Whatcom Creek
Post-Fire Evaluation – 10 Years After

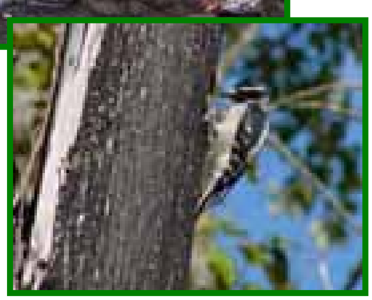
Prepared for:

City of Bellingham
Department of Public Works

Prepared by:

R2 Resource Consultants, Inc.
15250 NE 95th Street
Redmond, Washington 98052-2518

May 29, 2009



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Prepared by:

Susan W. Madsen
Tim Nightengale

R2 Resource Consultants, Inc.
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Acknowledgements

This report would not have been possible without the assistance of several City of Bellingham interns and the City-Sponsored WCC Crews. Brenna Forester and Kaci Radcliffe assisted with data collection and analysis, and were always cheerfully ready to help the authors as needed. The two WCC crews have contributed countless hours over the past eight years helping to construct, replant and maintain the restoration sites, and assisting with spawning surveys and other monitoring tasks. In addition crew lead Andy Wargo and Corps members Melissa Thompson and Michelle Toshack provided invaluable assistance with GIS maps. Bill and Debbie Cantrell of Cantrell and Associates Inc., provided valuable insight of revegetation activities immediately following the fire. Section 2.1 of this document was largely extracted from their 2007 Report, which is provided as Appendix A. Special thanks to Earle Steele, Bellingham Technical College Fisheries Program Manager, for supplying up to date data on hatchery returns and releases and providing valuable insight on historical fish runs.

EXECUTIVE SUMMARY

On June 10, 1999 an underground pipeline ruptured in Bellingham, Washington, releasing approximately 237,000 gallons of unleaded gasoline into Hannah Creek. Spilled gasoline flowed down Hannah Creek, entering Whatcom Creek through the soil and surface water. The unleaded gasoline flowed downstream in Whatcom Creek as surface flow. At approximately 4:55 pm the gasoline was ignited, resulting in an explosion and fire. These events resulted in the deaths of three people, and burning of approximately 26 acres of trees and vegetation, including 16 acres of mature second-growth forest within Whatcom Falls Park and 10 acres of third- or fourth-generation floodplain forest and meadow west of the park (Map 1). Fish and wildlife impacts were impossible to fully quantify. Field staff collected or observed more than 100,000 dead salmon, trout, lamprey, and crayfish in the days following the fire. Scientists concluded that all aquatic life in three miles of Whatcom Creek was killed through direct contact with the fuel or fumes, or when the fuel ignited.

Under the Oil Pollution Act (OPA) of 1990, the parties responsible for the release of petroleum products are liable for the costs to restore natural resources. An oversight board, called the Natural Resource Trustees was established; its members include: the United States Department of Commerce as represented by the National Oceanic and Atmospheric Administration; the United States Department of the Interior as represented by the United States Fish and Wildlife Service; the State of Washington as represented by the Department of Ecology; the Lummi Nation of Washington; the Nooksack Tribe of Washington; and the City of Bellingham, appointed by the Governor. The Trustees oversaw the initial emergency response actions and development of a Long-term Restoration Plan designed to determine the impacts of the spill on natural resources and identify measures that would be implemented to restore those injured resources. The plan included three primary components: 1) restoration actions, including emergency response and long-term restoration activities; 2) monitoring to track recovery of injured resources within the burn zone; and 3) monitoring and maintenance of sites where specific restoration actions were implemented. The Trustees and the Olympic Pipe Line Company have established a fund of $500,000 from which all long-term monitoring and maintenance activities related to this incident are supported.

Data utilized to complete the post-fire evaluation of Whatcom Creek were generated primarily through ongoing monitoring activities conducted by the City of Bellingham. The Post-Fire Evaluation report (R2 2009) provides a point-in-time re-evaluation of environmental conditions

in the burn zone in 2009 as compared to post-burn conditions and the original restoration plan goals.

The post-fire evaluation of the burn zone focuses on three aspects of the environment: 1) Biological Monitoring; 2) Physical and Chemical Monitoring; and 3) Photo documentation.

Within each broad group the following specific topics were investigated:

1. Biological Monitoring:
   - Vegetation;
   - Fish community;
   - Aquatic macroinvertebrates; and
   - Riparian and terrestrial wildlife.
2. Physical Monitoring:
   - Instream habitat;
   - Soil Erosion and Slope Stability; and
   - Water quality.
3. Photodocumentation.

Vegetation Ten years after the fire, aquatic and terrestrial ecosystems associated with Whatcom Creek are well on their way to recovery. Vegetation monitoring was conducted in 2000, and again in 2006-2007 (Cantrell and Associates 2007). Trees planted following the Whatcom Creek fire have been largely successful in survival and growth. While the number of young trees per acre has decreased slightly and the spacing between trees has increased slightly since 2000, this is to be expected as trees mature and naturally thin due to competition for resources. The number of trees per acre decreased by only 12 percent, while 95 percent of trees that remain have at least doubled in height, and 71 percent of the planted trees are 5-feet tall or taller. Average canopy cover in the Whatcom Creek study area increased from near zero in many areas to 47 percent, and will likely continue to rise as planted trees continue to grow. Control of invasive species remains an ongoing challenge, but periodic monitoring facilitates the early identification and treatment of problem sites. Immediate treatment of exposed soils appears to have successfully prevented ongoing erosion problems related to the fire.

Fish Community The City of Bellingham has conducted surveys of spawning salmon in the burn zone since 1999. City staff walk the stream every seven to ten days from September through March, counting live adult fish, salmon carcasses and redds (where salmon lay their eggs). In 2000 and 2001 nearly 100 Chinook per year were observed spawning in the burn zone. In 2002, few Chinook were observed, but 92 chum were counted within the burn zone. Since that time fewer than ten Chinook or chum have been observed in any year during spawning surveys. Chinook salmon, coho salmon and steelhead trout that return to Whatcom Creek are also counted at the Whatcom Falls Hatchery before being released upstream. The number of anadromous fish returning to the Whatcom Creek Hatchery since the fire has also been substantially lower.

Several factors confound determination of a cause and effect relationship between the fire and the decline in fish returns to Whatcom Creek. Concurrent with the 1999 fire, several salmon species in Puget Sound were listed as threatened under the Endangered Species Act (ESA). At the time of the burn, the Washington Department of Fish and Wildlife Hatchery Management policies were evolving in response to ESA listings of anadromous fish throughout the Pacific Northwest. Operations at the Maritime Heritage facility were altered to bring them in line with the Washington Wild Salmonid Policy and emphasize production of local stocks. Prior to the fire large numbers of juvenile fish from stocks originating outside of the Nooksack basin were released to the Whatcom Creek. Planting of Chinook salmon was halted in 1999. At the same time numbers of coho salmon and steelhead trout were reduced to around 5,000 fish of each species each year.

Since the fire, physical conditions in Whatcom Creek have been improving. Flows in Whatcom Creek have increased during the spawning season of Chinook, chum and coho as compared to before the burn. The increase is due to changes in flow management as well as an increase in the amount of water available when delivery of 51 cfs to the Georgia Pacific Paper Mill ceased in 2001. Increased flows provide better fish access, and more habitat in some seasons. In addition, habitat surveys show that physical habitat attributes and water quality have been maintained or improved by the emergency response and long-term restoration actions. As a result, while the fire may have contributed to reduced returns it seems unlikely that it is the major factor responsible for the observed decline in adult returns.

Aquatic macroinvertebrates Aquatic insects (macroinvertebrates) in Whatcom Creek were sampled at three sites for five years following the fire (1999-2003), and again in 2007. These data were compared to samples collected by Ecology in 1998 to assess recolonization and recovery. Sampling seven days after the fire showed an almost complete loss of the macroinvertebrate community (LaCroix 2001). Estimates of the mean density (individuals/ m^2) in October 1999 indicate that aquatic insects rapidly repopulated sampling sites on Whatcom

Creek following the fire. However, data indicate that the type of aquatic insects inhabiting the stream has changed. Three months after the fire, both the Racine and James Street sites showed an increase in minnow-tailed mayflies (Baetidae), which are known to be more tolerant of poor water quality conditions. By the fall of 2000, both sites showed a return of flat-headed mayflies (Heptageniidae), a less-tolerant family of mayflies that were common before the burn, which suggested recovery was at hand, but their numbers since that time have continued to be significantly less than that seen in pre-burn samples.

Results of the comparative analysis indicate a shift away from aquatic insect species that graze on algae and other materials on streambed gravels (scrapers), towards a community of species that gather fine particulate matter (collector-gatherers). The reduction of percent scrapers in 1999 suggests that Whatcom Creek is not as productive as it was before the fire, at least in terms of algal growth. Two indices that are commonly applied in macroinvertebrate studies are the Community Tolerance Index (CTI) and Benthic Index of Biological Integrity (B-IBI). Results using CTI give scores ranging from 6.1 to 7.2, with an overall average CTI score of 6.6. On a biotic index scale of 0 to 10, this average score indicates "fair" conditions, often a result of "fairly significant organic pollution." Scores for the B-IBI ranged from 12 to 28, out of a possible total of 50, indicating that the sites on Whatcom Creek are in "poor" to "fair" condition. It is unclear whether this effect is related to the fire or other urban impacts within the Whatcom Creek watershed.

Riparian and Terrestrial Wildlife – Riparian restoration along the Whatcom Creek corridor has benefited all animals that use riparian forest areas. Using settlement funds, the City of Bellingham has acquired and restored native vegetation on two large parcels of land, increasing the amount of protected riparian habitat by 13.5 acres. In addition, planting of riparian areas occurred throughout the 26-acre burn zone. Although few quantitative data are available on wildlife use of the area prior to the 1999 fire, it appears that wildlife communities currently inhabiting the burn zone are similar to those that would be expected to inhabit the area in an urban ecosystem. Deer, mink and beaver are commonly observed along Whatcom Creek, as are tracks and scat of otter, coyote, raccoons and other small to mid-size mammals. The numerous snags created by the fire may have increased habitat for some species such as cavity-nesting birds and mammals. However, non-native bird species appear to dominate cavities in more open areas (Dolan 2008).

Hydrology and Instream Habitat – Stream habitat was surveyed immediately following the burn in 1999, and again following the emergency response restoration actions in 1999 and 2000. Additional surveys were conducted in 2007 and 2009 to track changes over time. Prior to the emergency response actions, aquatic habitat conditions in Whatcom Creek were considered poor according to all available criteria. Wood placement and pool excavation as part of the Emergency Response resulted in short-term improvements of habitat. Subsequent instream habitat restoration projects have maintained improved habitat conditions, particularly downstream of Woburn Street. Throughout the stream the amount of wood and the number of pools is similar to or better than in 1999. Off-channel habitats and the meandering channel configuration established by restoration projects at Salmon Park, Cemetery Creek and Red Tail Reach have improved habitat complexity and substantially increased backwater habitat that serves as refugia for juvenile salmon during floods.

Soil Erosion and Slope Stability – One of the greatest fears immediately following the fire was that slopes would undergo severe erosion during heavy fall rains following the fire. Immediate treatment and riparian plantings, in combination with recovery of plants whose roots survived underground prevented this from happening. No major areas of erosion that could be directly related to the 1999 fire were observed in 2009. In general slopes in these areas are well vegetated and appear stable.

Water Quality – Monthly water quality measurements upstream and downstream of the burn site indicate that the fire does not appear to have had a substantial, long-term negative effects of water quality parameters that are closely linked to biotic health. The most direct effect of the fire and subsequent loss of vegetation within the burn zone would have been to reduce the cooling properties of streamside vegetation. However, the data indicate that the relatively warm water flowing out of Lake Whatcom continues to cool slightly as it flows through the Whatcom Creek gorge, despite the loss of streamside vegetation. Subsequent property acquisition and revegetation projects completed as part of the Long-term Restoration Plan will eventually improve riparian shading levels as compared to the pre-fire conditions.

Dissolved oxygen levels appear to have increased in the burn zone since the fire. Dissolved oxygen is strongly related to temperature, flow and turbulence. While data show that temperatures do not appear to have increased as a result of the fire, habitat restoration projects completed as part of the emergency response and subsequent Long-term Restoration Plan have increased the hydraulic complexity and turbulence, and this is likely contributing to the increased DO levels observed in the burn zone. Conductivity, pH and turbidity do not appear to have been affected by the fire.

1. OVERVIEW

On June 10, 1999 an underground pipeline ruptured in Bellingham, Washington, releasing approximately 237,000 gallons of unleaded gasoline into Hannah Creek. Spilled gasoline flowed down the Hannah Creek drainage, entering Whatcom Creek through both the soil and surface water. The unleaded gasoline flowed downstream in Whatcom Creek as surface flow. At approximately 4:55 pm the gasoline was ignited, resulting in an explosion. The subsequent fire burned approximately 25 acres of riparian vegetation along the Whatcom Creek corridor (Figure 1-1).

Under the Oil Pollution Act (OPA) of 1990, the parties responsible for the release of petroleum products are liable for the costs to restore natural resources. A Board of Trustees was convened, composed of representatives of the public agencies and tribes affected by the incident. The Trustees oversaw development of a Long-term Restoration Plan designed to determine the impacts of the spill on natural resources and identify measures that would be implemented to restore those injured resources. The plan included three primary components: 1) monitoring to track recovery of injured resources within the burn zone; 2) restoration actions, including the purchase, replanting and instream habitat enhancement on several properties within the burn zone; and 3) monitoring and maintenance of sites where specific restoration actions were implemented. This report describes the results of the burn-zone monitoring component. Companion reports describe restoration actions implemented as part of the long-term monitoring plan (R2 2009), and monitoring and maintenance conducted at those restoration sites (Forester 2009).

This 2009 burn zone monitoring report is intended to provide a point-in-time re-evaluation of environmental conditions in the burn zone in 2009 as compared to post-burn conditions and the original restoration plan goals. Data utilized to complete this report were generated primarily through ongoing monitoring activities conducted by the City of Bellingham. Where data gaps occurred, targeted data collection was conducted to document current conditions within the burn zone. Information generated by this “snapshot” assessment will be used to develop recommendations for ongoing monitoring and or maintenance activities (if any) in the burn zone.

The post-burn evaluation of the burn zone focuses on three aspects of the environment: 1) Biological Monitoring; 2) Physical and Chemical Monitoring; and 3) Photodocumentation.

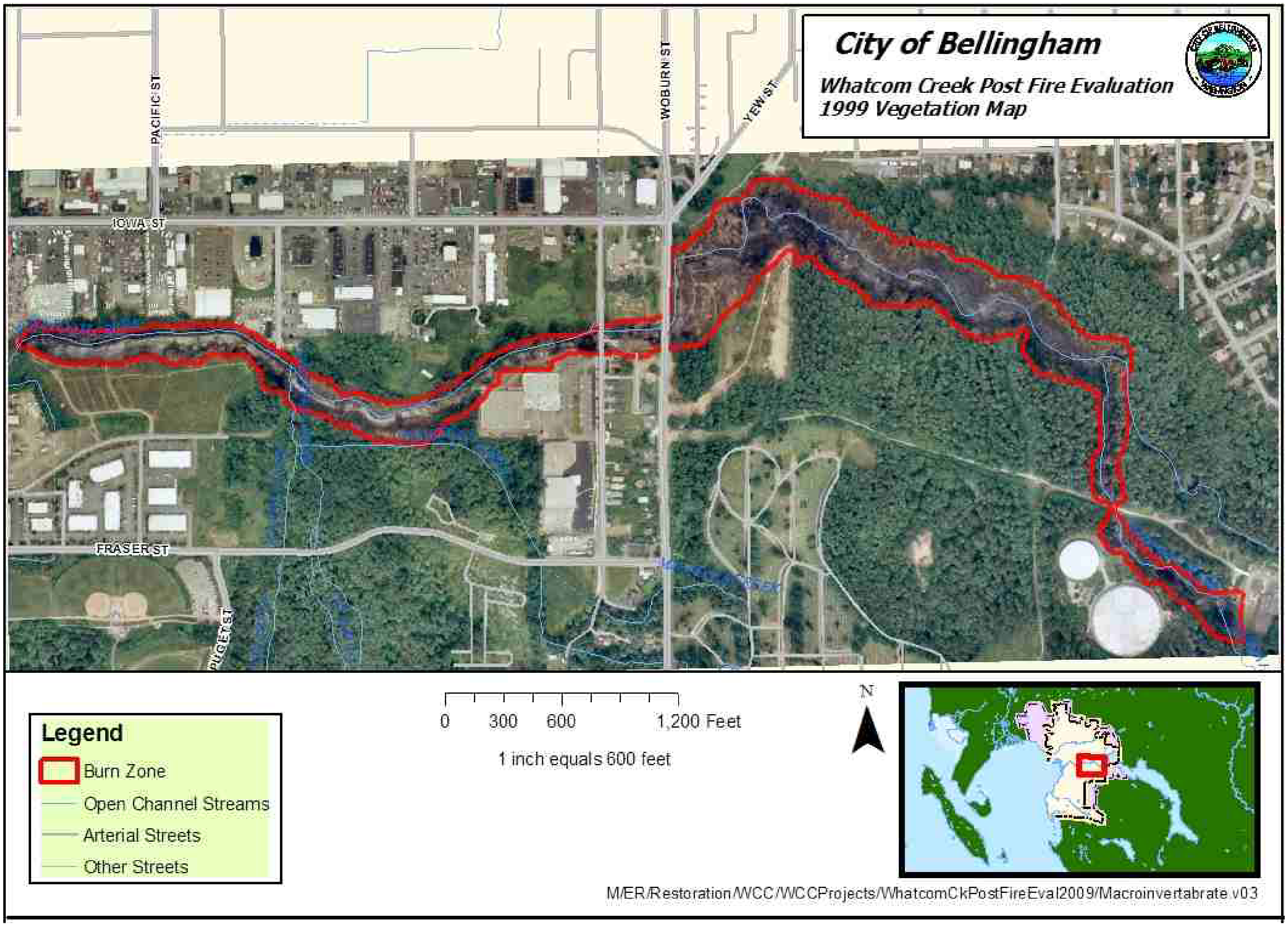

Figure 1-1. Burn zone associated with the June 10, 1999 Olympic Pipeline fuel spill and explosion along Whatcom Creek, Bellingham, Washington.

Within each broad group the following specific topics were investigated:

4. Biological Monitoring:
    - Vegetation;
    - Fish community;
    - Aquatic macroinvertebrates; and
    - Riparian and terrestrial wildlife.
5. Physical Monitoring:
    - Instream habitat;
    - Soil Erosion and Slope Stability; and
    - Water quality.
6. Photodocumentation.

Sections 2, 3 and 4 describe the current conditions in the burn zone based on existing data. Section 5 summarizes the results of this assessment and provides recommendations for further monitoring or maintenance activities within the burn zone. Section 6 provides a list of references consulted when preparing this document. Supporting materials are provided as Appendices to this report.

2. BIOLOGICAL MONITORING

Biological monitoring focuses on four biotic communities associated with Whatcom Creek: riparian vegetation, fisheries resources, aquatic macroinvertebrates, and riparian and terrestrial wildlife.

2.1 VEGETATION

2.1.1 Introduction

The 1999 fire resulted in the destruction of approximately 26 acres of mature forest and other riparian vegetation along Whatcom Creek (Figure 1-1). An Emergency Response (ER) Plan was prepared outlining actions to clean-up and stabilize the stream and riparian area, and to partially mitigate the impacts of the explosion and fire. Emergency Restoration efforts included immediate replanting of native trees and understory vegetation, and an aggressive weed control program. A planting plan produced by Cantrell and Associates, Inc. was included in the ER Plan (OPC 1999). The goal of the planting plan and the subsequent site preparation and tree planting was to stabilize erosion prone areas and to decrease invasive plant establishment by successful establishment and reestablishment of high quality native plant communities and closed canopies both within the burn zone, and in selected plant communities adjacent to the burn zone. Planting was conducted to achieve targeted percent areal cover goals for native vegetation. The target for year 10 was sixty percent cover. Planting started in 1999. Additional planting was conducted in the fall of 2000-2001.

Monitoring of the revegetation efforts was conducted by Cantrell and Associates. Limited vegetation monitoring surveys were conducted following the fire in August through September 2000. Similar surveys were repeated between December 2006 and March 2007 to document the success or re-vegetation efforts within the burn zone. A report describing the results of those efforts (Cantrell and Associates, Inc. 2007) is included as Appendix A. The following material has been extracted from that report.

2.1.2 Methods

A limited vegetation monitoring survey of the Whatcom Creek burn zone was conducted by Cantrell and Associates, Inc. during August through September 2000 (Cantrell and Associates, 2007). The study area was divided into eight polygons representing a range of disturbance and planting regimes (Figure 2-1). A total of 75 10-foot radius data plots were placed randomly at approximately 100-foot intervals to sample vegetation throughout the areas planted in 1999 –

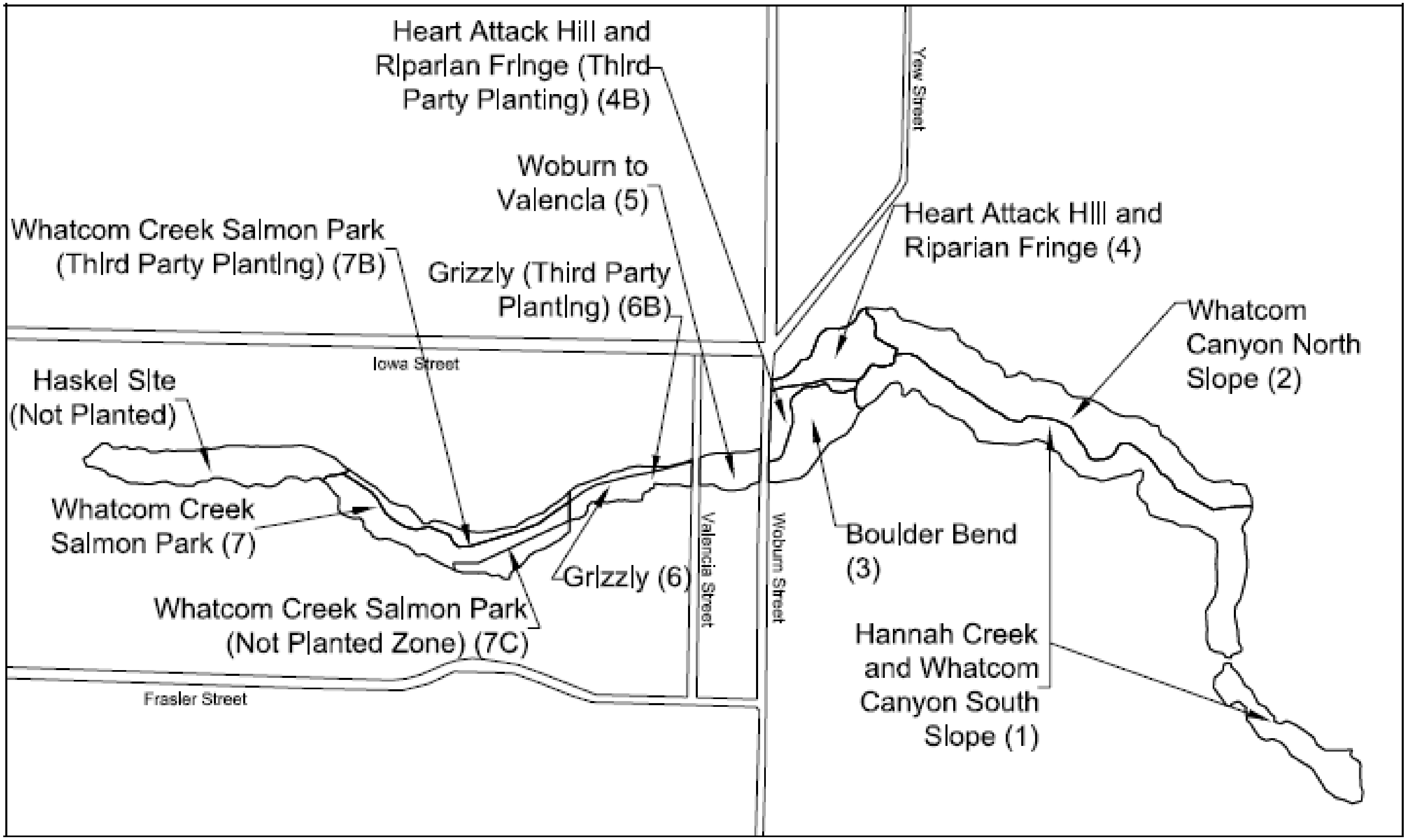

Figure 2-1. Vegetation planting zones in the Whatcom Creek burn zone (from Cantrell and Associates 2007).

2000. Sample plots were located in four of the eight planting polygons. Tree density within the sample plots was recorded, along with the percent cover of each species and estimated tree height.

The study area for the 2006-2007 monitoring study included the eight planting polygons. Sample plots used to measure quantitative data were located within six of the planting polygons. Qualitative data were collected within the remaining two polygons, in which long-term restoration activities not associated with the ER have occurred. Monitoring associated with reforestation projects within these two polygons are reported separately by the City of Bellingham in the companion Restoration Monitoring report (Forester 2009).

Vegetation in the Whatcom Creek burn zone planted after the Whatcom Creek fire was sampled in December 2006 through March 2007 using 10-foot radius circular sample plots. The boundary of each sample plot was determined using a 10-foot aluminum pole held parallel to the ground by a person standing at the plot center. If a tree's trunk made contact with the pole it was determined to be within the sample plot. A distance of approximately 100-feet separated each sample plot. Distances between sample plots were determined by moving the 10-foot pole laterally through the vegetation ten times. The number of trees within each plot along with their species was noted. Large trees within sample plots that were established prior to the Whatcom Creek fire were recorded; however only planted and naturally recruited trees were utilized in analyzing data. No attempt was made to distinguish between planted and naturally recruited vegetation.

Trees were segregated into five size classes: 0-2 feet, 2-5 feet, 5-10 feet, 10-15 feet, and >15 feet. The diameter at breast height (DBH) was estimated for all trees exceeding 15-feet in height. The percent cover of each plant species within the sample plots was also estimated and recorded. When recording the percent cover provided by trees, data were collected and analyzed for planted and recruited trees along with trees that established themselves prior to the Whatcom Creek fire. The herbaceous understory was not thoroughly investigated because the study was conducted during the winter months. A photograph was taken of each sample plot that was representative of the surrounding vegetation.

2.1.3 Results

2.1.3.1 Native Trees

In 2000 a total of 584 planted trees were identified in the 75 data plots. Results from this study showed an average spacing between trees of 6.35 feet with an average of 1,079 trees per acre.

The study indicated that there was robust growth of planted trees after the first summer following planting. The 2000 monitoring effort averaged 2 plots per acre. Polygons 6, 6B, 7C, and 8 were not sampled in the 2000 monitoring effort. In 2008 an average of 4 plots per acre were surveyed across the eight planting polygons.

Tree Density

The regions of the study area within the burn zone planted by Cantrell and Associates, Inc. as part of the Emergency Response Planting Plan (polygons 1, 2, 4, 6, and 7) were resurveyed in 2006-2007. The average tree density of young trees (trees that were planted or established themselves following the Whatcom Creek fire) in these polygons was 951 trees per acre with an average spacing of 7 feet (Table 2-1). Polygon 1 (Hannah Creek and Whatcom Canyon South Slope) contained the highest young tree density and the smallest tree spacing, while polygon 4 (Heart Attack Hill and Riparian Fringe) contained the lowest tree density and the largest tree spacing for the planted burn zone polygons. No planted or recruited trees were located within plots in polygons 7C and 8, and therefore they contained 0 trees per acre and the spacing between trees could not be determined.

Table 2-1. Plots per acre, tree density and tree spacing (of young trees) in the eight Whatcom Creek burn zone polygons in which quantitative data were collected (from Cantrell and Associates 2007).

Polygon Name	Plots per Acre	Trees per Acre	Tree Spacing (ft)
1. Hannah Creek and Whatcom Canyon South Slope	3.6	1,191	6
2. Whatcom Canyon North Slope	2.6	1,136	6.2
4. Heart Attack Hill and Riparian Fringe	5.2	619	8.4
6. Grizzly	5.0	773	7.9
6B. Grizzly (Third Party Planting)	4.9	694	7.9
7. Whatcom Creek-Salmon Park	3.7	1,034	6.5
7C. Whatcom Creek-Salmon Park (Not Planted Zone)	1.9	0	NA
8. Haskell Site (Red-tail Reach)	0.9	0	NA

NA=Not applicable

Average young tree density was higher in 2000 than in 2006/2007 (Table 2-2). In 2000, there was an average of 1,079 trees per acre compared to 951 trees per acre in 2006/2007. However, young trees were denser in 2006/2007 compared to 2000 in polygons 1 and 2. Average tree spacing was greater in 2006/2007 compared to 2000. Polygons 1 and 2 also had a lower tree spacing in 2006/2007 compared to 2000. Polygons 6, 6B, 7C, and 8 were not sampled in the 2000 monitoring effort.

Table 2-2. Comparison of young tree density and spacing in the Whatcom Creek burn zone in 2006-2007 and 2000 (from Cantrell and Associates 2007).

	Trees per Acre		Tree Spacing	
Polygon Name	**2006-2007**	**2000**	**2006-2007**	**2000**
1. Hannah Creek and Whatcom Canyon South Slope	1,191	1,178	6	6.1
2. Whatcom Canyon North Slope	1,136	870	6.2	7.1
4. Heart Attack Hill and Riparian Fringe	619	971	8.4	6.2
6. Grizzly	773	NS	7.9	NS
6B. Grizzly (Third Party Planting)	694	NS	7.9	NS
7. Whatcom Creek-Salmon Park	1,034	1,295	6.5	5.8
7C. Whatcom Creek-Salmon Park (Not Planted Zone	0	NS	NA	NS
8. Haskell Site (Red-tail Reach)	0	NS	NA	NS
Average for ER planted burn zone	951	1,079	7	6

NS=Not sampled; NA= Not Applicable

Species Composition

Within portions of the burn zone planted as part of the ER, the most prevalent young tree species were Douglas-fir, western redcedar, red alder, western hemlock, sitka spruce, bigleaf maple, black cottonwood, and paper birch respectively (Figure 2-2). Polygon 1 contained relatively high percentages of red alder and western hemlock trees compared to the other polygons. Polygon 4 contained a higher percentage of black cottonwood trees compared to the other polygons. Polygons 7C and 8 did not contain young trees within sample plots in 2007. Polygon 8 (the Haskell Site now known as Red Tail Reach) was planted with native vegetation in 2009 as part of the Red Tail Reach restoration project.

The Whatcom Creek burn zone differed slightly in tree composition in 2006/2007 compared to 2000 (Figure 2-3). The percent tree composition of bigleaf maple trees remained similar, while the percent of Douglas-fir, red alder, Sitka spruce, and paper birch trees increased and the percent of western redcedar, and western hemlock trees decreased in 2006/2007 compared to 2000.

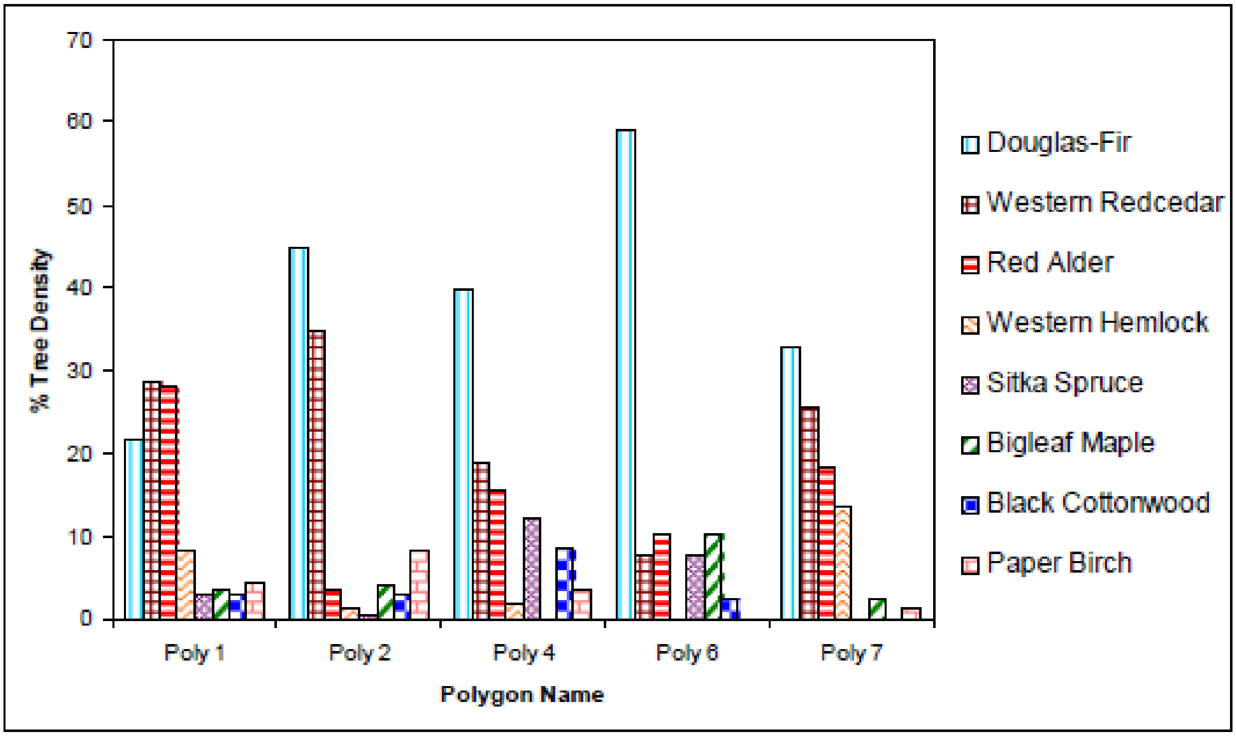

Figure 2-2. The percent composition of young tree species in the polygons within the burn zone that were planted as part of the Emergency Response Planting Plan (from Cantrell and Associates 2007).

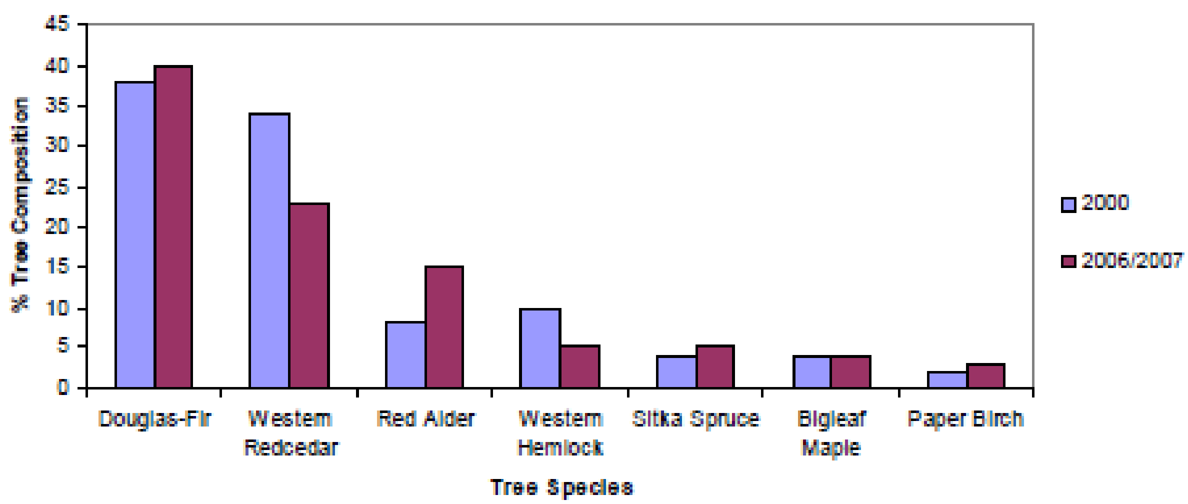

Figure 2-3. Percent composition of different tree species within the Whatcom Creek burn zone in 2000 and 2006-2007 (from Cantrell and Associates 2007).

Canopy Cover

The average percent tree cover including both young and old trees in the burn zone planted as part of the ER was 47 percent (Table 2-3). Polygons 1 and 4 had the largest percent tree cover while Polygon 7 had the smallest percent tree cover. The Haskel Site polygon (Polygon 8) was not planted as part of the ER and did not contain any trees within sample plots in 2007. The percent tree cover for the Emergency Response Planting Plan planted burn zone varied in comparison to pre-existing tree cover (Figure 2-4). Polygon 6 contained the smallest percent tree cover relative to estimated conditions that existed immediately prior to the burn (22% and 80% respectively), while Polygon 4 contained the highest tree cover relative to pre-existing conditions (61% and 76% respectively).

Table 2-3. The percent tree cover including both old and young trees in the 8 Whatcom Creek burn zone polygons in which quantitative data were collected (from Cantrell and Associates 2007).

Polygon Name	Tree Cover (%)
1. Hannah Creek and Whatcom Canyon South Slope	64
2. Whatcom Canyon North Slope	55
4. Heart Attack Hill and Riparian Fringe	61
6. Grizzly	22
6B. Grizzly (Third Party Planting)	22
7. Whatcom Creek-Salmon Park	32
7C. Whatcom Creek-Salmon Park (Not Planted Zone)	53
8. Haskell Site (Red-tail Reach)	0

The dominant canopy cover tree species for the sampled polygons within the burn zone planted as part of the ER were Douglas-fir, red alder, bigleaf maple, western redcedar, black cottonwood, western hemlock, paper birch, Sitka spruce, and bitter cherry respectively (Figure 2-5). These percentages include the canopy coverage provided by large trees that were not killed or re-sprouted from their bases following the1999 fire. Polygons 2 and 6 had the highest percent canopy cover of Douglas fir (Table 2-4). The largest western redcedar canopy cover was found in polygon 2 and the Non-Burn Zone Understory Planting polygon. Polygons 1, 2, and 4 had the largest bigleaf maple canopy coverage. Red alder was prevalent in the canopy of polygons 1, 7C and 4. Black cottonwood comprised the largest canopy coverage of polygon 4. The largest canopy coverage of western hemlock was found in polygons 1 and 2.

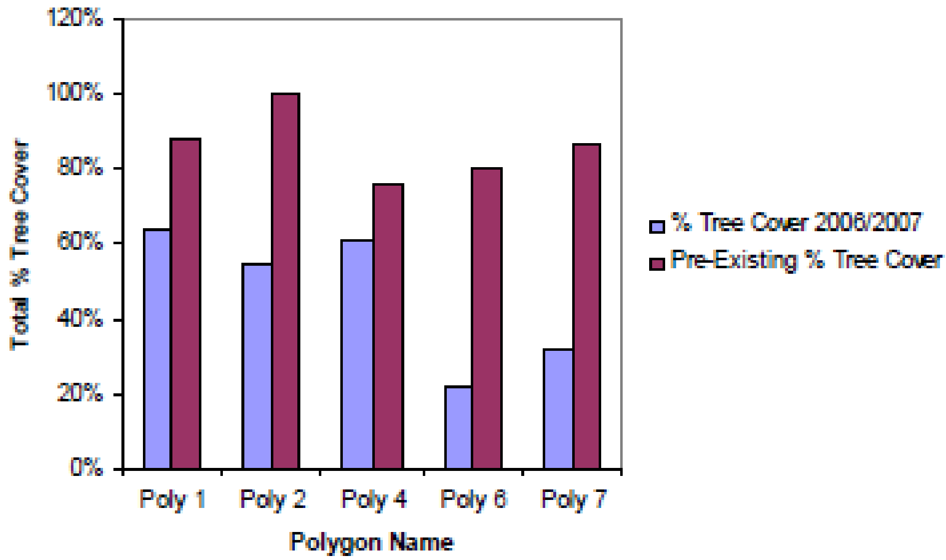

Figure 2-4. The pre-existing and 2006-2007 tree cover (including young and old trees) in polygons planted as part of the Emergency Response Planting Plan (from Cantrell and Associates 2007).

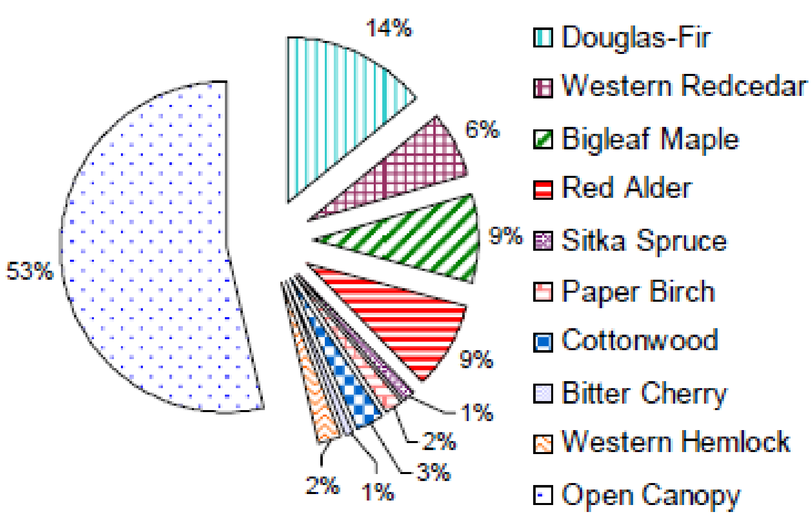

Figure 2-5. The percent of total canopy cover of different tree species in the burn zone planted as part of the Emergency Response Planting Plan (from Cantrell and Associates 2007)

Table 2-4. The percent tree canopy cover of various tree species in the eight Whatcom Creek burn zone polygons in which quantitative data were collected (from Cantrell and Associates 2007).

	Tree Cover (%)							
Polygon Name	**Douglas -fir**	**Western Redcedar**	**Bigleaf Maple**	**Red Alder**	**Sitka Spruce**	**Paper Birch**	**Black Cottonwood**	**Western Hemlock**
1. Hannah Creek/Whatcom Canyon South Sl.	12	10	11	21	1	3	2	4
2. Whatcom Canyon North Sl.	20	14	11	3	0	2	0	5
4. Heart Attack Hill	14	3	18	10	2	1	13	0
6. Grizzly	16	1	2	1	2	0	0	0
6B. Grizzly (Third Party Planting)	3	4	0	1	0	0	15	0
7. Whatcom Crk-Salmon Park	6	4	5	9	0	3	0	2
7C. Whatcom Crk-Salmon Park (Not Planted Zone	0	0	10	35	0	0	8	0
8. Haskell Site (Red-tail Reach)	0	0	0	0	0	0	0	0

Tree Height

Most young trees in the burn zone areas planted as part of the ER are currently 5-10 feet tall (Figure 2-6). The 2-5 foot tree height category contained the second highest percentage of trees followed by the 10-15 foot, >15 foot and 0-2 foot height categories respectively. Polygon 1 contained the highest percentage of large young trees >15 feet in height, while polygon 6B contained the largest amount of small trees 0 -2 feet in height.

2.1.3.2 Invasive Weeds

The locations of heavily weeded areas in 2007 are presented Figure 2-7. The average percent invasive weed cover for the Emergency Response Planting Plan planted burn zone was 17% (Table 2-5). Himalayan blackberry was the most common invasive weed encountered. Of the burn zone polygons planted as part of ER (polygons 1, 2, 4, 6, and 7), polygon 7 had the highest percent cover of invasive weeds (33%), and the Polygon 5 had the lowest percent cover of invasive weeds (5%). The Haskell Site (Polygon 8) was almost entirely comprised of herbaceous invasive vegetation in 2007. This site was cleared and planted with native vegetation in 2009 as part of the Red Tail Reach Restoration Project. Other areas identified as having high weed loads by the 2007 report are being treated as part of ongoing maintenance activities.

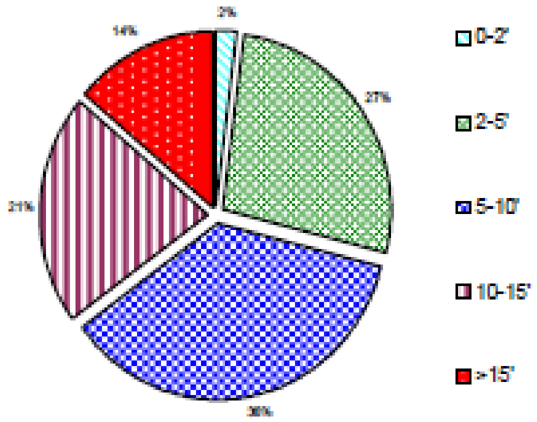

Figure 2-6. The percent of trees of within different height categories in portions of the burn zone planted as part of the Emergency Response Planting Plan (from Cantrell and Associates 2007).

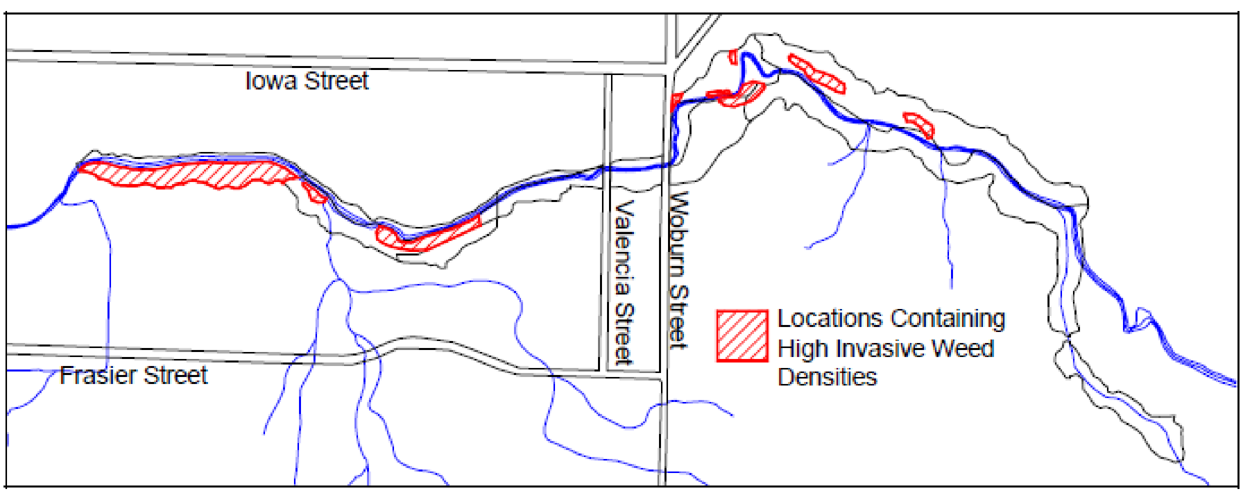

Figure 2-7. Locations containing high invasive weed densities within the Whatcom Creek study area in 2006-2007 (from Cantrell and Associates, 2007)

Table 2-5. The percent cover of invasive weed species in the 6 polygons in which quantitative data was gathered (from Cantrell and Associates 2007).

Polygon Name	Invasive Weed Cover (%)
1. Hannah Creek and Whatcom Canyon South Slope	5
2. Whatcom Canyon North Slope	18
4. Heart Attack Hill and Riparian Fringe	26
6. Grizzly	5
6B. Grizzly (Third Party Planting)	4
7. Whatcom Creek-Salmon Park	33
7C. Whatcom Creek-Salmon Park (Not Planted Zone)	54
8. Haskell Site (Red-tail Reach)	95
Average for burn zone planted as part of ER	17

2.1.4 Discussion

Trees planted following the Whatcom Creek fire have been largely successful in survival and growth. While the number of young trees per acre has decreased slightly and the spacing between trees has increased slightly since 2000, this is to be expected as trees mature and naturally thin due to competition for resources. The number of trees per acre decreased by only 12 percent, while 95 percent of trees have at least doubled in height, and 71 percent of young trees are 5-feet tall or taller.

Average canopy cover in the Whatcom Creek study area increased from near zero in many areas to 47 percent and will likely continue to rise as planted trees continue to grow. While the 2006-2007 areal cover falls slightly short of the projected areal cover goal of 50 percent by for the fifth year following planting, planted trees have grown significantly with little mortality and will likely reach the target 60 percent cover for year ten. Factors that have likely slowed planted tree areal cover advancement include competition from dense understory plants and invasive weeds, and localized mortality due to falling tree branches and other disturbances.

Polygons 4 and 6 contained the lowest density of young trees among the polygons within the ER Planting Plan planted burn zone (polygons 1, 2, 4, 6, and 7). Polygon 4 could contain fewer young trees due to the prevalence of invasive weeds in this region. Polygon 6 is a narrow riparian zone with a thick understory in its western region. These characteristics limit the number of trees that could be planted within the polygon, and the survival of young trees as they compete for light with understory species. Young tree mortality due to fallen branches from large dead trees that were killed during the Whatcom Creek fire could also account for a reduction in tree survival in Polygon 6.

Douglas-fir was the most prevalent young tree species observed in the study area as was expected. Western redcedar was the second most prevalent tree species observed. Western hemlock was found in greater abundance in Polygon 1 compared to Polygon 2. This reflects the original ER planting schedule that was developed to account for differences in light availability on the north and south sides of the Whatcom Creek canyon. Higher abundances of young red alder than were planted in the study area indicate a high level of natural recruitment of this species within the study area. This is due to red alder's characteristics as a colonizer species following a disturbance. The percent tree cover of different polygons was measured including the cover provided by old large trees that survived the Whatcom Creek fire. Polygons 6 and 7 had the lowest percent tree cover of the ER planted burn zone polygons. Polygon 6 is a narrow riparian zone with very few large living trees. Polygon 7 contained few living large trees near Whatcom Creek's edge where trees were planted. The lack of these large trees within polygon 6 and 7 reduces the canopy cover within these polygons. The relatively large canopy cover provided by bigleaf maple, red alder, and black cottonwood trees in the study area was provided mostly by large trees that survived the Whatcom Creek fire.

The majority of young trees within the study area are currently between 2-feet and 10-feet in height. There were few trees that were less than 2-feet in height. This suggests that there has been little recent recruitment of trees from natural seed sources occurring within the study area. Some young trees within the study area already exceeded 20-feet in height. Many of these tall trees were naturally recruited red alder trees.

The percent cover of invasive weed species varied by location within the study area. The most prevalent invasive species observed was Himalayan blackberry. Dense patches of Himalayan blackberry were located in some areas of the study area. The majority of the study area contained at least some cover by Himalayan blackberry. The greatest cover of invasive species was located in polygons 4, 7 and 8. Within these and other polygons, patches of invasive weeds (mostly Himalayan blackberry) grew over planted tree species and dominated the vegetation cover. In these areas, trees have to compete with invasive species for light availability and other resources. Invasive weeds could lead to the mortality of planted trees, decrease native vegetation biodiversity, and reduce habitat for wildlife. The Haskell Site (Polygon 8) was dominated by herbaceous invasive weeds in 2006-2007 but was cleared and replanted with native vegetation in 2008-2009 as part of the Red Tail Reach Restoration Project.

Comparisons of data obtained from the current study with those acquired in 2000 indicate little mortality and substantial growth of planted vegetation. The increase in the percent composition of Douglas-fir, red alder and paper birch since 2000 is likely due to the natural recruitment of these trees. The reduction in the percent composition of other tree species (especially western redcedar) is due to the mortality of a portion of these planted trees, and to the increase in the numbers of other species (especially red alder) due to recruitment.

2.2 FISH COMMUNITY

2.2.1 Introduction

Anadromous fish use of Whatcom Creek was historically limited by the falls at the mouth of Whatcom Creek (hereafter referred to as Lower Falls; RM 0.01). Apparently adult upstream passage at this site was extremely difficult. Nevertheless, anadromous fish historically attained passage intermittently in some years at certain flow levels. There is recent speculation that ongoing urbanization may have increased erosion of the rock falls increasing the degree of passage difficulty over time (NOAA 2002). The historic records are inconclusive regarding species use of the creek, but there are various inferences of steelhead, coho, chum and sea-run cutthroat utilization. It has been generally concluded the available pre-1940 habitat in Whatcom Creek was underutilized with respect to the potential carrying capacity (RW Beck 1984) and that it offered limited production for coho salmon, steelhead and cutthroat trout. Anadromous fish that make it upstream of Lower Falls are able to access approximately two miles of habitat in mainstem Whatcom Creek, upstream to the base of a second, impassible falls located at RM 2.2 (hereafter referred to as Middle Falls). Flows in Whatcom Creek are controlled by the City of Bellingham and managed primarily to maintain target lake levels; a discussion of hydrologic conditions in recent years is provided in Section 3.1.1.

Regardless of historic use, the records indicate anadromous fish did not occur in the creek between the early 1940s and 1978 due to physical habitat destruction and reduced water quality related to urban and industrial development of the area. Between 1978 and the early 1980s various juvenile fish stocking programs were initiated in Whatcom Creek. In 1980 a fish ladder was built to provide continuous access for returning adults above Lower Falls, and the Whatcom Creek fish hatchery began operation at the mouth of the creek at the converted sewage treatment plant facility. At this time anadromous fish were reintroduced into the creek. The hatchery is operated by Bellingham Technical College (BTC). Hatchery plants of fall Chinook, coho, chum, winter steelhead, sea-run cutthroat trout and resident trout occurred routinely between 1980 and 1999. Planting of Chinook ceased in 1999, and numbers of steelhead and coho released to the stream were dramatically cut. Chum salmon continue to be released at the hatchery.

Whatcom Creek currently supports a variety of native and non-native fish species, including two listed as threatened under the Endangered Species Act (ESA): Puget Sound Chinook salmon and Puget Sound steelhead trout. Six species of anadromous salmonids and trout utilize portions of Whatcom Creek for spawning and rearing, including fall Chinook, coho, chum and pink salmon, as well as winter steelhead, and coastal sea-run cutthroat trout. Incidental observations of juvenile sockeye salmon have also occurred in Whatcom Creek; however these fish are believed to be strays from the kokanee stocking program upstream in Lake Whatcom (NOAA 2002). Resident forms of cutthroat and rainbow trout are also present. Pacific lamprey have been observed spawning in Whatcom Creek (Gagner pers. comm. 2009), and it is likely that western brook lamprey are also present. Table 2-6 lists all fish species known to occur in Whatcom Creek.

Table 2-6. Fish species known to occur in Whatcom Creek within the burn zone.

Common Name	Scientific Name	Status
Chinook salmon	*Oncorhynchus tshawytscha*	Federal– threatened State – candidate
Steelhead/rainbow trout	*Oncorhynchus mykiss*	Federal - threatened
Coho salmon	*Oncorhynchus kisutch*	Federal –species of concern
Chum salmon	*Oncorhynchus keta*	No listing status
Pink salmon	*Oncorhynchus gorbuscha*	Federal –species of concern
Searun cutthroat/cutthroat trout	*Oncorhynchus clarki*	Federal –species of concern
Pacific lamprey	*Lampetra tridentatus*	No listing status
Western brook lamprey	*Lampetra richardsoni*	No listing status
Sculpin	*Cottus sp.*	No listing status
3-spine stickleback	*Gasterosteus aculeatus*	No listing status
Pea-mouth chub	*Mylocheilus caurinus*	No listing status
Bullhead catfish	*Ameiurus sp.*	?
Sockeye salmon	*Oncorhynchus nerka*	Non-native
Brook trout	*Salvelinus fontinalis*	Non-native
Largemouth bass	*Micropterus notius*	Non-native
Smallmouth bass	*Micropterus dolomieu*	Non-native
Pumpkinseed/bluegill	*Lepomis sp.*	Non-native

At the time of the burn, the Washington Department of Fish and Wildlife (WDFW) Hatchery Management policies were evolving in response to ESA listings of anadromous fish throughout the Pacific Northwest. Operations were altered to bring them in line with the Washington Wild Salmonid Policy and emphasize local stocks (Cope 1999, pers. comm.). After 1999 annual fish releases to Whatcom Creek were substantially reduced. Planting of Chinook salmon was halted. Numbers of coho salmon and steelhead trout were reduced to around 5,000 fish of each species. All adult Chinook, coho and steelhead are now placed upstream of the lower falls when they enter the hatchery rack. Some of the returning fish are now spawning naturally in Whatcom Creek. Large numbers of pink salmon (250,000 to 500,000/yr) and chum salmon (2,000,000/yr) continue to be released to the estuary. Returning adult pink and chum salmon are collected at the hatchery.

2.2.2 Methods

The objective of the post-burn assessment of the fish community in Whatcom Creek was to document fish use within the burn zone since the fire. The analysis was based on data from existing programs, including records of fish releases and adult returns from BTC's Whatcom Creek Hatchery, results of spawning surveys conducted by the City of Bellingham, and recreational catch data from the Washington Department of Fish and Wildlife.

The current status of naturally producing fish in Whatcom Creek is best represented by the number of adults returning to spawn within the affected area. Parameters of interest for each species include number of live spawners, number of carcasses and number of redds. Since 2000 the City of Bellingham has conducted spawning surveys in the affected area of Whatcom Creek that is accessible to anadromous salmonids (RM 1.2 to RM 2.2). Surveys generally commence in September and continue through late February or early March. This period covers the time when adult anadromous salmonids are present in Whatcom Creek (Figure 2-8). At least one survey is conducted prior to the beginning of spawning to ensure complete run coverage.

A trained and specifically assigned staff member supported by seasonal technicians conducts the spawning surveys. Surveyors enter the stream just upstream of Lincoln Creek and work upstream. Surveyors count the number of live fish, carcasses and redds, by species. Survey frequency is dependent on flow conditions; ideal frequency is seven to ten day intervals. However, high flows frequently preclude effective surveying during parts of the season. At flows above 200 cfs the stream becomes difficult to wade safely, and surveys are limited to spot checks. Spot checks are conducted from vantage points near the confluence of Cemetery Creek, the Valencia Street bridge, the Woburn Street bridge and along the east side of Woburn Street just upstream of the bridge where the Creek flows adjacent to the roadway.

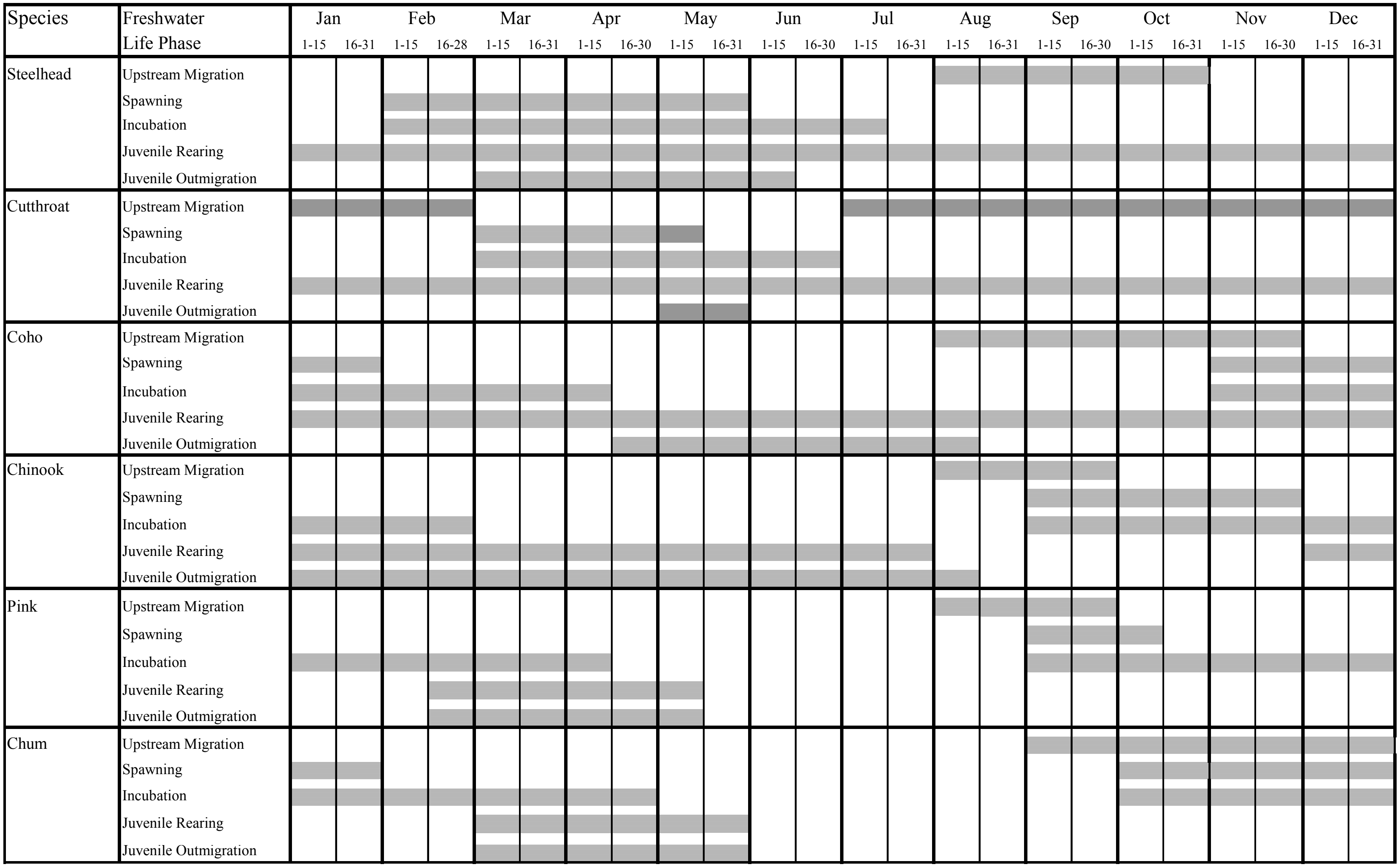

Figure 2-8. Life histories of salmonid fishes inhabiting Whatcom Creek.

Live fish are identified to species (if possible) and observed to determine if the fish is building or guarding a redd. Redds are associated with a species (if possible) and marked with flagging denoting the survey date and location. Carcasses are identified by species (if possible) and assessed to determine whether eggs or milt has been released. If there is a large amount of either, then it is noted that the fish died before successfully spawning. The caudal fin is then cut off to indicate that the carcass has been counted.

Adult Chinook, coho and steelhead returning to Whatcom Creek that enter the hatchery rack are counted, marked and released above the lower Falls. The BTC Technical College maintains a database of annual adult returns. These data likely provide a more consistent estimate of escapement to Whatcom Creek, although fish that ascend via the fish ladder or over the falls are not represented in the counts. Hatchery records from 1988 through 2008 were reviewed to provide a consistent analysis of pre-and post burn fish returns. Hatchery records of the number of juvenile salmonids released to Whatcom Creek during that period were also reviewed to provide context to adult fish returns.

2.2.3 Results

Since 1999 the number of anadromous fish returning to Whatcom Creek has generally been lower than pre-burn numbers. Available data are not sufficient to complete a rigorous statistical analysis; however general patterns are discussed below for four species: Chinook, coho, chum and steelhead.

2.2.3.1 Chinook

Chinook have been planted in Whatcom Creek since 1980; planting stock originated from the Samish hatchery, which used Green River stock. Chinook salmon returns to Whatcom Creek peaked in 1997-1998, with more than 800 fish returning to the Whatcom Creek hatchery (Figure 2-9). In 2000, following the burn, spawning escapement upstream of the hatchery was estimated at 206 adult Chinook (Campbell 2001). Two hundred and fifty-nine adult fish returned to the hatchery and were placed upstream of the lower falls in that year. Chinook returns remained high through 2002-2003, but then dropped substantially; since 2003 fewer than 100 Chinook have returned to the hatchery each year. It seems likely that the reason for the drop is the reduced number of juvenile fish releases rather than the impacts of the burn. Simple regression analysis indicated that Chinook returns to the Whatcom Creek hatchery showed a weak, but statistically significant correlation with the number of juveniles released to the system three prior (r^2 =0.23). The high returns recorded in 1997 and 1998 followed the release of over 1 million juvenile fish (fingerling plus yearling) to Whatcom Creek three years prior. Similarly, high returns in 2001-2002 followed high releases of juveniles in 1997 and 1998. In contrast, fewer than 200,000 Chinook were released in Whatcom Creek in1993, and adult returns to the hatchery were low in 1994. Excluding the year of the burn and the year immediately following the fire substantially increases the strength of the statistical relationship (r^2 =0.42), suggesting the fire may have had a short-term effect.

Chinook salmon in Whatcom Creek are believed to exhibit an ocean-type rearing strategy and thus typically leave freshwater within a few weeks after emergence (Campbell 2001). As a result Chinook rearing in the burn zone is believed to be limited.

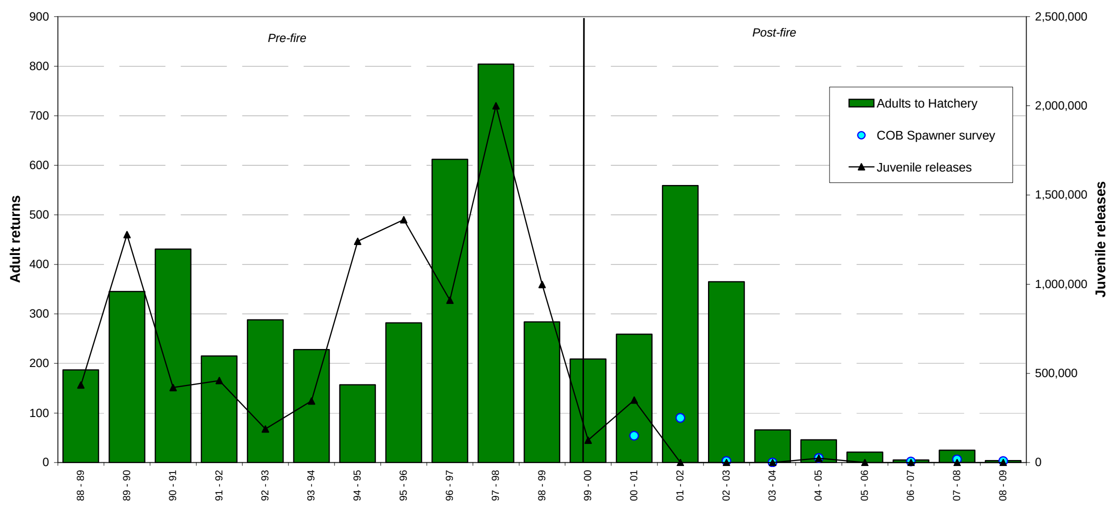

Figure 2-9. Whatcom Creek Chinook salmon juvenile releases, adult returns and spawner survey results for the period from 1988 through 2008.

2.2.3.2 Coho

Coho returns to the BTC hatchery peaked at near 600 fish in 1995-1996, but have declined since that time (Figure 2-10). The decline in coho returns does not appear to be related to the fire, as numbers began dropping several years before the event. The decline may be related to hatchery releases, as since 2002-2003 no more than 5,000 fish per year have been released to the system. However, the reduced numbers of fish observed in the late 1990s occurred despite the release of more than a million juvenile coho to Whatcom Creek in 1997. Regression analysis did not document a statistically significant relation ship between adult returns and juvenile releases three or four years prior.

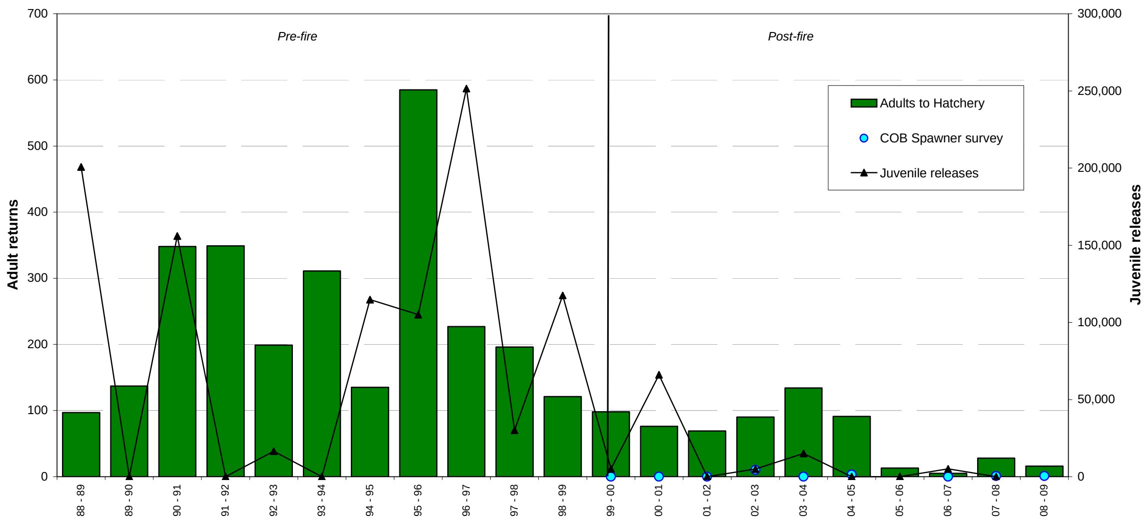

Figure 2-10. Whatcom Creek coho salmon juvenile releases, adult returns and spawner survey results for the period from 1988 through 2008.

Coho typically prefer small tributaries for spawning and are not generally observed in Whatcom Creek during spawning surveys. Coho are known to spawn in Cemetery Creek, and hundreds of juveniles resulting from natural production have been found in that stream (Forester 2009). Juvenile coho salmon also rear in Whatcom Creek within the burn zone. As this species tends to remain in freshwater for at least a year they are likely to be affected by changes in habitat. Habitat conditions are discussed in Section 3.1.

2.2.3.3 Chum

The vast majority of chum salmon either contribute to the local recreational fishery or return to the hatchery. Hatchery returns dropped immediately following the fire in 1999 and 2000, but rebounded in 2001 and 2002 (Figure 2-11). The relationship between fish returns and juvenile releases two year prior was weak but statistically significant (r^2=0.22).

Chum typically return to spawn at age two or three; the low returns in the fall of 2000-2001 may be related to smaller than normal than hatchery releases in 1999-2000. However, in the fall of 2001, two years after those low releases, more than 27,000 chum returned to the hatchery. In the fall of 2003 almost 100 chum were documented by spawning surveys in the Whatcom Creek index reach; however, in most years very few chum are recorded there. Chum are relatively weak swimmers, but in years when adult returns are high and flows are relatively low many of the fish make it over the falls (Steele, pers. comm. 2009). Such conditions occurred during the chum spawning season in 2003. Since that time, flows have typically been high during chum spawning season (Table 2-7) and few chum have been observed in Whatcom Creek during spawning surveys.

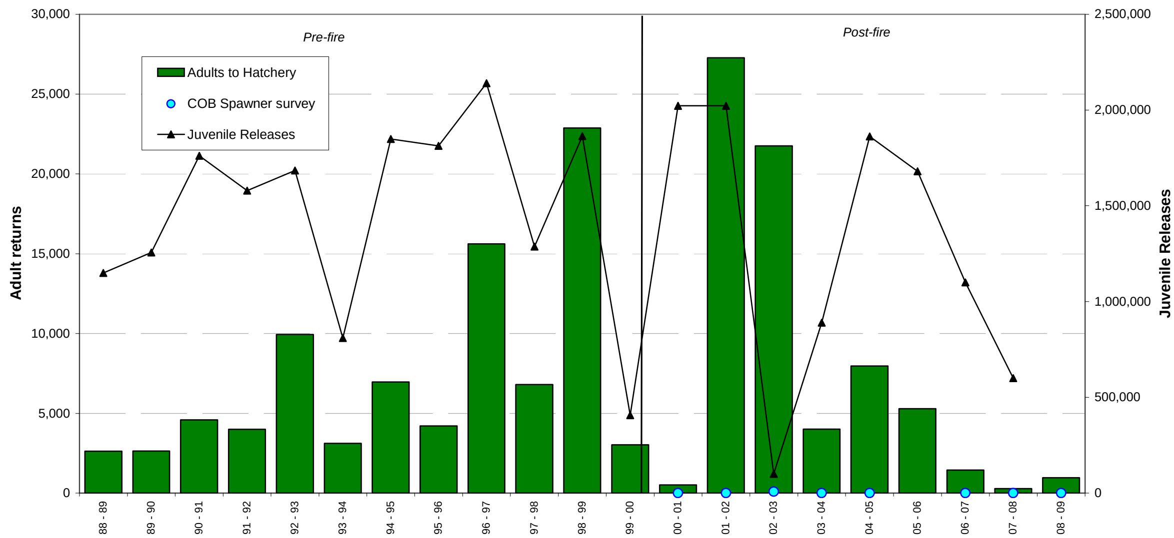

Figure 2-11. Whatcom Creek chum salmon juvenile releases, adult returns and spawner survey results for the period from 1988 through 2008.

Table 2-7. Average flow releases from Derby Pond into Whatcom Creek during the typical spawning period for anadromous salmonid species inhabiting Whatcom Creek.

Year	Pink (8/15-10/15)	Chinook (9/1-10/31)	Coho (9/15-11/30)	Chum (10/15-12/15)	Steelhead (11/30-3/31)
1993-1994	18 cfs	15 cfs	12 cfs	7 cfs	97 cfs
1994-1995	2 cfs	2 cfs	2 cfs	293 cfs	187 cfs
1995-1996	7 cfs	8 cfs	141 cfs	318 cfs	197 cfs
1996-1997	37 cfs	84 cfs	156 cfs	272 cfs	322 cfs
1997-1998	37 cfs	55 cfs	56 cfs	54 cfs	165 cfs
1998-1999	15 cfs	17 cfs	58 cfs	168cfs	313 cfs
1999-2000	38 cfs	38 cfs	38 cfs	177 cfs	210 cfs
2000-2001	4 cfs	2 cfs	2 cfs	3 cfs	70 cfs
2001-2002	7 cfs	46 cfs	116 cfs	246 cfs	314 cfs
2002-2003	9 cfs	9 cfs	18 cfs	31 cfs	90 cfs
2003-2004	5 cfs	144 cfs	306 cfs	510 cfs	157 cfs
2004-2005	55 cfs	122 cfs	204 cfs	310 cfs	194 cfs
2005-2006	36 cfs	35 cfs	151 cfs	174 cfs	232 cfs
2006-2007	23 cfs	138 cfs	138 cfs	221 cfs	259 cfs
2007-2008	447 cfs	269 cfs	270 cfs	126 cfs	179 cfs

2.2.3.4 Steelhead

Steelhead have been released to Whatcom Creek since hatchery operations commenced. Steelhead planted into Whatcom Creek were of mixed stock origin, coming from Bogachiel, Tokul, and or Chambers Creek (Steele pers. comm. 2009). More recently all steelhead are from Nooksack (Kendall hatchery). Prior to 1999 some returning adults were collected at the hatchery for broodstock. Starting in 1999 all steelhead that returned to the hatchery were moved upstream of the lower falls. Since that time, fewer than 16 steelhead have been intercepted at the hatchery rack annually (Figure 2-12). Flows tend to be relatively high during the period when steelhead are returning to Whatcom Creek (Table 2-6), and steelhead are strong leapers, thus adult fish are able to ascend upstream via the fish ladder or by passing the falls (Steele, pers. comm. 2009). The city attempts to conduct regular spawning surveys during the steelhead spawning period, but high flows frequently limit the surveyors ability to complete foot surveys, so available data likely underestimate actual fish numbers. Fewer than four steelhead have been observed annually in Whatcom Creek during spawning surveys since 2001.

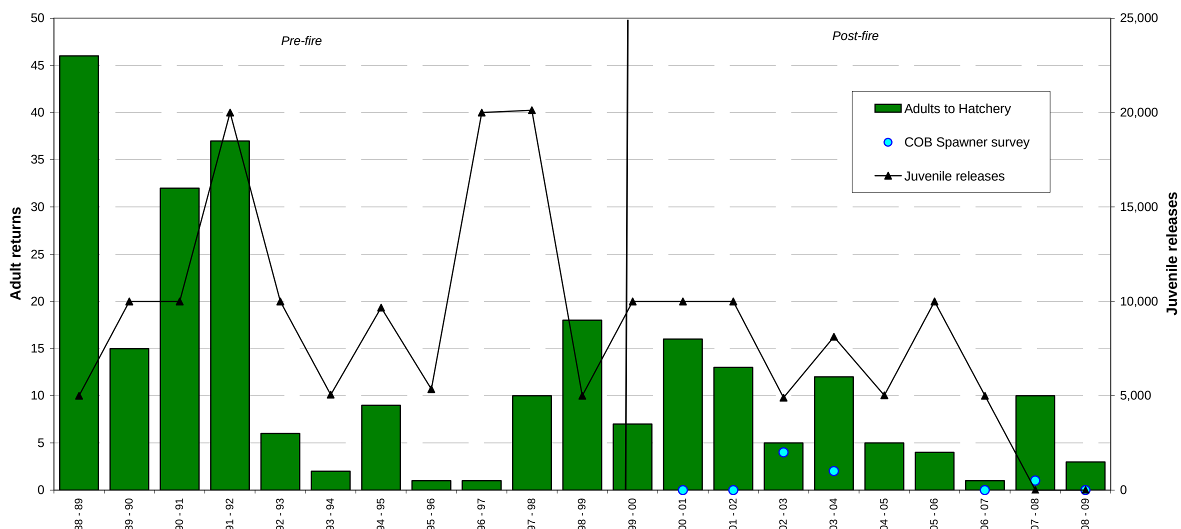

Figure 2-12. Whatcom Creek steelhead juvenile releases, adult returns and spawner survey results for the period from 1988 through 2008.

Whatcom Creek receives relatively heavy use by recreational steelhead fishermen; in 2009 fishermen reported catching and keeping 15 steelhead as of late January (Steele, pers. comm. 2009). Steelhead catch records between 1996 and 2003 indicate that the reported sport catch on Whatcom has been as high as 174 fish; the average reported sport catch over that period was 45 fish (BTC 2009). Whatcom Creek is open to recreational fishing from the mouth upstream to yellow markers installed below a small footbridge downstream of Dupont Street, and between Dupont Street and Woburn Street. Wild steelhead[1] must be released, but up to two hatchery steelhead per day may be retained from June 1 through February 28.

Steelhead trout rear in freshwater for at least one year prior to migrating to the ocean, and believed to be present in Whatcom Creek. Numerous juvenile rainbow/steelhead trout were observed during a 2008 fish removal operation conducted in Whatcom Creek in support of the Redtail Reach restoration project. It is unknown whether these fish represent hatchery plants from BTC, naturally produced resident rainbow trout, or naturally produced steelhead. Because of the stream-type life history this species is likely to be affected by changes in habitat. Habitat conditions are discussed in Section 3.1.

2.2.4 Discussion

Since 1999 the number of anadromous fish returning to Whatcom Creek has generally been substantially lower than pre-burn numbers. Concurrent with the 1999 fire, several salmonid species in Puget Sound were listed as threatened under the ESA. At the time of the burn, the Washington Department of Fish and Wildlife (WDFW) Hatchery Management policies were evolving in response to ESA listings of anadromous fish throughout the Pacific Northwest. Operations were altered to bring them in line with the Washington Wild Salmonid Policy and emphasize local stocks. Prior to the fire large numbers of juvenile fish were released into the system. Planting of Chinook salmon was halted in 1999. Numbers of hatchery planted coho salmon and steelhead trout were reduced to around 5,000 fish of each species each year.

While existing data are not sufficient to conduct a statistically rigorous analysis of cause and effect, it seems likely that the reduction in adult returns to Whatcom Creek is primarily related to the reduction in hatchery inputs. Fish passage projects and increased late summer flows have improved access to Whatcom Creek. Subsequent sections will show that habitat conditions and water have also improved since the burn. As a result, while the fire may have temporarily reduced spawning success it seems unlikely that it is responsible for the observed decline in adult returns.

[1] Wild steelhead and cutthroat have unclipped adipose and ventral fins.

2.3 AQUATIC MACROINVERTEBRATES

2.3.1 Introduction

The benthic macroinvertebrate community is an assemblage of numerous taxa of organisms, large enough to be seen by the unaided eye, that inhabit the sediment or bottom substrates in an aquatic environment for at least part of their life cycle (Klemm et al. 1990; Rosenberg and Resh 1993). Freshwater macroinvertebrates include nematodes, annelids, crustaceans, flatworms, mollusks, and insects, and are usually defined in size as being retained by mesh sizes between 0.2 to 0.5 mm. Insects are the most species-rich, and often most abundant, group of benthic macroinvertebrates residing in freshwater habitats (Hershey and Lamberti 2001; Ward 1992).

Aquatic insects and other macroinvertebrates are an essential component in the processes of an aquatic ecosystem, due to their position as consumers at the intermediate level of lotic food webs (Hynes 1970; Wallace and Webster 1996; Hershey and Lamberti 2001). Macroinvertebrates are involved in the recycling of nutrients and the decomposition of organic materials, serving as a conduit for the energy flow from organic matter resources to vertebrate populations, (Hershey and Lamberti 2001; Hauer and Resh 1996; Reice and Wohlenberg 1993; Klemm et al. 1990). The significant functional roles that macroinvertebrates play in the freshwater ecosystem stress the importance of the community in the study of stream ecology.

Today, benthic macroinvertebrates are included in the biological monitoring programs of many state and federal agencies largely due to the numerous advantages macroinvertebrates offer in detecting disturbance or environmental stress in rivers and streams (Barbour et al. 1999; Davis and Simon 1995; Carter and Resh 2001; King County 2002). Macroinvertebrate communities are usually more diverse than fish communities; in addition, they are abundant, easy to collect, somewhat sedentary, and have relatively short life spans of several months to a few years (Barbour et al. 1999). These characteristics allow macroinvertebrate communities to reflect local conditions and the recent past, making them good indicators of proximate, acute impacts and more chronic conditions, as well. They also represent an important food source for resident and anadromous fish species in Whatcom Creek.

With the importance of macroinvertebrates to stream ecology in mind, the objective of this post-burn assessment was to document the recolonization and recovery of the macroinvertebrate community within the burn zone in Whatcom Creek, utilizing existing and available data. A limited amount of macroinvertebrate data for the Whatcom Creek watershed was available prior to the incident. Historic macroinvertebrate data are available in Whatcom Creek (McBride and Shea 1982). However, the information is sparse and does not generally conform to current and accepted protocols for sampling and analysis of macroinvertebrate data. Furthermore, the data were collected during 1973 through 1982, which did not reflect the most recent pre-burn conditions in Whatcom Creek.

As part of the Lake Whatcom Watersheds Monitoring Project, the Department of Ecology (Ecology) Bellingham Field Office sampled macroinvertebrates to characterize the status of benthic populations in regional streams using the methods described in Plotnikoff (1994). Three sites were monitored in the lower Whatcom Creek drainage basin: two in the mainstem (near Racine and James streets) and one in Cemetery Creek. Data collected during October 1998, provide a baseline of macroinvertebrate condition prior to the June 10, 1999 incident.

Baseline sampling during October 1998 in the lower Whatcom Creek drainage basin indicated some habitat degradation had occurred, adversely influencing macroinvertebrate communities in the streams. Abundance and diversity of taxa were reduced compared to the reference site in Austin Creek and with respect to standard indices and diagnostics for a healthy productive ecosystem (Barbour et al. 1999). Whatcom Creek at James Street was the most severely affected sampling site, showing signs of channel urbanization and organic pollution. Cemetery Creek showed signs of high levels of fine sediment deposition and perhaps water quality problems that reduced species diversity and abundance. Macroinvertebrate communities were most vigorous in Whatcom Creek at Racine Street and showed evidence of taxa that are sensitive to habitat disturbances. Nevertheless, macroinvertebrate indices at Racine Street remained depressed compared to other healthy regional streams. Channel alteration and nutrient enrichment may have accounted for the lower community indices at this site. Scrapers dominated the functional food groups in Whatcom Creek at Racine, implying attached algae or periphyton were abundant and perhaps nutrient enrichment was an issue at this site. Nutrient enrichment is currently a concern in Whatcom Lake, which is the source of the majority of flow in Whatcom Creek.

A study of macroinvertebrates within the burn zone was also conducted immediately following the fire. Using the same methodology as Ecology (Bogdan 1998), LaCroix (2001) sampled the Racine and James Street sites and at the mouth of Cemetery Creek in June 1999, seven days after the fire, September 1999, and September 2000. Results showed nearly complete losses in the macroinvertebrate community seven days after the spill and fire in June 1999.

However, LaCroix (2001) found a substantial increase three months later, with an estimated density of 12,476 organisms/m^2 at Racine, and 6,057 organisms/m^2 at the James Street site, levels much higher than those estimated from R2's October 1999 samples collected at the same sites (2,858 organisms/m^2 at Racine, 1,685 organisms/m^2 at James). A copy of that report (LaCroix 2001) describing this effort is included as Appendix B.

2.3.2 Methods

2.3.2.1 Study Sites

The macroinvertebrate assessment conducted for this ten-year review used data collected from three sites located along Whatcom Creek (Figure 2-13). Two of these sites, one near Racine Street (Racine) and the other near James Street (James), were sampled by Ecology in 1998. These two sites, plus another just upstream of the middle Whatcom Falls (Middle Falls) were also used for additional macroinvertebrate collections from 1999 through 2003.

2.3.2.2 Data Sets

Three data sets were utilized in this post-burn analysis. First, data from Ecology's baseline sampling during October 1998 was included to reflect the condition of the benthic macroinvertebrate community prior to the burn. Invertebrate samples were collected on October 17, 18 and 26, 1998. Ecology sampled macroinvertebrates from a 2-ft^2 (0.186 m^2) area with a D-frame kick net, collecting four such samples at each survey site. These samples were pooled prior to analysis, and then subsampled using a random grid until approximately 300 organisms were identified (Bogdan 1998).

The second data set is from an unreleased study conducted by R2 Resource Consultants, Inc. (R2) shortly after the burn. This data set was selected due to the similarity in methods used for subsequent sampling. Four samples were collected at each of five study sites located along Whatcom Creek, using a D-frame kick-net sampler to sample a 2-ft^2 (0.186 m^2) area. All four samples were kept separate, not pooled, and all invertebrates in each sample were fully enumerated. Samples were collected every two to three months, from August 1999 through October 2000, to document seasonal patterns in macroinvertebrate abundance, diversity, and community structure at sites above the influence of the burn and at disturbed sites. Samples utilized for this present assessment were collected in October 1999 and October 2000 to minimize seasonal influences on the macroinvertebrate community. These dates also facilitate comparison with the Ecology baseline data collected in October 1998 to identify changes that could be attributed to the fire.

Figure 2-13. Location of macroinvertebrate samples sites in Whatcom Creek used for this analysis.

Finally, the City of Bellingham has collected samples along Whatcom Creek since 2001. Samples have been collected near Middle Falls, Racine Street, and James Street, following Ecology protocols (Plotnikoff and Wiseman 2001). Similar to the R2 data set, four samples are collected at each site using a D-frame kick-net to sample a 2-ft^2 (0.186 m^2) area. Samples collected from 2001 through 2003 were processed by the Institute of Watershed Studies at Western Washington University (Vandersypen et al. 2006). For those years, all four samples are analyzed separately, and all invertebrates in each sample were fully enumerated. In order to provide data reflecting conditions more recent than 2003, R2 processed additional samples collected by the City of Bellingham in 2007. Samples from 2007 were collected using the same field methods as noted above, but laboratory methods differed.

2.3.2.3 Laboratory Methods

The methodology for processing samples collected from 1999 through 2003 was to conduct full enumerations for each sample (Vandersypen et al. 2006). For 2007 samples, a Caton subsampling tray (Caton 1991) was used to acquire a 300-organism fixed-count (±20%) subsample. All invertebrates were removed from debris with the aid of a dissecting microscope (7-45x), and sorted into major taxonomic groups. Sorted debris was retained in a labeled, 60-ml bottle and stored for later QA/QC assessment. At the conclusion of the subsampling effort, a large-rare organism sort was performed on the unsorted portion of the sample to sort taxa that were not accurately represented in the sorted grids. This step is included in methods employed by the U.S. Geological Survey's National Water Quality Laboratory Biological Group (Moulton et al. 2000).

All invertebrates were then identified using appropriate taxonomic keys (Merritt et al. 2008, Adams 2004, Stewart and Stark 2002, Thorp and Covich 2001, Wiggins 1996) and enumerated. Large-rare organisms were tabulated separately from the subsample results. Insects were identified to the lowest practical taxonomic level, usually genus or, in some cases, species. Exceptions were the family Chironomidae (midge flies), which require additional specimen preparation for identifications lower than family, and immature and damaged specimens. Non-insects were identified to the lowest practical taxon (class, order, family, or genus).

Ten percent of the samples were re-sorted to determine the sorting efficiency. For this procedure, the processed detritus from a sample was obtained and re-sorted under a dissecting microscope at 12x magnification. All invertebrates were removed from the debris, identified, and enumerated. The target for a sample’s sorting efficiency was 90 percent or better.

2.3.2.4 Data Analysis

The raw data from all three sets were acquired. A review of the data revealed several taxa that are not typically classified as benthic macroinvertebrates. Terrestrial insects, planktonic taxa (Cladocera, Copepoda), and micro-invertebrates (Tardigrada) were removed from the data sets. Additionally, data sets sometimes differed in the taxonomic resolution at which identifications were made. The unpublished R2 data set (1999 and 2000) included Chironomidae taxa to genus level, whereas the 2001-2003 data recorded by Vandersypen et al. (2006) identified Chironomidae to family. Differences were resolved by summing all such differing entries to the lowest common taxonomic level, thus standardizing the taxonomy used for all data sets.

Once the data sets were made compatible, the taxonomic composition of each sample was used to generate a taxa-abundance matrix representing all samples in the data sets. Before the data were used to generate metric scores, large-rare organisms were combined with the subsample counts. To accomplish this objective, large-rare counts were multiplied by the proportion of the sample that was subsampled. For example, if a large-rare sort retrieved 10 *Pteronarcys* stoneflies in a sample, which required a 10 percent subsample, then 10 x 0.10 = 1 stonefly would be added to the subsample data.

After combining the components of each sample, the matrix was adjusted for different levels of taxonomy. When identifying macroinvertebrates, some specimens were either too immature or too damaged for identification at the genus-level, and could only be assigned to a taxonomic family or order. For instance, a sample may contain individuals identifiable only to the mayfly family Baetidae, yet also contain individuals clearly identified to one or more genera within this family (e.g., *Baetis tricaudatus*, *Diphetor hageni*.). This situation can lead to inflated estimates of the number of taxa in a sample.

To prevent the inflation of metrics, the abundances of these “parent” taxa were distributed proportionately among their composite taxa. This apportioning is similar to the method used by the USGS NAWQA studies to correct for “ambiguous taxa” (Cuffney et al. 1997). The abundances of “parent” taxa (orders, families) were retained in analysis when there were no composite taxa identified in the sample.

After applying the corrective measures used in preparing the taxa-abundance matrix, the data were used to calculate several descriptive metrics commonly used in aquatic ecological studies, including ten metrics that are used to calculate the Benthic Index of Biological Integrity (B-IBI) for Puget Sound lowland streams (Karr 1998; Karr and Chu 1999; SalmonWeb 2000; Morley and Karr 2002). A list of the metrics and indices calculated for each sample are given with brief descriptions in Table 2-8. The ten metrics for each site were scored using defined criteria for each metric (Table 2-9). Scores based upon the Genus level (SalmonWeb 2000) were tallied for a final B-IBI score ranging from 10-50. Based on these scores and regional reference conditions, stream condition, or stream "health," was determined (Table 2-10).

In this analysis, two metric groups differ from the traditional way they are calculated, using methods proposed by Wisseman (2004) for benthic invertebrate biomonitoring studies in western North America. For functional-feeding groups calculated in this analysis, taxa can be partitioned between several groups, rather than by a single allocation to a group. Allowing a multiple allocation recognizes both the facultative and obligate forms of feeding that are exhibited by many macroinvertebrate taxa (Cummins et al. 2008).

Tolerance-based metrics in this analysis utilize an index called the Community Tolerance Index (CTI) (Wisseman 2004), rather than the traditional modified Hilsenhoff Biotic Index (HBI). Instead, this analysis uses. The HBI was based on the nutrient enrichment tolerances of Midwest macroinvertebrate taxa, and as such, does not incorporate the full spectrum of habitat types and taxa found in western North America (Wisseman 2004). The CTI is primarily based on sensitivity to warm waters and low levels of dissolved oxygen, but is also based on sensitivity to disturbances, siltation, fouling of surfaces with filamentous algae or bacteria, as well as sensitivity to nutrient enrichment. The use of the CTI is this analysis follows the methodology currently used by King County to calculate the B-IBI for streams in the Greater Lake Washington and Green-Duwamish River watersheds (EVS 2005).

2.3.3 Results

An assortment of metrics was used to examine the response and recovery of the benthic macroinvertebrate community since 1999. For simplicity, metric results are presented in broader descriptive classes as depicted in Table 2-8. There are no 1998 estimates are available for comparison for the Middle Falls site.

Table 2-8. Biological metrics calculated to describe benthic macroinvertebrate (BMI) samples collected in Whatcom Creek, City of Bellingham from 1998-2003 and 2007.

Biological Metrics	Description	Predicted Response to Impairment
Abundance Measures		
Density	The total number of individuals collected in a unit area (m^2)	variable
Richness Measures		
Taxa Richness *	Total number of individual taxa	decrease
Ephemeroptera Taxa *	Number of mayfly taxa	decrease
Plecoptera Taxa *	Number of stonefly taxa	decrease
Trichoptera Taxa *	Number of caddisfly taxa	decrease
Shannon-Weiner Diversity Index	Summary metric that combines taxa richness and abundances, calculated with the natural logarithm (ln)	decrease
Composition Measures		
Percent Composition: Major Taxa	Relative abundances of: Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Chironomidae, non-chironomid Diptera, other Insect taxa, and non-insect taxa	variable
Percent Dominant Taxa *	Percent composition of the three most abundant taxa	increase
EPT:Chironomid Ratio	Ratio of EPT abundance to Chironomidae abundance, ranging from 0 to 1, with scores below 0.5 indicating more Chironomidae.	decrease
Tolerance/Intolerance Measures		
Community Tolerance Index (CTI)	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) and intolerant (lower values) as defined by Wisseman (2004)	increase
Intolerant Taxa *	Number of taxa in sample that are highly intolerant to impairment (tolerance value ≤ 4) as defined by Wisseman (2004)	decrease
Percent Tolerant Organisms *	Percent of organisms in sample that are highly tolerant to impairment (tolerance value ≥ 7) as defined by Wisseman (2004)	increase
Functional Feeding Groups		
Percent Collector-Gatherers	Percent of macrobenthos that gather fine particulate matter	increase
Percent Collector-Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Scrapers (Grazers)	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators *	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Percent Other Groups	Percent of macrobenthos that are either omnivorous, macrophyte or piercer herbivores, or parasites	variable
Habits /Life History Measures		
Clinger Taxa *	Number of taxa with physical adaptations that allow them to hold onto smooth substrates in fast water, as defined by Wisseman (1998, 2004)	decrease
Long-lived Taxa *	Number of taxa that require more than 1 year to complete their life-cycles (semi-voltine), as defined by Wisseman (2004)	decrease

* Indicates metric used in B-IBI for Puget Sound region (SalmonWeb 2000)

Table 2-9. Genus level scoring criteria for B-IBI metric calculation for benthic macroinvertebrate samples collected on Whatcom Creek, City of Bellingham, Washington.

	Scoring Criteria		
B-IBI Metric	**1**	**3**	**5**
Taxa Richness	< 14	14 – 28	> 28
Ephemeroptera Taxa	< 3.5	3.5 – 7	> 7
Plecoptera Taxa	< 2.7	2.7 – 5.3	> 5.3
Trichoptera Taxa	< 2.7	2.7 – 5.3	> 5.3
Percent Dominance (3)	> 75	55 – 75	< 55
Intolerant Taxa	< 2	2 – 4	> 4
Percent Tolerant Organisms	> 44	27 – 44	< 27
Percent Predators	< 4.5	4.5 – 9	> 9
Clinger Taxa	< 8	8 – 16	> 16
Long-Lived Taxa	< 4	4 – 8	> 8

Table 2-10. B-IBI score ranges used to evaluate biological condition of Whatcom Creek, City of Bellingham, Washington.

Biological Condition	B-IBI Score Range
Excellent	46 – 50
Good	38 – 44
Fair	28 – 36
Poor	18 – 26
Very Poor	10 – 16

2.3.3.1 Abundance and Richness Measures

Estimates of the mean macroinvertebrate density (individuals/ m^2) in October 1999 indicate that macroinvertebrates had rapidly repopulated all sites (Figure 2-14) following the near-total losses reported immediately following the fire on June 10, 1999 (LaCroix 2001). The James site shows a slight increase in density in October 1999, compared to October 1998 levels, possibly due to increased drift of macroinvertebrates from the upstream disturbance. Densities in 2000 appear stable and similar to 1998; however, large increases in densities at all three sites were seen in 2001, 2002, and 2003, especially at the Racine site, which totaled 21,754 individuals/m^2 in 2002. These density estimates show equally large amounts of variability, due mostly to differences between samples. Density at the James site in 2003 was significantly lower than the other two sites in that year (912.2 individuals/m^2), suggesting a possible disturbance downstream of the Racine site. Samples collected in 2007 show less variability, averaging from 3,602 individuals/m^2 at Racine to 5,287 individuals/m^2 at James Street.

Mean taxa richness measures in 1999 show a substantial reduction in comparison to Ecology's 1998 samples (11.3 vs. 20 at Racine, 17 vs. 20 at James), depicting the impact of the spill and fire (Figure 2-15). EPT taxa richness shows similar results (Figure 2-16). Taxa richness levels appear to return to pre-burn levels by 2001. Results also indicate significantly lower taxa and EPT richness at the James site in 2003, again suggesting some disturbance that year at the downstream end of the study area.

Mean diversity (H') results also confirm that the spill and fire in 1999 influenced the benthic macroinvertebrate community in Whatcom Creek. Mean diversity averaged 1.1 to 1.3 in 1999, compared to 2.1 in 1998 (Figure 2-17). In 2000 and 2001, diversity increased slightly, but remained lower than 1998 levels. By 2003 and 2007, diversity was similar to pre-burn levels, averaging 2.0.

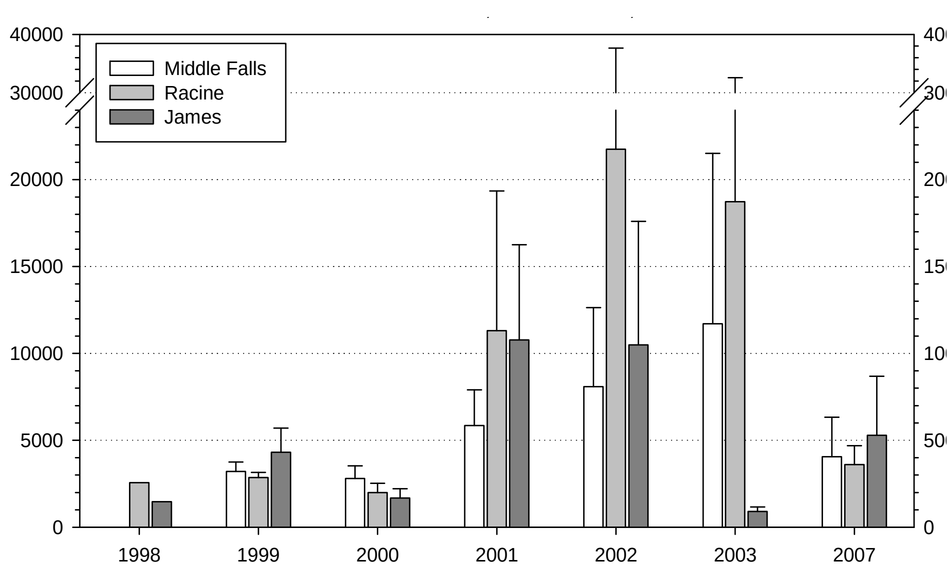

Figure 2-14. Mean estimated density (individuals/m^2) for benthic macroinvertebrate samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

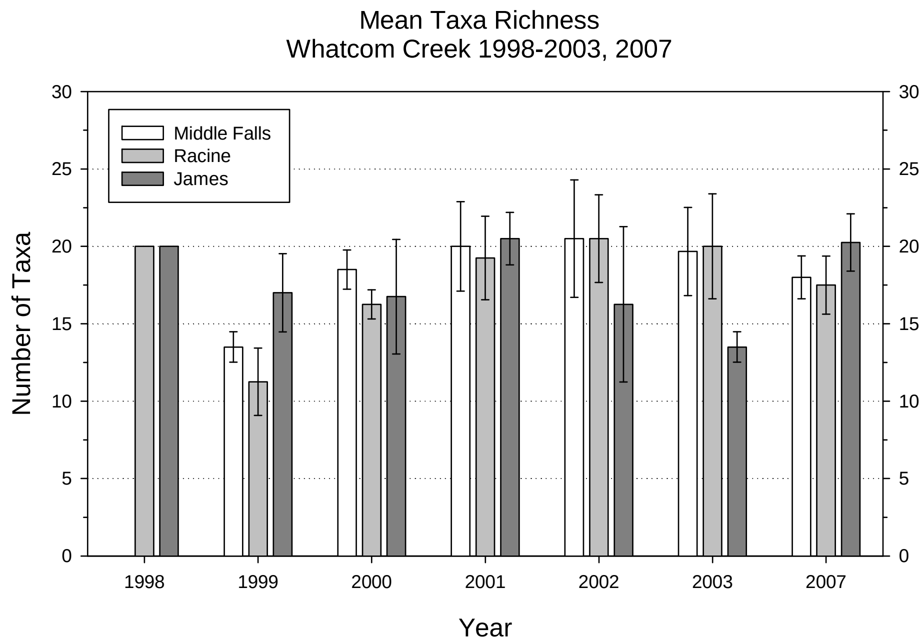

Figure 2-15. Mean total number of taxa in benthic macroinvertebrate samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

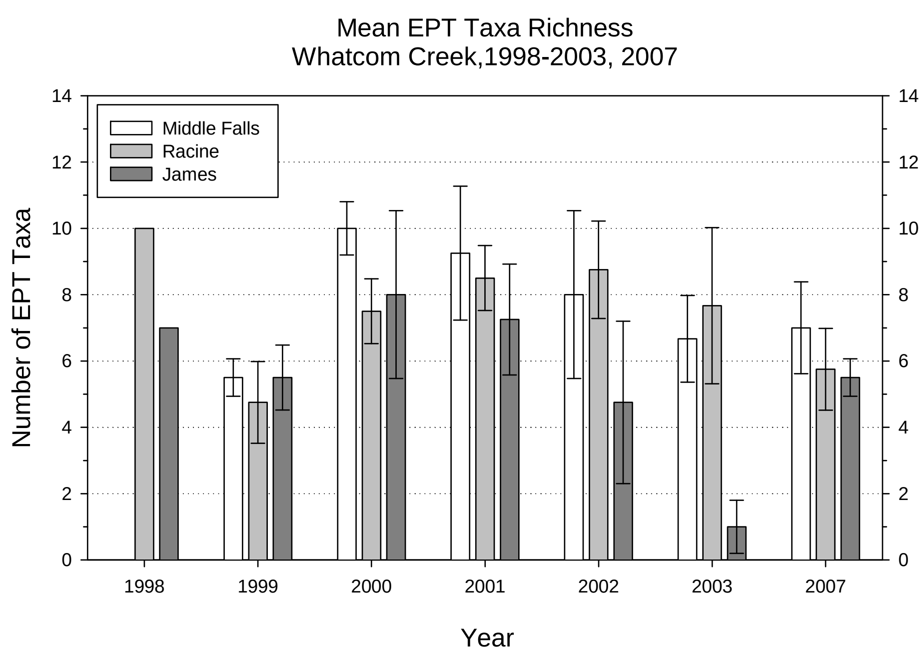

Figure 2-16. Mean number of Ephemeroptera, Plecoptera, and Trichoptera taxa in benthic macroinvertebrate samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

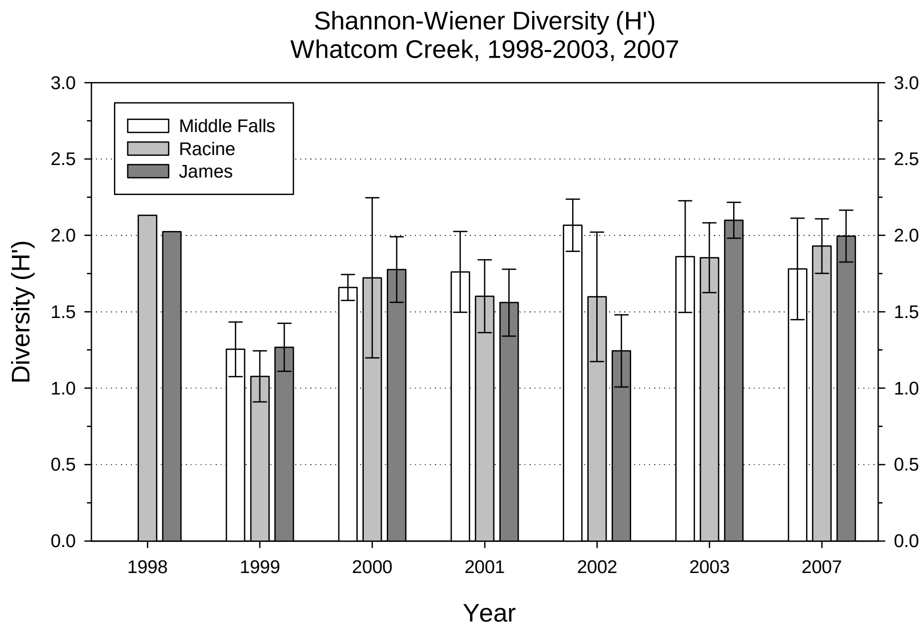

Figure 2-17. Mean estimated diversity for benthic macroinvertebrate samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

2.3.3.2 Composition Measures

To view the overall community structure of the Whatcom Creek benthic macroinvertebrate community from 1999 to 2007, relative abundances (percent composition) of 8 major taxonomic groups were calculated and graphically depicted in a group of stacked bar graphs for each site (Figures 2-18, 2-19, and 2-20). Results revealed the community at Middle Falls was initially comprised of nearly 80 percent Ephemeroptera in October 1999 and 2000 (Figure 2-18). In 1999, Ephemeroptera were largely represented by baetid mayflies (Figure 2-21), whereas in 2000, the community was comprised of 48 percent baetids (Figure 2-21), and 29 percent heptageniids (Figure 2-22). By 2001, mayflies declined to roughly 40 percent of the community's composition, replaced by simuliid blackfly larvae. In 2002 and 2003, the contribution of chironomid larvae increased, further replacing mayflies. By 2007, mayflies comprised 57 percent of the community, nearly all Baetidae (Figure 2-21), with a diverse remaining contribution of stoneflies, elmid beetle larvae, simuliids, and non-insect taxa.

The pre-burn community composition at the Racine site was comprised of over 60 percent mayflies, mostly *Rhithrogena* from the family Heptageniidae (Figure 2-22). After the burn in

1999, however, the composition shifted to nearly all Baetidae and Chironomidae (Figures 2-19, 2-21 and 2-23). By 2000, the community was once again dominated by Rhithrogena (40%), with 17.7 percent Baetidae. However, from 2001 to 2003, chironomids and simuliids (other Diptera) increased in their contributions to the community composition. By 2007, the community at Racine was comprised of baetids, chironomids, and various non-insect taxa, including amphipods and water mites; heptageniids contributed less than 2 percent in composition.

Non-insect taxa dominated the community sampled in 1998 at the James Street site, accounting for 56 percent of the sample (Figure 2-20). Most of these taxa were limpet snails from the family Ancylidae. After the burn in 1999, the community composition shifted to over 61 percent Baetidae (Figure 2-20 and 2-21). In 2000, the community was more balanced at 25 percent heptageniids, 31 percent chironomids, and an increase in dipterans from the family Empididae. In 2002 the community began to show increased contributions by non-insect taxa, comprising 89 percent of the community by 2003. In 2007, the macroinvertebrate community at the James site was again largely comprised of non-insect taxa and chironomids.

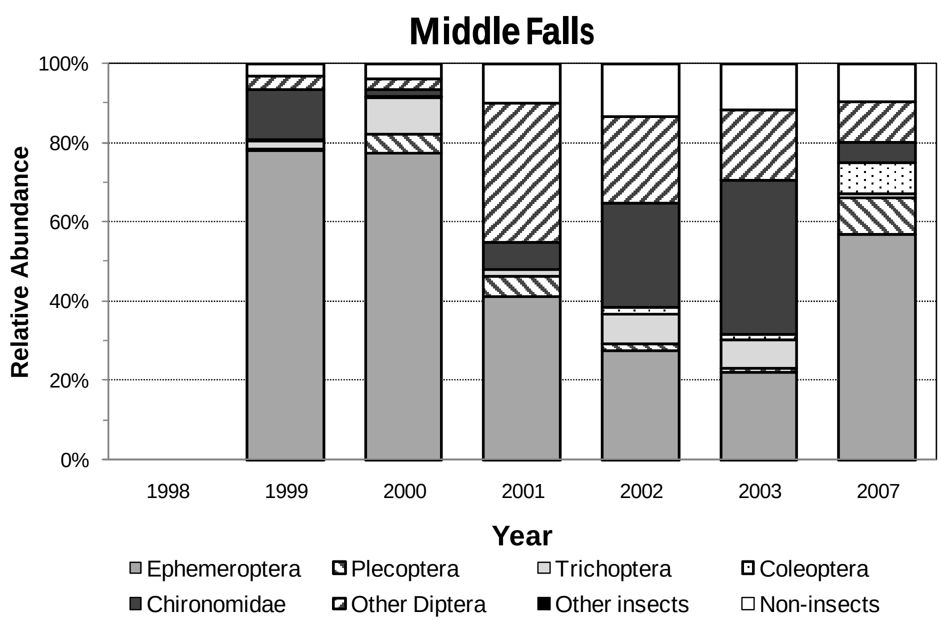

Figure 2-18. Mean relative abundances of the 8 major taxonomic groups of benthic macroinvertebrates collected at the Middle Falls site on Whatcom Creek in Bellingham, Washington during September/ October, 1999-2003, and 2007.

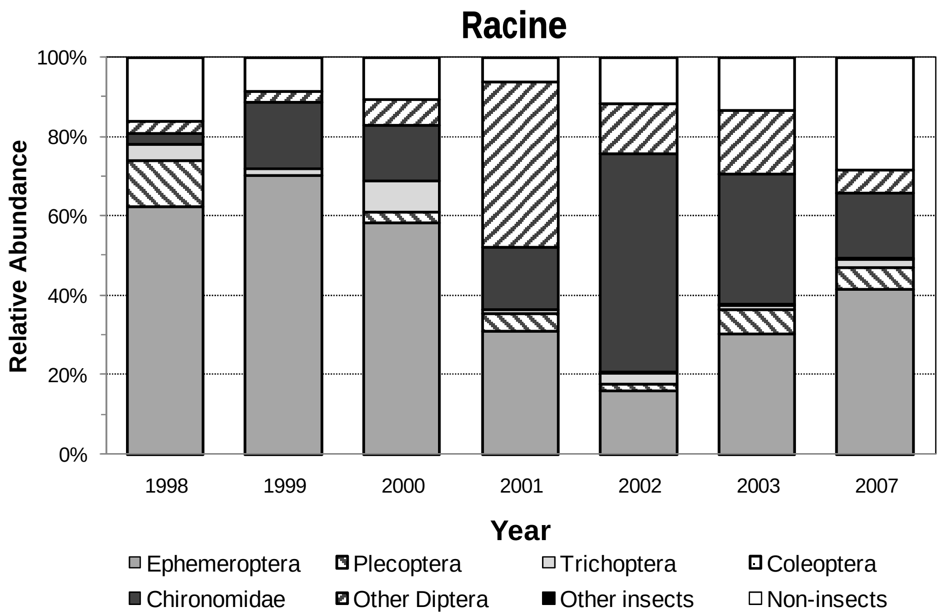

Figure 2-19. Mean relative abundances of the 8 major taxonomic groups of benthic macroinvertebrates collected at the Racine site on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007.

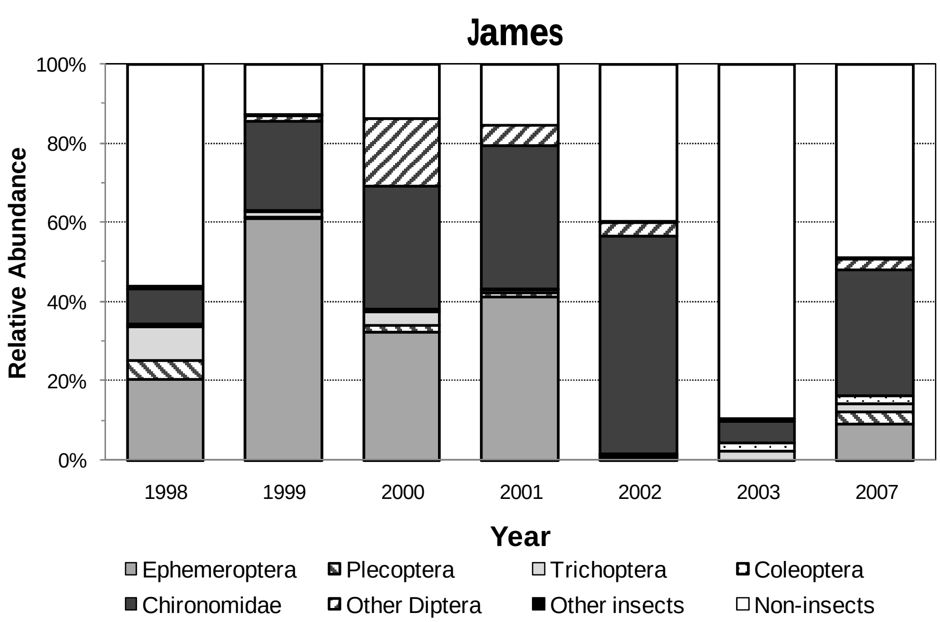

Figure 2-20. Mean relative abundances of the 8 major taxonomic groups of benthic macroinvertebrates collected at the James site on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007.

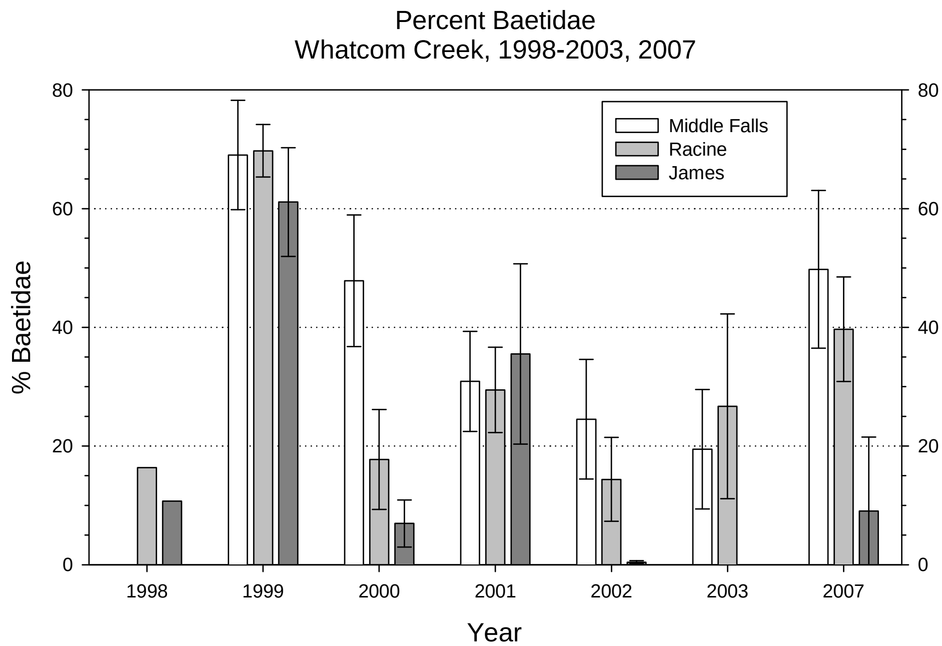

Figure 2-21. Mean relative abundances of the mayfly family Baetidae in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

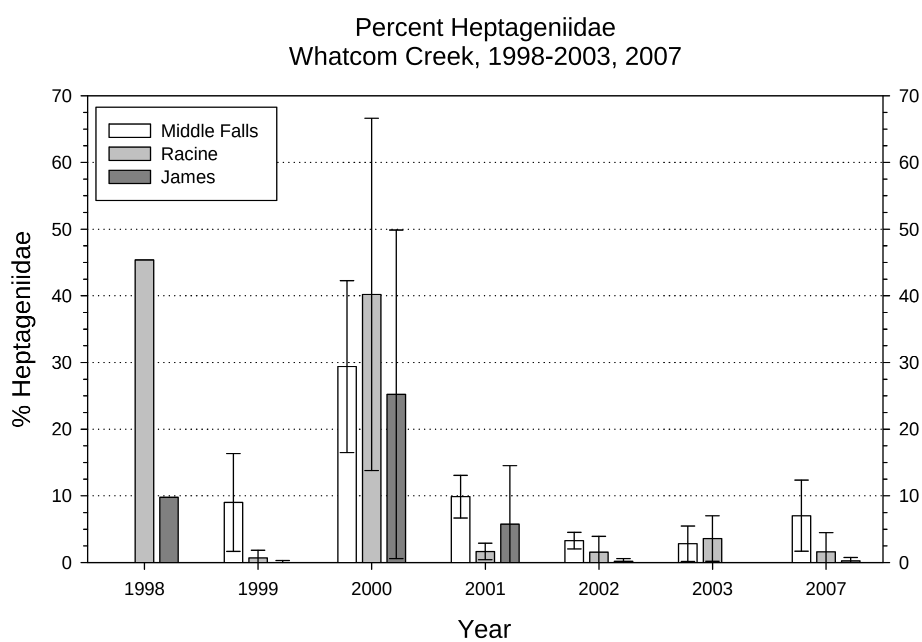

Figure 2-22. Mean relative abundances of the mayfly family Heptageniidae in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

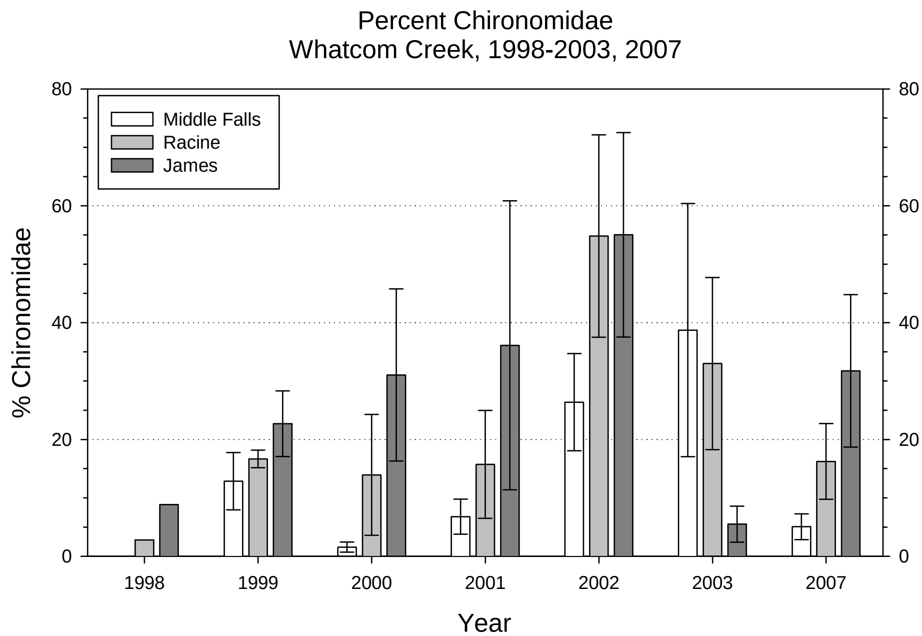

Figure 2-23. Mean relative abundances of the dipteran family Chironomidae in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

These results indicate that the benthic macroinvertebrate communities at the Whatcom Creek sites have shifted, and had not returned to a "pre-burn" composition as of 2007. Both Racine and James sites showed an increase in Baetidae following the gasoline spill and fire in 1999 (Figure 2-21). Both communities also had an increase in Heptageniidae the following year, in 2000, but the heptageniid contribution was significantly less than that seen in pre-burn samples. While it is uncertain what the pre-burn community composition was at Middle Falls, it is apparent that it had not stabilized by 2003. Additional analysis of this shift in community compositions was conducted using multivariate procedures, and is detailed further in Appendix C.

2.3.3.3 Functional Feeding Groups

The benthic macroinvertebrate communities in Whatcom Creek were dominated by collector-gatherers and scrapers over the period of 1998 to 2003, and in 2007 (Figure 2-24). Results from the 1998 samples show that both the Racine and James sites were composed of approximately 50 percent scraper taxa and 36 percent collector-gatherers (Figures 2-25 and 2-26). Starting in 1999, scraper percentages began to decline at the Racine and James sites, whereas the percent collector-gatherers increased to 60 percent. At the James site, these proportions remained stable through 2007, with a slight increase in the percentage of predators present (Figure 2-27). At the

Racine site, the contributions of scrapers continued to decline, whereas the percentage of predators increased. In addition, a sharp increase in the percent collector-filterers occurred in 2001 at both the Racine and Middle Falls sites (Figure 2-28). Middle Falls had the highest contributions of collector-filterers of the three sites, presumably due to its proximity to the lake outlet upstream, which would deliver food particles in the drift to the site.

These results indicate a shift away from a feeding strategy that grazes on periphyton and epilithic growth, towards one that gathers fine particulate matter. The reduction of percent scrapers in 1999 suggests that Whatcom Creek is not as productive as it was before the spill and fire, at least in terms of producing the epilithic growth for scraper taxa to consume. Additional analysis of this shift in the functional feeding groups was conducted using multivariate statistics, and is detailed further in Appendix C.

2.3.3.4 Tolerance Measures

Results using the Community Tolerance Index gives scores ranging from 6.1 to 7.2, and with an overall average CTI score of 6.6 (Figure 2-29). On a biotic index scale, this average score indicates "fair" conditions, often a result of "fairly significant organic pollution." Wisseman (2004) associates this score with an intermediate-to-tolerant taxa that would be associated either with low to mid-elevation streams in a valley or foothills, with cool to warm water, or with an open, warm foothill stream that was slightly enriched.

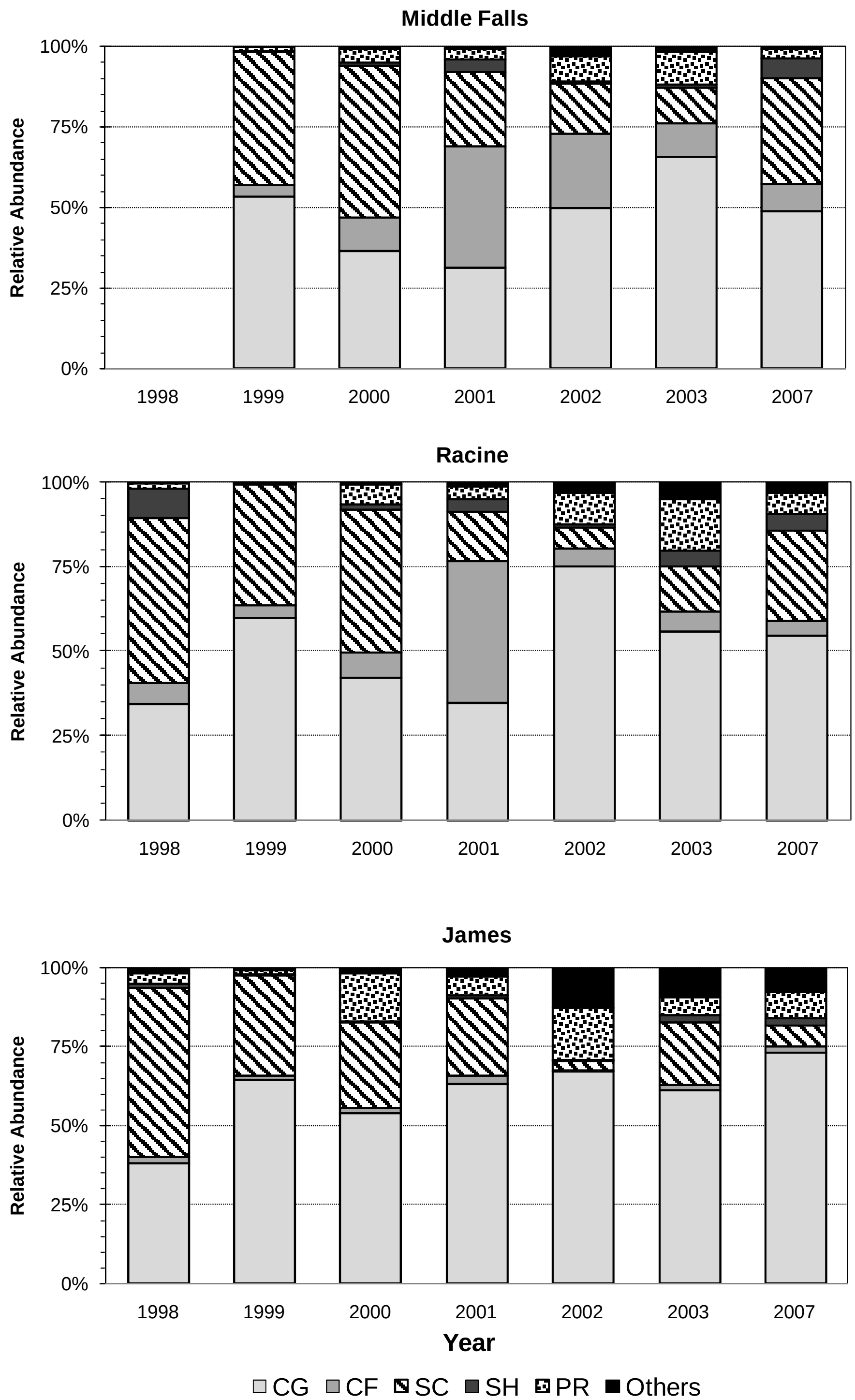

Figure 2-24. Mean relative abundances of the functional feeding groups in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007.

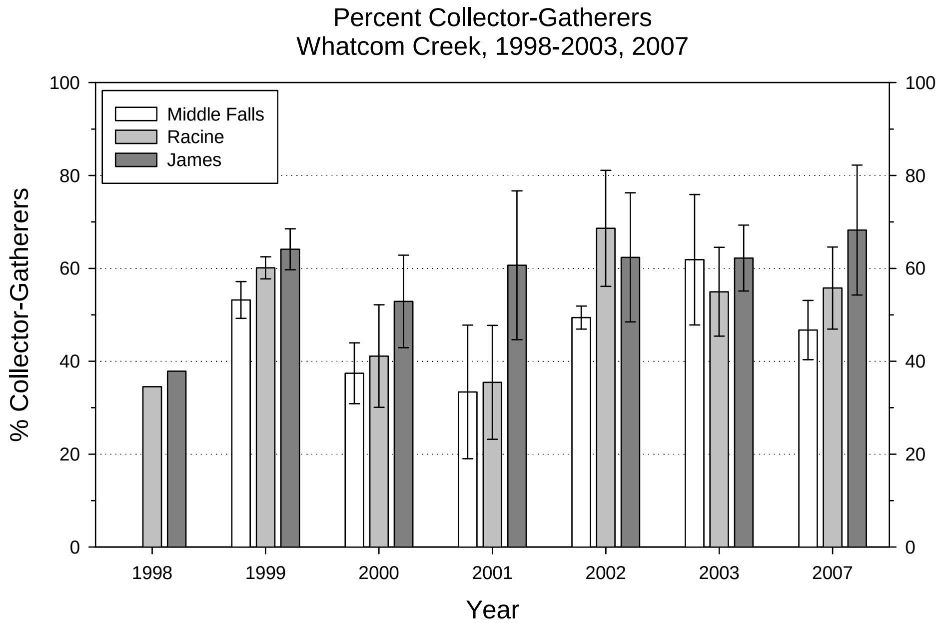

Figure 2-25. Mean relative abundances of the collector-gatherer feeding group in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

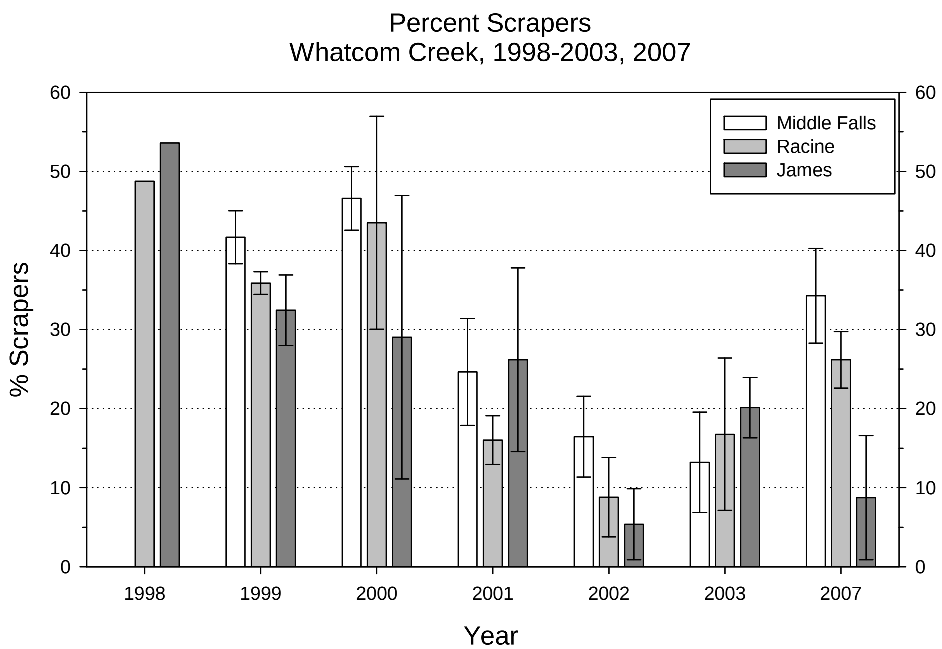

Figure 2-26. Mean relative abundances of the scraper feeding group in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

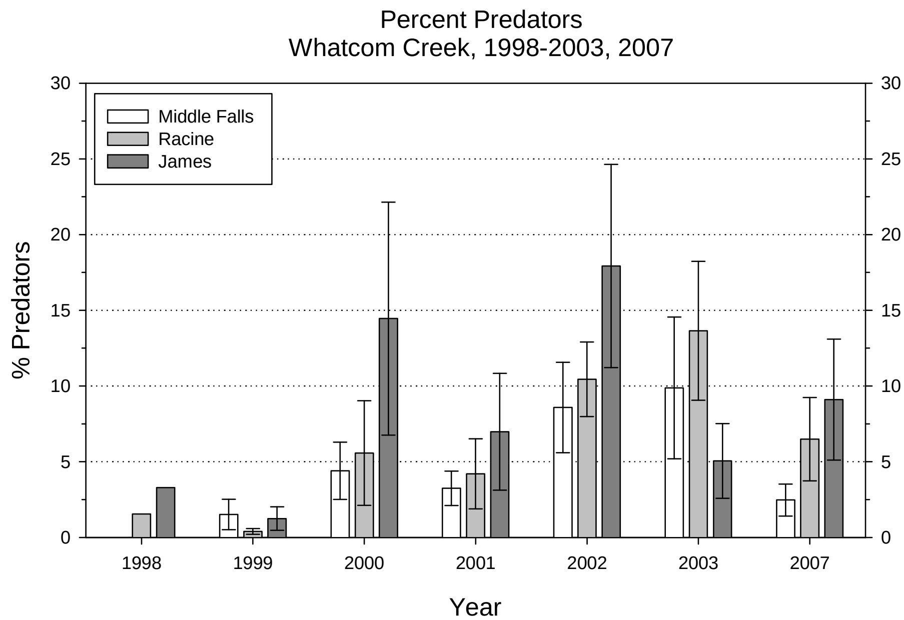

Figure 2-27. Mean relative abundances of the predator feeding group in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

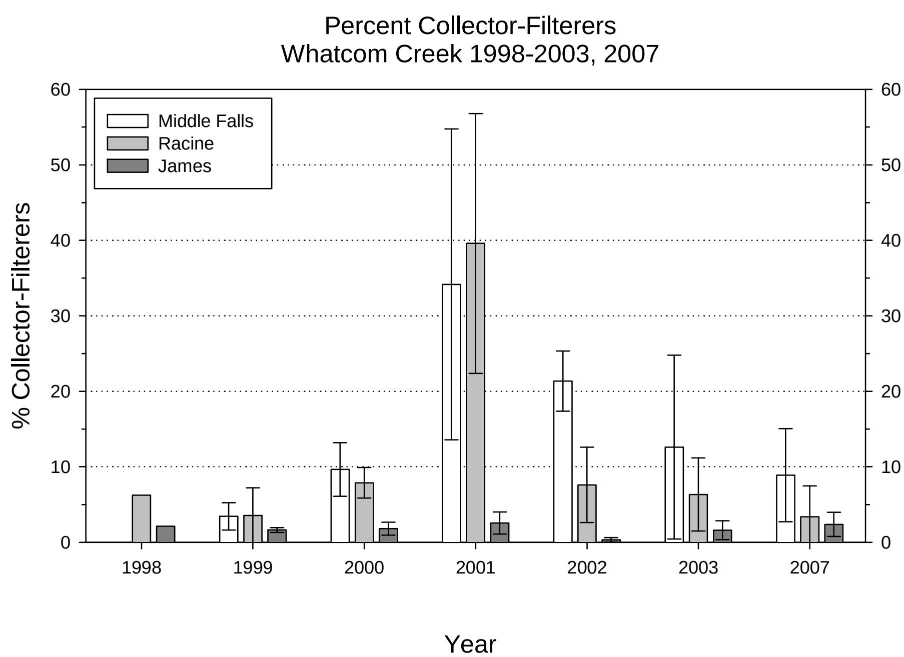

Figure 2-28. Mean relative abundances of the collector-filterer feeding group in benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals.

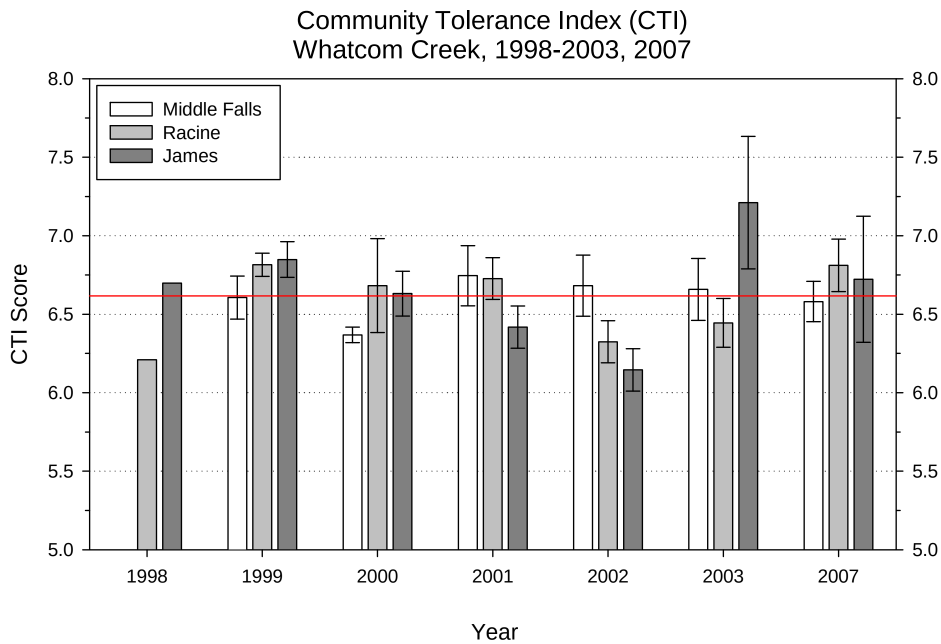

Figure 2-29. Mean scores of the Community Tolerance Index (CTI) for benthic macroinvertebrates samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007. Error bars represent 95% confidence intervals. Solid line represents the overall mean CTI score of 6.6 for all sites/years.

2.3.3.5 B-IBI

Index scores for the B-IBI were calculated for each site and year combination (Figure 2-30). At the Middle Falls site, scores ranged from 16 in 1999 to 24 in 2000 and 2002 (Table 2-11). For Racine, scores ranged from 12 in 1999 to 28 in 2002 (Table 2-12). At the James site, scores ranged from 16 in 1999 and 2003, to 24 in 2000, 2001, and 2002 (Table 2-13).

All sites had their lowest B-IBI scores during 1999, with the exception of James, which showed a low score during the year that many of the other metrics indicated a possible disturbance or impairment at that site (Figure 2-30). The low scores in 1999 indicate "very poor" stream conditions. Most of the scores calculated in this assessment indicate that the sites on Whatcom Creek are in "poor" condition. The exception was the Racine site's score of 28 in 2002, which qualifies as "fair" condition. Given that Whatcom Creek is a fairly urbanized stream in the Puget Sound region, these scores seem fairly appropriate. While the choice of tolerance values may be open to discussion, the B-IBI correctly identified conditions in 1999 as the poorest in comparison to other years.

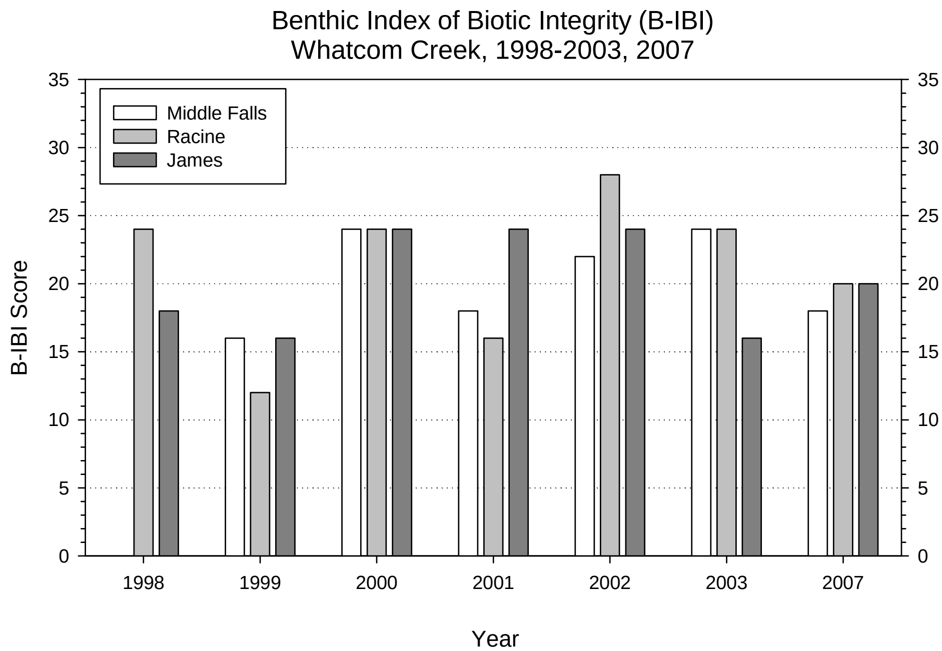

Figure 2-30. Calculated scores for the Benthic Index of Biotic Integrity (B-IBI) for benthic macroinvertebrate samples collected at three sites on Whatcom Creek in Bellingham, Washington during September/ October, 1998-2003, and 2007.

Table 2-11. Mean values for metrics calculated for the Middle Falls site on Whatcom Creek, Bellingham, Washington, and the scores for the Benthic Index of Biotic Integrity (B-IBI).

	10/28/1999	10/26/2000	9/12/2001	9/17/2002	9/15/2003	9/26/2007
Density (sq m)	3206.30	2795.93	5854.22	8090.42	11705.75	4051.55
Taxa Richness	13.5	18.5	20	20.5	19.67	18
Ephemeroptera Taxa	3.5	3.75	3.75	2.5	2.67	3
Plecoptera Taxa	0.75	3.25	3	2.5	1	2.25
Trichoptera Taxa	1.25	3	2.5	3	3	1.75
H'	1.25	1.66	1.76	2.07	1.86	1.78
% Ephemeroptera	78.2	77.4	41.2	27.8	22.3	56.9
% Plecoptera	0.2	4.9	5.4	1.4	0.9	9.1
% Trichoptera	2.1	9.5	1.4	7.6	7.0	1.0
% Coleoptera	0.2	0.1	0.0	1.8	1.6	8.0
% Chironomidae	12.9	1.6	6.8	26.4	38.7	5.1
% Diptera	3.4	2.6	35.2	21.7	17.7	10.2
% other insect	0	0	0	0	0	0
% non-insect	3.1	3.9	10.0	13.3	11.8	9.6
% Dominance (3)	86.1	80.6	75.8	64.9	73.2	73.6
EPT:Chironomid Ratio	0.86	0.98	0.88	0.58	0.45	0.92
CTI	6.61	6.37	6.75	6.68	6.66	6.62
Intolerant Taxa	2	5	1	2	2	3
% Tolerant Taxa	72.5	55.9	74.9	59.7	52.2	67.0
% Collector-Gatherer	53.2	37.4	33.4	49.4	61.9	46.7
% Collector-Filterer	3.4	9.6	34.2	21.4	12.6	8.9
% Scraper	41.7	46.6	24.6	16.4	13.2	34.3
% Shredder	0.1	0.9	3.4	0.8	0.7	6.6
% Predator	1.5	4.4	3.2	8.6	9.9	2.5
% Others	0.1	0.2	0.6	3.1	1.3	0.7
Clinger taxa	8.5	12.75	13	13.75	13	11.75
Long-Lived Taxa	1	3	1	2	2	3
B-IBI Scores						
% Dominance (3)	1	1	1	3	3	3
Taxa Richness	1	3	3	3	3	3
Ephemeroptera Taxa	3	3	3	1	1	1
Plecoptera Taxa	1	3	3	1	1	1
Trichoptera Taxa	1	3	1	3	3	1
Intolerant Taxa	3	5	1	3	3	3
% Tolerant Taxa	1	1	1	1	1	1
Clinger taxa	3	3	3	3	3	3
Long-Lived Taxa	1	1	1	1	1	1
% Predator	1	1	1	3	5	1
B-IBI	16	24	18	22	24	18

Table 2-12. Mean values for metrics calculated for the Racine site on Whatcom Creek, Bellingham, Washington, and the scores for the Benthic Index of Biotic Integrity (B-IBI).

	10/15/1998	10/28/1999	10/26/2000	9/11/2001	9/17/2002	9/15/2003	9/25/2007
Density (sq m)	2564.34	2857.82	2000.74	11310.18	21753.86	18731.00	3601.87
Taxa Richness	20	11.25	16.25	19.25	20.5	20	17.5
Ephemeroptera Taxa	5	2.75	3.5	3.75	3.5	3.7	3.25
Plecoptera Taxa	3	0	2.25	2.5	2.25	2	1.25
Trichoptera Taxa	2	2	1.75	2.25	3	2	1.25
H'	2.13	1.08	1.72	1.60	1.60	1.85	1.93
% Ephemeroptera	62.3	70.4	58.4	31.1	15.9	30.4	41.7
% Plecoptera	11.7	0.0	2.9	4.3	1.8	6.0	5.5
% Trichoptera	4.0	1.6	7.8	1.1	3.1	1.2	1.9
% Coleoptera	0.0	0.0	0.0	0.0	0.0	0.1	0.4
% Chironomidae	2.8	16.7	13.9	15.7	54.8	33.0	16.2
% Diptera	3.1	2.8	6.3	41.7	12.8	15.9	5.9
% other insect	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% non-insect	16.0	8.5	10.7	6.0	11.6	13.3	28.3
% Dominance (3)	63.9	91.4	72.8	83.3	76.8	69.8	70.7
EPT:Chironomid Ratio	0.97	0.81	0.82	0.72	0.29	0.53	0.74
CTI	6.21	6.81	6.68	6.73	6.32	6.45	6.81
Intolerant Taxa	2	2	2	1	3	4	2
% Tolerant Taxa	37.3	81.2	41.7	73.9	31.3	46.2	67.4
% Collector-Gatherer	34.5	60.1	41.1	35.4	68.6	55.0	55.7
% Collector-Filterer	6.3	3.5	7.9	39.6	7.6	6.3	3.4
% Scraper	48.8	35.9	43.5	16.0	8.8	16.8	26.2
% Shredder	8.5	0.0	1.4	3.2	1.3	4.5	4.4
% Predator	1.5	0.4	5.6	4.2	10.4	13.6	6.5
% Others	0.5	0.0	0.2	1.3	2.8	3.8	2.9
Clinger taxa	13	7	10	12.25	13.75	13.3	10.25
Long-Lived Taxa	1	1	2	2	4	3	1
B-IBI Scores							
% Dominance (3)	3	1	3	1	1	3	3
Taxa Richness	3	1	3	3	3	3	3
Ephemeroptera Taxa	3	1	3	3	3	3	1
Plecoptera Taxa	3	1	1	1	1	1	1
Trichoptera Taxa	1	1	1	1	3	1	1
Intolerant Taxa	3	3	3	1	3	3	3
% Tolerant Taxa	3	1	3	1	3	1	1
Clinger taxa	3	1	3	3	3	3	3
Long-Lived Taxa	1	1	1	1	3	1	1
% Predator	1	1	3	1	5	5	3
B-IBI	24	12	24	16	28	24	20

Table 2-13. Mean values for metrics calculated for the James site on Whatcom Creek, Bellingham, Washington, and the scores for the Benthic Index of Biotic Integrity (B-IBI).

	10/15/1998	**10/28/1999**	**10/26/2000**	**9/12/2001**	**9/19/2002**	**9/22/2003**	**9/25/2007**
Density (sq m)	1466.58	4316.33	1684.55	10784.09	10492.12	912.24	5286.84
Taxa Richness	20	17	16.75	20.5	16.25	13.5	20.25
Ephemeroptera Taxa	2	3.25	2.75	1.5	2	0	2.25
Plecoptera Taxa	3	0.25	2.25	2.75	1	0	1
Trichoptera Taxa	2	2	3	3	1.75	1	2.25
H'	2.03	1.27	1.78	1.56	1.24	2.10	2.00
% Ephemeroptera	20.5	61.3	32.6	41.3	0.7	0.0	9.3
% Plecoptera	4.9	0.1	1.5	1.2	0.2	0.0	2.9
% Trichoptera	8.6	1.7	3.5	0.8	0.7	2.5	2.0
% Coleoptera	0.6	0.1	0.7	0.0	0.2	2.0	2.3
% Chironomidae	8.9	22.7	31.0	36.1	55.0	5.5	31.7
% Diptera	0.6	1.6	16.9	5.2	3.8	0.7	2.7
% other insect	0.0	0.1	0.0	0.0	0.0	0.0	0.1
% non-insect	56.0	12.5	13.7	15.4	39.4	89.4	48.9
% Dominance (3)	64.2	90.2	75.0	80.5	89.6	59.4	69.4
EPT:Chironomid Ratio	0.79	0.73	0.52	0.56	0.03	0.27	0.28
CTI	6.70	6.85	6.63	6.42	6.15	7.26	6.72
Intolerant Taxa	0	1	2	2	2	2	1
% Tolerant Taxa	67.3	75.0	37.9	47.6	14.6	78.3	46.6
% Collector-Gatherer	37.8	64.1	52.9	60.7	62.4	62.2	68.2
% Collector-Filterer	2.1	1.6	1.8	2.6	0.3	1.6	2.4
% Scraper	53.6	32.4	29.0	26.2	5.4	20.1	8.7
% Shredder	1.6	0.0	0.3	0.9	0.1	1.9	2.9
% Predator	3.3	1.2	14.5	7.0	17.9	5.1	9.1
% Others	0.9	0.4	1.2	2.6	13.7	5.1	7.3
Clinger taxa	12	9.25	11.25	13.5	9.75	5.5	11
Long-Lived Taxa	0	5	2	4	2	1	3
B-IBI Scores							
% Dominance (3)	3	1	1	1	1	3	3
Taxa Richness	3	3	3	3	3	1	3
Ephemeroptera Taxa	1	1	1	1	1	1	1
Plecoptera Taxa	3	1	1	3	1	1	1
Trichoptera Taxa	1	1	3	3	1	1	1
Intolerant Taxa	1	1	3	3	3	3	1
% Tolerant Taxa	1	1	3	1	5	1	1
Clinger taxa	3	3	3	3	3	1	3
Long-Lived Taxa	1	3	1	3	1	1	1
% Predator	1	1	5	3	5	3	5
B-IBI	18	16	24	24	24	16	20

2.3.4 Discussion

The analysis of the macroinvertebrate data collected from Whatcom Creek from 1998 through 2003, and in 2007, showed that the June 1999 spill and fire, and subsequent restoration efforts, had a definite impact on the macroinvertebrate communities at the James and Racine Street sites. Sampling in October 1999 revealed decreased mean taxa richness, EPT richness, diversity, and B-IBI scores, and a changed taxonomic composition in the communities. At Racine, the *Rhithrogena* mayflies that dominated the community in 1998 were replaced by Baetidae, Plecoptera taxa were absent, and chironomids were more prevalent than the previous year. At the James Street site, the high numbers of limpet snails seen in 1998 were dramatically reduced in post-burn sampling in October 1999, replaced by high numbers Baetidae, and an increased presence of Chironomidae, gammarid amphipods, and oligochaete worms. These shifts in composition were also reflected in the compositions of functional feeding groups, with a reduced percentage of scraper taxa being replaced by an increased proportion of collector-gatherers.

In the early phases of colonization of a denuded streambed, bare substrates soon become covered with organic layers of an epilithic film, and as that film develops, “browsing” collector-gatherers will begin to occupy the area (Mackay 1992). Among the mayflies, Baetidae are usually the most abundant early colonizers (Shaw and Minshall 1980; Minshall and Petersen 1985; Gray and Fisher 1981; Waters 1964; Miyake et al. 2003). Chironomidae larvae and gammarid amphipods are also recorded among the first colonizers (Gray and Fisher 1981; Waters 1964; Mackay 1992). Filter-feeding taxa, such as blackfly larvae (Simuliidae), may also be attracted to the smooth, cleared surfaces of newly available substrates, but as periphyton begins to develop and add complexity to the surface texture, hydropsychid caddisflies may move in to replace the simuliids (Mackay 1992). The presence of algae may also begin to attract more scraper taxa.

By October 2000, 14 months following restoration efforts, many of the metrics appeared to return to the pre-burn levels seen in 1998. At Racine, taxa richness measures increased, B-IBI scores also improved, stonefly taxa were present again, and Heptageniidae numbers had increased to pre-burn levels, as well. At the James Street site, taxa richness measures and diversity showed levels approaching pre-burn conditions. Both EPT taxa richness and the B-IBI score were slightly better than those calculated for 1998. The community at the James site was no longer dominated by non-insect taxa, as in 1998, but now largely populated by *Rhithrogena*, with chironomids, and dance fly larvae (*Hemerodromia*).

These results suggest that the benthic macroinvertebrate community in Whatcom Creek was nearing the point of recovery to pre-burn conditions by 2000-2001. This observation is supported by another study conducted on Whatcom Creek investigating the effects of the spill and fire on the macroinvertebrate community (LaCroix 2001). Using the same methodology as Ecology (Bogdan 1998), LaCroix (2001) sampled the Racine and James Street sites and at the mouth of Cemetery Creek in June 1999, seven days after the fire, September 1999, and September 2000. Her study also used Ecology's October 1998 sampling as baseline. Results showed nearly complete losses in the macroinvertebrate community seven days after the spill and fire in June 1999.

However, LaCroix (2001) found a substantial increase three months later, with an estimated density of 12,476 organisms/m^2 at Racine, and 6,057 organisms/m^2 at the James Street site, levels much higher than those estimated from R2's October 1999 samples collected at the same sites (2,858 organisms/m^2 at Racine, 1,685 organisms/m^2 at James). These differences are largely due to the fact that LaCroix's (2001) sampling collected a larger number of Simuliidae larvae at Racine and James Street, which may be due to seasonality, patchy distribution, or to differences in methodology, and also included zooplankton, which this analysis did not include. Simuliid blackflies have modified mouthparts that are specialized cephalic fans that filter the water-column for fine particulate organic matter (FPOM), therefore making them highly dependent on flow (Adler and Currie 2008). Blackfly larvae have a patchy spatial distribution in streams (Hart 1986). Individuals often occur in large groups, anchoring themselves to smooth substrate surfaces and distribute themselves evenly, randomly, or in bands and clumps, depending on the age, species, and environmental conditions (Hart 1986**;** Mackay 1992; Adler and Currie 2008). As a result, the distributions of the Simuliidae at the Racine and James Street sites may have also been highly clustered in certain areas, resulting in differing estimates, depending on where samples were taken.

LaCroix (2001) did find taxa richness and EPT richness measures were lower than 1998 levels, similar to the results of this analysis. LaCroix (2001) concluded that, as of September 2000, the Whatcom Creek macroinvertebrate community did not appear to have been fully recovered from the spill and burn event of June 1999, due to the continued dominance of collector-gatherers and collector-filterers and a lower contribution of the scraper and shredder taxa that existed before the spill and burn. However, community similarity analyses and several metrics, including taxa richness, EPT richness, and the HBI all indicated partial recovery in the September 2000 samples.

The conclusions from LaCroix (2001) appear to be corroborated by the results from sampling from 2001 to 2003, when the responses of several metrics became more variable. Density estimates increased significantly, by a magnitude of as much as 4 times of those seen from 1998 through 2000, mostly due to an increased number of chironomids. The community composition of Heptageniidae declined to less than 10 percent; in accordance, the percentage of scrapers declined from roughly 40 percent to 10-15 percent. The percentage of predators increased from less than 5 percent in 1998 to an average of 7-10 percent in 2001 to 2003.

In addition, several metrics revealed large shifts in the benthic macroinvertebrate communities on Whatcom Creek during this period of 2001-2003. In September 2001, both Middle Falls and the Racine Street sites experienced a large increase in collector-filterers. This shift is also evident in the community composition, with an increase in *Simulium* spp. Simuliid blackflies have modified mouthparts that are specialized cephalic fans that filter the water-column for FPOM, so an increase in their numbers would suggest that Whatcom Creek was receiving an increased input of FPOM during or prior to this sampling period, possibly from Lake Whatcom. In contrast, the James Street site showed a large drop in density, taxa richness measures, and the B-IBI score in September 2003. Community composition percentages show that all mayflies disappeared from the James Street site, replaced entirely by amphipods and gastropods. These results suggest an impact or event that could have occurred pre-September in 2003 that may have impacted Whatcom Creek downstream of Racine, but upstream of the James site.

Results from 2007 appear most similar to those of 2000; density and taxa richness are similar, and diversity is close to 1998 levels. For community composition, Middle Falls is dominated by Baetidae, with *Rhithrogena*, Nemouridae stoneflies, elmid beetle larvae, and *Simulium* spp.; Racine is largely comprised of Baetidae and Chironomidae, with a large contribution of non-insect taxa; and James is dominated by non-insect taxa, mostly amphipods, isopods, and limpet snails, with many chironomids, but few numbers from EPT taxa.

While measures of taxa richness, EPT richness, and diversity are within the range of those seen in 1998, the results also indicate that the benthic macroinvertebrate communities at the Whatcom Creek sites are substantially different in 2007 in comparison to 1998. Both the Racine and James Street sites showed an increase in Baetidae following the spill and fire in 1999, followed by an increase in Heptageniidae the following year, in 2000. Since then, the heptageniid contribution has become significantly less than that seen in pre-burn samples. While it is uncertain what the pre-burn community composition was at Middle Falls, it is apparent that it had not stabilized by 2003.

One of the tools used in this analysis is the B-IBI, a multi-metric approach that compares what is found at a site to what is expected using a regional baseline condition that reflects little or no human impact (Karr and Chu 1999). Karr (1998) explains that the biological integrity of streams is directly influenced by human activity; therefore, measuring biological integrity provides an insight to the human impacts upon stream systems. The B-IBI scores calculated in this study revealed Whatcom Creek as a stream in "poor" condition; this is true both before June 1999 as well as during the subsequent recovery period following the event. It is clear that B-IBI scores were at the lowest level, “very poor,” during October 1999 sampling, immediately following the spill and burn. Since 2000, B-IBI scores have remained in the “poor” condition range (18-26), indicating high levels of human activity in the watershed that are impacting the stream’s biological integrity.

These comparisons also point to one limitation of this analysis: the lack of pre-burn data. Comparisons are limited to one composite sample in 1998 at each of only two sites, Racine and James; analysis is lacking any data on a pre-burn Middle Falls community. Thus, the assumption is made that those results from 1998 are truly representative of what the stream looked like before the June 1999 event. While the comparisons are useful, metrics such as the B-IBI are more informative of the overall condition of the stream, and can indicate improvements or degradation with a continued monitoring program.

2.4 RIPARIAN AND TERRESTRIAL WILDLIFE

2.4.1 Introduction

Because of its central location within a highly developed area of the City of Bellingham, Whatcom Creek represents an ecologically important area. Undeveloped streamside areas serve as habitat for urban wildlife, and the stream itself represents a travel corridor connecting Bellingham Bay with the Lake Whatcom Watershed. Prior to the fire the terrestrial ecosystem along the creek consisted of mature conifer forest upstream of Woburn Street, and a relatively narrow band of mature deciduous forest downstream of Woburn to the sewer line crossing. The fire resulted in the destruction of over 25 acres of vegetated habitat used by a wide range of wildlife. Table 2-14 lists species that had been observed or were believed likely to be in the burn zone prior to the fire.

2.4.2 Methods

Monitoring use of the site by riparian and terrestrial wildlife was integrated with other monitoring activities, and consisted primarily of compilation of a list of species observed to be using the site. Observations that documented wildlife use included direct sightings, tracks, scat or browse patterns. Where habitat utilization by Washington State Priority Species and/or Federally listed or candidate species is identified, sightings were reported to the WDFW Priority

Habitats and Species Program. Instances of wildlife harm due to human disturbance or site degradation by invasive mammals were also noted.

Table 2-14. Wildlife species potentially present in Whatcom Creek (from OPC 2002). Species listed in bold have been observed in the burn zone since 1999.

AMPHIBIANS			
Red-legged frog	***Rana aurora***	**Northwestern salamander**	***Ambystoma gracile***
Pacific Tree frog	***Hyla regilla***	**Long-toed salamander**	***Ambystoma macrodactylum***
Western toad	*Bufo boreas*	Ensatina	*Ensatina eschscholtzii*
Western red-backed salamander	*Plethodon vehiculum*	**Bull frog (non native)**	***Rana catesbeiana***
REPTILES			
Common garter snake	*Thamnophis sirtalis*	Rubber boa	*Charina bottae*
Northern alligator lizard	*Elgaria coerulea*	**Painted turtle**	***Chrysemys picta***
BIRDS			
Great blue Heron	***Ardea herodias***	**Chestnut-backed chickadee**	***Parus rufescens***
Green-backed heron	***Butorides virescens***	**Black-capped chickadee**	***Parus atricapillus***
Mallard duck	***Anas platyrhynchus***	**Dark-eyed junco**	***Junco hyemalis***
Wood duck	***Aix sponsa***	**Red-breasted nuthatch**	***Sitta canadensis***
Common Merganser	***Mergus merganser***	**Brown Creeper**	***Certhia americana***
Hooded merganser	***Lophodytes cucullatus***	**Bewick's wren**	***Thryomanes bewickii***
Canada goose	***Branta canada***	**Winter wren**	***Troglodytes troglodytes***
Swainson's Thrush	***Catharus ustulatus***	**Marsh wren**	***Cistothorus palustris***
Varied Thrush	***Ixoreus naevius***	**American Dipper**	***Cinclus mexicanus***
American Robin	***Turdus migratorius***	**Golden-crowned kinglet**	***Regulus satrapa***
Cedar Waxwing	***Bombycilla cedrorum***	**Ruby-crowned kinglet**	***Regulus calendula***
Yellow Warbler	***Dendroica petechia***	Western gull	*Larus ocidentalus*
Yellow-rumped warbler	***Dendroica coronata***	Glaucus winged gull	*Larus glaucescens*
MacGillivray's warbler	***Oporornis tolmiei***	**Tern sp.**	*Laridae* family
Wilson's warbler	***Wilsonia pusill***	Great-horned owl	*Bubo virginianus*
Orange-crowned warbler	***Vermivora celata***	Barred owl	*Stix varia*
Black-throated gray warbler	***Dendroica nigrescens***	**Vaux's swift**	***Chaetura vauxi***
Common yellowthroat	***Geothlypis trichas***	**Rufus hummingbird**	***Selasphorus rufus***
Western tanager	***Piranga ludoviciana***	**Belted kingfisher**	***Ceryle alcyon***
Spotted Towhee	***Pipilo maculatus***	**Red-breasted sapsucker**	***Sphyrapicus ruber***
Song sparrow	***Melospiza melodia***	**Downy woodpecker**	***Picoides pubescens***
White-crowned sparrow	***Zonotrichia leucophrys***	**Hairy woodpecker**	***Picoides villosus***

Table 2-14. Wildlife species potentially present in Whatcom Creek (from OPC 2002). Species listed in bold have been observed in the burn zone since 1999.

Chipping sparrow	*Spizella passerina*	**Northern flicker**	***Colaptes auratus***
Solitary vireo	*Vireo solitarius*	**Pileated Woodpecker**	***Dryocopus pileatus***
Stellar's jay	***Cyanocitta stelleri***	Olive-sided flycatcher	*Contopus borealis*
American crow	***Corvus brachyrhynchos***	**Willow flycatcher**	***Empidomax trailii***
Common raven	*Corvus Corax*	**Pacific slope flycatcher**	***Empidonax difficilis***
Tree swallow	***Tachycineta bicolor***	**Hammonds flycatcher**	***Empidonax hammondii***
Violet green swallow	***Tachycineta thalassina***	**Western wood peewee**	***Contopus sordidulus***
Barn swallow	*Hirundo rustica*	Ruffed grouse	*Bonasa umbellus*
Red-winged blackbird	***Agelaius phoeniceus***	**Killdeer**	***Charadrius vociferous***
Brewer's blackbird	*Euphagus cyanocephalus*	**Wilson's Snipe**	***Gallinago delicata***
Pine siskin	***Carduelis pinus***	**Bald eagle**	***Haliaetus leucocephalus***
Bushtit	***Psaltriparus minimus***	**Northern harrier**	***Circus cyneus***
Purple finch	***Carpodacus purpureus***	**Red-tailed hawk**	***Buteo jamaicensis***
House finch	*Carpodactus mexicanus*	Coopers Hawk	*Accipiter cooperii*
American Goldfinch	***Carduelis tristis***	Sharp-shinned hawk	*Accipiter striatus*
Black-headed grosbeak	***Pheucticus malanocephalus***	**Merlin**	***Falco columbarius***
Fox Sparrow	***Passeralla iliaca***	**Golden-crowned sparrow**	***Zono trichia atricapilla***
Common Nighthawk	***Chordeiles minor***	**Brown-headed cowbird**	***Molothrus ater***
Rock dove (non-native)	*Columba livia*	**European starling (non-native)**	***Sturnus vulgaris***
		MAMMALS	
Vagrant shrew	*Sores vagrans*	**Coyote**	***Canis latrans***
Coast mole	*Scanapus orarius*	Red fox	*Vulpes vulpes*
Douglas squirrel	*Tamiasciuris douglasii*	River otter	*Lutra canadensis*
Townsend's chipmunk	*Tamias townsendii*	Striped skunk	*Mephitus mephitus*
Deer mouse	*Peromyscus maniculatus*	**Black-tailed deer**	***Odocoilus hemionus columbianaus***
Muskrat	*Ondatra ziebethicus*	Little Brown bat	*Mytotis lucifugus*
Beaver	***Castor canadensis***	**Raccoon**	***Procyon lotor***
Mountain beaver	*Aplodontia rufa*	**Mink**	**Neovison vison**
Virginia opossum (non-native)	*Didelphis virginiana*	**Eastern cottontail rabbit (non-native)**	***Sylvilagus floridanu***
Norway rat (non-native)			

Rigorous, formal studies of wildlife use in the burn zone were beyond the scope of the monitoring plan and budget. However targeted surveys for amphibians and breeding birds have been conducted at the Cemetery Creek and Salmon Park Restoration sites as part of the companion Restoration Monitoring program (Forester 2009). In addition, City staff worked with a student at WWU to conduct a study of cavity nesting birds in snags within the lower portion of the burn zone (Dolan 2008). These data were all used to document wildlife use of the burn zone.

2.4.3 Results

2.4.3.1 Amphibians/reptiles

Twelve species of amphibians and reptiles were identified as being potentially present in the burn zone (Table 2-14). Five of the ten native amphibians and reptiles have been observed in the burn zone since the fire: Red-legged frog, pacific tree frog, northwestern salamander, long-toed salamander and common garter snake. Two non-native species are currently present in the burn zone: bullfrog and painted turtle.

2.4.3.2 Birds

A preliminary list of birds likely to occur in the burn zone that was compiled by WDFW in 1999 included 78 species. Since 2006 more than 66 bird species have been heard or observed within the burn zone (Table 2-14). Seven of these species are listed as Priority Species by the State of Washington (Table 2-15).

Table 2-15. Bird species with special status that have been documented to be present in the Whatcom Creek burn zone since 2006.

Common Name	WA Department of Fish and Wildlife Designation
Bald eagle	Priority Species (Criterion 1 – Species of Concern)
Merlin	Priority Species (Criterion 1 – Species of Concern)
Pileated woodpecker	Priority Species (Criterion 1 – Species of Concern)
Vaux’s swift	Priority Species (Criterion 1 – Species of Concern)
Great blue heron	Priority Species (Criterion 2 - Vulnerable Aggregations)
Hooded merganser	Priority Species (Criterion 3 - Species of Recreational, Commercial, and/or Tribal Importance that are Vulnerable)
Wood duck	Priority Species (Criterion 3 - Species of Recreational, Commercial, and/or Tribal Importance that are Vulnerable)

Four of the birds listed as Priority Species are cavity nesters. One of the most visible effects of the 1999 fire is the creation of numerous dead snags along the stream. Today many of these snags contain cavities that may provide habitat for those species. A study of cavity nesting birds in the downstream section of the burn in 2008 found that while red-shafted flickers, pileated woodpeckers and black-capped chickadees were using cavities in fire-burned snags, non-native European starlings aggressively displaced native birds, either taking over the cavity or driving off native birds then abandoning the site, allowing subsequent use by non-native house sparrows. Literature suggests that starling use is concentrated in open areas near grassy fields (Whitehead et al. 1995), and thus is possible that this species is less of a problem in the upstream portion of the burn zone where dead snags are surrounded by nature unburned forest.

Several species of raptors have been documented as nesting in or near the burn zone. A red-tail hawk nest and juveniles were observed to be affected by the 1999 fire. Since that time red-tail hawks have continued to nest near the confluence of Cemetery and Whatcom Creeks. In 2009 an osprey nest was observed on one of the snags created by the fire near the confluence of Hannah and Whatcom Creeks (Figure 2-31). Although nesting has not been confirmed in the area, merlins, bald eagles and harriers have all been observed perching or foraging in the burn zone.

Preservation of forested sites and restoration of native riparian vegetation within the study area has also benefited other bird species. Species that remain in the Pacific Northwest all year (e.g., black-capped and chestnut backed chickadee, song sparrow, brown creeper, junco, spotted towhee, and Bewick’s wren) are routinely detected during early season breeding bird surveys conducted at the Cemetery Creek and Salmon Park Restoration sites. Neotropical migrants, including at least seven warbler species, thrushes and flycatchers arrive and exhibit breeding behavior in April and May. As planted riparian habitats continue to mature the burn zone offers a variety of habitats ranging from open gravel bars and stream margins to mature coniferous forest.

Figure 2-31. Osprey nest in burn zone near confluence of Hannah and Whatcom Creeks, February 2009.

2.4.3.3 Mammals

Mammal species identified in the burn zone are consistent with common urban wildlife. The Washington Department of Fish and Wildlife identified nineteen mammal species that are likely to inhabit the burn zone (Table 2-14). Observations used to document mammal use include direct sightings, tracks, scat, or browse patterns. Five mammal species have been conclusively identified in the burn zone, including eastern cottontail, beaver, black-tailed deer, raccoon, mink and coyote. Inspection of scat indicates the possible presence of river otter (*Lontra canadensis*).

Monitoring of restoration areas conducted since 2006 has documented some damage to plantings by urban wildlife. Newly planted cedar, hemlock and other tree species are routinely protected from animal browsing by caging. Beaver damage to larger trees has been ameliorated by the placement of fencing around the bole of the trees. Beaver activity will be monitored and the deterrent program may be upgraded if damage continues. At this time, there is no evidence that human use is causing disturbance that is detrimental to the mammalian wildlife community.

2.4.4 Discussion

Although few quantitative data are available on wildlife use of the area prior to the 1999 fire, it appears that wildlife communities currently inhabiting the burn zone are similar to those that would be expected to inhabit the area in an urban ecosystem. The burn may to have increased habitat for some species such as cavity-nesting birds and mammals. However, non-native species appear to predominate in more open areas.

Riparian restoration has benefited all animals that use riparian forest areas. As part of the Settlement Agreement the City of Bellingham has acquired and restored native vegetation on two large parcels of land, increasing the amount of protected riparian habitat by 13.5 acres. Acquisition of these properties and restoration of riparian habitats throughout the remainder of the burn benefit all fish and wildlife species. Instream projects constructed at Salmon Park, Cemetery Creek and Red Tail Reach also have both direct and indirect benefits for wildlife. Direct effects include increased structure and cover for bird, mammal and amphibian species that utilize habitats along the stream margin. Indirect benefits include enhanced forage opportunities.

3. PHYSICAL MONITORING

3.1 HYDROLOGY AND INSTREAM HABITAT

3.1.1 Hydrology

3.1.1.1 Introduction

Streamflows in Whatcom Creek have been regulated since 1937 by the City of Bellingham when Whatcom Lake Dam was built for the primary purpose of water supply. Stream flow data have been recorded since around 1994 at the Control Dam near the outlet to Derby Pond. In 2002 a gage was installed at Dupont Street. The location of the gage sites is depicted in Figure 3-1. Data from these sites were reviewed to generate a general description of the flow regime in Whatcom Creek. While the fire would not have influenced flows in Whatcom Creek, hydrologic data provide an important context for interpreting changes in other monitoring parameters. External factors that change flows may influence conditions in Whatcom Creek as much or more than the fire itself.

3.1.1.2 Methods

The available flow records were reviewed for completeness. Monthly and annual flow statistics were calculated for each site before and after the burn using all available data. The annual peak flow for each water year was identified. A daily time series was constructed for the time that data both gage sites had a common period of record (i.e., 2003-2007) to qualitatively evaluate the relationship between flow releases at the control dam and flows at the Dupont gage site.

3.1.1.3 Results

The longest relatively continuous recent hydrologic data set for Whatcom Creek comes from the Derby Pond gage site, where flows have been recorded relatively consistently since 1994. That gage site is located upstream of the burn zone. A second gage was installed at Dupont Street in 2003. A visual assessment of daily flow time series for those gage sites indicates that flow patterns at the Derby Pond gage are generally representative of flows at Dupont Street, at least for the period in which overlapping data exist (Figure 3-2). Flow releases at Derby Pond account for approximately 62 percent of the flow at the Dupont Street gage on average. However, the proportion of flow represented by releases at Derby pond varies from around 20 to 80 percent. An in-depth analysis of flow patterns is beyond the scope of this report. Nonetheless, visual inspection suggests that Derby Pond flows represent a smaller proportion of the overall flow in the spring and early summer when flows are held back to maintain lake levels, and a higher

Figure 3-1. Location of stream gage sites on Whatcom Creek.

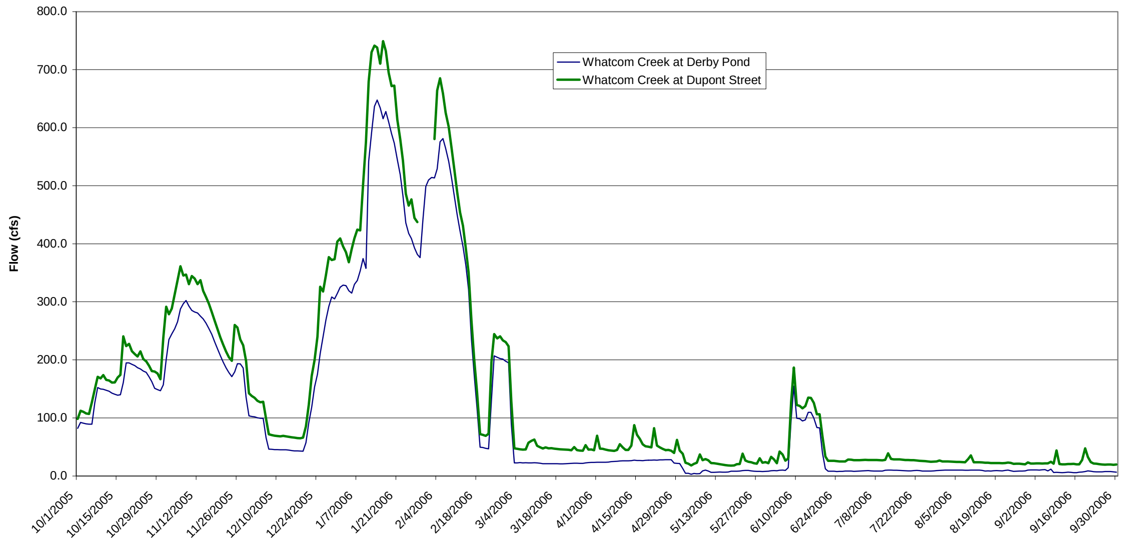

Figure 3-2. Comparison of average daily flows at the Derby Pond and Dupont Street gage sites for a typical water year.

proportion of overall flow in the fall and winter when excess flows are released to maintain storage capacity in Lake Whatcom.

Daily flows in Whatcom Creek generally represent a bimodal annual distribution (Figure 3-3). Flows are highest in the late fall and winter, with sharp peaks resulting from large rainstorms. A secondary period of relatively high flows can occur in April and May; however, flows in these months are highly variable and can be very low in some years (Table 3-1). Consistently low flows occur in the late summer from July through September.

Peak flows largely occur due to winter rain events. Since 1993 the highest mean daily flow recorded in Whatcom Creek was 981 cfs on March 25, 2007 at the Dupont Street gage; flow releases from Derby Pond on that date were 866 cfs (Figure 3-4). However, it is likely that the flow event that occurred on June 12, 2001 when flow of 942 cfs was recorded at Derby Pond was larger if contributions from tributaries and stormwater downstream of Derby Pond were factored in. More recently, flow releases of more than 1,200 cfs were recorded at the Derby Pond site in January, 2009. Data from that event are still provisional.

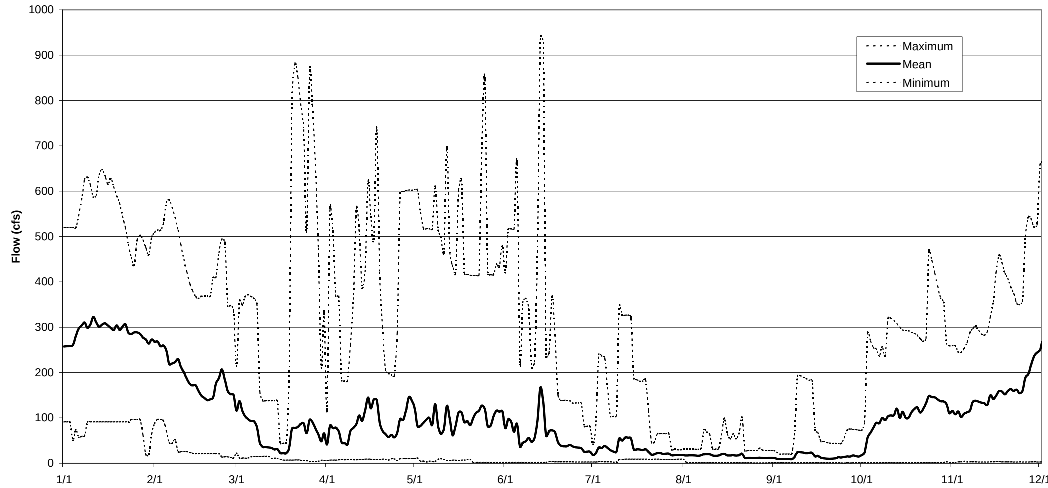

Figure 3-3. Daily flow data at the Whatcom Creek at Derby Pond gage site for the period from 1994 through 2008.

Table 3-1. Average monthly flows at the Whatcom Creek at Derby pond gage site from 1994 through 2008.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1994[1]	93	102	142	109	11	42	9					
1995[1]												**419**
1996	266	194	17	52	208	17	17	1	1	165	229	386
1997	366	318	217	117	86	94	81	28	21	87	48	70
1998	420	136	29	43	24	28	17	21	17	**16**	106	386
1999	389	376	107	53	22	7	33	32	48	28	114	484
2000	257	67	22	90	179	127	23	16	2	1	3	35
2001	151	80	16	10	87	127	11	9	7	84	208	519
2002[1]		295	**74**	208	89		113	**23**	8		25	
2003[1]	**206**	99	28	288								
2004	200	242	22	22	11	11	10	9	8	232	280	378
2005	263	116	10	168	29	11	11	9	8	147	230	119
2006	462	326	30	26	7	44	9	9	8	62	286	310
2007	410	142	163	70	45	25	21	14	32	181	90	179
2008	233	198	47	36	125	151	39	23	25	146	202	126
Avg.	286	192	66	92	71	57	30	16	15	104	152	284

[1]Substantial data gaps exist. Bold entries represent months with at least 10% of data missing; blanks represent months where flow data was available for <50% of the days.

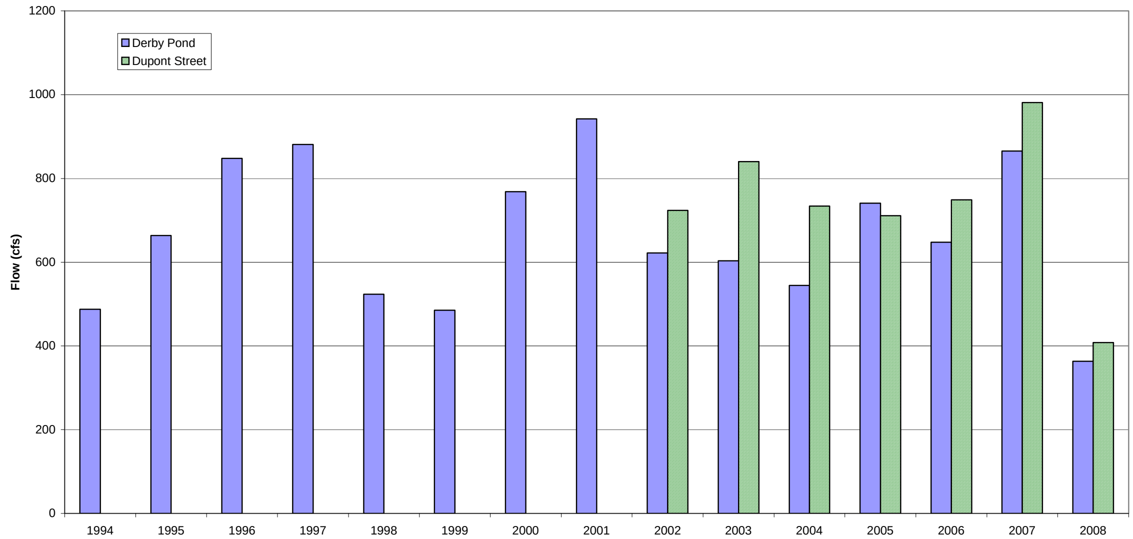

Figure 3-4. Maximum daily average flows recorded in Whatcom Creek since 1994.

3.1.1.4 Discussion

Management of flows from Lake Whatcom to Whatcom Creek is complex. Historically Lake Whatcom received flow from four main tributaries and drained downstream through Whatcom Creek to Bellingham Bay. Since 1962 water from the Middle Fork Nooksack has been diverted into Lake Whatcom to augment the City of Bellingham's drinking water supply. Since the ESA listing of salmon in 1999, the city has voluntarily adjusted the timing and flow amount diverted to the lake. Also, prior to 2001, the city withdrew and delivered up to 33 million gallons per day from the lake (equivalent approximately 51 cfs) to the Georgia Pacific. The city is required to maintain a lake level of less than 314.94 feet, and typically draws the lake down in the fall to provide flood storage. During the summer, lake levels have been maintained near the maximum allowed to ensure adequate supply and to support recreational uses.

All of the factors described above influence flow releases to Whatcom Creek. In turn, streamflow affects many of the monitoring factors evaluated in this report, including habitat availability and quality and water quality. Although the 1999 fire did not directly affect streamflows in Whatcom Creek the information provided above is used as context for the following sections.

3.1.2 Instream Habitat

3.1.2.1 Introduction

The incident on June 10, 1999 burned approximately 1.6 miles of stream habitat in Hanna and Whatcom Creeks. Habitat was surveyed following the burn in July 7, 1999, following emergency restoration actions in September 1999, and again in September 2000 following ER efforts. Habitat surveys were repeated in June 2007 to document changes in habitat conditions in the decade following the fire. An abbreviated survey was performed in February 2009 to measure habitat units and count LWD following completion of the Red Tail Reach Restoration Project at the downstream end of the burn zone. Wetted widths were not measured during that survey as flows were higher than for previous surveys.

The longitudinal profile of the creek, from its outlet to the mouth at Bellingham Bay, is shown in Figure 3-5. The area affected by the burn was classified into stream segments and reaches based on channel morphology, flow and fish access. Discrete channel segments were identified based on slope, confinement, and dominant bedform. The upper 1.2 miles of stream, from Whatcom Falls Park to just upstream of Woburn Street is a canyon-cascade channel type that occupies a deeply incised, bedrock-controlled valley. The upper segment consists of 1.1 miles of channel upstream of Middle Falls that is not accessible to anadromous fish. The 1600-feet of stream immediately below Middle Falls that is accessible to anadromous fish was designated Reach 1 (RM 2.5 to RM 2.2). Downstream of Woburn Street, Whatcom Creek flows onto a wide, flat valley and becomes a pool riffle channel type. The pool-riffle channel type that was affected by the incident (RM 2.2 to RM 1.5) was designated as Reach 2.

The objectives of the physical habitat monitoring were to confirm that habitat conditions developed during the emergency restoration phase have been maintained or improved throughout the affected reach and to confirm that engineered features created during the emergency phase of the restoration and maintain structural integrity.

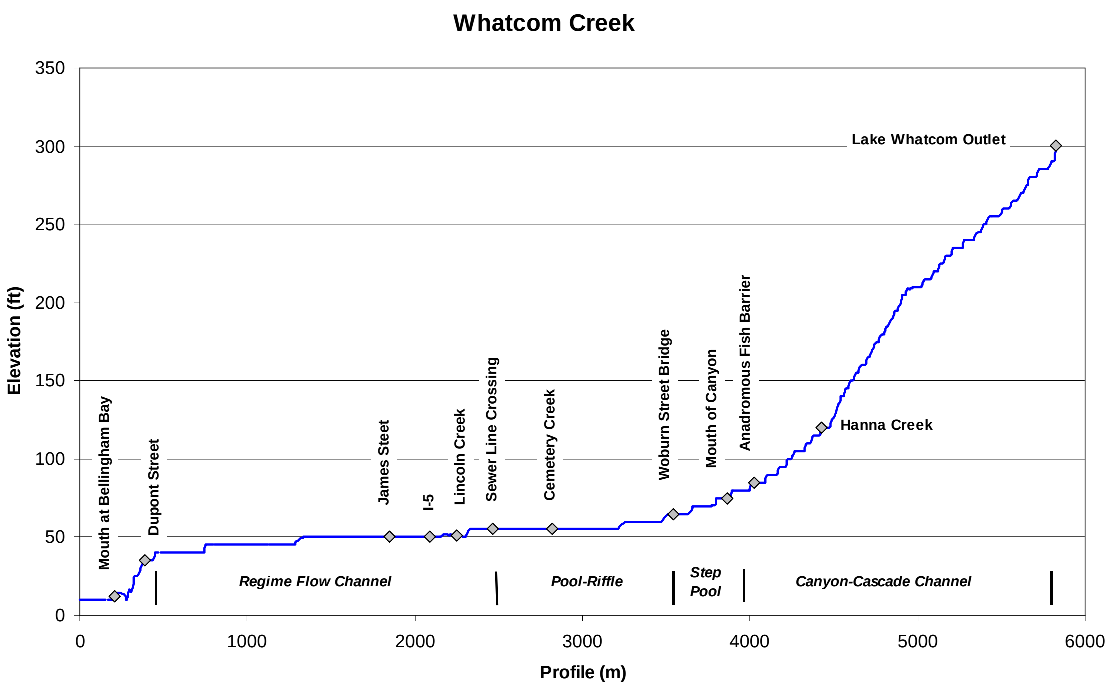

Figure 3-5. Longitudinal profile of Whatcom Creek.

3.1.2.2 Methods

Habitat surveys were conducted following a modified version of the TFW protocols for habitat units (Pleus et al. 1999) and large woody debris (LWD) (Schuett-Hames et al. 1999). The habitat surveys were conducted by two individuals on foot working in an upstream direction. Habitat units were identified to the meso-scale (Table 3-2). Specific lengths of each habitat type were measured by using a hip-chain recording the start and end of each habitat unit, or a Kevlar tap recording the total length of each unit. For each habitat unit, observations were recorded of wetted channel width and substrate composition. For pool units, the outlet control depth and maximum depth were measured to facilitate calculation of residual pool depth. Residual pool depth is a discharge-independent measure of the depth of a pool relative to the depth of the adjacent downstream hydraulic control structure that controls the total water depth in the pool, such as gravel bar or a log. Residual pool depth represents the difference between the elevation of the deepest point (maximum depth) within the pool unit and the elevation of the crest (outlet depth) that forms the pool's hydraulic control.

Table 3-2. Meso-scale habitat units used for Whatcom Creek habitat surveys.

Riffle	An area of predominantly fast water, with notable surface agitation; subunits are separated into coarse-bedded and fine- bedded riffles;
Pool	An area of predominantly slow moving deep water;
Step-pool	A series of relatively small, shallow pools (as compared to pool units) separated by discrete channel spanning accumulations of large bed materials that are organized into steps;
Run/glide	An area of relatively deep (compared to riffle), fast water with minimal surface agitation;
Cascade	An area of extreme surface turbulence and swift velocities. May incorporate small pockets of other habitat types.

The survey of LWD in Whatcom Creek generally followed procedures described in the Timber Fish and Wildlife Ambient Monitoring Manual (Schuett-Hames et al. 1999) LWD surveys were conducted concurrent with completion of the fish habitat surveys. Survey attributes included diameter, length, channel location, wood type, orientation and stability. Additionally, the relative location of each LWD piece observed within the stream channel was associated with the habitat unit that it occupied.

No records of the specific number or configuration of LWD structures installed during ER were located. The current condition of engineered features created during the emergency restoration phase was evaluated by comparing available photographs of structures, and by visually evaluating the structure function (i.e., pool formation, sediment storage, bank protection). Habitat conditions currently associated with each structure were measured (i.e., pool depth, pool area, spawning gravel area). The information was collected concurrently with stream habitat surveys.

Habitat surveys were conducted in July and September 1999, September 2000 by R2 Resource Consultants, in August 2007 by staff from the City of Bellingham, and February 2009 by staff from R2 and the City of Bellingham. The July 1999 survey occurred prior to ER efforts, and is presumed to be generally representative of conditions that were present prior to the fire. The September 1999 surveys were conducted immediately after ER habitat restoration efforts were completed, but prior to seasonal high flows. The September 2000 surveys captures habitat conditions following one year of high flows, and the August 2007 surveys represent conditions eight years following ER efforts, and incorporate changes resulting from the Cemetery Creek and Salmon Park restoration projects that were implemented as part of the long-term restoration plan. An additional instream restoration project was completed in the Red Tail Reach project area (between the sewer line crossing and Racine Street) in September 2008. In January 2009 a large flood occurred, redistributing LWD altering habitat throughout the burn zone. Walk-through surveys were conducted in February 2009 to evaluate changes resulting from those events.

The quality of habitat in Whatcom Creek for anadromous fish was rated using habitat condition diagnostics developed for watershed analysis (WFPB 1999) and ESA evaluations (NMFS 1996). Those diagnostics were developed based on conditions typically found in undisturbed forest streams. While they do not necessarily represent realistic target conditions in an urban stream such as Whatcom Creek, they do provide a semi-quantitative means of evaluating the long-term effects of the burn and subsequent restoration actions on habitat in Whatcom Creek. Habitat condition diagnostics are presented in Table 3-3.

Table 3-3. Indices of pool habitat condition and LWD for interpretation of field survey results and habitat analysis (adapted from WFPB 1999 and NMFS 1996).

Pool Parameter	Stream Reach	Channel Morphology	Habitat Quality Good	Fair	Poor
% Pool[1]	Reach 1	2-5% Gradient: <50ft wide	>40%	30-40%	<30%
	Reach 2	<2% Gradient: <50ft wide	>55%	40-55%	<40%
Pool Frequency[1]	Reach 1	2-5% Gradient: <50ft wide	<2 channel widths/pool	2-4 channel widths/pool	>4 channel widths/pool
	Reach 2	<2% Gradient: <50ft wide	<2 channel widths/pool	2-4 channel widths/pool	>4 channel widths/pool
Pool Spacing[2]	Reach 1	2-5% Gradient: <50ft wide	>34 pools/mile		<34 pools/mi
	Reach 2	<2% Gradient: <50ft wide	>39 pools/mile		<39 pools/mi
LWD pieces per channel width[1]	Reach 1	<50ft wide	>2	1-2	<1
	Reach 2	<50ft wide	>2	1-2	<1
Key pieces per channel width	Reach 1	30-65 ft wide	>0.5	0.2-0.5	<0.2
	Reach 2	30-65 ft wide	>0.5	0.2-0.5	<0.2
LWD pieces/mile[2]	Reach 1	2-5% Gradient: <50ft wide	>80 pieces/mile (diameter > 24"; length > 50')		>80 pieces/mile (diameter > 24"; length > 50')
	Reach 2	<2% Gradient: <50ft wide	>80 pieces/mile (diameter > 2"; length > 50')		>80 pieces/mile (diameter > 2"; length > 50')

[1]From WFPB 1999

[2]From NMFS 1998

Data analysis focused on three main habitat components: Habitat Composition, Pool Assessment, and Large Woody Debris. Results for each of the three components are presented below. The discussion for each component is organized by Survey Reach, as the response and recovery observed since the fire varied between reaches.

3.1.2.3 Results

Habitat Units

Emergency restoration actions aimed at restoring habitat consisted primarily of pool excavation and placement of LWD to provide cover and create hydraulic conditions that would maintain deep pools that provide high quality habitat for salmonid fishes. In general streams with a diversity of habitat types are considered to provide better habitat for fish; however, that diversity and the type of habitats present is a function of channel type. Results are presented below for each Whatcom Creek survey reach.

Reach 1 Prior to the burn, habitat in Reach 1 consisted primarily of step-pool sequences, pools and riffles (Table 3-4). Immediately following the ER efforts the proportion of pool habitat increased by approximately 4 percent, to 33 percent. Those increases did not persist; in 2000, one year following ER actions, the proportion of pools in Reach 1 had declined to 24 percent. By 2007, the number of pools had rebounded to approximately 31 percent, slightly more than had existed before the burn. However, in February 2009, approximately one month after a major flood event, the proportion of pool habitat had dropped to 26 percent, the lowest level observed since the burn. More run and glide habitat was documented during that survey, and, since it was done at a somewhat higher flow (37 cfs versus around 13 cfs) it is possible that some of the habitats classified as runs or glides would be counted as pools at a lower flow. Riffle and cascade habitat consistently accounted for around 60 percent of the length of Reach 1. No subsequent restoration activities were conducted in Reach 1 following the ER, except for replanting of stream adjacent riparian zones. Habitat data colleted over the ten-year period following the burn confirms the relative stability of this channel type.

Reach 2 Observed changes in habitat since the fire and subsequent emergency restoration were greater in Reach 2 than in Reach 1 (Table 3-4). This is consistent with Reach 2 having a pool-riffle morphology that tends to be more responsive to disturbances. Before the fire, habitat in Reach 2 consisted primarily of slow water habitat types (pools and run/glide), with riffles accounting for only 22 percent of the total habitat. Emergency response actions transformed run/glide habitat into additional pools, or riffles. Unlike in Reach 1, these changes persisted for at least one year. However, by 2007 mainstem pool habitats had reverted to run/glide habitat types, and fewer pools existed than before the burn. Riffle habitats created as a result of ER actions remained relatively stable.

Table 3-4. Whatcom Creek habitat types as a percent of the total channel length from 1999 through 2009.

Habitat Type	July 1999 (pre-emergency response)	September 1999 (post emergency response)	September 2000	August 2007	February 2009
		Reach 1			
Cascade	4%	8%	12%	10%	9%
Riffle	57%	55%	62%	49%	46%
Pool	29%	33%	24%	31%	26%
Run/glide	8%	0%	0%	10%	19%
Other	2%	2%	2%	4%	0%
		Reach 2			
Cascade	0%	0%	0%	0%	0%
Riffle	22%	28%	39%	36%	43%
Pool	44%	54%	49%	24%	27%
Run/glide	34%	18%	11%	38%	30%
Other	0%	0%	0%	2%	0%

In 2008 a major habitat restoration project was completed in the downstream end of Reach 2 in the area known as "Red Tail Reach". The primary focus of that project was to create off-channel habitats and fast, deep pools in the mainstem suitable for Chinook and steelhead. Large woody debris was placed throughout the site to enhance pools. In 2009 the overall amount of pool habitat in Reach 2 had increased slightly, to around 27 percent, with the creation of five pools in this section of channel where only one had existed in 2007. The amount of riffle habitat also increased, from 36 to 43 percent.

Off-channel habitats associated with Reach 2 also increased substantially as a result of long-term restoration projects. In 2006, two backwater sloughs were created adjacent to the main channel in a section of the stream known as Salmon Park. These areas contain LWD and cover, and provide low velocity refuges during high flows. In 2008 three similar, but larger off channel habitat features were created by the Red Tail Reach Project mentioned above. These backwater sloughs represent off-channel habitats and are thus not represented by the assessment of mainstem habitat types by length presented in Table 3-4. However, the represent an important habitat component for juvenile rearing that was not present in Whatcom Creek prior to the instream projects.

Pool Assessment

The pool assessment utilized detailed data from individual pools to evaluate the quality of habitat provided by this type of unit. Metrics commonly used to evaluate pool quality include maximum and residual depth, which is used to assess the quality of the pool for adult holding habitat, pool spacing and frequency, which provide information on habitat complexity, and the pool forming factor which provides information on the processes responsible for maintaining pool habitat with the reach. Results are presented below for each Whatcom Creek survey reach.

Reach 1 – The typical pool spacing in step-pool channels like Reach 1 is on the order of 1 to 4 channel widths between pools (Montgomery and Buffington, 1993). Pool spacing in step-pool channels is not very sensitive to LWD loading. Conversely, the typical pool spacing in self-formed pool-riffle channels such as Reach 2 is on the order of 5 to 7 channel widths between pools (Montgomery and Buffington, 1993). Pool spacing is a primary channel attribute that is very sensitive to LWD loading in pool-riffle channel types and thus the frequency of pools can be increased in this channel type to approximately 2 to 4 channel widths between pools under conditions of high LWD loading (Montgomery et al. 1995).

Prior to ER activities a total of 10 pools were identified Reach 1, representing a pool spacing of 4.1 channel widths between pools or approximately 32 pools in a mile of stream length. Pools encompassed 29 percent of the total reach length (Table 3-5). Restoration activities added two pools to Reach 1, reducing the pool spacing from 4.1 to 3.4 channel widths between pools or up to almost 40 pools per mile compared to the original channel conditions (Table 3-5). These changes persisted through 2007; in 2000 the number of pools had increased to 17, with a spacing of 2.4 channel widths between pools and a frequency of almost 55 pools per mile. The number of pools had declined slightly by 2007, but remained higher than for the initial pre-restoration conditions. In January 2009 a large flood occurred; preliminary reports suggest that over 1,200 cfs were released at the Derby Pond control dam for several days (Forester, pers. comm. 2009) Surveys conducted following this event revealed that the number of pools in Reach 1 had decreased. Pools remained following the storm were large, deep bedrock controlled pools.

Pools in Reach 1 tended to be relatively shallow before the restoration efforts, with an average residual pool depth of only 2.1 feet. The average residual pool depth and number of deep holding pools steadily increased following restoration activities (Table 3-5). In 2007 the average residual pool depth was 3.0 feet, and there were seven pools with a maximum depth of more than

3 feet, more than double the number that had existed prior to the emergency response actions. Six of the pools, including most of the deepest units, were formed by bedrock. Three of the pools were formed by structures placed during the ER. Some of the increase in maximum depth may be related to flow; during surveys conducted in 1999 and 2000 flows ranged from 1-3 cfs, while in 2007 flows during the survey period were around 13 cfs. However, residual pools depths also increased significantly and this parameter is not flow dependant. Residual pool depths decreased slightly in 2009, but all of the large holding pools observed before the flood remained.

Table 3-5. Pool characteristics in Whatcom Creek burn zone from 1999 through 2009.

	7/6/1999[1]	**9/22/1999[1]**	**9/28/2000[1]**	**8/23/2007[2]**	**2/13/2009[1]**
REACH 1					
Pool Tally	10	12	17	14	9
Pool % (by length)	29%	33%	24%	31%	26%
Pool spacing (cw/pool)	4.1	3.4	2.4	2.9	5.2
Pools frequency (pools/mi)	32.3	38.7	54.8	45.2	30
# of holding pools (max. depth>3ft)	3	6	7	7	3
Average residual pool depth (ft)	2.1	2.3	2.5	3.0	2.8
Pool Area (ft^2)	18,250	22,758	24,737	18,112	ND
REACH 2					
Pool Tally	7	12	12	12	11
Pool % (by length)	44%	54%	49%	24%	27%
Pool spacing (cw/pool)	12.7	7.4	7.4	7.4	10.1
Pools frequency (pools/mi)	10.4	17.9	17.0	17.9	13.0
# of holding pools (max. depth>3ft)	3	3	5	6	7
Average residual pool depth (ft)	3.0	2.7	2.9	2.3	3.8
Pool Area (ft^2)	51,932	57,982	28,600	21,353	ND

[1] R2 Resource Consultants unpublished data

[2] City of Bellingham

The present pool spacing in Reach 1 remains consistent with that typically found in self-formed step-pool channels (Montgomery and Buffington 1993). Overall, the changes in pool habitat observed between 1999 and 2007 improved the pool conditions in Reach 1 from a poor/fair fish habitat condition rating to a fair/good rating under various guidelines presented by NMFS (1996) and WFBP (1999). However, following the flood in January 2009 pool habitat conditions would be classified as poor according to those guidelines. It is worth noting that those habitat condition ratings were not designed for steep or bedrock controlled channels such as Reach 2, and thus should be applied with caution.

Reach 2 Reach 2, the stream section downstream of the Woburn Bridge to the sewer line crossing, originally consisted of a total of 7 pools encompassing 44 percent of the habitat by length and representing a frequency of approximately 13 channel widths between pools (Table 3-5). According to Montgomery and Buffington (1993) this pool-riffle channel section should be capable of maintaining on the order of 12 to 17 pools, five to seven more pools than existed prior to restoration activity. The original abundance of pools was considered to be of poor habitat value according to WFPB (1999) watershed analysis guidelines and NMFS would regard this level of pool habitat as functioning at risk to Chinook salmon production (Table 3-3). These habitat guidelines are appropriate for pool-riffle channel types like Reach 2. The pre-restoration pool situation in Whatcom Creek in 1999 was consistent with what might be expected under engineered channel banks and an LWD assessment that indicated low levels of LWD in the creek.

The ER actions and subsequent habitat enhancement projects have increased the number of pools in Reach 2, with a concomitant increase in pool spacing (Table 3-5). The improvement in pool frequency observed following the ER actions has not persisted. In 2007 pools represented only 24 percent of Reach 2 by length, a decline of roughly 50 percent compared to the restored condition, and substantially less than had existed prior to the fire. In 2009, following a habitat enhancement project that added pools to this reach, the percent of pool habitat by area increased slightly, and the number of pools in the treated area increased. However, that increase was offset by a loss of pools elsewhere in Reach 2; the loss of pools elsewhere in Reach 2 may have been caused by a large flood that occurred approximately 3-weeks prior to the 2009 habitat surveys. The average residual pool depth increased substantially throughout Reach 2.

Prior to the burn, and immediately after ER actions pool habitat conditions in Reach 2 were rated poor to fair in Reach 2 (Table 3-5). By 2007 pool habitat conditions were rated poor by all standards (Table 3–3). The majority of pools identified in 2007 were formed by bedforms (meanders). Only two of the pools were clearly associated with LWD structures placed as part of the ER efforts. In 2009, while the percent and frequency of pools was still rated as poor according to NMF and WDFW standards, 45 percent of the pools present were formed by LWD, and provided excellent holding and hiding cover for both juvenile and adult fish.

Large Woody Debris

Large woody debris benefits fish habitat in a number of ways. Wood provides hiding cover for fish, and serves as substrate for macroinvertebrates and other organisms consumed by fish. In some channel types large woody debris or jams play an important role in the formation of pools. In other cases LWD serves primarily to increases hydraulic complexity, store sediment and protect banks from erosion. Total LWD counts, the number of large pieces of LWD per mile, and key-sized piece tallies in both reaches prior to ER efforts represented poor habitat conditions for salmonid fishes based on watershed habitat diagnostics (WFPB 1999) and NMFS (1996) guidelines for properly functioning habitat (Table 3-6). In addition, little of the available LWD functioned to form pools. Many pieces were in later stages of decay and most were of deciduous origin, especially within Reach 2 downstream of Woburn Street (OPC 2002). Restoration activities included removal of the existing, contaminated, burned or decayed pieces of wood and replacement with fresh large pieces of conifer, especially large quantities of cedar. The trees were oriented at different angles along the bank and cabled together and to shore for stability. Results of the LWD surveys are presented below for each Whatcom Creek survey reach.

Reach 1 Surveys conducted immediately after ER efforts were completed indicated a substantial improvement in LWD in nearly every diagnostic category in Reach 1 (Table 3-6). One year later, the habitat survey showed continued improvement in LWD diagnostics, with ongoing recruitment of riparian trees that added complexity to the engineered habitat structures and contributed to in-channel habitat forming function. The only habitat structure lost during 1999/2000 high flow winter events was the wood placed in Pixie Pool (OPC 2002). Wood from that structure was translocated downstream and trapped by other instream structures.

Surveys conducted in 2007 indicate that LWD recruitment continued in Reach 1. Reach 1 contained substantially more LWD in 2007 than in 2000. LWD diagnostics from Reach 1 in 2007 indicate that LWD levels were rated fair to good for most diagnostic criteria (Table 3-3). However, in 2009 many of the smaller, unstable pieces of LWD had been washed out of Reach 1 during the January 2009 flood As a result LWD levels dropped, and diagnostic criteria generally indicated that LWD was functioning at only fair levels.

In Reach 1, 60 percent of all the wood present in 2009 (including individual pieces and jams) was contributing to pool formation. The majority of pools in this Reach are formed by bedrock, however LWD contributed to the formation of two pools. In one of those cases the LWD consisted of a structure that had been placed during ER efforts.

Table 3-6. LWD characteristics in Whatcom Creek burn zone from 1999 through 2009.

	July 6, 1999	**Sept 22, 1999**	**Sept 28, 2000**	**Aug 23, 2007**	**Feb 13, 2009**
REACH 1					
LWD tally	45	62	95	193	67
Pieces per channel width	0.9	1.2	1.9	5.8	1.4
Large Pieces/mile	9[1]	12[1]	18[1]	54	27
Key Pieces	4	6	7	14	NA
Key Pieces per channel width	0.08	0.12	0.14	0.42	NA
Percent of LWD in Zone 1	73%	74%	53%	73%	66%
Percent of LWD in Zone 2	27%	26%	47%	27%	34%
Percent of LWD contributing to pool formation	4%	18%	21%	28%	60%
REACH 2					
LWD total	55	64	78	310	309
Pieces per channel width	0.6	0.7	0.9	3.5	3.5
Large Pieces/mile	9[1]	11[1]	13[1]	45	38
Key Pieces	1	1	2	33	NA
Key Pieces per channel width	0.01	0.01	0.02	0.4	NA
Percent of LWD in Zone 1	71%	77%	85%	89%	92%
Percent of LWD in Zone 2	29%	23%	15%	11%	8%
LWD contributing to pool formation	16%	16%	36%	38%	78%

[1]No data on LWD size is available for 1999-2000; assumes that the proportion of LWD > 24" diameter is the same as for 2007.

Reach 2 As in Reach 1, ER efforts resulted in a substantial improvement in LWD in nearly every diagnostic category in Reach 2 from July to September 1999 (Table 3-6). One year later, the habitat survey showed continued improvement in LWD diagnostics, with ongoing recruitment of riparian trees that added complexity to the engineered habitat structures and contributed to in-channel habitat forming function. By 2007 the amount of LWD in Reach 2 had increased substantially. LWD diagnostics from Reach 2 in 2007 indicate that LWD levels were rated fair to good for most diagnostic criteria (Table 3-3). The amount of LWD in Reach 2 remained high in 2009, and data collected during that survey likely underestimate the actual amount as much of the materials was stored in large jams that made identification of the true number of smaller pieces difficult.

The majority of LWD is currently located in Zone 1 (the wetted low flow channel), and much of it is contributing to pool formation. In Reach 2, five of the eleven pools surveyed were formed by LWD. Structures placed during the Red Tail Reach Restoration Project, or by LWD jams accumulating on wood placed as part of that project accounted for four of those pools. Three remnant ER structures were identified that no longer contributed to pool formation.

3.1.2.4 Discussion

Prior to the ER actions habitat conditions in Whatcom Creek were considered poor according to all available criteria. The ER resulted in short-term improvements of habitat in Reach 1. ER Actions and subsequent instream habitat restoration projects in Reach 2 have maintained substantially improved habitat conditions in Reach 2. Throughout the stream the amount of LWD and number of pools is similar to or better than in 1999. Habitat complexity has also increased, particularly in Reach 2, where restoration projects have added off-channel habitat and established a meandering channel more typical of unmanaged lowland streams.

3.2 SOIL EROSION AND SLOPE STABILITY

3.2.1 Introduction

Walk through surveys conducted immediately following the fire concluded that the event had resulted in an extreme increase in erosion hazard (Jones Engineers Inc., 1999). Emergency response actions were implemented to rapidly and aggressively address this risk. Emergency response actions implemented to prevent erosion included placement of geotextiles, hydroseeding, and planting native vegetation in areas where soils were exposed by the fire (OPC 1999). Large woody debris was placed in stream channels to protect banks and reduce erosive energy.

3.2.2 Methods

The entire burn zone was re-assessed in February 2009 to identify areas of eroding soils. Surveys were conducted by walking the burn zone starting at the upstream end on Hannah Creek and working downstream. Notes and photos were taken at 100-foot intervals. Areas of erosion were photograph as encountered. The length and height of each eroding area was estimated, and composition and amount of material delivered to the stream was described.

3.2.3 Results

No major areas of erosion that could be directly related to the 1999 fire were observed in 2009. The stream banks along upper Hannah Creek supported a dense stand of 10-year old alders. Extensive areas of recently deposited sand and gravel were observed surrounding the base of these trees. Recent sediment deposits are associated with a major rain event that occurred in January 2009 and do not represent on-going erosion within the burn zone. Steep slopes adjacent to lower Hannah Creek and Whatcom Creek from the confluence with Hannah Creek downstream to the Woburn Street bridge were identified as being the areas most likely to have ongoing erosion problems. In general, slopes in these areas were well vegetated and appeared stable. Only one measurable erosion site was identified in this area. That site was small (12-feet high by 20-feet wide), and likely represents natural inner gorge mass-wasting processes typical of steep confined channels such as lower Hannah Creek. Occasional bare slopes were observed in the Whatcom Creek canyon, but these areas generally consisted primarily of exposed and weathering sandstone, and thus do not represented accelerated erosion related to the fire.

Extensive bank erosion was observed in the Salmon Park area. Bank erosion is occurring in areas that had been treated as part of the Salmon Park and Cemetery Creek Restoration Projects. Although erosion is delivering sediment to Whatcom creek in these areas, volumes are small relative to the overall bedload transport capacity. Bank erosion as the channel adjusts to the new configuration is not unexpected, and represents a natural channel process in this pool-riffle channel type, contributing to increased habitat complexity in these areas (Section 3.1).

3.2.4 Discussion

Erosion control methods implemented immediately following the fire, and subsequent revegetation have successfully prevented ongoing erosion related to the fire. Some bank erosion is occurring within instream habitat restoration project areas. However, such erosion is a normal response in dynamic pool-riffle channels of the type that restoration is aimed at creating and is contributing to habitat complexity.

3.3 WATER QUALITY

3.3.1 Introduction

The 1999 fuel spill and fire had both direct and indirect effects of water quality in Whatcom Creek. Direct effects included delivery of organic hydrocarbons, post-event sampling of these compounds was conducted immediately following the fire and continued for several years until levels returned to background conditions. Data describing the results of those efforts have been reported elsewhere and are not repeated here.

The burn indirectly affected water quality by reducing shade and groundcover adjacent to Whatcom Creek. Reduced shade can lead to increased temperatures and decreased DO levels, while reduced groundcover decreases filtration of overland flow which may result in increased loadings of fine sediment, fecal coliform and other pollutants. Monitoring of temperature, DO, turbidity and fecal coliform was conducted to confirm that conditions within the burn zone are on a recovery trajectory that will support attainment of Washington State surface water quality standards for those parameters in Whatcom Creek.

3.3.2 Methods

Water quality in Whatcom Creek has been monitored monthly as part of the City of Bellingham's Urban Stream Monitoring (USM) program since 1990. Measurements are recorded once per month using a Quanta Hydro Lab. Data collected from Whatcom Creek upstream and downstream of the burn zone were reviewed for the pre-burn and post-burn periods. The upstream water quality sampling site is located at Derby Pond, near the outlet of Lake Whatcom (Figure 3-6). The downstream Water Quality Sampling site is located at Interstate 5 (I-5), just downstream of the burn zone. Water quality sampling was conducted by the City of Bellingham's state certified laboratory.

The data were divided into pre-burn (1990-1999) and post-burn (2000-2007) populations. Each population was further subdivided into wet season (November through April) and dry season (May through October) sample sets. Simple univariate statistics were generated for each sample set (i.e., mean/median/variance/standard deviation). Pre-burn data sets for each site were compared to determine if the populations were comparable between sites. An f-test was conducted to determine whether the sample subsets being compared had equal or unequal variances. A student's T-test for paired samples was used to determine whether the mean of each parameter was different before and after the fire.

Data collected as part of the USM program represent spot measurements and thus cannot be used to draw conclusions regarding cause and effect in the burn zone. However, they are sufficient to highlight ongoing water quality issues that may be associated with the burn.

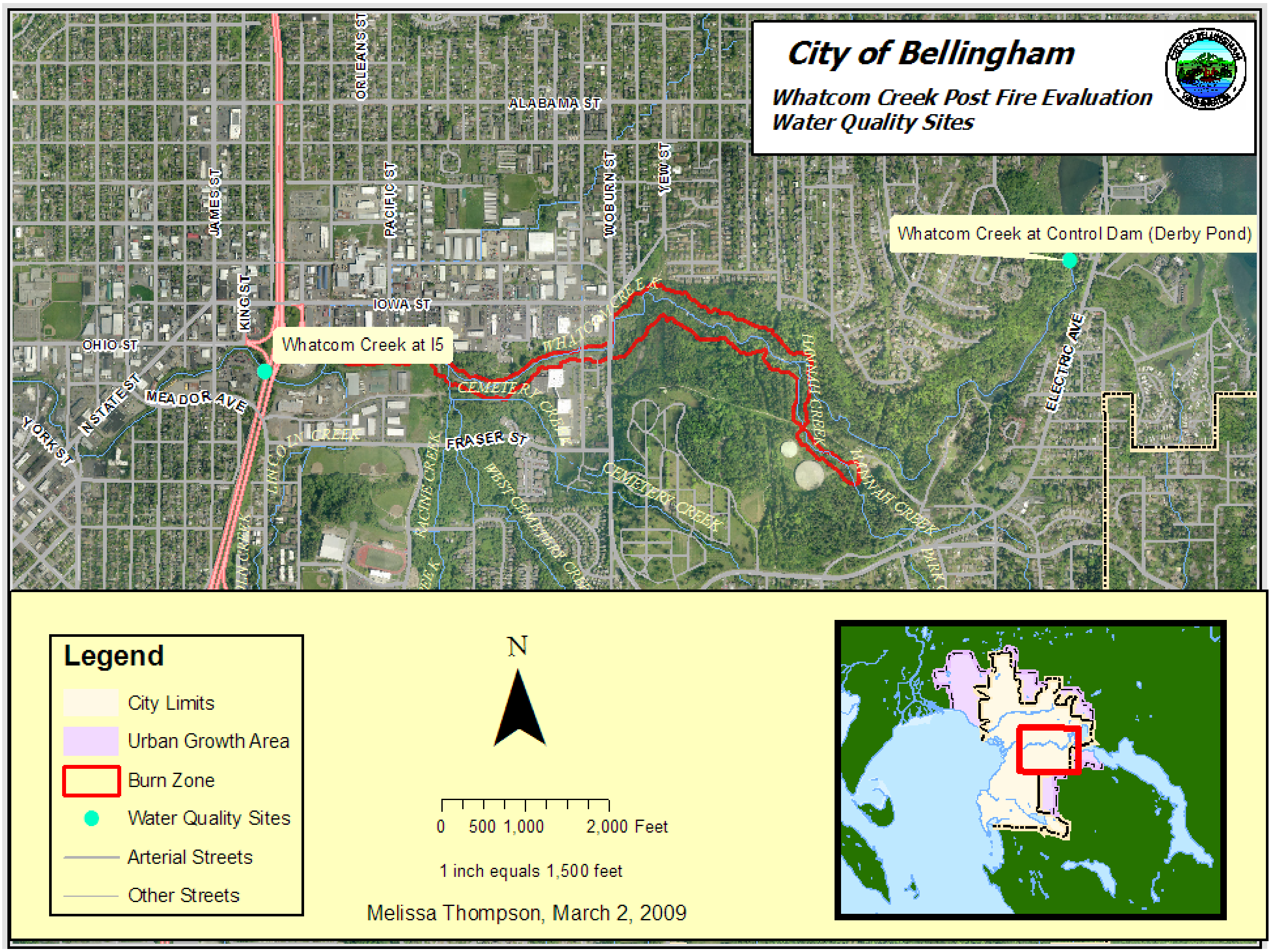

Figure 3-6. Location of Water Quality Stations on Whatcom Creek utilized by the City of Bellingham's Urban Streams Monitoring Program

3.3.3 Results

3.3.3.1 Temperature

The temperature at the downstream measurement site is generally a function of the upstream water temperature plus the change in temperature due to solar radiation or radiational cooling. As a result, data from the two sites are autocorrelated and thus the parameter of primary interest was the temperature difference between the two sites.

Over the ten years prior to the fire, monthly spot temperatures measured at the upstream sample site (Control Dam) during the wet season averaged 8.3ºC. During the same period temperatures at the downstream site (I-5) averaged 7.9ºC. Differences between the wet season temperatures measured at each site were not statistically significant (alpha= 0.05). Following the fire, monthly spot temperatures measured at the upstream sample site (Control Dam) during the wet season averaged 7.7ºC. During the same period temperatures at the downstream site (I-5) averaged 7.7ºC. The difference in temperature between the two sites was not significantly different before and after the fire (alpha= 0.05), however, the mean difference did decline substantially. Comparison plots indicate that the difference between the two sites has been somewhat less variable since the fire (Figure 3-7).

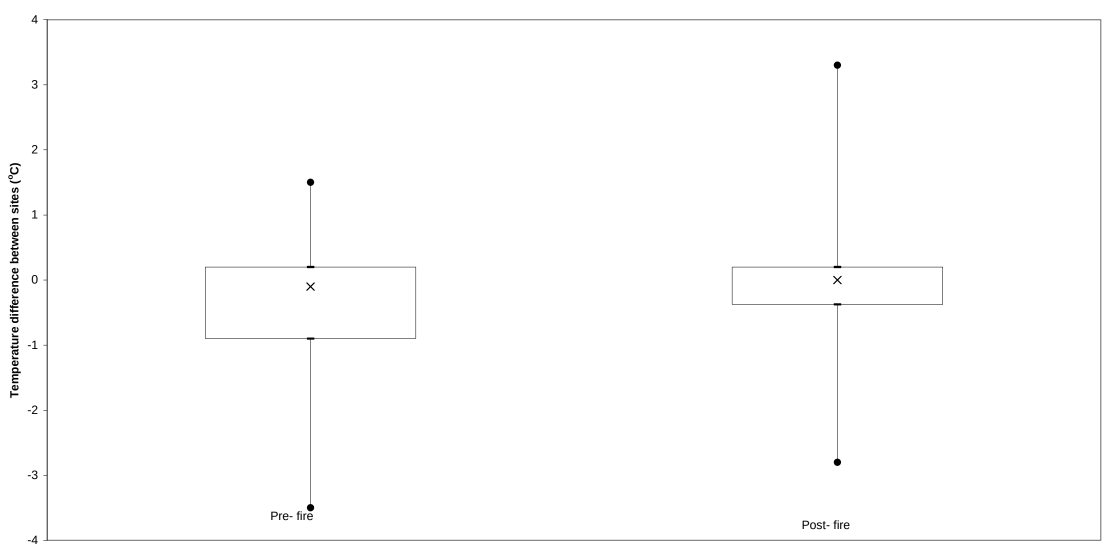

Figure 3-7. Summary statistics for wet season difference in temperature up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

Spot temperatures measured at the Control Dam during the dry season averaged 17.3. During the same period, temperatures at the I-5 site averaged 16.2ºC. The Students t-test indicated that dry season temperatures cooled significantly while flowing through the burn zone before the fire. Following the fire, monthly spot temperatures measured at the upstream sample site (Control Dam) during the dry season averaged 17.4ºC as compared to 16.3ºC at the downstream site. The data indicate that temperatures at the downstream site continue to be significantly lower than those measured at the Control Dam during the dry season. However, the difference in temperature between the two sites was not significantly different (alpha =0.5) before and after the fire. Figure 3-8 presents comparison of the temperature difference between the two sites before and after the fire.

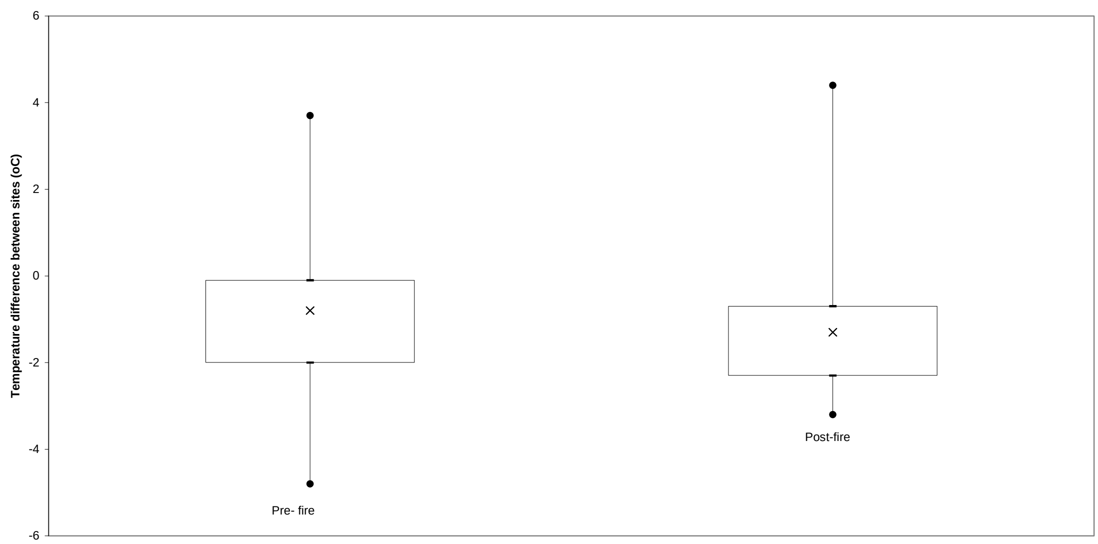

Figure 3-8. Summary statistics for dry season difference in temperature up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

Spot measurements at both sites have been generally higher than state water quality standards since sampling began in 1990. Prior to 2006 the state standard applicable to Whatcom Creek indicated that spot temperatures should not exceed 16ºC. Current standards focus on the 7-day average daily maximum temperature, and require that in Whatcom Creek the7DADMax should not exceed 16ºC. Spot data reviewed for this study are not sufficient to calculate that statistic; however temperatures in excess of 16ºC were common at both sites. Continuous recorders installed in support of the Red Tail Reach restoration project located just upstream of the I-5 sample site indicate that the 7DADMax has exceeded the standard annually since 2004 (COB unpublished data).

3.3.3.2 pH

State water quality standards indicate that streams in western Washington should have pH in the range of 6.5 to 8.5 (Ecology 2006). The pH in Whatcom Creek generally falls within this range, with rare excursions below 6.5 (Figures 3-9 and 3-10). Prior to the burn pH at the Control Dam and I-5 were not significantly different during the wet season. No significant changes in pH were observed following the burn.

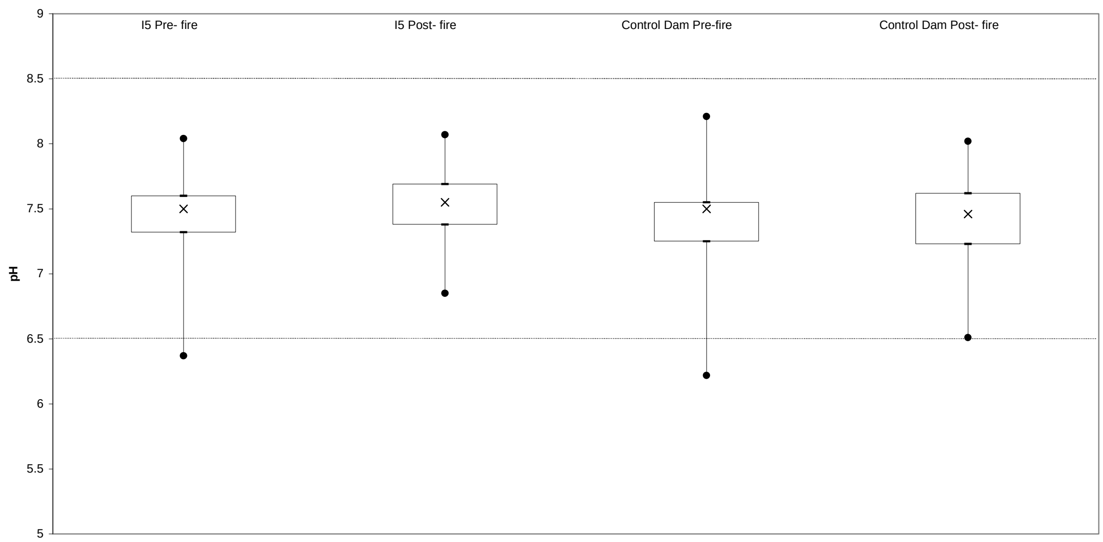

Figure 3-9. Summary statistics for wet season pH up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

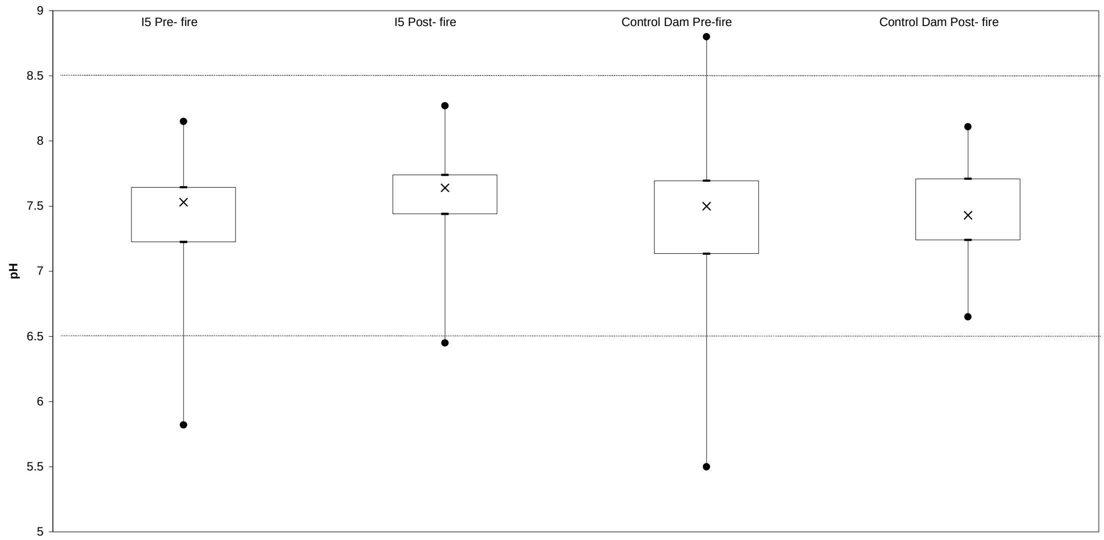

Figure 3-10. Summary statistics for dry season pH up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

3.3.3.3 Dissolved Oxygen

The state water quality standard for Dissolved Oxygen (DO) in streams classified as providing core summer habitat for salmonids is 9.5 mg/L. DO levels in Whatcom Creek generally exceed that standard during the wet season (Figure 3-11). Prior to the fire there was no statistically significant difference in monthly spot measurements of DO between the two stations during the wet season. Wet season DO levels increased significantly at both stations following the fire, and DO levels at the downstream site (I-5) have been significantly higher than those at the upstream site since that time.

Dry season DO levels generally exhibit a similar pattern (Figure 3-12). Dry season DO levels at the two stations were similar prior to the fire. After the fire dry season DO levels at the upstream site (Control Pond) did not change significantly. However, DO levels at the I-5 site increased significantly as compared to pre-fire levels and are now increase significantly as they flow through the burn zone.

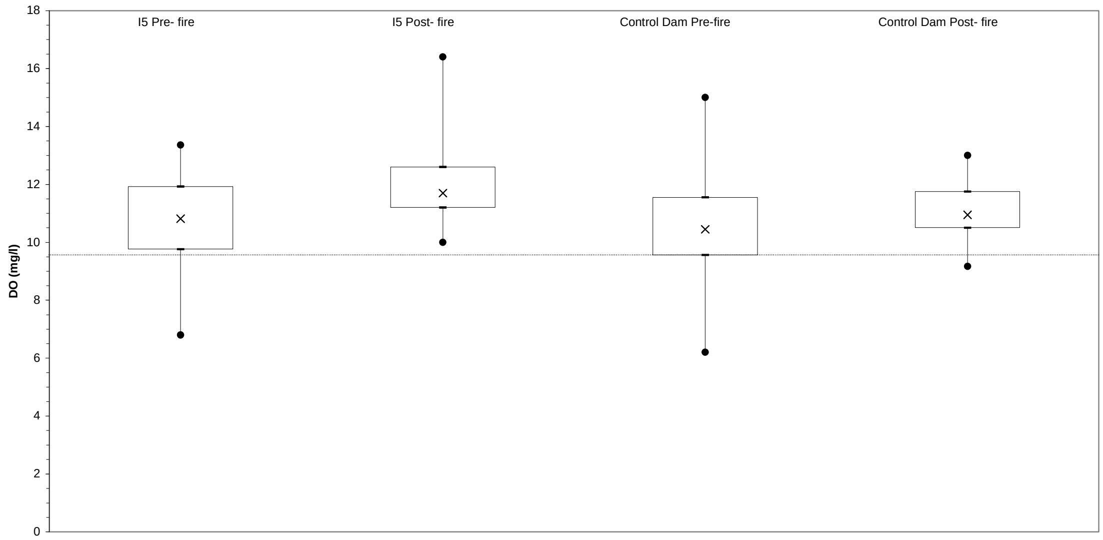

Figure 3-11. Summary statistics for monthly wet season DO samples up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

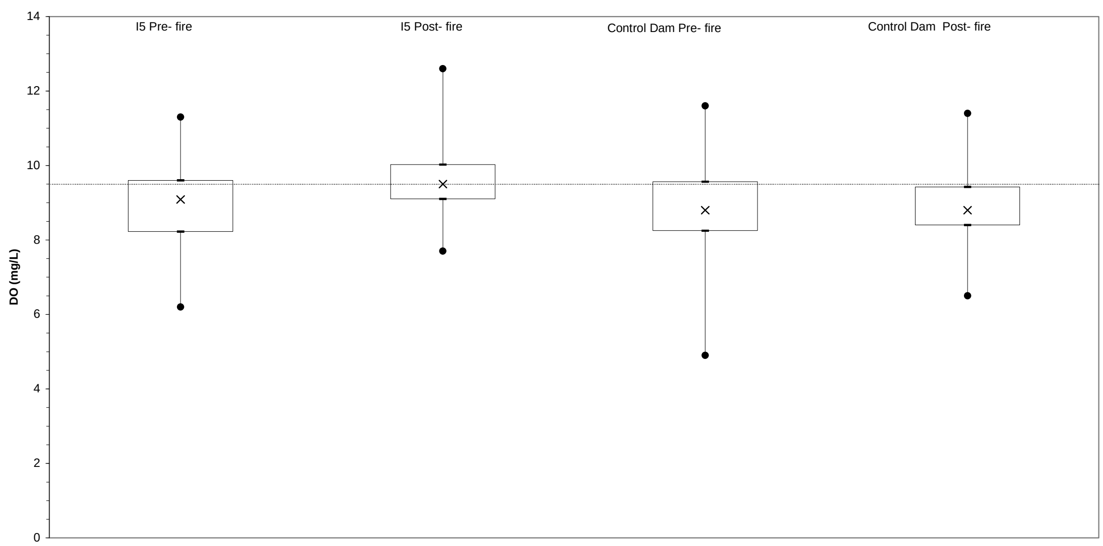

Figure 3-12. Summary statistics for monthly dry season DO samples up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

Prior to the fire DO levels in Whatcom Creek during the dry season were lower than the state standard on almost 75 percent of the sample dates. Since the fire the increased DO levels at the I-5 site have resulted in DO levels meeting state standards on more than 50 percent of the sample dates.

3.3.3.4 Turbidity

The state water quality standard for turbidity is a human-caused increase of more than 10 percent above background (<5NTU increase at levels <50 NTUS). Turbidity varies widely both spatially and temporally, and thus spot samples such as those collected in the city's USM monitoring program are of limited use for discerning trends over time, particularly in the absence of flow data from the sample date.

Examination of simple univariate statistics is helpful for drawing some general conclusion on the range of turbidity levels typically encountered. Figures 3-13 and 3-14 depict the median, 25^{th} and 75^{th} percentile range and the maximum and minimum turbidity values encountered over roughly 20 years of monthly sampling in Whatcom Creek. These data show that more than 75 percent of the samples collected documented turbidity of less than 5 NTUs. Turbidity values were generally lower at the upstream Control Dam sample site, and this is largely due to the fact that water at that site comes from Lake Whatcom, a large body of water in which suspended sediments and other materials that would contribute to high turbidity values are able to settle out. Turbidity values increase slightly at the downstream station.

High turbidity values are generally associated with high flow events, and thus are not representative of background conditions. Turbidity values of more than 20 NTUs that were clearly associated with high flows were removed from the data set (n=1 from we season; n=2 from dry season), and then a Student's t-test was used to compare the average background turbidity at the I-5 sample site before and after the fire. The mean background turbidity value prior to the fire during the wet season was 3.5 NTUs (n=44) as compared to 3.4 NTUs following the fire (n=45). During the dry season the mean background value before the fire was 1.9 NTUs, as compared to 2.4 NTUs after the fire; however the difference was not statistically significant, nor would it be sufficient to be considered at WQ exceedance according to current state standards. A time series plot of the data from the I-5 sample site indicates that the frequency of turbidity values greater than 10 NTUs does not appear to differ substantially before and after the fire (Figure 3-15).

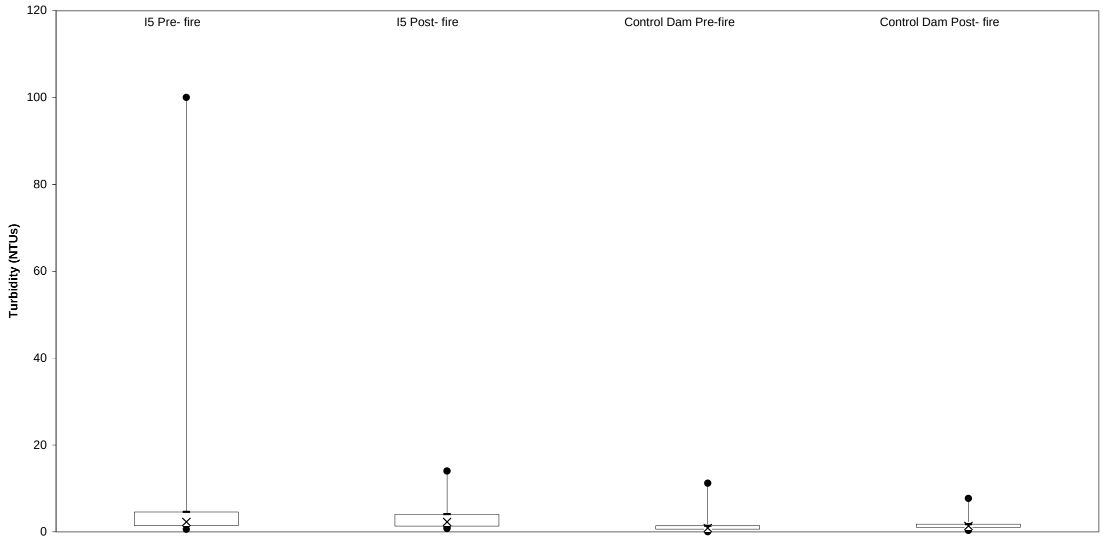

Figure 3-13. Summary statistics for monthly wet season turbidity measurements up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

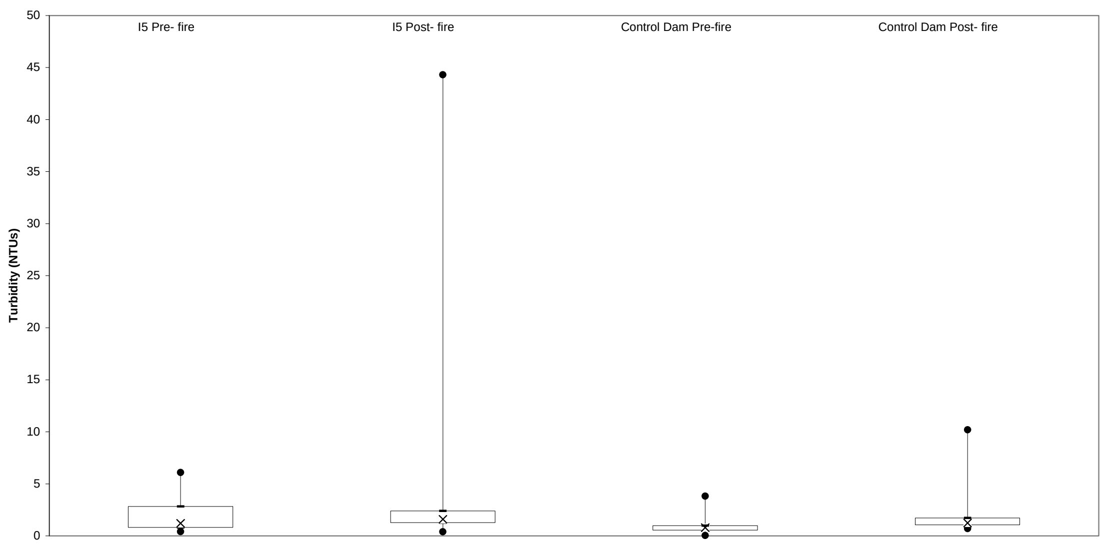

Figure 3-14. Summary statistics for monthly dry season turbidity measurements up and downstream of the burn zone before and after the fire. Median is represented by x, and the boxed area encompasses the 25th to 75th percentiles. Tails represent maximum and minimum values for the period of record (1999-2008).

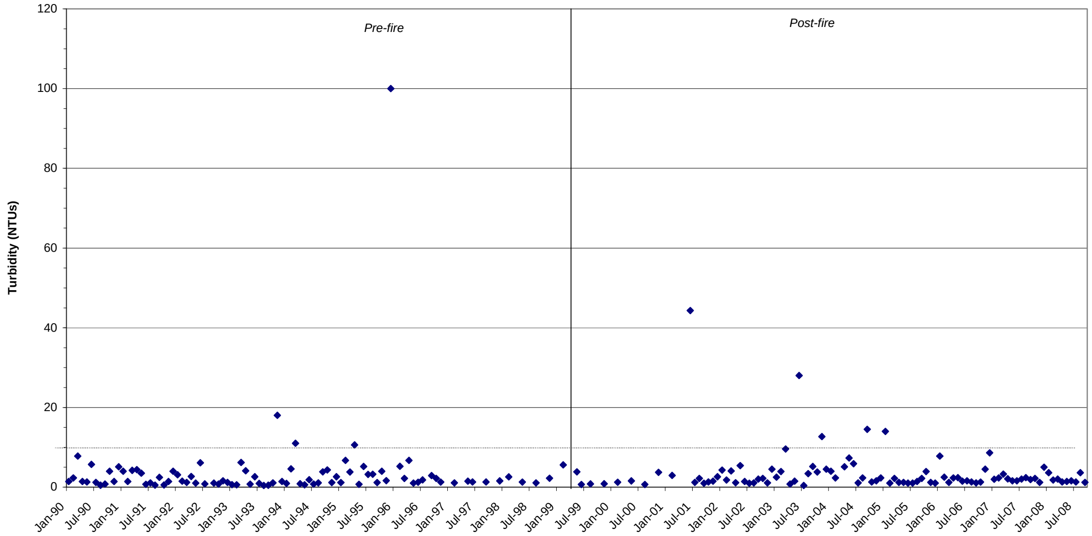

Figure 3-15. Monthly turbidity measurements at the Whatcom Creek at I-5 sample site, located just downstream of the burn zone, from 1999-2008.

3.3.4 Discussion

Monthly water quality measurements upstream and downstream of the burn site indicate that the fire does not appear to have had a substantial, long-term negative effect. The most direct effect of the fire and subsequent loss of vegetation within the burn zone would have been to reduce the cooling properties of streamside vegetation. However, the data indicate that the relatively warm water flowing out of Lake Whatcom continues to cool slightly as it flows through the burn zone, despite the loss of streamside vegetation. This may be because the area where the stream would be most vulnerable to temperature effects (i.e., the open, low gradient area downstream of Woburn Street) had relatively sparse riparian canopy cover to begin with (Figure C-1). Subsequent property acquisition and revegetation projects completed as part of the long-term restoration plan will eventually improve riparian shading levels as compared to the pre-fire conditions.

Dissolved oxygen levels appear to have increased in the burn zone since the fire. Dissolved oxygen is strongly related to temperature, flow and turbulence. While the USM data show that temperatures do not appear to have increased as a result of the fire, habitat restoration projects completed as part of the emergency response and subsequent long-term restoration plan have increase the hydraulic complexity and turbulence, and this is likely contributing to the increased DO levels observed in the burn zone.

The rapid response aimed at protecting exposed soils from erosion successfully prevented the development of large chronic erosion features related to the fire (Section 3.2). No apparent increases in turbidity levels have been documented in the years after the burn, supporting the conclusion that soils and hillslope processes are fully recovered.

4. PHOTO DOCUMENTATION

4.1 INTRODUCTION

The preceding sections and attempted to quantify various aspects of the recovery of Whatcom Creek following the fire. This section provides images taken immediately after the fire and in subsequent years that photographic documents changes in the Whatcom Creek corridor.

4.2 METHODS

Photographs taken by various individuals and organizations following the fire were compiled and reviewed. New photographs were taken on February 20, 2009 at sites that could be accurately identified from previous images.

4.3 RESULTS

Photographs were taken throughout Whatcom Creek following ER efforts in September 1999. Nine of those sites were reoccupied in February 2009. Paired photos of each site are provided in Figures 4-1 through 4-9.

4.4 DISCUSSION

Paired photos taken in September 1999 and in February 2009 document substantial recovery of the burn zone. Many of the standing dead snags have been removed due to safety hazards, particularly at the Boulder Bend site. As described in Section 2.1, revegetation of riparian zones has been successful. The streamside corridor currently supports a dense understory of native shrubs with interspersed deciduous and hardwood trees.

Figure 4-1. Looking downstream at Pixie Pool: Top February 20, 2009. Bottom: September 1999 following emergency response.

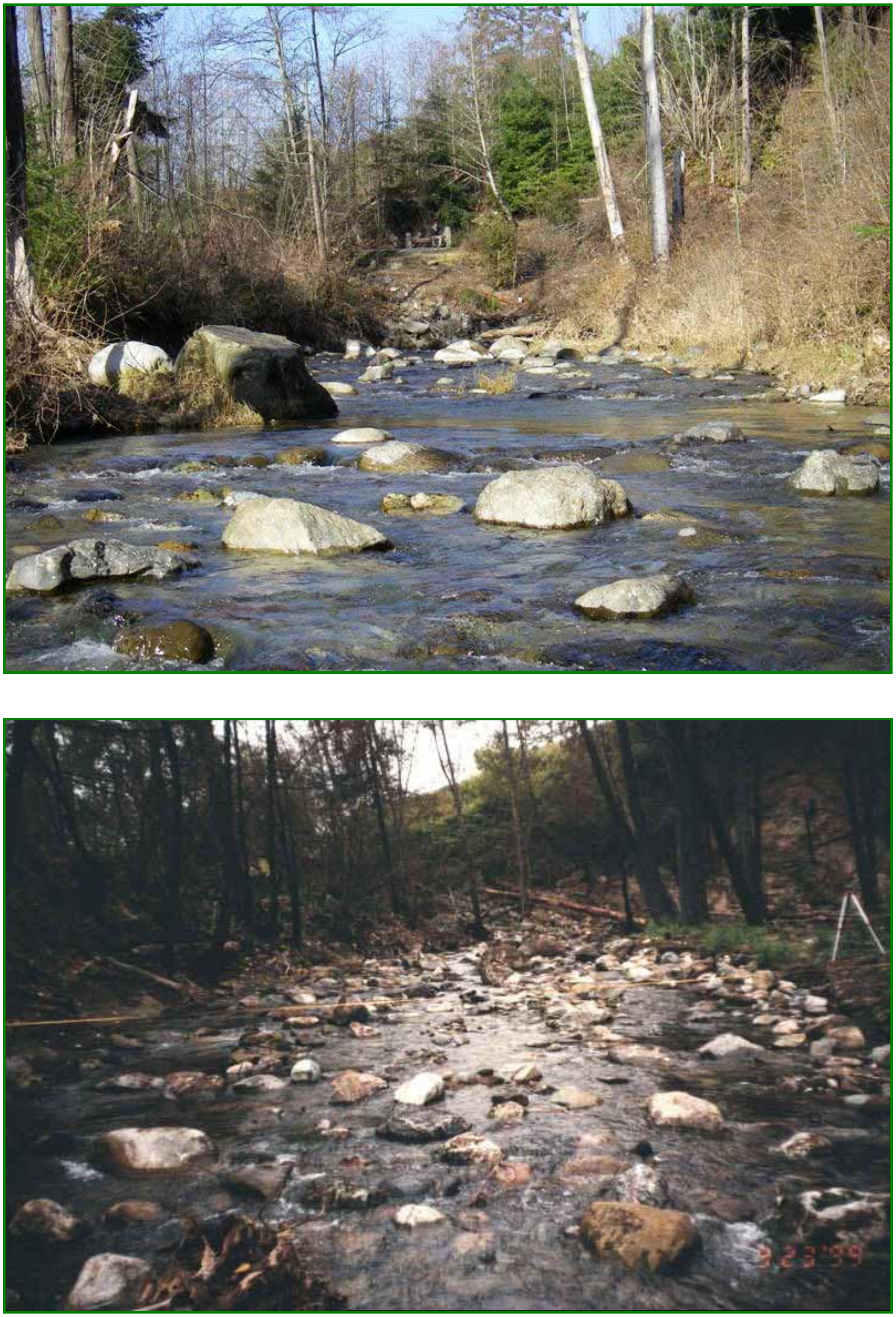

Figure 4-2. Looking upstream toward Heart Attack: Top February 20, 2009. Bottom: September 1999 following emergency response.

Figure 4-3. Looking upstream from Boulder Bend: Top February 20, 2009. Bottom: September 1999 following emergency response.

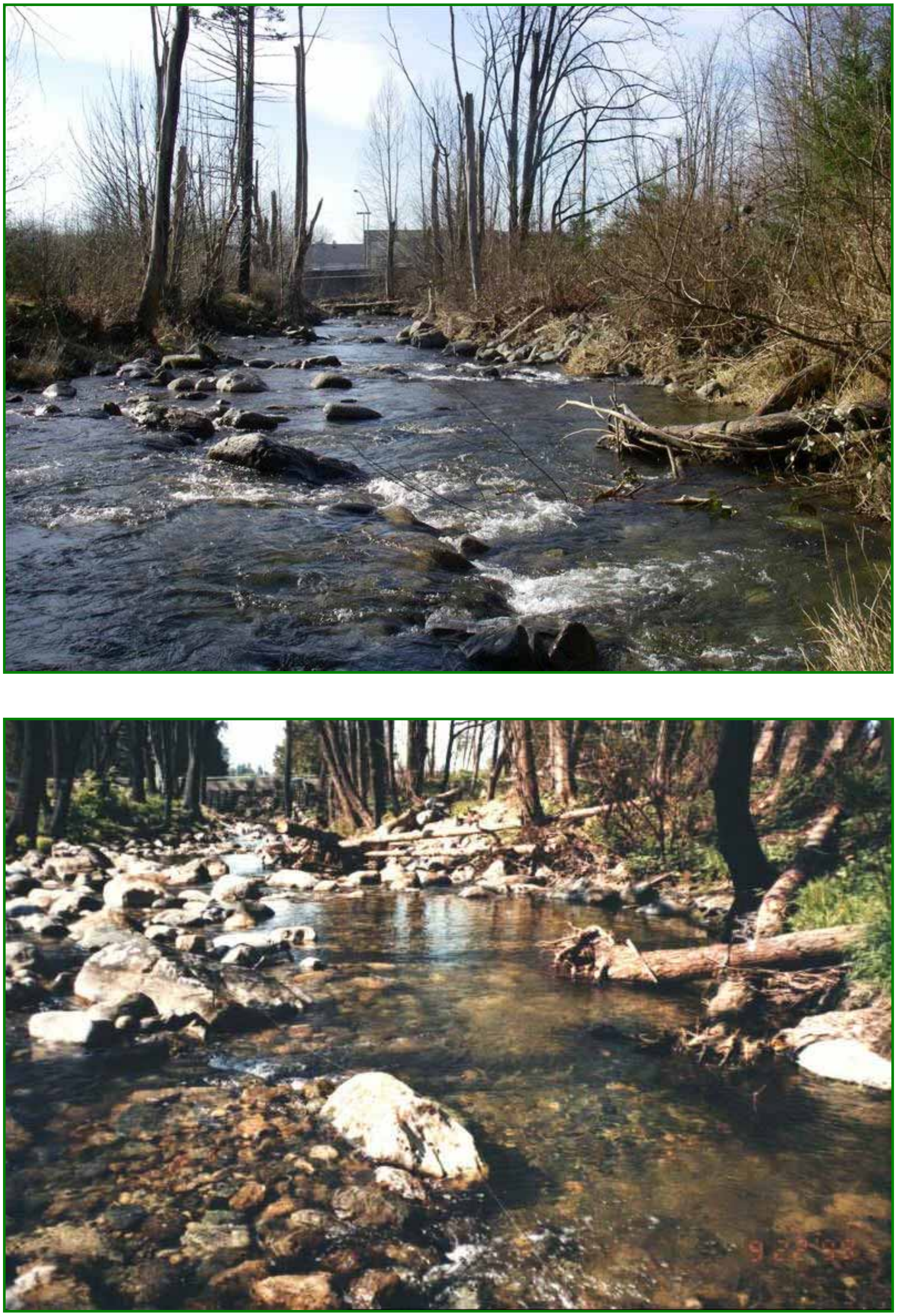

Figure 4-4. Looking downstream from Boulder Bend towards Woburn Street: Top February 20, 2009. Bottom: September 1999 following emergency response.

Figure 4-5. Looking downstream along Woburn: Top February 20, 2009. Bottom: September 1999 following emergency response.

Figure 4-6. Looking downstream from Noburn Street bridge: Top February 20, 2009. Bottom: September 1999 following emergency response.

Figure 4-7. Looking upstream at Woburn Street: Top February 20, 2009. Bottom: September 1999 following emergency response.

Figure 4-8. Looking downstream from Valencia Street: Top February 20, 2009.
Bottom: September 1999 following emergency response.

Figure 4-9. Looking downstream towards Grizzly Industries: Top February 20, 2009. Bottom: September 1999 following emergency response.

5. CONCLUSIONS

Ten years after the fire, aquatic and terrestrial ecosystems associated with Whatcom Creek are well on their way to recovery. Trees planted following the Whatcom Creek fire have been largely successful in survival and growth. While the number of young trees per acre has decreased slightly and the spacing between trees has increased slightly since 2000, this is to be expected as trees mature and naturally thin due to competition for resources. The number of trees per acre decreased by only 12 percent, while 95 percent of trees have at least doubled in height, and 71 percent of young trees are 5-feet tall or taller. Average canopy cover in the Whatcom Creek study area increased from near zero in many areas to 47 percent and will likely continue to rise as planted trees continue to grow. Control of invasive species remains an ongoing challenge, but periodic monitoring facilitates the early identification and treatment of problem sites. Immediate treatment of exposed soils appears to have successfully prevented ongoing erosion problems related to the fire.

Riparian restoration has benefited all animals that use riparian forest areas. As part of the Settlement Agreement the City of Bellingham has acquired and restored native vegetation on two large parcels of land, increasing the amount of protected riparian habitat by 13.5 acres. Although few quantitative data are available on wildlife use of the area prior to the 1999 fire, it appears that wildlife communities currently inhabiting the burn zone are similar to those that would be expected to inhabit the area in an urban ecosystem. Large snags resulting from the burn may have increased habitat for some species such as cavity-nesting birds and mammals. However, non-native species appear to dominate available cavities in more open areas.

Since 1999 the number of anadromous fish returning to Whatcom Creek has generally been substantially lower than pre-burn numbers. Concurrent with the 1999 fire, several salmonid species in Puget Sound were listed as threatened under the ESA. At the time of the burn, the Washington Department of Fish and Wildlife (WDFW) Hatchery Management policies were evolving in response to ESA listings of anadromous fish throughout the Pacific Northwest. Operations were altered to bring them in line with the Washington Wild Salmonid Policy and emphasize local stocks. Prior to the fire large numbers of juvenile fish were released to the system. Planting of Chinook salmon was halted in 1999. Numbers of coho salmon and steelhead trout were reduced to around 5,000 fish of each species each year.

While existing data are not sufficient to conduct a statistically rigorous analysis of cause and effect, it seems likely that the reduction in adult returns to Whatcom Creek is primarily related to the reduction in hatchery inputs. Fish passage projects and increased late summer flows have improved access to Whatcom Creek. Subsequent sections will show that habitat conditions and water have also improved since the burn. As a result, while the fire may have temporarily reduced spawning success it seems unlikely that it is responsible for the observed decline in adult returns.

Aquatic macroinvertebrates – Aquatic insects (macroinvertebrates) in Whatcom Creek were sampled at three sites for five years following the fire (1999-2003), and again in 2007. These data were compared to samples collected by Ecology in 1998 to assess recolonization and recovery. Sampling seven days after the fire showed an almost complete loss of the macroinvertebrate community (LaCroix 2001). Estimates of the mean density (individuals/ m2) in October 1999 indicate that aquatic insects rapidly repopulated sampling sites on Whatcom Creek following the fire. However, data indicate that the type of aquatic insects inhabiting the stream has changed. Three months after the fire, both the Racine and James Street sites showed an increase in minnow-tailed mayflies (Baetidae), which are known to be more tolerant of poor water quality conditions. By the fall of 2000, both sites showed a return of flat-headed mayflies (Heptageniidae), a less-tolerant family of mayflies that were common before the burn, which suggested recovery was at hand, but their numbers since that time have continued to be significantly less than that seen in pre-burn samples.

Analysis results indicate a shift away from aquatic insect species utilizing a feeding strategy that grazes on algae and other materials that grows on streambed gravels (scrapers), towards a community of species that gathers fine particulate matter (collector-gatherers). The reduction of percent scrapers in 1999 suggests that Whatcom Creek is not as productive as it was before the spill and fire, at least in terms of producing the algal growth. Results using the Community Tolerance Index give scores ranging from 6.1 to 7.2, with an overall average CTI score of 6.6. On a biotic index scale of 0 to 10, this average score indicates "fair" conditions, often a result of "fairly significant organic pollution." Scores for the Benthic Index of Biological Integrity (B-IBI) ranged from 12 to 28, out of a possible total of 50, indicating that the sites on Whatcom Creek are in "poor" to "fair" condition. It is unclear whether this effect is related to the fire or other urban impacts within the Whatcom Creek watershed.

Prior to the ER actions aquatic habitat conditions in Whatcom Creek were considered poor according to all available criteria. The ER resulted in short-term improvements of habitat upstream of Woburn Street (Reach 1). ER Actions and subsequent instream habitat restoration projects downstream of Woburn Street (Reach 2) have maintained improved habitat conditions. Throughout the stream the amount of LWD and number of pools is similar to or better than in

1999. Habitat complexity has also increased, particularly downstream of Woburn Street, where restoration projects have added off-channel habitat and established a meandering channel more typical of unmanaged lowland streams.

Monthly water quality measurements upstream and downstream of the burn site indicate that the fire does not appear to have had a substantial, long-term negative effect of water quality parameters that are closely linked to biotic health (i.e. temperature, DO, conductivity, turbidity). The most direct effect of the fire and subsequent loss of vegetation within the burn zone has been the reduction in shade and associated cooling properties of mature streamside forest vegetation. However, the data indicate that the relatively warm water flowing out of Lake Whatcom continues to cool slightly as it flows through the burn zone, despite the loss of shade. This may be because the area where the stream would be most vulnerable to temperature effects (i.e., the open, low gradient area downstream of Woburn Street) had a relatively narrow riparian corridor cover to begin with. Subsequent property acquisition and revegetation projects completed as part of the long-term restoration plan will eventually improve riparian shading levels as compared to the pre-fire conditions.

Dissolved oxygen levels appear to have increased in the burn zone since the fire. Dissolved oxygen is strongly related to temperature, flow and turbulence. While the monitoring data show that temperatures do not appear to have increased through the burn zone as a result of the fire, habitat restoration projects completed as part of the ER and subsequent long-term restoration plan have increased the hydraulic complexity and turbulence, and this is likely contributing to the increased DO levels observed in the burn zone.

6. REFERENCES

Adams, J.W. 2004. Stream bugs as biomonitors: Guide to Pacific Northwest macroinvertebrate monitoring and identification. CD-ROM. Xerces Society, Portland, Oregon.

Adler, P.H. and D.C. Currie. 2008. Simuliidae. Pages 825-846 *in* R.W. Merritt, K.W. Cummins, and M.B. Berg editors. An introduction to the aquatic insects of North America, 4th ed. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish. Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington D.C.

Bogdan, M.J. 1998. Benthic macroinvertebrate sampling plan for selected creeks within the Lake Whatcom watershed and its tributaries. Washington Department of Ecology, Bellingham Field Office, Bellingham, Washington.

Campbell, R.F. 2001. Review of fall Chinook salmon spawner survey data for Whatcom Creek, 2000. Report Prepared For Equilon Enterprises, LLC Houston, Texas by R2 Resource Consultants, Redmond, Washington. January 2001. 17 pp + app.

Cantrell and Associates. 2007. Whatcom Creek Post-Fire Re-Vegetation Monitoring Report. Consultant report prepared for the City of Bellingham Department of Environmental Resources, Bellingham, Washington. 96 p.

Carter, J.L. and V.H. Resh. 2001. After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. Journal of the North American Benthological Society 20(4): 658-682.

Caton, L.W. 1991. Improving subsampling methods for the EPA "Rapid Bioassessment" benthic protocols. Bulletin of the North American Benthological Society. 8(3): 317-319.

City of Bellingham (COB). 2009. Unpublished water quality data collected in support of the CCWF 2004 Grant. Department of Environmental Resources. Bellingham, Washington.

Cope, M. 1999. Personal communication. Letter from Mick Cope, Washington Department of Fish and Wildlife to M. McCrander, Equilon Resources. January 11, 1999.

Cuffney, T.F., M.R. Meadow, S.D. Porter, and M.E. Kurtz. 1997. Distribution of fish, benthic invertebrate, and algal communities in relation to physical and chemical conditions, Yakima River basin, Washington, 1990. U.S. Geological Survey Water-Resources Investigations Report 96-4280.

Cummins, K.W., R.W. Merritt, and M.B. Berg. 2008. Ecology and distribution of aquatic insects. Pages 105-122 *in* R.W. Merritt, K.W. Cummins, and M.B. Berg editors. An introduction to the aquatic insects of North America, 4th ed. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Davis, W.S. and T.P. Simon. 1995. Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers, CRC Press, Boca Raton, Florida.

Dolan, K. 2008. Survey of the cavity nesting birds of Whatcom Creek. Unpublished Senior Project report. Western Washington University, Bellingham, Washington.

EVS (EVS Environmental Consultants). 2005. Benthic macroinvertebrate study of the Greater Lake Washington and Green-Duwamish River Watersheds, Year 2003 data analysis. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, Washington.

Forester, B. 2009. Whatcom Creek Restoration Project Report: 2007-2008. Report prepared by the City of Bellingham Department of Environmental Resources. Bellingham, Washington. http://www.cob.org/services/environment/restoration

Gagner, M. 2009. Personal Communication. Conversation with Mike Gagner, Fisheries Biologist, R2 Resource Consultants, Redmond Washington. December, 2008.

Gray, L.J. and S.G. Fisher. 1981. Post flood recolonization pathways of macroinvertebrates in a lowland Sonoran desert stream. American Midland Naturalist 106: 249-257.

Hart, D.D. 1986. The adaptive significance of territoriality in filter-feeding larval blackflies (Diptera: Simuliidae). Oikos. 46(1): 88-92.

Hauer, F.R. and V.H. Resh. 1996. Benthic macroinvertebrates. Pages 339-369 *in* F.H. Hauer and G.A. Lamberti, editors. Methods in stream ecology. Academic Press, San Diego, California.

Hershey, A.E. and G.A. Lamberti. 2001. Aquatic insect ecology. Pages 733-775 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, California.

Hynes, H.B.N. 1970. The ecology of running waters. University of Toronto Press, Toronto, Ontario. 555 p.

Jones Engineers, Inc., 1999. Whatcom Creek fire corridor inspection and erosion mitigation plan. Report prepared for the City of Bellingham, Bellingham, Washington. 4 p. plus Appendices.

Karr, J.R, and E.W Chu. 1999. Restoring life in running waters: better biological monitoring. Island Press, Washington, D.C.

Karr, J.R. 1998. Rivers as sentinels: using the biology of rivers to guide landscape management. Pages 502-528 in R.J. Naiman and R.E. Bilby, editors. River ecology and management: lessons for the Pacific coastal ecosystem. Springer, New York.

King County. 2002. Greater Lake Washington and Green-Duwamish River watersheds wadeable freshwater streams benthic macroinvertebrate sampling and analysis plan. Prepared by King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, Washington.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA/600/4-90/030, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio.

LaCroix, R. 2001. Macroinvertebrate re-colonization of Whatcom Creek after a fuel spill, fire and restoration. M.S. thesis, Western Washington University, Bellingham, Washington.

Mackay, R.J. 1992. Colonization by lotic macroinvertebrates: a review of processes and patterns. Canadian Journal of Fisheries and Aquatic Sciences 49: 617-628.

McBride, T. and D. Shea. 1982. An investigation of the water quality and benthic invertebrates of Whatcom Creek, Bellingham, WA. Institute for Watershed Studies, Western Washington University, Bellingham, Washington. Unpublished report.

Merritt, R.W., K.W. Cummins, and M. Berg. 2008. An introduction to the aquatic insects of North America. Fourth Edition. Kendall/Hunt Publishing Co., Iowa.

Minshall, G.W. and R.C. Petersen, Jr. 1985. Towards a theory of macroinvertebrate community structure in stream ecosystems. Archiv für Hydrobiologie 104(1): 49-76.

Miyake, Y., T. Hiura, N. Kuhara, and S. Nakano. 2003. Succession in a stream invertebrate community: A transition in species dominance through colonization. Ecological Research 18: 493-501.

Montgomery, D. R. and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Department of Natural Resources, Washington State Timber/Fish/Wildlife Agreement, Report TFW-SH10-93-002. Olympia, Washington.

Montgomery, D.R., J.M Buffington, R. Smith, K. Schmidt, and G. Pess. 1995. Pool spacing in forest channels, Water Resources Research, v. 31, 1097-1105.

Morley, S.A. 2000. Effects of urbanization on the biological integrity of Puget Sound lowland streams: restoration with a biological focus. M.S. thesis. University of Washington, Seattle.

Morley, S.A. and J.R. Karr. 2002. Assessing and restoring the health of urban streams in the Puget Sounds Basin. Conservation Biology 16(6): 1498–1509.

Moulton, S.R., II, J.L. Carter, S.A. Grotheer, T.F. Cuffney, and T.M. Short. 2000. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory - Processing, taxonomy, and quality control of benthic macroinvertebrate samples. U.S. Geological Survey Open-File Report 00-212.

National Marine Fisheries Service (NMFS). 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. Prepared by the Environmental and Technical Services Division, Habitat Conservation Branch. August.

Olympic Pipeline Company (OPC). 1999. Emergency restoration plan for Whatcom Creek and Whatcom Falls Park, Bellingham, Washington. Report prepared by the Olympic Pipeline Company.

National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service. Nooksack tribe, Lummi Nation, State of Washington, and City of Bellingham. 2002. Restoration plan and environmental assessment for the June 10, 1999, Olympic Pipeline gasoline spill into Whatcom Creek, Bellingham, Washington. Report available for download at www.darcnw.noaa.gov/whatcom.htm

Pleus, A.E., D. Schuett-Hames, and L. Bullchild. 1999. Timber-Fish-Wildlife (TFW) monitoring program method manual for the habitat unit survey. Prepared for the Washington State Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-003. DNR#105. June.

Plotnikoff, R.W. 1994. Instream biological assessment monitoring protocols: benthic macroinvertebrates. Publication #94-113, Washington Department of Ecology, Olympia, WA.

Plotnikoff, R.W. and C. Wiseman. 2001. Benthic macroinvertebrate biological monitoring protocols for rivers and streams: 2001 revision. Washington Department of Ecology, Olympia, WA. Ecology Publication no. 01-03-028.

R.W. Beck and Associates. 1984. Whatcom Creek flood management improvements. Consultant report prepared for the City of Bellingham department of Public Works. Bellingham, Washington.

R2 Resource Consultants (R2). 2009. Executive Summary: Whatcom Creek Fire: 10 Years After. Consultant report prepared for the City of Bellingham (*in press*).

Reice, S.R. and M. Wohlenberg. 1993. Monitoring freshwater benthic invertebrates and benthic processes: Measures for assessment of ecosystem health. Pages 287-305 *in* D.M. Rosenberg and V.H. Resh, editors. Freshwater biomonitoring and benthic macroinvertebrates. Routledge, Chapman and Hall, Inc., New York, New York.

Rosenberg, D.M. and V.H. Resh. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates. Pages 1-9 *in* D.M. Rosenberg and V.H. Resh, editors. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York.

SalmonWeb. 2000. Benthic index of biological integrity (B-IBI) for the Puget Sound Lowlands. On the SalmonWeb website. <http://www.cbr.washington.edu/salmonweb/bibi/>. Last updated on December 20, 2000.

Schuett-Hames, D., A.E. Pleus, J. Ward, M. Fox, and J. Light. 1999. *TFW Monitoring Program: Method Manual for the Large Woody Debris Survey*. Prepared for the Washington State Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-004. DNR #106. June.

Shaw, D.W. and G.W. Minshall. 1980. Colonization of an introduced substrate by stream macroinvertebrates. Oikos 34: 259-271.

Steele, E. 2009. Personal communication. Telephone conversation between S. Madsen (R2) and Earle Steele, Fisheries Program Manager, Bellingham Technical College, Bellingham, Washington. January 30, 2009.

Stewart, K.W. and B.P. Stark. 2002. Nymphs of North American stonefly genera (Plecoptera). Second Edition. The Caddis Press, Columbus, Ohio.

Thorp, J.H. and A.P. Covich. 2001. Ecology and classification of North American freshwater invertebrates. Second Edition. Academic Press, Inc., San Diego, California.

Vandersypen, J., D. Love and R.A. Matthews. 2006. Urban streams monitoring project final report. Report produced by the Institute for Watershed Studies, Western Washington University for City of Bellingham Department of Environmental Resources. Bellingham, Washington, September 8, 2006.

Wallace, J.B. and J.R. Webster. 1996. The role of macroinvertebrates in stream ecosystem function. Annual Review of Entomology 41: 115-139.

Ward, J.V. 1992. Aquatic insect ecology: 1. biology and habitat. John Wiley and Sons, New York.

Washington State Department of Ecology (Ecology). 2006. *Water Quality Standards for Surface Waters of the State of Washington*, Chapter 173-201A WAC. Publication # 06-10-091. Olympia, Washington. 113 pgs.

Waters, T.F. 1964. Recolonization of denuded stream bottom areas by drift. Transactions of the American Fisheries Society 93: 311-315.

WFPB (Washington Forest Practices Board). 1997. Standard methodology for conducting watershed analysis (under Chapter 222-22 WAC). Washington State Department of Natural Resources, Olympia, Washington.

Whitehead S.C., Wright J., and Cotton P.A. 1995. Winter field use by European starling *Sturnus vulgaris*: habitat preferences and the availability of prey. Journal of Avian Biology 26: 193-202.

Wiggins, G.B. 1996. Larvae of the North American caddisfly genera (Trichoptera). Second Edition. University of Toronto Press Inc., Toronto, Ontario, Canada.

Wisseman, R.W. 1998. NuWiss Master 98 benthic macroinvertebrate database (with an additional clinger database compiled by Leska Fore) on the SalmonWeb website. <http://www.cbr.washington.edu/salmonweb/taxon/NuWiss.Master98-2.xls> and <http://www.cbr.washington.edu/salmonweb/taxon/clingertaxa.xls>. Last Updated February 12, 2002.

Wisseman, R.W. 2004. Appendix B. Ecological and life history attributes of freshwater benthic invertebrates found in the Clackamas River and adjacent drainages, Oregon. Coding parameters for community analysis. *In* Wisseman, R. and K. Doughty. 2004. Characterization of benthic invertebrate communities in the Clackamas River watershed, Oregon. Clackamas Hydroelectric Relicensing Project, Water Quality 3 (WQ3) Studies. Portland General Electric, Portland, Oregon.

APPENDIX A

Cantrell and Associates Report

APPENDIX B

LaCroix 2001 – Masters Thesis

APPENDIX C

Aquatic Macroinvertebrates – Statistical Analysis

Appendix C
Benthic Macroinvertebrates – Statistical Analysis

Summary tables and plots of the benthic macroinvertebrate data collected from Whatcom Creek from 1998 through 2007 suggested that a shift in community composition and in functional feeding groups had possible occurred over the study years. In order to verify and validate these observations, additional statistical analyses were implemented on select variables from the Whatcom Creek benthic macroinvertebrate data.

Methods

Two multivariate procedures, principle components analysis (PCA) and cluster analysis, were utilized to explain the relative contribution of different metrics or taxa to observed grouping patterns seen in the Whatcom Creek benthic macroinvertebrate community from 1998 to 2007.

Principle Components Analysis

PCA is a data analysis tool usually used to reduce the number of variables in a data set, while retaining as much information as possible (Hintze 1998). PCA calculates an uncorrelated set of variables, referred to as factors or principal components, ordered so that the first few retain most of the variation present in the original variables (Hintze 1998). For Whatcom Creek benthic macroinvertebrate data, PCA was used to create an ordination plot placing numerous site cases along a set of axes based upon the average functional feeding group compositions and the average abundance or percent abundance of the family-level taxonomic groups from each site from each year.

The goal of ordination is to preserve differences between samples, to reduce the dimensionality of the data, and to create a set of independent covariates from a set of correlated variables. The general approach is to define a new set of axes that describe the majority of the variability in the multivariate data. The first axis is a vector fitted to the direction of maximum variability in the data. Successive axes are orthogonal (perpendicular) to the existing axes, with each additional axis explaining a smaller portion of the total variation in the data.

Feeding groups and family-level taxon variables were represented by arrows with the direction and length of each arrow plotted to indicate the amount of influence that variable had upon the two axes. Sites were plotted in the ordination in relation to those metrics and taxonomic variables found at the site, thus similar sites would be located closer together. Using the statistics program MVSP (Kovach 2005), PCA was used on the data set to observe any grouping patterns.

Cluster Analysis

Cluster analyses using the Bray-Curtis measure of dissimilarity were used to group sites and years by the similarity of their community structure. This dissimilarity measure has demonstrated a relatively robust ability to capture ecological patterns across a wide variety of assumptions about the sampling populations (Faith et al. 1987). The Bray-Curtis distance relies upon quantitative estimates of each taxon's abundance to estimate dissimilarity; each taxon's abundance is used as a multivariate axis whereby the actual distance in multivariate space for each pair of samples in measured to determine how similar samples are to each other. Unlike a simple Euclidean distance, the Bray-Curtis distance is calculated as the total absolute difference between variables and not as the squared difference between variables (Digby and Kempton 1987). The unweighted pair groups method (UPGMA), a hierarchic, agglomerative algorithm using average linkage techniques, was used to generate groupings from this similarity matrix using MVSP (Kovach 2005). This cluster analysis produces a tree-like diagram called a dendrogram that illustrates the similarity of samples based on their relative distances to each other in multivariate space.

For the Whatcom Creek data set, cluster analyses were conducted on the percent abundance data for each family-level taxa and for functional feeding groups. These variables were averaged for each combination of site and year available, for a total of 20 site/year cases. These averages were then square-root transformed and used in the cluster analysis to group the site/year combinations using the statistics program MVSP (Kovach 2005). Results were displayed using dendrograms scaled from 0 to 1, indicating the proportion of dissimilarity. Sites clustering together at lower values are considered more similar to each other than those sites grouping at higher values.

Results

First, a PCA was run with the mean abundances of family-level taxonomic groups, so as to present an ordination plot with 20 cases representing each site/year, as opposed to 72 points plotted for each sample, thus making the plot easier to interpret. The PCA biplots (Figures C-1 and C-2) reveal temporal relationships previously shown in the simple plots, with the first three axes explaining approximately 84 percent of the data set’s variation. Axis 1 appears to be a gradient of abundance, with years of higher abundances (2001-2003) to the right largely due to higher densities of Chironomidae (Figure C-1). Axis 2 is strongly influenced by the abundances of Baetidae and Simuliidae, and the addition of Axis 3 further defines the gradient of the abundance of baetids and simuliids (Figure C-2). Samples from 1998, 1999, 2000, and 2007 are grouped together to the left along Axis 1, due to lower abundances, but are further separated by Axes 2 and 3, showing that sites in 1999 had higher Baetidae abundances (Figure C-2). The PCA biplot also indicates that the Middle Falls and Racine Street sites show an increased abundance of Simuliidae in 2001, and that the site at James Street is noticeably different from the other sites in five of the seven years of sampling, grouping to the negative side of Axis 2, and indicating a larger influence of gastropods, water mites, and chironomids (Figure C-2).

For the PCA run with the mean percent abundances of family-level taxonomic groups, the first three axes explain approximately 82 percent of the data set's variation. The PCA biplots (Figures C-3 and C-4) further define the differences in community composition between years. Axis 1 shows a gradient between high percent abundance of Baetidae to Chironomidae (Figure C-3), whereas Axes 2 and 3 show the influence of higher Heptageniidae and Gastropoda compositions (Figure C-4). The pooled samples from the Department of Ecology's 1998 survey that serve as a "pre-burn" baseline for this study clearly separate from post-burn sampling, due to the higher percent abundance of heptageniid mayflies. As was noted in the simple plots, the biplots indicate an increased percent abundance of Baetidae in 1999 sampling, but sampling in 2000 shows a resurgence of heptageniids (Figures C-3 and C-4). The biplots also indicate that sampling in 2001-2003 and 2007 was influenced by higher percent compositions of baetids and chironomids, although the biplots again indicate an increased contribution of simuliids in 2001 (Figure C-4).

The cluster analysis conducted on mean percent abundances of family-level taxonomic groups reveals groupings similar to those demonstrated by the PCA results. Results for the cluster analysis are presented in Figure C-5. The dendrogram depicts the relative similarity of samples from each zone based on the proportional abundance of each family. Sites/years are indicated next to the corresponding tips of the dendrogram branches. Moving from the trunk of the tree to its branch tips (i.e., from left to right) corresponds to a progressively finer division of the samples into more homogeneous groups. By inspecting the pattern of branching, it is possible to determine which sites and years are most similar with respect to their taxonomic composition, which is measured as the distance between samples in multivariate space. Samples joining each other at the far right of the dendrogram are most similar, whereas samples joined at the far left are most dissimilar.

The dendrogram's branching pattern suggests a shifting in taxonomic composition following the burn in 1999. The analysis shows three larger cluster groups and two smaller clusters. James

Street in 2003 immediately separates out at a dissimilarity of 0.627, indicating a substantially different community composition that further suggests a disturbance or event at that site during that period. The baseline sampling in 1998 clustered together with samples from 2000, separating from the rest of the site/years at a dissimilarity of 0.432. This grouping suggests that Whatcom Creek may have been approaching post-burn recovery by 2000, at least in terms of the community composition.

The largest lowermost cluster is formed by sites sampled post-burn. Again, sampling from the James Street site in 2002 and 2007 form a smaller cluster at a dissimilarity of 0.417, differing from other sites/years due to a higher percentage of water mites. Sampling conducted shortly after the burn in 1999 forms another cluster at a dissimilarity of 0.372, separating from the remainder of sites/years from 2001-2003 and 2007.

A PCA was run with the mean percent compositions of each functional feeding group for each site/year (totaling 20 cases). The first two axes accounted for 92.8 percent of the variation in FFG metrics. The PCA biplot (Figure C-6) again revealed temporal relationships previously shown in previous plots: pre-burn baseline data in 1998 and sampling at Middle Falls and Racine Street in 2000 were composed of a higher percentage of scrapers, largely the heptageniid mayfly *Rhithrogena*. Sampling in 2001 at Middle Falls and Racine Street are separated from other sites/years due to the increased percentage of collector-filterers, corresponding to the increased abundance of simuliid blackflies. Samples from 1999 are grouped together more centrally, showing an equal composition of collector-gatherers and scrapers, mostly reflective of the feeding habitats of baetid mayflies which were highly abundant during that period.

Cluster analysis of the functional feeding group components groups the sites/years similar to the PCA analysis, although all sites/years show a dissimilarity of less than 0.36 (Figure C-7). The three site/years with higher percent collector-filterers are immediately grouped together at a dissimilarity of 0.342. Next, percent scrapers are grouped with the 1998 baseline samples and Middle Falls and Racine Street sampling from 2000 separated out at a dissimilarity of 0.314. The remaining site/years are clustered according to the size of their collector-gatherer component. This lower cluster further divides into two more clusters, apparently separating the sites/years by the proportion of collector-gatherers and scrapers.

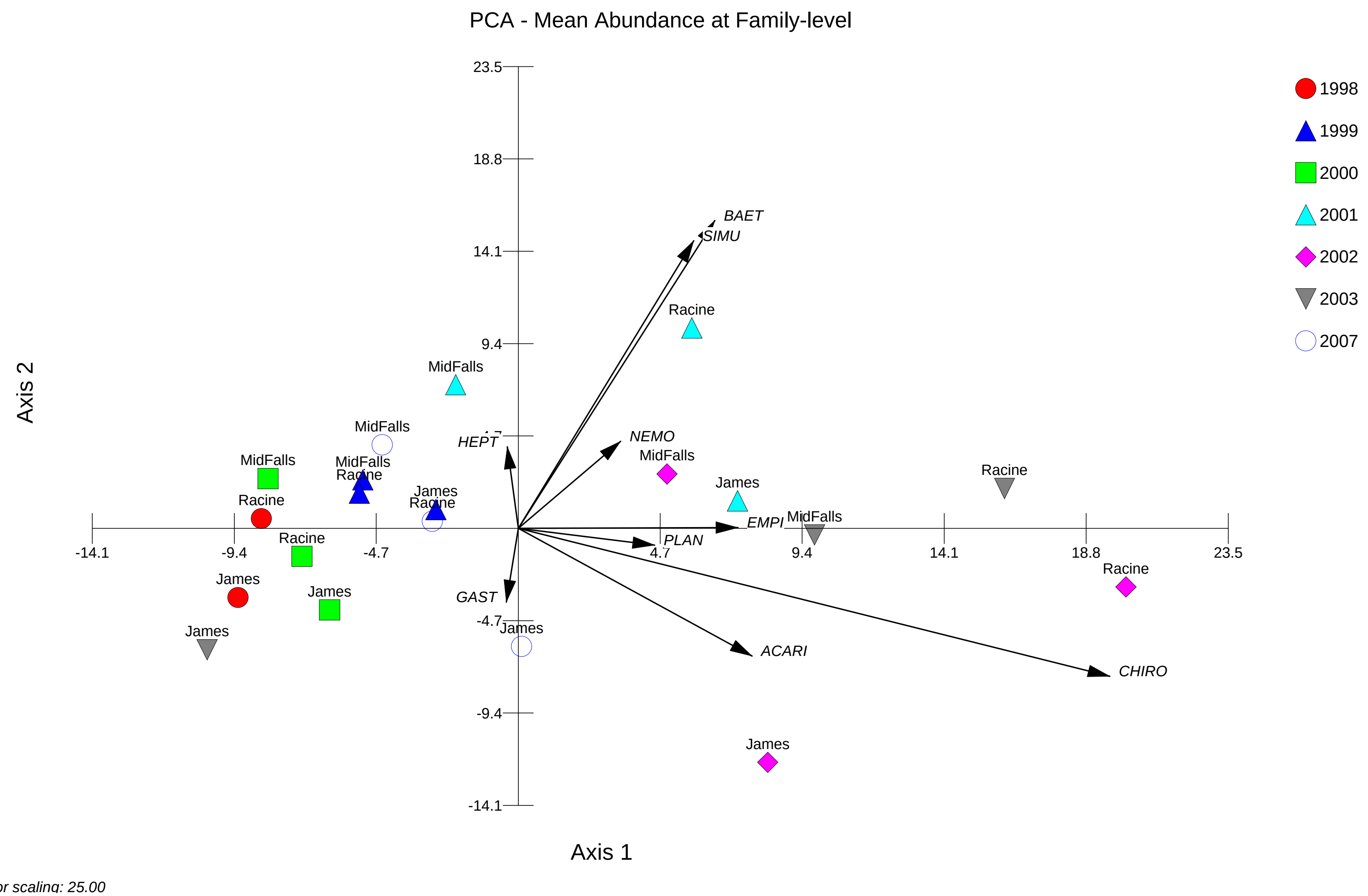

Figure C-1. Axis 1 and 2 of a Principal Components Analysis (PCA) plotting the 20 cases of each site/year benthic macroinvertebrate sampling from Whatcom Creek along gradients of mean abundances of family-level taxa. Note that longer arrows represent stronger gradients, and short arrows represent weaker gradients. (ACARI=Acari (water mites); BAET=Baetidae; CHIRO=Chironomidae; EMPI=Empididae; GAST=Gastropoda; HEPT=Heptageniidae; NEMO=Nemouridae; PLAN=Planariidae)

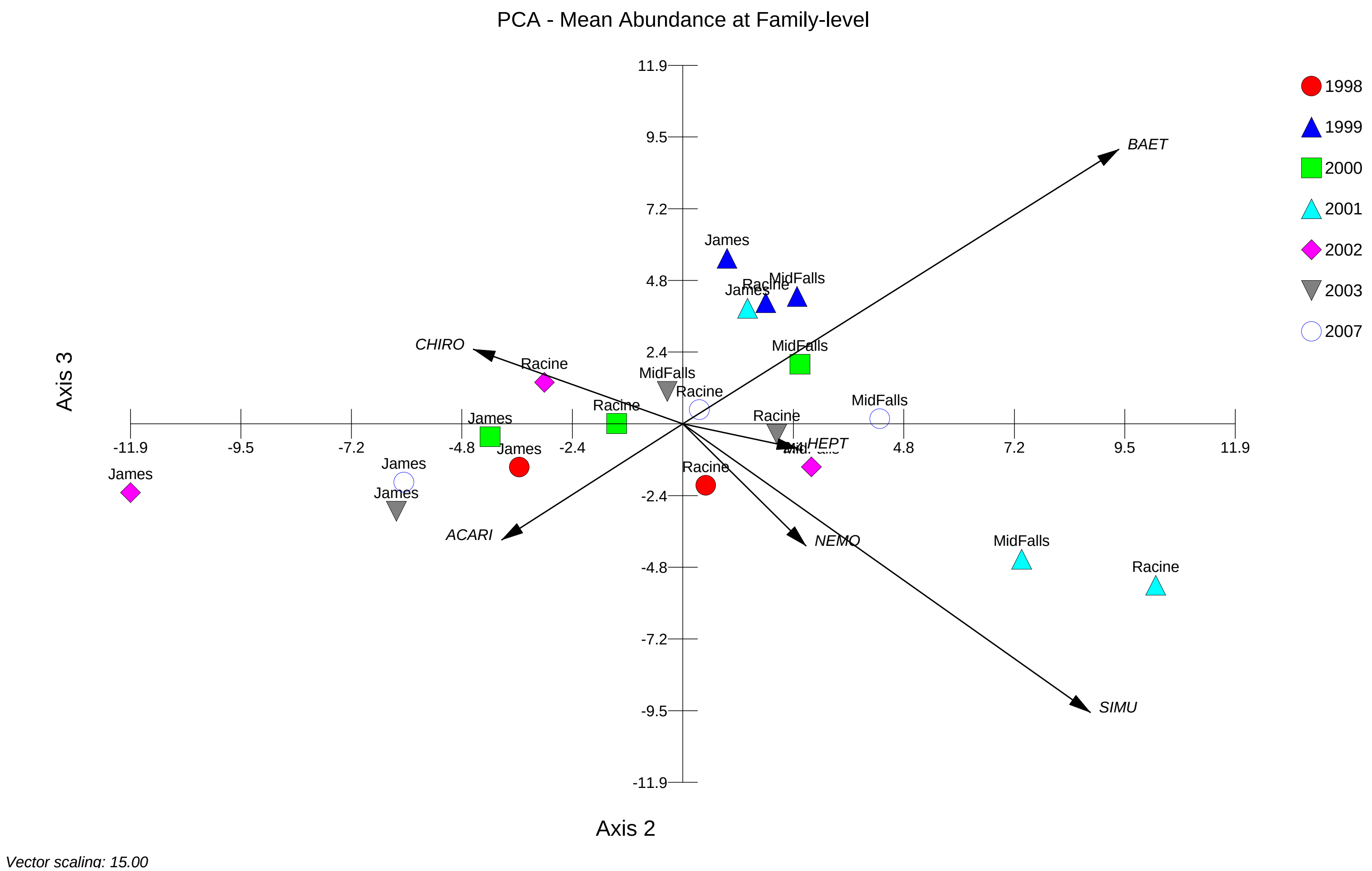

Figure C-2. Axis 2 and 3 of a Principal Components Analysis (PCA) plotting the 20 cases of each site/year benthic macroinvertebrate sampling from Whatcom Creek along gradients of mean abundances of family-level taxa. Note that longer arrows represent stronger gradients, and short arrows represent weaker gradients. (ACARI=Acari (water mites); BAET=Baetidae; CHIRO=Chironomidae; HEPT=Heptageniidae; NEMO=Nemouridae)

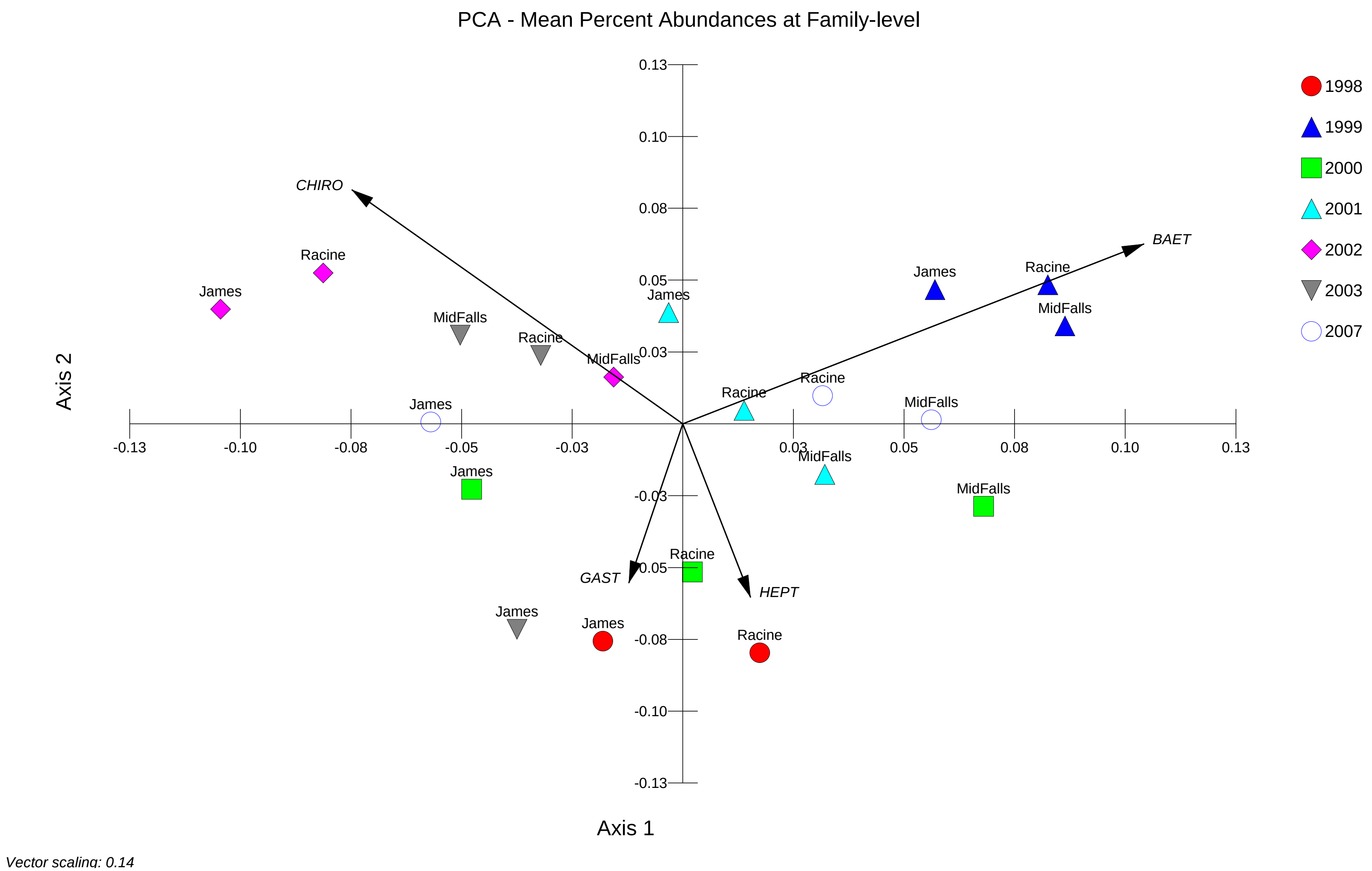

Figure C-3. Axis 1 and 2 of a Principal Components Analysis (PCA) plotting the 20 cases of each site/year benthic macroinvertebrate sampling from Whatcom Creek along gradients of mean percent abundances of family-level taxa. Note that longer arrows represent stronger gradients, and short arrows represent weaker gradients. (BAET=Baetidae; CHIRO=Chironomidae; EMPI=Empididae; GAST=Gastropoda; HEPT=Heptageniidae)

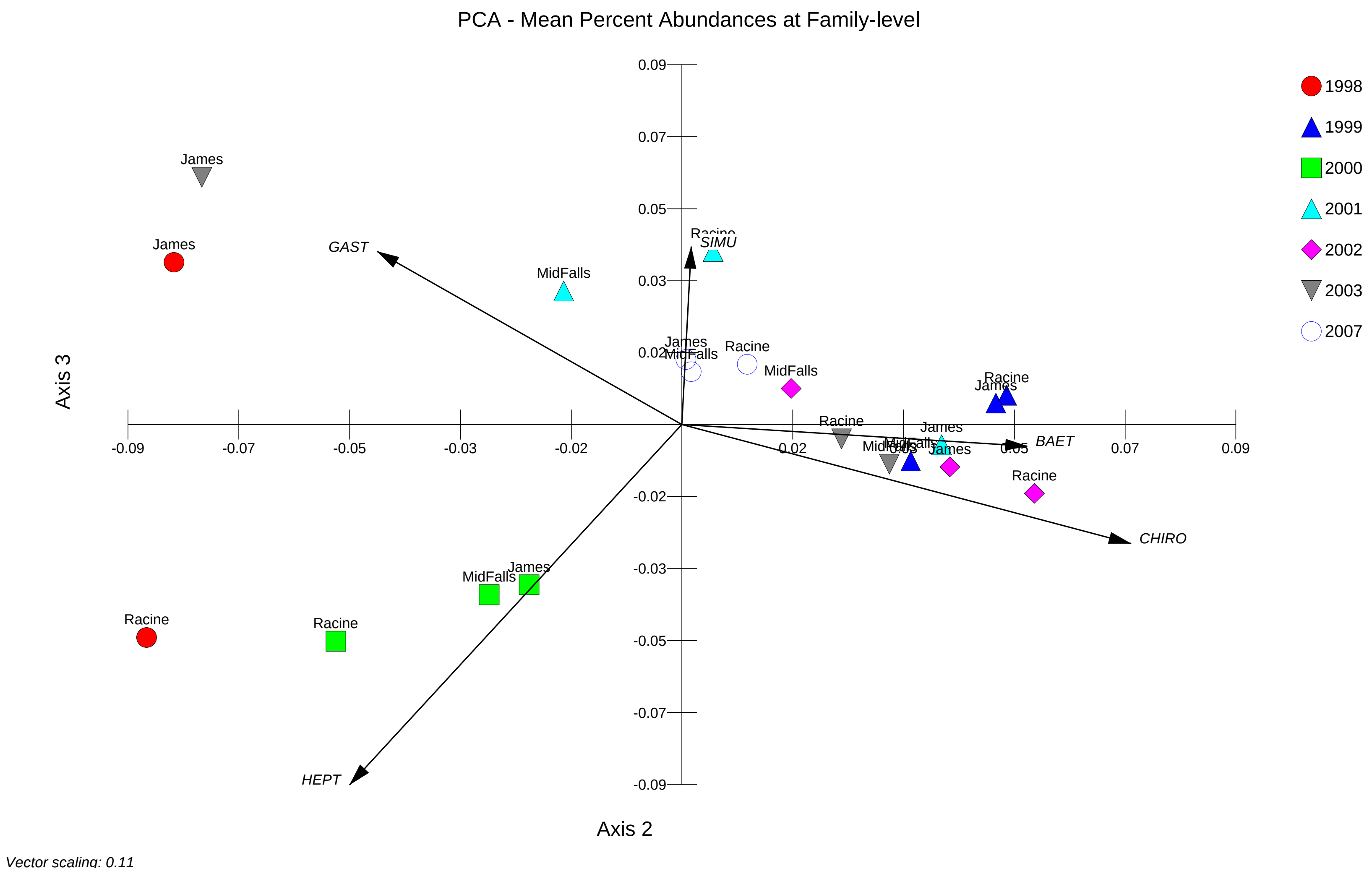

Figure C-4. Axis 2 and 3 of a Principal Components Analysis (PCA) plotting the 20 cases of each site/year benthic macroinvertebrate sampling from Whatcom Creek along gradients of mean percent abundances of family-level taxa. Note that longer arrows represent stronger gradients, and short arrows represent weaker gradients. (BAET=Baetidae; CHIRO=Chironomidae; GAST=Gastropoda; HEPT=Heptageniidae; SIMU=Simuliidae)

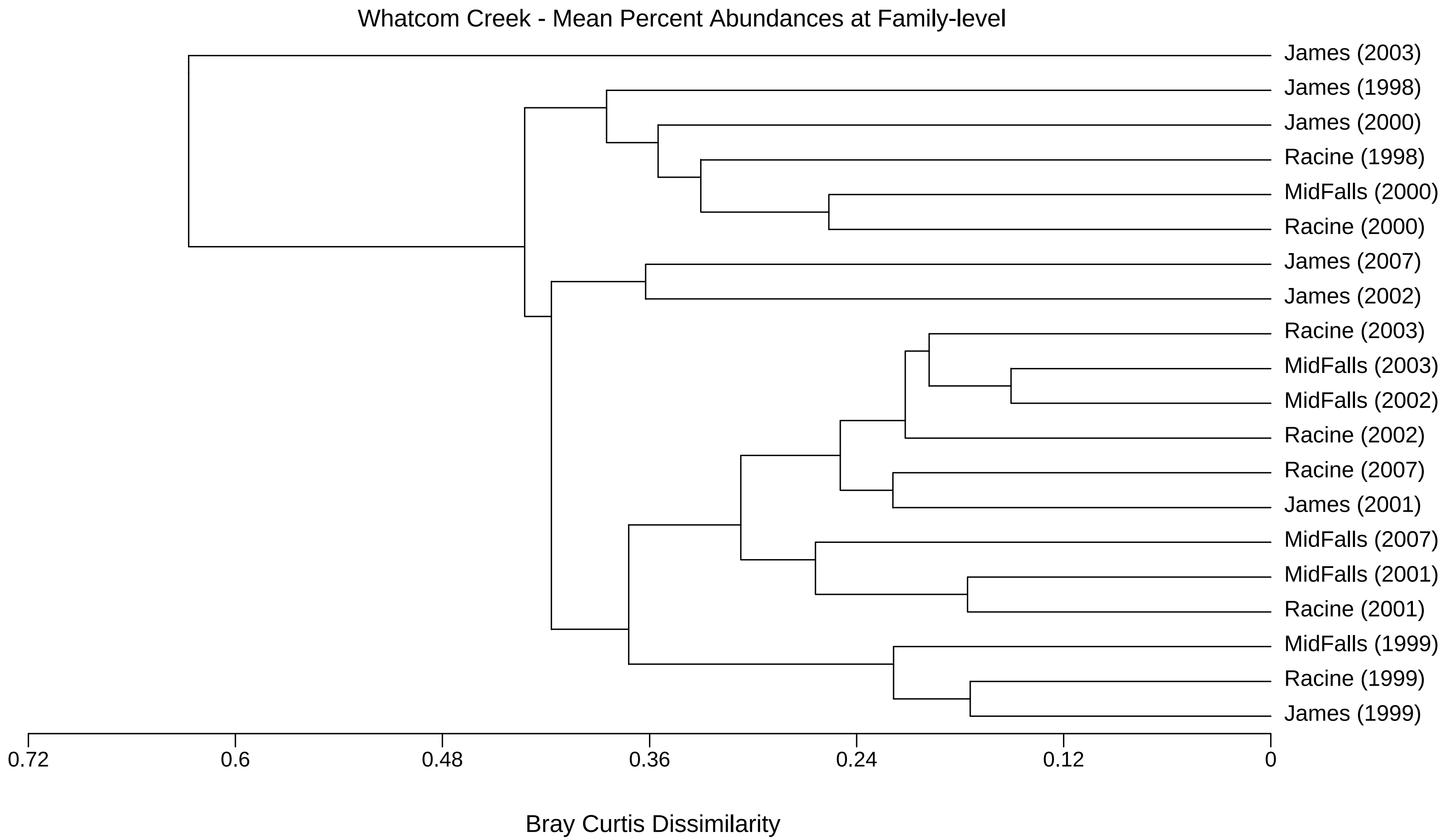

Figure C-5. Hierarchal cluster analysis using the Bray Curtis Dissimilarity measure to separate 20 cases of site/year benthic macroinvertebrate sampling from Whatcom Creek by their similarities in their mean percent abundances of family-level taxa.

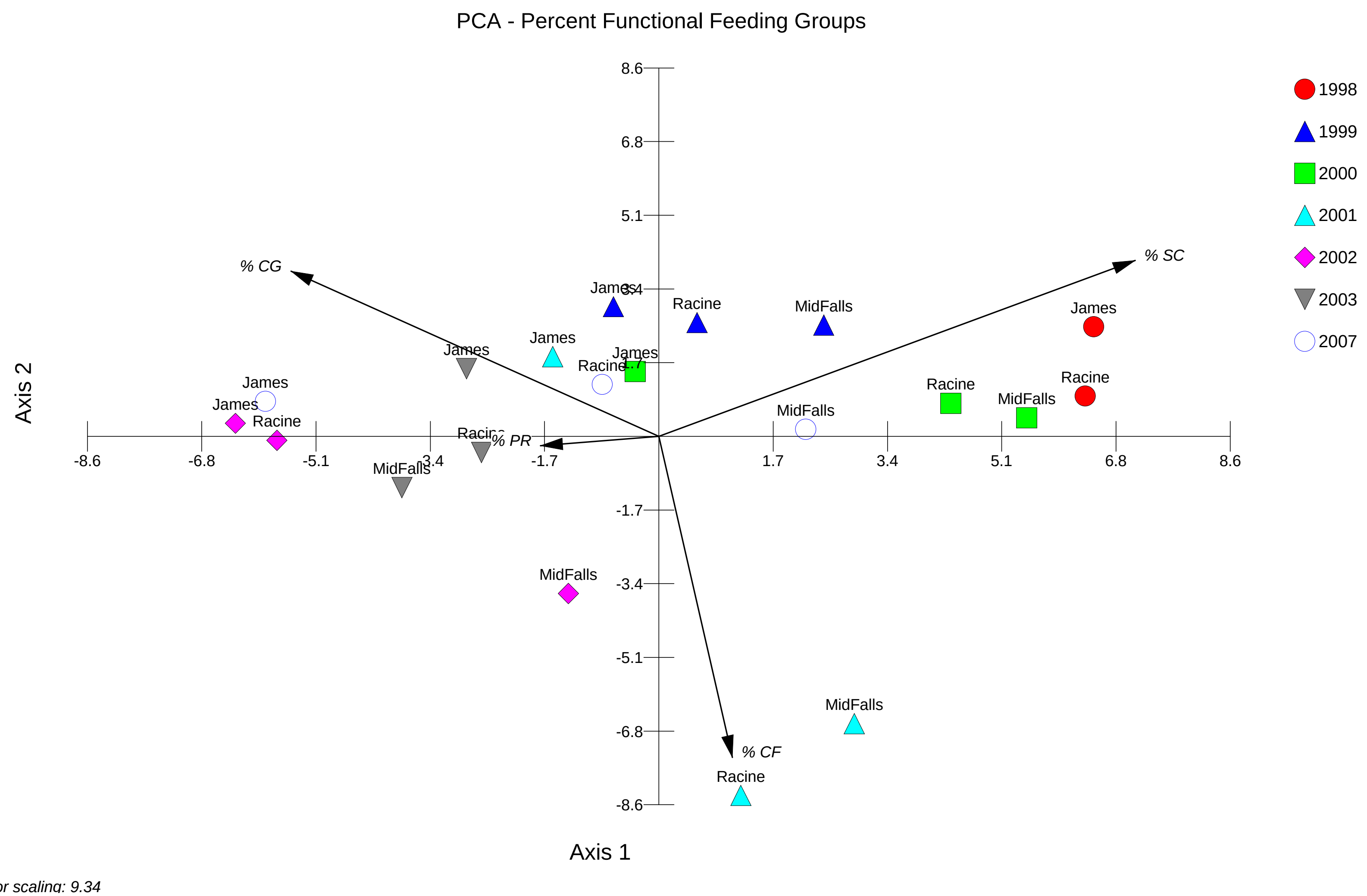

Figure C-6. Principal Components Analysis (PCA) plotting the 20 cases of site/year benthic macroinvertebrate sampling from Whatcom Creek along gradients of mean percent abundances of the functional feeding groups. Note that longer arrows represent stronger gradients, and short arrows represent weaker gradients. (CG=Collector-gatherer; CF=Collector-filterer; SC=Scraper; PR=Predator)

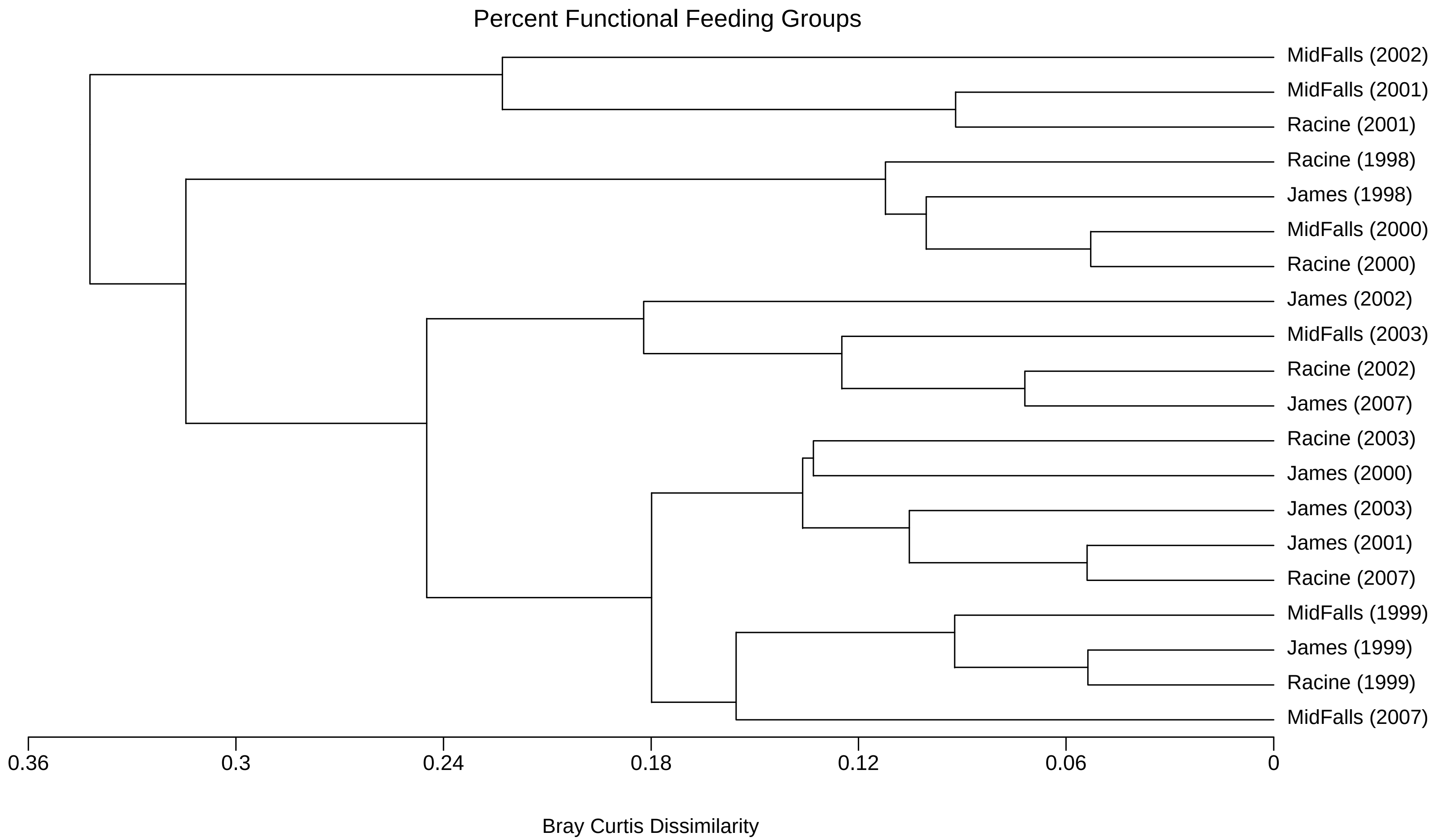

Figure C-7. Hierarchal cluster analysis using the Bray Curtis Dissimilarity measure to separate 20 cases of site/year benthic macroinvertebrate sampling from Whatcom Creek by their similarities in their mean percent abundances of the functional feeding groups (Collector-Gatherer, Collector-Filterer, Shredder, Scraper, Predator).

REFERENCES

Digby, P.G.N. and R.A.Kempton. 1987. Multivariate Analysis of Ecological Communities. Chapman and Hall, New York. 206 pp.

Faith, D.P., P.R. Minchin and L. Belbin. 1987. Compositional dissimilarity as a robust measure of ecological distance. Vegetatio 69:57-68.

Hintze, J. L. 1998. Number Cruncher Statistical Systems. Kaysville, UT.

Kovach, W.L. 2005. MVSP - A MultiVariate Statistical Package for Windows, ver. 3.1. Kovach Computing Services, Pentraeth, Wales, U.K.