 14 sites. This reflects a very low percent contribution of tolerant taxa throughout the Lake Creek drainage.

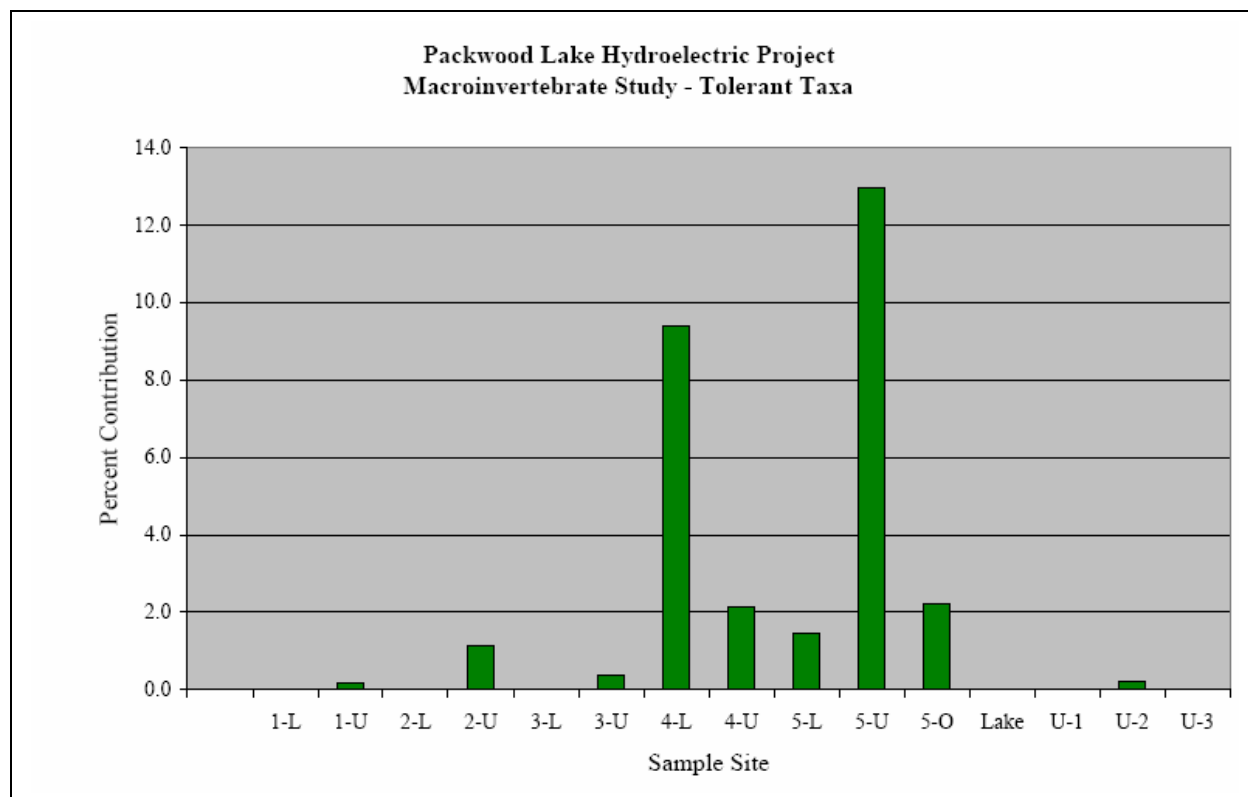


Figure 4-12. Tolerant Taxa Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

4.3.8 Intolerant Taxa

Intolerant taxa percent contribution is the total percent contribution of taxa in a sample that have been assigned CTI tolerance values from 0-3. “Intolerant” taxa require cool/cold water temperatures year-round, high levels of dissolved oxygen, and relatively clean, hard substrates.

Along an idealized longitudinal stream profile, one might expect to have the highest intolerant taxa levels in the headwaters of the stream where water is coolest, cleanest, and substrates tend to be cobble, boulder, and bedrock. One might also expect to find a gradual decrease, in a downstream direction, in the presence of intolerant taxa as gradient decreases, water temperatures increase, and nutrient enrichment accelerates.

The Lake Creek drainage did not appear to follow the profile for an idealized stream (Figure 4-13). Intolerant taxa percent contribution was lowest (less than 10%) in upper Lake Creek where high percent fines occurs in the substrate, and Reach 5 of lower Lake Creek where outflow from the lake is warm relative to other stream reaches. The percent contribution of intolerant taxa increased markedly through Reach 4 to a high of 42 % at site 3-U. Percent contribution then gradually decreased in a downstream direction to a value of 12 % at site 1-L.

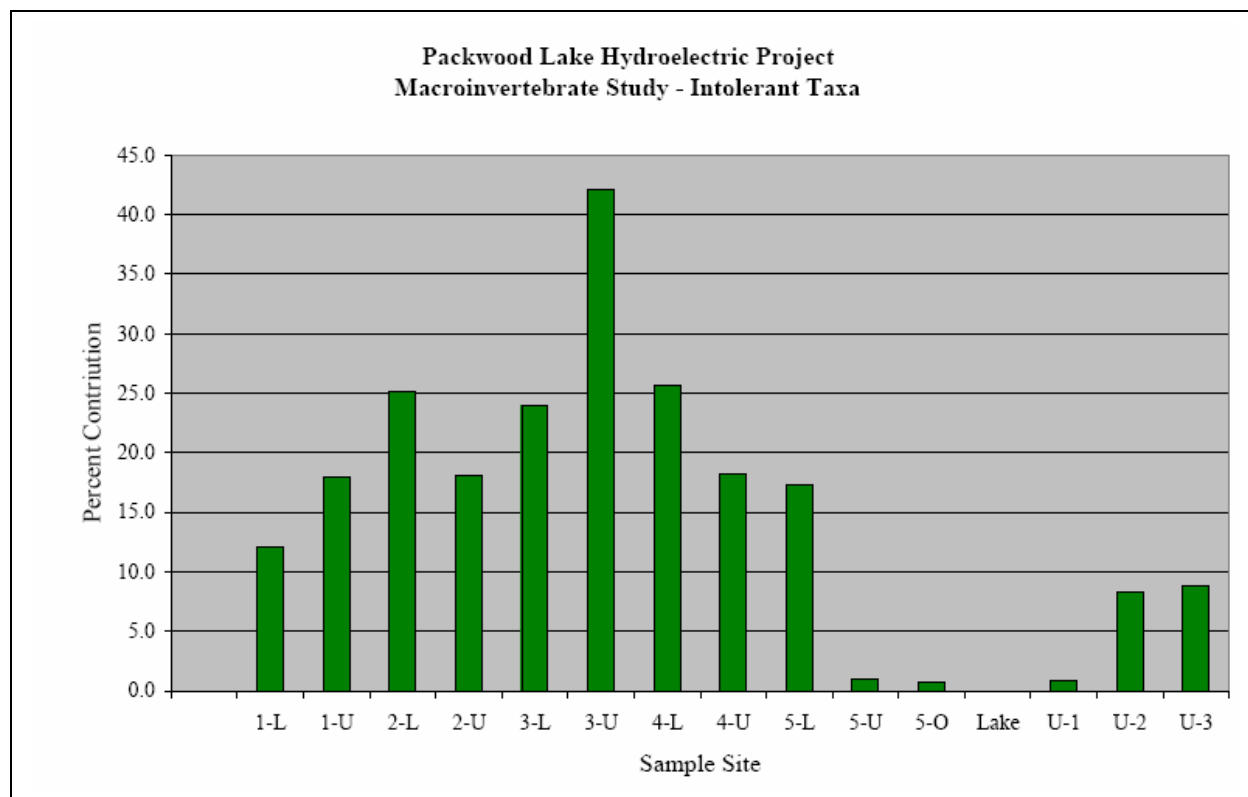


Figure 4-13. Intolerant Taxa Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

4.3.9 Semi-Voltine Species

Semi-voltine taxa are invertebrates whose life cycles span more than one year. In other words, semi-voltine species produce less than one generation per year. Because large, long-lived organisms are usually active in aquatic habitats for long periods of time, there is more opportunity for them to be exposed to adverse environmental conditions. The number and diversity of semi-voltine taxa usually declines with increasing level of environmental stress (Ricklefs 1979).

Semi-voltine species were found at all sites and in all reaches on Lake Creek. A total of 17 semi-voltine taxa were identified in Upper and lower Lake Creek., but were generally found in low numbers (Figure 4-14). Semi-voltine taxa had a percent contribution of less than 10% at all sites except site 3-U, which had a percent composition of 31%. Two genera, *Doroneuria* and *Yoraperla*, are long-lived stoneflies that represented 10% and 15% of the total community composition at this site.

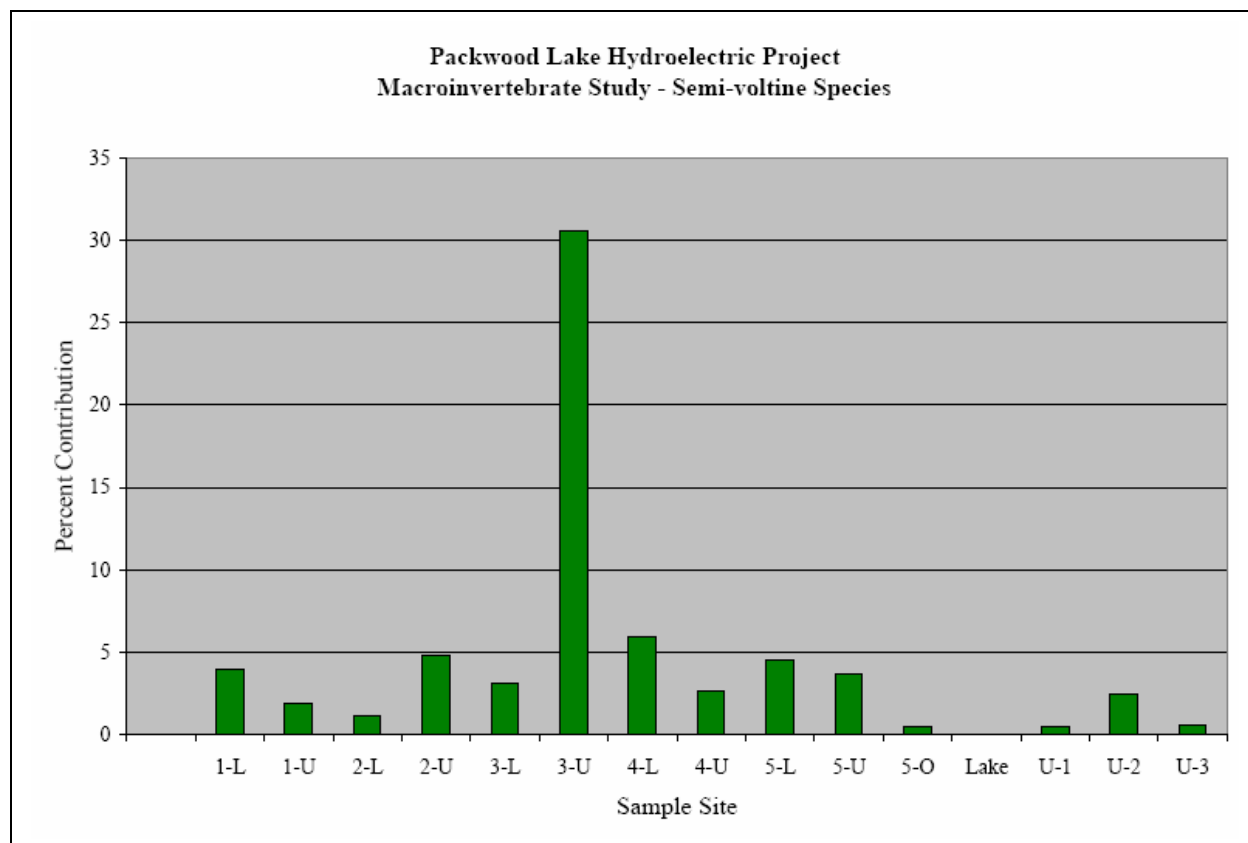


Figure 4-14. Semi-Voltine Species Percent Contribution in October 2005 at 14 Sample Sites on Lake Creek

4.4 Rare, ROD, Sensitive, and Species of Concern

Literature reviews were completed prior to field work in October 2005. Literature indicated that federal and state Threatened, Endangered, and Species of Concern (SOC) were unlikely to occur in Project waters. Review of the Washington State Watch List also suggested that no species were anticipated to be found.

Sampling in October 2005, indeed, resulted in no Threatened, Endangered, SOC or Watch List species found. Based on the types of aquatic habitats encountered during sampling and best professional judgment, it is highly unlikely that any such species would be encountered in the Project area (R. Wisseman, Pers. Comm. July 9, 2006).

5.0 DISCUSSION

The study sought to examine changes in benthic macroinvertebrate communities above and below physical features of the Project, and to seek and identify any Threatened, Endangered or other species of interest in the Project area. The bypass reach of Lake Creek, was evaluated.

Ideally, a macroinvertebrate analysis would use comparative data derived from reference conditions in space or time. Because reference conditions for the Project area are not available,

as an alternative, differences in individual community parameters were presented and discussed for Lake Creek. Using information above and below hydro-development has been the typical alternative approach (Armitage 1984, Brusven 1984, Zimmermann & Ward 1984).

The bypass reach of Lake Creek lies below Packwood Lake and flows 5.3 miles to its confluence with the Cowlitz River (EES Consulting 2005). Macroinvertebrate samples from the bypass reach were compared to samples from Upper Lake Creek above Packwood Lake. Metrics evaluated included: species composition and distribution, invertebrate abundance, total taxa richness, EPT taxa richness, percent Dominant (3 taxa), major invertebrate groups abundance, feeding group percent contribution, percent contribution of tolerant taxa, percent contribution of intolerant taxa, and percent contribution of semi-voltine species. A summary of findings follow:

Duplicate samples and sorting efficiency:

Duplicate samples collected at site 1-L were only generally comparable. Differences between duplicate samples likely reflect micro-geographic variability in habitats and invertebrate community composition rather than differences in field techniques.

- Complete samples were sorted for all sites except site 3-U. Site 3-U was sorted using a $\frac{3}{4}$ sub-sample. Approximately 750 organisms were sorted from the site 3-U sample, exceeding 500-organism target count designated in laboratory protocols.
- The 500-organism target count was not achieved for a number of Lake Creek sample sites. This reflects low macro-invertebrate densities (Figure 4-1) throughout Lake Creek. Low densities likely are the result of low nutrient levels throughout the Lake Creek drainage.
- Sorting of Lake Creek samples was more efficient than the 10 % total error standard identified by the US EPA (1995).

Species composition and distribution:

- Approximately 55% of the taxa identified were rare or uncommon with no apparent trend or association with stream characteristics or project impacts.
- Fifteen taxa (13%) were mostly limited in their distribution to the Upper Lake Creek reach, above Packwood Lake.
- Eleven taxa (9.5%) were mostly restricted to Reach 5 of lower Lake Creek, preferring the warmer lake outflow that has higher phytoplankton biomass for nutrients.
- Four taxa (3.5%) were limited to an area approximately midway between the Packwood Lake outlet and the confluence of lower Lake Creek with the Cowlitz River. These four taxa were found primarily at sites 3-U and 4-L, which may be influenced by accretion of cold groundwater, as suggested by the presence of intolerant and long-lived (semi-voltine) taxa.

- Four taxa (3.5%) that favor larger rivers and streams were, not surprisingly, found in highest abundance near the confluence of Lake Creek with the Cowlitz River. Two of the four large-system taxa, *Skwala* and *Arctopsyche grandis*, might well be in highest abundance in Reach 1 of lower Lake Creek because of association with a larger population in the Cowlitz River.
- The remaining 18 taxa (15.5%) were either common throughout lower Lake Creek or were common throughout both Upper and lower Lake Creek.

Invertebrate abundance:

- Invertebrate abundance in both Upper and lower Lake Creek rated “low” as compared with similar west-Cascade mountainous streams (Wisseman 1996). This appeared to be more associated with low nutrient availability in the entire drainage, rather than due to Project effects. In fact, the highest abundance was on lower Lake Creek (site 5-O) immediately downstream of Packwood Lake and the Project diversion.

Total taxa richness:

- Total Taxa richness was generally “low” as compared with similar west-Cascade mountainous streams (Wisseman 1996). Increases in total taxa richness in a downstream direction appeared to be associated with increased channel stability, greater habitat complexity, and reduced disturbance regimes downstream from Packwood Lake. This suggests that changes were more likely driven by changes in natural gradients rather than by Project impacts.

EPT taxa richness:

- EPT taxa richness followed a similar pattern as total taxa richness. EPT taxa richness was generally “low” as compared with similar west-Cascade mountainous streams (Wisseman 1996). Increases in habitat complexity, nutrient availability and channel stability downstream from Packwood Lake were most likely the major factor causing increases in EPT Taxa richness scores in lower Lake Creek.

Percent dominant (3 taxa):

- Percent dominant (3 taxa) ratings improved in a downstream direction, with ratings of good throughout Reaches 1, 2, 3 and site 4-L. The poor rating at site 5-O is likely the result of a limited number of taxa taking advantage of the warmer, nutrient-rich water leaving Packwood Lake. Please note that site 5-U, approximately 0.1 miles downstream from site 5-O, achieved a percent dominant rating of good.

Major invertebrate group abundance:

- All major invertebrate groups that one would expect to find in a mid-order, montane, forested stream were present and generally in expected densities. Stoneflies (Plecoptera), caddisflies (Trichoptera), and mayflies (Ephemeroptera) were relatively common and most abundant in

habitats one would expect them to inhabit. Most other lotic habitat taxa were found in Lake Creek, through in lower densities than mayflies, caddisflies, as stonesflies as would be expected in a healthy, mid-order, montane, forested stream.

- Equally as informative as what invertebrate groups were found is information about the invertebrate groups were not found. Macroinvertebrate taxa common in lentic (still) water bodies were either not found, or found in very low numbers. These taxa included: true bugs (Hemiptera), dragonflies (Odonata), beetles (Coleoptera), true flies (Diptera), and non insects (e.g. Nematoda, Amphipoda, Copepoda).

Feeding group:

- The shredder feeding groups was most prevalent in the Upper Lake Creek reach.
- The filterer feeding group was generally the most prevalent feeding group downstream from Packwood Lake through reaches 4 and 5.
- Although feeding group composition was more mixed in reaches 1, 2, and 3 as compared with sites upstream, the most prevalent feeding group in these reaches was the grazing feeding group.
- These findings are very consistent with what one might expect in a mid-order, forested stream like Lake Creek that has a lake influence just upstream of reaches 4 and 5.

Tolerant taxa:

- Tolerant taxa represented less than 10% of the community composition at all sites except 5-U. Site 5-U had a tolerant taxa level of 13%, suggesting that this site had warmer water and higher nutrients than other reaches of Upper and lower Lake Creek.

Intolerant taxa:

- Intolerant taxa were present in significant numbers (greater than 10 % contribution) in all reaches of the lower Lake Creek bypass reach. As one might expect, intolerant taxa levels immediately below Packwood Lake were very low (0.7% and 0.9% at sites 5-O and 5-U, respectively). Intolerant taxa percent contribution, however, was found to be 17% just 0.3 miles below the lake outlet and was found to be as much a 42% of the community composition at site 3-U. This suggests that lower Lake Creek is a healthy, rather than impaired stream.

Semi-voltine species:

- Less than 10% of the community composition was represented by semi-voltine species at all sites in Upper and lower Lake Creek, except site 3-U. It is difficult to attribute low semi-voltine levels to Project or non-project factors, as numbers were low throughout the drainage.

Changes in metrics along the longitudinal profile of the Lake Creek drainage were generally consistent with expectations that energy flow and benthic invertebrate community structure will shift in a gradual fashion along a gradient of increasing stream size (and decreasing elevation) in a watershed (Vannote et al. 1980). Rapid changes in metrics immediately downstream from Packwood Lake (e.g. high invertebrate abundance, reduced total taxa and EPT richness, and presence of “tolerant” taxa) were generally limited to the area immediately below the lake (approximately 0.1 to 0.3 river miles). These effects are more likely the result of natural influences of Packwood Lake rather than Project operation. The outflow from the lake is warm relative to upstream and downstream water temperatures. The outflow also is higher in nutrients due to phytoplankton production in the lake’s surface waters. These differences result in the changes in the aquatic invertebrate community.

Reduced flow out of Packwood Lake has the effect of shortening the stream length populated by tolerant taxa. Natural mean monthly outflow from Packwood Lake for August through October ranges 71 cfs to 56 cfs. The Project releases 3 cfs just downstream of Packwood Lake. The natural flow would have the effect of extending the length of channel with warm water temperatures. EPT and total taxa richness in downstream reaches would likely be lower without the Project. The aquatic invertebrate community characteristic of Reach 5 would extend further downstream.

There is no indication that Threatened, Endangered, Species of Concern or Watch List Species occur within Project waters. Considering the types of aquatic habitats encountered during sampling and using best professional judgment, it is highly unlikely that any such species would be encountered in the Project area (R. Wisseman, Pers. Comm., July 9 2006).

6.0 LITERATURE CITED

- Armitage, P.D. 1984. Environmental changes induced by stream regulation and their effect on lotic macroinvertebrate communities. pp. 139-166 in: Lillehammer, A & S.J. Saltveit (eds.), *Regulated Rivers*. Oslo University Press, Oslo, Norway.
- Barbour, M.T., J.B. Stribling, & J.R. Karr. 1995. Multimetric approach for establishing biocriteria and measuring biological condition. pp. 63-77 in Davis, W.S. & T.P. Simon (editors). *Biological assessment and criteria: tools for water resource planning and decision making*. Lewis Publishing, Boca Raton, Florida.
- Barbour, M.T., J. Gerritsen, B.D. Snyder & J.B. Stribling 1999. Revision of rapid bioassessment protocols for use in streams and rivers- periphyton, benthic macroinvertebrates, and fish. Washington D.C., U.S. Environmental Protection Agency, Office of Water Report, EPA 841-D-97-002 (variously paged).
- Brusven, M.A. 1984. The distribution and abundance of benthic insects subjected to reservoir-release flows in the Clearwater River, Idaho, USA. pp 167-180 in: Lillehammer, A & S.J. Saltveit (eds.), *Regulated Rivers*. Oslo University Press, Oslo, Norway.

- Chutter, F.M. 1972. An empirical biotic index of the quality of water in South African streams and rivers. *Water Research* 6: 19-30.
- EES Consulting. 2006. Draft Water Quality Interim Report: 1st Year Study Results for Energy Northwest's Packwood Lake Hydroelectric Project, FERC No. 2244. Lewis County, Washington. 87 pp.
- EES Consulting. 2005. Final Lake Creek Physical Habitat Assessment Survey. Prepared for Energy Northwest. Packwood Lake Hydroelectric Project, FERC No. 2244. Lewis County, Washington. 10 pp.
- Energy Northwest. 2004. Pre-application Document. Packwood Lake Hydroelectric Project, FERC Project No. 2244. November 10, 2004.
- Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. *The Great Lakes Entomologist*, 20: 31-39.
- Karr, J.R. & E.W. Chu. 1999. Restoring life in running waters: better biological monitoring. Island Press, Washington, D.C.
- Merritt, R.W. & K.W. Cummins. 1996. An introduction to the aquatic insects of North America. Third edition. 862 pp. Kendall/Hunt Publishing Company, Dubuque, Iowa.
- NBAWG 2002 (unpublished draft). Level 3 standard taxonomic effort for benthic invertebrate biomonitoring studies in the Pacific Northwest. www.xerces.org
- Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross & R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. Assessment and Water Protection Division, U.S. Environmental Protection Agency, Report EPA/440/4-89-001. Washington, D.C. Revisions (1996) available at www.epa.gov/OWOW/monitoring/AWPD/RBP/ch1main.html
- Stanford, J.A. & J.V. Ward. 1983. Insect species diversity as a function of environmental variability and disturbance in stream systems. Pp 265-278 in: Barnes, J.R. & G.W. Minshall (eds.) *Stream Ecology-Applications and Testing of General Ecological Theory*. Plenum Publishers, New York.
- Strobel, C.J., D.J. Klemm, L.B. Lobring, J.W. Eichelberger, A. Alford-Stevens, B.B. Potter, R.F. Thomas, J.M. Lazorchak, G.B. Collins, and R.L. Graves, Eds. August 1995. Environmental Monitoring and Assessment Program (EMAP) Laboratory Methods Manual – Estuaries. Volume 1 – Biological and Physical Analyses. EPA/620/R-95/008.
- ROD. 1994. Record of decision for amendments to the Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of habitat for late-successional and old-growth forest

- related species within the range of the northern spotted owl. U.S. Department of Agriculture, Forest Service, Portland, Oregon. ii + 73 pp.; vii = 143 pp.
- USDA Forest Service. 2005. Comments on PAD and Scoping Document 1 and Study Requests. Packwood Lake Project Number 2244-012. March 11, 2005.
- U.S. Environmental Protection Agency. 1990. Biological Criteria: National Program Guidance for Surface Waters. Office of Water Regulations and Standards. U.S. EPA, Washington, D.C. EPA-440/5-90-004.
- Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R. & C.E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*. 37: 130-137.
- Ward, J.V. 1992. *Aquatic Insect Ecology 1. Biology and Habitat*. John Wiley & Sons, Inc. New York. 438 pp.
- Washington Administrative Code. 2003. Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC. Amended July 1, 2003.
- Washington Department of Fish and Wildlife. 2006. State Threatened, Endangered, and Species of Concern. <http://wdfw.wa.gov/wlm/diversite/soc/soc.htm>
- Washington Department of Ecology (Ecology). 2004. Water Quality Certifications for Existing Hydropower Dams: Preliminary Guidance Manual. Pub. No. 04-10-022. Olympia WA.
- WDOE 2001. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams. Publication No. 01-03-028.
- Williams, D.D. & N.E. Williams. 1998. Invertebrate communities from freshwater springs: what can they contribute to pure and applied ecology? In: Botosaneanu, L. (ed.), *Studies in Crenobiology*, Backhuys Publishers, Leiden, 261 pp.
- Wisseman, R.W. 1996. Version 1.0. Unpublished ecological coding attributes for freshwater invertebrate taxa in western North America. Available from the author in electronic format. This version of the coding is in general use by agencies in western North America, including the Oregon Department of Environmental Quality.
- Wisseman, R.W. 1996b (unpublished). Benthic invertebrate biomonitoring and bioassessment in western montane streams. Aquatic Biology Associates, Inc., Corvallis, Oregon. 12 pp + tables.
- Wisseman, R.W. July 9, 2006. Personal Communication.
- Zimmermann, H.J. & J.V. Ward. 1984. A survey of regulated streams in the Rocky Mountains of Colorado, USA. pp. 251-262. In: Lillehammer, A & S.J. Saltveit (eds.), *Regulated Rivers*. Oslo University Press, Oslo, Norway

APPENDIX A

Taxa List

Table A-1. Taxa Rare or Absent in Lake Creek Reaches Immediately Below the Packwood Lake Outlet, and Usually in Unstable/Scoured Substrates Above the Lake

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
<i>Turbellaria</i>	4	5	3	5	12	27	0	5	0	0	0		0	9	0
<i>Oligochaeta</i>	4	9	5	8	5	43	19	4	0	0	0		0	1	0
<i>Rhithrogena</i>	4	30	16	8	3	27	0	0	0	0	0		20	4	70
<i>Doroneuria</i>	3	4	1	14	8	100	4	1	0	1	0		0	0	0
<i>Pteronarcys princeps</i>	3	1	1	3	4	18	7	4	0	0	0		0	0	0
<i>Oligophlebodes</i>	3	12	30	26	11	4	0	0	0	0	0		0	1	0
<i>Heterlimnius</i>	24	32	18	7	12	41	23	38	0	0	0		0	0	0

Table A-2. Taxa Restricted to or Preferring Reaches of Lake Creek Influenced by Outflow from Packwood Lake

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
<i>Pisidium</i>	1	0	0	0	0	0	0	0	0	42	546		0	0	0
<i>Ferrissia</i>	0	0	0	0	0	0	0	0	0	1	0		0	0	0
<i>Physa/Physella</i>	0	0	0	0	0	0	0	0	0	1	0		0	0	0
<i>Menetus</i>	0	0	0	0	0	0	41	9	5	39	17		0	0	0
<i>Gammarus</i>	0	0	0	0	0	0	0	0	0	4	10		0	0	0
<i>Hyalella</i>	0	0	0	0	0	0	0	0	0	3	0		0	0	0
<i>Cordulegaster</i>	0	0	0	0	0	0	0	0	0	11	0		0	0	0
<i>Ephemerella excrucians</i>	1	1	0	12	4	16	1	1	3	8	103		1	0	0
<i>Hesperoperla pacifica</i>	0	0	0	0	0	0	0	0	0	1	7		0	0	0
<i>Hydropsyche</i>	54	51	15	57	27	13	59	167	284	132	503		0	1	0
<i>Xenochironomus</i>	0	0	0	0	0	0	0	0	0	0	7		0	0	0

Table A-3. Taxa Restricted to or in Greatest Abundance at Site 3-U and Site 4-L

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
<i>Pristinicola hemphilli</i>	0	0	0	0	0	0	15	0	0	0	0		0	0	0
<i>Frisonia picticeps</i>	1	1	0	0	0	30	0	0	1	0	0		0	0	0
<i>Yoraperla mariana</i>	0	0	0	4	1	147	4	4	0	3	0		1	8	0
<i>Parapsyche elsis</i>	0	0	0	0	0	27	5	0	0	0	0		1	0	0

Table A-4. Taxa Generally Restricted to the Sample Reach in Upper Lake Creek

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
<i>Ameletus</i>	1	0	1	0	0	2	0	0	0	0	0		89	0	3
<i>Baetis bicaudatus</i>	0	0	0	0	0	0	0	0	0	0	0		0	11	5
<i>Ephemerella dorothea infrequens</i>	0	0	0	0	0	0	0	0	0	0	0		0	19	9
Taeniopterygidae	0	0	0	0	0	2	0	0	0	0	0		383	20	257
<i>Dicranota</i>	0	0	0	0	0	0	0	0	0	0	0		0	7	0
<i>Rhabdomastix</i>	0	0	0	0	0	0	0	0	0	0	0		0	4	0
<i>Pagastia</i>	0	0	0	0	0	0	0	0	0	0	0		0	19	0
<i>Parorthocladius</i>	0	0	0	0	0	2	0	0	0	0	0		0	16	0

Table A-5. Common, Ubiquitous Taxa Found at Most Reaches/Sites Above and Below Packwood Lake

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
<i>Baetis tricaudatus</i>	142	196	86	165	122	91	62	54	116	35	3		49	11	36
<i>Caudatella hystrix</i>	0	20	4	3	27	14	8	26	46	0	3		0	0	8
<i>Drunella doddsi</i>	2	15	8	16	1	5	9	7	1	0	0		3	3	3
<i>Drunella spinifera</i>	0	4	0	8	0	7	3	4	26	0	0		0	0	0
<i>Cinygmula</i>	6	14	8	19	3	29	3	0	0	0	0		23	15	0
<i>Epeorus grandis</i>	12	22	24	19	47	2	31	1	34	0	0		0	1	12
<i>Zapada cinctipes</i>	25	22	5	26	19	18	3	4	0	8	60		1	103	1
<i>Zapada Oregonensis Group</i>	4	4	4	8	9	9	4	5	4	1	0		1	99	7
<i>Rhyacophila Brunnea/Vemna Group</i>	6	9	1	9	12	11	8	8	8	7	3		0	3	1
<i>Simulium</i>	15	7	5	0	1	0	8	0	19	34	33		12	32	0
<i>Eukiefferiella</i>	12	14	0	0	1	16	11	8	1	5	10		14	107	0
<i>Brillia</i>	4	3	0	0	1	0	1	0	0	23	0		0	19	0
<i>Paraleptophlebia</i>	6	5	3	7	1	36	0	0	0	1	3		0	5	0

Table A-6. Occasional or common taxa in most reaches below Packwood Lake.

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
<i>Ironodes</i>	5	11	3	5	3	9	20	39	9	3	0		0	0	0
<i>Glossosoma</i>	24	51	24	15	0	20	3	3	4	0	0		0	0	0
<i>Micrasema</i>	29	80	49	45	58	82	19	24	49	20	3		0	1	0
<i>Antocha</i>	10	8	1	36	50	38	7	27	14	1	0		0	0	0
<i>Rheotanytarsus</i>	1	0	0	4	7	7	0	22	1	18	0		0	0	0

Table A-7. Taxa Typically Encountered in Lower Elevation, Larger Streams

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
<i>Skwala</i>	4	3	0	0	0	0	0	0	0	0	0		0	0	0
<i>Amiocentrus aspilus</i>	1	0	0	4	3	0	0	0	0	0	0		0	0	0
<i>Brachycentrus americanus</i>	1	0	1	3	0	0	0	0	0	0	0		0	0	0
<i>Arctopsyche grandis</i>	8	0	1	0	0	0	0	0	0	0	0		0	0	0

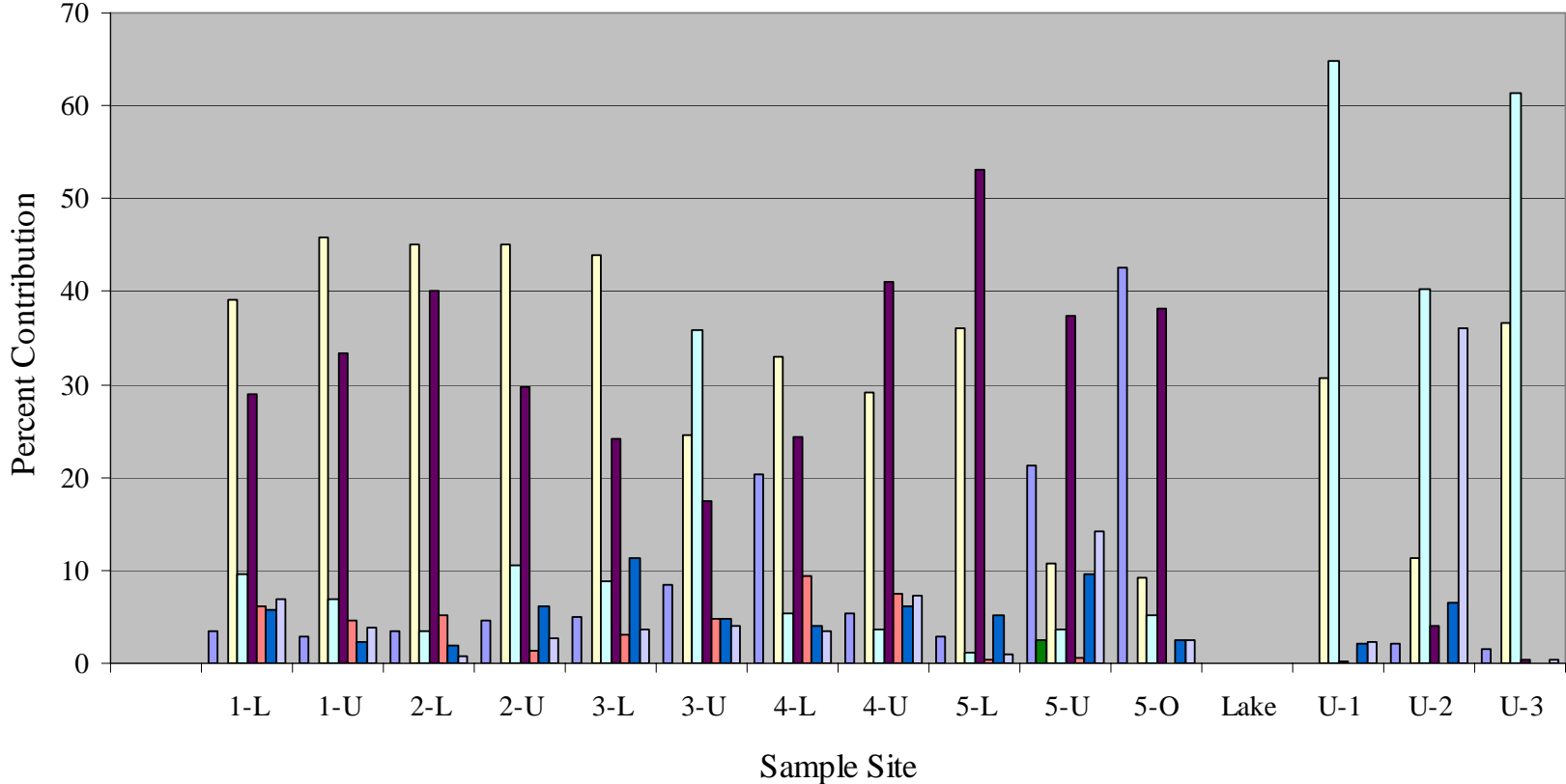
Table A-8. Miscellaneous Rare or Uncommon Taxa with No Apparent Trend, or Abundance Too Low to Assess Patterns or Trends

Sample Site Name	Lower Lake Creek											Packwood Lake	Upper Lake Creek Unregulated		
	1-L	1-U	2-L	2-U	3-L	3-U	4-L	4-U	5-L	5-U	5-O		U-1	U-2	U-3
Nematoda	4	0	0	7	0	0	11	5	9	0	3		0	1	1
Pisicolidae	0	0	1	0	0	0	0	0	0	0	0		0	0	0
Acari	4	5	3	7	7	14	3	3	4	3	0		0	1	5
<i>Dipheter hageni</i>	1	0	0	1	0	4	0	1	0	0	10		0	0	0
<i>Attenella delantala</i>	0	0	1	0	0	0	0	0	0	0	0		0	1	0
<i>Drunella coloradensis</i>	0	0	0	0	0	2	0	0	0	0	0		0	5	0
<i>Serratella tibialis</i>	1	0	0	0	0	0	0	0	0	0	0		0	0	0
<i>Epeorus</i>	0	3	0	3	0	0	4	14	1	0	0		0	0	0
Capniidae	0	0	0	1	0	5	0	0	0	0	0		0	1	0
Chloroperlidae	0	0	0	3	0	5	0	0	0	0	0		0	1	0
<i>Kathroperla perdita</i>	0	3	0	0	0	0	0	0	0	0	0		0	0	0
<i>Sweltsa</i>	1	5	0	4	0	7	1	0	0	0	0		1	24	1
Leuctridae	1	0	0	0	0	0	0	0	0	0	0		0	0	0
<i>Malenka</i>	0	0	0	0	0	0	0	0	0	1	0		0	0	0
<i>Soyedina</i>	0	0	0	0	0	0	0	0	0	0	0		0	3	0
<i>Visoka cataractae</i>	1	3	0	0	0	4	0	0	0	0	0		0	0	0
<i>Zapada columbiana</i>	0	0	0	0	0	0	0	0	0	0	0		0	1	0
Perlodidae	2	1	0	0	0	5	0	0	0	0	0		0	3	0
<i>Isoperla</i>	0	0	0	0	0	0	0	0	0	0	3		1	0	14
<i>Megarctys</i>	0	1	0	0	0	2	0	0	0	0	0		0	5	3
<i>Yoraperla brevis</i>	0	0	0	0	0	0	0	0	3	0	0		0	0	0
<i>Lepidostoma</i>	0	1	0	0	0	0	0	1	3	0	0		0	0	0
<i>Lepidostoma cascadense</i>	3	7	0	1	3	2	0	0	0	0	0		0	0	0
<i>Ecclisomyia</i>	0	0	0	0	0	0	0	0	0	0	0		0	1	0
<i>Wormaldia</i>	1	1	0	0	0	0	1	1	0	0	0		0	0	0
<i>Himalopsyche phryganea</i>	0	0	0	0	0	0	0	1	0	0	0		0	0	0
<i>Rhyacophila</i>	0	1	0	1	0	2	0	0	0	0	0		0	15	0
<i>Rhyacophila Betteni Group</i>	1	3	1	0	0	4	3	0	0	1	7		0	0	0
<i>Rhyacophila blarina</i>	0	0	0	0	0	0	0	0	0	0	0		0	3	0
<i>Rhyacophila grandis</i>	0	0	0	0	0	0	0	0	0	0	0		0	1	0
<i>Rhyacophila Hyalinata Group</i>	1	8	11	5	1	0	4	0	0	0	0		0	0	0
<i>Rhyacophila narvae</i>	0	8	3	1	1	0	0	0	0	0	0		0	0	0
<i>Rhyacophila pellisa/valuma</i>	1	0	0	1	0	2	3	0	0	0	0		0	0	0
<i>Neophylax</i>	4	0	0	7	0	9	0	4	1	0	0		0	0	0
<i>Neophylax splendens</i>	0	0	1	0	0	0	0	0	0	0	0		0	0	0
<i>Ampumixis dispar</i>	0	0	0	1	1	5	15	0	0	1	0		0	0	0
<i>Cleptelmis addenda</i>	0	0	0	0	0	0	0	0	3	1	0		0	0	0
<i>Lara</i>	4	0	0	0	1	2	1	0	0	0	0		0	0	0
<i>Narpus</i>	1	0	0	0	0	0	1	0	0	0	0		0	0	0
Ceratopogoninae	0	0	0	0	1	0	0	0	0	0	0		0	0	0
<i>Dixa</i>	0	0	0	0	0	0	0	0	0	4	0		0	0	0
<i>Chelifera/Metachela</i>	0	0	0	0	0	0	0	1	1	3	0		0	0	0
<i>Oreogeton</i>	1	0	0	0	0	0	0	0	0	0	0		0	0	0
<i>Wiedemannia</i>	0	0	0	0	0	2	0	0	0	0	0		0	0	0
<i>Glutops</i>	1	0	0	0	0	4	1	3	0	0	0		0	0	0
<i>Maruina</i>	0	1	0	0	0	0	1	0	0	0	0		0	0	0
<i>Pericoma</i>	0	0	0	0	1	0	0	0	0	0	0		0	0	0
<i>Prosimulium</i>	1	0	0	0	0	2	0	0	0	0	0		0	0	0
<i>Limonia</i>	0	0	0	0	0	2	0	0	0	0	0		0	0	0
<i>Cladotanytarsus</i>	0	0	0	0	0	0	0	0	1	0	0		0	0	0
<i>Diplocladius</i>	0	0	0	0	0	0	0	0	0	0	0		0	1	0
<i>Eukiefferiella Devonica Group</i>	0	1	0	0	1	0	1	0	1	1	0		0	0	0
<i>Metricnemus</i>	0	0	0	0	0	0	0	0	0	1	0		0	0	0
<i>Microsectra</i>	4	3	0	5	3	4	0	0	0	3	0		0	5	0
<i>Microtendipes</i>	0	1	0	7	0	2	0	1	0	5	0		0	0	0
<i>Orthocladus Complex</i>	0	0	0	0	0	2	0	3	0	0	0		0	9	0
<i>Orthocladus</i>	0	0	0	0	0	0	0	0	0	0	0		0	1	0
<i>Parametricnemus</i>	0	0	0	0	1	0	0	0	0	0	0		0	0	0
<i>Stilocladus</i>	0	0	0	0	0	0	0	0	0	0	0		0	1	0
<i>Symposiocladius</i>	0	0	0	0	0	2	0	0	0	0	0		0	0	0
<i>Tanytarsus</i>	0	0	0	0	0	0	0	0	0	1	3		0	0	0
<i>Thienemanniella</i>	1	1	0	0	0	0	0	0	0	0	0		0	0	0
<i>Thienemanniella Complex</i>	1	0	0	0	0	0	0	0	0	3	13		0	0	0
<i>Tvetenia Bavarica Group</i>	7	0	0	0	1	0	0	1	0	0	0		0	3	0

APPENDIX B

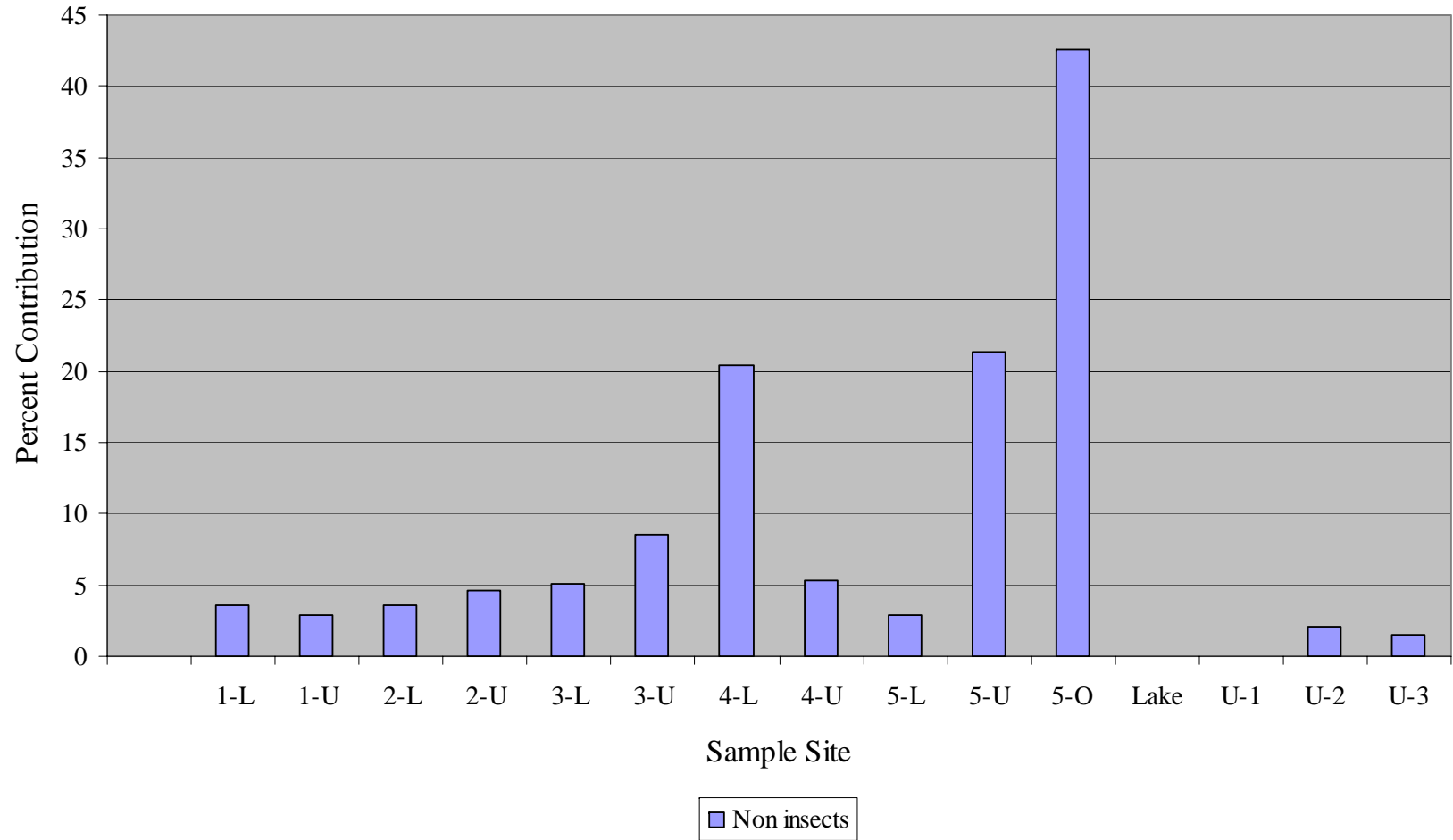
Invertebrate Groups - Percent Contribution

**Packwood Lake Hydroelectric Project
Macroinvertebrate Study - Major Invertebrate Groups**

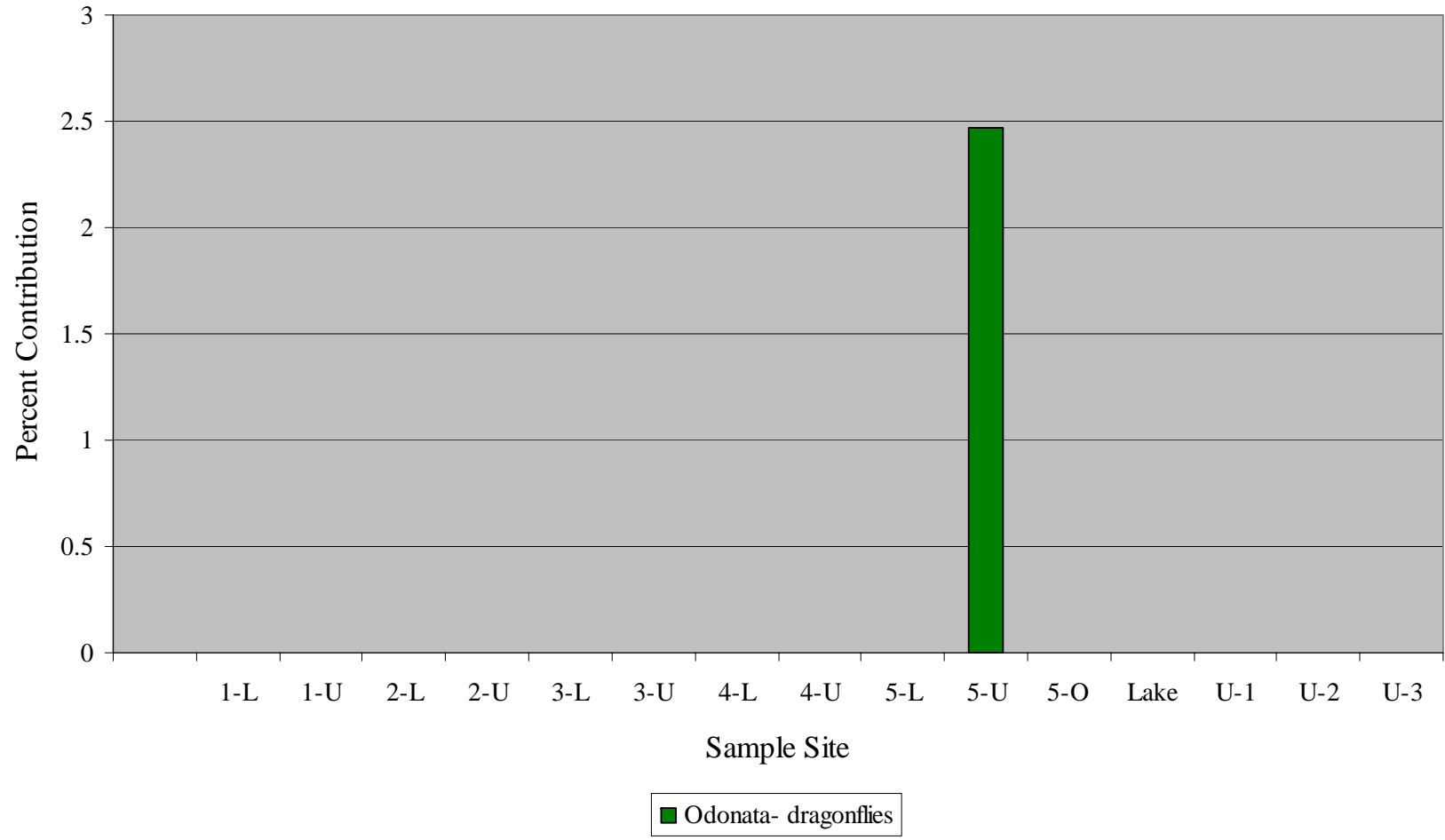


- Non insects
- Odonata- dragonflies
- Ephemeroptera- mayflies
- Plecoptera- stoneflies
- Trichoptera- caddisflies
- Coleoptera- beetles
- Misc. Diptera- true flies
- Diptera: Chironomidae- midges

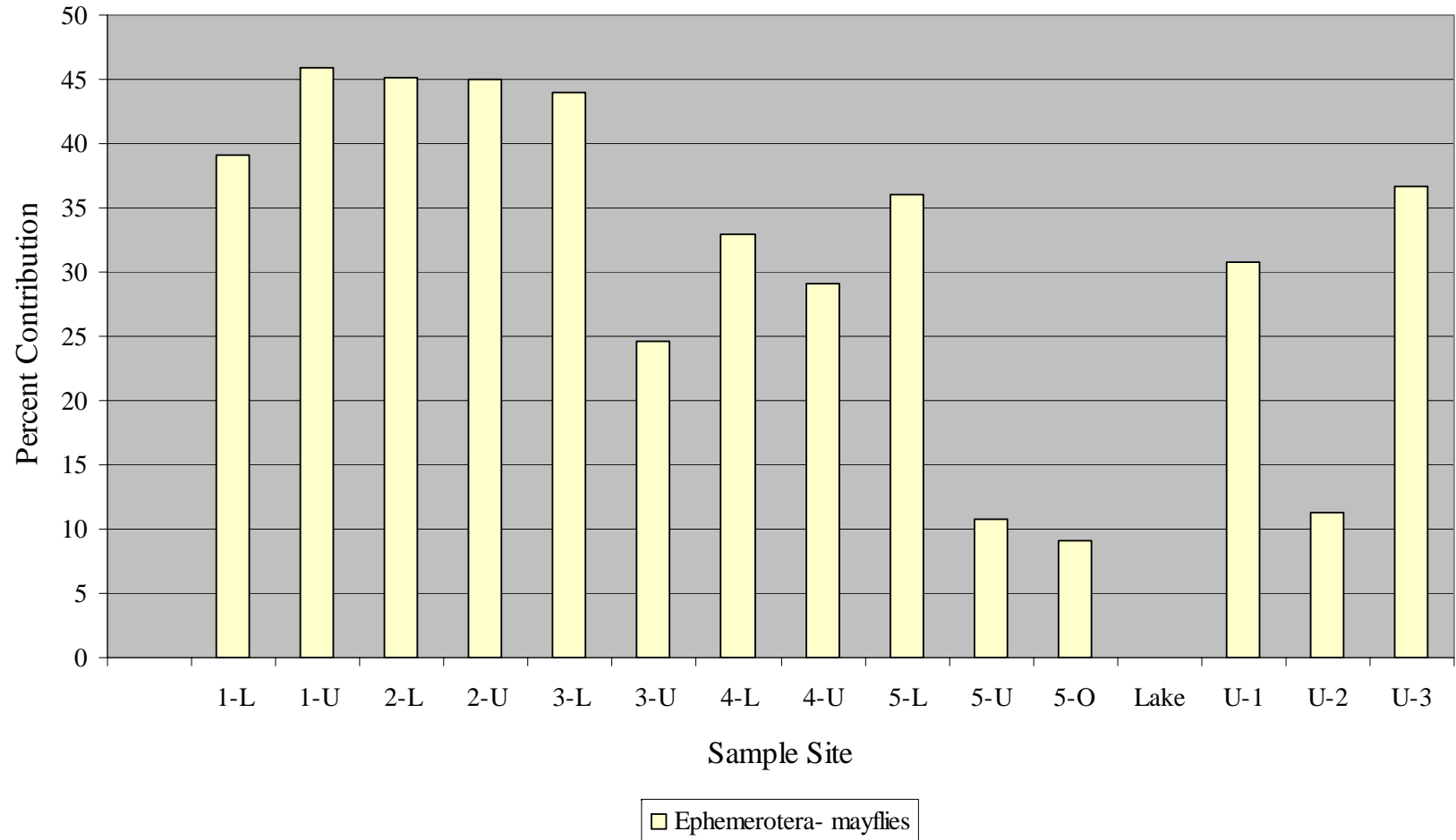
Packwood Lake Hydroelectric Project Macroinvertebrate Study



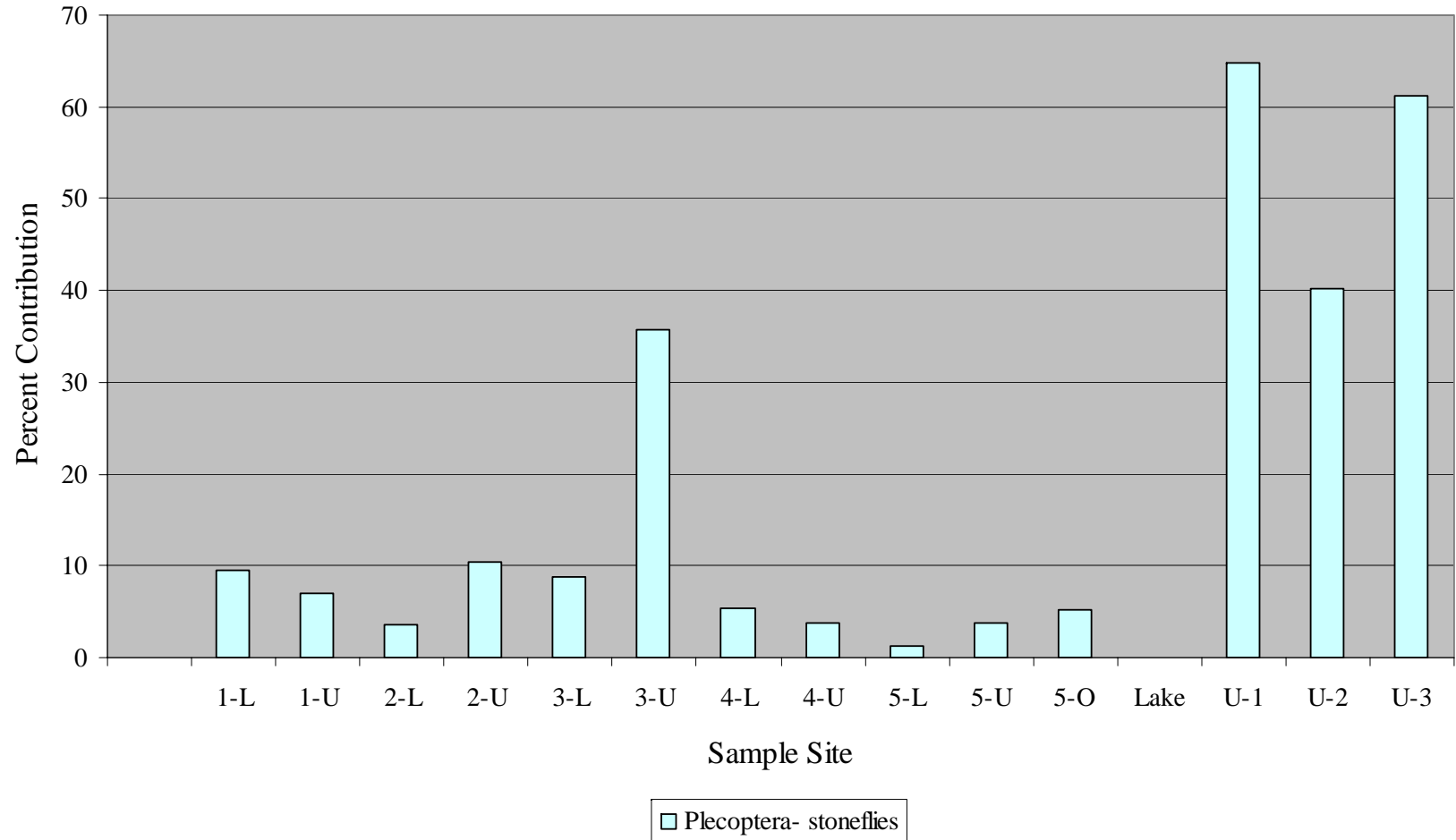
**Packwood Lake Hydroelectric Project
Macroinvertebrate Study**



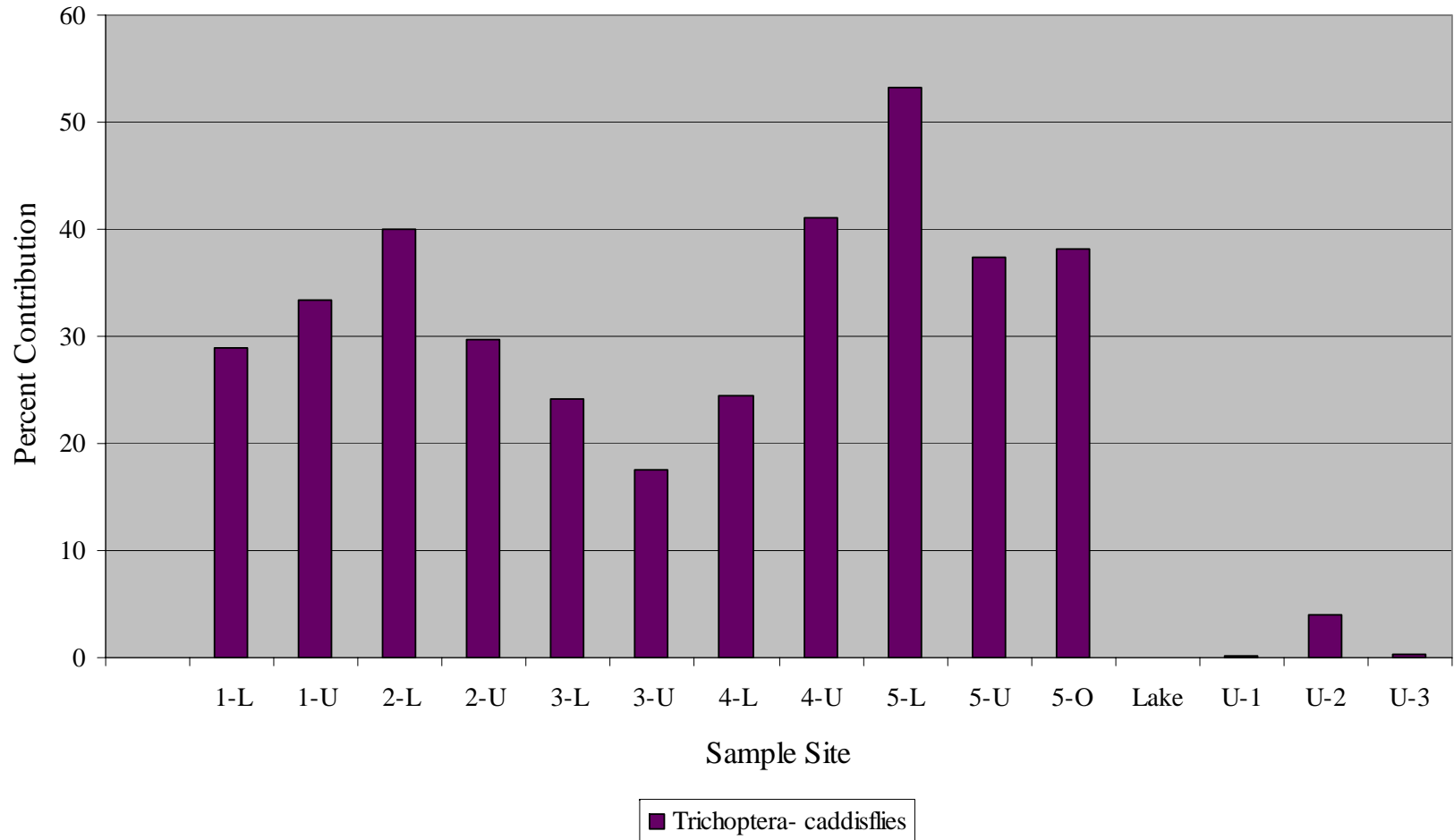
Packwood Lake Hydroelectric Project Macroinvertebrate Study



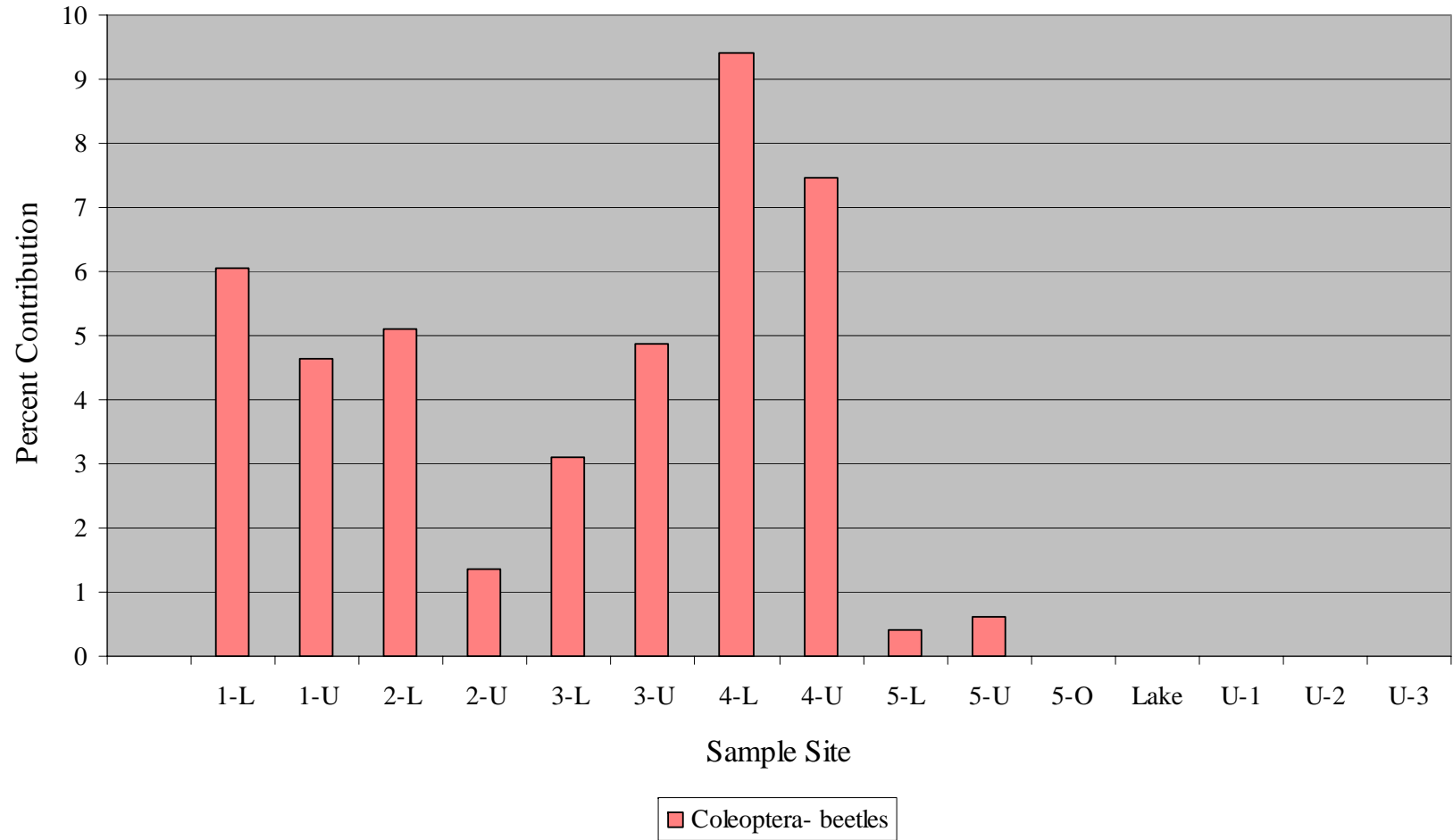
**Packwood Lake Hydroelectric Project
Macroinvertebrate Study**



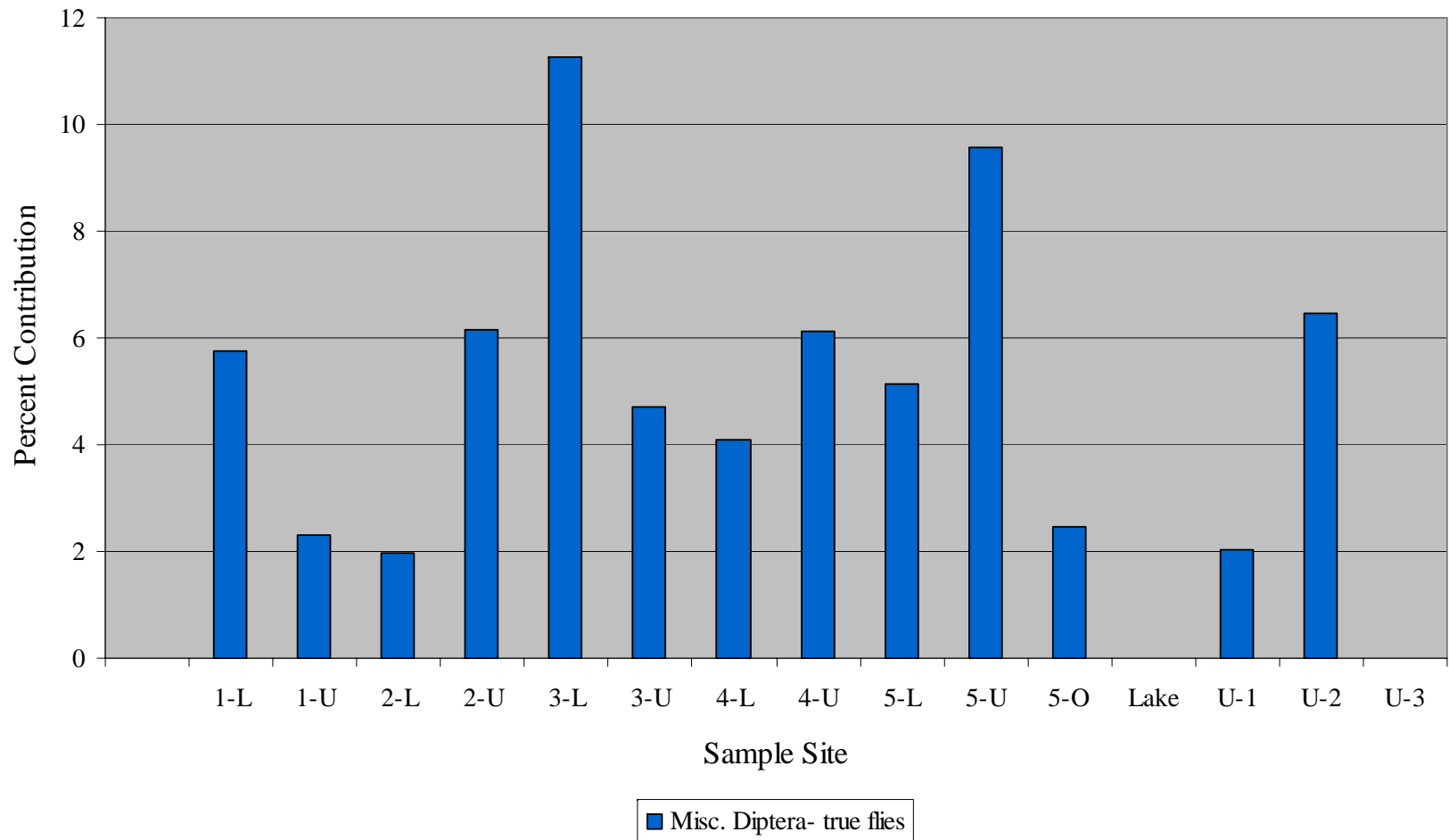
**Packwood Lake Hydroelectric Project
Macroinvertebrate Study**



Packwood Lake Hydroelectric Project Macroinvertebrate Study



Packwood Lake Hydroelectric Project Macroinvertebrate Study



**Packwood Lake Hydroelectric Project
Macroinvertebrate Study**

