BioAnalysts, Inc.

Assessment of Spawning and Habitat in three Puget Sound Streams, Washington

T. W. Hillman
J. R. Stevenson
D. J. Snyder

Report to:
Airport Communities Coalition
City Hall
21630 11th Avenue South
Des Moines, WA 98198

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EXECUTIVE SUMMARY

We surveyed habitat composition and condition, abundance and distribution of redds (nests), and characteristics of the spawning populations of salmon and trout in Miller, Walker, and Des Moines creeks, tributaries of Puget Sound, during the 1998-1999 spawning season. We divided each survey stream into reaches based on geomorphology, channel confinement, and gradient. For habitat work, we randomly selected sampling sites, each 100 m long, within each reach. In November, we surveyed multiple 100 m sites that contained 4,215 m^2 in Miller Creek, 2,347 m^2 in Walker Creek, and 6,391 m^2 in Des Moines Creek. Within the sites we described generally the habitat composition and condition with 11 descriptors. On several occasions during the period mid-October to mid-March, we surveyed by foot all reaches on each stream for redds and salmon and trout carcasses. We surveyed 6.5 km of Miller Creek, 3.7 km of Walker Creek, and 4.2 km of Des Moines Creek.

Habitat composition and condition varied among reaches within streams and among the three streams. Habitat diversity typically increased in an upstream direction in the survey streams. Turbulent fast water habitat was the most common habitat type in the lower reaches of all streams, while non-turbulent fast water and scour pools increased in frequency in the upper reaches. Dammed pool habitat was relatively rare in all streams. Cover components such as woody debris, undercut banks, and boulder cover were relatively scarce in all streams surveyed. Canopy cover, however, was quite extensive in all reaches of all streams. Shrubs and trees were typically the dominant streamside vegetation. Fine sediments differed among reaches within streams and among streams. Fine sediments and sediment depths tended to increase in an upstream direction. Within pools in upper reaches on Miller and Walker creeks, percent surface fines approached 100%. Des Moines Creek typically had lower percent surface fines than did Miller or Walker creeks.

We counted a total of 148 redds during the 1998-1999 spawning season: 21 coho *Oncorhynchus kisutch* redds, 5 chum *O. keta* redds, and 9 of unknown origin in Miller Creek; 66 coho redds, 7 chum, and 1 cutthroat *O. clarki* redd in Walker Creek; and 22 coho, 16 chum, and 1 of unknown origin in Des Moines Creeks. Although time of spawning varied somewhat among streams, coho spawned primarily during November, while chum spawned during November to mid-January. Although sample

size was small (n = 1), cutthroat began spawning in March. Coho and chum spawned almost entirely in the lower reaches of each stream. In Walker Creek, however, coho spawned in all reaches, but their redds were most abundant in Reach 2. We found one cutthroat trout redd in the lowest reach on Walker Creek. Redds of unknown origin were located in upper reaches on Miller and Des Moines creeks. We found no steelhead *O. mykiss* redds.

We sampled a total of 150 carcasses during surveys on the three streams: 63 coho, 6 chum, and 1 steelhead on Miller Creek; 42 coho and 3 chum on Walker Creek; and 30 coho, 3 chum, and 2 steelhead on Des Moines Creek. We estimated female:male ratios of 1 : 1.17, 1 : 1.10, and 1.50 : 1 for coho salmon in Miller, Walker, and Des Moines creeks, respectively. We did not compare ratios for other species because of small sample sizes. Although mean lengths of salmon and trout differed little among steams, lengths differed between species and gender. On average, coho were larger than steelhead. Chum were on average larger than both coho and steelhead. Female coho were generally larger than males. We found little difference in sizes of male and female chum, but sample size was small. The percent of eggs voided by female coho was typically low in all streams. Female coho in Des Moines Creek voided fewer eggs than did females in Miller and Walker creeks. The few chum that we sampled voided all their eggs. Over 75% of the coho that spawned in the three streams were of hatchery origin. We found one steelhead and no chum of hatchery origin.

INTRODUCTION

In this report, prepared for the Airport Communities Coalition, we examine habitat characteristics and fish spawning in Miller, Walker, and Des Moines creeks, Washington. Because these streams will to some degree be affected by the proposed airport expansion, our purpose was to (1) describe generally the current habitat composition and (2) document where, when, and how many salmon and trout redds (nests) occur within the three streams. In addition, we described population characteristics of salmon and trout based on examination of carcasses.

STUDY AREA

Miller Creek basin is located within King County, west and northwest of Seattle-Tacoma International Airport (Figure 1). The airport forms the eastern boundary of the basin, and the city of Normandy Park lies to the south. The plateau edge above Seahurst and the hills north of Arbor Lake form the western and northern boundaries, respectively. The total drainage area is approximately 1,922 hectares (ha) (NRPD & SWMD 1987). Miller Creek falls from an elevation of about 110 meters (m) to where it meets Puget Sound at Miller Beach. Several small streams flow into Miller Creek. Walker Creek is one of the largest. It rises (ca. 90 m) in the wetlands west of the airport and flows toward and then parallel to Miller Creek. Walker Creek drains into Miller Creek about 0.4 kilometers (km) upstream from Miller Beach on Puget Sound. Large portions of both Miller and Walker creeks are developed, both commercially and residentially.

Des Moines Creek basin, located south of Miller Creek basin, drains an area of about 1,500 ha near the center of the Seattle-Tacoma metropolitan area (DMCBC 1997). Des Moines Creek falls from an elevation of about 106 m to where it meets Puget Sound at Des Moines Creek Beach Park (Figure 2). Like Miller Creek, Des

Moines Creek has several small tributaries. The two largest tributaries, known informally as the East Fork and the West Fork, converge on the Tyee Golf Course about 3.7 km upstream from the mouth of Des Moines Creek. The East Fork flows out of Bow Lake primarily through a series of subsurface pipes. The West Fork flows out of the Northwest Ponds complex located at the western edge of Tyee Golf Course. Most of the basin is heavily urbanized, and includes residential and commercial land uses.

METHODS

In this study we examined general habitat composition and condition within randomly selected sites on Miller, Walker, and Des Moines creeks. We also conducted salmon and trout spawning surveys throughout entire reaches on those streams. Thus, we did not conduct spawning surveys within randomly selected sites. Below we describe in more detail the methods we used to assess habitat composition and salmon and trout spawning within the three streams.

Habitat

To assess general habitat composition and condition in Miller, Walker, and Des Moines creeks, we first divided the streams into reaches based on geomorphology. Miller Creek has two distinct geomorphic segments (NRPD & SWMD 1987). The lower portion of the basin (river kilometer 0-2.8) is an asymmetrical valley, initially cut into the drift plain by outwash streams (below First Avenue South). Using the most recent (1995) USGS 7.5 minute series topographic map, we divided the lower segment into two reaches based on apparent channel confinement and gradient Figure 1). Reach 1 extended from river kilometer (Rkm) 0-0.6, while Reach 2 extended from Rkm 0.6-2.8. The upper basin lies on a rolling-till plateau, with outwash sediment partially filling broad swales. Here (upstream from First Avenue South) the stream is low gradient and there are several wetlands, lakes, and depressions. We divided this segment into two reaches. Reach 3 extended from Rkm 2.8-5.4 and Reach 4 from Rkm 5.4-7.5. Because of small stream size, difficult sampling conditions, and time constraints, we ended sampling in Reach 4 just downstream from Sunny Terrace School (Rkm 6.5).

Walker Creek also has two distinct geomorphic segments (NRPD & SWMD 1987). Like Miller Creek, the lower segment is an asymmetrical valley in which Walker Creek has cut a deep ravine (below First Avenue South) (Figure 1). Using the USGS topographic map, we divided this segment into two reaches based on apparent channel confinement and gradient: Reach 1 from Rkm 0-0.5 and Reach 2 from Rkm 0.5-2.1. The upper segment of Walker Creek (upstream from First Avenue South) rises in the wetlands on the rolling-till plateau. This segment consisted of one reach extending from Rkm 2.1-3.6. This sampling reach ended downstream from the wetlands (where Walker Creek originates) just east of Des Moines Memorial Drive.

Like Miller and Walker creeks, Des Moines Creek has two distinct geomorphic segments. In the lower segment (Rkm 0-2.7), the stream descends steeply through a ravine before it empties into Puget Sound. We divided this segment into three reaches based on apparent channel confinement and gradient: Reach 1 extended from Rkm 0-0.8, Reach 2 from Rkm 0.8-2.0, and Reach 3 from Rkm 2.0-2.7 (Figure 2). In the upper segment the stream flows on a low-gradient plateau. This segment consisted of one reach extending from Rkm 2.7-4.2. This reach ended just downstream from the Northwest Ponds complex located at the western edge of Tyee Golf Course.

After dividing the streams into distinct reaches, we randomly selected 100-m long sites within each reach for habitat sampling. Before selecting sites, we divided each reach into 100-m long units. We measured reach lengths from downstream to upstream. A most-upstream unit less than 100 m was not considered for sampling. For example, there were 21.6 possible sampling units in Reach 2 on Miller Creek. But because we excluded upstream units less than 100-m long, we had only 21 units available in Reach 2.

From the array of units available in each reach, we randomly selected either four

100-m long units or 30% of the available units, whichever was less, to serve as sampling sites for habitat work. This resulted in 12 habitat sampling sites on Miller Creek: two in Reach 1, four in both Reaches 2 and 3, and two in Reach 4. We randomly selected 10 habitat sampling sites on Walker Creek: two in Reach 1 and four in both Reaches 2 and 3. On Des Moines Creek we randomly selected 13 habitat sites: two in Reach 1, four in Reach 2, three in Reach 3, and four in Reach 4.

During November 1998, we described both the habitat types and general habitat conditions within each randomly-selected site on Miller, Walker, and Des Moines creeks. Following Hawkins et al. (1993) Level II classification, we defined a habitat type as an area of the stream with relatively homogeneous depth and flow that was bounded by sharp gradients in both depth and flow (i.e., turbulent fast water, non-turbulent fast water, scour pool, and damned pool) (Table 1). Thus, for each site we described two different riffle and pool types. For a habitat type to be classified as a habitat unit, the habitat type had to be equal to or longer than the mean width of the wetted channel.

We defined habitat condition as discrete stream variables that collectively create site-specific aquatic habitat for fish. Here our purpose was to describe habitat conditions within each site. For consistency, the same individuals measured the following habitat variables at each sampling site:

Length

Within a site we measured habitat unit length at the center of the wetted channel from the downstream end of the unit to the upstream end.

Wetted width

We recorded the wetted channel width for each habitat unit within a site. We measured across the wetted channel perpendicular to the flow at the point (visually estimated) that represented the mean width of the habitat unit.

Maximum depth

We measured maximum depth in all habitat types within a site. We measured it at the deepest point (not necessarily the center) in the habitat unit.

Residual pool depth

We calculated residual pool depth as the difference between maximum pool depth and maximum tailcrest depth.

Sediment depth

We measured fine sediment depths (particles <2 mm; e.g., sand, silt, and clay) only in pool habitat types. We measured sediment depth at the center of the pool with a 1/4 inch (9.84 mm) stainless-steel rod with a blunt end. We pushed the rod into the fine sediments until it hit particles larger than sand.

Percent surface fines

We visually estimated the percentage of the wetted streambed surface area within a habitat unit that was covered with fine sediments (materials <2 mm). We reported these scores for every habitat unit regardless of habitat type.

Percent boulder cover

We visually estimated the percent of the wetted surface area of the habitat unit that had boulder cover (included submerged and partially submerged boulders). Platts et al. (1983) defined boulders as any substrate with a particle diameter size greater than 30.5 cm.

Dominant riparian vegetation

We identified riparian habitat as the dominant vegetation along the left and right streambanks (Platts et al. 1987). The rating considered all material (organic and inorganic) on or above the streambank that offered streambank protection from erosion and stream shading, and that provided cover or resting security for fish. We rated the area adjacent to the 100-m site that covered the exposed stream bottom, bank, and 10 feet (3.05 m) beyond the top of the bank. We rated the stream channel with a numbered code for vegetation dominance (Table 2).

Percent woody debris cover

We visually estimated the percent of the wetted surface area of the habitat unit that was covered with woody debris. We defined woody debris as any wood (logs, root wads, and brush) within the water column. The wood did not have to be totally submerged in the water.

Percent streambank undercut

We visually estimated the percentage of the water surface area in a habitat unit that was covered or influenced by undercut banks. The water surface level does not influence this reading.

Percent canopy cover

We visually estimated the percent of the water surface area in a habitat unit that was shaded by vegetation (grasses, shrubs, and trees) that hung over the stream above the stream surface.

We summarized habitat type and habitat condition for each reach. These summaries described the mean habitat conditions of the various reaches. For habitat variables expressed as percentages, we calculated their means as the ratio of two random variables. For example, the mean percentage of fines within a reach was calculated by dividing the sum area of fines within all sampling sites of the reach by the sum total area of all sites sampled within that reach. This quotient was then multiplied by 100.

Spawning Surveys

We surveyed each stream for salmon and trout redds and carcasses by foot several times (typically biweekly) during the period mid-October 1998 to mid-March 1999. We surveyed 6.5 km of Miller Creek from just downstream from Sunny Terrace School to Puget Sound, 3.7 km of Walker Creek from Des Moines Memorial Drive to Puget Sound, and 4.2 km of Des Moines Creek from the Northwest Ponds complex to Puget Sound. Observers noted the number and location of redds in field notebooks and also recorded fish species, water temperature, and location of each redd. To avoid recounting redds on successive surveys we constructed detailed maps of each spawning site. Redds identified in each site were recorded on the maps. This method allowed us to more accurately track development of individual redds in each site. To maintain consistency, the same observer surveyed streams on successive dates.

We described the population structure of spawned salmon and trout by collecting and analyzing data from carcasses. We recorded location, species, and gender, and measured the fork length, mid-orbital to hypural (MOH), and post-orbital to hypural (POH) lengths of all carcasses encountered. We checked salmon for adipose fin clips and tags (indicative of hatchery origin). For about every fifth fish encountered, we collected at least five scales from the third row above the lateral line, between the dorsal and adipose fins (scales have not been analyzed at this time). We also opened female carcasses to visually estimate degree of egg voiding. We summarized fish length data by calculating mean and standard errors. We used both arithmetic (AM) and geometric (GM) means to summarize percent egg voidance. The geometric mean is probably most appropriate,[1] but because it is rarely used in the literature, we also reported the arithmetic mean.

RESULTS AND DISCUSSION

Habitat

Habitat type

The mean number of habitat units per site (measure of habitat diversity) varied little among reaches in Miller and Walker creeks (Table 3). The number of habitat units per site was greater in Miller Creek (4-5 units/site) than in Walker Creek (4 units/site). In Des Moines Creek, the mean number of habitat units per site decreased in an upstream direction (Table 3). That is, the number of habitat units per site was greatest in Reach 1 (6 units/site) and least in Reaches 3 and 4 (2-3 units/site).

[1]The geometric mean finds use in averaging ratios where it is desired to give each ratio equal weight, and in averaging percent changes.

Turbulent fast water habitat made up the greatest percentage of habitat in Reaches 1, and 2 (below First Avenue South) on Miller Creek (Figure 3). Although scour pools made up less than 20% of the habitat in Reaches 1 and 2, scour pools increased in an upstream direction. Habitat types varied more in Reaches 3 and 4 (upstream from First Avenue South) than in Reaches 1 and 2 (Figure 3). Non-turbulent fast water and scour pools made up the largest percentage of habitat in Reach 3, while turbulent and non-turbulent fast water constituted the greatest percentage of habitat in Reach 4. Culverts were more common in Reaches 3 and 4 on Miller Creek than in reaches below First Avenue South.

Turbulent and non-turbulent fast water made up the greatest percentage of habitat in Reaches 1 and 2 (downstream from First Avenue South) on Walker Creek (Figure 4). Scour pools constituted less than 5% of the habitat in both reaches. In Reach 3 (upstream from First Avenue South), non-turbulent fast water made up about 60% of the habitat, while culverts constituted about 15% of the stream length. Dammed pools were more common in Reach 3 than in Reaches 1 and 2 on Walker Creek.

In Des Moines Creek, turbulent fast water habitat made up 80-95% of the habitat in Reaches 1, 2, and 3 (Figure 5). Scour pools and non-turbulent fast water made up a small percentage of the habitat types in these reaches. These observations are consistent with those of Resource Planning et al. (1994) and DMCBC (1997). All four habitat types occurred in Reach 4 on Des Moines Creek (Figure 5). Turbulent and non-turbulent fast water made up the greatest percentage of habitat (95%) in Reach 4, while scour and dammed pools constituted only about 5% of the habitat.

Habitat condition

Habitat conditions varied among reaches within Miller, Walker, and Des Moines creeks (Table 4). Although mean maximum depths and residual pool depths of given habitat types varied little among reaches in Miller Creek, sediment depths and percent surface fines tended to increase in an upstream direction. Surface fines covered 88-

100% of the streambed in pools in Reaches 3 and 4 on Miller Creek. Woody debris and boulder cover varied among reaches in Miller Creek. Woody debris was most abundant in Reach 2, while boulder cover was present in Reaches 2, 3, and 4, but rare in Reach 1. Undercut bank cover was lacking throughout Miller Creek. Percent canopy cover was high throughout Miller Creek, with shrubs and trees as the dominant riparian vegetation.

In Walker Creek, water depths varied little with given habitat types among reaches, but sediment depths and percent surface fines varied widely among reaches (Table 4). Sediment depths were highest in Reaches 1 and 3, and surface fines completely covered bottoms of pools in Reach 3. Woody debris, boulder cover, and undercut banks were relatively scarce in all reaches on Walker Creek, while percent canopy cover was high in all reaches. Shrubs and trees were the dominant riparian vegetation in all reaches. Grass was a common streamside vegetation in Reach 1.

In Des Moines Creek, water depths (maximum depths and residual pool depths) tended to increase in an upstream direction (Table 4). Pools were deepest in Reach 4. Sediment depths and percent surface fines appeared to be less in Des Moines Creek than in Miller and Walker creeks. Woody debris and undercut banks were lacking in all reaches on Des Moines Creek. Resource Planning et al. (1994) and DMCBC (1997) also reported a lack of woody debris in Des Moines Creek. Boulder cover was highest in Reaches 2 and 3 and relatively scarce in Reach 1. Percent canopy cover was high in all reaches on Des Moines Creek. Shrubs and trees were the dominant riparian vegetation in all reaches.

Spawning

Redd counts

We counted a total of 148 redds (nests) during the 1998-1999 spawning season: 35 redds in Miller Creek, 74 in Walker Creek, and 39 in Des Moines Creek. In Miller Creek we found 21 coho *Oncorhynchus kisutch* redds, 5 chum *O. keta* redds, and 9 redds of unknown origin. The small size of the latter redds suggest that they likely belonged to resident cutthroat trout *O. clarki.* In Walker Creek we counted 66 coho redds, 7 chum redds, and 1 cutthroat trout redd. In Des Moines Creek we counted 22 coho redds, 16 chum redds, and 1 of unknown origin.

Time of spawning differed among species and streams (Table 5). In Miller and Walker creeks, coho spawning occurred primarily during November. In Des Moines Creek, however, coho began spawning in October and continued through November. Peak coho spawning occurred around mid-November in all streams. Chum salmon spawned only during November in Miller Creek, but during November to mid-January in Walker and Des Moines creeks. Peak spawning of chum occurred around late-November. Although sample size was small, cutthroat trout began spawning in March.

Redds were not distributed evenly among survey reaches on Miller, Walker, and Des Moines creeks (Table 6). Coho and chum spawned only in Reaches 1 and 2 on Miller Creek (downstream from First Avenue South). There the highest densities of redds for both species occurred in Reach 1 (18 and 5 redds/km, respectively). We found the 9 redds of unknown origin in Reach 3. In Walker Creek, coho spawned in all reaches, but their redds were most abundant in Reach 2 (34 redds/km). Chum spawned only in Reaches 1 and 2 on Walker Creek. Densities of chum redds were highest in Reach 1 (6 redds/km). One cutthroat trout redd was observed in Reach 1 on Walker Creek. In Des Moines Creek, coho spawned only in Reaches 1 and 2, with highest redd abundance in Reach 1 (26 coho redds/km). Chum spawned only in Reach 1, while one redd of unknown origin occurred in Reach 3.

Population structure

We sampled a total of 150 carcasses in Miller, Walker, and Des Moines creeks during the 1998-1999 survey period (Table 7; Appendix A). In Miller Creek we sampled 63 coho, 6 chum, and 1 steelhead *O. mykiss*: in Walker Creek we sampled 42 coho and 3 chum. We sampled 30 coho, 3 chum, and 2 steelhead in Des Moines Creek. Our systematic samples indicate that male coho outnumbered females by 1.17 and 1.10 in Miller and Walker creeks, respectively. In contrast, female coho outnumbered males by a factor of 1.50 in Des Moines Creek. We did not compare sex ratios for other species because of small sample sizes.

Mean sizes of salmon and trout differed little among streams (Table 7). Mean lengths (post-orbital to hypural length (POH)) of female coho differed at most by only 1.6 cm among the three streams. Mean lengths (POH) of male coho differed by 1.3 cm among streams. In all survey streams, female coho were on average larger than male coho, generally exceeding males by about 3-4 cm (POH). Chum salmon were typically larger than coho. Although sample size was small, lengths (POH) of chum differed little among streams or between sexes (Table 7). We sampled only three steelhead during our surveys. These fish were on average smaller than both coho and chum salmon.

Percent egg voidance was low and varied among the survey streams (Table 7). On average, female coho in Walker Creek voided more eggs (AM = 37%; GM = 61%) than did female coho in Miller and Des Moines creeks. Female coho in Des Moines Creek voided the fewest eggs (AM = 16%; GM = 51%). The few female chum that we sampled (n = 6) voided 100% of their eggs. In contrast, the few steelhead we sampled (n = 3) voided no eggs. In other words, these steelhead died before spawning.

The majority of coho salmon that spawned in the three streams were of hatchery origin (bore adipose fin clips) (see Appendix A). In Miller Creek, 83% of the females and 79% of the male coho salmon were of hatchery origin, while in Walker Creek all coho sampled were hatchery fish. In Des Moines Creek, 78% and 75% of the respective female and male coho that we sampled were of hatchery origin. We found no chum salmon of hatchery origin. That is, all chum sampled within the three streams were wild. Of the three steelhead sampled in the study area, only one was of hatchery origin.

ACKNOWLEDGMENTS

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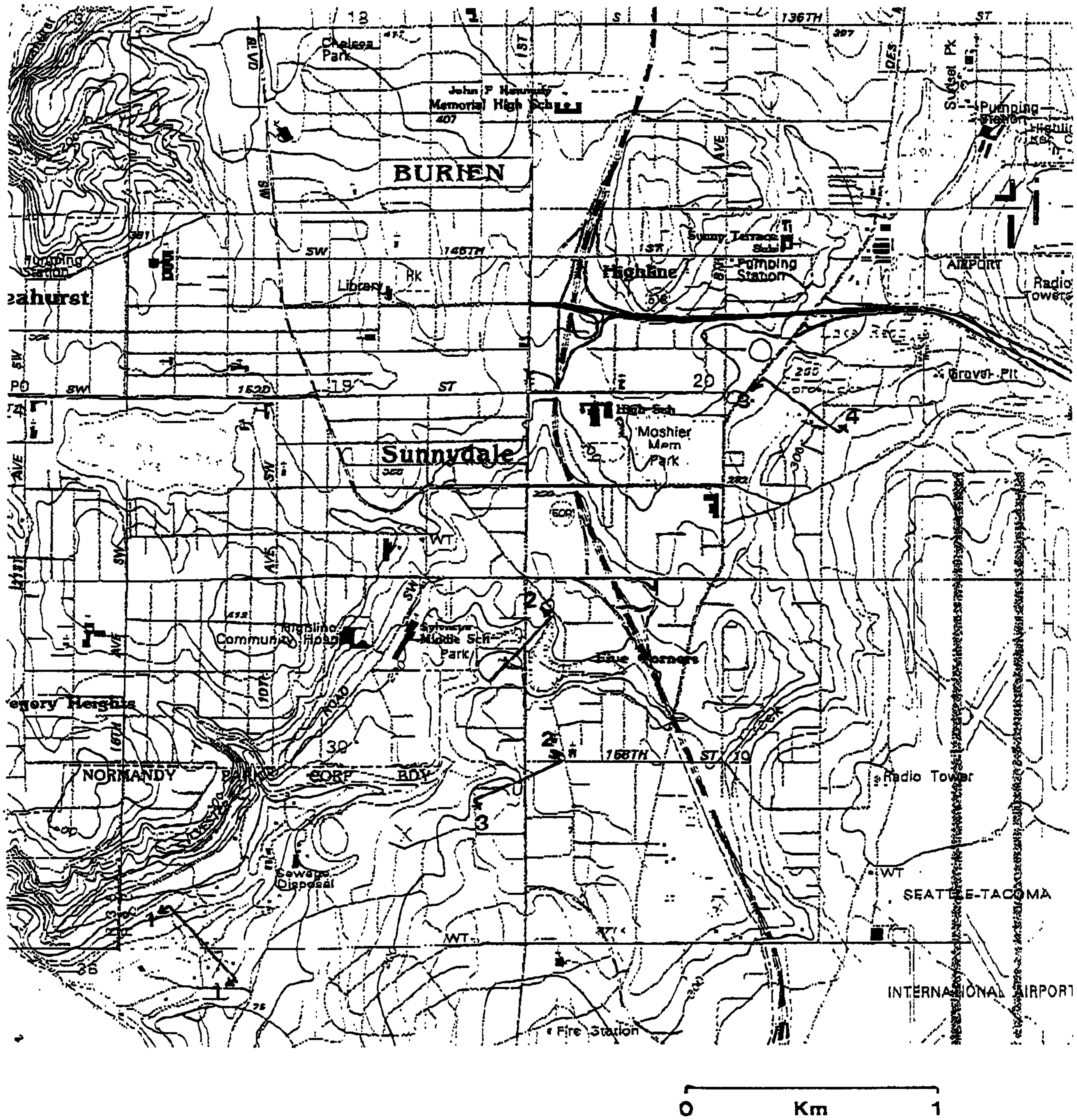

Figure 1. Locations of study reaches on Miller and Walker creeks, Washington. Map is from USGS 7.1 minute series, 1:24,000 scale, Des Moines Quad, revised 1995.

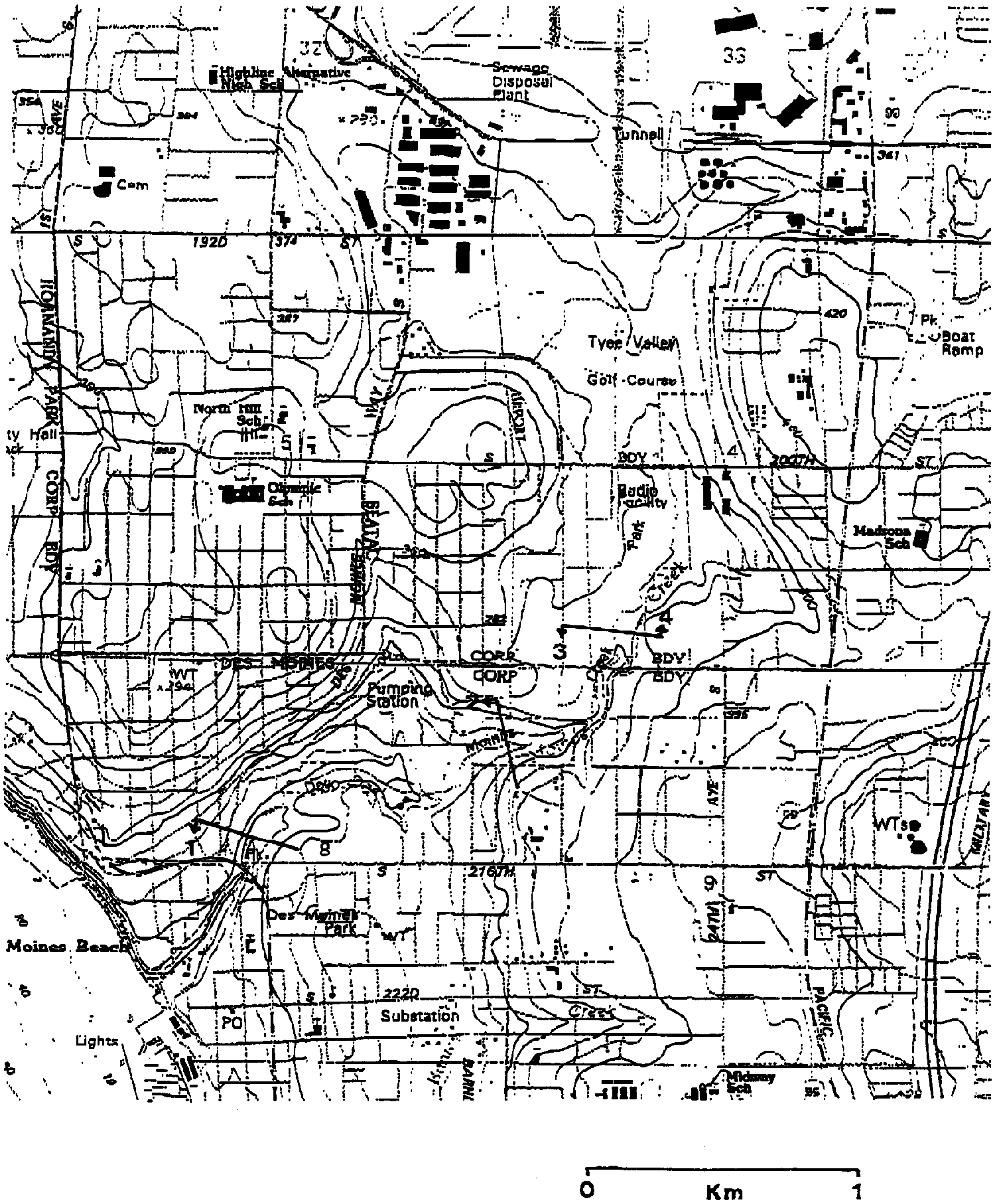

Figure 2. Locations of study reaches on Des Moines Creek, Washington. Map is from USGS 7.1 minute series, 1:24,000 scale, Des Moines Quad, revised 1995.

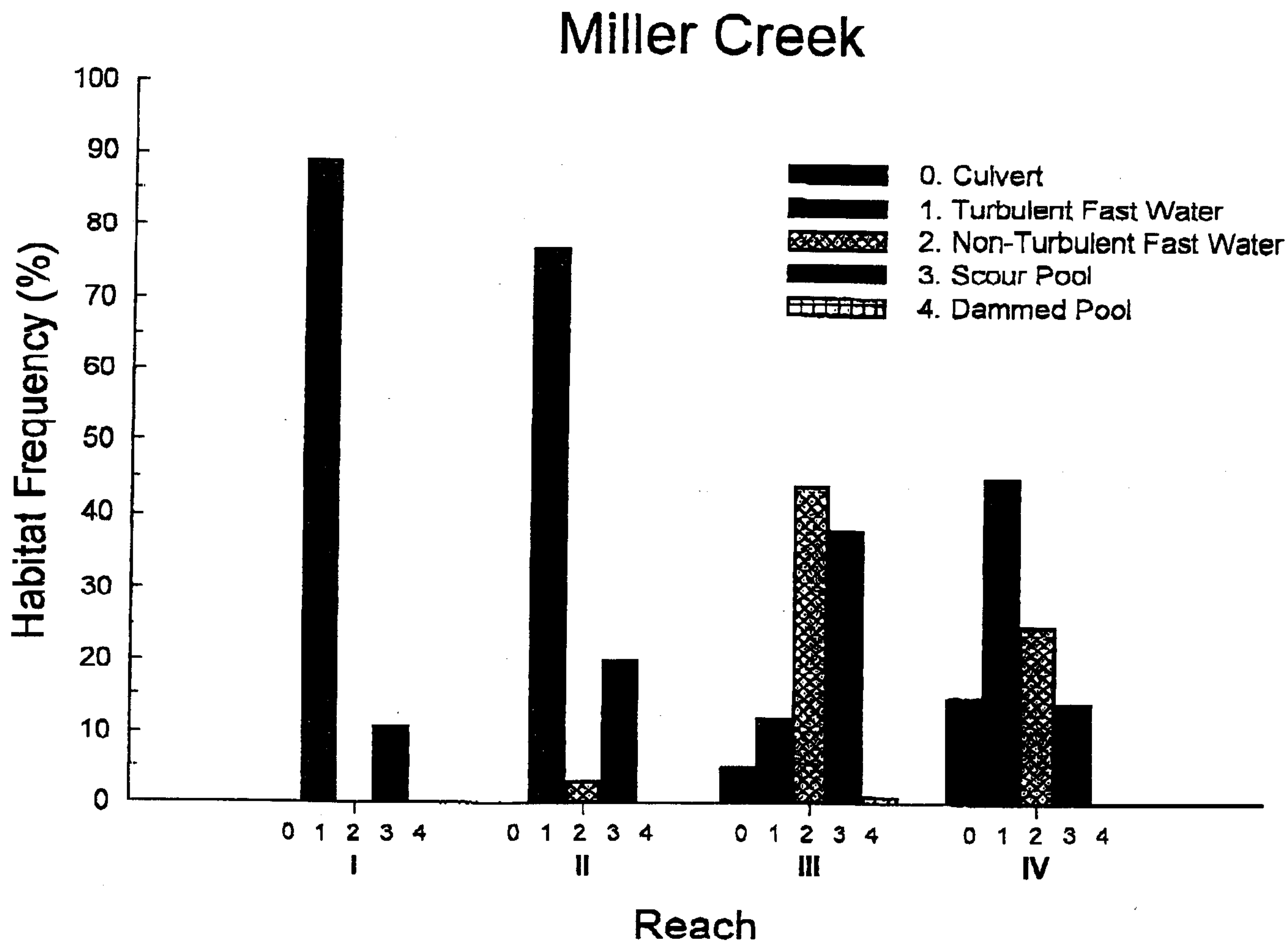

Figure 3. Percent frequency of habitat types (based on stream length) within reaches on Miller Creek, November 1998.

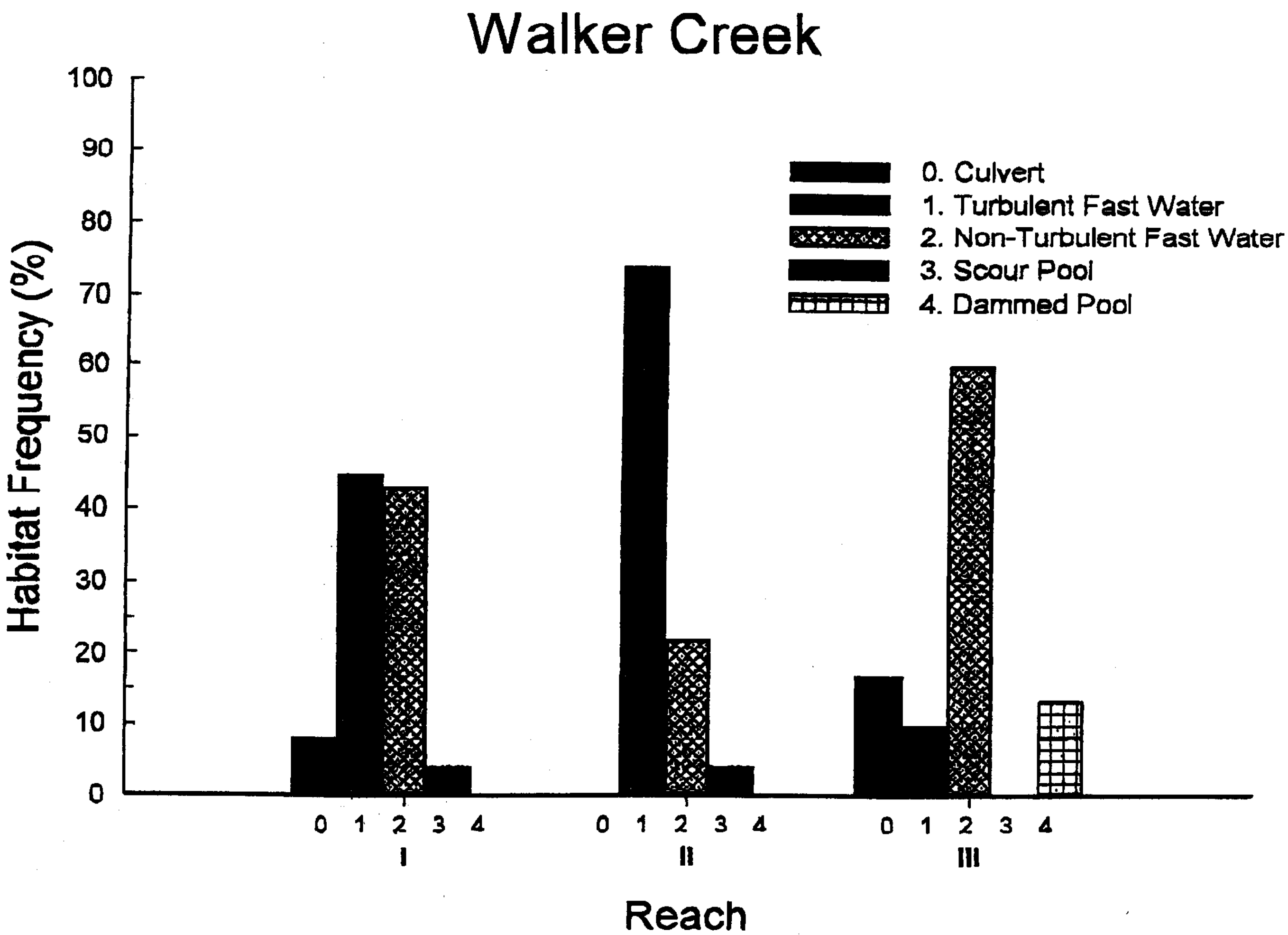

Figure 4. Percent frequency of habitat types (based on stream length) within reaches on Walker Creek, November 1998.

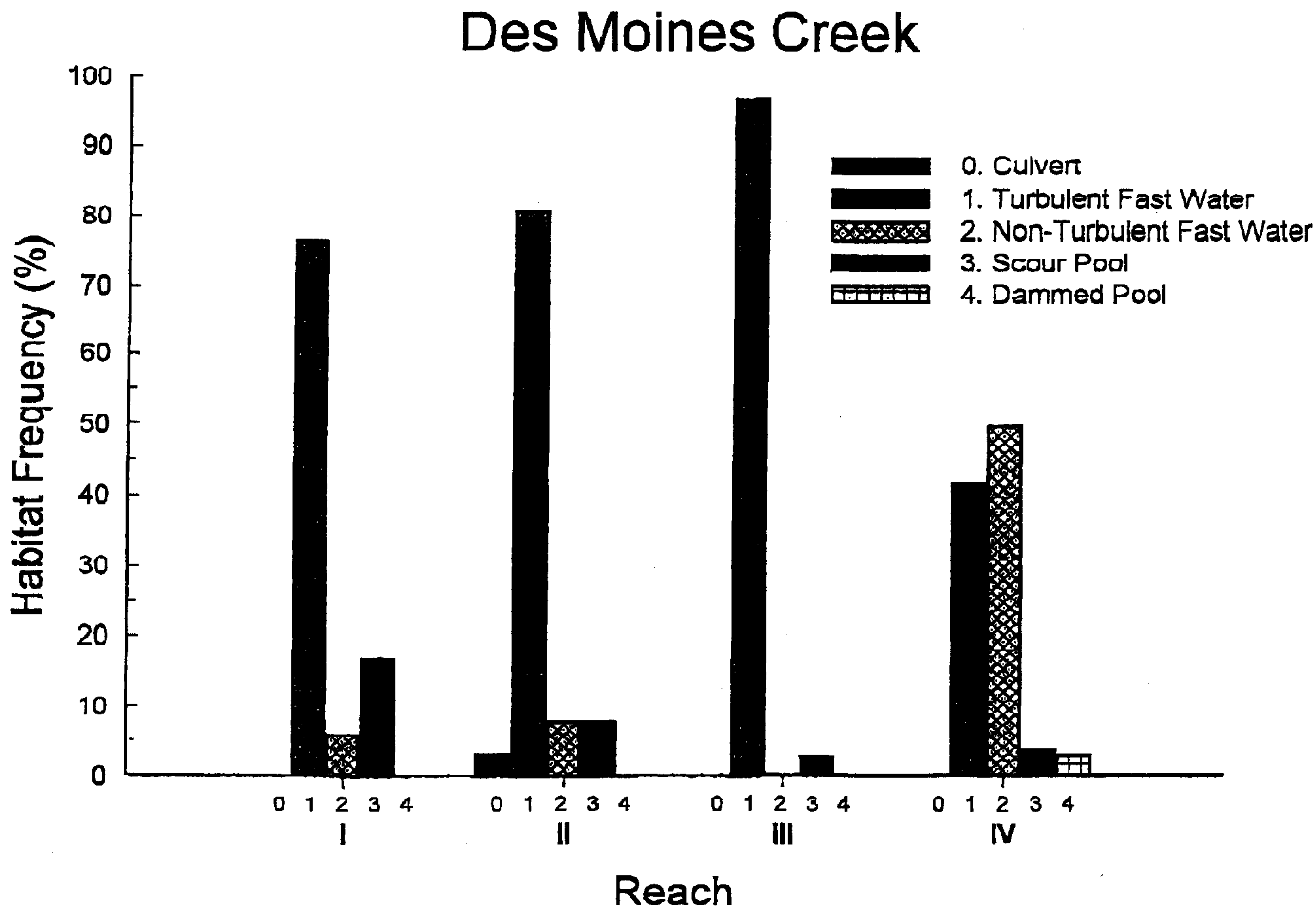

Figure 5. Percent frequency of habitat types (based on stream length) within reaches on Des Moines Creek, November 1998.

Table 1. Codes and examples of the four habitat types used in the Level II classification of Hawkins et al. (1993).

Code	Habitat type	Examples
1	Turbulent Fast Water	Falls, Cascades, Rapids, Riffles, Chutes
2	Non-Turbulent Fast Water	Sheets, Runs, Glides
3	Scour Pool	Eddies, Trenches, Mid-channel pools, Lateral pools, Plunge pools
4	Dammed Pool	Debris, Beaver, Landslide, Backwater, Abandoned channel

Table 2. Riparian rating codes used to describe the dominant streamside vegetation (Platts et al. 1987).

Rating	Description
5	Shrubs are the dominant streamside vegetation.
4	Tree forms are the dominant streamside vegetation.
3	Grass forms are the dominant streamside vegetation.
2	Forbs are the dominant streamside vegetation.
1	Over 50% of the streambank has no vegetation and the dominent bank material is made up of such materials as soil, rock, bridge materials, road materials, culverts, and mine tailings.

Table 3. Summary of stream habitat in Miller, Walker, and Des Moines creeks, Washington, 1998.

Stream	Reach	Reach length (km)	No of 100 m sites sampled	Area sampled (m^2)	Mean No of diff hab types per site	Mean No of hab units per site
Miller	1	0.6	2	769.0	2	4
	2	2.2	4	1633.7	2	5
	3	2.6	4	1412.4	3	5
	4	2.1	2	399.8	3	5
Walker	1	0.5	2	442.2	3	4
	2	1.6	4	1052.2	2	4
	3	1.5	4	852.9	3	4
Des Moines	1	0.8	2	879.7	3	6
	2	1.2	4	2023.7	2	4
	3	0.7	3	1606.5	1	2
	4	1.5	4	1880.9	1	3

Table 4. Description of habitat conditions within different habitat types within reaches on Miller, Walker, and Des Moines creeks, 1998. See Tables 1 and 2 for descriptions of habitat types and riparian vegetation, respectively.

Stream	Reach	Habitat type	No. of hab. units sampled	Habitat area sampled (m^2)	Mean max. depth (cm)	Mean residual pool depth (cm)	Mean sed. depth (cm)	Mean % fines	Dom rip. veg.	Mean % woody debris	Mean % boulder cover	Mean % undercut banks	Mean % canopy cover
Miller	1	1	4	678.5	57			NA	5	6	1	4	80
		3	3	90.5	78	53	18	NA	5	5	0	4	56
Miller	2	1	12	1162.4	41			15	5	4	12	3	43
		2	1	64.8	39			35	5	10	2	5	80
		3	9	406.5	76	53	3	35	5	14	4	1	54
Miller	3	1	4	137.5	34			27	5	1	15	3	86
		2	6	590.8	58			62	5	3	11	2	88
		3	5	661.8	83	61	14	88	5	9	2	5	70
		4	1	22.3	53	45	11	100	4	1	0	0	100
Miller	4	1	3	154.7	47			17	5	0	3	3	85
		2	2	123.7	56			NA	4	5	65	5	75
		3	2	121.4	85	59	35	100	4	5	0	2	90
Walker	1	1	3	196.7	54			NA	5	3	1	6	66
		2	4	201.4	54			NA	3	3	3	3	62
		3	1	44.1	41	11	98	NA	5	1	0	0	85

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Table 4. Concluded.

Stream	Reach	Habitat type	No. of hab. units sampled	Habitat area sampled (m^2)	Mean max. depth (cm)	Mean residual pool depth (cm)	Mean sed. depth (cm)	Mean % fines	Dom rip. veg.	Mean % woody debris	Mean % boulder cover	Mean % undercut banks	Mean % canopy cover
Walker	2	1	8	753.0	47			20	5	9	19	4	80
		2	4	230.6	52			73	5	5	4	9	84
		3	2	68.6	60	37	6	70	5	3	0	9	100
Walker	3	1	3	73.9	39			83	5	3	5	3	82
		2	5	501.0	60			92	5	3	4	8	86
		4	1	278.0	100	NA	70	100	5	13	0	0	48
D. Moines	1	1	6	600.7	37			11	5	2	5	0	81
		2	1	47.1	45			15	5	19	5	0	90
		3	4	231.9	62	36	NA	33	5	5	4	0	99
D. Moines	2	1	7	1660.5	62			6	5	5	41	2	55
		2	2	160.5	64			24	5	11	19	1	66
		3	3	202.7	92	54	0	13	4	11	7	2	97
D. Moines	3	1	4	1557.5	81			5	5	3	73	3	72
		3	1	49.0	67	22	0	18	4	18	3	1	80
D. Moines	4	1	4	907.8	67			27	5	3	21	3	45
		2	5	859.0	96			82	5	7	6	1	84
		3	1	58.2	111	80	NA	NA	5	5	2	0	100
		4	1	55.9	77	64	NA	NA	5	10	3	2	100

Table 5. Numbers of salmon and trout redds observed during spawning ground surveys on Miller, Walker, and Des Moines creeks, 1998-1999.

Survey period	Reach	Number of new redds					
		Coho	Chum	Steelhead	Cutthroat	Unknown	Total
			Miller Creek				
19-Oct	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
26-Oct	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
16-Nov	1	8	2	0	0	0	10
	2	8	0	0	0	0	8
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
30-Nov	1	3	1	0	0	0	4
	2	2	2	0	0	0	4
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
14-Dec	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
11-Jan	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0

Table 5. Continued.

Survey period	Reach	Number of new redds					
		Coho	Chum	Steelhead	Cutthroat	Unknown	Total
25-Feb	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
16-Mar	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	9	9
	4	0	0	0	0	0	0
Total		**21**	**5**	**0**	**0**	**9**	**35**
			Walker Creek				
19-Oct	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
23-Oct	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
16-Nov	1	7	1	0	0	0	8
	2	51.	1	0	0	0	52
	3	0	0	0	0	0	0
30-Nov	1	1	1	0	0	0	2
	2	4	1	0	0	0	5
	3	3	0	0	0	0	3
14-Dec	1	0	0	0	0	0	0
	2	0	1	0	0	0	1
	3	0	0	0	0	0	0

Table 5. Continued.

Survey period	Reach	Number of new redds					
		Coho	Chum	Steelhead	Cutthroat	Unknown	**Total**
11-Jan	1	0	1	0	0	0	1
	2	0	1	0	0	0	1
	3	0	0	0	0	0	0
25-Feb	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
16-Mar	1	0	0	0	1	0	1
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Total		**66**	**7**	**0**	**1**	**0**	**74**
			Des Moines Creek				
19-Oct	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
29-Oct	1	2	0	0	0	0	2
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
16-Nov	1	16	3	0	0	0	19
	2	1	0	0	0	0	1
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0

Table 5. Concluded.

Survey period	Reach	Number of new redds					
		Coho	Chum	Steelhead	Cutthroat	Unknown	**Total**
30-Nov	1	3	9	0	0	0	**12**
	2	0	0	0	0	0	**0**
	3	0	0	0	0	0	**0**
	4	0	0	0	0	0	**0**
14-Dec	1	0	2	0	0	0	**2**
	2	0	0	0	0	0	**0**
	3	0	0	0	0	0	**0**
	4	0	0	0	0	0	**0**
12-Jan	1	0	2	0	0	0	**2**
	2	0	0	0	0	0	**0**
	3	0	0	0	0	1	**1**
	4	0	0	0	0	0	**0**
25-Feb	1	0	0	0	0	0	**0**
	2	0	0	0	0	0	**0**
	3	0	0	0	0	0	**0**
	4	0	0	0	0	0	**0**
17-Mar	1	0	0	0	0	0	**0**
	2	0	0	0	0	0	**0**
	3	0	0	0	0	0	**0**
	4	0	0	0	0	0	**0**
Total		**22**	**16**	**0**	**0**	**1**	**39**

Table 6. Total numbers and densities (redds/kilometer) of salmon and trout redds within reaches on Miller, Walker, and Des Moines creeks, 1998-1999.

			Coho		Chum		Steelhead		Cutthroat		Unknown	
Reach	Rkm	Length (km)	Number	Density	Number	Density	Number	Density	Number	Density	Number	Density
Miller Creek												
1	0.0-0.6	0.6	11	18.3	3	5.0	0	0.0	0	0.0	0	0.0
2	0.6-2.8	2.2	10	4.5	2	0.9	0	0.0	0	0.0	0	0.0
3	2.8-5.4	2.6	0	0.0	0	0.0	0	0.0	0	0.0	9	3.5
4	5.4-7.5	2.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Walker Creek												
1	0.0-0.5	0.5	8	16.0	3	6.0	0	0.0	1	2.0	0	0.0
2	0.5-2.1	1.6	55	34.4	4	2.5	0	0.0	0	0.0	0	0.0
3	2.1-3.6	1.5	3	2.0	0	0.0	0	0.0	0	0.0	0	0.0
Des Moines Creek												
1	0.0-0.8	0.8	21	26.3	16	20.0	0	0.0	0	0.0	0	0.0
2	0.8-2.0	1.2	1	0.8	0	0.0	0	0.0	0	0.0	0	0.0
3	2.0-2.7	0.7	0	0.0	0	0.0	0	0.0	0	0.0	1	1.4
4	2.7-4.2	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Table 7. Summary statistics on salmon and trout carcasses collected on spawning grounds within Miller, Walker, and Des Moines creeks, 1998-1999 (data appear in Appendix A). Size of fish was reported as fork length (FL), mid-orbital to hypural length (MOH), and post-orbital to hypural length; SE = standard error of the mean.

Species	Sex	Sample size	Mean % egg voidance		FL (cm)		MOH (cm)		POH (cm)	
			Arithmetic	Geometric	Mean	SE	Mean	SE	Mean	SE
Miller Creek										
Chum	F	5	100	100	67.0	2.2	56.8	1.7	55.5	1.4
	M	1			67.0		55.0		54.0	
Coho	F	29	28	79	51.9	0.9	42.0	0.6	41.0	0.7
	M	34			49.6	0.9	39.3	0.7	38.6	0.7
Steelhead	F	1	0	0	42.0		36.0		35.5	
Walker Creek										
Chum	M	3			70.2	0.4	56.3	0.7	55.3	0.7
Coho	F	20	37	61	51.1	0.7	42.4	0.6	41.6	0.6
	M	22			47.2	1.4	37.9	1.2	37.3	1.1
Des Moines Creek										
Chum	F	1	100	100	63.0		54.5		53.5	
	M	2			74.0	3.5	58.8	2.3	57.8	2.3
Coho	F	18	16	51	50.8	0.8	41.1	0.6	40.6	0.6
	M	12			47.4	1.3	37.8	0.9	37.3	0.9
Steelhead	F	2	0	0	43.3	15.8	35.0	13.0	34.5	13.0

Appendix A. Characteristics of carcasses and date and location of retrieval on spawning grounds within Miller, Walker, and Des Moines creeks, 1998-1999. Asterix (*) denotes an adipose fin-clipped fish: FL = fork length. MOH = mid-orbital to hypural length, and POH = post-orbital to hypural length.

Species	Date	Reach	Sex	Length (cm) FL	MOH	POH	Percent egg voidance
			Miller Creek				
Chum	11/30	1	F	66.0	55.5	54.5	100
	11/30	1	F	69.0	59.0	58.0	100
	12/16	1	F	70.0	59.0	58.0	100
	12/16	2	F	59.0	51.0	50.5	100
	1/11	1	F	71.0	59.5	58.5	100
	12/16	2	M	67.0	55.0	54.0	
Coho	11/13	1	F*	50.0	40.0	39.5	100
	11/13	1	F*	56.0	43.0	42.0	0
	11/13	1	F*	52.0	42.0	41.5	0
	11/13	1	F*	60.0	46.5	45.5	0
	11/13	1	F*	46.0	37.5	37.0	0
	11/13	1	F*	57.5	45.5	44.5	0
	11/14	2	F*	50.0	40.5	40.0	0
	11/14	2	F*	54.0	44.0	43.0	0
	11/14	2	F*	56.0	46.0	45.0	60
	11/14	2	F*	47.0	39.5	38.5	100
	11/14	2	F	49.0	40.0	39.5	100
	11/14	2	F*	55.0	44.5	43.5	0
	11/14	2	F*	53.5	44.0	43.5	70
	11/14	2	F*	50.5	40.5	40.0	70
	11/16	1	F	51.0	42.0	41.5	0
	11/16	1	F*	49.5	41.0	40.5	0
	11/16	1	F*	52.0	43.0	42.5	100

Appendix A. Continued.

Species	Date	Reach	Sex	Length (cm) FL	MOH	POH	Percent egg voidance
Coho	11/16	1	F	46.0	38.0	37.5	0
	11/16	1	F*	51.0	42.5	42.0	0
	11/16	1	F*	55.0	45.0	44.0	50
	11/16	1	F*	58.5	48.0	47.0	0
	11/16	1	F*	52.5	41.5	41.0	90
	11/16	1	F	46.0	36.0	35.5	70
	11/16	2	F*	50.5	41.0	40.5	0
	11/16	2	F*	55.0	43.0	42.0	0
	11/30	1	F*	41.0	34.5	34.0	0
	11/30	2	F*	50.0	40.0	39.5	0
	11/30	2	F*	48.0	39.5	39.0	0
	11/30	2	F	61.5	50.0	49.0	0
	11/13	1	M*	31.0	25.0	24.5	
	11/13	1	M*	50.0	40.0	39.5	
	11/13	1	M*	43.5	35.0	34.0	
	11/13	1	M*	49.0	39.0	38.5	
	11/13	1	M*	51.0	41.0	40.0	
	11/13	1	M*	44.0	35.5	35.0	
	11/13	1	M*	43.0	34.5	34.0	
	11/14	2	M*	46.5	38.0	37.5	
	11/14	2	M*	50.0	40.0	39.5	
	11/14	2	M*	52.0	41.5	40.0	
	11/14	2	M*	51.5	41.0	40.5	
	11/14	2	M*	53.5	42.0	41.0	
	11/14	2	M	48.0	37.5	37.0	
	11/14	2	M	46.5	36.5	35.0	
	11/14	2	M*	47.0	37.5	37.0	

Appendix A. Continued.

Species	Date	Reach	Sex	Length (cm) FL	Length (cm) MOH	Length (cm) POH	Percent egg voidance
Coho	11/14	2	M*	51.5	41.0	40.5	
	11/14	2	M*	51.0	41.5	41.0	
	11/14	2	M*	50.0	40.0	39.5	
	11/16	1	M	48.0	37.5	37.0	
	11/16	1	M	52.5	41.5	40.5	
	11/16	1	M*	50.0	40.0	39.5	
	11/16	1	M	58.0	45.5	44.5	
	11/16	1	M	52.0	40.5	40.0	
	11/16	1	M*	49.0	37.5	37.0	
	11/16	1	M*	44.5	35.0	34.5	
	11/16	2	M*	43.0	34.0	33.5	
	11/16	2	M*	50.0	40.5	40.0	
	11/30	1	M*	48.5	39.0	38.5	
	11/30	1	M*	52.5	41.5	41.0	
	11/30	2	M	60.0	46.0	45.0	
	11/30	2	M*	54.0	43.0	42.5	
	11/30	2	M*	60.0	46.0	45.0	
	11/30	2	M*	47.5	37.0	36.5	
	11/30	1	M*	57.0	46.0	45.0	
Steelhead	2/26	2	F	42.0	36.0	35.5	0
			Walker Creek				
Chum	11/30	1	M	70.0	55.0	54.0	
	11/30	1	M	71.0	57.0	56.0	
	11/30	1	M	69.5	57.0	56.0	
Coho	11/15	2	F*	45.5	37.0	36.5	0
	11/15	2	F*	51.5	43.5	43.0	100
	11/15	2	F*	54.5	44.0	43.0	30

Appendix A. Continued.

Species	Date	Reach	Sex	Length (cm) FL	MOH	POH	Percent egg voidance
Coho	11/15	2	F*	52.5	41.5	41.0	0
	11/15	2	F*	44.5	37.5	37.0	70
	11/15	2	F*	50.0	42.0	41.0	0
	11/15	2	F*	55.0	45.5	45.0	0
	11/15	2	F*	51.0	41.5	41.0	0
	11/16	1	F*	52.0	42.5	42.0	0
	11/16	1	F*	52.0	42.0	41.5	50
	11/16	2	F*	56.0	45.5	45.0	0
	11/16	2	F*	52.5	43.5	43.0	70
	11/16	2	F*	49.0	40.0	39.5	0
	11/16	2	F*	56.5	47.0	46.0	0
	11/16	2	F*	47.5	40.0	39.5	10
	11/16	2	F*	51.5	45.5	45.0	100
	11/16	2	F*	52.0	43.0	42.5	100
	11/16	2	F*	50.0	41.0	40.5	100
	11/17	2	F*	50.5	42.0	41.0	0
	11/30	2	F*	47.0	40.0	39.5	100
	11/15	2	M*	51.0	40.5	40.0	
	11/15	2	M*	48.5	39.0	38.0	
	11/15	2	M*	46.5	37.5	37.0	
	11/15	2	M*	54.0	43.5	43.0	
	11/15	2	M*	47.0	38.5	38.0	
	11/15	2	M*	53.5	42.5	41.5	
	11/15	2	M*	56.0	44.0	43.0	
	11/15	2	M*	54.0	44.0	43.5	
	11/15	2	M*	44.5	35.5	35.0	
	11/15	2	M*	48.0	39.0	38.5	

Appendix A. Continued.

Species	Date	Reach	Sex	Length (cm) FL	MOH	POH	Percent egg voidance
Coho	11/15	2	M*	42.0	33.5	33.0	
	11/16	1	M*	47.0	36.5	36.0	
	11/16	1	M*	43.0	34.5	34.0	
	11/16	1	M*	47.0	37.5	37.0	
	11/16	1	M*	50.0	39.5	39.0	
	11/16	2	M*	32.5	25.0	24.5	
	11/16	2	M*	30.5	24.5	24.0	
	11/16	2	M*	48.0	39.0	38.5	
	11/16	2	M*	43.0	34.5	34.0	
	11/17	2	M*	45.0	37.0	36.5	
	11/17	3	M*	51.0	41.5	41.0	
	11/30	1	M*	57.0	46.0	45.5	
			Des Moines Creek				
Chum	12/18	1	F	63.0	54.5	53.5	100
	12/18	1	M	77.5	61.0	60.0	
	1/12	1	M	70.5	56.5	55.5	
Coho	11/18	1	F*	54.0	43.5	43.0	0
	11/18	1	F*	52.0	42.5	42.0	0
	11/18	1	F*	58.0	44.5	43.5	0
	11/18	1	F	52.5	43.0	42.5	0
	11/18	1	F	47.0	38.0	37.5	50
	11/18	1	F*	53.5	43.0	42.5	0
	11/18	1	F*	53.5	44.0	43.5	0
	11/18	1	F	51.0	40.5	40.0	20
	11/18	1	F*	49.0	40.5	40.0	0
	11/18	1	F*	49.0	40.0	39.5	0
	11/18	1	F*	49.0	40.0	39.5	0

Appendix A. Concluded.

Species	Date	Reach	Sex	Length (cm)			Percent egg voidance
				FL	MOH	POH	
Coho	11/18	1	F*	48.0	40.0	39.5	70
	12/1	1	F	51.0	41.0	40.5	0
	12/1	1	F*	49.0	40.0	39.5	50
	12/1	1	F*	50.5	41.0	40.5	0
	12/1	1	F*	56.0	45.0	44.0	0
	12/1	1	F*	46.0	37.0	36.5	0
	12/1	1	F*	45.5	36.5	36.0	100
	10/29	1	M	38.0	31.0	30.5	
	10/29	1	M	42.0	35.0	34.0	
	11/18	1	M*	49.0	39.5	39.0	
	11/18	1	M*	56.5	44.5	43.5	
	11/18	1	M*	48.0	38.5	38.0	
	11/18	1	M*	48.0	38.5	38.0	
	11/18	1	M*	48.5	38.0	37.5	
	11/18	1	M*	51.0	40.5	40.0	
	11/18	1	M*	47.0	37.0	36.5	
	11/18	1	M*	50.0	39.0	38.5	
	12/1	1	M	46.0	36.5	36.0	
	12/1	1	M*	45.0	36.0	35.5	
Steelhead	12/18	2	F*	59.0	48.0	47.5	0
	1/12	1	F	27.5	22.0	21.5	0