U.S. Fish & Wildlife Service

Distribution and Habitat Use of Fish in Seattle's Streams

Final Report, 2005 and 2006

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Seattle Public Utilities

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EXECUTIVE SUMMARY

In 2005 and 2006, we conducted a comprehensive survey of Seattle's streams to determine fish distribution. Information from this inventory will aid the City of Seattle with their future management decisions. The survey consisted of two major parts: 1) a survey of all streams to determine the overall distribution of each fish species (single-pass electrofishing), and 2) surveys of long-term reference sites (multiple-pass electrofishing) to estimate fish abundance. Fish distribution surveys were conducted during the summer and winter. Reference site surveys were conducted in at least one site of the five major watersheds (Piper's Creek, Thornton Creek, Longfellow Creek, Fauntleroy Creek, and Taylor Creek). Fish communities in the reference sites were sampled for abundance, biomass, and diversity.

During both parts of the study, we also collected stream habitat information. Stream habitat surveys were conducted on 37 out of the 49 stream systems. Of the 37 streams surveyed, we collected habitat data on a total of 149 sites. In general, habitat conditions appeared good in Piper's Creek, Thornton Creek, and Longfellow Creek. In Taylor Creek and Fauntleroy Creek, many sections were shallow and had little pool habitat. In the smaller stream systems, habitat conditions often did not appear conducive to supporting fish populations. Often much of the stream was in a long culvert and may be a barrier to upstream fish movements. The wetted stream width was often narrow and there was little streamflow. These streams tended to be shallow (maximum depth < 0.25 m) and have little pool habitat. Also, the substrate was predominantly sand with little gravel or larger substrates.

Summer surveys, indicated cutthroat trout *Oncorhynchus clarkii* were widespread in Piper's Creek, Thornton Creek, and Taylor Creek. Only one cutthroat trout was ever collected in Longfellow Creek despite a large amount of available habitat. Additionally, cutthroat trout were absent in other southwest stream systems. Additional research is needed to better understand why cutthroat trout are rare in the southwest streams including Longfellow Creek but abundant in other similar-sized streams. Winter surveys of Piper's Creek and South Branch of Thornton Creek documented the presence of cutthroat trout in more upstream locations.

Juvenile coho salmon *O. kisutch* were observed in all of the five major watersheds as well as Durham Creek; however, it's unclear if they were naturally-produced or were part of an enhancement project. Rainbow trout *O. mykiss* were rarely collected and were only observed in Thornton Creek, Ravenna Creek, Longfellow Creek, and Puget Creek. The only location we ever observed juvenile Chinook salmon *O. tshawytscha* was in Taylor Creek, near its mouth on Lake Washington.

Threespine stickleback *Gasterosteus aculeatus* were also widespread in Seattle stream systems but were usually found in large numbers in ponds or low-velocity areas of streams. The only freshwater species of cottids found in Seattle streams were coastrange sculpin *Cottus aleuticus* and prickly sculpin *C. asper*. Cottids were only found in the low reaches of streams. Because of their poor swimming ability and they undergo a pelagic larvae phase in downstream areas (Lake Washington or Puget Sound), their ability to inhabit upstream areas can be limited by small instream barriers such as small cascades and weirs. Introduced fish species observed included four centrarchid species and four other species. Introduced species were primarily observed in the Thornton Creek mainstem and the North Branch of Thornton Creek.

A total of nine reference sites were established in the major watersheds. Salmonid biomass estimates in Thornton Creek and Piper's Creek drainages were generally higher than the other three systems. The density of salmonids in our reference sites in the South Branch of Thornton Creek and Piper's Creek appeared to be high in comparison to other lowland streams in the Pacific Northwest.

To assess ecosystem health, we used a fish index of biotic integrity (FIBI) that has been developed for other Puget Sound lowland streams. FIBI scores were generally low in Piper's Creek and Thornton Creek watersheds, primarily due to the relatively high abundance of cutthroat trout and lack of other species such as coho salmon and cottids. FIBI scores were generally higher in Longfellow Creek and Fauntleroy Creek than other Seattle streams, largely because few cutthroat trout were present and coho salmon made up a high percentage of the catch. However, the FIBI scores from these streams may have been artificially high because juvenile coho salmon may have been outplanted.

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INTRODUCTION

The presence or absence of fishes in streams is an important determinant for stream and riparian zone management regimes. In Washington State, streams are often classified according to the presence of fishes, particularly anadromous salmonids. Resource management decisions are guided by these resulting stream classifications. The stream classification system is used in urban streams as well as rural and forested stream environments. In 2005 and 2006, we conducted a comprehensive survey of Seattle's streams to determine the presence, abundance, and diversity of fish. The survey consisted of two major parts: a survey of all streams to determine the overall distribution of each fish species (single-pass electrofishing), and surveys of long-term reference sites (multiple-pass electrofishing) to estimate fish abundance. The first fish distribution surveys were conducted from June to October 2005. Additional surveys were conducted in February 2006 to determine if fish distributions changed according to season. Reference site surveys were conducted in the winter and fall in 2005 and during the summer in 2006. Surveys were conducted in the five major watersheds. Fish communities in the reference sites were sampled for abundance, biomass, and diversity.

Seattle Public Utilities has identified 49 urban watersheds within the Seattle City limits (Figure 1). Of the 49 watersheds, five (Piper's Creek, Thornton Creek, Longfellow Creek, Fauntleroy Creek, and Taylor Creek) are considered major watersheds based on the size of the watershed and amount of available stream habitat. In 1999, Wild Fish Conservancy (Washington Trout 2000) conducted an initial stream typing and fish barrier survey of these five creeks and other streams. However, surveys were only conducted during the summer period and most of the small creeks were not surveyed. In addition, some fishes, such as sculpins (Table 1), were not identified to species and the distribution of some species may not have been underestimated. Prior to the Washington Trout (2000) survey, most electrofishing surveys were conducted in either Thornton Creek or Piper's Creek. Results of surveys from Thornton Creek (Muto and Shefler 1983; Ludwa et al. 1997) indicated cutthroat trout were abundant and few other fish were present.

Surveys of Piper's Creek by Pfeifer (1984) and Thomas (1992) found cutthroat trout, sculpin, and juvenile coho salmon were common in the lower reach (river kilometer [Rkm] 0-0.65), but only cutthroat trout were present in the upper reach (Rkm 6.5-1.75). In addition to fish surveys, the city has collected a wide variety of other information on their major streams. This includes: culvert assessments, habitat assessments, channel condition assessments, riparian assessments, streamflow monitoring, salmonid spawning surveys, smolt trapping, and benthic invertebrate sampling (City of Seattle 2007). Most of the monitoring and research efforts on Seattle's streams have been focused on the larger streams of the five major watersheds. Streams in the smaller watersheds and smaller tributaries of the five watersheds have received little attention. One important objective of this study was to provide the City of Seattle with habitat and fish distribution on all streams, not just the large streams of the five major watersheds.

The native ichthyofauna of Pacific Northwest streams consists largely of members of the families Salmonidae (salmon, trout, charr, and whitefish) and Cottidae (sculpins). Information on the distribution and habitat requirements of salmonids has been studied extensively. In contrast, the distribution and habitat requirements of cottids are not well known (Tabor et al. 2007a). Because cottids are not economically important and they can be difficult to identify, researchers usually collect minimal information on these fish. As part of our assessment, we were interested in collecting detailed information of cottid distribution. Because they are more commonly present near the stream's mouth, we conducted supplemental surveys at these areas to accurately determine the distribution of each cottid species and identify potential barriers that may limit their upstream movement.

The streams of Seattle lie within a heavily urbanized area. Of the five major watershed, the percent of impervious surfaces ranges from 38% in the Fauntleroy Creek watershed to 59% for the Thornton Creek watershed (City of Seattle 2007). Effects of urbanization to the health of the stream ecosystem include: increased peak streamflow, reduced substrate size, reduction in large woody debris, reduction in the pool depth, increased water temperatures, increased levels of chemical contaminants, reduction in benthic invertebrate diversity and abundance, and changes in fish assemblage including introductions of exotic species (Karr 1998). Changes to the fish assemblage often include an increase in the proportion of cutthroat trout and reduction in abundance of other salmonids and sculpin (Serl 1999).

The overall objectives of this study included:

1. Assess habitat quality to previously unsurveyed smaller streams to better inform the City's future management decisions – Chapter 1.

2. Classify Seattle's urban streams and stream reaches according to the current Washington State stream classification system – Chapter 2.

3. Determine the presence/absence, distribution, species composition, and relative abundance of fish (salmonids and non-salmonids) in all City of Seattle streams – Chapter 2.

4. Quantify fish abundance and biomass and collect habitat information at reference sites (including potential restoration sites in Thornton Creek) in the five major watersheds – Chapter 3.

5. Use a fish index of biotic integrity (FIBI) to assess ecosystem health – Chapter 4.

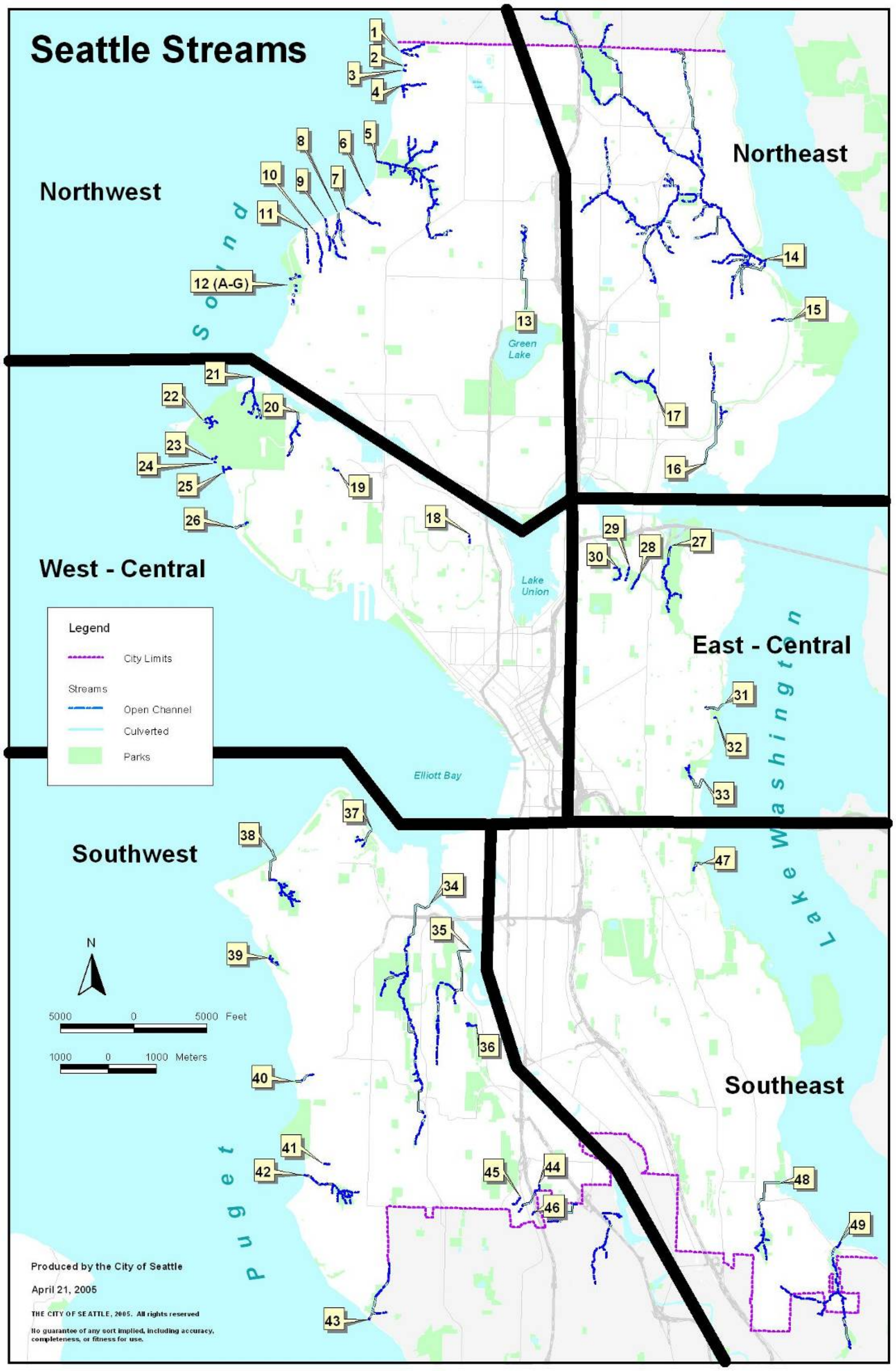

Figure 1 - Map of the City of Seattle displaying the 49 stream systems within the city limits (purple lines).

Table 1 - Scientific and common names of native and nonnative fishes of Seattle's streams and ponds mentioned in this report.

Family Genus and species	**Common Name**	**Native/Nonnative**
Petromyzontidae	Lamprey (Unknown species)	Native
Salmonidae		
Oncorhynchus tshawytscha	Chinook salmon	Native
Oncorhynchus kisutch	Coho salmon	Native
Oncorhynchus clarkii	Cutthroat trout	Native
Oncorhynchus mykiss	Rainbow trout	Native
Cyprinidae		
Carassius auratus	Goldfish	Nonnative
Cyprinus carpio	Common carp (Koi)	Nonnative
Mylocheilus caurinus	Peamouth	Native
Cobitidae		
Misgurnus anguillicaudatus	Oriental weatherfish	Nonnative
Ictaluridae		
Ameriurus nebulosus	Brown bullhead	Nonnative
Gasterosteidae		
Gasterosteus aculeatus	Threespine stickleback	Native
Centrarchidae		
Micropterus salmonides	Largemouth bass	Nonnative
Micropterus dolomieui	Smallmouth bass	Nonnative
Ambloplites rupestris	Rock bass	Nonnative
Lepomis gibbosus	Pumpkinseed	Nonnative
Cottidae		
Cottus aleuticus	Coastrange sculpin	Native
Cottus asper	Prickly sculpin	Native
Clinocottus acuticeps	Sharpnose sculpin	Native
Leptocottus armatus	Pacific staghorn sculpin	Native
Ammodytidae		
Ammodytes hexapterus	Pacific sand lance	Native

CHAPTER 1. STREAM PHYSICAL HABITAT SURVEYS

Introduction and Method*s*

Past habitat surveys of Seattle's streams have focused on the large streams of the five major watersheds. Little attention has been given to smaller streams. Information on these other streams will allow managers to make informed decisions on land-use management and potential restoration projects. As part of our fish distribution surveys, we collected stream habitat information at all the sites we surveyed, which included both small streams and large streams of the five major watersheds.

Stream habitat surveys were conducted on most streams during the fish distribution surveys (see Chapter 2). We attempted to survey all streams of the 49 watersheds; however, lack of access, private property issues, or general inaccessibility prevented us from surveying a few of the smaller streams. Streams that were accessible were first surveyed for fish use and then physical habitat. For convenience, the 49 watersheds were grouped into six geographical areas (Figure 1). Stream names and sample locations were based on SPU GIS maps, which divide each stream into 100 feet intervals from a confluence or stream mouth. Sample locations were also converted to meters. At each site, we divided the stream into habitat units, generally following the procedures of Pleus et al. (1999), except we classified some habitat units as glides, which were shallow habitats with low water velocities (no turbulence). All stream habitat data measurements were measured to the nearest tenth of a meter using a hand held stadia rod or a laser rangefinder. Habitat data collected were as follows:

<u>Length</u>- The length of each site was measured along the thalweg from the downstream end to the upstream end of the site. Any habitat units within the site were also measured in this manner.

<u>Wetted width</u>- The wetted width was measured at three equidistance locations along the measured length of each habitat unit. Working upstream, a measurement was taken at ¼ distance from the downstream end, at ½ of the length of the site, and at ¾ the length of the site. These were then averaged to obtain an average wetted width.

<u>Depth</u>- An average and maximum depth was recorded at each habitat and each site. The average depth was measured by randomly placing the hand held stadia rod at different locations within the habitat and averaging these values. The maximum depth of the habitat was collected by simply using the stadia rod to find the deepest part of the habitat. If the habitat unit was a

pool, the depth was measured at the deepest part and at deepest part of the tailout (pool outlet). By subtracting the tailout depth from the maximum pool depth, we calculated a residual pool depth. If more than one habitat type was in a single site, the maximum depth, or the deepest habitat of all the habitats was used as the maximum depth for the entire site. The average depth of a site containing multiple habitats was obtained by averaging the average depths of all the habitats.

Substrate- Substrate values were collected by visually identifying the types of substrates and then estimating the percent for each within each habitat type. Substrate values were recorded as: sand/silt, gravel, cobble, boulders, or rip rap.

Discharge or streamflow- If possible, streamflow (measured in cubic feet per second, cfs) was measured at the mouth of each stream. For medium- and large-sized streams we generally followed the procedures of Pleus (1999). We placed a metric tape across the mouth of the stream and divided the stream width into 12-20 cells. In the middle of each cell, the water depth and average water velocity was measured. Average water velocity was measured at 60% of the total depth from the surface with a Marsh -McBirney® model-2000 portable flowmeter. Stream discharge could then be calculated by the equation;

$$Q = \sum A_i V_i \; ;$$

where Q is discharge or streamflow; A_i is the cross sectional area [width x depth] for cell i; and V_i is the average velocity of cell i.

If the stream had little streamflow and was too shallow for the flowmeter to work, we often used a volumetric measurement method (Rantz et al. 1982) to collect the streamflow data. We tried to find a location were the stream dropped over a short waterfall (i.e., outflow of a perched culvert) and the entire flow could be captured in a bucket. At some sites, we created a small dam in the stream using sandbags and placed a 10-cm-diameter pipe on the top of the dam for the water to flow through. A bucket was quickly placed below the pipe or waterfall and was allowed to fill. After the bucket was close to being full, it was removed quickly and the amount of water in the bucket was measured. A stopwatch was used to time the duration water was flowing into the bucket. This was done at least three times to get an average streamflow.

Temperature and conductivity- We also recorded the temperature (°C), and the conductivity (μS, micro-Siemens) by the use of a Hanna® portable waterproof multi-range conductivity /TDS meter model HI 9635. Conductivity measurements were taken to provide information for adjusting the settings of the backpack electrofishing unit.

Results

Stream habitat surveys were conducted on 37 out of the 49 stream basins. Streams #'s 2, 3, 6, 7, 11, 16, and 23-25 were not surveyed because they were inaccessible, and Streams #'s 36, 41 and 43 were not surveyed because these streams were completely dry. Of the 37 streams surveyed, we collected habitat data on a total of 149 fish distribution sites. Due to the City's already extensive habitat data on the mainstems of Piper's, Thornton, Longfellow, Fauntleroy, and Taylor Creeks, habitat data presented is focused mainly on the smaller streams throughout the city and the lesser known tributaries of the five major creeks.

Northwest region.-- The northwest region contains approximately 12 streams (streams system #'s 1–13) from the city's northern border with the City of Shoreline, south to and including Golden Gardens Park, and east to Licton Springs Park (Figure 1). The largest stream in this region is Piper's Creek, which includes Mohlendorph Creek and Venema Creek and several smaller tributaries. Habitat data was collected on 3 sites on stream system #1, one of which was a 0.093 ha man-made pond (Table 1.1). Substrate in the pond was 100% sand/silt. Upstream of the pond, the stream was small, shallow, and had mostly sand/silt substrate. Downstream of the pond we surveyed a 75-m long site which was heavily landscaped and flowed through several sections with culverts. This section was high gradient with two vertical drops, one of 1.5 m and another of 7 m. The substrate in this section appeared to be all cobble.

Table 1. 1 - Size and maximum depth of ponds sampled in Seattle, 2005-2006. Appendix number is the map which displays the location of each site. For irregular shaped ponds, more than one width is given.

Region stream system #	Pond name	Appendix	Area (ha)	Length (m)	Widths (m)	Maximum depth (m)
Northwest region						
1	Unnamed PS01 Pond	1.1	0.093	27.4	34.1	4.0
Northeast region						
14	Matthews Creek Pond	1.8	0.035	22	16	1.5
14	Littles Creek Pond	1.13	0.000	192.5	25	--
14	Jackson Park Golf Course Pond A	1.13	0.000	107	55	2.1
14	Jackson Park Golf Course Pond B	1.13	0.000	113	49	2.7
14	Jackson Park Golf Course Pond C	1.13	0.000	175	19,50	--
14	Thornton-South Branch - Unnamed trib at Rm 4,230 - pond	1.16	0.024	24	10	1.0
14	South Branch Thornton -NSCC Pond	1.16	0.000	196	31	--
West-central region						
21	Scheuerman Creek Pond	1.20	0.030	24.5	12.3	1.3
21	Scheuerman Cr. - unnamed trib A - Pond A	1.20	0.035	22	16.1	1.5
21	Scheuerman Cr. - unnamed trib A - Pond B	1.20	0.033	25.4	12.9	1.0
21	Scheuerman Cr. - unnamed trib A - Pond C	1.20	0.021	21	10	2.0
22	Sewer Plant Beach Pond	1.20	0.000	220	8,21,11	1.5
22	Unnamed Trading Post Pond	1.20	0.074	30.6	24.2	0.75
East-central region						
27	Washington Park Creek - Japanese Gardens Pond	1.21	0.000	95	13,25,25	1.5
27	Washington Park Creek - Unnamed trib A Pond	1.21	0.070	26	27	1.2
Southeast region						
48	Mapes Creek - Kabota Gardens Pond A	1.29	0.012	15	8	--
48	Mapes Creek - Kabota Gardens Pond B	1.29	0.040	50	8	--
48	Mapes Creek - Kabota Gardens Pond C	1.29	0.014	17	8	--

Habitat data was collected from a 3.1-m long section of stream system #4 that ran along a private drive near the stream mouth. The average depth at this site was 0.01 m with a maximum depth of 0.02 m. Substrate was 15 % sand/silt and 85 % gravel.

On Piper's Creek (stream system #5), we collected habitat data from four sites from three small unnamed tributaries. On the mainstem of Piper's Creek, we surveyed a combined total length of 510 m, with an average width of 2.6 m, an average depth of 0.1 m and an average maximum depth of 0.3 m, with the deepest recorded depth of 0.75 m (Table 1.2). Riffles were the dominant habitat type comprising 50%, along with glides 24 %, and pools 26 %. Substrate in Piper's Creek was composed mostly of fines and gravel (Table 1.3). Several smaller tributaries of Piper's Creek were also surveyed. The tributaries adjacent to the treatment plant and immediately downstream were just small springs emanating from the hillside (Figure 1.1) and had no fish habitat. Upstream of the treatment plant, we surveyed three small tributaries, each of which had a high percentage of gravel and cobble (Table 1.3).

Or the most part, Mohlendorph Creek was dry during the summer 2005 survey and was resurveyed in the winter of 2006. A 12.1 m long section starting at the mouth of Mohlendorph Creek was surveyed which had an average width of 1.6 m, an average depth of 0.09 m with a max depth of 0.25 m, which was taken from the pool at the confluence with Venema Creek (Figure 1.2). Substrate in Mohlendorph Creek, upstream of the weir, was primarily composed of gravel with some sand and cobble. Venema Creek was surveyed 600 m upstream from the confluence with Piper's Creek. At this site we sampled a 50 m section comprised of two riffles and one pool, which was the deepest part of this site. Substrate was composed mostly of sand with some gravel (Table 1.3).

Table 1. 2 - Stream habitat data for streams surveyed in the northwest region, October 2005. Locations of sample sites are displayed in Appendices 1.1-1.7. Max = maximum. Percent riffles and pools/glides are the percent of the total stream area.

Stream system #	Sample #	Stream Name	Date Surveyed	Distance from mouth (m)	Distance from mouth (ft)	Mean wetted width (m)	Mean depth (m)	Max depth (m)	% riffles	% pools/glides
1	3	Unnamed PS01 - North Fork	4-Oct	155-201	510-661	1.15	0.05	0.11	100.0	0.0
4	4	Broadview Cr - North Fork	4-Oct	235-238	770-780	0.36	0.01	0.02	100.0	0.0
5	25	Piper's Creek	6-Oct	0-29	0-95	3.20	0.15	0.4	0.0	100.0
5	6	Piper's Creek	6-Oct	29-61	95-200	2.50	0.07	0.2	23.1	76.9
5	7	Piper's Creek	6-Oct	247-297	810-974	3.05	0.11	0.75	55.2	44.8
5	8	Piper's Creek	6-Oct	550-600	1,804-1,968	3.89	0.21	0.75	73.8	26.2
5	18	Venema Creek	20-Oct	595-645	1,950-2,114	1.07	0.07	0.4	92.2	7.8
5	21	Unnamed trib H	11-Oct	0-50	0-164	1.13	0.08	0.22	70.3	29.7
5	22	Unnamed trib H	11-Oct	250-300	820-984	1.32	0.10	0.4	37.1	62.9
5	10	Piper's Creek	6-Oct	1,284-1,337	4,210-4,384	2.65	0.18	0.54	45.9	54.1
5	23	Unnamed trib K	11-Oct	0-54	0-177	1.00	0.05	0.14	100.0	0.0
5	11	Piper's Creek	11-Oct	1,570-1,620	5,150-5,314	2.61	0.14	0.26	73.8	26.2
5	12	Piper's Creek	11-Oct	1,716-1,766	5,630-5,794	1.60	0.08	0.24	47.5	52.5
5	24	Unnamed trib M	11-Oct	0-7.5	0-25	0.50	0.04	0.06	100.0	0.0
5	13	Piper's Creek	11-Oct	2,043-2,074	6,700-6,802	0.80	0.02	0.1	0.0	100.0
8	33	Unnamed PS06 - West Fork	25-Oct	884-894	2,900-2,933	1.00	0.03	0.1	100.0	0.0
8	30	Unnamed PS06 - East Fork	25-Oct	61-81	200-266	0.50	0.05	0.19	100.0	0.0
12	42	Unnamed PS14	14-Oct	-61-0	-200-0	1.25	0.02	0.05	100.0	0.0
13	45	Licton Springs Creek	25-Oct	1,600-1,622	5,249-5,322	2.23	0.11	1.1	10.4	89.6

Table 1. 3 - Total combined substrate scores for streams in the northwest region.

Stream system #	Stream name	# of sites	Substrate score (%) Silt/Sand	Gravel	Cobble	Boulders	Rip rap
1	Unnamed PS01	3	58	2	40		
4	Broadview Creek	1	15	85			
5	Piper's Creek	9	42	39	8	11	
5	Venema Creek	1	60	23	15	2	
5	Mohlendorph Creek	1	15	70	15		
5	Unnamed trib H	2	26	39	26	3	6
5	Unnamed trib K	1	50	50			
5	Unnamed trib M	1	5	60	35		
8	Unnamed PS06 - West Fork	2	80	20			
9	Unnamed PS07	1	50	50			
10	Unnamed PS08	1	100				
12	Unnamed PS11	2	50				50
12	Unnamed PS14	1	100				
13	Licton Springs Creek	2	87	12			1

Figure 1. 1 - Photo taken of Piper's Creek - unnamed trib F close to its mouth on Piper's Creek, October 2005.

Figure 1. 2 - Photo looking upstream at the weir pool at the mouth of Mohlendorph Creek, sample location 310, February 7, 2006. This was the deepest spot recorded on Mohlendorph Creek. Two cutthroat trout were captured at this location. The stream flows from the upper-center of the photo, through the weir, and into the pool at the bottom of the photo. This location was dry during the summer sampling of 2005.

Stream system #’s 8-10 were generally shallow (< 0.1 m average depth) and were dominated primarily by fine sediment (Table 1.3; Figure 1.3). Stream systems #’s 8-10 also had large amounts of introduced plant species throughout their basins. Stream system #12 (A-G) also had high amounts of fine sediment and was overall very shallow (Table 1.3). Habitat surveys of Licton Spring Creek, (stream system #13), was taken at two sites within Licton Springs Park. The site located at Rm 1,600 (5,249 ft) was 22.5 m long with an average width of 2.4 m, an average depth of 0.3 m with a max depth of 1.1 m, which was recorded at culvert at the south end of the park (Figure 1.4). We also surveyed upstream of this point at Rm 1,808 (5,930 ft) in a much deeper (maximum depth, 0.9 m) and wider (wetted width, 2.0 m) section.

Figure 1. 3 - Photos of stream system # 8, October 25, 2005. The left photo was taken of Unnamed PS06 –West Fork in Homewood Park (sample location 33; Rm 884 [2,900 ft]) showing the overall shallow depth of the stream at this site and dominant fine substrate. The right photo is of the Unnamed PS06 –East Fork (sample location 30; Rm 61 [200 ft]). The stream at this point is down cut more than 0.5 m.

Figure 1. 4 - Photo taken of the culvert that Licton Springs Creek flows into at the south end of Licton Springs Park, October 25, 2005 (Rm 1,595 [5,230 ft]). Note there are two branches flowing into the culvert. At the time of our survey, water was only flowing in from the top branch in the photo.

Northeast region.-- The northeast region consists primarily of the streams in the Thornton Creek drainage (stream system #14). In this drainage, we surveyed five sites on the mainstem, five sites on the North Branch, and six sites on the South Branch. Within the Thornton Creek watershed we were able to survey 35 sites on 18 separate tributaries.

The mainstem of Thornton Creek (Rm 0-2,237 [0-7,336 ft]) is a low gradient reach with primarily sand or gravel substrate (Table 1.4). In some locations, the banks were armored with rip rap and the boulders of the rip rap were an important component of the overall substrate composition. The mainstem has a good mixture of riffles and large, deep pools (Table 1.5).

Close to the mouth of Thornton Creek, there are several small tributaries that converge and enter the main stem of Thornton Creek downstream of Sand Point Way. Habitat in this area has largely been influenced by human development and many of these small tributaries flow through several culverts before entering Thornton Creek. Matthews Creek, the lowest downstream tributary of Thornton Creek, flows approximately 120 m from a culvert and through a pond before it enters Thornton Creek. We surveyed the pond close to the mouth of Matthews Creek which was 16-m long by 22-m wide and 1.5 m at its deepest point. Upstream of the pond we surveyed a small pool and glide at Rm 120 [394 ft](Figure 1.5). The pool was 6.1-m long by 7.5-m wide with a maximum depth of 0.5 m. The glide was 7.2-m long by 1.2-m wide with a maximum depth of 0.32 m and surrounded on both sides by rip rap. Substrate was composed of 80% fines, 10% gravel, and 10% rip rap for both habitats. Further upstream, where Matthews Creek enters the culvert, at the Sand Point Country Club Golf Course, the stream was dry.

On Thornton Creek about 300 m upstream from the mouth at Lake Washington is the confluence of Maple Creek. We surveyed two sites on the mainstem of Maple Creek, one at the mouth and a second 400 m upstream from the mouth on the upstream of the culvert that is under 45th Ave NE. At the mouth of Maple Creek, there is a small cascade of about 0.75 m in height. Upstream of this point the creek flows from a culvert under Sand Point Way NE and forms a small pool/glide that is approximately 2 m wide and 5 m long and dominated by fine substrate (Figure 1.6). Maple Creek then becomes a small (<

1.0 m wetted width), shallow (0.1 m, maximum depth) riffle and flows through private property before entering Thornton Creek. At the upper site, we sampled a 50-m long riffle upstream of the culvert under 45th Ave NE that was 1.0-m wide with a maximum depth of 0.13 m. Substrate composition was 50% sand and 50% gravel. A culvert at the downstream end was perched 1.2 m above the creek.

Table 1. 4 - Total combined substrate scores for streams in the northeast region.

Stream system #	Stream name	# of sites	Substrate score (%)				
			Silt/Sand	Gravel	Cobble	Boulders	Rip rap
14	Thornton Creek -mainstem	5	66	22	1		12
14	Matthews Creek	2	87	6			7
14	Unnamed trib C	1	100				
14	Maple Creek	3	50	50			
14	Unnamed trib A	2	93	7			
14	Unnamed trib B	1	40	60			
14	Mock Creek	2	73	27			
14	North Branch Thornton Creek	5	15	63	17		6
14	Littlebrook Creek	5	9	45	46		
14	Littles Creek	1	25	50	25		
14	South Branch Thornton Creek	6	25	24	49	1	1
14	Meadowbrook Creek	2	100				
14	Kramer Creek	1	92	5	1	2	
14	Unnamed trib C	1	80	20			
14	Willow Creek	5	39	27	16	10	8
14	East Fork Willow Creek	2	20	40	40		
14	Victory Creek	1	10	10			80
15	Inverness Creek	1	95	5			
17	Ravenna Creek	2	85	15			

Table 1. 5 - Stream habitat data for streams surveyed in the northeast region, August-October 2005. Locations of sample sites are displayed in Appendices 1.8-1.18. Max = maximum. Percent riffles and pools/glides are the percent of the total stream area.

Stream system #	Sample #	Stream Name	Date surveyed	Distance from mouth (m)	Distance from mouth (ft)	Mean wetted width (m)	Mean depth (m)	Max depth (m)	% riffles	% pools/glides
14	50	Thornton Creek - mainstem	22-Aug	30-80	98-262	3.00	0.60	1.20	0.0	100.0
14	70	Unnamed trib C	29-Aug	0-30	0-98	0.40	0.02	0.04	100.0	0.0
14	72	Maple Creek	29-Aug	418-468	1,370-1,534	1.10	0.08	0.13	100.0	0.0
14	71	Unnamed trib A	29-Aug	302-352	990-1,154	0.80	0.05	0.06	100.0	0.0
14	73	Unnamed trib A	29-Aug	671-721	2,200-2,364	0.63	0.05	0.10	100.0	0.0
14	74	Unnamed trib B	29-Aug	271-321	890-1,054	0.70	0.07	0.20	100.0	0.0
14	52	Thornton Creek - mainstem	31-Aug	326-426	1,070-1,398	5.17	0.16	0.68	15.9	84.1
14	53	Thornton Creek - mainstem	30-Aug	509-609	1,670-1,998	4.24	0.20	0.60	26.9	73.1
14	54	Thornton Creek - mainstem	12-Sep	1,159-1,209	3,800-3,964	3.30	0.33	0.80	80.8	19.2
14	76	Mock Creek	15-Sep	0-20	0-66	0.70	0.03	0.13	100.0	0.0
14	77	Mock Creek	15-Sep	305-335	1,000-1,098	0.50	0.03	0.07	100.0	0.0
14	56	North Branch Thornton	12-Sep	680-731	2,230-2,397	2.50	0.16	0.65	58.2	41.8
14	78	Littlebrook Creek	8-Sep	0-50	0-164	1.00	0.20	0.45	0.0	100.0
14	79	Littlebrook Creek	8-Sep	381-431	1,250-1,414	2.00	0.20	0.73	0.0	100.0
14	81	Littlebrook Creek	23-Sep	2,345-2,370	7,690-7,772	0.50	0.02	0.05	100.0	0.0
14	82	Littlebrook Creek	23-Sep	2,697-2,737	8,846-8,977	0.50	0.02	0.06	100.0	0.0
14	83	Littles Creek	5-Oct	1,043-1,090	3,420-3,574	--	0.02	0.26	93.6	6.4
14	57	North Branch Thornton	17-Sep	1,424-1,474	4,670-4,834	2.62	0.13	0.45	68.7	31.3
14	58	North Branch Thornton	19-Sep	2,061-2,124	6,760-6,967	3.25	0.19	0.65	66.2	33.8
14	59	North Branch Thornton	7-Sep	2,851-2,901	9,350-9,514	2.32	0.13	0.40	72.4	27.6
14	60	North Branch Thornton	7-Sep	3,537-3,557	11,600-11,666	2.50	0.10	0.20	100.0	0.0
14	61	North Branch Thornton	7-Sep	4,177-4,227	13,700-13,864	2.28	0.14	0.36	0.0	100.0
14	62	South Branch Thornton	27-Sep	0-45	0-148	0.28	0.16	0.42	100.0	0.0
14	86	Meadowbrook Creek	20-Sep	0-56	0-184	0.90	0.10	0.20	0.0	100.0
14	88	Meadowbrook Creek	20-Sep	372-522	1,220-1,712	4.00	0.70	1.50	0.0	100.0
14	89	Unnamed trib C	27-Sep	0-6.8	0-22	0.14	0.02	0.04	100.0	0.0
14	90	Willow Creek	20-Sep	0-50.5	0-166	1.48	0.12	0.40	34.4	65.6
14	91	Willow Creek	27-Sep	195-210	820-869	1.00	0.05	0.60	100.0	0.0
14	95	Unnamed trib E	21-Sep	0-32	0-105	1.05	0.14	0.46	58.3	41.7
14	96	Unnamed trib E	21-Sep	335-371	1,099-1,215	0.59	0.06	0.20	75.4	24.6
14	92	Willow Creek	21-Sep	299-337	980-1,105	1.17	0.09	0.29	52.8	47.2
14	93	Willow Creek	21-Sep	881-933	2,890-3,061	1.05	0.13	0.28	22.5	77.5
14	94	Willow Creek	21-Sep	1,503-1,521	4,930-4,989	0.90	0.08	0.14	0.0	100.0
14	64	South Branch Thornton	21-Sep	1,276-1,336	4,185-4,382	2.92	0.27	0.90	55.5	44.5
14	65	South Branch Thornton	22-Sep	2,195-2,242	7,200-7,354	2.73	0.13	0.48	18.5	81.5
14	97	Victory Creek	27-Sep	215-248	705-813	0.40	0.02	0.20	81.3	18.8
14	66	South Branch Thornton	22-Sep	3,061-3,108	10,040-10,194	3.22	0.20	0.42	21.0	79.0
14	67	South Branch Thornton	22-Sep	3,598-3,655	11,800-11,987	1.93	0.27	0.63	3.4	96.6
14	199	South Branch Thornton	1-Sep	4,649-4,669	15,250-15,316	2.20	0.35	0.60	0.0	100.0
15	100	Iverness Creek	28-Sep	229-264	750-865	0.40	0.03	0.08	100.0	0.0
17	105	Ravenna Park Creek	4-Oct	152-202	500-664	1.50	0.10	0.20	100.0	0.0
17	106	Ravenna Park Creek	5-Oct	534-584	1,750-1,914	1.50	0.08	0.16	100.0	0.0

Figure 1. 5 - Photo of a small pool on Matthews Creek (looking downstream), sample location 316, Rm 112-127 (366-415 ft), February 8, 2006. At the bottom left of the photo, the stream emerges from a long culvert.

Figure 1. 6 - Photo taken of Maple Creek (Rm 76 [250 ft]) looking upstream to where it flows under Sand Point Way NE, August 29, 2005.

Habitat conditions in North Branch of Thornton Creek appear to be good in most areas. Some areas are armored with rip rap. Several large, deep pools were usually present in each study section. The North Branch of Thornton Creek has two main tributaries, Littlebrook Creek and Littles Creek. The lower 1,000 m of Littlebrook Creek is daylighted, of which the lower 400 m appears to have available fish habitat. Upstream the stream is shallow with few pools (Table 1.5). The lower 500 m of Littles Creek is in culvert. The upstream daylighted reach appears to consist primarily of riffles and is relatively shallow (Table 1.5). Within Jackson Park Golf Course there are four large ponds, three adjacent to the North Branch of Thornton Creek and one on Little Creek. The average depth each pond is about 1.6 m and maximum depth is at least 2 m deep for each pond.

The South Branch of Thornton Creek is mostly daylighted from its mouth to 5th Avenue (Rm 3,807). Upstream of this the stream appears to be in a culvert until a small pond next to a Park and Ride just east of I-5, near 1st Ave and 100th St (Figure 1.7). Also there is a large pond and a small low-gradient stream on the west side of I-5 near North Seattle Community College (NSCC) that may be the headwaters of the South Branch of Thornton Creek (Appendix 1.16). The exact connection between the NSCC pond and the Park and Ride pond is unclear. Similar to the North Branch, habitat conditions in South Branch of Thornton Creek (downstream of 5th Avenue) appear to be good in most areas (Figure 1.8). Several large, deep pools were usually present in each study section. Also, LWD was present in some areas.

The other streams in the northeast region consist of Inverness Creek, Yesler Creek, and Ravenna Creek. We were unable to survey Yesler Creek, which was inaccessible. Only the upper reaches of Ravenna Creek are daylighted. The stream drains to Lake Washington through University Slough in Union Bay. We sampled two sites in Ravenna Creek; both had only riffle habitat (Table 1.5). The maximum depth was only 0.2 m and the substrate at both sites consisted of 85% sand/silt and 15% gravel (Table 1.4). Inverness Creek was substantially smaller than Ravenna Creek, it had a wetted width of 0.4 m and a maximum depth of only 0.08 m (Table 1.5).

Figure 1. 7 - Photo of small pond (sample location 98; Rm 171-191 [56-626 ft]) on an unnamed trib at Rm 4,230 to the South Branch of Thornton Creek. This site is next to the Park and Ride just east of I-5, near 1st Ave and 103rd St.

Figure 1. 8 - Photo of Steve Damm, USFWS taking habitat measurements on the South Branch of Thornton Creek, sample location 64, Rm 1,300 (4,262 ft), September 21, 2005.

West-central region.— All streams in the west-central region are relatively small and shallow with low streamflows and little pool habitat (Tables 1.6 and 1.7; Figures 1.9 and 1.10). Substrate was predominantly sand in each stream (Table 1.8). None of the creeks appear to be passable to fish moving upstream from Puget Sound or the Lake Washington Ship Canal. The mouth of Scheuerman Creek has a perched culvert (Figure 1.9) and Wolfe Creek goes through a long culvert before draining into Salmon Bay (Figure 1.10). In addition to stream habitat, there are a few ponds in the region (especially in the Scheuerman Creek system) that are capable of supporting fish populations.

Table 1. 6 - Stream habitat data for streams surveyed in the west-central region, August-September 2005. Locations of sample sites are displayed in Appendices 1.19 and 1.20. Max = maximum. Percent riffles and pools/glides are the percent of the total stream area.

Stream system #	Sample #	Stream Name	Date Surveyed	Distance from mouth (m)	Distance from mouth (ft)	Mean wetted width (m)	Mean depth (m)	Max depth (m)	% riffles	% pools/glides
18	110	Mahteen Creek	19-Aug	46-86	150-281	0.40	0.05	0.10	100	0
19	111	Lawton Creek	17-Aug	46-96	150-314	0.30	0.02	0.05	100	0
20	112	Wolfe Creek	19-Aug	159-209	520-684	0.76	0.10	0.20	100	0
21	114	Scheuerman Creek	25-Aug	24-74	80-244	1.14	0.08	0.17	85.7	14.3
21	116	Scheuerman Creek	19-Aug	280-325	919-1,066	0.39	0.05	0.10	100	0
21	117	Scheuerman Creek	19-Aug	451-481	1,480-1,578	0.60	0.02	0.50	0	100
21	118	Unnamed trib A	19-Aug	0-50	0-164	0.45	0.05	0.06	100	0
22	122	Owl's Creek	29-Sep	0-12	0-39	0.80	0.04	0.14	100	0
26	126	Unnamed PS21	25-Aug	242-262	795-861	0.55	0.05	0.09	80	20

Table 1. 7 - Streamflow, water temperature, and conductivity measurements at various sites in Seattle streams, July-October 2005. Method is the methodology used to measure streamflow; either using a flowmeter method (F) or a volumetric measurement method (V); $F_{<10}$ indicates we were not able to take 10 measurements and thus the streamflow estimate may be inaccurate. Measurements were usually taken sometime between 900 and 1500 h. Conductivity measurements were taken to provide information for adjusting the settings of the backpack electrofishing unit.

Stream system #	Stream name	Distance from mouth (m)	(ft)	Method	Streamflow (cfs)	Temperature (°C)	Conductivity (µS)
1	Unnamed PS01	10	33	$F_{<10}$	0.041	10.4	309
4	Broadview Creek	235	770	$F_{<10}$	0.011	11.5	259.9
5	Piper's Creek	87	285	F	1.108	12.9	262
10	Unnamed PS08	116	380	$F_{<10}$	0.026	12	283.1
12	Unnamed PS11	24	80	$F_{<10}$	0.063	12.4	297.2
12	Unnamed PS14	-61	-200	$F_{<10}$	0.026	12.5	230.2
14	South Branch Thornton Creek	0	0	F	1.640	12.7	250.8
14	Unnamed trib C	0	0	$F_{<10}$	0.029	12.9	253
14	Willow Creek	0	0	F	0.440	14	255.1
14	Unnamed trib E	0	0	$F_{<10}$	0.028	12	232.9
14	Victory Creek	215	705	$F_{<10}$	0.113	15.2	168.4
15	Inverness Creek	229	750	$F_{<10}$	0.041	13.3	290.1
17	Ravenna Creek	152	500	F	0.729	11.2	270
18	Mahteen Creek	46	150	$F_{<10}$	0.095	--	--
19	Lawton Creek	46	150	$F_{<10}$	0.030	13.9	271.6
20	Wolfe Creek	159	520	$F_{<10}$	0.050	14.9	261.6
21	Scheuerman Creek	0	0	V	0.176	12.2	310
22	Owl's Creek	0	0	$F_{<10}$	0.025	12.8	293.7
26	Unnamed PS21	242	795	V	0.055	15	262.3
27	Washington Park Creek	110	164	V	0.026	15.6	156.7
29	Interlaken Creek - Middle Reach	0	0	V	0.0045	15.5	178.5
30	Interlaken Creek - West Reach	0	0	$F_{<10}$	0.018	13.4	214.5
31	Madrona Creek - Middle Reach	90	295	V	0.0031	--	--
32	Unnamed LW01	0	0	V	0.015	--	--
35	Puget Creek	1,195	3,920	V	0.0057	--	--
35	Unnamed trib B	7	23	V	0.0035	--	--
35	Unnamed trib A	14	46	V	0.0069	--	--
38	Schmitz Creek	726	2,380	F	0.269	14	264.8
38	Unnamed trib G	15	49	V	0.034	14	228.5
39	Mee-Kwa-Mooks Creek	0	0	V	0.061	13.4	336
39	Unnamed trib A	0	0	V	0.020		
40	Pelly Creek	128	420	V	0.0016	14.7	224.1
42	Fauntleroy Creek	0	0	F	0.650	14.3	255
44	Durham Creek	186	610	F	0.500	13.4	305
49	Taylor Creek	0	0	F	0.382	--	--
49	East Fork Taylor Creek	0	0	F	0.012	--	--
49	West Fork Taylor Creek	0	0	F	0.146	--	--

Table 1. 8 - Total combined substrate scores for streams in the west-central region.

Stream system #	Stream name	# of sites	Substrate score (%)				
			Silt/Sand	Gravel	Cobble	Boulders	Rip rap
18	Mahteen Creek	1	100				
19	Lawton Creek	1	100				
20	Wolfe Creek	2	100				
21	Scheuerman Creek	4	71	19	7	3	
21	Unnamed trib A	1	99	1			
22	Owl's Creek	2	85	15			
26	Unnamed PS21	1	95	5			

Figure 1. 9 - Photos of Wolfe Creek (stream system #20, sample location 112), August 19, 2005. The left photo was taken at the downstream end of the daylighted section where it enters into a culvert (Rm 159 [520 ft]). The right photo shows the overall shallow depth of this stream at this site and the predominantly sand substrate (Rm 169 [554 ft]).

Figure 1. 10 - Photos of Scheuerman Creek (stream system #21), August 25, 2005. The left photo was taken at the creek mouth where it exits a culvert and then drops sharply to Puget Sound. The right photo of Scheuerman Creek at Rm 55 (180 ft) was taken approximately 30 m upstream of the culvert and shows the overall shallow depth of this stream.

East-central region.— The largest stream in this region is Washington Park Creek. The stream has a perched culvert at Rm 110 (361 ft) which most likely restricts upstream movements of fish. The stream is approximately 1,650 m long and has some pool habitat (Table 1.9) and some riparian vegetation that could provide cover for fish; however the stream is relatively small with little streamflow (0.026 cfs) and predominantly sand/silt substrate (Table 1.10). At the upper end of this system there are two ponds, the koi pond in the Japanese Gardens and a small pond on Unnamed trib A. The streams in the Interlaken and Madrona Parks are quite small and shallow with steep gradients. Frink Creek had more streamflow but was still a small, shallow stream.

Table 1. 9 - Stream habitat data for streams surveyed in the east-central region, July-August 2005. Locations of sample sites are displayed in Appendices 1.21 and 1.22. Max = maximum; dashes indicate that no data was collected. Percent riffles and pools/glides are the percent of the total stream area.

Stream system #	Sample #	Stream Name	Date Surveyed	Distance from mouth (m)	Distance from mouth (ft)	Mean wetted width (m)	Mean depth (m)	Max depth (m)	% riffles	% pools/glides
18	130	Washington Park Creek	11-Aug	0-50	0-164	0.85	0.12	0.50	34.0	66.0
19	230	Washington Park Creek	11-Aug	50-110	164-360	0.85	0.14	0.47	64.7	35.3
20	131	Washington Park Creek	11-Aug	807-857	2,646-2,810	0.77	0.06	0.19	82.0	18.0
28	134	Interlaken Creek - East Reach	17-Aug	80-90	262-295	0.10	--	--	--	--
29	135	Interlaken Creek - Unnamed reach	19-Aug	0-20	0-66	0.15	0.01	0.01	100	0
29	136	Interlaken Creek - Middle Reach	19-Aug	0-50	0-164	0.10	0.01	0.50	100	0
30	137	Interlaken Creek - West Reach	19-Aug	0-30	0-98	0.50	0.03	0.08	100	0
31	138	Madrona Creek - Middle Reach	10-Aug	90-110	295-361	0.40	0.01	0.02	100	0
31	139	Unnamed LW01	10-Aug	0-10	0-33	0.45	0.05	0.15	100	0
33	140	Frink Cr	28-Jul	701-721	2,300-2,366	0.20	0.03	0.20	100	0

Table 1. 10 - Total combined substrate scores for streams in the east-central region.

Stream system #	Stream name	# of sites	Substrate score (%) Silt/Sand	Gravel	Cobble	Boulders	Rip rap
27	Washington Park Creek	4	85	6	9		
28	Interlaken Creek (East and Unnamed Reach)	2	100				
29	Interlaken Creek - Middle Reach	1	90				10
30	Interlaken Creek - West Reach	1	100				
31	Madrona Creek - Middle Reach	2	100				
32	Unnamed LW01	1	25			75	
33	Frink Creek	2	75	20	5		

Southwest region.— The largest stream in the southwest region is Longfellow Creek. We surveyed a total of 10 sites on the mainstem of Longfellow Creek. Habitat conditions appear to be generally good throughout the 5.7 km that we surveyed. Large, deep pools are common. Of the daylighted sections of Puget Creek, only the lower 60 m had any water during the summer. Upstream the streambed was dry. Most of the streamflow in Puget Creek is from Unnamed trib A (Figure 1.11; Table 1.7). The best fish habitat in the Puget Creek system is the lower 14 m of this tributary which includes a plunge pool at the base of a culvert (Figure 1.11). We did not assess habitat above the culvert but the gradient is steep and it's doubtful if there is any available habitat. Another small tributary to Puget Creek at Rm 1,207 (3,960 ft) also adds some streamflow.

Figure 1. 11 - Photo taken of the lower 13 m of Puget Creek - Unnamed trib A. The photo was taken on February 8, 2006. Most of the streamflow in Puget Creek comes from this tributary.

The lower section of Schmitz Creek is in a culvert, which is a complete barrier to upstream fish movements (SPU/WFC, unpublished fish passage data). Upstream of the culvert, the stream is located in forested park. The lower 700 m of the daylighted reach is about 1.5-m wide with only a few small, shallow pools (Table1.11) and little woody debris. The substrate is predominantly sand (Table 1.12). Overall, Schmitz Creek appears to have limited available fish habitat. Fauntleroy Creek is the second largest stream in the southwest region. Upstream of the lower culvert, several pieces of large woody debris have been added as part of a restoration effort. The amount of pool habitat decreases in upstream areas. The substrate is predominantly sand throughout the stream.

The furthest downstream section of Durham Creek (stream system #44) that is daylighted is located in the South Park Pea Patch. This stream section has a low gradient and has adequate pool habitat and cover due to large amounts of water cress *Nasturtium officinale*. Just upstream of this section is a steep culvert which may restrict upstream movements of fish. Upstream the stream is in a culvert under Highway 509. Between Myers Way S and Highway 509 there are three streams, it appears the middle stream is directly connected to Durham Creek. The downstream location of the north stream

(Unnamed DW02; stream system #45) is unclear. The south stream (Hamm Creek – North Fork, stream system #46) is part of the Hamm Creek system, which is primarily outside of the city limits. Although these three streams have adequate habitat and streamflow, they appear to be above impassable culverts.

Table 1. 11 - Stream habitat data for streams surveyed in the southwest region, July-October 2005. Locations of sample sites are displayed in Appendices 1.23-1.28. Max = maximum; dashes indicate that no data was collected. Percent riffles and pools/glides are the percent of the total stream area.

Stream system #	Sample #	Stream Name	Date Surveyed	Distance from mouth (m)	Distance from mouth (ft)	Mean wetted width (m)	Mean depth (m)	Max depth (m)	% riffles	% pools/glides
34	150	Longfellow Creek	1-Aug	1,006-1,086	3,300-3,562	2.36	0.17	0.70	31.0	69.0
34	146	Golf Course trib	1-Aug	0-27	0-89	0.30	0.10	0.20	0.0	100.0
34	147	Unnamed trib A	1-Aug	15-35	50-116	0.10	0.05	0.10	--	--
34	151	Longfellow Creek	1-Aug	1,951-2,001	6,400-6,564	3.00	0.50	1.00	0.0	100.0
34	152	Longfellow Creek	1-Aug	2,622-2,657	8,600-8,715	1.78	0.13	0.35	76.2	23.8
34	153	Longfellow Creek	2-Aug	3,009-3,079	9,870-10,100	2.13	0.15	0.30	63.8	36.2
34	154	Longfellow Creek	2-Aug	3,628-3,695	11,900-12,120	2.23	0.15	0.55	42.4	57.6
34	155	Longfellow Creek	2-Aug	4,238-4,288	13,900-14,064	4.00	0.25	0.65	0.0	100.0
34	156	Longfellow Creek	2-Aug	4,549-4,596	14,920-15,074	2.10	0.09	0.90	89.0	11.0
34	148	Unnamed trib B	2-Aug	0-10	0-33	0.10	0.02	0.05	--	--
34	149	Unnamed trib C	3-Aug	0-3	0-10	0.50	0.01	0.05	0.0	100.0
34	157	Longfellow Creek	3-Aug	5,555-5,603	18,220-18,377	1.67	0.12	0.85	67.5	32.5
34	158	Longfellow Creek	3-Aug	6,085-6,132	19,960-20,114	1.78	0.15	0.50	39.5	60.5
34	159	Longfellow Creek	4-Aug	6,311-6,358	20,700-20,854	1.51	0.14	0.45	51.1	48.9
35	160	Puget Creek	9-Aug	1,195-1,249	3,920-4,097	0.73	0.07	0.27	51.7	48.3
35	161	Unnamed trib A	9-Aug	0-6.5	0-21	0.30	0.05	0.10	100.0	0.0
35	162	Unnamed trib B	9-Aug	0-13.5	0-44	1.29	0.16	0.61	35.5	64.5
37	164	Fairmount Creek	28-Jul	277-282	910-926	0.10	0.04	0.20	100.0	0.0
38	165	Schmitz Creek	10-Aug	726-776	2,380-2,544	1.50	0.10	0.14	100.0	0.0
38	166	Schmitz Creek	10-Aug	1,018-1,068	3,340-3,504	1.50	0.10	0.27	80.0	20.0
38	167	Schmitz Creek	10-Aug	1,284-1,334	4,210-4,374	1.50	0.10	0.20	100.0	0.0
38	170	Unnamed trib G	10-Aug	0-15	0-49	0.40	0.03	0.06	100.0	0.0
38	168	Schmitz Creek	10-Sep	1,360-1,395	4,460-4,575	1.50	0.03	0.07	100.0	0.0
38	171	Schmitz Creek	10-Aug	1,473-1,488	4,830-4,879	0.40	0.04	0.07	100.0	0.0
38	169	Unnamed trib K	10-Aug	0-15	0-49	0.70	0.04	0.07	100.0	0.0
39	172	Mee-Kwa-Mooks Creek	10-Aug	0-10	0-33	0.28	0.03	0.10	100.0	0.0
39	272	Unnamed trib A	10-Aug	0-10	0-33	0.20	0.015	0.04	100.0	0.0
40	173	Pelly Creek	10-Aug	128-138	420-453	0.30	0.02	0.08	100.0	0.0
42	180	Fauntleroy Creek	18-Aug	0-15	0-49	1.10	0.09	0.15	12.7	87.3
42	181	Fauntleroy Creek	18-Oct	152-255	500-838	--	--	0.46	--	--
42	183	Fauntleroy Creek	18-Aug	712-762	2,335-2,499	1.50	0.06	0.25	85.0	15.0
42	184	Unnamed trib A	18-Aug	0-20	0-66	--	--	--	100.0	0.0
44	190	Durham Creek	9-Aug	55-75	180-246	2.53	--	0.53	0.0	100.0
44	191	Durham Creek	9-Aug	186-236	610-774	1.86	0.19	0.42	90.9	9.1
45	193	Durham Creek	2-Aug	450-487	1,476-1,598	0.90	0.05	0.34	100.0	0.0
45	194	Unnamed DW02	2-Aug	140-150	460-493	1.00	0.06	0.20	100.0	0.0
46	192	Hamm Creek - North Fork	2-Aug	61-111	200-364	1.50	0.20	0.50	0.0	100.0

Table 1. 12 - Total combined substrate scores for streams in the southwest region.

Stream system #	Stream Name	# of sites	Substrate score (%)				
			Silt/Sand	Gravel	Cobble	Boulders	Rip rap
35	Puget Creek	1	10	70	20		
35	Unnamed trib A	1		19	81		
37	Fairmount Creek	1	100				
38	Schmitz Creek	4	82	18			
38	Unnamed trib G	1	100				
39	Mee-Kwa-Mooks Creek	1	95	5			
40	Pelly Creek	1	100				
42	Fauntleroy Creek	4	84	14	2		
42	Unnamed trib A	1	100				
44	Durham Creek	3	87	7	6		
45	Unnamed DW02	1	45	8	35	12	
46	Hamm Creek - North Fork	1	100				

Southeast region.— The southeast region consists of only three stream systems: Mt. Baker Creek, Mapes Creek, and Taylor Creek. The lower sections of both Mt. Baker Creek and Mapes Creek are in culverts. The daylighted section of Mt. Baker Creek is only about 100-m long and is relatively small; however, there are three man-made barriers that create three small pools (each roughly 13-m long by 3.5-m wide). We surveyed 38 m upstream of the pools and the stream is only 0.1 m wide (Table 1.13). Mapes Creek is a substantially larger stream system, with the lower 900 m of the stream in a culvert. The daylighted section of Mapes Creek is generally small with mostly sand substrate (Table 1.14). The stream also includes three ponds (total length, 82 m) in the Kabota Gardens.

Taylor Creek is the largest stream in the southeast region. An impassable culvert under Rainier Avenue limits upstream movement of fish in Taylor Creek. Habitat conditions in the lower 500 m are generally good and includes good pool habitat. Upstream, pools are infrequent and those that are present are usually small and shallow. In the headwaters, the stream splits into two forks (East Fork and West Fork). Most of the summer streamflow is from the West Fork (Table 1.7).

Table 1. 13 - Stream habitat data for streams surveyed in the southeast, June-July 2005. Locations of sample sites are displayed in Appendices 1.29 and 1.30. Max = maximum. Percent riffles and pools/glides are the percent of the total stream area.

Stream system #	Sample #	Stream Name	Date surveyed	Distance from mouth (m)	Distance from mouth (ft)	Mean wetted width (m)	Mean depth (m)	Max depth (m)	% riffles	% pools/glides
47	200	Mount Baker Creek	25-Jul	213-298	700-979	1.82	0.31	0.55	7.1	92.9
48	201	Mapes Creek	25-Jul	994-1,029	3,260-3,375	1.10	0.16	0.40	41.6	58.4
49	203	Taylor Creek	30-Jun	0-50	0-164	2.48	0.09	0.30	29.0	71.0
49	205	Taylor Creek	30-Jun	777-827	2,550-2,714	1.75	0.10	0.25	100.0	0.0
49	206	East Fork Taylor Creek	7-Jul	30-80	100-264	1.24	0.03	0.25	96.8	3.2
49	207	East Fork Taylor Creek	19-Jul	107-157	350-514	1.27	0.09	0.25	83.2	16.8

Table 1. 14 - Total combined substrate scores for streams in the southeast region.

Stream system #	Stream Name	# of sites	Substrate score (%) Silt/Sand	Gravel	Cobble	Boulders	Rip rap
47	Mt.Baker Creek	1	84	6	10		
48	Mapes Creek	2	98	1	1		
49	Taylor Creek	3	39	39	18	4	
49	East Fork Taylor Creek	2	57	35	8		
49	West Fork Taylor Creek	1	50	30	15	5	

CHAPTER 2. FISH DISTRIBUTION SURVEYS AND STREAM TYPING

Introduction and Methods

Fish distribution surveys.-- We surveyed each stream in Seattle to determine the distribution of each fish species (salmonids and non-salmonids). Results of these fish surveys as well as habitat surveys (Chapter 1) were then used to classify each stream. Fish surveys were primarily conducted during the summer low-flow period of June to October 2005. We also sampled select locations during winter-flow conditions in February of 2006 to determine if the fish distribution had expanded to more upstream areas. In areas that we detected a range expansion, we surveyed again during summer low-flow period in August 2006 to determine if conditions between summer 2005 and 2006 were similar. Sampling sites were determined with the aid of maps and aerial photos of each watershed. We used a systematic sampling scheme to survey each watershed. Sample stream sections were generally 300 to 500 m apart for each stream, except in Thornton Creek where sample sections were 800 to 1,000 m apart. The first sample section began at the mouth of the stream, or as in many cases, where the stream enters a culvert that then transports the stream to Puget Sound, the Duwamish River, or Lake Washington. The exact location of each survey sample section was often based on accessibility and recognizable landmarks (i.e., bridges or culverts). We attempted to locate areas of a stream where sample section lengths could be at least 50 m in length and incorporate at least two habitat types (pools, riffles, or glides). This was not always the case and sample sections were sometimes less than 50 m in length with only a single habitat type. Supplemental sample sections were also surveyed at some areas to sample high quality habitat (i.e., deep pools) or more precisely document the distribution of each cottid species in the lower reaches of major creeks. Stream names and sample locations were based on SPU GIS maps, which divide each stream into 100 feet intervals from a confluence or stream mouth. Sample locations were also converted to meters.

Our primary method of sampling consisted of backpack electrofishing using a Smith-Root LR-24® electrofisher system. Backpack electrofishing was generally conducted in an upstream direction with one or more individuals following behind or along side the electrofisher operator to collect the stunned fish. Fish that were stunned by the electrical field were removed from the stream with long handle dip nets and placed in a recovery bucket. Additional surveys were conducted in September 2006 with a lamprey electrofishing unit (University of Wisconsin model #ABP-2) to attempt to find additional lamprey sites. We also used, when necessary, beach seines or gill nets to collect fish. Beach seines were used in ponds or deep waters of slow moving streams. The beach seine was 9.1-m long and 1.8-m deep, with a 1.8-m deep by 1.8-m long bag in the center. The mesh size in the wings was 6-mm stretch mesh, while the bag was 2-mm stretch mesh. We also used gill nets to sample some ponds for salmonids. Gill nets were between 6.5 and 12.5 m in length, 2.0 m deep with 2-cm square mesh. Nets were deployed perpendicular to shore and secured on both banks. Gill nets were deployed at dusk and removed just after sunrise. We also conducted snorkel surveys at a few pond sites to survey a large area. Snorkel surveys were conducted at night and were only done during the winter. We also included a dewatering site on Thornton Creek in which all fish were removed with electrofishing equipment.

After sampling was completed at each reach, captured fish were placed in an anesthetizing water bath of MS-222. Fish were identified and the length (nearest mm) was measured. After fish had recovered, they were then placed back into the stream from the habitat that they were captured from. Often a digital photo was taken of the fish. Unidentifiable species were retained for identification in the laboratory. Comparisons of fish size between sites or habitat types were made with nonparametric tests: a Mann-Whitney U test (two samples) or a Kruskal-Wallis test and multiple comparison procedures (more than two samples; Conover 1999).

Stream typing.-- All streams that were surveyed for fish (this chapter) and habitat (Chapter 1) were classified according to the Washington Department of Natural Resources interim and permanent stream typing system (WAC 222-16-031) (Table 2.1). The interim and permanent water typing methods relies on collecting both physical habitat parameters and fish presence/absence to obtain a water typing classification. This classification is then represented by a number (interim), or letter / letter combination (permanent), that is then given to indicate the stream type. Since this stream typing classification scheme was developed for more forested, less developed areas, it is often difficult to assign typing for streams in a heavily urbanized areas.

Table 2. 1 - Washington Department of Natural Resources water typing conversion table.

Interim Water Typing	Permanent Water Typing
Type 1	Type "S"
Type 2 and 3	Type "F"
Type 4	Type "Np"
Type 5	Type "Ns"

Definitions of each stream typing system and classification are as follows:

Interim Water Typing Definitions

Type 1 Water, means all waters, within their ordinary high-water mark, as inventoried as "shorelines of the state" under chapter 90.58 RCW and the rules promulgated pursuant to chapter 90.58 RCW, but not including those waters' associated wetlands as defined in chapter 90.58 RCW.

Type 2 Water, means segments of natural waters which are not classified as Type 1 Water and have a high fish, wildlife, or human use. These are segments of natural waters and periodically inundated areas of their associated wetlands, which:

(a) Are diverted for domestic use by more than 100 residential or camping units or by a public accommodation facility licensed to serve more than 10 persons, where such diversion is determined by the department to be a valid appropriation of water and only considered Type 2 Water upstream from the point of such diversion for 1,500 feet or until the drainage area is reduced by 50 percent, whichever is less;

(b) Are diverted for use by federal, state, tribal or private fish hatcheries. Such waters shall be considered Type 2 Water upstream from the point of diversion for 1,500 feet, including tributaries if highly significant for protection of downstream water quality. The department may allow additional harvest beyond the requirements of Type 2 Water designation provided by the department of fish and wildlife, department of ecology, the affected tribes and interested parties that:

(i) The management practices proposed by the landowner will adequately protect water quality for the fish hatchery; and

(ii) Such additional harvest meets the requirements of the water type designation that would apply in the absence of the hatchery;

(c) Are within a federal, state, local or private campground having more than 30 camping units: Provided, That the water shall not be considered to enter a campground until it reaches the boundary of the park lands available for public use and comes within 100 feet of a camping unit.

(d) Are used by fish for spawning, rearing or migration. Waters having the following characteristics are presumed to have highly significant fish populations:

(i) Stream segments having a defined channel 20 feet or greater within the bankfull width and having a gradient of less than 4 percent.

(ii) Lakes, ponds, or impoundments having a surface area of 1 acre or greater at seasonal low water; or

(e) Are used by fish for off-channel habitat. These areas are critical to the maintenance of optimum survival of fish. This habitat shall be identified based on the following criteria:

(i) The site must be connected to a fish bearing stream and be accessible during some period of the year; and

(ii) The off-channel water must be accessible to fish through a drainage with less than a 5% gradient.

Type 3 Water, means segments of natural waters which are not classified as Type 1 or 2 Waters and have a moderate to slight fish, wildlife, or human use. These are segments of natural waters and periodically inundated areas of their associated wetlands which:

(a) Are diverted for domestic use by more than 10 residential or camping units or by a public accommodation facility licensed to serve more than 10 persons, where such diversion is determined by the department to be a valid appropriation of water and the only practical water source for such users. Such waters shall be considered to be Type 3 Water upstream from the point of such diversion for 1,500 feet or until the drainage area is reduced by 50 percent, whichever is less;

(b) Are used by fish for spawning, rearing or migration. The requirements for determining fish use are described in the board manual section 13. If fish use has not been determined:

(i) Waters having any of the following characteristics are presumed to have fish use:

(A) Stream segments having a defined channel of 2 feet or greater within the bankfull width in Western Washington; or 3 feet or greater in width in Eastern Washington; and having a gradient of 16 percent or less;

(B) Stream segments having a defined channel of 2 feet or greater within the bankfull width in Western Washington; or 3 feet or greater within the bankfull width in Eastern Washington, and having a gradient greater than 16 percent and less than or equal to 20 percent, and having greater than 50 acres in contributing basin size in Western Washington or greater than 175 acres contributing basin size in Eastern Washington, based on hydrographic boundaries;

(C) Ponds or impoundments having a surface area of less than 1 acre at seasonal low water and having an outlet to a fish stream;

(D) Ponds of impoundments having a surface area greater than 0.5 acre at seasonal low water.

(ii) The department shall waive or modify the characteristics in (i) of this subsection where:

(A) Waters have confirmed, long term, naturally occurring water quality parameters incapable of supporting fish;

(B) Snowmelt streams have short flow cycles that do not support successful life history phases of fish. These streams typically have no flow in the winter months and discontinue flow by June 1; or

(C) Sufficient information about a geomorphic region is available to support a departure from the characteristics in (i) of this subsection, as determined in consultation with the department of fish and wildlife, department of ecology, affected tribes and interested parties.

Type <u>4</u> Water, means all segments of natural waters within the bankfull width of defined channels that are perennial nonfish habitat streams. Perennial streams are flowing waters that do not go dry any time of a year of normal rainfall and include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow.

Type <u>5</u> Waters, means all segments of natural waters within the bankfull width of the defined channels that are not Type 1, 2, 3, or 4 Waters. These are seasonal, nonfish habitat streams in which surface flow is not present for at least some portion of the year and are not located downstream from any stream reach that is a Type 4 Water. Type 5 Waters must be physically connected by an above-ground channel system to Type 1, 2, 3, or 4 Waters.

For purposes of this section:

(a) "Residential unit" means a home, apartment, residential condominium unit or mobile home, serving as the principal place of residence.

(b) "Camping unit" means an area intended and used for:

(i) Overnight camping or picnicking by the public containing at least a fireplace, picnic table and access to water and sanitary facilities; or

(ii) A permanent home or condominium unit or mobile home not qualifying as a "residential unit" because of part time occupancy.

(c) "Public accommodation facility" means a business establishment open to and licensed to serve the public, such as a restaurant, tavern, motel or hotel.

(d) "Natural waters" only excludes water conveyance systems which are artificially constructed and actively maintained for irrigation.

(e) "Seasonal low flow" and "seasonal low water" mean the conditions of the 7-day, 2-year low water situation, as measured or estimated by accepted hydrologic techniques recognized by the department.

(f) "Channel width and gradient" means a measurement over a representative section of at least 500 linear feet with at least 10 evenly spaced measurement points along the normal stream channel but excluding unusually wide areas of negligible gradient such as marshy or swampy areas, beaver ponds and impoundments. Channel gradient may be determined utilizing stream profiles plotted from United States geological survey topographic maps (See board manual section 23).

Permanent Water Typing Definitions

Type S Water means all waters, within their bankfull width, as inventoried as "shorelines of the state" under chapter 90.58 RCW and the rules promulgated pursuant to chapter 90.58 RCW including periodically inundated areas of their associated wetlands.

Type F Water means segments of natural waters other than Type S Waters, which are within the bankfull widths of defined channels and periodically inundated areas of their associated wetlands, or within lakes, ponds, or impoundments having a surface area of 0.5 acre or greater at seasonal low water and which in any case contain fish habitat or are described by one of the following four categories:

(a) Waters, which are diverted for domestic use by more than 10 residential or camping units or by a public accommodation facility licensed to serve more than 10 persons, where such diversion is determined by the department to be a valid appropriation of water and the only practical water source for such users. Such waters shall be considered to be Type F Water upstream from the point of such diversion for 1,500 feet or until the drainage area is reduced by 50 percent, whichever is less;

(b) Waters, which are diverted for use by federal, state, tribal or private fish hatcheries. Such waters shall be considered Type F Water upstream from the point of diversion for 1,500 feet, including tributaries if highly significant for protection of downstream water quality. The department may allow additional harvest beyond the requirements of Type F Water designation provided the department determines after a landowner-requested on-site assessment by the department of fish and wildlife, department of ecology, the affected tribes and interested parties that:

(i) The management practices proposed by the landowner will adequately protect water quality for the fish hatchery; and

(ii) Such additional harvest meets the requirements of the water type designation that would apply in the absence of the hatchery;

(c) Waters, which are within a federal, state, local, or private campground having more than 10 camping units: Provided, That the water shall not be considered to enter a campground until it reaches the boundary of the park lands available for public use and comes within 100 feet of a camping unit, trail or other park improvement;

(d) Riverine ponds, wall-based channels, and other channel features that are used by fish for off-channel habitat. These areas are critical to the maintenance of optimum survival of fish. This habitat shall be identified based on the following criteria:

(i) The site must be connected to a fish habitat stream and accessible during some period of the year; and

(ii) The off-channel water must be accessible to fish.

Type Np Water means all segments of natural waters within the bankfull width of defined channels that are perennial nonfish habitat streams. Perennial streams are flowing waters that do not go dry any time of a year of normal rainfall and include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow.

Type Ns Water means all segments of natural waters within the bankfull width of the defined channels that are not Type S, F, or Np Waters. These are seasonal, nonfish habitat streams in which surface flow is not present for at least some portion of a year of normal rainfall and are not located downstream from any stream reach that is a Type Np Water. Ns Waters must be physically connected by an above-ground channel system to Type S, F, or Np Waters.

For purposes of this section:

(a) "Residential unit" means a home, apartment, residential condominium unit or mobile home, serving as the principal place of residence.

(b) "Camping unit" means an area intended and used for:

(i) Overnight camping or picnicking by the public containing at least a fireplace, picnic table and access to water and sanitary facilities; or

(ii) A permanent home or condominium unit or mobile home not qualifying as a "residential unit" because of part time occupancy.

(c) "Public accommodation facility" means a business establishment open to and licensed to serve the public, such as a restaurant, tavern, motel or hotel.

(d) "Natural waters" only excludes water conveyance systems which are artificially constructed and actively maintained for irrigation.

(e) "Seasonal low flow" and "seasonal low water" mean the conditions of the 7-day, 2-year low water situation, as measured or estimated by accepted hydrologic techniques recognized by the department.

(f) "Channel width and gradient" means a measurement over a representative section of at least 500 linear feet with at least 10 evenly spaced measurement points along the normal stream channel but excluding unusually wide areas of negligible gradient such as marshy or swampy areas, beaver ponds and impoundments. Channel gradient may be determined utilizing stream profiles plotted from United States geological survey topographic maps (see board manual section 23).

(g) "Intermittent streams" means those segments of streams that normally go dry.

(h) "Fish habitat" means habitat which is used by any fish at any life stage at any time of the year, including potential habitat likely to be used by fish which could be recovered by restoration or management and includes off-channel habitat.

SPU GIS Water Typing Decision Guidelines

Water typing (WT) is a state-sanctioned classification process used to map the distribution of freshwater fish and fish habitat. SPU uses water typing maps of the City's freshwater watercourses for the following purposes: to inform fish use decisions related to permit applications for City instream maintenance or CIP projects, fish removal for same, and for watershed restoration planning activities in the urban watersheds. These maps are not intended to be applied directly to land use regulations.

These guidelines are based on State Forest Practices WAC (222-16-030 and 222-16-031), on the Forest Practices Board Manual (Chapter 13), and on Wild Fish Conservancy's WT Team's extensive field application of the State's water typing protocol (thousands of miles of water typing in Washington for federal, state, and local governments, and for private industry).

Fishbearing versus Non-fishbearing (Type 2 or 3 *vs*. Type 4 or 5)

1. Biological Criterion: If fish are present – the State considers the body of water to be fish-bearing (Type F = Type 2 or 3). The State does not distinguish between native and non-native species, or between planted and naturally produced fish – everything counts. If fish are found to be present in one part of a watershed, fish presence is assumed to exist from that point, downstream.
2. Physical Criteria: The State encourages the use of physical parameters to identify fish-bearing reaches because fish could be missed at the time of sampling, or fish might be sparse or absent because there is a downstream man-made barrier to fish passage. The State does not distinguish between partial and full barriers to fish passage. In order for a watercourse to be classified as fish-bearing in lieu of documented fish presence, it must meet both of the following criteria:
    a. The channel must be ≥ 2 feet bankfull width, AND
    b. The downstream gradient must be < 20% (averaged over 100 feet), when the upstream drainage area is > 50 acres. If the drainage area is ≤ 50 acres, the gradient must be ≤ 16 % (averaged over 500 feet).
3. In addition, ponds, wetlands with standing water, or impoundments are considered to be fish-bearing if ≥ 0.5 acre, at low water.

Note - because urban streams have so many road crossings (in effect, a series of dams with flat reaches upstream of each, because sediment deposition) – it might be necessary to average the gradient over a longer distance – 500 to 1000 feet – for some of the more difficult calls. In addition, urban creeks often do not have easily discernable bankfull widths because channels are incised. In these instances, use the closest sections (upstream or downstream) with bankfull widths, and/or rely on the Channel Condition Report 2008.

Type 2 versus Type 3

Note: The State no longer makes the distinction between Type 2 and Type 3, and consequently, the following criteria are based upon the descriptions of Type 2 and Type 3 from State Forest Practices WAC (222-16-031) and the Forest Practices Board Manual (Chapter 13), and from WFC's field application. The distinction between Type 2 and Type 3 offers more detailed information about existing or potential fish use in a watercourse. In many jurisdictions, Type 2 waters receive greater protection from adjacent land-use activities than Type 3 waters, because they are wider and/or have higher fish, wildlife, or human use than Type 3 waters upstream.

1. Physical Criteria:
    a. Mainstem Reach: In order for a mainstem water body to be Type 2, it must meet both of the following physical criteria:
        i. The channel must be ≥ 20 feet bankfull width, AND
        ii. The downstream gradient must be < 4%.
    b. Off-channel Reach: In order for an off-channel water body to be Type 2, it must meet both of the following physical criteria:
        i. The channel must be connected to a fish-bearing stream and be accessible during some period of the year, AND
        ii. The connection between the off-channel habitat and the fish-bearing stream must be < 5%.

OR

2. Biological Criteria: The watercourse has high use for fish (existing or potential). The regulations define 'high use' as providing habitat to support spawning, rearing, and/or migration. Wild "Fish Conservancy , in the field, interprets this as supporting more than one species and/or more than one life stage.
3. In addition, ponds, wetlands with standing water, or impoundments are considered to be Type 2 if ≥ 1 acre, at low water.

Results

During the summer low-flow period (June-October 2005), we surveyed a total of 176 sample sections throughout the 49 watersheds. A total of 36 sample sections were resurveyed during the winter.

Fish Distribution by Region

Northwest region.-- The Piper's Creek system was the only system in the northwest region in which we captured fish. In our surveys of Piper's Creek, we found cottids upstream to Rm 61 (200 ft), coho salmon up to the confluence of Venema Creek at Rm 640 (2,100 ft), and cutthroat trout up to Rm 1,750 (5,740 ft). During the summer 2005 surveys, we found the cutthroat trout distribution only extended upstream to two large culverts (twin culverts) at Rm 1,654 (5,423 ft)(Table 2.2). During the winter 2006 surveys, we collected three cutthroat trout between 100 and 250 m upstream of the twin culverts and two cutthroat trout were collected from the same area in August 2006 (Table 2.3).

In Venema Creek, we found cutthroat trout from the mouth to a large log jam located at Rm 320 (1,050 ft). We sampled a few sites (including a few spot samples) upstream of the log jam during the summer of 2005 and winter of 2006 but did not capture any fish. We sampled Mohlendorph Creek during the summer of 2005, but there was little streamflow, and no fish were captured. Mohlendorph Creek was re-sampled during the winter of 2006 and we captured two juvenile cutthroat trout at the mouth below the cement weir and another juvenile cutthroat trout 50 m upstream of the mouth. These were the only three fish we captured during all of our surveys on Mohlendorph Creek.

We also captured cutthroat trout on two other tributaries to Piper's Creek. Three cutthroat trout were collected in the lower 20 m of Piper's Creek - Unnamed trib H (called North Creek in Thomas 1992) and five cutthroat trout were captured in the lower 84 m of Piper's Creek - Unnamed trib K (called Viewlands Creek in Thomas 1992).

Table 2. 2 - Number of fish collected in the Northwest region watersheds during fish distribution surveys, October 2005. NS = no sample. Gear used was either electrofishing (E), beach seine (B), or not fished (NF, only habitat information collected). Locations of sample sites are displayed in Appendices 1.1-1.7. Fish caught of sample #'s greater than 500 are results from the first pass of reference site sampling (Chapter 3). Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. Fish species (number caught) are coho salmon (COH), cutthroat trout (CUT), coastrange sculpin (CRS), prickly sculpin (PKS), staghorn sculpin (SHS), and shortnose sculpin (SNS).

Stream system #	Sample #	Stream name	Date Sampled	Distance from mouth (m)	Distance from mouth (ft)	Gear	Stream Type	Number caught					
								COH	CUT	CRS	PKS	SHS	SNS
1	1	Unnamed PS01 - North Fork	4-Oct	10	33	NF	4						
1	2	Unnamed PS01 - North Fork	4-Oct	107-134	350-439	B	4						
1	3	Unnamed PS01 - North Fork	4-Oct	155-201	510-661	E	4						
2	NS	Unnamed PS02	--				4						
3	NS	Unnamed PS03	--				4						
4	4	Broadview Creek - North Fork	4-Oct	235-238	770-780	E	4						
5	5	Piper's Creek	6-Oct	-175-0	-574-0	E	2					32	2
5	25	Piper's Creek	6-Oct	0-29	0-95	E	2	1	3	13	10	4	
5	6	Piper's Creek	6-Oct	29-61	95-200	E	2		12	13			
5	7	Piper's Creek	6-Oct	247-297	810-974	E	2	6	71				
5	8	Piper's Creek	6-Oct	550-600	1,804-1,968	E	2	3	47				
5	510	Venema Creek	19-Oct	0-50	0-164	E	3		11				
5	20	Mohlendorph Creek	20-Oct	0-20	0-66	E	3						
5	516	Mohlendorph Creek	19-Oct	100-150	328-492	E	4						
5	514	Venema Creek	20-Oct	270-320	886-1,050	E	3		5				
5	18	Venema Creek	20-Oct	595-645	1,950-2,114	E	3						
5	501	Piper's Creek	19-Oct	762-812	2,500-2,664	E	2		35				
5	21	Unnamed trib H	11-Oct	0-50	0-164	E	3		3				
5	22	Unnamed trib H	11-Oct	250-300	820-984	E	3						
5	10	Piper's Creek	6-Oct	1,284-1,337	4,210-4,384	E	3		55				
5	23	Unnamed trib K	11-Oct	0-54	0-177	E	3		3				
5	26	Unnamed trib K	11-Oct	54-104	177-341	E	3		2				
5	11	Piper's Creek	11-Oct	1,625-1,654	5,330-5,423	E	3		4				
5	12	Piper's Creek	11-Oct	1,716-1,766	5,630-5,794	E	3						
5	24	Unnamed trib M	11-Oct	0-7.5	0-25	E	4						
5	13	Piper's Creek	11-Oct	2,043-2,074	6,700-6,802	E	3						
5	14	Piper's Creek	11-Oct	2,338-2,388	7,670-7,834	E	3						
6	NS	Unnamed PS04	--										
7	NS	Unnamed PS05	--										
8	32	Unnamed PS06 - West Fork	25-Oct	203-213	665-698	E	3						
8	33	Unnamed PS06 - West Fork	25-Oct	884-894	2,900-2,933	E	3						
8	30	Unnamed PS06 - East Fork	25-Oct	61-81	200-266	E	3						
8	31	Unnamed PS06 - East Fork	25-Oct	405-415	1,330-1,363	E	3						
9	35	Unnamed PS07	25-Oct	24-26	80-87	E	4						
10	36	Unnamed PS08	12-Oct	116-146	380-478	E	4						
11	NS	Unnamed PS09	--				5						
12	44	Unnamed PS10	14-Oct	0	0	NF	4						
12	40	Unnamed PS11	14-Oct	24	80	NF	4						
12	41	Unnamed PS11	14-Oct	183	600	NF	4						
12	43	Unnamed PS13	14-Oct	0	0	NF	4						
12	42	Unnamed PS14	14-Oct	-61-0	-200-0	E	4						
13	45	Licton Springs Creek	25-Oct	1,600-1,622	5,249-5,322	E	3						

Table 2. 3 - Number of fish collected or observed (snorkeler counts) during winter/spring surveys, February-April 2006. Appendix number is the map which displays the location of each sample site. Gear used was either electrofishing (E), beach seine (B), or snorkel survey (S). Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. T-NB = Thornton Creek – North Branch; G.C. = golf course. Fish species (number caught) are cutthroat trout (CUT), rainbow trout (RBT), Chinook salmon (CHK), threespine stickleback (STB), coastrange sculpin (CRS), prickly sculpin (PKS), largemouth bass (LMB), and sunfish (SUN, pumpkinseed and juvenile sunfish combined).

Region	Sample			Date	Distance from mouth			Stream	Number caught							
stream #	#	Appendix	Stream name	sampled	(m)	(ft)	Gear	type	CHK	CUT	RBT	STB	CRS	PKS	LMB	SUN
Northwest																
5	312	1.3	Piper's Creek	7-Feb	1,716-1,866	5,630-6,070	E	3		3						
5	311	1.2	Venema Creek	7-Feb	320-620	1,050-2,034	E	3								
5	310	1.2	Mohlendorph Creek	7-Feb	0-35	0-115	E	3		4						
5	321	1.2	Mohl. Cr. - East Fork	7-Feb	0-5	0-16	E	4								
13	309	1.7	Licton Springs Creek	13-Apr	1,600-1,690	5,249-5,545	E	3								
13	322	1.7	Licton Springs Creek	13-Apr	1,808-1,838	5,930-6,028	E	3								
Northeast																
14	316	1.8	Matthews Creek	8-Feb	112-127	366-415	E	3		46						
14	303	1.11	Littlebrook Creek	8-Feb	381-401	1,250-1,316	E	3								
14	338	1.12	T-NB-unnamed trib at Rm 2,730	8-Feb	25-35	82-115	E	4								
14	334	1.13	Littles Creek	8-Feb	1,128-1,175	3,700-3,854	E	3								
14	335	1.13	Littles Creek Pond	8-Feb	1,143-1,168	3,750-3,832	S	3								
14	323	1.13	Jackson Park G.C. Pond A	8-Feb	4,192	13,750	S	3								34
14	336	1.13	Jackson Park G.C. Pond B	8-Feb	4,360	14,300	S	3								
14	337	1.13	Jackson Park G.C. Pond C	8-Feb	4,451	14,600	S	3		14					1	3
14	314	1.10	Meadowbrook Creek	8-Feb	0-50	0-164	E	3		2						
14	313	1.10	Meadowbrook Creek Pond	8-Feb	372-472	1,220-1,548	B	3								
14	320	1.16	Victory Creek	8-Feb	215-248	705-813	E	4								
14	315	1.15	Willow Creek	8-Feb	299-324	980-1,062	E	3								
14	302	1.16	South Branch Thornton	15-Feb	4,232-4,247	13,880-13,929	E	3		3		1				
East-central																
27	339	1.21	Washington Park Creek	15-Feb	0-25	0-82	E	3						1		
27	324	1.21	Washington Park Creek	15-Feb	105-110	344-361	E	3		1						
27	325	1.21	Washington Park Creek	15-Feb	832-857	2,728-2,810	E	3								
Southwest																
34	333	1.24	Longfellow Creek	15-Feb	1,768-1,796	5,800-5,892	E	3								
34	317	1.24	Longfellow Creek	15-Feb	2,622-2,690	8,600-8,823	E	3								
35	305	1.25	Puget Creek	9-Feb	1,195-1,255	3,920-4,117	E	3								
35	318	1.25	Unnamed trib A	9-Feb	3-6.5	10-21	E	3			1					
44	326	1.28	Durham Creek	9-Feb	450-487	1,476-1,598	E	3								
45	327	1.28	Unnamed DW02	9-Feb	140-150	460-493	E	3								
46	328	1.28	Hamm Creek - North Fork	9-Feb	61-111	200-364	E	3								
43	329	1.28	Seola Beach Creek	9-Feb	160-170	525-558	E	4								
Southeast																
48	330	1.29	Mapes Creek -ponds	9-Feb	1,488-1,564	4,880-5,130	B	3								
49	307	1.30	Taylor Creek	13-Apr	0-88	0-290	E	2	1	6		2	28	3		
49	308	1.30	Taylor Creek	13-Apr	88-134	290-440	E	2		6						
49	300	1.30	Taylor Creek	16-Feb	1,138-1,159	3,734-3,800	E	3								
49	340	1.30	East Fork Taylor Creek	16-Feb	0-15	0-49	E	3								
49	341	1.30	West Fork Taylor Creek	16-Feb	0-20	0-66	E	3								

Northeast region. -- In Thornton Creek, we captured fish from the mouth up to the headwaters of the north and south branches (Tables 2.4 and 2.5). Over 52% of the fish we collected in mainstem habitats of the Thornton Creek system were cutthroat trout, which ranged throughout the system. Other native species collected in Thornton Creek were coho salmon, rainbow trout, threespine stickleback, lamprey, prickly sculpin, and coastrange sculpin. We also captured several introduced fish species including rock bass, largemouth bass, and pumpkinseed. The only introduced fish collected in the South Branch of Thornton Creek system were some pumpkinseed, which were only captured in Kramer Creek. We also captured fish in seven different tributaries of Thornton Creek (Matthews Creek, Maple Creek, Meadowbrook Creek, Kramer Creek, Willow Creek, Littlebrook Creek, and an unnamed trib of the South Branch at Rm 4,230 [13,874 ft]). Fish captured in the tributaries were also mainly cutthroat trout. Fish distributions in the tributaries appeared to be limited by barriers, such as culverts and other man-made obstacles. Most tributary fish were captured within 100 m of the mouth. In Matthews Creek and Maple Creek, we only captured fish downstream of the culvert at Sand Point Way to the confluence with Thornton Creek. On Littlebrook Creek, we only captured fish in a small section downstream from the culvert under 115th St to the confluence with the North Branch of Thornton Creek. In Willow Creek, we only captured fish downstream of the culvert under 98th St. to the confluence with the South Branch of Thornton Creek.

During the fish distribution surveys, 15 coho salmon were collected between the mouth of Thornton Creek to the Meadowbrook Retention Pond intake structure at Rm 1,996 (6,548 ft). Upstream only one coho salmon was ever collected, which was captured during our reference site sampling on Kramer Creek (200 m upstream from the Meadowbrook Retention Pond intake structure).

Ravenna Park Creek was the only other creek in the northeast region in which we collected any fish. We collected two rainbow trout that were approximately 200 m upstream from where the creek enters the culvert at the south end of Ravenna Park.

Yesler Creek (Stream #16) was not sampled due to inaccessibility and Inverness Creek (Stream #15) was sampled but no fish were captured.

Table 2. 4 - Number of fish collected during fish distribution surveys in the Thornton Creek (stream system #14) mainstem, North Branch of Thornton Creek, and tributaries, August-October 2005. The mouth of the North Branch Thornton Creek is the confluence of the South Branch and North Branch of Thornton Creek. Gear used was either electrofishing (E) or beach seine (B). Locations of sample sites are displayed in Appendices 1.8-1.13. Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. Fish species (number caught) are coho salmon (COH), cutthroat trout (CUT), threespine stickleback (STB), bass (rock bass and largemouth bass combined; BAS), sunfish (SUN, pumpkinseed and juvenile sunfish combined), coastrange sculpin (CRS), prickly sculpin (PKS), lamprey ammocoetes (LPU), and oriental weatherfish (OWF). Sample #55 was a part of a dewatering project and all fish were removed and counted.

Sample		Date	Distance from mouth			Stream	Number caught								
#	Stream name	Sampled	(m)	(ft)	Gear	Type	COH	CUT	STB	BAS	SUN	CRS	PKS	LPU	OWF
50	Thornton Creek - mainstem	22-Aug	30-80	98-262	E,B	2	6		3				74		
68	Matthews Creek Pond	22-Aug	15-37	49-121	B	3			58				2		
268	Matthews Creek	22-Aug	37-52	121-171	E	3						2			
70	Unnamed trib C	29-Aug	0-30	0-98	E	3									
51	Thornton Creek - mainstem	22-Aug	250-300	820-984	E	2		7				74	46		
69	Maple Creek	22-Aug	34-84	110-274	E	3		13							
71	Unnamed trib A	29-Aug	302-352	990-1,154	E	3									
73	Unnamed trib A	29-Aug	671-721	2,200-2,364	E	3									
74	Unnamed trib B	29-Aug	271-321	890-1,054	E	3									
72	Maple Creek	29-Aug	418-468	1,370-1,534	E	3									
75	Maple Creek	20-Sep	838-878	2,750-2,881	E	3									
52	Thornton Creek - mainstem	31-Aug	326-426	1,070-1,398	E	2	1	25		1		201	111	4	2
53	Thornton Creek - mainstem	30-Aug	509-609	1,670-1,998	E	2	9	135	43		5	7			
54	Thornton Creek - mainstem	12-Sep	1,159-1,209	3,800-3,964	E	2	1	67	31		17	1			
76	Mock Creek	15-Sep	0-20	0-66	E	3									
77	Mock Creek	15-Sep	305-335	1,000-1,098	E	3									
55	Thornton Creek - mainstem	15-Aug	1,951-1,996	6,400-6,548	E	2	7	421	1	3	2	1			
56	North Branch Thornton	12-Sep	680-731	2,230-2,397	E	2		142			2				
78	Littlebrook Creek	8-Sep	0-50	0-164	E	3		26							
79	Littlebrook Creek	8-Sep	381-431	1,250-1,414	E	3									
80	Littlebrook Creek	12-Sep	805-825	2,640-2,706	E	3									
81	Littlebrook Creek	23-Sep	2,345-2,370	7,690-7,772	E	3									
82	Littlebrook Creek	23-Sep	2,697-2,737	8,846-8,977	E	3									
83	Littles Creek	5-Oct	1,043-1,090	3,420-3,574	E	3									
84	Littles Creek Pond	5-Oct	1,200-1,225	3,937-4,019	B	3									
57	North Branch Thornton	17-Sep	1,424-1,474	4,670-4,834	E	2		111			4				
58	North Branch Thornton	19-Sep	2,061-2,124	6,760-6,967	E	2		80			2				
59	North Branch Thornton	7-Sep	2,851-2,901	9,350-9,514	E	2		42							
60	North Branch Thornton	7-Sep	3,537-3,557	11,600-11,666	E	2		15			1				
61	North Branch Thornton	7-Sep	4,177-4,227	13,700-13,864	E	2		125		1	27				
85	Jackson Park Golf Course Pond A	26-Sep	4,192	13,750	E,B	3					73				
285	Jackson Park Golf Course Pond B	26-Sep	4,360	14,300	E,B	3									
286	Jackson Park Golf Course Pond C	26-Sep	4,451	14,600	E,B	3				6	6				

Table 2. 5 - Number of fish collected during fish distribution surveys in the South Branch of Thornton Creek and other streams (stream system #'s 15-17) in the northeast region, September-October 2005. The mouth of the South Branch Thornton Creek is the confluence of the South Branch and North Branch of Thornton Creek. NS = no sample. NSCC = North Seattle Community College. Gear used was either electrofishing (E), beach seine (B), or gill nets (G). Locations of sample sites are displayed in Appendices 1.10, 1.14-1.18. Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. Fish species (number caught) are coho salmon (COH), cutthroat trout (CUT), rainbow trout (RBT), and threespine stickleback (STB).

Stream	Sample		Date	Distance from mouth			Stream	Number caught			
system #	#	Stream name	Sampled	(m)	(ft)	Gear	Type	COH	CUT	RBT	STB
14	62	South Branch Thornton	27-Sep	0-45	0-148	E	2		51		
14	86	Meadowbrook Creek	20-Sep	0-56	0-184	E	3				
14	88	Meadowbrook Pond	20-Sep	372-522	1,220-1,712	B, E	3				
14	524	Kramer Creek	28-Sep	0-108	0-354	E	3	1	35		
14	521	South Branch Thornton	13-Oct	534-688	1,804-2,257	E	2		177		
14	89	Unnamed trib C	27-Sep	0-6.8	0-22	E	4				
14	90	Willow Creek	20-Sep	0-50.5	0-166	E	3		38		
14	91	Willow Creek	27-Sep	195-210	820-869	E	3		29		
14	95	Unnamed trib E	21-Sep	0-32	0-105	E	3		12		
14	96	Unnamed trib E	21-Sep	335-371	1,099-1,215	E	3				
14	92	Willow Creek	21-Sep	299-337	980-1,105	E	3				
14	93	Willow Creek	21-Sep	881-933	2,890-3,061	E	3				
14	94	Willow Creek	21-Sep	1,503-1,521	4,930-4,989	E	3				
14	64	South Branch Thornton	21-Sep	1,276-1,336	4,185-4,382	E	2		95		
14	65	South Branch Thornton	22-Sep	2,195-2,242	7,200-7,354	E	2		29		13
14	97	Victory Creek	27-Sep	215-248	705-813	E	3				
14	66	South Branch Thornton	22-Sep	3,061-3,108	10,040-10,194	E	2		17	1	4
14	67	South Branch Thornton	22-Sep	3,598-3,655	11,800-11,987	E	2		1		78
14	98	Unnamed trib at Rm 4,230 - pond	26-Oct	171-191	560-626	B, G	3				180
14	99	South Branch Thornton-NSCC pond	1-Sep	4,512-4,532	14,800-14,866	B, G	3				161
14	199	South Branch Thornton-NSCC slough	1-Sep	4,649-4,669	15,250-15,316	B, E	3				47
15	100	Iverness Creek	28-Sep	229-264	750-865	E	4				
16	NS	Yesler Creek	--				3				
17	105	Ravenna Park Creek	4-Oct	152-202	500-664	E	3			2	
17	106	Ravenna Park Creek	5-Oct	534-584	1,750-1,914	E	3				

West-central region.-- The west-central region contained nine streams (Streams #'s 18–26), of which only four locations in Discovery Park were found to have any fish (Table 2.6). Three of the locations were slow-water habitats of the Scheuerman Creek drainage, and several threepine stickleback were captured at each location. The first site was a man-made pool (14-m long by 5-m wide; maximum depth 0.34) at Rm 159 (520 ft). The other two locations were small ponds (maximum depths, 1.5 and 1.0 m) on Scheuerman Creek – Unnamed trib A. A third pond at the headwaters of this tributary did not contain any fish. For the three locations combined, a total of 113 threespine stickeleback were captured with a beach seine. We also collected a single goldfish in another pond located in the center of Discovery Park. We were unable to survey Streams #'s 23-25 due to inaccessibility. We did not capture any fish in Streams #'s 18–20, 22, and 26.

Table 2. 6 - Number of fish collected in the west-central region watersheds during fish distribution surveys, August-October 2005. NS = no sample. Gear used was either electrofishing (E), beach seine (B), or not fished (NF, only habitat information collected). Locations of sample sites are displayed in Appendices 1.19 and 1.20. Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. Fish species (number caught) are goldfish (GDF) and threespine stickleback (STB).

Stream system #	Sample #	Stream name	Date sampled	Distance from mouth (m)	(ft)	Gear	Stream type	Number caught GDF	STB
18	110	Mahteen Creek	19-Aug	46-86	150-281	E	4		
19	111	Lawton Creek	17-Aug	46-96	150-314	E	4		
20	112	Wolfe Creek	19-Aug	159-209	520-684	E	3		
20	113	Wolfe Creek	24-Aug	442-452	1,450-1,483	E	3		
21	114	Scheuerman Creek	25-Aug	24-74	80-244	E	3		
21	115	Scheuerman Creek	25-Aug	159-173	520-566	B, E	3		43
21	118	Unnamed trib A	19-Aug	0-50	0-164	E	3		
21	119	Unnamed trib A - pond	25-Aug	189-229	620-750	B, E	3		59
21	120	Unnamed trib A - pond	25-Aug	296-317	970-1,040	B, E	3		11
21	121	Unnamed trib A - pond	25-Aug	380-399	1,245-1,310	E	3		
21	116	Scheuerman Creek	19-Aug	280-325	919-1,066	E	3		
21	117	Scheuerman Creek	19-Aug	451-481	1,480-1,578	E	3		
21	217	Scheuerman Creek - pond	25-Aug	780-811	2,560-2,662	B	4		
22	122	Owl's Creek	29-Sep	0-12	0-39	E	4		
22	123	Unnamed PS17	29-Sep	52	170	NF	4		
22	124	Sewer Plant Beach Pond	3-Oct	0-18	0-59	B	3		
22	125	Unnamed Trading Post Pond	3-Oct	0	0	B	3	1	
23	NS	Unnamed PS18	--						
24	NS	Unnamed PS19	--						
25	NS	Unnamed PS20	--						
26	126	Unnamed PS21	25-Aug	242-262	795-861		4		

East-central region.-- The east-central region contains seven streams (stream systems #'s 27-33) of which only the Washington Park Creek drainage (stream system #27) contained fish (both native and introduced species; Table 2.7). Within the stream habitat of Washington Park Creek, we only collected fish in the lower 110 m. A perched culvert at the upstream end of this section appeared to be a barrier to fish moving upstream. Cutthroat trout and prickly sculpin were collected in the plunge pool below the culvert (maximum depth 0.47 m). Threespine stickleback, prickly sculpin, and smallmouth bass were collected near the mouth of the creek. Upstream, fish were only collected in two ponds. All fish were most likely introduced into the ponds. Fourteen goldfish and seven brown bullhead were collected in a small pond on Washington Park Creek – Unnamed trib A. Also, 37 koi (ornamental common carp) and 22 goldfish were collected in Japanese Gardens Pond at the headwaters of Washington Park Creek.

Table 2. 7 - Number of fish collected in the east-central region watersheds during fish distribution surveys, July-August 2005. Gear used was either electrofishing (E) or beach seine (B). Locations of sample sites are displayed in Appendices 1.21 and 1.22. Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. Fish species (number caught) are goldfish (GDF), common carp (koi, CRP), brown bullhead (BBH), threespine stickleback (STB), smallmouth bass (SMB), and prickly sculpin (PKS). Sample #133 is known as the Japanese Garden Pond.

Stream	Sample		Date	Distance from mouth			Stream	Number caught					
system #	#	Stream name	sampled	(m)	(ft)	Gear	type	GDF	CRP	BBH	STB	SMB	PKS
27	130	Washington Park Creek	11-Aug	0-50	0-164	E	3				4	1	4
27	230	Washington Park Creek	11-Aug	50-110	164-360	E	3						3
27	131	Washington Park Creek	11-Aug	807-857	2,646-2,810	E	3						
27	132	Unnamed trib A - pond	11-Aug	64-89	210-292	B	3	14		7			
27	133	Washington Park Creek - pond	22-Aug	1,588-1,677	5,210-5,500	B	3	22	37				
28	134	Interlaken Creek - East Reach	17-Aug	80-90	262-295	E	4						
28	135	Interlaken Creek - Unnamed reach	19-Aug	0-20	0-66	E	4						
29	136	Interlaken Creek - Middle Reach	19-Aug	0-50	0-164	E	4						
30	137	Interlaken Creek - West Reach	19-Aug	0-30	0-98	E	4						
31	138	Madrona Creek - Middle Reach	10-Aug	90-110	295-361	E	4						
32	139	Unnamed LW01	10-Aug	0-10	0-33	E	4						
33	140	Frink Creek	28-Jul	488-538	1,600-1,764	E	3						
33	141	Frink Creek	28-Jul	701-721	2,300-2,366	E	3						

Southwest region.-- The southwest region contains 13 streams (stream system #'s 34-46) of which Longfellow Creek, Puget Creek, Fauntleroy Creek, and Durham Creek contained fish. In Longfellow Creek, we only captured fish in a few sections (Table 2.8). At the mouth (just upstream from where Longfellow Creek enters the lowest culvert to the Duwamish River) we captured 17 threespine stickleback, 2 prickly sculpin, and 1 Pacific staghorn sculpin. We didn't catch another fish until Rm 3,009 (9,870 ft) where three unidentified trout (most likely rainbow trout) were collected. Between Rm 3,628 (11,900 ft) and 4,288 (14,064 ft), we captured three rainbow trout, and three juvenile coho salmon. No other fish were captured upstream of this point on Longfellow Creek despite adequate habitat.

Puget Creek was sampled in the summer of 2005 and no fish were collected. However in the winter surveys of 2006, we captured a 224 mm FL rainbow trout in a small pool of Puget Creek – Unnamed trib A (Figure 2.1). This tributary is 50 m upstream from the lower end of the daylighted section of Puget Creek. The tributary appears to have more streamflow than Puget Creek during base flow conditions. In the summer of 2006, we sampled this pool again but did not capture any fish.

Fauntleroy Creek is a major creek in this region that has an annual return of coho salmon. In the intertidal area, we only collected three Pacific sand lance. Upstream at the upper edge of the intertidal area, we collected four juvenile coho salmon and four Pacific staghorn sculpin . In our surveys further upstream, we only captured juvenile coho salmon (*n* = 23), which were collected as far upstream as Rm 762 (2,499 ft)(Table 2.8).

There are three stream systems (#'s 44-46) in the southeast part of the southwest region, of which fish were only collected in Durham Creek (stream system #44). In this stream, we collected 14 threespine stickleback and 3 juvenile coho salmon in South Park Pea Patch, the lowest daylighted section. This stream section has a low gradient and has adequate pool habitat and cover (large amounts of water cress *Nasturtium officinale*). Just upstream of this section is a steep culvert and no fish were observed in the stream section immediately above the culvert or further upstream. The other two stream systems (Unnamed DW02 [#45] and Hamm Creek – North Fork[#46]) had adequate habitat and streamflow conditions to support fish but most likely these streams are perched above impassable culverts.

Table 2. 8 - Number of fish collected in the southwest region watersheds during fish distribution surveys, August-September 2005. NS = no sample. Gear used was either electrofishing (E) or not fished (NF, only habitat information collected). Locations of sample sites are displayed in Appendices 1.23-1.28. Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. Fish species (number caught) are coho salmon (COH), rainbow trout (RBT), unidentified trout (UDT), threespine stickleback (STB), prickly sculpin (PKS), Pacific staghorn sculpin (SHS), and Pacific sand lance (PSL).

Stream	Sample		Date	Distance from mouth			Stream	Number caught						
system #	#	Stream name	sampled	(m)	(ft)	Gear	typing	COH	RBT	UDT	STB	PKS	SHS	PSL
34	150	Longfellow Creek	1-Aug	1,006-1,086	3,300-3,562	E	3				17	2	1	
34	146	Golf Course trib	1-Aug	0-27	0-89	E	4							
34	147	Unnamed trib A	1-Aug	15-35	50-116	E	4							
34	151	Longfellow Creek	1-Aug	1,951-2,001	6,400-6,564	E	3							
34	152	Longfellow Creek	1-Aug	2,622-2,657	8,600-8,715	E	3							
34	153	Longfellow Creek	2-Aug	3,009-3,079	9,870-10,100	E	3			3				
34	154	Longfellow Creek	2-Aug	3,628-3,695	11,900-12,120	E	3	3	2					
34	155	Longfellow Creek	2-Aug	4,238-4,288	13,900-14,064	E	3		1					
34	156	Longfellow Creek	2-Aug	4,549-4,596	14,920-15,074	E	3							
34	148	Unnamed trib B	2-Aug	0-10	0-33	E	5							
34	149	Unnamed trib C	3-Aug	0-3	0-10	E	4							
34	257	Longfellow Creek	3-Aug	4,933-4,983	16,180-16,344	E	3							
34	157	Longfellow Creek	3-Aug	5,555-5,603	18,220-18,377	E	3							
34	158	Longfellow Creek	3-Aug	6,085-6,132	19,960-20,114	E	3							
34	159	Longfellow Creek	4-Aug	6,311-6,358	20,700-20,854	E	3							
35	160	Puget Creek	9-Aug	1,195-1,249	3,920-4,097	E	3							
35	162	Unnamed trib B	9-Aug	0-6.5	0-21	E	4							
35	161	Unnamed trib A	9-Aug	0-13.5	0-44	E	3							
36	163	Unnamed DW01 (dry)	28-Jul	0	0	NF	5							
37	164	Fairmount Creek	28-Jul	277-282	910-926	E	3							
38	165	Schmitz Creek	10-Aug	726-776	2,380-2,544	E	3							
38	166	Schmitz Creek	10-Aug	1,018-1,068	3,340-3,504	E	3							
38	167	Schmitz Creek	10-Aug	1,284-1,334	4,210-4,374	E	3							
38	170	Unnamed trib G	10-Aug	0-15	0-49	E	4							
38	168	Schmitz Creek	10-Aug	1,360-1,395	4,460-4,575	E	3							
38	169	Unnamed trib K	10-Aug	0-15	0-49	E	4							
38	171	Schmitz Creek	10-Aug	1,473-1,488	4,830-4,879	E	4							
39	172	Mee-Kwa-Mooks Creek	10-Aug	0-10	0-33	E	4							
39	272	Unnamed trib A	10-Aug	0-10	0-33	E	4							
40	173	Pelly Creek	10-Aug	128-138	420-453	E	4							
41	NS	Unnamed PS22	--			NF								
42	179	Fauntleroy Creek	18-Aug	-70-0	-230-0	E	3							3
42	180	Fauntleroy Creek	18-Aug	0-17	0-56	E	3	4					4	
42	181	Fauntleroy Creek	18-Oct	152-255	500-838	E	3	10						
42	182	Fauntleroy Creek	23-Aug	454-479	1,490-1,572	E	3	4						
42	183	Fauntleroy Creek	18-Aug	712-762	2,335-2,499	E	3	9						
42	184	Unnamed trib A	18-Aug	0-20	0-66	E	4							
43	185	Seola Beach Creek (dry)	18-Aug	160	525	NF	5							
44	190	Durham Creek	9-Aug	55-75	180-246	E	3	4			12			
44	191	Durham Creek	9-Aug	186-236	610-774	E	3							
44	193	Durham Creek	2-Aug	450-487	1,476-1,598	E	3							
45	194	Unnamed DW02	2-Aug	140-150	460-493	E	3							
46	192	Hamm Creek - North Fork	2-Aug	61-111	200-364	E	3							

Figure 2. 1 - Photo of the rainbow trout captured in Puget Creek – Unnamed trib A (sample location 318), February 9, 2006.

Southeast region.-- This region only contains three streams (stream systems #'s 47-49): Mt. Baker Creek, Mapes Creek, and Taylor Creek. No fish were collected in Mt. Baker Creek. At Mapes Creek, we sampled at Rm 994 (3,260 ft) and the Kubota Garden Ponds at Rm 1,488 (4,880 ft). The only fish collected in Mapes Creek were two threespine stickleback collected at Rm 994 (3,260 ft).

Taylor Creek is the largest creek in this section and flows north into Lake Washington. We sampled from the mouth of the creek at Lake Washington to the headwaters of the west fork (Table 2.9). In the lower 50 m of the stream, we collected one juvenile Chinook salmon, 20 juvenile coho salmon, 29 coastrange sculpin, 30 cutthroat trout, and 17 threespine stickleback. We also observed a single unidentified lamprey just above our site. Upstream from this site, the only fish we collected were juvenile coho salmon and cutthroat trout (Table 2.9). We did not collect any fish in Taylor – East Fork Creek, but we captured three cutthroat trout in Taylor – West Fork Creek in a small pool close to the confluence. This was the furthest upstream site where we captured fish on Taylor Creek.

Table 2. 9 - Number of fish collected in the southeast region watersheds during fish distribution surveys, August-September 2005. Gear used was either electrofishing (E) or not fished (NF, only habitat information collected). Locations of sample sites are displayed in Appendices 1.29-1.30. Stream type indicates the Washington State Department of Natural Resources interim water typing classification system on a scale of 1 to 5. Fish species (number caught) are Chinook salmon (CHK), coho salmon (COH), cutthroat trout (CUT), threespine stickleback (STB), and coastrange sculpin (CRS).

Stream	Sample		Date	Distance from mouth			Stream	Number caught				
system #	#	Stream name	sampled	(m)	(ft)	Gear	type	CHK	COH	CUT	STB	CRS
47	200	Mount Baker Creek	25-Jul	213-298	700-979	E	4					
48	201	Mapes Creek	25-Jul	994-1,029	3,260-3,375	E	3				2	
48	202	Mapes Creek	26-Jul	1,488-1,753	4,880-5,750	E	3					
48	209	Unnamed trib C	26-Jul	58-83	190-272	E	4					
49	203	Taylor Creek	30-Jun	0-50	0-164	E	2	1	20	30	17	33
49	204	Taylor Creek	30-Jun	439-489	1,440-1,604	E	2		51	9		
49	205	Taylor Creek	30-Jun	777-827	2,550-2,714	E	3		1	5		
49	206	East Fork Taylor Cr.	7-Jul	30-80	100-264	E	3					
49	207	East Fork Taylor Cr.	19-Jul	107-157	350-514	E	3					
49	208	West Fork Taylor Cr.	19-Jul	24-74	80-244	E	3			3		
49	210	West Fork Taylor Cr.	19-Jul	1,150	3,772	NF	4					

Fish Distribution by Species

Petromyzontidae, lampreys.—During fish distribution surveys, we only collected lamprey (ammoceotes) in Thornton Creek at Rm 326-426 (1,070-1,398 ft). We did observe one unidentified adult lamprey in Taylor Creek (Rm 70 [230 ft]) during winter surveys but it was not captured. Additional surveys for lamprey were conducted in the lower reach of Taylor Creek and Fauntleroy Creek in September 2006 with a lamprey electrofishing unit; however, no lamprey was collected. Further surveys with the lamprey electrofishing unit are needed; however, initial results indicate lampreys are rare in Seattle streams. Species identification of lamprey was not done but they were most likely western brook lamprey *Lampetra richardsoni*, which have been observed in other Lake Washington basin streams.

Salmonidae, salmon and trout.-- Cutthroat trout was the dominant salmonid species captured during the ichthyofauna surveys. They were common in Thornton Creek, Taylor Creek, and Piper's Creek drainages. Additionally, a large cutthroat trout

(211 mm FL) was collected in the lower section on Longfellow Creek (reference site; see Chapter 3) and another cutthroat trout (103 mm FL) was collected near the mouth of Washington Park Creek during 2006 winter surveys (Table 2.3). In the Thornton Creek drainage they were present from the mouth upstream to the headwaters of both the North and South Branches, including the tributaries Matthews Creek, Maple Creek, Meadowbrook Creek, Willow Creek, and Littlebrook Creek (Figure 2.2). Three cutthroat trout were also collected from a small pond by the Park and Ride east of I-5, near 1st Ave and 100th St. during the 2006 winter surveys (Table 2.3; Figure 2.3). We also documented the presence of cutthroat trout in Jackson Park Golf Course pond C during winter surveys (Table 2.3). Overall, cutthroat trout collected made up over 53% of the total number of fish caught throughout the Thornton Creek drainage (n = 1,684, mean FL = 93.3 mm; range, 40-291 mm FL) and was the dominant species caught at most sites (Figure 2.4). The size of cutthroat trout was significantly larger in tributaries than in the mainstem areas (Figure 2.5; Mann-Whitney U test; $P < 0.001$). Spawning may occur primarily in the mainstem and age-0 fish may be slow to colonize the tributaries. Alternatively, the mainstem may have lower catch efficiency for large fish than the tributaries because of the higher wetted width. In the Piper's Creek drainage, they were found from the mouth to Rm 1,750 (5,740 ft) on the mainstem, in Venema Creek to Rm 320 (1,050 ft), and in the lower 50 m of Mohlendorph Creek (Figure 2.2). Cutthroat trout were also collected from two other tributaries of Piper's Creek (Unnamed tribs H and K). Unlike Thornton Creek, there was no significant difference in size between the tributaries and mainstem of Piper's Creek (Figure 2.6; Mann-Whitney U test; $P = 0.058$). The wetted width of the mainstem area is substantially smaller than Thornton mainstem and perhaps our catch efficiency was higher in the Piper's Creek mainstem. Cutthroat trout made up over 71% of the total number of fish captured in the Piper's Creek drainage (n = 266; mean FL, 100.2 mm; range, 55-215 mm FL; Figure 2.7). Cutthroat trout were also collected in the Taylor Creek drainage from the mouth up to Rm 827 (2,714 ft) and near the mouth of the West Fork at Rm 30 (100 ft). Cutthroat trout represented 27% of the fish collected in the Taylor Creek drainage (n = 58; mean FL, 114.6 mm; range 47-235 mm FL).

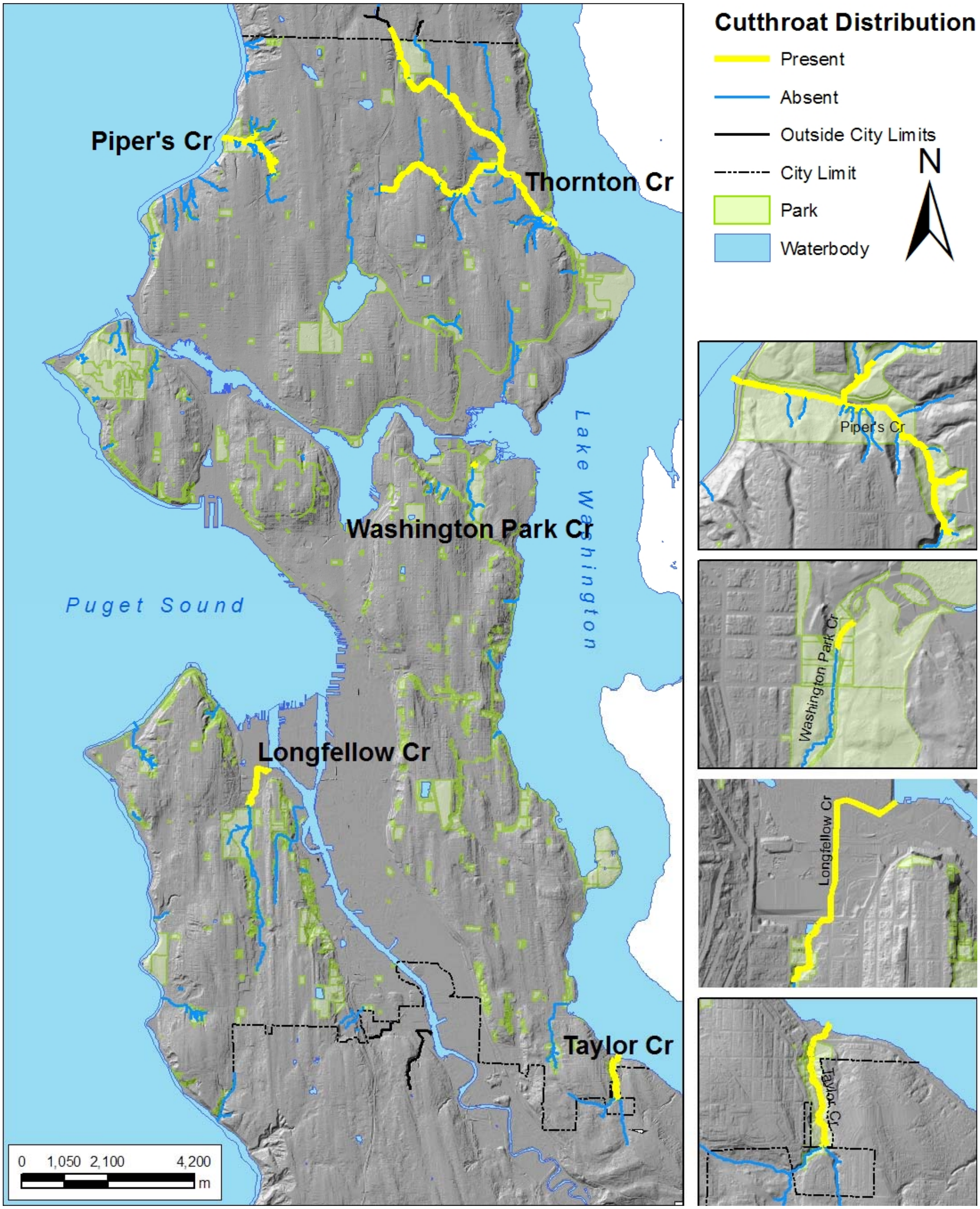

Figure 2. 2 - Distribution of cutthroat trout in Seattle's streams, 2005-2006 (except Longfellow Creek which was updated based on 2009 sampling [K. MacNeale, NOAA Fisheries, unpublished data]).

Figure 2. 3 - Photo of cutthroat trout captured in the South Branch of Thornton Creek (sample location 302; Rm 4,232 [13,880 ft]) the Park and Ride just east of I-5, near 1st Ave and 100th St. during the 2006 winter surveys.

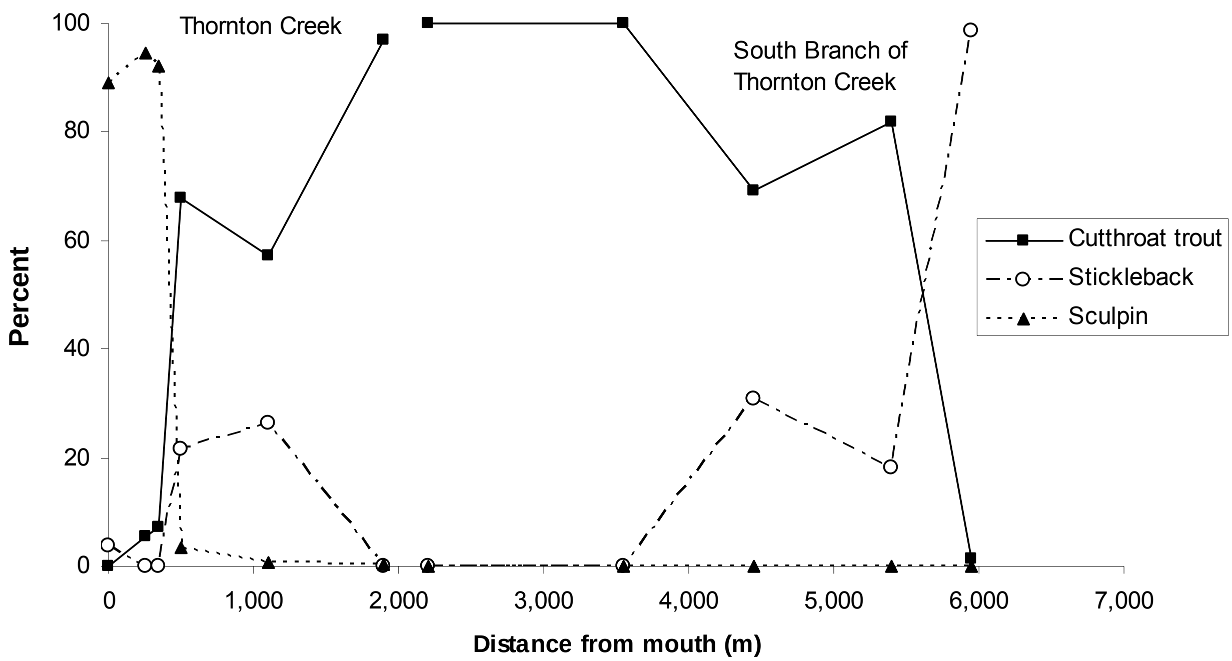

Figure 2. 4 - Relative abundance of the three main types of fish in the Thornton Creek system, August-October 2005. The distance from mouth (m) is the distance from the stream mouth on Lake Washington. In some cases, the total percent for a site may not add to 100% because other fish (lamprey, coho salmon, and centracrhids) are not displayed. At Rm 2,237 (7,336 ft), the South Branch and the North Branch merge together to form the lower mainstem of Thornton Creek. The North Branch is not displayed; cutthroat trout was the dominant fish species at each site (mean, 95% of catch; range 82-100%) in the North Branch.

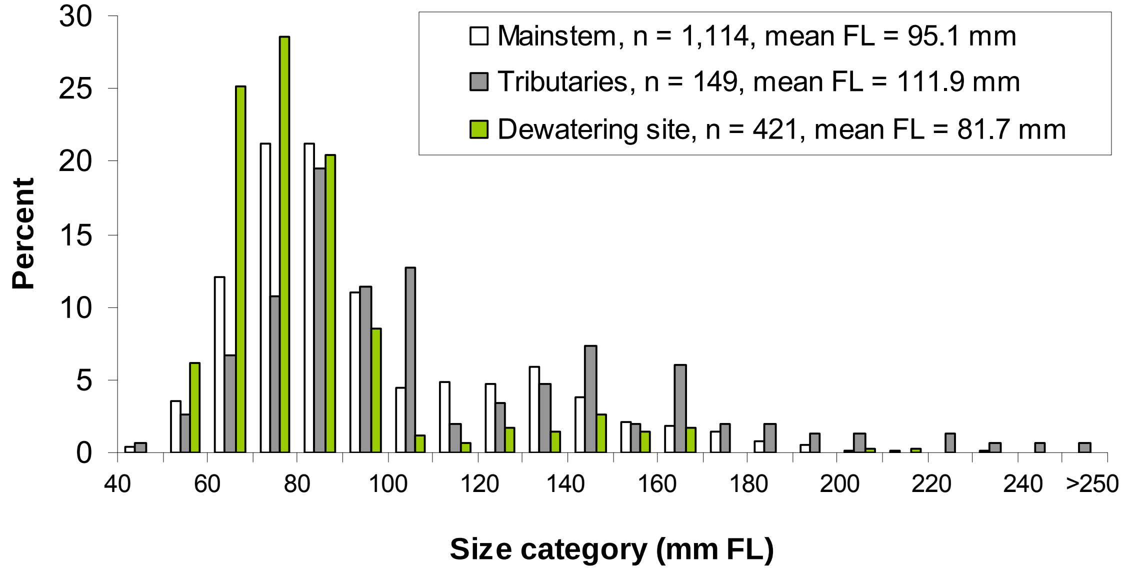

Figure 2. 5 - Length frequency (10-mm FL increments) of cutthroat trout collected from Thornton Creek mainstem and tributaries and at a dewatering site at Rm 1,951 (6,400 ft). Total number of cutthroat trout sampled and mean fork length is given.

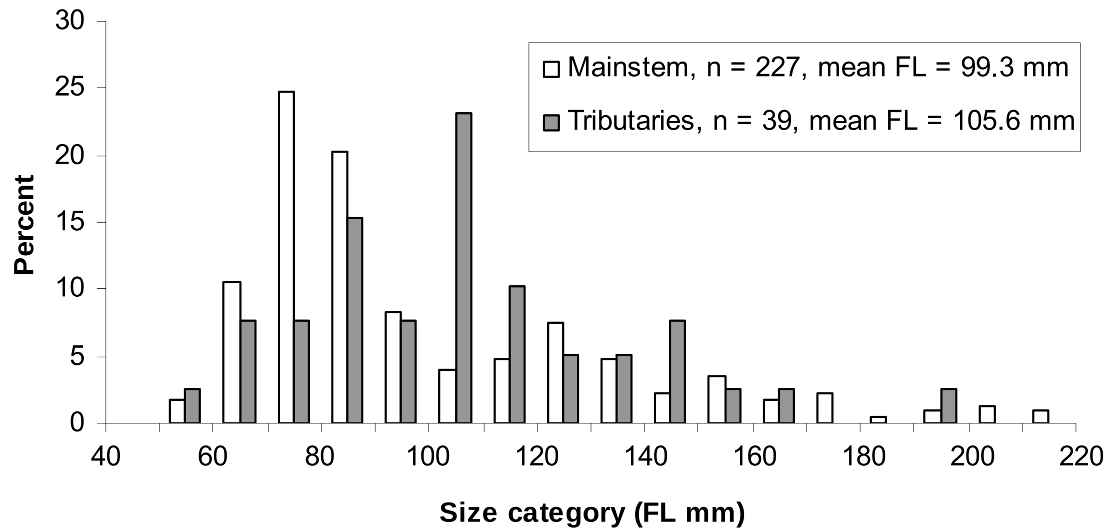

Figure 2. 6 - Length frequency (10-mm FL increments) of cutthroat trout collected from Piper's Creek mainstem and tributaries, October 2005. Total number of cutthroat trout sampled and mean fork length is given.

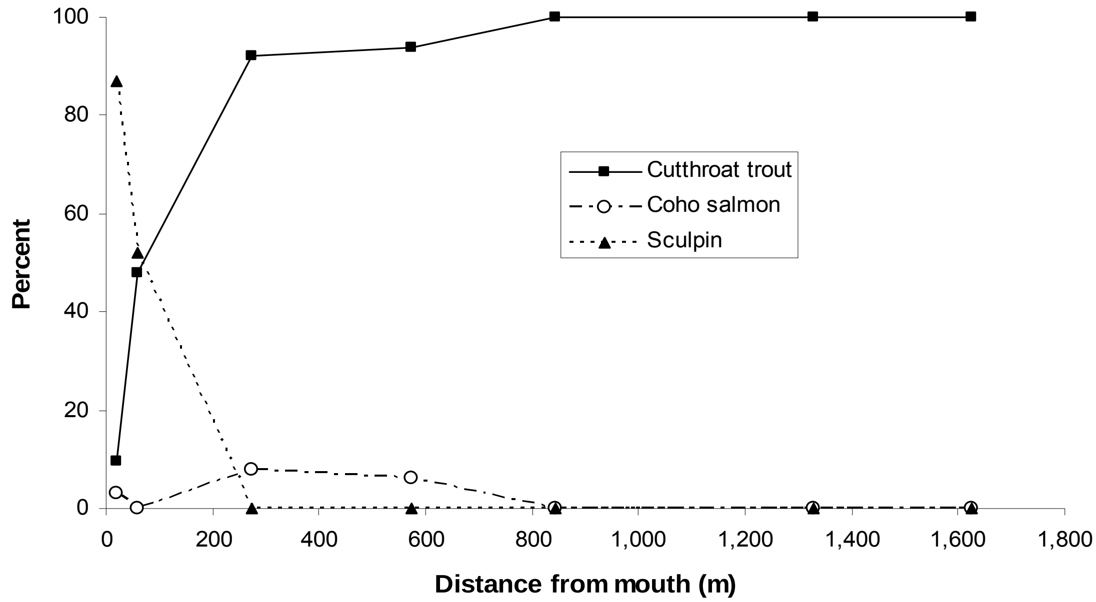

Figure 2. 7 - Relative abundance of the three main types of fish in Piper's Creek (mainstem only), October 2005. The distance from mouth (m) is the distance from the stream mouth on Puget Sound.

Few rainbow trout were captured in both the summer and winter sampling. Small numbers of rainbow trout were found in Thornton Creek, Ravenna Creek, and Longfellow Creek during the 2005 summer surveys (Figure 2.8). Additionally, a single rainbow trout was collected in Puget Creek during the winter surveys. Rainbow trout captured in Thornton Creek, Longfellow Creek, and perhaps other locations seemed to have some phenotypic characteristics of cutthroat trout (i.e., somewhat longer bottom jaw and very faint "slash" marks under lower jaw) and may have been hybrids. Genetic analysis of these individuals is needed to help determine their identification.

Figure 2. 8 - Photos of rainbow trout captured in Longfellow Creek (top photo) and Ravenna Creek (bottom photo) during the 2005 summer surveys.

Juvenile coho salmon were captured in Piper's Creek, Thornton Creek, Kramer Creek, Longfellow Creek, Fauntleroy Creek, Taylor Creek, and a section of Durham Creek (Figure 2.9). In Piper's Creek they were present from the mouth to Rm 600 (1,968 ft). Coho salmon only made up 3.4% of the total number of fish collected in the Piper's Creek drainage (*n* = 10; mean FL, 81.1 mm, range, 78-88 mm FL). Coho salmon were also collected in the Thornton Creek drainage, but were only found in the lower 2 km of the mainstem and two individuals were collected from Kramer Creek during our depletion-removal sampling. Less than 1% of the total catch in the Thornton Creek drainage was coho salmon (*n* = 24; mean FL, 84 mm; range, 72-97 mm FL). During fish distribution surveys, only three coho salmon were captured in Longfellow Creek at Rm 3,650 (11,972 ft) and four in the Durham Creek (Table 2.8). In the Fauntleroy Creek drainage, coho salmon were captured up to Rm 762 (2,499 ft)(Table 2.8). There is a barrier at Rm 393 (1,290 ft) under California Ave SW, and coho salmon found above this point were most likely stocked there by local enhancement groups. Coho salmon were the dominant species present and made up 73% of all fish collected in the Fauntleroy Creek drainage (*n* = 19; mean FL, 68.2 mm; range, 54-79 mm FL). Coho salmon were also captured in the Taylor Creek drainage and were found up to Rm 827 (2,714 ft). Coho salmon made up 34% of the total catch in the Taylor Creek drainage (*n* = 72, mean FL 63.3 mm; range, 40-82 mm FL).

The only two juvenile Chinook salmon collected during our surveys were collected near the mouth of Taylor Creek. Both were collected in the lower 34 m of the stream.

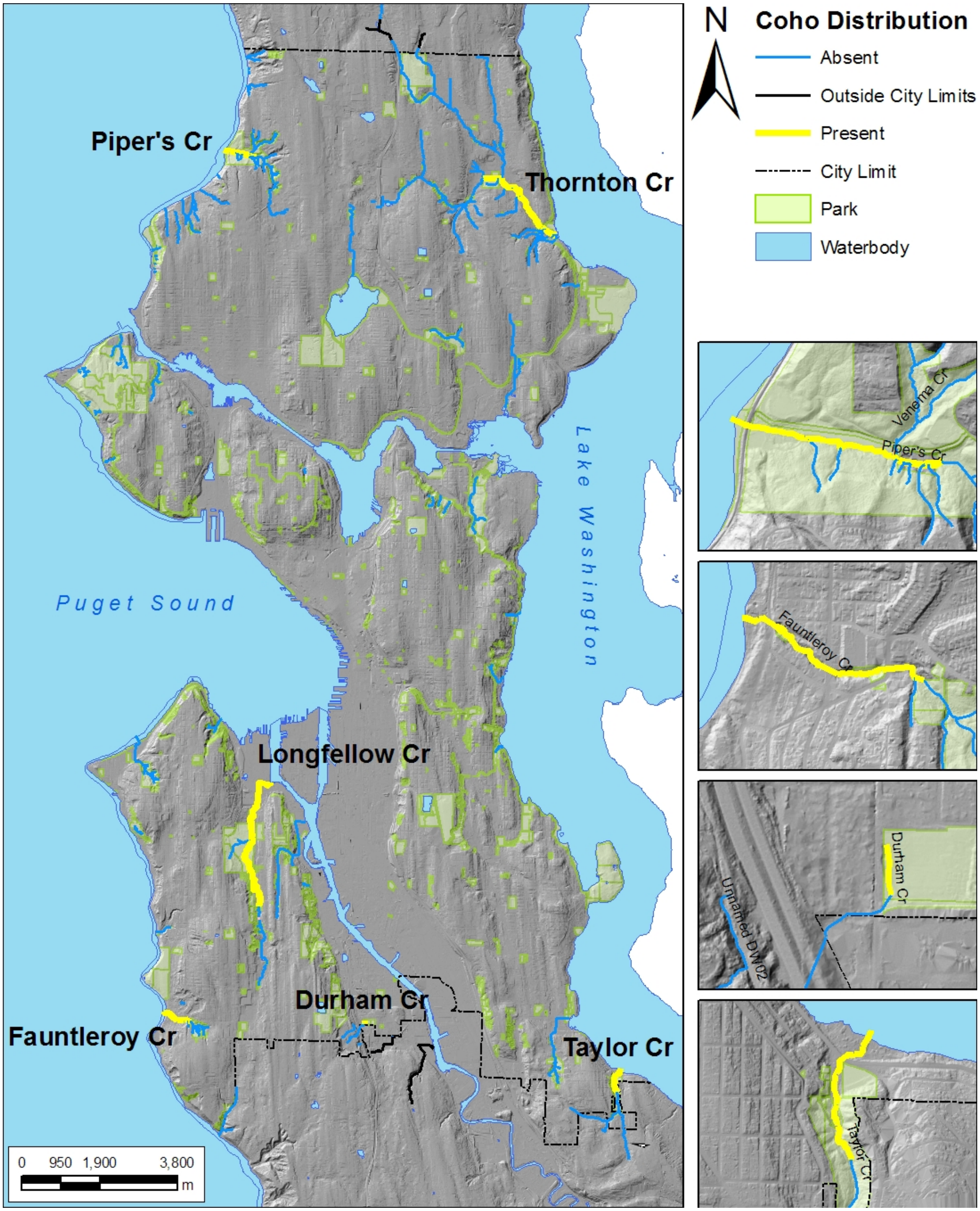

Figure 2. 9 - Distribution of juvenile coho salmon in Seattle's streams, 2005-2006.

Gasterosteidae, sticklebacks.-- Threespine stickleback was one of the most wide-ranging species, occurring in one or more streams or ponds of each region except the Northwest region (Figure 2.10). They were present in seven drainages and were the only fish species present in Mapes Creek, Scheuerman Creek, and the upland ponds of South Branch of Thornton Creek. In the Thornton Creek drainage, they were present from upland ponds of South Branch of Thornton Creek to the mouth but were absent in North Branch of Thornton Creek. At most stream sites, cutthroat trout were the dominant fish species present and threespine stickleback represented a small portion of the catch; however, at one 50 m reach in upper South Branch of Thornton Creek (Rm 3,800) where only one cutthroat trout was collected, threespine stickleback were abundant (n = 78; mean FL, 47.9 mm; range, 29-76 mm FL). In Scheuerman Creek, they were found in three ponds (n = 113; Figure 2.11) but were never collected in the stream. The lower 50 m of Taylor Creek was sampled in late June 2005 and 17 adult threespine stickleback (mean FL, 76.8 mm; range, 60-84 mm FL) were collected. Based on the sample date and their size, these were probably spawning adults from Lake Washington. The convergence pool of Thornton Creek with Lake Washington is probably also used as a spawning area for lake threespine stickleback, but because we sampled this area in late August we probably missed their spawning period.

Threespine stickleback appeared to be especially abundant in ponds and were usually associated with submerged aquatic vegetation. In streams, they were usually observed in quiet areas of pools. Proximity to a pond or lake appears to influence their abundance. For example, their abundance in the Thornton Creek system was much higher near Lake Washington and the upland ponds of the South Branch (Figure 2.4).

The size of threespine stickleback collected in ponds (mean FL, 35.3 mm) was generally smaller than the size collected in streams (mean FL, 43.7 mm)(Mann-Whitney U test, $P < 0.001$). Generally, small fish < 30 mm FL were not collected in streams (Figure 2.12). However, this may be partly because of differences in collection techniques. In streams, we primarily used electrofishing equipment and small threespine stickleback may be difficult to stun or may have been overlooked because of their small size. In ponds, we primarily used beach seines which may have adequately sampled all sizes of threespine stickleback. Alternatively, threespine stickleback may spawn primarily in the ponds and those observed in streams are subadults that have moved downstream from ponds. Also, streams often had large predators such as cutthroat trout which may have consumed small threespine stickleback.

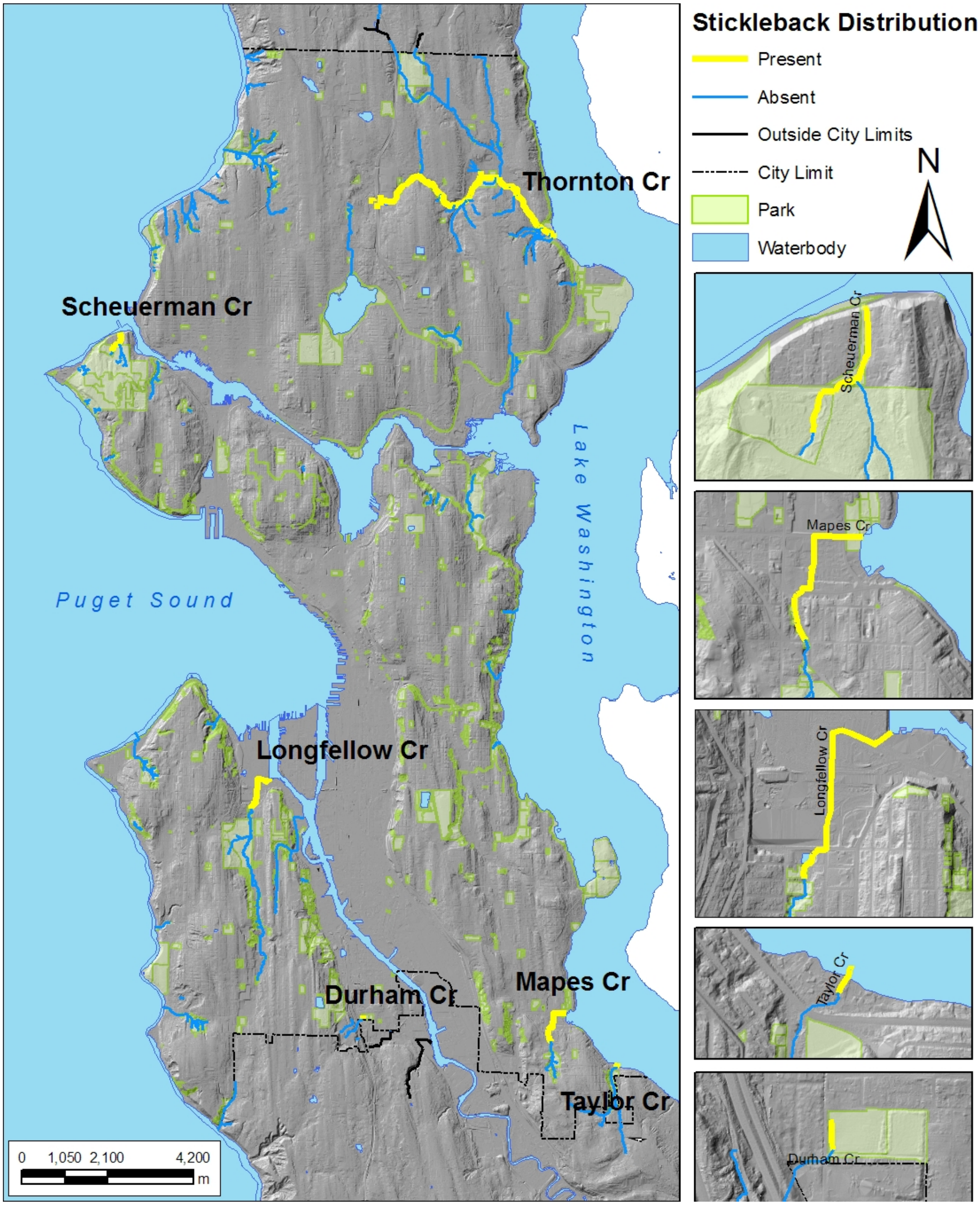

Figure 2. 10 - Distribution of threespine stickleback in Seattle's streams and ponds, 2005-2006.

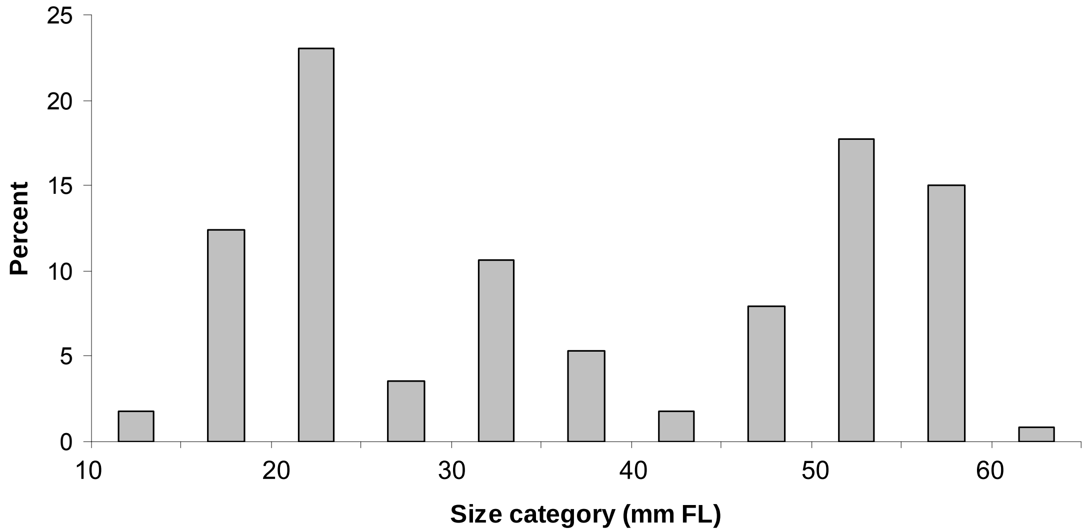

Figure 2. 11 - Length frequency (5-mm FL increments) of threespine stickleback (*n* = 113) collected in three ponds in the Scheuerman Creek basin, August 25, 2005. Data from all sites were combined.

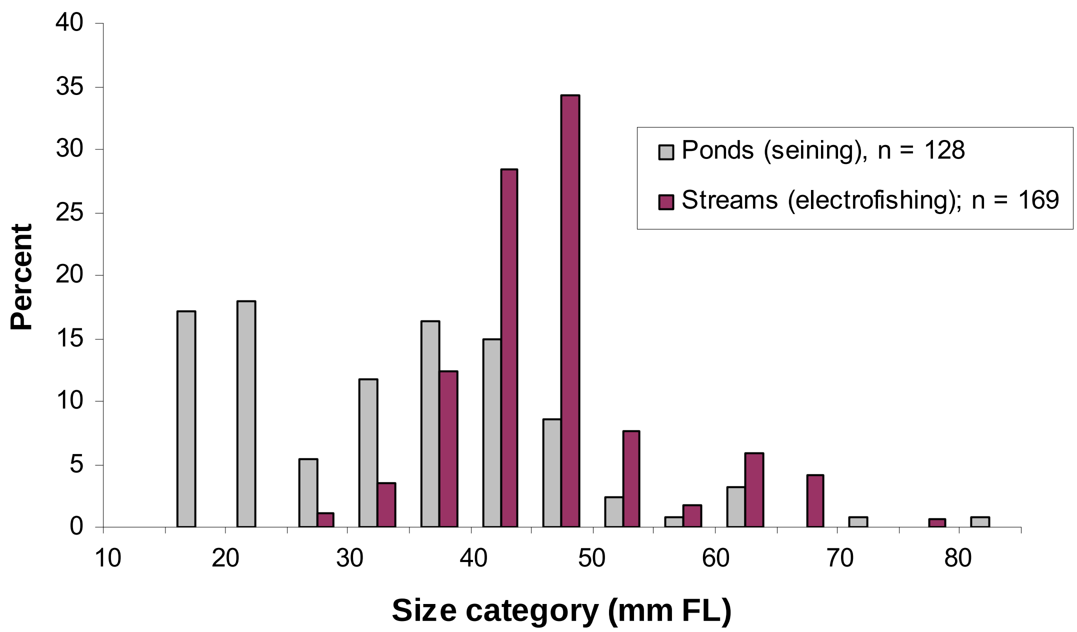

Figure 2. 12 - Length frequency (5-mm FL increments) of threespine stickleback collected in pond and stream habitat of Thornton Creek basin, August-October 2005. Data from all sites were combined.

Cottidae, sculpins.-- In Thornton Creek, cottids were found as far upstream as the Meadowbrook Pond intake structure at Rm 1,996 (6,548 ft)(Figure 2.13). However, the weirs (Rm 427 [1,400 ft]; 0.3 m vertical drop; Figure 2.14) at Sand Point Way appeared to act as a partial barrier to cottids. No prickly sculpin were found above the weirs but were found immediately below the weir. Coastrange sculpin were found above Sand Point Way but were significantly larger than those below the weir (Mann-Whitney *U* test, $P < 0.001$) and catch rates were substantially lower. Of the three sites above Sand Point Way where cottids were found, we only collected a total of nine coastrange sculpin. All coastrange sculpin above the weir were at least 87 mm TL (mean TL, 96.4 mm), while those below Sand Point Way ranged from 30 to 109 mm TL ($n = 378$; mean TL, 52.2 mm) Thus, the weir appeared to be passable by only large coastrange sculpin. The ratio of prickly sculpin to coastrange sculpin tended to decrease at more upstream sites. Near the mouth in the convergence pool all cottids were prickly sculpin, but at 250-300 m from the mouth 38% were prickly sculpin, and at 350-400 m from the mouth 28% were prickly sculpin. These ratios were also influenced by the amount of pool/glide/riffle habitat available. In pools, 64% of the cottids were prickly sculpin, while they represented only 18% and 12% of the cottids in glides and riffles, respectively. Coastrange sculpin and prickly sculpin in pools were larger than those in riffles or glides (Figure 2.15; Krukal-Wallis tests and multiple comparisons; $P < 0.05$). Within the Thornton Creek basin, both prickly sculpin and coastrange sculpin were also found in Matthews Creek; prickly sculpin were in the small pond near the mouth and coastrange sculpin were in the creek above the pond.

Similar to Thornton Creek, the only cottid species found above a weir at Rm 30 (100 ft)(Figure 2.14; vertical drop, 0.3 m) on Piper's Creek was coastrange sculpin (mean TL, 64.4 mm; range, 38-97 mm TL) and they were significantly larger than coastrange sculpin below the weir (mean TL, 42.7 mm; range, 27-52 mm TL)(Mann-Whitney *U* test, $P < 0.001$). Prickly sculpin and Pacific staghorn sculpin were found immediately below the weir but not above. At Taylor Creek, the upstream distribution of cottids appeared to be stopped by a short waterfall (0.3 m vertical drop; Figure 2.16) 92 m upstream from Lake Washington. Cottids were not collected immediately above this location or in several upstream locations. Of the cottids collected, 93% were coastrange sculpin (*n* = 27; mean TL, 41.8 mm; range, 26-101 mm TL) and 7% were prickly sculpin.

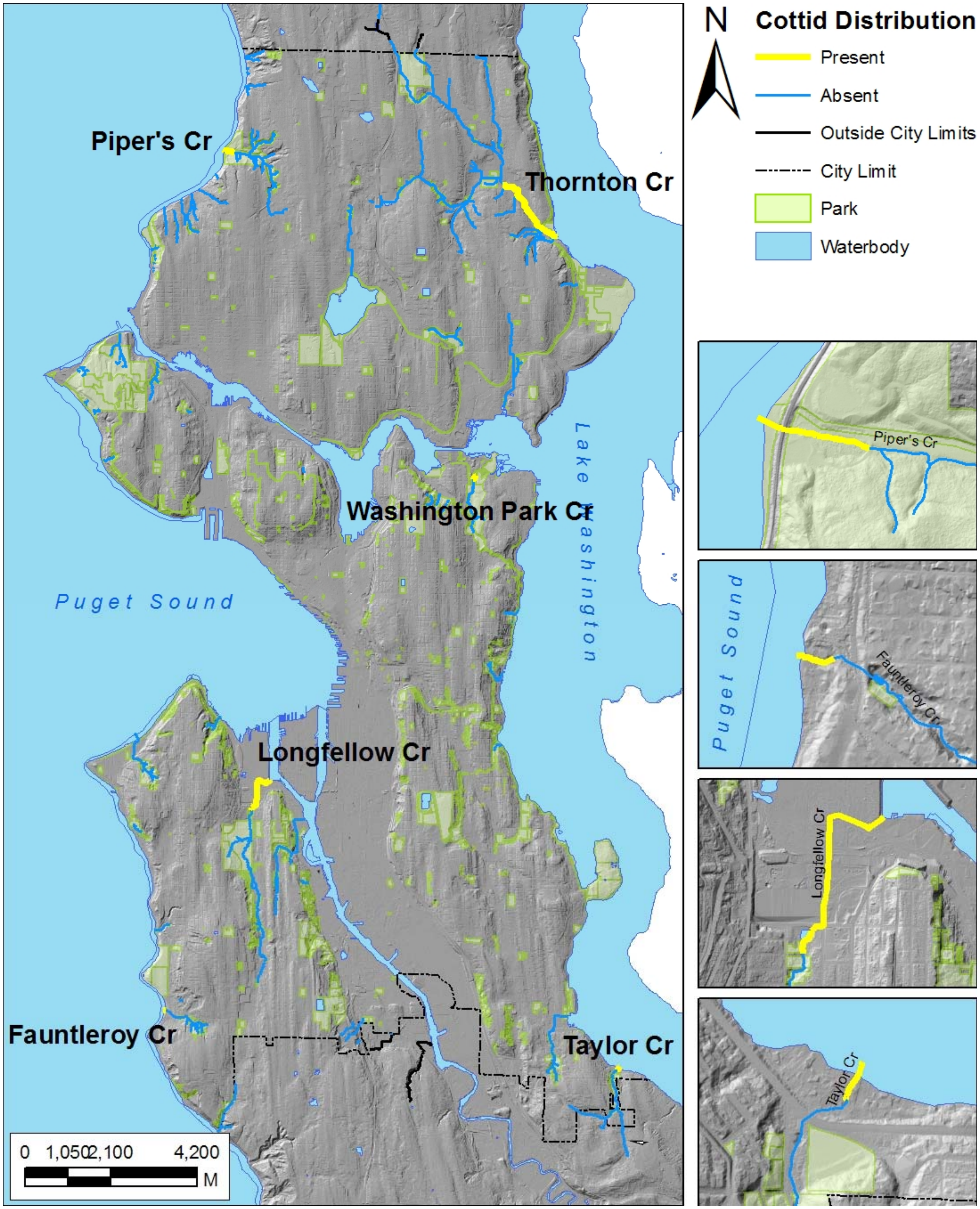

Figure 2. 13 - Distribution of cottids in Seattle's streams and ponds, 2005-2006.

The only cottid species in Washington Park Creek was prickly sculpin (*n* = 5), which were found either at the mouth of the creek or 105 m upstream in a plunge pool at the base of a culvert (0.8 m vertical drop; Figure 2.17). The only cottid species observed in Fauntleroy Creek was Pacific staghorn sculpin, which were only observed near the mouth in the intertidal area. Cottids collected in Longfellow Creek were mostly large prickly sculpin (*n* = 9; mean TL, 128 mm; range, 97-154 mm TL) and were only observed up to Rm 1,098 (3,600 ft). One juvenile Pacific staghorn sculpin was also collected.

Figure 2. 14 - Weirs in Thornton Creek (top panel, Rm 427 [1,400 ft]) and Piper's Creek (lower panel, Rm 33 [100 ft]) that appear to act as a partial barrier to upstream movement of cottids.

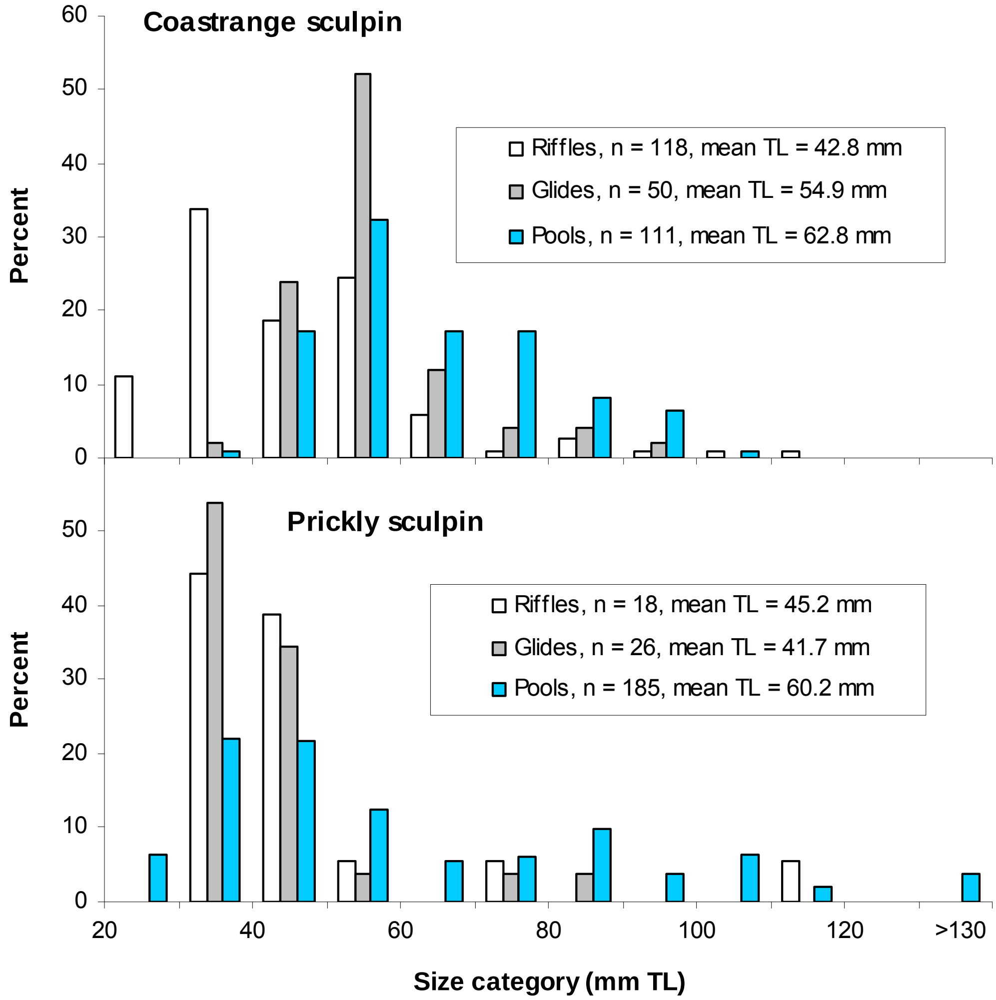

Figure 2. 15 - Length frequency (10-mm FL increments) of coastrange sculpin and prickly sculpin from the lower Thornton Creek mainstem. Total number of scuplin sampled and mean total length is given.

Figure 2. 16 - Short waterfall in lower Taylor Creek (Rm 88 [290 ft]) that appears to act as a complete barrier to upstream movement of cottids and juvenile salmonids. Several cottids were collected in the pool at the bottom of the photo but no cottids were ever collected upstream.

Figure 2. 17 - Culvert on Washington Park Creek (Rm 110 [360 ft]); that appears to act as a complete barrier to upstream movements of fish. Prickly sculpin and cutthroat trout were collected in the plunge pool shown but not upstream of the culvert.

Centrarchidae, sunfishes and black bass.-- Centrarchids observed in Seattle streams included smallmouth bass, largemouth bass, rock bass, and pumpkinseed. The only smallmouth bass (39 mm FL) collected was captured at the mouth of the Washington Park Creek. We assume that smallmouth bass only rarely use Seattle streams that drain into Lake Washington or the Lake Washington Ship Canal (LWSC). Rock bass, pumpkinseed, and largemouth bass were only found in the Thornton Creek watershed. In contrast to threespine stickleback, centrarchids were abundant in North Branch of Thornton Creek but absent in the South Branch of Thornton Creek system, except for a few pumpkinseed in Kramer Creek. Adult rock bass and pumpkinseed and juvenile largemouth bass were primarily collected in a pond at the Jackson Park Golf Course. Pumpkinseed was the most numerous nonnative species captured. Additionally, we often collected several unidentified juvenile sunfish in Thornton Creek (including North Branch of Thornton Creek), which we assumed were juvenile pumpkinseed.

Other introduced fish (Cyprinidae, Cobitidae, Ictaluridae).-- Introduced cyprinids observed in the study area included only goldfish and koi (an ornamental variety of common carp). Goldfish were found in three ponds, two in Washington Park and one in Discovery Park. Because a wide range of sizes were observed (range, 18-170 mm FL) in the Washington Park ponds, the goldfish populations appear to be self-sustaining through natural reproduction. Only one goldfish was collected in the Discovery Park and thus it's unclear if this represents a reproducing population. Koi were only observed in the Japanese Garden Pond in Washington Park and because they appear to be abundant and were present in a wide range of sizes, they probably are a naturally-producing population.

Two oriental weatherfish (family Cobitidae) were collected in the lower reach of Thornton Creek. Previous sampling has indicated they occur primarily in the LWSC, Lake Washington, and the Sammamish River (Tabor et al. 2001; E. Jeanes, R2 Resources, pers. comm.). Earlier sampling of Thornton Creek has also only found them in the lower reach (R. Tabor, unpublished data). Perhaps the weirs at Sand Point Way serve as a barrier to the upstream movement of this species.

Brown bullhead (family Ictaluridae) were collected at one location, a small pond in Washington Park. All fish appeared to be juveniles (range, 59-81 mm FL). Because we only made one seine haul in shallow water, we probably missed the adult fish.

Stream typing

Results of stream typing are displayed in a series of maps in Appendix 1. The largest stream system in the northwest region is Piper's Creek (stream system #5), which contains stream reaches ranging from type 2 to 5. The mainstem of Piper's Creek from the mouth to the "twin pipes" (large culverts) at Rm 1,654 (5,423 ft) was classified as type 2 because of the stream size and high abundance of cutthroat trout (Appendices 1.2 and 1.3). Upstream to the headwaters of Piper's Creek was typed as type 3 along with most of Venema Creek, the lower section of Mohlendorph Creek, and the lower sections of two unnamed tributaries (Appendices 1.2 and 1.3). Typing of these sections was based on either fish presence (cutthroat trout) or physical habitat (wetted width > 0.6 m). Most other streams sections in the Piper's Creek basin were classified as type 4.

Of the other streams in the northwest region, only Unnamed PS06 (East and West Forks) and Licton Springs Creek were typed as a type 3 stream. Other stream reaches were typed as either a type 4 or 5. We did not collect any fish in Unnamed PS06 (stream system #8; Appendix 1.4) but it was categorized as type 3 because it met the habitat requirements for stream typing – wetted widths > 0.6 m (Figure 1.3). Licton Springs Creek (stream system #13; Appendix 1.7) also was classified as type 3 based on habitat characteristics - wetted widths were usually greater than 1.5 m. Stream typing on the stream system #'s 1-4 were categorized as type 4 due to lack of fish presence and habitat characteristics (Appendix 1.1). Streams system #'s 9-11 (Appendix 1.5) were typed as 5 whereas stream system #12 (Appendix 1.6)) was classified as type 4. .

Because of the stream size and high abundance of cutthroat trout, the lower mainstem of Thornton Creek and most of the North and South Branches were classified as type 2 (Appendices 1.8-1.16). The lower reaches of many tributaries were stream type 3. Upper reaches of these tributaries were stream type 4. Although no fish were found above the confluence of Maple Creek, or above 100^{th} street on Willow Creek, or in

Little's Creek, these streams were classified as type 3 base on habitat characteristics. Inverness Creek (stream system #15) was classified as type 4 (Appendix 1.18) due to habitat characteristics – wetted width was only 0.4 m and average depth was 0.03 m. Ravenna Park Creek was categorized as type 3 (Appendix 1.18) based on the presence of rainbow trout and habitat characteristics – average wetted width, 1.50 m)

Within the west-central region, Wolfe Creek, Scheuerman Creek, and a small unnamed tributary to Scheuerman Creek were typed as 3, while all other streams in this region were type 4 or 5 (Appendices 1.19 and 1.20). Wolfe Creek was typed as type 3 based on habitat characteristics - mean wetted width of 0.73 m and a mean depth of 0.1 m. Scheuerman Creek and a small unnamed tributary to Scheuerman Creek was typed as type 3 based on the presence of fish (threespine stickleback) as well as habitat characteristics – wetted width was usually greater than 0.6 m. Mahteen Creek and Lawton Creek were typed as type 4 based on average wetted widths < 0.4 m and little streamflow. Owl's Creek had a mean wetted width of 0.80 m but had little streamflow and was shallow (average depth, 0.04 m).

Washington Park Creek was the only stream system that had type 3 stream reaches in the east-central region, while all other stream systems had only type 4 or 5 stream reaches (Appendices 1.21 and 1.22). The average wetted width was greater than 0.75 m for each sample reach of Washington Park Creek. For the other stream systems (Interlaken Creeks, Madrona Creek, Frink Creek, and Unnamed LW01), the creeks were small (< 0.5 m wetted width) with little streamflow.

The mainstem of Longfellow Creek was typed as type 3 as well as the lower 260 m of the Golf Course trib. Unnamed tribs B and C of Longfellow Creek were typed as type 4 (Appendices 1.23 and 1.24) because they were small streams (< 0.5 m wetted width) with little streamflow. Within the Puget Creek stream system, the mainstem reach between Rm 1,195 and 1,265 (3,920-4,150 ft) and the lower 14 m of Unnamed trib A were typed as type 3 based on the presence of a rainbow trout and habitat characteristics (wetted width > 0.7 m). Upstream Puget Creek is mostly intermittent and was typed as a type 4 stream to Rm 2,041 (6,695 ft)(Appendix 1.25). Further upstream the stream was dry and typed as a type 5 stream. Although we did not find any fish in Schmitz Creek, its mainstem was still a type 3 stream (reach average wetted width, 0.7 – 1.5 m). The tributaries of Schmitz Creek were all typed as type 4 stream because they were small streams (< 0.4 m wetted width) with little streamflow (Appendix 1.26). Mee-Kwa-Mooks Creek was typed as a type 4 based on average wetted width of 0.28 m. Pelly Creek had a wetted width of 0.3 m and had little streamflow and was typed as a type 4 in the lower section and type 5 in the upper section (Appendix 1.27). The lower 64 m of Fauntleroy Creek were typed as type 2 based on occurrence of adult coho salmon (Wild Fish Conservancy spawning surveys). Upstream to the confluence with Unnamed trib E, Fauntleroy Creek was a type 3 stream (wetted widths > 1.0 m). The headwaters and tributaries of Fauntleroy Creek were typed as type 4 (Appendix 1.27). Because the streambed was dry, Seola Beach Creek was classified as type 5 (Appendix 1.28). Durham Creek was typed as a type 3 stream (Appendix 1.28) based on the presence of fish in the lower section and habitat characteristics (wetted widths ≥ 0.90 m) and adequate streamflow in the upper section reaches. Similarly Unnamed DW02 and Hamm Creek – North Fork were typed as type 3 based on habitat characteristics (wetted widths ≥ 1.00 m) and adequate streamflow.

Of the three stream systems in the southeast region, Mapes Creek and Taylor Creek were typed as 3 and Mt. Baked typed as a type 4 stream. Mt. Baker Creek was typed as a type 4 stream based on the limited size of the watershed and small streamflow. The wetted width was > 1.5 m but this was largely due to man-made structures. Mapes Creek was typed as type 3 based on the presence of fish (threespine stickleback) as well as habitat characteristics – wetted width > 1.0 m. The lower 495 m of Taylor Creek were typed as type 2 based partially on occurrence of fish including adult coho salmon (Wild Fish Conservancy spawning surveys) and partially on habitat characteristics (bankfull width > 6 m). Upstream to the confluence of the East Fork and West Fork, Taylor Creek was typed as a type 3 stream based on the presence of cutthroat trout. The West Fork of Taylor Creek was typed as a type 3 stream based on prior stream surveys ((Washington Trout 2000). The East Fork of Taylor Creek was typed as a type 3 from its confluence with the West Fork to a small tributary at Rm 181(595 ft)(Unnamed trib D). The typing was based on a wetted width > 1.2 m. Upstream of this tributary the stream was classified as a type 4 stream.

Discussion

Several streams and ponds were void of fish. Generally, the lack of fish appeared to be due to one or more of three possible explanations: 1) small headwater streams with little available habitat, 2) presence of barriers and loss of connectivity to fish-bearing systems, and 3) severely degraded habitat conditions. Many of the small streams we examined that were void of fish had streamflows less than 0.03 cfs and the average wetted width was less than 0.7 m. Even under ideal conditions, streams of this size would probably be void of fish most of the year. Latterell et al. (2003) found the upstream extent of trout in western Cascade Mountains was influenced by gradient, stream size, and pool availability. In most Seattle's streams, trout distribution did not appear to be constrained by gradient; however, stream size and pool availability may be important factors. In a study of 79 headwater streams in southwestern Washington, Fransen et al. (1998) found streams needed to have a mean annual flow of at least 0.5 cfs to have the potential to produce the minimum amount of food needed to sustain a fish. Although we only sampled in the summer low-flow period, many of small streams we surveyed were unlikely to meet this criteria. Alternatively, cutthroat trout and juvenile coho salmon may inhabit streams as small as 1.2 m bankfull width (Rosenfeld et al. 2000) and thus many of the Seattle's fishless streams may be large enough to support fish. Also, fish-bearing streams in the western Cascade Mountain area are generally present in watersheds that are at least 22 ha (Trotter 2000). On a cursory examination of watershed sizes, many of the fishless streams in Seattle area appear to occur in watersheds that are large enough to support fish-bearing streams. Perhaps under pristine conditions, many of these fishless streams had fish populations.

At some locations, such as Willow Creek, Maple Creek, and Washington Park Creek, a steep or perched culvert appeared to prevent fish from utilizing available upstream habitat. Additionally, in some systems (i.e., Durham Creek, Schmitz Creek, and Puget Creek) the lower section of the stream is in a long culvert and its unclear if the culvert is a barrier to fish movements. In all the five major watersheds, less than 40% of the stream length expected to support anadromous fish is accessible (City of Seattle 2007). In most cases, impassable culverts limit salmonids moving upstream.

The habitat conditions of urban streams including Seattle's streams are often severely degraded. The number, size, and depth of pools are greatly reduced. For example, Schmitz Creek had reasonable streamflow but few pools were present and those that were present had maximum depths less than 0.2 m, which provide little cover for juvenile salmonids. The lack of woody debris and prevalence of fine sediments in many reaches of Seattle streams also are indicative of low-quality habitat conditions. In a study of the five major watersheds, the amount of low-quality habitat ranged from 29% in Fauntleroy Creek to 56% in Thornton Creek (City of Seattle 2007). In the smaller streams we surveyed, the percent of low-quality habitat often appeared to be even higher, although it was not directly measured.

In general, our results were consistent with Wild Fish Conservancy results (Washington Trout 2000). The distribution of most fish including cutthroat trout and sculpins appears to be quite similar between the two studies. However, there were a few notable differences. One major difference was the difference of fish distribution in Venema Creek. Wild Fish Conservancy observed fish up to the headwaters (approximately Rm 861 [2,825 ft]), while we only observed them up to a logjam at Rm 320 (1,050 ft). A small landslide (approximately Rm 700 [2,296 ft]) had occurred in this drainage a few months before our survey, which may have extirpated trout from the upper reaches. Another major difference was the upstream extent of fish in Taylor Creek. We observed fish up to Rm 30 (100 ft) of Taylor - West Fork (1,189 m from the mouth of Taylor Creek), while Wild Fish Conservancy (Washington Trout 2000) only observed fish up to a perched culvert at Rm 493 (1,620 ft). Apparently, the culvert, which was replaced in 1999, allowed fish to move upstream. Additionally, we conducted winter surveys and were able to document fish use in Puget Creek as well as upstream of the "twin pipes" on Piper's Creek, and upper reach of South Branch Thornton Creek. Wild Fish Conservancy (Washington Trout 2000) observed juvenile Chinook salmon in Piper's Creek and Thornton Creek, while we only observed one Chinook salmon at the mouth of Taylor Creek. Wild Fish Conservancy surveys were conducted from late June to mid July, 1999. We may have missed the occurrence of juvenile Chinook salmon in many streams because many of our surveys were done after July when the vast majority of juvenile Chinook salmon had already outmigrated.

Previous studies have found that as watersheds become more urbanized the ratio of juvenile coho salmon abundance to cutthroat trout abundance decreases (Scott et al. 1986; Serl 1999; Horner and May 1998; Seiler et al. 2005). Horner and May (1998) found the coho/cutthroat ratio is greater than 2:1 in watersheds with low levels of development and 0.5/1 in highly urbanized streams. Thornton Creek and Piper's Creek systems appear to fit this pattern for urbanized stream systems. The ratios were 0.016:1 for Thornton Creek and 0.048:1 for Piper's Creek. Taylor Creek had a much higher ratio (1.24:1) but juvenile coho salmon were most likely from an outplanting. A complete barrier to upstream movements of salmonids is located at Rm 140 (459 ft)(City of Seattle 2007). Most coho salmon were collected above this barrier.

In contrast to Piper's Creek, Thornton Creek, and Taylor Creek, cutthroat trout appear to be extremely rare (one cutthroat trout collected from approximately 500 m of stream length sampled) in Longfellow Creek despite a large amount of available habitat (Figure 2.17). Typically, cutthroat trout occupy a wide-range of habitats in western Washington and are especially abundant in urbanized systems (Serl 1999). They are usually found further upstream than other fish species (Trotter 2000) and are abundant in Puget Sound and lowland lakes like Lake Washington. One possibility for the lack of cutthroat trout in Longfellow Creek is the long culvert at the lowest stream section which may serve as is a barrier. However, it would seem unlikely that the culvert is a hydrologic or visual barrier to cutthroat trout since adult coho salmon as well as cottids can move upstream through the culvert and there are a number of skylights along its 700-m course. The stream appears to be more turbid than other streams but it's doubtful if this would dramatically reduce their abundance. The lack of cutthroat trout may be related to contaminants. High rates of pre-spawning mortality of adult coho salmon have been observed in Longfellow Creek and researchers believe it's likely caused by exposure to environmental contaminants (Reed et al. 2004). However, both Piper's Creek and Thornton Creek have also been documented to have high rates of pre-spawning mortality of adult coho salmon (J. Davis, USFWS, personal communication). Resident fish such as cutthroat trout may be impacted by other contaminants that are more common in Longfellow Creek than the other two streams or the input of contaminants may occur during other times of the year when adult coho salmon are not present. For example, high pesticide levels in the summer could impact trout prey base and limit the overall production of cutthroat trout. Also, some type of contaminant spill may have occurred and greatly reduced the population of cutthroat trout. In a survey of Longfellow Creek in September 2009 by NOAA Fisheries and USFWS, 34 cutthroat trout were captured between Rm 1,066 and 1,418 (3,495-4,650 ft)(K. MacNeale, NOAA Fisheries, unpublished data). Thus, stream conditions may be improving for cutthroat trout. Ongoing studies by NOAA Fisheries, USFWS, and others will continue to monitor fish populations in Longfellow Creek and may help explain the large differences in cutthroat trout abundance between the creek systems.

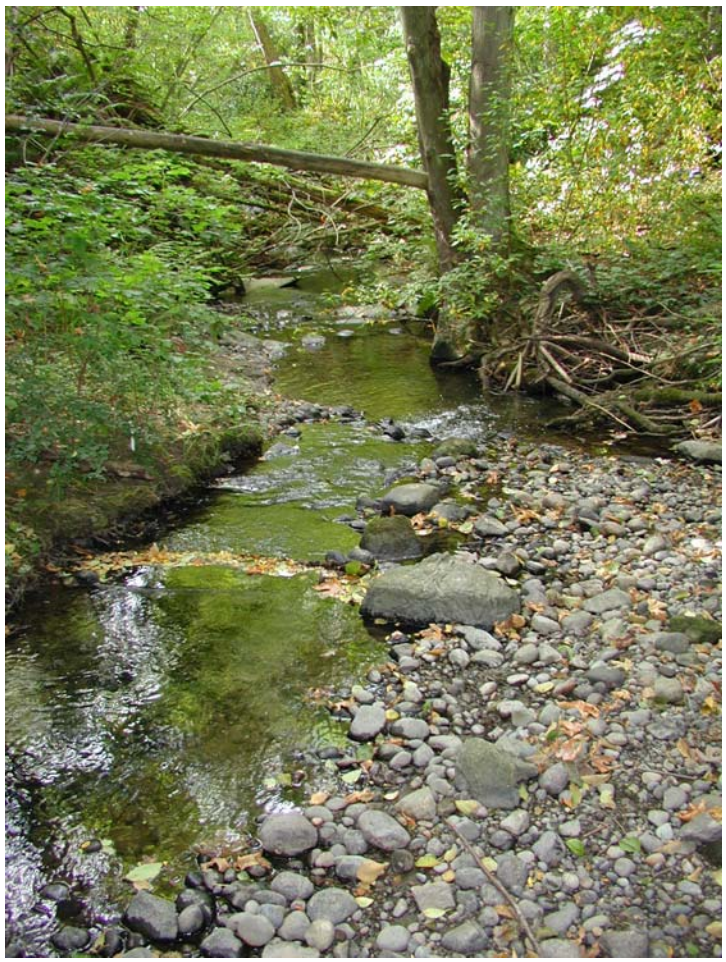

Figure 2. 18 - Photo of Longfellow Creek at Rm 3,650 (11,972 ft), August 2, 2005. In this 50 m reach, only three juvenile coho salmon and two rainbow trout were collected. Streams with similar habitat conditions in other regions of Seattle would be expected to have large numbers of cutthroat trout present.

The lack of cutthroat trout was also evident in other southwest streams. Juvenile coho salmon or rainbow trout were collected in Fauntleroy Creek, Puget Creek, and Durham Creek but cutthroat trout were never collected. Similar to Longfellow Creek, each of these streams does have a culvert close to its estuary but it's unclear if they are barriers to cutthroat trout. The lack of cutthroat trout may be related to the size of the creek. However, Venema Creek and Kramer Creek are similar-sized creeks and cutthroat trout were abundant. The level of environmental contaminants in these creeks is not known. Additional research is needed to better understand why cutthroat trout are rare in the southwest streams including Longfellow Creek but abundant in other similar-sized streams.

Size of cutthroat trout in Thornton Creek and Piper's Creek suggests they are growing rapidly in comparison to other streams. In these two streams, the length frequency (late-August to October) of cutthroat trout suggested there were probably at least three age classes present: age-0 (50-100 mm FL), age-1 (150-180 mm FL), and age-2 (180-240 mm FL). Peak spawning of coastal cutthroat trout generally occurs in February in this area and fry typically emerge from their redds sometime from March to June and by September they are 51-76 mm FL (Trotter 2008). In an assessment of six streams (three reaches per stream) in the Lake Washington basin, Serl (1999) found the average size of age-0 cutthroat trout ranged from 52.1 to 77.1 mm FL in mid-summer. The size of age-0 cutthroat trout in Thornton Creek and Piper's Creek appears to be closer to the high end of the streams studied by Serl (1999). Similarly, the size of age-1 and age-2 cutthroat trout in Thornton Creek and Piper's Creek appears to be at the high end of other streams in the Lake Washington basin (Serl 1999).

High growth rates of cutthroat trout in Thornton Creek and Piper's Creek are somewhat surprising because many intolerant prey types (i.e. Plecoptera, Trichoptera, and Ephemeroptera) are missing or rare in these urban streams (Leavy et al. 2008). However, more tolerant taxa including chironomids, other dipteran larvae, oligochaetes, and amphipods may be abundant and may be important prey resources for cutthroat trout. Even in more pristine systems, much of the diet of juvenile cutthroat trout may consist of these tolerant prey types (Lowry 1966; Glova 1984). Other prey items such as threespine stickleback, larval suckers, fish eggs, and terrestrial invertebrates may be abundant at times and become important components of cutthroat trout diet (Martin 1984; Tabor and Chan 1996; Beauchamp et al. 2007). Also, the lack of competition from juvenile coho salmon and sculpins (Glova 1987) may cause growth rates to be higher in these streams than other streams where competitors are abundant.

At some locations, we were unclear if the observed fish were part of a self-sustaining population or were simply recently stocked fish. This was particularly true for juvenile coho salmon. At Fauntleroy Creek, Durham Creek, and Piper's Creek, members of local enhancement groups indicated coho salmon were often stocked. A few rainbow trout were collected in Ravenna Creek and its unclear how these fish got there. Most likely they were stocked fish. A single goldfish was collected in a Discovery Park pond and may have been recently stocked by a local resident.

Besides the Washington Trout (2000) surveys, there has been few comprehensive surveys of Seattle's stream except in Thornton Creek and Piper's Creek. Results of surveys from Thornton Creek (Muto and Shefler 1983; Ludwa et al. 1997; Leavy et al. 2007) found the same general fish distribution as we observed. In all studies, cutthroat trout was the dominant species collected, the cutthroat trout to juvenile coho salmon ratio was low, and sculpin were only collected in sites close the creek mouth.

Comprehensive surveys of Piper's Creek were conducted by Pfeifer (1984) in 1984 and by Thomas (1992) in 1991 and 1992. Results of those studies and this study are summarized in Table 2.10. There were three notable differences between the studies. First, the number of cutthroat trout/stream length we collected was substantially higher than the other two studies. We collected our samples in October while the other studies were conducted in July or May; however we would expect the trout population to be lower in October as the number of age-0 trout is reduced over the over the course of the summer. Secondly, the distribution and abundance of cottids appears to have been reduced from 1984 to 2005. Thirdly, Thomas (1992) was the only study to document the presence of Pacific giant salamanders *Dicamptodon tenebrosus*.

Table 2. 10 - Electrofishing results of three studies (Pfeifer 1984, Thomas 1992, and this study) of Piper's Creek. The month and year are when the stream was sampled. The lower reach extends from the railroad culvert (Rm 0.0) to the sewage treatment culvert (Rm 650) and the upper reach is from the sewage treatment culvert to the "twin pipes" (Rm 1,654 [5,423 ft]). Pfeifer (1984) only sampled up to the sewage treatment culvert, while Thomas (1992) sampled up to the twin pipes. For this study, we only used data from sites that would match the other studies. Pfeifer (1984) used multiple-pass electrofishing whereas single-pass eleactrofishing was used by the other studies. We used data from Pfeifer's first pass to make comparisons to the other studies.

				Catch			Number per stream length (m)			Percent of catch		
Study	Month, Year	Reach	Distance surveyed (m)	Cutthroat	Coho	Cottids	Cutthroat	Coho	Cottids	Cutthroat	Coho	Cottids
Pfeifer	July-84	Lower	66	8	15	57	0.12	0.23	0.86	10.0	18.8	71.3
Thomas	May-91	Lower	600.6	56	32	39	0.09	0.05	0.06	44.1	25.2	30.7
Thomas	May-92	Lower	600.6	395	16	86	0.66	0.03	0.14	79.5	3.2	17.3
Tabor	October-05	Lower	132	132	10	13	1.00	0.08	0.10	85.2	6.5	8.4
Thomas	May-91	Upper	419.5	80	0	0	0.19	0.00	0.00	100	0	0
Thomas	May-92	Upper	419.5	157	0	0	0.37	0.00	0.00	100	0	0
Tabor	October-05	Upper	100	90	0	0	0.90	0.00	0.00	100	0	0

The increase of cutthroat trout abundance may be due to several factors including stream restoration efforts, reduction in angling effort, and reduction in the abundance of other fish and salamanders. In the summer of 1991, log and rock weirs were installed, which increased the pool-to-riffle ratio from 0.13 to 0.29 (Thomas 1992). Additionally, several K-weirs were installed in 1998 and modified in 1999. The creation of larger, deeper, and more frequent pools may have greatly increased the abundance of cutthroat trout. Also, competition and predation by sculpin and Pacific giant salamanders could have reduced the abundance of cutthroat trout in the 1980's and 1990's. Additionally, hatchery rainbow trout were sometimes stocked into upper Piper's Creek in the 1980's, which may have competed or possibly displaced some cutthroat trout. In 2005, the abundance of competitors and predators of cutthroat trout appears to be reduced.

Pfeifer (1984) found cottids were abundant in both areas he sampled in the lower reach of Piper's Creek. In contrast, Thomas (1992) and this study found few cottids were present in the lower reach. Currently, a small weir is located just upstream of the railroad culvert that may limit recruitment of young cottids to the lower reach. The date this weir was constructed is unknown.

Combined, Thomas (1992) collected 16 Pacific giant salamanders in 1991 and 1992. Pfeifer (1984) did not document the presence of Pacific giant salamanders but he may have missed them because he only sampled the lower 1.0 km and Thomas (1992) found they were primarily upstream of this location. We conducted several surveys throughout the basin and salamanders were never observed. Pacific giant salamanders have been shown to be sensitive to increased sedimentation (Welsh and Ollivier 1998). Also, substrate conditions (high embeddedness and few large substrates) and the lack of large woody debris in Piper's Creek may have affected salamander abundance. The cumulative effects of urbanization may have caused Pacific giant salamanders to be extirpated from this system.

Threespine stickleback commonly live for one year, spawn in May through August, and die shortly after spawning (Moyle 2002; Wydoski and Whitney 2003). However, a lifespan of 2-5 years is not uncommon (Baker 1994). In Lake Washington, they only live for one year (Eggers et al. 1978). Basic life-history information of threespine stickleback in Seattle's streams and ponds is not known. In Thornton Creek and Scheuerman Creek, we sampled in August through October after the spawning season and found there may be two perhaps three age groups present (Figures 2.11 and 2.12). Based on length frequencies, fish 10-30 mm were probably age 0, fish 30-60 mm were age 1 and fish > 60 mm may have been age 2. A delay in their maturity may be due to slower growth rates than Lake Washington. Prey availability and low winter and high summer water temperatures (combined with possible low dissolved oxygen levels) may limit their growth. Also, stormwater and other contaminants may reduce growth and delay maturity.

Across their native distribution, threespine stickleback inhabit a vast array of habitat types, from small streams to large lakes to the marine environment including the open ocean (McPhail 2007). Both resident and anadromous forms occur. Typically, they are found in the lower reaches of coastal streams and occur upstream to major fish barriers such as waterfalls. In some areas, they have been introduced, probably as a result of contamination with some type of fish transfer (i.e. trout plantings or baitfish). In Seattle's lakes, ponds, and streams, they also inhabit a large variety of habitat types. They are also an important component of the pelagic zone in Lake Washington. They are widespread throughout the South Branch of Thornton Creek. In the Scheuerman Creek system and Mapes Creek, they were the only species present. They were also abundant in several ponds and appeared to be closely associated with aquatic macrophytes. They are native to Lake Washington but it is unclear if their distribution in Seattle's streams and ponds is a part of the native distribution or is result of introductions.

Although cottids are an abundant, widespread group of fish in the Pacific Northwest, they have a limited distribution in Seattle streams. They were present in six drainages and were usually only found in the lower reaches, often only a few meters from Lake Washington or Puget Sound. The cottids found within the streams of WRIA 8 (Lake Washington basin and a few nearby small independent drainages can be divided within three types: 1) estuarine species, 2) lowland freshwater species, and 3) upland freshwater species. Although there is often a large degree of overlap, these groups generally occupy different areas of a basin. Estuarine species are primarily found in the lower sections of streams that are under tidal influence; lowland freshwater species are widespread in lowland lakes and usually found in the lower reaches of streams and rivers; and upland freshwater species are found in the middle and upper reaches of streams and rivers and upland lakes such as Chester Morse Lake.

The vast majority of estuarine cottids were Pacific staghorn sculpin. Young Pacific staghorn sculpin often move upstream in the spring and can tolerate areas with low salinity (Wydoski and Whitney 2003). The farthest upstream we collected a Pacific staghorn sculpin (44 mm TL) was in Longfellow Creek at river kilometer 0.8. Other estuarine cottids, such as sharpnose sculpin, occasionally enter freshwater but their numbers are usually quite low in comparison to Pacific staghorn sculpin.

Lowland freshwater cottids in the Lake Washington basin consist of coastrange sculpin and prickly sculpin. Both species have planktonic larvae, relatively small eggs, and have higher fecundity rates than most other freshwater cottids (Wydoski and Whitney 2003). They migrate downstream in the spring to spawn, and after spawning, adults and juveniles migrate upstream in the summer and fall (Morrow 1980). Additionally, both species inhabit lacustrine and estuarine environments.

Because the lowland sculpin species typically spawn in lower stream reaches and are not strong swimmers, their ability to disperse to upstream habitats can be limited by small barriers. For some sculpin species, such as the European bullhead *C. gobio*, impassable barriers may be as low as 18-20 cm (Utzinger et al. 1998). Mason and Machodori (1976) found obstructions 30 cm high were impassable to prickly sculpin and 45 cm high were impassable to coastrange sculpin. Shapovalov and Taft (1954) suggested that low-head dams (approximately 90 cm high) were an effective method of eliminating upstream populations of prickly sculpin and coastrange sculpin. In a recent study of sculpin barriers in northwest Washington, LeMoine (2007) found that perched culverts and fish ladders often limited the upstream distribution of prickly sculpin and coastrange sculpin. Our results appear to be consistent with these studies. The upstream distribution of prickly sculpin appeared to be stopped by barriers on Thornton Creek, Taylor Creek, Piper's Creek, and Washington Park Creek. Likewise, the upstream distribution of coastrange sculpin was stopped by the same barrier on Taylor Creek; however, a few coastrange sculpin were found above barriers on Thornton Creek and Piper's Creek. These fish were mostly large individuals, suggesting the barriers limited the upstream movement of small coastrange sculpin but some large individuals were able to move upstream of the barriers probably because of their superior swimming ability.

Upland freshwater cottids in the Lake Washington basin consist of riffle sculpin *C. gulosus*, torrent sculpin *C. rhotheus*, and shorthead sculpin *C. confusus* (Tabor et al. 2007a). These species have larger eggs and lower fecundity than the lowland species (Wydoski and Whitney 2003). Larvae can be either demersal (riffle sculpin) or planktonic (shorthead sculpin). None of the upland species were observed in Seattle streams. Shorthead sculpin typically inhabit coldwater streams and thus would not be expected to inhabit Seattle's streams. However, riffle sculpin and torrent sculpin are widespread in tributaries to Lake Washington and Lake Sammamish and thus would be expected to occur in some Seattle streams such as Thornton Creek. For example, riffle sculpin and torrent sculpin are common in May Creek, a similar-sized stream as Thornton Creek. Reasons why the upper reaches of Thornton Creek and other streams are void of upland cottids is unclear. Increased urbanization often leads to severe changes in stream habitat conditions such as higher peak flows, elevated water temperatures, reduction in water quality and reduction of habitat quality (i.e., reduction in the amount of woody debris and pools). The effects of high peak flows may be especially deleterious to cottid populations (Erman et al. 1988).

If cottid populations have been extirpated and habitat conditions improve, coastrange sculpin and prickly sculpin, which are widespread in Lake Washington and in nearshore areas of Puget Sound, can easily move into the lower stream reaches. However, their upstream distribution will be limited by barriers. Upland cottid species may have a difficult time returning to many streams once they have been extirpated. They often have a restricted home range and disperse slowly. For example, Moyle (2002) noted that riffle sculpin in a small stream California took over 18 months to recolonize a riffle that went dry that was 500 m downstream of a large population. The upland cottid species have not been documented in Puget Sound or Lake Washington. Large lakes such as Lake Washington may also serve as a barrier to dispersal to other streams due to predation from prickly sculpin and exotic fishes such as yellow perch *Perca flavescens* and smallmouth bass.

Attempts to rehabilitate urban streams should consider the reintroduction of upland cottids. In particular, riffle sculpin and torrent sculpin would be good candidates for a recolonization experiment. These species can complete their life-cycle in a relatively small area. Reintroduction of sculpin would provide valuable information on stream habitat conditions and help identify factors affecting their survival. These types of experiments may provide valuable information on why more urbanized systems tend to have few sculpin (Matzen and Berge 2008). Freshwater sculpin have been used as an indicator species of stream health (Gray et al. 2004; Gray et al. 2005; Adams and Schmetterling 2007). Groups of sculpin could be introduced into different streams and different habitat types to understand factors affecting their survival. Locations with both stream and pond habitat such as Littles Creek in Jackson Park Golf Course would have diverse habitat conditions where cottid populations would be more likely to withstand high-flow conditions. The introduced sculpin should be PIT tagged and their movements monitored with mobile and stationary receivers to understand factors (i.e. high flow events) related to their movements. Additionally, sculpin in other less-developed watersheds such as May Creek could be PIT tagged and their movements compared to sculpin movements in Thornton Creek.

Introduction of any species should be considered carefully before any decision is made. Impacts to the existing ecosystem can often be difficult to predict, particularly in systems that have a complex food web. Impacts of introduced sculpin to the ecosystem would likely be due to predation and/or competition with native salmonids. Sculpin have been documented to prey on juvenile salmonids and salmonid eggs in many systems (Foote and Brown 1998; Tabor et al. 2007b); however, sculpin do not appear to be a major predator in most cases (Moyle 1977). Sculpin may also compete with salmonids for benthic macroinvertebrates. The degree of competition can vary between size and species of salmonid present (Zimmerman and Vondracek 2007). Alternatively, sculpin may provide a valuable prey resource for stream-dwelling salmonids. Consumption of small sculpin by cutthroat trout and other salmonids has been documented in Pacific Northwest streams and rivers (Lowry 1966; Price 2006). Exactly how sculpin would affect the food web and salmonid populations is difficult to predict. If sculpin are introduced, monitoring of salmonid and sculpin diet and growth and the macroinvertebrate community will be needed to understand their interrelationships.

Managers should also consider removing man-made barriers that limit the upstream movement of coastrange sculpin and prickly sculpin. Currently, barriers on Piper's Creek, Thornton Creek, and Washington Park Creek appear to restrict upstream movement of these cottids. Monitoring efforts before and after the barriers are removed would provide information on movements of prickly sculpin and coastrange sculpin into upstream reaches.

In addition to constraints to upstream movements of cottids, small barriers may also restrict the distribution of juvenile salmonids. Juvenile Chinook salmon and coho salmon often move into non-natal tributaries to use as rearing areas, sometimes for several months. Juvenile cutthroat trout may also move into small streams but it is difficult to determine whether a stream is a natal or non-natal stream because adults can spawn in small streams. Because the abundance of juvenile coho salmon and Chinook salmon is low in Seattle's streams it is usually difficult to assess whether a particular obstacle is a barrier. Little information is available on what constitutes a barrier to juvenile salmonids. In earlier surveys of Matthews Creek (Tabor et al. 2004), we observed several juvenile coho salmon at the base of a log weir and they did not appear to move upstream until the lake level rose and the weir was no longer a barrier. Juvenile Chinook salmon, however, were able to move upstream past the barrier even when the lake level was low. In Taylor Creek, juvenile Chinook salmon have only been observed up to the small waterfall at Rm 88 (290 ft). Presumably this waterfall, that is a barrier for cottids, is also barrier for juvenile Chinook salmon.

Nonnative fish species were collected in some streams; however their abundance was generally low in comparison to native fish species. The species of nonnative fish in Seattle's streams are not well-adapted to inhabit small streams and do not appear to be a significant threat to the ecosystem health. Most nonnative fish collected were juvenile sunfish from upstream ponds. In fact they may be somewhat beneficial; as juvenile sunfish move out of pond habitats they may become a food source for native salmonids such as cutthroat trout. Another species, oriental weatherfish was collected in lower Thornton Creek as early as 1998 (Resource Planning Associates 1998), yet there does not appear to be any large increase in their abundance.

In some ponds, nonnative species including largemouth bass, rock bass, pumpkinseed, and brown bullhead may dominate the fish fauna. In these habitats they could impact the abundance of native fishes through predation and perhaps competition. If native fishes inhabit the pond throughout the year (threespine stickleback and sculpin) or are only present when water temperatures are cool (cutthroat trout and juvenile coho salmon), they could have some overlap with nonnative fishes and could be negatively impacted. Additionally, amphibians, crayfish, and other pond organisms may be impacted by introductions of nonnative fishes.

CHAPTER 3. REFERENCE SITE FISH DENSITIES

Introduction and Methods

A key element of management of Seattle's streams is long-term monitoring, which includes effectiveness monitoring of stream restoration projects and long-term monitoring to assess changes in ecosystem health. Within each of the five major watersheds, we undertook more intensive sampling of the fish community at one or more sites. These sites will serve as reference sites, which will be sampled again and again to assess long-term changes in the fish community. Sites in Thornton Creek watershed were selected because they are restoration sites (Table 3.1). Instream restoration work of the Maple Leaf Reach of the South Branch of Thornton Creek was completed in 2008, which included the addition of two logjams and some large boulders. We conducted pre-project monitoring of this site in 2005 and 2006. Within the Thornton Creek basin, we also conducted pre-project monitoring of the lower section of Kramer Creek. The city plans to reconfigure the convergence area and stream channel; however, the exact project plan and schedule is not known at this time. Sites in Piper's Creek will be used to assess upland land-use changes to reduce stormwater flows and create a more natural drainage pattern. Sites in the other three major watersheds will serve as long-term reference sites to assess ecosystem health. Our reference site in Taylor Creek is above a man-made barrier, that the city plans to be removed, but it may be several years before the barrier is removed. Our sampling will provide baseline information once the barrier is removed. One site was surveyed on each stream, except Venema Creek where two sites were surveyed, one below the confluence with Mohlendorph Creek and one above the confluence. Reference sites were between 50 and 130 m long.

We used depletion procedures to determine the overall fish abundance and biomass in each site. Multiple-pass electrofishing was conducted to capture fish. We first divided each site into habitat units: riffles, pools, and glides. Block nets (5.8-m long by 1.2-m high with 5-mm square mesh) were used to isolate each habitat unit. Once all the nets were in place, crews waited approximately 15 minutes before sampling. Depending on the size of the reach, two or three crew members worked together to

Table 3. 1 - Location (Rm, river kilometer) and sample dates of reference sites surveyed within Seattle's streams. Appendix number is the map which displays the location of each sample site (sample #).

Stream system #	Stream Name	Distance from mouth (m)	(ft)	Date Sampled	Sample #	Appendix
5	Piper's Creek	762-812	2,500-2,664	3-Mar-05	500	1.2
				19-Oct-05	501	1.2
				29-Sep-06	502	1.2
	Venema Creek - lower	0-50	0-164	3-Mar-05	510	1.2
				19-Oct-05	511	1.2
				29-Sep-06	512	1.2
	Venema Creek - upper	200-250	656-820	3-Mar-05	513	1.2
		270-320	886-1,050	20-Oct-05	514	1.2
				29-Sep-06	515	1.2
	Mohlendorph Creek	100-150	328-492	19-Oct-05	516	1.2
14	South Branch Thornton Creek	534-688	1,804-2,257	24-Feb-05	520	1.10
				13-Oct-05	521	1.10
				2-Aug-06	522	1.10
	Kramer Creek	0-108	0-354	25-Feb-05	523	1.10
				28-Sep-05	524	1.10
				26-Jul-06	525	1.10
34	Longfellow Creek	1,054-1,126	3,460-3,693	7-Aug-06	530	1.23
42	Fauntleroy Creek	227-332	750-1,088	18-Oct-05	540	1.27
				8-Aug-06	541	1.27
49	Taylor Creek	439-539	1,440-1,768	17-Oct-05	550	1.30
				3-Aug-06	551	1.30

collect fish from each habitat. One person was used to operate the electrofisher and one or two were needed to net the stunned fish. Electrofishing was conducted with pulsed DC current set at 200 to 300 volts depending on the stream conductivity and effectiveness of stunning the fish. Sampling began at the downstream end. At least three passes were conducted. We stopped sampling on the third pass if the catch (number of fish) on the third pass was less than 50% of the catch on the second pass. If a 50% depletion of fish was not achieved on the third pass for any habitat, a fourth or sometimes a fifth pass was conducted until a 50% depletion was achieved. Fish from each pass and each habitat type were kept in separate buckets. Fish were anesthetized with MS-222 and identified. The fish length (nearest mm) and weight (nearest 0.1 g) were measured. After fish had been processed and released and the block nets removed, we conducted a habitat survey of the reference site. Habitat data collected included:

Habitat length- Stream length from the downstream end of the habitat to the upstream end via the thalweg of the stream.

Habitat width- The wetted width of the habitat was calculated from the mean of three equidistant width measurements: ¼, ½, and ¾ of the stream length of each habitat unit.

Depth- A mean and maximum depth was recorded at each habitat unit. The average depth was measured by randomly placing the hand held stadia rod at different locations within the habitat and averaging those values. The maximum depth of the habitat was collected by using the stadia rod to find the deepest part of each habitat unit. For pools we also measured the depth of the tailout or pool outlet. The tailout measurement is taken at the shallowest part (lengthwise) of the pool and the deepest part of the tailout (cross-section). The residual pool depth is the maximum pool depth minus the tailout depth.

Large woody debris- At each habitat unit, LWD was counted. A piece of large woody debris was any wood that was over 2 m in length and was 10-cm wide at the midpoint and was in contact with the stream. Procedures followed the TFW methodology for Level 1 (Zone 1) surveys of LWD (Schuett-Hames et al. 1999).

Estimated population ($\hat{N}$) size for each reference site was calculated using the procedures of Carle and Strub (1978). A single population estimate was made for each site. We did not make a estimate for each habitat unit because the number of fish in each habitat unit was usually too low to make a precise population estimate.

Results

Piper's Creek Watershed.-- Piper's Creek reference site was sampled on three occasions: March 3, 2005, October 19, 2005, and September 29, 2006. At this location, the mean stream width was 2.8 m, maximum depth was 0.5 m, and the habitat consisted of approximately 26% pools (by area), 48% riffles and 26% glides (Table 3.2). Ninety-nine percent (191 of 193) of the fish captured at this site were cutthroat trout. The other two fish were coho salmon; one appeared to be a returning adult and was not used in our density estimates. The estimated population size ($\hat{N}$) of cutthroat trout was similar between March 2005 ($\hat{N}$ = 43) and October 2005 ($\hat{N}$ = 44), but was substantially higher in September 2006 ($\hat{N}$= 117; Table 3.3). In September 2006, 77% of the cutthroat trout were < 100 mm FL; whereas in March 2005 and October 2005, 47% and 29%, respectively were < 100 mm FL (Figure 3.1).

Table 3. 2 - Habitat information and number of fish collected in different habitat types of reference sites in the Piper's Creek watershed. %Fish is the percent of fish for each reference site that was collected in each habitat type (not adjusted by area). NA = no data available.

Site location	Date Sampled	Habitat Types	Number of Habitats	Combined Lengths (m)	Mean Wetted Width (m)	Area (m^2)	Mean Depth (m)	Maximum Depth (m)	# of Fish Captured	% Fish
Mainstem	3-Mar-05	Riffle	2	35.5	2.8	99.4	0.10	0.17	21	56.8
		Pool	1	2.5	1.8	4.5	0.20	0.50	5	13.5
		Glide	1	10.0	3.1	31.0	0.15	0.20	11	29.7
	19-Oct-05	Riffle	4	24.5	2.1	51.5	0.15	0.30	13	30.2
		Pool	2	17.5	3.4	59.5	0.20	0.45	20	46.5
		Glide	2	9.5	4.6	43.7	0.20	0.40	10	23.3
	29-Sep-06	Riffle	3	19.5	2.6	50.8	0.09	0.10	18	15.9
		Pool	4	19.2	2.5	48.0	0.30	0.42	64	56.6
		Glide	1	11.1	3.2	35.5	0.19	0.28	31	27.4
Lower Venema Cr	3-Mar-05	Riffle	5	41.6	1.4	58.2	0.10	0.15	17	58.6
		Pool	4	9.5	2.1	20.0	0.20	0.47	12	41.4
	19-Oct-05	Riffle	6	40.2	1.2	48.2	0.05	0.15	3	25.0
		Pool	4	13.1	1.9	24.9	0.25	0.38	7	58.3
		Glide	1	2.5	1.3	3.3	0.10	0.61	2	16.7
	28-Sep-06	Riffle	8	37.3	1.3	48.5	0.08	NA	12	27.9
		Pool	7	16.4	1.8	29.5	NA	1.80	31	72.1
Upper Venema Cr	3-Mar-05	Riffle	5	41	1.5	61.5	0.17	0.21	3	42.9
		Pool	4	8	1.5	12.0	0.31	0.39	4	57.1
	20-Oct-05	Riffle	5	19.9	1.2	23.9	0.05	0.16	0	0.0
		Pool	2	3	1.7	5.1	0.13	0.30	2	28.6
		Glide	3	9	1.7	15.3	0.11	0.22	4	57.1
		Cascade	1	18	2.8	50.4	0.04	0.20	1	14.3
	29-Sep-06	Riffle	4	38.4	1.2	46.1	0.05	NA	3	42.9
		Pool	2	2.25	1.5	3.4	NA	0.25	1	14.3
		Cascade	1	10.97	0.8	8.8	0.06	NA	3	42.9
Mohlendorph Cr	19-Oct-05	Riffle	8	44.7	0.88	15.9	0.02	0.11	0	--
		Glide	8	15.9	1.08	44.7	0.06	0.20	0	--

Table 3. 3 - Population and density estimates of reference sites in Piper's Creek and Thornton Creek watersheds. Data is for cutthroat trout except data in parentheses which is for all fish combined. Other fish included rainbow trout, coho salmon, threespine stickleback, and pumpkinseed. Population estimates were calculated using depletion techniques of Carl and Strub (1978). Biomass (fish (g)/m²) is calculated by multiplying Fish/m² by the average weight (g) for each species. No fish were collected in Mohlendorph Creek and it is not included in this table.

Watershed	Site location	Date sampled	Estimated population	Mean length (mm)	Mean weight (g)	Fish / m	Fish / m²	Fish (g) / m²	Length of unit (m)	Mean wetted width (m)	Area (m²)
Piper's Creek	Mainstem	3-Mar-05	43	119.7	20.50	0.90	0.32	6.56	48.0	2.8	134.9
		19-Oct-05	43	113.9	21.10	0.83	0.28	5.91	51.5	3.0	154.5
		29-Sep-06	116 (117)	91.7	11.60	2.35 (2.35)	0.87 (0.87)	10.09 (10.15)	49.8	2.7	134.5
	Venema Cr (lower)	3-Mar-05	29	113.1	21.80	0.57	0.37	8.07	51.1	1.5	78.2
		19-Oct-05	12	126.6	26.70	0.22	0.16	4.27	55.8	1.4	76.4
		28-Sep-06	43 (44)	90.8	11.30	0.80 (0.82)	0.55 (0.57)	6.22 (6.45)	53.7	1.5	77.9
	Venema Cr (upper)	3-Mar-05	7	104.1	15.40	0.14	0.10	1.54	49.0	1.5	73.5
		19-Oct-05	7	106.4	14.50	0.14	0.07	1.02	49.9	1.9	94.8
		29-Sep-06	7	79.4	6.00	0.14	0.12	0.72	51.6	1.1	58.3
Thornton Creek	South Branch	24-Feb-05	241	98.3	10.10	1.90	0.69	6.97	126.9	2.8	351.5
		13-Oct-05	309 (310)	87.6	8.34	2.70 (2.70)	1.06 (1.06)	8.77 (8.77)	114.8	2.6	293.9
		2-Aug-06	489	50.7	3.44	4.80	1.76	6.05	101.9	2.7	277.2
	Kramer Creek	25-Feb-05	76 (85)	108.0	15.80	0.70 (0.79)	0.57 (0.64)	9.01 (9.67)	107.5	1.2	133.3
		28-Sep-05	31 (32)	121.4	24.80	0.29 (0.30)	0.25 (0.26)	6.20 (6.25)	107.3	1.2	123.4
		26-Jul-06	52 (55)	87.2	11.15	0.50 (0.53)	0.43 (0.45)	4.79 (5.45)	104.6	1.2	121.3

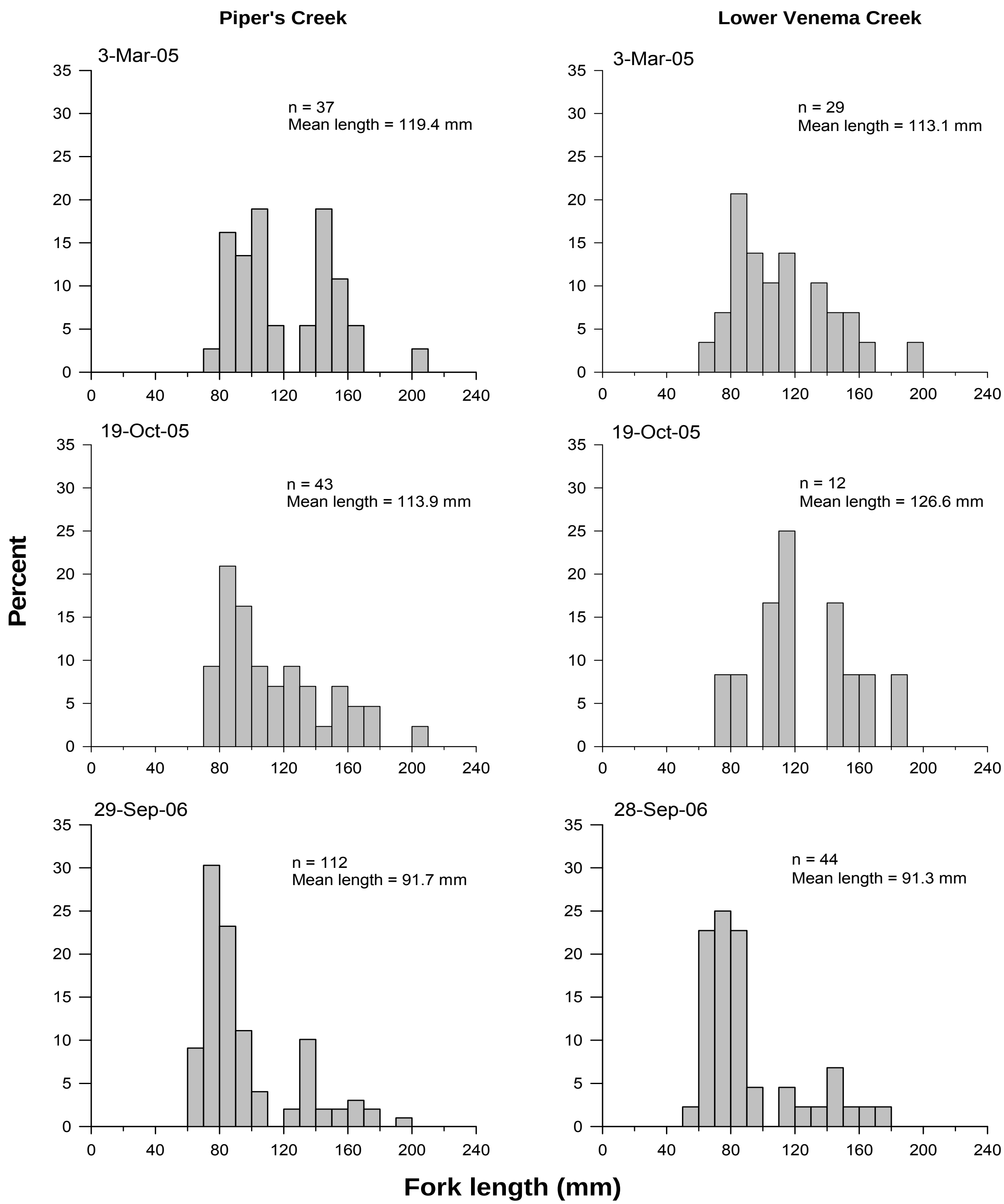

Figure 3. 1 - Length frequency (10-mm FL increments) of cutthroat trout collected from the reference site of Piper's Creek and lower Venema Creek. Total number of cutthroat trout sampled and mean length is given in each panel.

The two reference sites on Venema Creek were sampled three times; each time within a day of sampling Piper's Creek. The lower Venema site had a mean wetted width of 1.45 m and a maximum depth of 0.61 m. Stream habitat at this site was composed of approximately 32% pools (by area), 62% riffles and 1% glides. For the three dates combined, 85 fish were collected (does not include several chum salmon fry that originated from an acclimation pond), 84 were cutthroat trout and one was a rainbow trout. The estimated populations of cutthroat trout varied from 12 on October 19, 2005 to 43 on September 29, 2006. Overall, 59% of the cutthroat trout were collected in pools yet only 32% of the habitat by area was composed of pools.

The upstream reference site of Venema Creek was originally sampled in March of 2005 from Rm 200 to 250 (656-820 ft) but was later moved further upstream to Rm 270-320 (886-1,050 ft) for the October 2005 and September 2006 sampling periods. Only cutthroat trout were collected during each sampling period. The estimated population size ($\hat{N}$ = 7) was the same for each sampling period. For all surveys combined, 90.5% of the cutthroat trout were less than 120 mm (N = 21; range, 71-152 mm FL). On average, pools made up roughly 9% of the habitat area, but 33% of the fish were collected in pools.

A reference site was also established on Mohlendorph Creek between Rm 100 and 161 (328-492 ft) and was surveyed on October 19, 2005. However, because no fish were captured and there was little streamflow and available habitat, we did not resurvey this site. The site had a mean wetted width of 0.93 m and a maximum depth of 0.20 m. Stream habitat at this site was composed of approximately 70% riffles (by area) and 30% glides.

Thornton Creek watershed.— The reference site on the South Branch of Thornton Creek (Maple Leaf Reach) was substantially larger (307 m^2) than any other reference site (range, 77-192 m^2). This site was located approximately 550 m from where the South Branch merges with the North Branch. Little LWD was present at this site (Table 3.4). Habitats at this site were composed of approximately 8% pools (by area), 59% riffles, 33% glides (Table 3.5). Large numbers of cutthroat trout were collected on each sampling date. Except of one threespine stickleback, they were the only species captured at this site. The estimated abundance of cutthroat trout increased in each sampling period from February 2005 to August 2006 (Table 3.3). Most cutthroat trout were between 50 and 100 mm FL (range, 39-200 mm FL; Figure 3.2).

Our other reference site in the Thornton Creek watershed was Kramer Creek, a small tributary of the South Branch of Thornton Creek. The lowest 160 m of the stream was used as a reference site; however 52.5 m of this length were in seven culverts, which we could not sample and were not included in the analysis. The downstream end of the site was a convergence pool with the South Branch of Thornton Creek. The mean wetted width of the entire site was 1.18 m and had a maximum depth of 0.7 m. Stream habitat at this site was composed of 23% pools (by area) and 77% glides (Table 3.5). Cutthroat trout was the primary species captured (*n* = 167), however three threespine stickleback, nine pumpkinseed, and one juvenile coho salmon were also captured. The highest abundance of cutthroat trout was on February 25, 2005 ($\hat{N}$ = 76) and the lowest was on September 26, 2006 ($\hat{N}$ = 31). Therefore, this tributary may be better habitat for trout in the winter (high-flow conditions) than during the late summer (low-flow conditions).

Table 3. 4 - Number and density (number of pieces /100 m) of large woody debris (LWD) at reference sites in Seattle's streams, 2005-2006. Each piece of LWD was at least 2 m long and 10 cm at the midpoint.

Stream system	Site Location	Date Sampled	Length Sampled (m)	Total # of LWD	LWD / 100 m
Piper's	Mainstem	3-Mar-05	52	2	3.8
		19-Oct-05	51.5	5	9.7
	Lower Venema Cr.	3-Mar-05	51	8	15.7
		19-Oct-05	55.8	7	12.5
	Upper Venema Cr.	3-Mar-05	49	1	2.0
		20-Oct-05	49.9	6	12.0
	Mohlendorph	19-Oct-05	60.6	0	0.0
Thornton	South Branch	24-Feb-05	126.9	1	0.8
		13-Oct-05	114.8	2	1.7
		2-Aug-06	101.9	3	2.9
	Kramer Creek	25-Feb-05	107.5	0	0.0
		28-Sep-05	107.3	0	0.0
		26-Jul-06	104.6	0	0.0
Longfellow	Mainstem	7-Aug-06	71.8	15	20.9
Fauntleroy	Mainstem	18-Oct-05	103.3	31	30.0
		8-Aug-06	102.9	51	49.6
Taylor	Mainstem	17-Oct-05	119.2	10	8.4
		3-Aug-06	99.7	17	17.1

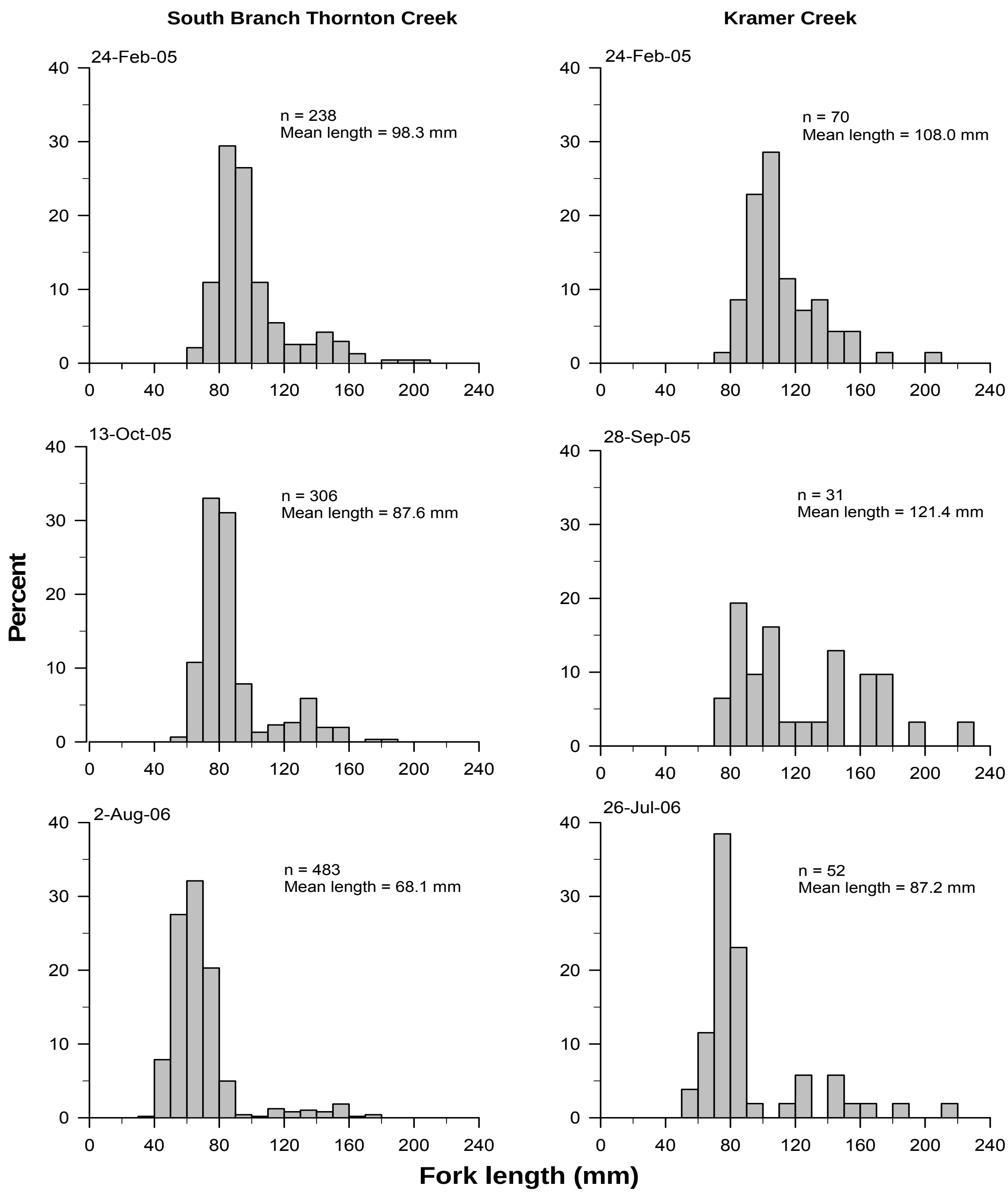

Figure 3. 2 - Length frequency (10-mm FL increments) of cutthroat trout collected from the reference site of South Branch Thornton Creek (Maple Leaf Site) and Kramer Creek. Total number of cutthroat trout sampled and mean length is given in each panel.

Table 3. 5 - Habitat information and number of fish collected in different habitat types of reference sites in the Thornton Creek watershed. %Fish is the percent of fish for each reference site that was collected in each habitat type (not adjusted by area). CV = convergence pool.

Site location	Date Sampled	Habitat Type	Number of Habitats	Combined Lengths (m)	Mean Wetted Width (m)	Area (m^2)	Mean Depth (m)	Maximum Depth (m)	# of Fish Captured	% Fish
South Branch Thornton Cr	24-Feb-05	Riffle	5	73.5	2.9	213.0	0.15	0.38	75	32
		Pool	3	25.9	2.7	70.0	0.25	0.45	81	34
		Glide	2	27.5	2.4	66.0	0.20	0.35	82	34
	13-Oct-05	Riffle	5	56.6	2.6	144.3	0.11	0.27	88	29
		Pool	1	2.2	2.4	5.2	0.15	0.32	7	2
		Glide	5	56.0	2.6	145.0	0.15	0.31	211	69
	2-Aug-06	Riffle	5	40.6	2.8	113.7	0.15	0.31	108	22
		Glide	3	30.1	3.1	93.3	0.17	0.37	208	43
		Run	3	31.2	2.3	71.8	0.10	0.21	167	35
Kramer Cr	25-Feb-05	Pool	2	8.2	1.8	14.7	0.20	0.40	19	24
		Glide	5	95.2	1.1	104.8	0.20	0.45	37	47
		CV	1	4.1	2.8	11.5	0.25	0.50	23	29
	28-Sep-05	Pool	2	8.9	1.7	15.2	0.15	0.38	7	22
		Glide	5	94.2	1.0	94.2	0.28	0.38	7	22
		CV	1	4.2	3.5	14.7	0.40	0.88	18	56
	26-Jul-06	Pool	2	7.8	1.7	13.3	0.18	0.35	24	43
		Glide	5	92.2	1.0	90.4	0.13	0.46	15	27
		CV	1	4.6	3.9	17.9	0.40	0.70	17	30

Longfellow Creek.— The reference site in Longfellow Creek was only sampled once, August 2006. The reference site was 71 m with a mean wetted width of 2.7 m and a maximum depth of 0.56 m. Habitat at this site was comprised of 42% pools (by area), 7% riffles, and 51% glides (Table 3.6). The estimated fish abundance was 88 coho salmon, 80 threespine stickleback, and 7 prickly sculpin (Table 3.7). Coho salmon lengths ranged between 60 and 110 mm FL (mean FL, 81.8 mm) and threespine stickleback between 20 and 80 mm FL (mean FL, 38.6 mm; Figure 3.3). The total fish biomass estimate was generally low compared to other references sites in similar-sized streams (Piper's Creek and South Branch Thornton Creek; Figure 3.4). Many of the fish were collected in glides at the lower end of the site that had undercut banks. Twenty-three percent of the fish were collected in pools, 1% in riffles and 76% in glides.

Fauntleroy Creek.-- The reference site on Fauntleroy Creek was sampled twice, once in 2005 and again in 2006. The reference site was located at Rm 227-332 (750-1,088 ft) and was 103 m long with an average wetted width of 1.37 m. On both occasions, few fish were collected and only juvenile coho salmon were collected. The estimated population size of coho salmon varied from 14 in October 2005 to 32 in August 2006. A large percentage of juvenile coho salmon were less than 90 mm for October 2005 and less than 80 mm for August 2006 (Figure 3.5). Stream habitat was composed of 7% pools (by area) 79% riffles, and 14% glides. Sixty-five percent of juvenile coho salmon were taken from pools, 18% from riffles, and 17% from glides.

Taylor Creek.— The Taylor Creek reference site was the only site to have large numbers of both cutthroat trout and juvenile coho salmon present (Table 3.7; Figure 3.6). Taylor Creek has an impassable barrier downstream of our reference site. Therefore, the juvenile coho salmon were outplanted and the cutthroat trout were from a resident population that does not have any input from the lake. For both sample dates, cutthroat trout represented close to 75% of the fish biomass, but only 43 to 64% of the population size. Similar to reference sites on Longfellow Creek and Fauntleroy Creek, fish biomass was also low in Taylor Creek. Stream habitat consisted of 60% riffles, 11% pools, and 29% glides, while average fish catch consisted of 22% in riffles, 29% in pools, and 49% in glides.

Table 3. 6 - Habitat information and number of fish collected in different habitat types of reference sites in the Longfellow Creek, Fauntleroy Creek, and Taylor Creek. %Fish is the percent of fish for each reference site that was collected in each habitat type (not adjusted by area).

Site location	Date Sampled	Habitat Types	Number of Habitats	Combined Lengths (m)	Mean Wetted Width (m)	Area (m^2)	Mean Depth (m)	Maximum Depth (m)	# of Fish Captured	% Fish
Longfellow Cr	7-Aug-06	Riffle	1	7.1	1.9	13.5	0.15	0.34	2	1
		Pool	3	21.0	3.8	79.8	0.25	0.56	42	29
		Glide	4	43.0	2.3	98.9	0.20	0.42	101	70
Fauntleroy Cr	18-Oct-05	Riffle	7	70.6	1.4	98.8	0.05	0.10	7	50
		Pool	6	16.0	1.3	20.8	0.20	0.50	5	36
		Glide	5	16.7	1.5	25.1	0.10	0.20	2	14
	8-Aug-06	Riffle	6	93.0	1.3	120.9	0.15	0.40	25	81
		Glide	3	9.9	1.4	14.3	0.10	0.20	6	19
Taylor Cr	17-Oct-05	Riffle	10	75.2	1.5	114.3	0.09	0.12	4	11
		Pool	2	6.8	2.6	17.8	0.20	0.45	13	35
		Glide	7	37.2	1.6	58.8	0.15	0.30	20	54
	3-Aug-06	Riffle	9	62.8	1.8	113.0	0.10	0.15	44	33
		Pool	4	8.4	2.7	22.5	0.20	0.48	31	23
		Glide	5	28.5	1.8	51.3	0.15	0.21	59	44

Table 3. 7 - Population and density estimates of reference sites in Longfellow Creek, Fauntleroy Creek, and Taylor Creek. Population estimates were calculated using depletion techniques of Carl and Strub (1978). Biomass (fish (g)/m²) is calculated by multiplying Fish/m² by the average weight (g). Species captured were coho salmon (COH), cutthroat trout (CUT), threespine stickleback (STB), and prickly sculpin (PKS).

Stream	Date sampled	Species	Estimated population	Mean length (mm)	Mean weight (g)	Fish / m	Fish / m²	Fish (g) / m²	Length of Unit (m)	Mean wetted width (m)	Area (m²)
Longfellow Creek	7-Aug-06	COH	88	81.7	7.20	1.24	0.44	3.17	71.0	2.7	192.4
		STB	80	38.6	0.70	0.10	0.40	0.28			
		PKS	7	128.0	27.70	1.13	0.04	1.11			
Fauntleroy Creek	18-Oct-05	COH	14	89	8.60	0.14	0.10	0.86	103.3	1.4	144.6
	8-Aug-06	COH	32	71.5	5.00	0.31	0.23	1.15	102.9	1.34	137.9
Taylor Creek	17-Oct-05	COH	21	80.0	6.10	0.18	0.11	0.67	119.2	1.6	190.7
		CUT	16	133.0	31.38	0.13	0.08	2.51			
	3-Aug-06	COH	48	41.3	3.60	0.48	0.29	1.04	99.7	1.7	168.5
		CUT	86	63.9	5.10	0.86	0.51	2.60			

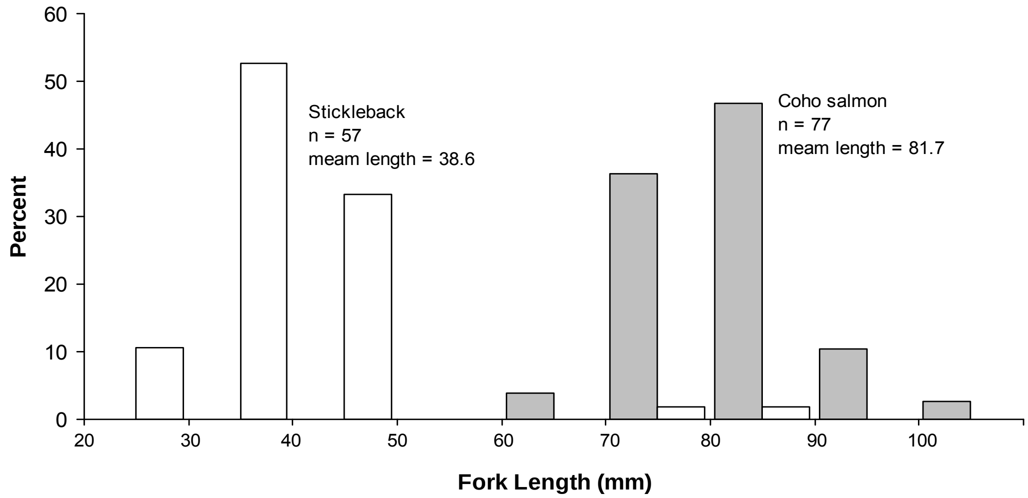

Figure 3. 3 - Length frequency (10-mm FL increments) of threespine stickleback (open bars) and juvenile coho salmon (shaded bars) collected from the reference site of Longfellow Creek, August 7, 2006. Total number of fish sampled and mean length is also given.

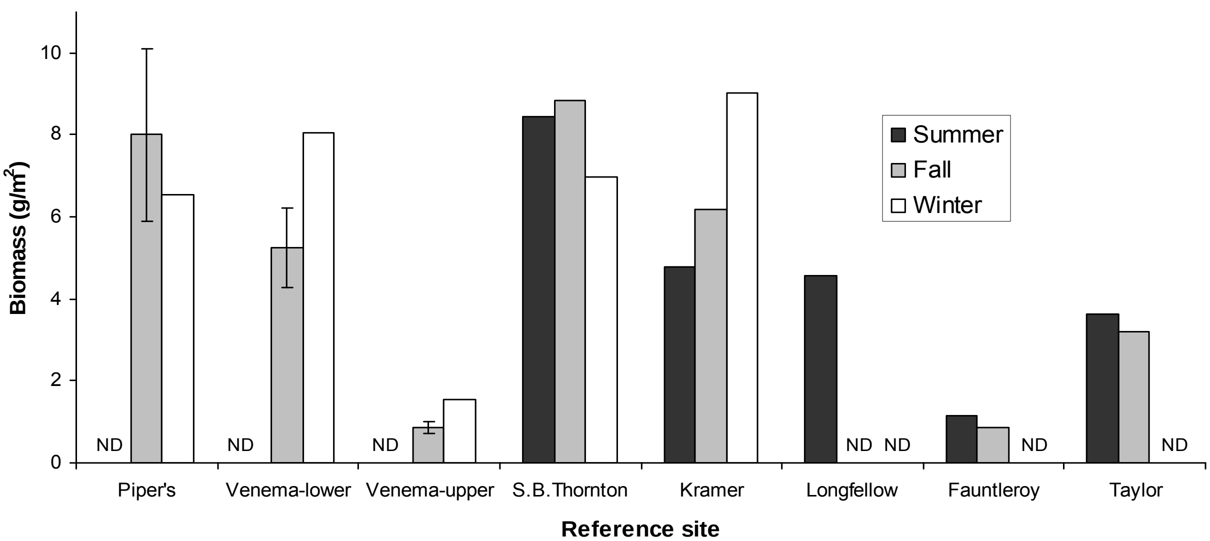

Figure 3. 4 - Salmonid biomass estimates (g/m^2) for different seasons at eight reference sites, 2005-2006. Error bars represent the range of two observations. If no error bar is shown, it indicates it was only sampled once for a particular season. S.B. Thornton = South Branch of Thornton Creek; ND = no data.

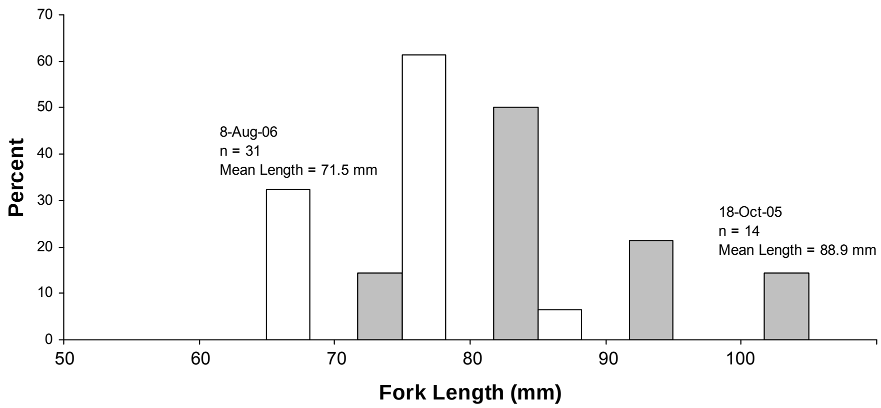

Figure 3. 5 - Length frequency (10-mm FL increments) of juvenile coho salmon collected from the reference site of Fauntleroy Creek, October 18, 2005 (shaded bars) and August 6, 2006 (open bars). Total number of fish sampled and mean length is also given.

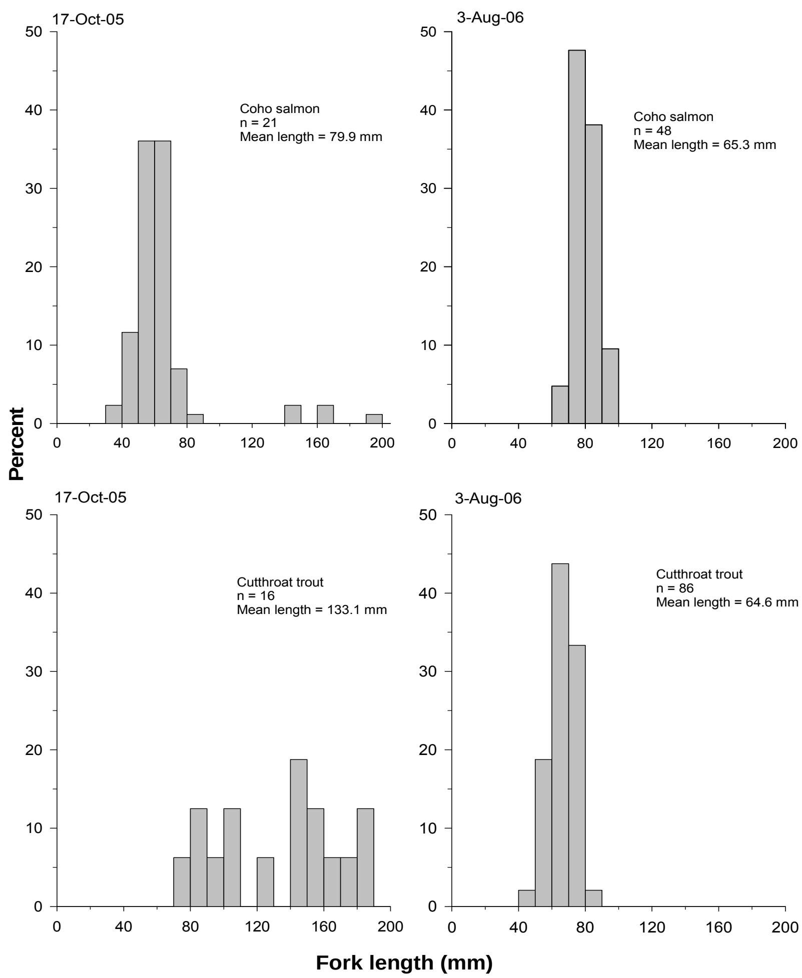

Figure 3. 6 - Length frequency (10-mm FL increments) of coho salmon and cutthroat trout collected from the reference site of Taylor Creek. Total number of fish sampled and mean length is also given.

Discussion

Our reference-site surveys provide essential baseline information for future comparisons to examine changes after restoration activities or examine long-term changes in ecosystem health. Restoration work has been completed in the Maple Leaf Reach of the South Branch Thornton Creek and additional surveys are needed to determine the effectiveness of the restoration project. Our reference-site surveys in the Piper's Creek watershed are part of ongoing monitoring by NOAA Fisheries to assess a large natural drainage project. Restoration projects are in the planning stage for Kramer Creek (reconfigure stream channel) and Taylor Creek (remove barrier). In Longfellow Creek, ongoing studies are being conducted by NOAA Fisheries and USFWS to determine the cause of pre-mortality of adult coho salmon. If the cause is identified and stream habitat conditions improve, resampling of our reference site could provide valuable information.

The density of salmonids in our reference sites in the South Branch of Thornton Creek and Piper's Creek appears to be high in comparison to other lowland streams in the Pacific Northwest. For example, Roni (2000) sampled 30 lowland streams in Washington and Oregon during the summer low period using the same techniques we used. He used streams that had a bankfull width of 4 to 12 m. We did not measure bankfull width but our reference sites on South Branch of Thornton Creek (2.7 m wetted width) and Piper's Creek (2.8 wetted width) probably fit within this range. Using our summer samples for comparison, we observed a density of 4.8 salmonids/m in South Branch of Thornton Creek. Roni (2000) only observed a density higher than this in one stream (range, 0.22 to 5.03 salmonids/m). We did not sample Piper's Creek in the summer but we did sample in late September and we observed a density of 2.4 salmonids/m, which is higher than 80% of the streams sampled by Roni (2000). In the streams sampled by Roni (2000), coho salmon, steelhead, and cutthroat trout were present; whereas, in the South Branch of Thornton Creek and Piper's Creek almost all fish were cutthroat trout. The density of cutthroat trout (fish/m) in these two reference sites was approximately 1.2 to 96 times higher (assuming all unidentified juvenile trout were cutthroat trout) than in any stream sampled by Roni (2000).

Kramer Creek had an unexpectedly high abundance of fish. The creek is relatively small and has little woody debris or other structure. The creek runs along a road and is open with no forested canopy (Figure 3.7). The stream is a series of plunge pools and glides separated by culverts that are under residential driveways. Many of the fish we collected in Kramer Creek were from the convergence pool with the South Branch of Thornton Creek. The convergence pool was relatively deep (maximum depth, 0.5-0.88 m), which may provide adequate cover for large cutthroat trout. Also, at the head end of each plunge pool, the depth was relatively deep, which may provide adequate trout habitat. The creek also had a large amount of water cress and other emergent vegetation, which may provide cover and food (macroinvertebrates) for trout (Figure 3.7). Research of streams in the Pacific Northwest has shown that open streams may be more productive and have a higher abundance of salmonids than streams with a forested canopy (Hawkins et al.1983).

Of the three sample dates, cutthroat trout abundance in Kramer Creek was highest during the winter sample. In contrast, winter cutthroat trout abundance in South Branch of Thornton Creek was slightly lower than the summer or fall samples. The abundance of other species (pumpkinseed, threespine stickleback, and juvenile coho salmon) in Kramer Creek was also highest in the winter. The lower part of Kramer Creek may provide good winter habitat because it has a low gradient and may not have high water velocities during storm events. Also, salmonids generally seek cover during the winter and the emergent vegetation in Kramer Creek may provide the necessary cover. Winter flow conditions in the South Branch of Thornton Creek may cause some cutthroat trout to move into smaller tributaries such as Kramer Creek.

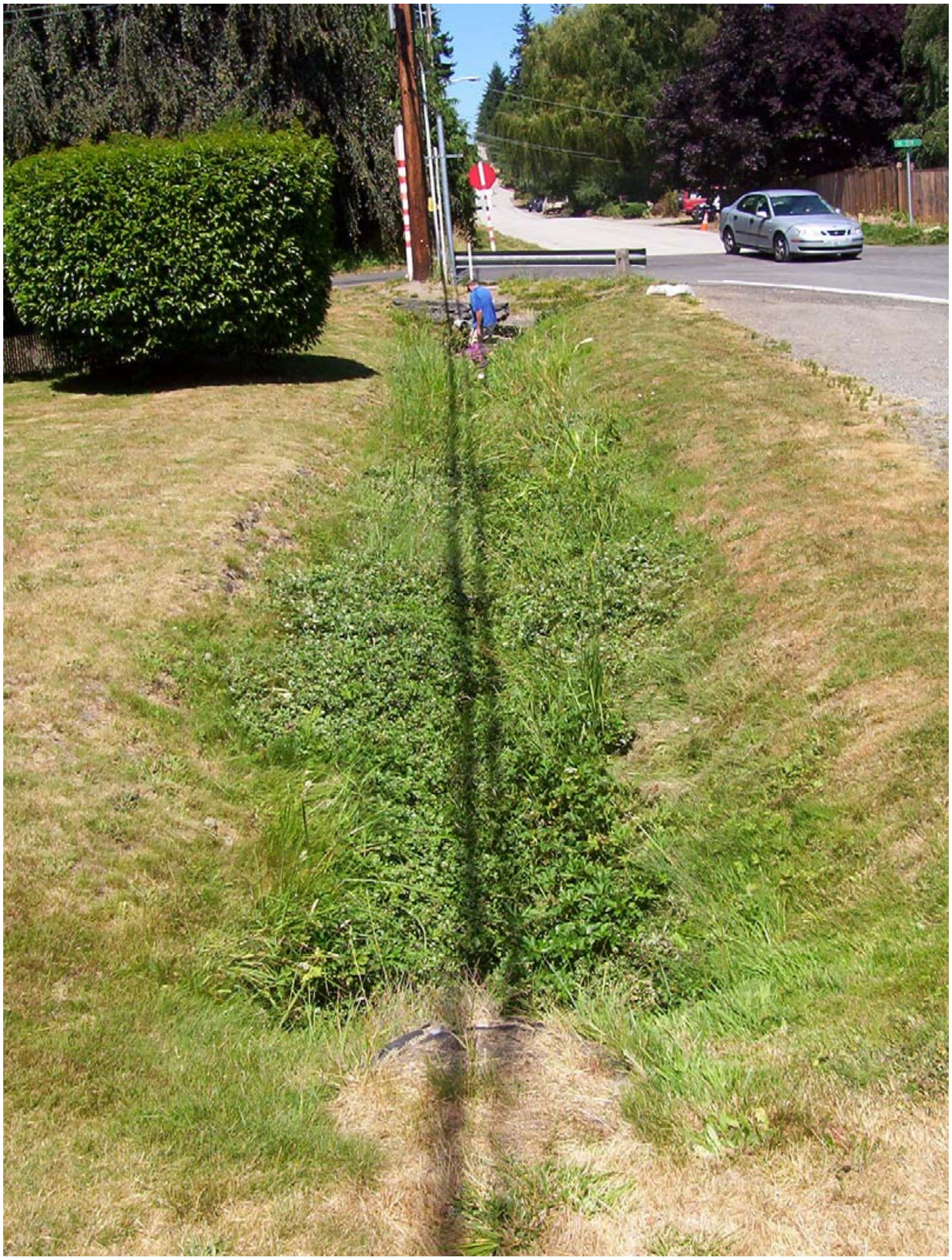

Figure 3. 7 - Photo of the upstream end of the Kramer Creek reference site, July 2006. Water flows from the top of the photo to the bottom of the photo.

CHAPTER 4. FISH INDEX OF BIOTIC INTEGRITY

Introduction and Methods

To assess ecosystem health, we used a fish index of biotic integrity (FIBI) that has been developed for Puget Sound lowland streams (Matzen and Berge 2008). This particular FIBI was developed from 70 sites in 30 subbasins in the Lake Washington basin, which included three sites in Thornton Creek. The index has six metrics and each metric is scored from 1 (lowest) to 4 (highest) (Table 4.1). Therefore, FIBI scores can range from 6 to 24. The index was developed for second- and third-order streams and may not be useful for first-order streams because few fish species are usually present in first-order streams even under pristine conditions. We calculated FIBI scores for each index and reference site in second- and third-order streams where fish were present.

Table 4. 1 - Metric scoring of the fish index of biotic integrity (FIBI) of Matzen and Berge (2008). Scores are determined by the percentage of the total number of fish sampled.

	Score			
Metrics	1	2	3	4
Percent invertivore individuals	<35	35-55	55-75	≥75
Percent invertivore/piscivore individuals	≥65	45-65	25-45	<25
Percent coho salmon individuals	<5	5-25	25-41	≥41
Percent cutthroat trout individuals	≥65	45-65	25-45	<25
Percent sculpin individuals	<0.5	0.5-10	10-40	≥40
Percent individuals of the most abundant species	≥80	65-80	50-65	<50

Results

Overall, FIBI scores were generally low, primarily due to the relatively high abundance of cutthroat trout and lack of other species such as coho salmon and cottids (Tables 4.2 and 4.3). Half of the FIBI scores for the index sites were less than 10. FIBI scores were generally higher in Longfellow Creek and Fauntleroy Creek than other Seattle streams, largely because few cutthroat trout were present and coho salmon were common. However, the FIBI scores from these streams may have been artificially high because juvenile coho salmon may have been outplanted. FIBI scores of Taylor Creek may have also been high due to outplantings of juvenile coho salmon. Within each basin, FIBI scores were usually highest close to the mouth of the creek and scores were often lowest at upstream locations. The presence of cottids and other fish species (besides cutthroat trout) close to the mouth of creek resulted in higher scores.

Table 4. 2 - Fish index of biotic integrity (FIBI) scores and number of fish caught at reference sites in Seattle streams. FIBI scores can range from 6 to 24. Location (Rm) is the downstream end of the site. COH = juvenile coho salmon, CUT = cutthroat trout; SAL = other salmonids; STB = threespine stickleback; COT = cottids.

Stream		Location	Date	FIBI	Number caught				
system #	Stream	(Rm)	sampled	score	COH	CUT	SAL	STB	COT
5	Piper's Cr.	800	3-Mar-05	6		27			
			19-Oct-05	9	1	43			
			29-Sep-06	6		112			
5	Lower Venema Cr.	0	3-Mar-05	6		29			
			19-Oct-05	6		12			
			29-Sep-06	6		43	1		
14	South Branch Thornton Cr.	550	24-Feb-05	6		238			
			13-Oct-05	6		306		1	
			2-Aug-06	6		483			
34	Longfellow Cr.	100	7-Aug-06	20	89	1		59	7
43	Fauntleroy Cr.	250	18-Oct-05	18	14				
			8-Aug-06	18	31				
49	Taylor Cr.	1,500	17-Oct-05	13	69	102			
			3-Aug-06	13	49	86			

Table 4. 3 - Fish index of biotic integrity (FIBI) scores and number of fish caught at index sites in Seattle streams, 2005. FIBI scores can range from 6 to 24. Location (Rm) is the downstream end of the site. LPU = lamprey, unidentified ammocoetes; COH = juvenile coho salmon, CUT = cutthroat trout; SAL = other salmonids; STB = threespine stickleback; CEN = centrarchids; COT = cottids.

Stream		Location	FIBI	Number caught						
system #	Stream	(Rm)	score	LPU	COH	CUT	SAL	STB	CEN	COT
5	Piper's Cr.	0	17		1	15				40
		250	9		6	71				
		500	9		3	47				
		1,175	6			55				
14	Lower Thornton Cr.	0	21		6			3		74
		250	15			7				120
		350	18	4	1	25			1	312
		500	13		9	135		43	5	7
		1,100	14		1	67		31	17	1
		1,900	12		7	421			5	1
14	North Branch Thornton Cr.	2,900	6			142			2	
		3,650	6			111			4	
		4,300	6			80			2	
		5,150	6			42				
		5,900	6			15			1	
		6,650	6			125			28	
14	South Branch Thornton Cr.	0	6			51				
		1,350	6			90				
		2,250	7			29		13		
		3,200	7			17	1	4		
		3,750	12			1		78		
34	Longfellow Cr.	0	18					17		3
		2,150	9				3			
		2,850	17		2		2		1	
		3,400	9				1			
42	Fauntleroy Cr.	0	23		4					4
		150	18		2					
		450	18		4					
		725	18		9					
49	Taylor Cr.	0	19		20	30	2	17		33
		1,500	15		51	9				
		2,800	9		1	5				

Discussion

The FIBI of Matzen and Berge (2008) was developed to evaluate the relationship between urbanization and fish assemblages in Puget Sound lowland streams. As expected, FIBI scores of Seattle's streams were generally low and reflected the high degree of urbanization in each watershed. Matzen and Berge (2008) found a strong negative relationship between FIBI scores and percent total impervious area (TIA). For the five major watersheds, percent TIA ranges from 38 to 59% (City of Seattle 2007). Based on a regression developed by Matzen and Berge (2008), FIBI scores in these watersheds should range from approximately 6 to 12. Nineteen of 35 sites (54%) we sampled were close to the expected value (Figure 4.1).

However, at some sites, scores were higher than expected given the amount of urbanization (Figure 4.1). A regression developed from all of our sampling sites indicated a different relationship between FIBI scores and TIA than the relationship observed by Matzen and Berge (2008). The FIBI of Matzen and Berge (2008) may not work in some urban areas where the overall abundance of fish is generally low and many of the fish are planted. The FIBI scores are based on percentages and in streams with low fish abundance, slight differences in the catch could substantially change the FIBI score. Outplanting of juvenile coho salmon and the mysterious lack of cutthroat trout in Longfellow Creek and Fauntleroy Creek probably resulted in higher than expected FIBI scores. FIBI scores were also higher than expected near the mouth of each creek. These scores were often high because large numbers of prickly sculpin and coastrange sculpin were present that commonly move upstream from estuaries and lakes. Because these species are more tolerant of warm water temperatures than most other cottid species (Zaroban et al. 1999) and generally only inhabit the lower reaches of small streams, they may not be the best indicator of ecosystem health. The presence or absence of less tolerant cottid species that must complete their entire life cycle in the stream would probably be a better metric. Also, our results underscore the need to sample several sites in each basin and not just rely on scores from one site near the creek mouth.

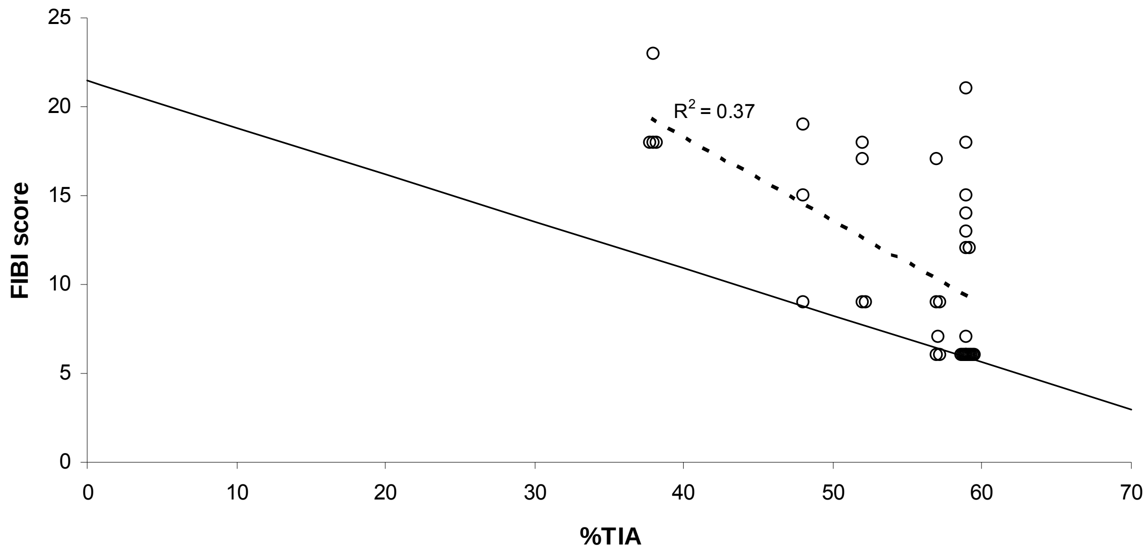

Figure 4. 1 - Relationship between fish index of biotic integrity (FIBI scores, open circles, n = 35) and percent total impervious area (%TIA) for five basins with the City of Seattle. The lower regression line (solid line) is the predicted line based on sampling by Matzen and Berge (2008); the upper line (dashed line) is based on observed FIBI scores in City of Seattle streams. Values used for %TIA include: Fauntleroy Creek – 38%, Taylor Creek – 48%, Longfellow Creek – 52%, Piper's Creek basin – 57% and Thornton Creek basin– 59%. Some %TIA values were altered slightly for display purposes (reduce overlapping values).

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REFERENCES

Adams, S.B. and D.A. Schmetterling. 2007. Freshwater sculpins: phylogenetics to ecology. Transactions of the American Fisheries Society 136:1736-1741.

Baker, J.A. 1994. Life history variation of female threespine stickleback. Pages 144-187 *in* M.A. Bell and S.A. Foster, editors. The evolutionary biology of the threespine stickleback. Oxford University Press, Oxford.

Beauchamp, D.A., C. Sergeant, N.C. Overman, and M.M. Mazur. 2007. Piscivory on juvenile salmon and alternative prey in Lake Washington. Draft report, University of Washington, Seattle.

Carle, F.L. and M.R. Strub. 1978. A new method for estimating population size from removal data. Biometrics 34:621-630.

City of Seattle. 2007. State of the waters 2007, volume I: Seattle watercourses. Seattle, Washington.

Conover, W.J. 1999. Practical nonparametric statistics. John Wiley and Sons, New York.

Eggers, D.M., N.W. Bartoo, N.A. Rickard, R.E. Nelson, R.C. Wissmar, R.L. Burgner, and H. Devol. 1978. The Lake Washington ecosystem: the perspective from the fish community production and forage base. Journal of the Fisheries Research Board of Canada 35:1553-1571.

Erman, D. C., E. D. Andrews, and M. Yoder-Williams. 1988. Effects of winter floods on fishes in the Sierra Nevada. Canadian Journal of Fisheries and Aquatic Sciences 45:2195-2200.

Foote, C. J. and G. S. Brown. 1998. Ecological relationship between freshwater sculpins (genus *Cottus*) and beach spawning sockeye salmon (*Oncorhynchus nerka*) in Iliamna Lake, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 55:1524-1533.

Fransen, B.R., R.E. Bilby, S. Needham, and J.K. Walter. 1998. Delineating fish habitat based on physical characteristics associated with the upper extent of fish distributions. Paper presented at the 1998 Annual General Meeting, North Pacific International Chapter, American Fisheries Society, Alderbrook Inn, Union, Washington.

Glova, G.J. 1984. Management implications of the distribution and diet of sympatric populations of juvenile coho salmon and coastal cutthroat trout in small streams in British Columbia, Canada. Progressive Fish-Culturist 46:269-277.

Glova, G.J. 1987. Comparison of allopatric cutthroat trout stocks with those sympatric with coho salmon and sculpins in small streams. Environmental Biology of Fishes 20:275-284.

Gray, M.A, R.A. Cunjak, and K.R. Munkittrick. 2004. Site fidelity of slimy sculpin (*Cottus cognatus*): insights from stable carbon and nitrogen analysis. Canadian Journal of Fisheries and Aquatic Sciences 61:1717-1722.

Gray, M.A, R.A. Curry, and K.R. Munkittrick. 2005. Impacts of nonpoint inputs from potato farming on the populations of slimy sculpin (*Cottus cognatus*). Environmental Toxicology and Chemistry 24:2291-2298.

Hawkins, C.P., M.L. Murphy, N.H. Anderson, and M.A. Wilzbach. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the Northwestern United States. Canadian Journal of Fisheries and Aquatic Sciences 1173-1185.

Horner, R. R. and C. W. May. 1998. Watershed urbanization and the decline of salmon in Puget Sound streams. Pages 19-40 *in* Salmon in the City Conference, Mount Vernon , Washington, May 20-21, 1998.

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 from the Pacific Coastal ecoregion. Springer, New York.

Latterell, J.J, R.J. Naiman, B.R. Fransen, and P.A. Bisson. 2003. Physical constraints on trout (*Oncorhynchus* spp.) distribution in the Cascade Mountains: a comparison of logged and unlogged streams. Canadian Journal of Fisheries and Aquatic Sciences 60:1007-1017.

Leavy, T.R., P. Bakke., and R.J. Peters. 2008. Influence of habitat complexity and floodplain reconnection projects on the physical and biological conditions of Seattle urban streams: pre-project monitoring, final progress report, 2005-2007. Report of the U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington.

LeMoine, M. 2007. Barriers to upstream migration of prickly sculpin *Cottus asper* and coastrange sculpin *Cottus aleuticus*. Master's thesis, Western Washington University, Bellingham.

Lowry, G.R. 1966. Production and food of cutthroat trout in three Oregon coastal streams. Journal of Wildlife Management 30:754-767.

Ludwa, K., G. Lucchetti, K.L. Fresh, and K. Walter. 1997. Assessing stream-dwelling fishes in basins of the Lake Washington watershed, summer 1996. King County Department of Natural Resources, Seattle, Washington.

Martin, D. J. 1984. Growth, food consumption, and production of cutthroat trout in relation to food supply and water temperature. Pages 135-144 *in* J.M. Walton and D.B. Houston, editors. Proceedings of the Olympic wild fish conference, March 23-25, 1983. Fisheries Technology Program, Peninsula College and Olympic National Park, Port Angeles, Washington.

Mason, J. C. and S. Machodori. 1976. Populations of sympatric sculpins, *Cottus aleuticus* and *Cottus asper*, in four adjacent salmon-producing coastal streams on Vancouver Island, B.C. Fishery Bulletin 74:131-141.

Matzen, D.A. and H.B. Berge. 2008. Assessing small-stream biotic integrity using fish assemblages across an urban landscape in the Puget Sound lowlands of western Washington. Transactions of the American Fisheries Society 137:677-689.

McPhail, J.D. 2007. The freshwater fishes of British Columbia. University of Alberta Press, Edmonton.

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company, Anchorage.

Moyle, P. B. 1977. In defense of sculpins. Fisheries 2(1):20-23.

Moyle, P. B. 2002. Inland fishes of California. University of California Press, Berkeley.

Muto, M. and L. Shefler. 1983. Game fish distribution in selected streams within the Lake Washington drainage basin. Report of Washington Department of Game to METRO, Water Quality Division, Seattle, Washington.

Pfeifer, B. 1984. A survey of Piper's Creek in Seattle, Washington. Fisheries Management Division, Washington State Game Department, Olympia.

Pleus, A.E. 1999. TFW Monitoring Program method manual for the wadeable stream discharge method. Report TFW-AM9-99-009 of Northwest Indian Fisheries Commission to Washington Department of Natural Resources, Olympia, Washington.

Pleus, A.E., D. Schuett-Hames, and L. Bullchild. 1999. TFW Monitoring Program method manual for the habitat unit survey. Report TFW-AM9-99-003 of Northwest Indian Fisheries Commission to Washington Department of Natural Resources, Olympia, Washington.

Price, B.E. 2006. The summer feeding ecology of rainbow trout (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarkii*) in the Cedar River, Washington. Master's thesis, The Evergreen State College, Olympia, Washington.

Rantz, S.E. and others. 1982. Measurement and computation of streamflow: volume I. Measurement of stage and discharge. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

Reed, L., K. Lynch, K. Paulsen, B. McMillan, M. Myers, G. Ylitalo, J. Labenia, T. Collier, and N. Scholz. 2004. High rates of pre-spawn mortality in coho salmon (*Oncorhynchus kisutch*) in urban streams in Puget Sound basin. Proceedings of the 2003 Georgia Basin/Puget Sound Research Conference, Vancouver, British Columbia.

Resource Planning Associates. 1998. Lower Thornton Creek evaluation of salmonid habitat conditions and opportunities. Task 1 memorandum, Report of Resource Planning Associates to Seattle Public Utilities, Seattle, Washington.

Roni, P. 2000. Responses of fishes and salamanders to instream restoration efforts in western Oregon and Washington streams. Doctoral dissertation. University of Washington, Seattle.

Rosenfeld, J., M. Porter, and E. Parkinson. 2000. Habitat factors affecting the abundance and distribution of juvenile cutthroat trout (*Oncorhynchus clarki*) and coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 57:766-774.

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. Report TFW-AM9-99-004 of Northwest Indian Fisheries Commission to Washington Department of Natural Resources, Olympia, Washington.

Scott, J.B., C. R. Steward, and Q. J. Stober. 1986. Effects of urban development on fish population dynamics in Kelsey Creek, Washington. Transactions of the American Fisheries Society 115:555-567.

Seiler, D., L. Peterson, J. Serl, and R. Tabor. 2005. Cutthroat trout as successful urbanites. Proceeding of the 2005 coastal cutthroat trout symposium, status, management, biology, and conservation. Port Townsend, Washington, September29-October1, 2005.

Serl, J. D. 1999. The response of stream fish communities of the Lake Washington watershed to various magnitudes of urbanization. Master's thesis, University of Washington, Seattle.

Shapovalov, L. and A. C. Taft. 1954. The life histories of steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kitsch*). California Department of Fish and Game, Fish Bulletin 98.

Tabor, R.A. and J. Chan. 1996. Predation on sockeye salmon fry by piscivorous fishes in the lower Cedar River and southern Lake Washington. Miscellaneous report. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, Washington.

Tabor, R.A., K.L. Fresh, D.K. Paige, E.J. Warner, and R.J. Peters. 2007a. Distribution and habitat use of cottids in the Lake Washington basin. American Fisheries Society Symposium 53:25-40.

Tabor, R.A., J. A. Schuerer, H. A. Gearns, and E. P. Bixler. 2004. Nearshore habitat use by juvenile Chinook salmon in lentic systems of the Lake Washington basin, annual report, 2002. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington.

Tabor, R.A., E. Warner, and S. Hager. 2001. An oriental weatherfish (*Misgurnus anguillicaudatus*) population established in Washington State. Northwest Science 75:72-76.

Tabor, R.A., E. J. Warner, K.L. Fresh, B.A. Footen and J.R. Chan. 2007b. Ontogenetic diet shifts of prickly sculpin in the Lake Washington basin, Washington. Transactions of the American Fisheries Society 136:1801-1813.

Thomas, G.L. 1992. Restoration of fish habitat in Piper's Creek, Seattle, Washington. Report of Prince William Sound Science Center to Municipality of Metropolitan Seattle, Washington.

Trotter, P.C. 2000. Headwater fishes and their uppermost habitats: a review as background for stream typing. Timber, Fish, and Wildlife Report TFW-ISAG1-00-001 to Washington Department of Natural Resources, Olympia, Washington.

Trotter, P.C. 2008. Cutthroat: native trout of the west. University of California Press, Berkeley.

Utzinger, J., C. Roth, and A. Peter. 1998. Effects of environmental parameters on the distribution of bullhead *Cottus gobio* with particular consideration of the effects of obstructions. Journal of Applied Ecology 35:882-892.

Washington Trout. 2000. Water typing and fish distribution within the City of Seattle. Draft report, May 18, 2000.

Welsh, H.H. Jr. and L.M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. Ecological Applications 8:1118-1132.

Wydoski, R.S., and R.R. Whitney. 2003. Inland fishes of Washington. University of Washington Press, Seattle.

Zaroban, D.W., M.P. Mulvey, T.R. Maret, R.M. Hughes, and G.D. Merrit. 1999. Classification of species attributes for Pacific Northwest freshwater fishes. Northwest Science 73:81-92.

Zimmerman, J.K.H. and B. Vondracek. 2007. Interactions between slimy sculpin and trout: slimy sculpin growth and diet in relation to native and nonnative trout. Transactions of the American Fisheries Society 136:1971-1800.