Distribution and Abundance of Fish, and Measurement of Available Habitat in the Tualatin River Basin Outside of the Urban Growth Boundary

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ABSTRACT

We conducted fish, habitat, and water quality surveys on ten tributaries of the Tualatin River and two reaches of the upper Tualatin River as part of an effort to assess the biotic health of the watershed. We sampled lower, middle, and upper reaches of most streams. Habitat surveys were conducted in the summers of 1999 and 2000, whereas fish and water quality surveys were conducted in summer, fall, winter, and spring 1999-2001. Periodic monitoring is needed to ensure that important habitat and existing populations of native fish are protected. We found 16 fish species from 7 families during seasonal sampling. The native reticulate sculpin *Cottus perplexus,* was the most abundant and widely distributed species. Accounting for 62.6% of our total catch, the reticulate sculpin was found in all stream reaches sampled. Largemouth bass was the only introduced species found, contributing 0.1% of the total catch. Native and introduced species moderately or very tolerant of habitat degradation made up 83.7% of the total catch, whereas native species sensitive to habitat degradation accounted for only 16.3% of the catch. Glides were the most common habitat type, and soil was the most common substrate. Little woody debris was found in any stream. Using the fish assemblage data collected, we calculated seasonal index of biotic integrity (IBI) scores for each stream reach sampled. Biotic integrity scores were used to evaluate the need for restoration and enhancement within Tualatin tributaries. Of 86 biotic integrity scores calculated, none were found to be considered acceptable, twelve were marginally impaired, and the remaining scores were considered severely impaired.

INTRODUCTION

The Tualatin basin has become increasingly influenced by urban and agricultural development due primarily to the rapid expansion of urban as well as rural growth. The basin currently supports a growing population of greater than 350,000 residents. The hydrology and landscape of the basin has been changed by modification of original stream channels and the inundation of natural floodplains resulting from agricultural, industrial, and forest practices (Shively 1993). The Oregon Department of Fish and Wildlife (ODFW), the Tualatin River Watershed Council and the Tualatin Soil and Water Conservation District are concerned with the affects that these changes have on water quality, fish habitat, and fish assemblages throughout the basin.

In recent years extensive water quality investigations have been conducted throughout the basin (Ervin et al. 1993) though little information concerning aquatic habitat and fish assemblages exists. ODFW has conducted occasional fish surveys of Tualatin tributaries and the Oregon Fish Commission conducted aquatic inventories in 1958-59 (Willis et al. 1960). These inventories were single day events and focused mainly on salmonids and salmonid habitat in the mainstem Tualatin River. From 1993-95, ODFW conducted the first round of comprehensive fish and habitat surveys to establish a baseline condition of 15 streams in the Tualatin basin (Friesen and Ward 1996).

Residential, commercial, and agricultural growth and development continue throughout the Tualatin River drainage. Restoration and preservation efforts of aquatic habitat have been initiated by a number of private and government organizations. Objectives of this study are to (1) seasonally sample throughout the Tualatin River drainage to evaluate the abundance and distribution of fish and crayfish species, (2) conduct aquatic inventory surveys in the Tualatin River drainage to collect information on available aquatic habitat and, (3) identify relationships between aquatic habitat characteristics and fish species abundance in the Tualatin River drainage. In this report we begin to collect baseline information on the current status and condition of fish assemblages and habitat in rural Tualatin River tributaries. These findings will help ODFW meet its goal to maintain optimum populations and distribution of the basin's fish resources to provide the greatest recreational, commercial, economic, and no consumptive benefits to future and present generations of Oregon citizens (ODFW 1993).

Study Area

The Tualatin River flows from its headwaters in the Coast Range of Northwestern Oregon to its confluence with the Willamette River at river kilometer 46.1 (Figure 1). The Tualatin River drainage consists of a 712 square-mile area situated west of the Portland metropolitan area, with the majority of the basin being located within Washington County.

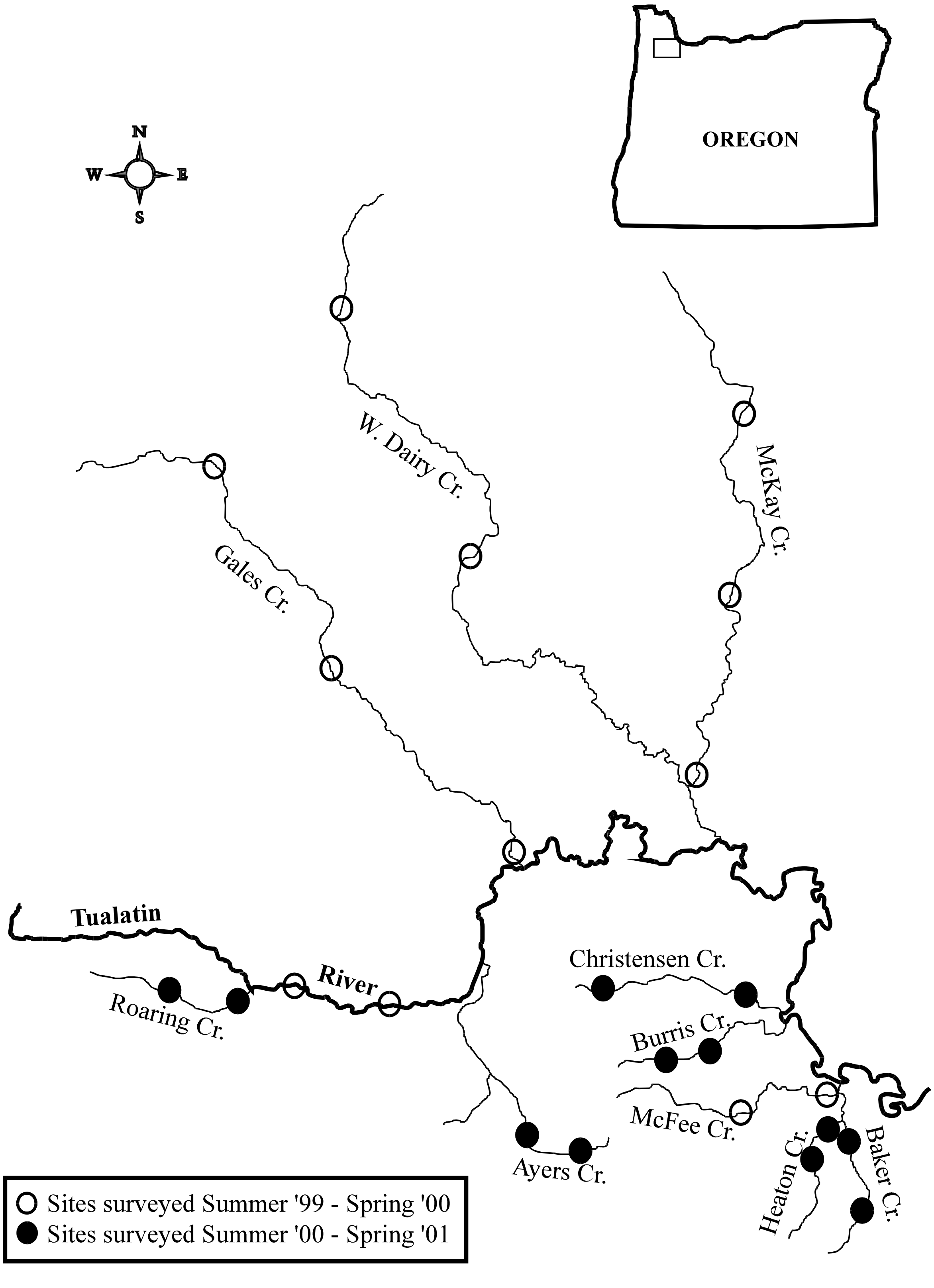

Figure 1. Tualatin River and tributaries surveyed, 1999-2001.

The study area included ten tributaries of the Tualatin River and two reaches of the upper Tualatin River above the town of Gaston (Figure 1). We identified and sampled 24 reaches within these streams. The reaches ranged in length from 665-1122 meters (Appendix A), and were generally located near the mouth, middle and headwaters of each stream.

METHODS

Habitat Surveys

During the summer of 1999 and 2000 we conducted aquatic habitat surveys in each of the twenty-four stream reaches. We used standardized protocols developed by ODFW to describe and quantify stream habitat. The methods were developed by Bisson et al. (1982) and Hankin and Reeves (1988), and modified by Moore et al. (1993).

We surveyed three reaches each of Gales and McKay creeks and two reaches each of Ayers, Baker, Burris, Christensen, Heaton, McFee, Roaring, and W. Dairy creeks, and the upper Tualatin River (Figure 1). We used 1:24,000 United States Geological Survey (USGS) maps to select reaches to be surveyed. Reaches were selected to represent lower, middle, and upper sections of each stream. Criteria used to select stream reaches were (1) how well each reach represented the overall stream, (2) ease of accessibility, and (3) the acquisition of landowner permission to access the property on a seasonal basis.

Starting at a predetermined point, we described general physical characteristics such as channel and valley form, vegetation class, land use and stream flow. We then walked upstream dividing the stream by habitat types such as pool, glide, riffle, etc. Within each habitat unit we visually estimated unit length and width, percent undercut bank, percent active bank erosion, and percent shade. We measured average depth in all units, with the exception pools, in which we measured maximum depth and depth at pool tail crest. We estimated the percentage of each substrate type within each habitat unit. Substrate types were categorized as silt and organic (silt containing fine sediment often containing a large proportion of organic material); sand (<0.2 cm.); gravel (between 0.2 and 6 cm.); cobble (6 to 25 cm.); boulders; and bedrock. We also noted habitat features such as beaver activity, culverts, and possible fish passage barriers.

Every habitat unit was given a woody debris rating depending on wood composition as it relates to fish habitat. A rating of one to five was given, with one being little or no wood, and five being large amounts of wood creating cover and refuge. In addition, we noted the configuration, type, location, and size of root wads and pieces of wood measuring at least 1.5-3.0 cm in width and 3m in length.

Fish Surveys

To estimate the relative abundance of fish species in each stream reach we used a three-pass removal method (Armour et al. 1983). A 100m section of each stream reach was selected based on accessibility, landowner approval, and how well the section represented the entire reach. We used a Smith-Root model-12 backpack electrofishing unit was used to conduct the surveys. Depending on water conductivity, the electrofishing unit was set to between 100 and 400 volts.

Before starting we placed block nets at the lower and upper ends of the 100m section to ensure population enclosure. We then made three successive passes starting at the downstream end of the stream section and working upstream. During each pass fish were netted and held in a holding tank until the completion of pass. After each pass all fish collected were enumerated, identified to species, measured to the nearest millimeter (a maximum of 50 fish per species), and checked for any anomalies (parasites, wounds, or any other physical abnormalities). Before starting the next pass all fish were released below the downstream block net. If no salmonids were collected during the second pass, a third pass was not conducted. We also collected and enumerated all crayfish during each pass. Fish sampling was conducted once in each stream reach during summer, fall, winter, and spring.

Water Quality

We collected water quality measurements in each stream reach concurrent with fish surveys. We measured conductivity (ns), turbidity (ntu), dissolved oxygen (% sat. & mg/l), salinity (ppt), water temperature (°C), stream velocity (m/s), and total dissolved solids (mg/l). All measurements were collected before electrofishing was started and were taken from an undisturbed site with characteristics representative of the entire reach.

Index of Biotic Integrity

The index of biotic integrity (Karr et al. 1986) is a commonly used tool for determining the biological integrity of streams. The IBI consists of a numerical score calculated from field survey data. A set of scoring criteria based on fish assemblage characteristics is used to calculate the IBI score (Table 1). We used the IBI developed and tested by Hughes et al. (1998) for wadeable streams in the Willamette Valley. Scoring criteria for this IBI were based on pre-settlement stream conditions, species ranges, habitat requirements, and reference sites. We used a continuous scoring of 0.0-10.0 for individual metrics and 0-100 for the IBI score.

We modified the IBI slightly in applying it to Tualatin streams. Hughes et al. (1998) includes a "native top carnivore" metric as one of three trophic guild measurements. Species that we found in Tualatin streams listed as native top carnivores by Hughes et al. (1998) were northern pikeminnow, coho salmon, chinook salmon, cutthroat trout, rainbow trout, and torrent sculpin (Appendix C). Because these species are usually carnivorous only at larger sizes and few were captured in our surveys, the native top carnivore metric was not use in our IBI. We adopted relative tolerance and trophic group classifications used by Zaroban et al. (1999) for use with the IBI scoring criteria. Other metrics and their scoring criteria remained unchanged. Because the IBI developed by Hughes only included first through third order streams, we included fourth order streams in the same scoring category as second and third order streams.

An IBI score was calculated for each seasonal fish survey. Mean IBI values were determined for seasons, streams, and reaches. Biotic integrity was judged as acceptable (≥75), marginally impaired (51-74), and severely impaired (≤50) Hughes et al. (1998). We assigned an IBI score of 0.0 to those reaches that contained no fish.

Table 1. Scoring criteria for IBI metrics used for Tualatin rural streams. Raw data values at low (and lower) end of the ranges are scored as zero; those at the high (and higher) end are scored as 10; scores for intermediate values are calculated by dividing the raw value by the score range. Modified from Hughes et al. (1998).

	Raw values	
Metric	Stream order 1	Stream orders 2-4
Taxonomic richness		
Number of native families	0-4	0-7
Number of native species	0-5	0-11
Habitat guilds		
Number of native benthic species	0-3	0-7
Number of native water column species	0-2	0-4
Number of hider species	0-4	0-4
Number of sensitive species	0-2	0-5
Number of native non-guarding lithophil nester species[a]	0-3	0-3
Percent tolerant individuals	10-0	10-0
Trophic guilds		
Percent filter-feeding individuals	0-10	0-10
Percent omnivores	10-0	10-0
Individual health and abundance		
Percent of target species that include lunkers[b]	0-100	0-100
Percent individuals with anomalies	2-0	2-0

[a]Species that create nests in gravel or cobble substrate.

[b]Lunkers are relatively old, large individuals of the following species and sizes (fork length): prickly sculpin (100 mm), torrent sculpin (100 mm), rainbow trout (300 mm), cutthroat trout (250 mm), chiselmouth (300 mm), northern pikeminnow (300 mm), and largescale sucker (300 mm).

We used Spearman correlation (Zar 1984) to evaluate relationship among habitat data and seasonal and mean IBI scores for each reach. Unlike habitat sampling, water quality measurements were taken seasonally, for this reason we used seasonal water quality data with seasonal IBI scores when determining correlation. We used a decision level of $P \leq 0.05$ to determine statistical significance.

RESULTS

Habitat Surveys

Glides (characterized by uniform depth and flow) were the most common habitat type in 15 of 24 reaches (Figure 2; Appendix B). Pools (low gradient, non-uniform depth) were the next most common habitat type, being found primarily in upper stream reaches and upper Tualatin River reaches. Riffles (faster flow and higher gradient) were also found predominantly in upper reaches and upper Tualatin River reaches with the exceptions of middle reaches of Roaring and Burris creeks where it was the most abundant habitat type. Rapids (Swift, turbulent flow with higher gradient) were the least common habitat type and were only found in upper reaches of Gales Creek, McKay Creek, Christensen Creek, and both reaches of Roaring Creek. The “Other” category consisted primarily of steps (short units with abrupt, discrete breaks in channel gradient), and was most abundant in upper reaches.

The most abundant substrate type was soil, which consisted of silt/organic material and sand (Figure 2). Soil was the dominant substrate in lower and middle reaches. Rock, a combination of gravel and cobble, was most common in upper reaches and in both upper Tualatin River reaches. Boulder and bedrock substrate was found primarily in upper reaches and the upper Tualatin and comprised a small portion of available habitat.

Actively eroding bank was most common in lower and middle reaches, and comprised more than 50% of the bank in 4 of 24 reaches. Undercut banks comprised less than 20% of the total bank area in all reaches except lower Gales Creek (27.3%) and middle Christensen (46.7%). Shade exceeded 50% in most streams and was similar among lower (75.0%), middle (58.7%), and upper (73.3%) reaches. The index of woody debris was generally low (<2.0) for most stream reaches. Highest mean wood ratings were found at middle Christensen creek (3.0) and middle Roaring creek (3.5)

Fish Surveys

We conducted 86 electrofishing surveys in 24 stream reaches during summer, fall, winter, and spring, 1999-2001. A total of 6,658 fish were collected representing 16 species and 7 families (Table 2; Appendix C). The number of individual fish collected was highest in Roaring Creek (1,257). We found the most species (12) in Gales Creek. Reticulate sculpin comprised the highest percent of our overall catch (62.6%), followed by cutthroat trout (14.2%), and torrent sculpin (6.9%). Introduced species contributed 0.16% of the total catch. Upper reaches contained the highest number of salmonids, whereas the middle reaches contained a higher number of redside shiners and brook lamprey (Figure 3).

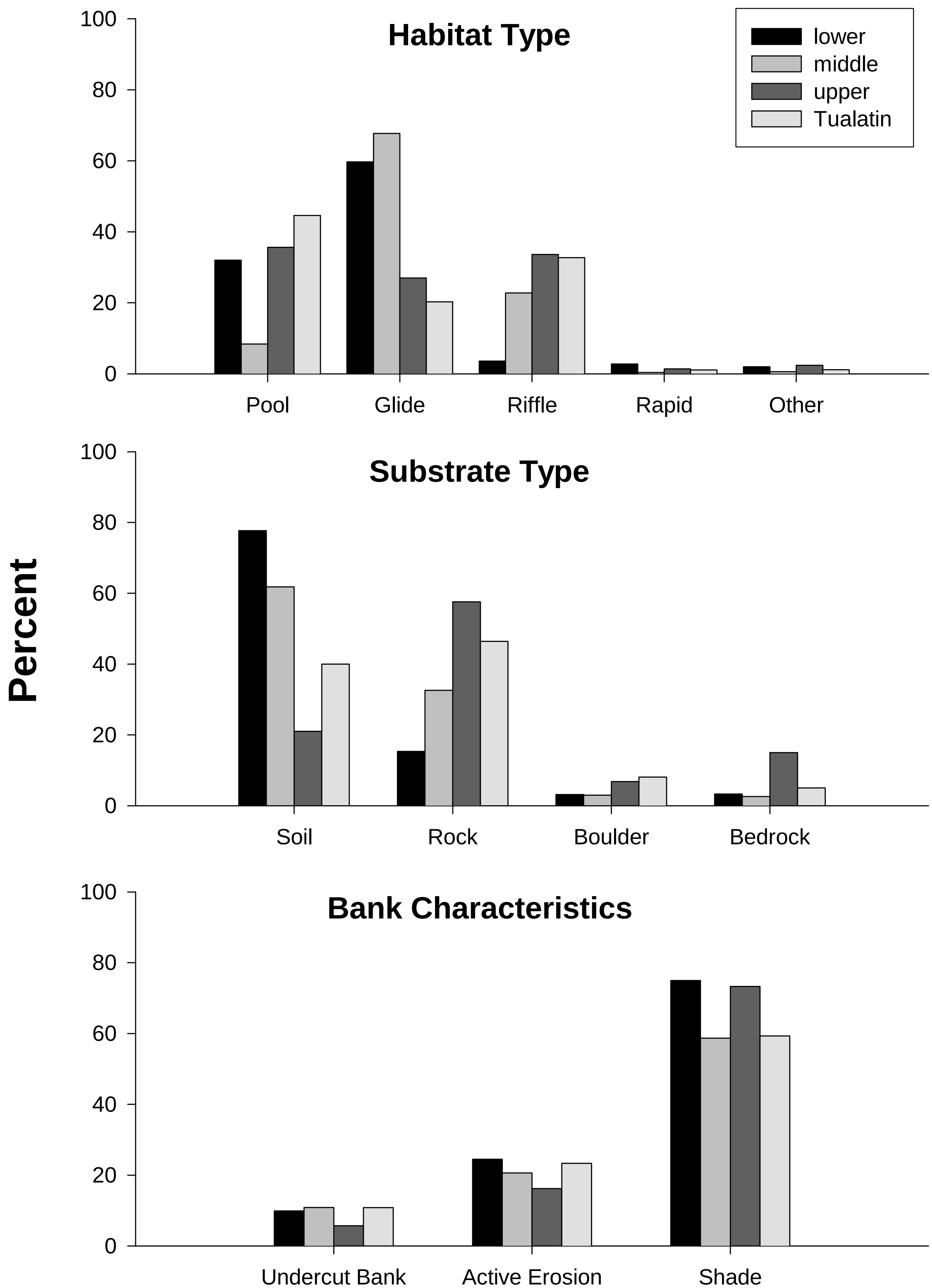

Figure 2. Mean values for habitat characteristics of reaches sampled, 1999-2001.

Table 2. Fish collected in 22 reaches of 10 tributaries of the Tualatin River and 2 reaches of the upper Tualatin River in summer, fall, winter, and spring 1999-2001. Relative tolerance and trophic group classifications from Zaroban et al. (1999).

Family, Species	Relative tolerance	Adult trophic group	Percent of Catch	No. of streams (reaches)
Petromyzontidae				
Western Brook lamprey *Lampetra richardsoni*	Intermediate	--[a]	2.99	11 (19)
Unidentified *Lampetra* spp.	Intermediate	--	0.08	2 (3)
Salmonidae				
Chinook salmon *Oncorhynchus tshawytscha*	Sensitive	Insectivore	0.08	1 (1)
Coho salmon *Oncorhynchus kisutch*	Sensitive	Insectivore	0.54	3 (4)
Cutthroat trout *Oncorhynchus clarkii*	Sensitive	Insectivore	14.18	11 (19)
Rainbow trout *Oncorhynchus mykiss*	Sensitive	Insectivore	1.01	5 (7)
Mountain whitefish *Prosopium williamsoni*	Intermediate	Insectivore	0.02	1 (1)
Unidentified Salmonidae	Sensitive		0.56	5 (6)
Cyprinidae				
Northern pikeminnow *Ptychocheilus oregonensis*	Tolerant	Piscivore	0.11	1 (2)
Redside shiner *Richardsonius balteatus*	Intermediate	Insectivore	3.12	5 (6)
Speckled dace *Rinichthys osculus*	Intermediate	Insectivore	4.18	9 (12)
Longnose dace *Rhinichthys cataractae*	Intermediate	Insectivore	0.51	2 (3)
Gasterosteidae				
Threespine stickleback *Gasterosteus aculeatus*	Tolerant	Insectivore	0.32	5 (6)
Catostomidae				
Largescale sucker *Catostomus macrocheilus*	Tolerant	Omnivore	0.53	5 (6)
Centrarchidae[b]				
Largemouth bass Micropterus salmoides	Tolerant	Piscivore	0.11	1 (1)
Unidentified *Lepomis* spp.	Tolerant		0.05	2 (2)
Cottidae				
Reticulate sculpin *Cottus perplexus*	Intermediate	Insectivore	62.57	11 (24)
Torrent sculpin *Cottus rhotheus*	Intermediate	Piscivore	6.88	5 (7)
Prickly sculpin *Cottus asper*	Intermediate	Insectivore	2.21	4 (7)

[a] Adults do not feed
[b] Introduced family

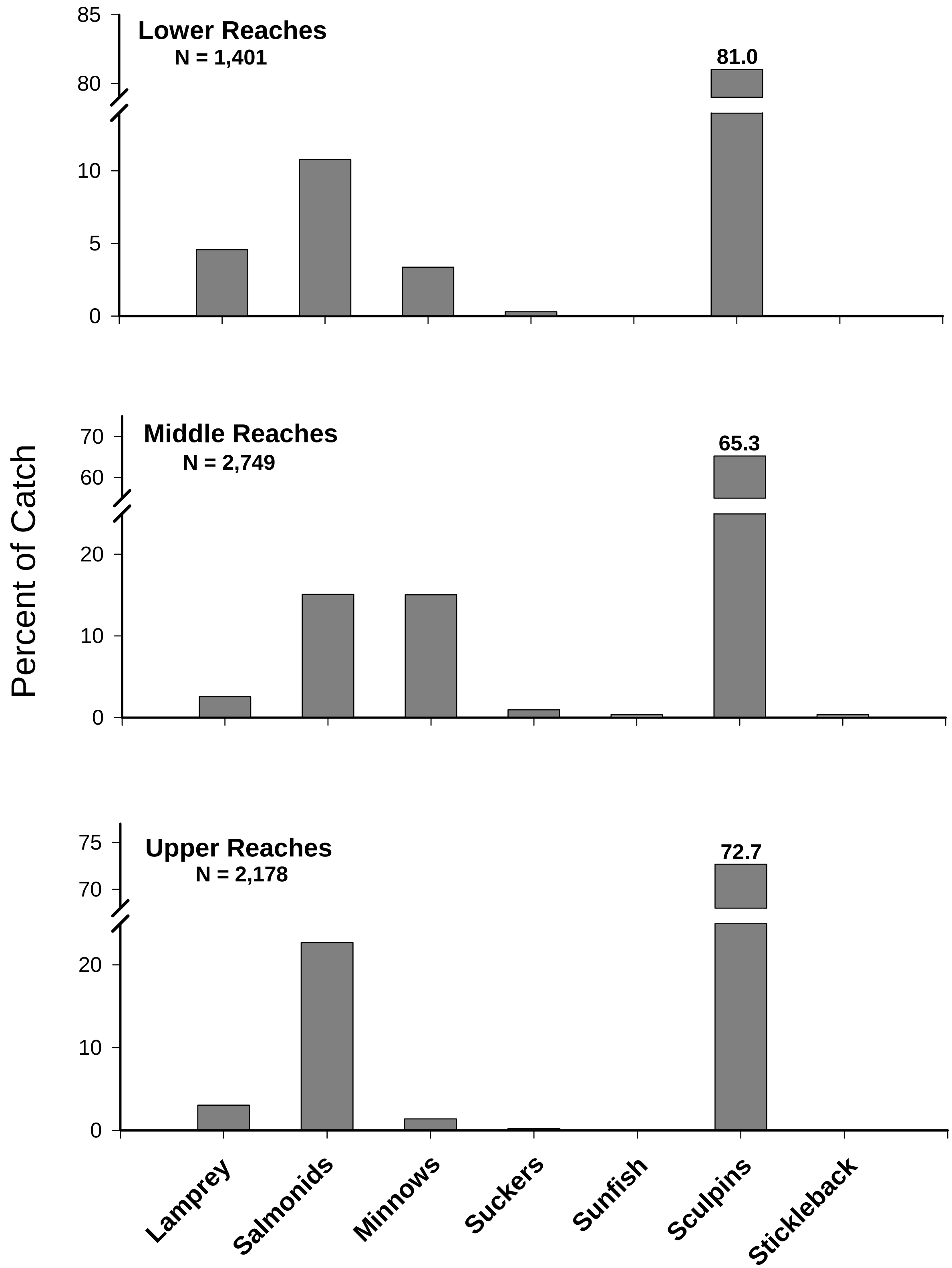

Figure 3. Family composition of fish collected in tributaries of the Tualatin River, 1999-2001.

Species moderately or very tolerant of warm temperatures, organic pollution, and sedimentation made up 83.6% of the total catch (Table 2), consisting mainly of reticulate sculpin. Other relatively tolerant species included northern pikeminnow, largescale sucker, and largemouth bass. The most common species sensitive to habitat degradation were cutthroat trout (14.2%), torrent sculpin (6.9%), and western brook lamprey (3.0%).

The majority of the fish collected were insectivores (Table 2). The only omnivores found were largescale suckers. Torrent sculpin, largemouth bass and northern pikeminnow were the only piscivorous species collected.

Fish with anomalies were rare and comprised only 2.0% of the total catch (Table 3). Most of the anomalies were in the form of fin damage, scars, and other deformities. Parasites were found mostly during fall sampling. Anomalies were most numerous in reaches of McKay and Ayers creeks, and least numerous in Christensen Creek and the upper Tualatin River.

We found the most crayfish (42) in upper McFee Creek, and the fewest in middle McFee Creek (1). The majority of crayfish were seen during summer sampling (164), followed by spring (59), fall (41) then winter (2) (Appendix B).

Water Quality

Water quality varied among streams and seasons (Appendix C). Water temperatures were highest during summer sampling in reaches of Gales, McKay, Dairy and Burris creeks, and the lowest during winter sampling in reaches of Burris, Baker and Heaton creeks. Dissolved oxygen levels were highest in the streams with the lowest temperatures. Water temperatures generally dropped during fall and winter, but rose again in spring. We found moderate variation in pH among streams and seasons (range 6.0-9.4).

Index of Biotic Integrity

Index of biotic integrity scores are summarized in Table 4. IBI scores are shown by reach and season, seasonal mean by reach, and stream mean. The mean IBI score for all reaches combined was 39.3, and varied from 34.7 during winter to 42.4 during spring. Upper Burris Creek had the lowest (28.1) mean IBI score; and lower Roaring Creek had the highest (54.4) mean IBI score. Scores were highly variable for some reaches and seasons, but remained consistent for others. Middle Christensen for example ranged from 21.8 in summer to 48.2 in spring, whereas upper upper Burris Creek remained at 28.1 during all four seasons. The only species caught at upper Burris Creek was reticulate sculpin.

We observed the highest seasonal IBI scores during summer sampling in lower Roaring Creek (69.0) and during spring sampling middle W. Dairy Creek (53.4). The lowest seasonal reach IBI scores were observed during spring in upper Christensen Creek (0.0) and during summer sampling in lower McKay Creek (19.8). Because no fish were caught in upper Christensen spring sampling, it was given an IBI score of 0.0.

Table 3. Anomalies found in fish collected from tributaries of the Tualatin River and two reaches of the upper Tualatin River, 1999-2001.

	Anomalies		
Stream, reach	Number of fish (% of catch)	Number with parasites	Number with deformities
Gales			
Lower	2 (1.1)	2	0
Middle	11 (1.6)	7	4
Upper	4 (1.7)	2	2
McFee			
Middle	0 (0.0)	0	0
Upper	17 (2.8)	7	10
McKay			
Lower	7 (4.3)	3	4
Middle	6 (5.0)	1	5
Upper	6 (1.0)	0	6
W. Dairy			
Middle	0 (0.0)	0	0
Upper	8 (2.2)	3	5
Upper Tualatin River			
Middle	0 (0.0)	0	0
Upper	0 (0.0)	0	0
Ayers			
Middle	36 (15.7)	36	0
Upper	1 (0.1)	1	0
Baker			0
Middle	5 (2.8)	0	5
Upper	0 (0.0)	0	0
Burris			0
Middle	18 (5.0))	18	0
Upper	0 (0.0)	0	0
Christensen			0
Middle	0 (0.0)	0	0
Upper	1 (4.4)	0	1
Heaton			0
Lower	1 (0.2)	1	0
Middle	5 (3.9)	4	1
Roaring			0
Lower	2 (0.3)	2	0
Middle	4 (0.6)	1	3

Table 4. Index of biotic integrity (IBI) scores for Tualatin River tributary stream reaches, 1999-2001. Scores were considered acceptable, marginally impaired, or severely impaired if they were ≥75, 51-74, or ≤50, respectively (Hughes et al. 1998). NS = no survey.

		IBI score					
Stream	Reach	Summer	Fall	Winter	Spring	Mean	Stream Mean
Ayers	Middle	36.5	37.7	28.3	48.7	37.8	
	Upper	40.5	51.8	51.8	49.8	48.5	43.1
Baker	Middle	40.1	34.9	31.4	36.6	35.8	
	Upper	31.5	31.5	25.0	31.5	29.9	32.8
Burris	Middle	40.7	54.1	49.8	39.8	46.1	
	Upper	28.1	28.1	28.1	28.1	28.1	37.1
Christensen	Middle	21.8	31.3	34.2	48.2	33.9	
	Upper	33.9	41.9	46.4	0.0	30.6	32.2
Gales	Lower	47.1	NS	NS	42.8	45.0	
	Middle	49.8	37.8	33.2	52.7	43.4	
	Upper	40.1	53.3	27.5	37.9	39.7	42.7
Heaton	Middle	47.2	36.6	45.3	43.3	43.1	
	Upper	39.0	43.4	36.6	45.8	41.2	42.2
McFee	Middle	43.3	28.1	NS	50.9	40.8	
	Upper	53.2	45.6	36.6	51.1	46.6	43.7
McKay	Lower	19.8	27.1	NS	45.5	30.8	
	Middle	36.9	NS	NS	44.8	40.9	
	Upper	47.2	32.6	43.1	47.7	42.7	38.1
Roaring	Lower	69.0	48.8	48.4	51.5	54.4	
	Middle	36.1	30.8	36.6	36.6	35.0	44.7
Tualatin R.	Middle	44.4	NS	NS	34.5	39.5	
	Upper	51.3	49.1	40.5	49.2	47.5	43.5
W. Dairy	Middle	44.6	NS	NS	53.4	49.0	
	Upper	33.2	45.6	39.8	46.6	41.3	45.2

Statistically significant correlations were rare among habitat characteristics and seasonal mean IBI scores (Table 5). Of the 60 individual correlations calculated, only five significant relationships were found. We found significant positive correlations among winter IBI scores and number of boulders (P=0.02), and percent gravel or cobble substrate (P=0.03). Significant positive correlations were also seen among spring IBI scores and percent units with eroding banks (P=0.002) and mean IBI scores and mean percent undercut bank. The only significant negative relationship found was among winter IBI scores and percent silt or san substrate. We found no significant relationships among IBI scores and water quality measurements (Table 6).

DISCUSSION

Species sensitive to habitat degradation (salmonids, torrent sculpin, and western brook lamprey) were found primarily in stream reaches above obvious signs of habitat degradation. Habitat characteristics associated with these reaches include higher gradient, swift water, rocky substrate, lower water temperatures and a higher percent of shade. Important salmonid spawning and rearing habitat is most likely to be found in upper reaches of all streams surveyed.

A few sunfish (unidentified *Lepomis* spp. and largemouth bass) were the only fish found that are extremely tolerant of warm temperatures, organic pollution and sedimentation (Hughes et al. 1998). These individuals were found only in the middle reaches of McKay, Christensen, and W. Dairy creeks. Excluding reticulate sculpin, which were found in all 24 stream reaches sampled, species moderately tolerant of habitat degradation were found predominantly in lower and middle reaches. These reaches also contained relatively few sensitive species such as salmonids, which may indicate the presence of factors limiting the production of these species.

Crayfish populations in tributaries of the Tualatin River appear to be healthy. Crayfish were found in all reaches, with the exception of upper Christensen. Observations of crayfish were highest during summer sampling then declined during fall and winter with a marginal increase during spring. The high variability of crayfish counts among seasons was most likely due to changes in flow and turbidity during fall and winter months. In addition, crayfish become completely inactive during winter (Oregon State University Extension Service 1978)

Historically, coho salmon were not found in the Tualatin River basin. However, with the addition of a fish ladder at Willamette falls, the possibility of strays from other basins entering the Tualatin River, and previous introduction of hatchery stocks, some natural production of coho salmon is now occurring in the basin. We observed juvenile coho salmon in reaches of Gales Creek, lower Roaring Creek and the upper Tualatin River.

Sustained water temperatures of above 12.8°C are considered too high for salmonid spawning and rearing, and temperatures above 20°C can have detrimental effects on other cold water species (DEQ 2000). None of the reaches sampled were found to have water temperatures above 20°C and only four reaches were above 12.8°C.

Table 5. Spearman correlation coefficients for comparisons of index of biotic integrity (IBI) scores with habitat data summarized for all stream reaches, 1999-2001. Statistically significant relationships (P<0.05) are denoted with an asterisk (*).

	IBI				
Habitat variable	Summer	Fall	Winter	Spring	Mean
% units with eroding banks	0.22	0.15	-0.35	0.60*	0.22
Mean pool depth (m)	0.23	-0.10	-0.35	0.01	-0.09
Mean % shading	0.01	0.29	0.26	0.00	0.16
Number of boulders	0.07	0.27	0.49*	-0.15	0.19
Mean % undercut bank	0.26	0.07	0.26	0.31	0.41*
Mean wood rating	-0.36	0.11	0.18	-0.36	-0.27
% of units with wood rating >2	-0.21	-0.07	0.29	-0.28	-0.11
% silt or sand substrate	-0.09	-0.15	-0.45*	0.08	-0.24
% gravel or cobble substrate	0.04	0.15	0.45*	-0.09	0.22
% surface area as fast water units (m^2)	-0.01	-0.36	-0.39	0.08	-0.18
% surface area as glides (m^2)	-0.10	-0.17	-0.38	0.27	-0.18
% surface area as pools (m^2)	0.02	-0.29	0.06	-0.26	-0.06

Table 6. Spearman correlation coefficients for comparisons of index of biotic integrity (IBI) scores with water quality variables in Tualatin River tributary stream reaches, 1999-2001. The "mean" column compares mean IBI score and mean water quality variable for all seasons combined. Strongly correlated variables (P<0.05) are denoted with an asterisk (*).

	IBI				
Water quality variable	Summer	Fall	Winter	Spring	Mean
Turbidity (NTU)[a]	-0.22	-0.33	-0.31	-0.08	-0.08
Percent oxygen saturation	-0.11	-0.09	-0.01	-0.07	-0.08
Dissolved oxygen (mg/L)	-0.02	-0.12	0.11	-0.02	0.15
Temperature (°C)	-0.17	0.05	-0.18	0.02	-0.25
Water velocity (m/s)	0.15	-0.02	0.24	-0.14	0.04
Conductivity (μS/cm)[b]	-0.22	0.11	0.03	0.20	-0.12
Total dissolved solids (mg/L)	-0.20	-0.04	0.30	0.23	-0.08

[a]nephelometric turbidity unit
[b]microSeimens/cc

Dissolved oxygen levels above 11mg/L are considered adequate to support salmonid spawning and rearing (DEQ 2000). Dissolved oxygen levels were above 11mg/L at 23 of 41 of our seasonal site surveys. Most dissolved oxygen levels above 11mg/L occurred during winter and spring. None of the sites surveyed had dissolved oxygen levels below 5.5mg/L.

Stream pH levels usually range from 6.5 to 8.5, although wide variation can occur because of local watershed geology (DEQ 2000). All of the sites we sampled ranged from 6.0 to 9.4.

Of the 86 IBI scores we calculated none fell within the range to be considered acceptable, 12 were considered marginally impaired and the remaining IBI scores were considered severely impaired. We suggest prioritizing aquatic habitat enhancement projects within Tualatin tributaries according to biotic integrity scores. This is similar to the methods used to prioritize habitat enhancement in an earlier Tualatin tributaries study conducted by ODFW (Ward, editor. 1995). Aquatic habitat in the vicinity of stream reaches with higher IBI scores should be protected and conserved. These reaches contain relatively healthy fish assemblages, and in general have a greater amount of quality aquatic habitat. Reaches with moderate and poor IBI scores should be considered for habitat restoration and enhancements projects. These reaches are more likely to benefit from habitat enhancement projects.

Due to the continued urban and rural growth within the Tualatin River basin, revisiting these stream reaches on a periodic basis is recommended. To ensure that the biotic integrity of Tualatin tributaries is preserved and maintained, future studies should be conducted and the findings compared with those of this and previous studies to determine the need for future aquatic habitat enhancement and preservation.

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APPENDIX A

Stream Reach Locations

Appendix Table A-1. Approximate location of reaches designated during aquatic habitat inventories of Gales, McFee, McKay, W. Dairy Creeks, and the upper Tualatin River, 1999.

Stream	Reach	Location
Gales	Lower	Mouth to upstream 1002 meters.
	Middle	Confluence with Clear Cr. to upstream 1000 meters.
	Upper	Confluence with Beaver Cr. to upstream 991 meters.
McFee	Middle	Confluence with Baker Cr. to upstream 1000 meters.
	Upper	Confluence with Gulf Canyon Cr. to upstream 973 meters.
McKay	Lower	Mouth to upstream 1000 meters.
	Middle	Entrance to pond at South Ave. to upstream 1035 meters.
	Upper	Bridge crossing on Collins Rd. to upstream 879 meters.
W. Dairy	Middle	Confluence with Park Farms Cr. to upstream 1008 meters.
	Upper	Confluence with Cummings Cr. to upstream 665 meters.
Tualatin River	Middle	Bridge crossing at Mt. Richmond Rd. to upstream 960 meters.
	Upper	Bridge at SW South Rd to upstream 1122 meters.

Appendix Table A-2. Approximate location of reaches designated during aquatic habitat inventories of rural tributaries of the Tualatin River, and the upper Tualatin River, 1999-2000.

Stream	Reach	Location
Ayers	Middle	North Valley Rd. to upstream 841 meters.
	Upper	Second culvert crossing at Dopp Rd to upstream 1020 meters.
Baker	Middle	Confluence of Baker and Heaton to upstream 997 meters.
	Upper	SW Kruger Rd to upstream 925 meters.
Burris	Middle	SW Laurel Rd. to upstream 1022 meters.
	Upper	End of Stickney Dr. to upstream 778 meters.
Christensen	Middle	Highway 219 to upstream 1030meters.
	Upper	SW Dixon Mill Rd. to upstream 1000 meters.
Heaton	Middle	Siefert Rd to upstream 896.
	Upper	NE Mountain Home Rd. to upstream 852.
Roaring	Lower	Mouth to upstream 615 meters.
	Middle	Road crossing upstream 923 meters.

APPENDIX B

Habitat Inventory Data

Appendix Table B-1. Habitat summary for reaches of Tualatin River tributaries and upper Tualatin River, summer 1999. L = lower reach, M = middle reach, and U = upper reach. Woody debris is a rating of wood complexity as it relates to fish habitat and ranges from 1 to 5 with 5 being the most complex (Moore et al. 1993).

	Stream					
	Gales			McKay		
	L	M	U	L	M	U
Meters sampled	1002	1000	991	1000	1035	879
Habitat type (%)						
Pool	35.8	9.9	41.1	32.1	24.5	24.7
Glide	63.3	46.2	3.3	67.1	75.0	10.4
Riffle	0.0	40.2	49.1	0.0	0.0	57.3
Rapid	0.0	2.4	5.5	0.0	0.0	0.7
Other	0.9	1.3	1.0	0.8	0.5	6.8
Substrate (%)						
Soil	96.1	5.4	4.6	98.1	100.0	8.4
Rock	3.9	70.5	66.4	1.0	0.0	69.9
Boulder	0.0	1.9	7.9	0.1	0.0	21.3
Bedrock	0.0	22.2	24.1	0.0	0.0	0.5
Bank type (%)						
Eroding	34.4	8.8	16.4	60.1	28.1	8.1
Undercut	27.3	2.4	4.4	0.1	5.5	8.2
Shade (%)	55.7	46.9	67.8	69.6	80.5	85.8
Gradient (%)	0.0	0.8	1.2	0.2	0.0	1.8
Woody debris	1.3	1.1	1.1	1.1	1.3	1.1

Appendix Table B-2. Habitat summary for reaches of Tualatin River Tributaries and upper Tualatin River, summer 1999. L = lower reach, M = middle reach, and U = upper reach. Woody debris is a rating of wood complexity as it relates to fish habitat and ranges from 1 to 5 with 5 being the most complex (Moore et al. 1993).

	Stream					
	W. Dairy		McFee		Upper Tualatin R.	
	M	U	M	U	M	U
Meters sampled	1008	665	1000	973	960	1122
Habitat type (%)						
Glide	4.4	26.4	11.7	28.4	56.2	38.4
Pool	93.3	36.0	77.0	49.8	26.2	17.1
Riffle	1.9	30.8	9.5	21.6	17.2	41.1
Rapid	0.0	0.0	0.0	0.0	0.0	1.7
Other	0.4	6.8	1.8	0.1	0.4	1.7
Substrate (%)						
Soil	100.0	29.8	91.3	40.5	63.5	20.0
Rock	0.0	66.3	7.7	59.5	35.8	55.5
Boulder	0.0	3.9	1.0	0.0	0.2	14.9
Bedrock	0.0	0.0	0.0	0.0	0.0	9.2
Bank type (%)						
Eroding	71.6	24.9	60.8	59.7	13.5	31.8
Undercut	0.0	10.2	10.7	7.3	5.4	15.6
Shade (%)	71.1	63.9	52.9	40.2	47.9	69.1
Gradient (%)	0.4	1.7	0.4	0.5	0.2	0.6
Woody debris	1.0	1.2	1.3	1.0	1.2	1.2

Appendix Table B-3. Habitat summary for reaches of Tualatin River Tributaries and upper Tualatin River, summer 2000. L = lower reach, M = middle reach, and U = upper reach. Woody debris is a rating of wood complexity as it relates to fish habitat and ranges from 1 to 5 with 5 being the most complex (Moore et al. 1993).

	Stream					
	Ayers		Baker		Burris	
	M	U	M	U	M	U
Meters sampled	841	1020	997	925	1022	778
Habitat type (%)						
Glide	93.4	11.7	95.4	3.7	15.0	100.0
Pool	0.0	10.5	2.5	71.1	14.9	0.0
Riffle	6.4	72.4	1.3	25.2	69.2	0.0
Rapid	0.0	0.6	0.0	0.0	0.0	0.0
Other	0.2	4.8	0.7	0.1	0.8	0.0
Substrate (%)						
Soil	37.3	14.3	90.0	34.4	23.6	11.3
Rock	61.1	48.7	10.0	59.6	65.5	42.1
Boulder	1.6	1.3	0.0	3.2	4.0	3.1
Bedrock	0.0	36.1	0.0	2.7	7.9	43.6
Bank type (%)						
Eroding	33.1	24.1	5.7	3.9	11.0	1.9
Undercut	10.8	6.9	2.5	3.8	8.9	1.3
Shade (%)	66.8	90.0	52.1	79.7	77.1	75.5
Gradient (%)	1.0	3.6	0.7	2.7	2.3	17.4
Woody debris	2.5	1.0	1.8	2.4	2.8	1.3

Appendix Table B-4. Habitat summary for reaches of Tualatin River Tributaries and upper Tualatin River, summer 2000. L = lower reach, M = middle reach, and U = upper reach. Woody debris is a rating of wood complexity as it relates to fish habitat and ranges from 1 to 5 with 5 being the most complex (Moore et al. 1993).

	Stream					
	Christensen		Heaton		Roaring	
	M	U	L	M	L	M
Meters sampled	1030	1000	896	852	615	923
Habitat type (%)						
Glide	83.5	0.8	72.6	97.2	35.5	1.1
Pool	16.5	82.4	25.0	0.0	35.1	0.0
Riffle	0.0	12.3	2.2	2.8	12.0	96.8
Rapid	0.0	4.5	0.0	0.0	11.3	2.0
Other	0.0	0.0	0.2	0.0	6.0	0.1
Substrate (%)						
Soil	90.7	25.0	98.2	93.2	16.3	6.3
Rock	9.3	64.4	1.4	6.8	57.0	71.6
Boulder	0.0	11.7	0.4	0.0	12.1	18.7
Bedrock	0.0	0.0	0.0	0.0	13.6	2.3
Bank type (%)						
Eroding	23.5	1.0	8.9	4.2	10.1	4.4
Undercut	46.7	1.6	6.9	5.5	7.9	3.6
Shade (%)	56.9	67.4	80.4	46.1	87.4	47.7
Gradient (%)	0.0	7.8	0.7	1.8	4.1	5.1
Woody debris	3.0	2.2	1.8	2.8	2.9	3.5

APPENDIX C

Fish Survey Data

Appendix Table C-1. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, summer 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
Species	L	M	U	L	M	U
Western brook lamprey	4	6	0	0	1	2
Unidentified lamprey	0	0	1	0	0	0
Coho salmon	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	1	0	0	0	2	98
Rainbow trout	0	2	11	0	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	1	3	0	0	0	0
Redside shiner	32	43	0	0	0	0
Speckled dace	2	40	0	0	1	0
Longnose dace	0	32	0	0	0	0
Largescale sucker	3	2	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	2	0
Reticulate sculpin	60	112	54	41	57	55
Torrent sculpin	0	5	64	0	0	11
Prickly sculpin	1	2	0	0	0	56
Crayfish	1	7	3	9	1	18

Appendix Table C-2. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, summer 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
Species	M	U	M	U	M	U
Western brook lamprey	4	0	6	4	4	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	1	44	0	37	0	2
Rainbow trout	0	0	0	3	0	1
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	2
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	22	0
Speckled dace	0	0	0	6	7	2
Longnose dace	0	0	0	0	0	0
Largescale sucker	2	0	0	2	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	1	0	0	0	0	0
Reticulate sculpin	25	89	35	147	60	33
Torrent sculpin	0	17	0	0	0	6
Prickly sculpin	1	30	0	0	5	15
Crayfish	2	7	1	28	5	15

Appendix Table C-3. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, fall 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
Species	L[a]	M	U	L	M[a]	U
Western brook lamprey	--	0	2	0	--	0
Unidentified lamprey	--	2	0	0	--	0
Coho salmon	--	0	0	0	--	0
Chinook salmon	--	0	0	0	--	0
Cutthroat trout	--	0	1	2	--	67
Rainbow trout	--	0	15	0	--	0
Mountain whitefish	--	0	0	0	--	0
Unidentified salmonid	--	0	0	0	--	0
Northern pikeminnow	--	3	0	0	--	0
Redside shiner	--	62	0	0	--	4
Speckled dace	--	46	0	0	--	0
Longnose dace	--	0	0	0	--	0
Largescale sucker	--	12	0	1	--	0
Threespine stickleback	--	0	0	0	--	0
Unidentified Lepomis	--	0	0	0	--	0
Reticulate sculpin	--	26	21	34	--	14
Torrent sculpin	--	11	10	0	--	20
Prickly sculpin	--	9	0	0	--	0
Crayfish	--	0	0	0	--	2

[a]Not sampled due to high flows and turbidity.

Appendix Table C-4. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, fall 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
Species	M[a]	U	M	U	M[a]	U
Western brook lamprey	--	3	0	4	--	0
Unidentified lamprey	--	0	0	0	--	0
Coho salmon	--	0	0	0	--	0
Chinook salmon	--	0	0	0	--	0
Cutthroat trout	--	11	0	22	--	5
Rainbow trout	--	0	0	2	--	2
Mountain whitefish	--	0	0	0	--	0
Unidentified salmonid	--	0	0	0	--	0
Northern pikeminnow	--	0	0	0	--	0
Redside shiner	--	0	0	0	--	0
Speckled dace	--	0	0	8	--	3
Longnose dace	--	0	0	0	--	0
Largescale sucker	--	0	0	1	--	0
Threespine stickleback	--	0	0	0	--	0
Unidentified Lepomis	--	0	0	0	--	0
Reticulate sculpin	--	20	8	98	--	17
Torrent sculpin	--	8	0	0	--	26
Prickly sculpin	--	10	0	0	--	16
Crayfish	--	0	0	6	--	2

[a]Not sampled due to high flows and turbidity.

Appendix Table C-5. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, winter 1999-2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
Species	L[a]	M	U	L[a]	M[a]	U
Western brook lamprey	--	0	0	--	--	0
Unidentified lamprey	--	0	0	--	--	0
Coho salmon	--	0	0	--	--	0
Chinook salmon	--	0	0	--	--	0
Cutthroat trout	--	0	0	--	--	9
Rainbow trout	--	0	2	--	--	1
Mountain whitefish	--	0	0	--	--	0
Unidentified salmonid	--	0	0	--	--	0
Northern pikeminnow	--	0	0	--	--	0
Redside shiner	--	0	0	--	--	0
Speckled dace	--	48	0	--	--	0
Longnose dace	--	0	0	--	--	0
Largescale sucker	--	0	0	--	--	0
Threespine stickleback	--	0	0	--	--	0
Unidentified Lepomis	--	0	0	--	--	0
Reticulate sculpin	--	27	5	--	--	3
Torrent sculpin	--	15	1	--	--	5
Prickly sculpin	--	0	0	--	--	0
Crayfish	--	0	0	--	--	0

[a]Not sampled due to high flows and turbidity.

Appendix Table C-6. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, winter 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
Species	M[a]	U	M[a]	U	M[a]	U
Western brook lamprey	--	0	--	0	--	0
Unidentified lamprey	--	0	--	0	--	0
Coho salmon	--	0	--	0	--	0
Chinook salmon	--	0	--	0	--	0
Cutthroat trout	--	2	--	2	--	1
Rainbow trout	--	0	--	0	--	1
Mountain whitefish	--	0	--	0	--	0
Unidentified salmonid	--	0	--	0	--	0
Northern pikeminnow	--	0	--	0	--	0
Redside shiner	--	0	--	0	--	0
Speckled dace	--	0	--	0	--	0
Longnose dace	--	0	--	0	--	0
Largescale sucker	--	0	--	0	--	0
Threespine stickleback	--	0	--	0	--	0
Unidentified Lepomis	--	0	--	0	--	0
Reticulate sculpin	--	3	--	6	--	4
Torrent sculpin	--	1	--	0	--	1
Prickly sculpin	--	0	--	0	--	0
Crayfish	--	0	--	0	--	0

[a]Not sampled due to high flows and turbidity.

Appendix Table C-7. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, spring 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
Species	L	M	U	L	M	U
Western brook lamprey	1	2	0	2	1	6
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	1	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	0	0	1	3	1	32
Rainbow trout	0	0	1	0	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	1	13	0	0	11
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	8	4	0	0	0	0
Speckled dace	1	31	0	0	0	0
Longnose dace	0	0	1	0	0	0
Largescale sucker	0	1	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	65	126	31	79	56	106
Torrent sculpin	0	6	8	0	0	92
Prickly sculpin	0	0	0	0	0	0
Crayfish	3	0	0	5	2	9

Appendix Table C-8. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, spring 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
Species	M	U	M	U	M	U
Western brook lamprey	3	6	5	18	0	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	4
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	1	14	1	20	0	11
Rainbow trout	0	0	0	1	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	7	0	0	0	2
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	15	0	0	0	2	0
Speckled dace	0	0	1	9	0	0
Longnose dace	0	0	0	0	0	1
Largescale sucker	0	0	0	2	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	41	82	89	214	16	53
Torrent sculpin	0	10	0	0	1	8
Prickly sculpin	2	0	0	0	0	0
Crayfish	5	1	0	2	1	0

Appendix Table C-9. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, summer 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
Species	M	U	M	U	M	U
Western brook lamprey	1	1	2	0	3	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	8	18	15	0	18	0
Rainbow trout	0	0	0	0	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0
Speckled dace	0	0	5	0	21	0
Longnose dace	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	50	47	71	14	57	9
Torrent sculpin	0	0	0	0	0	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	0	1	3	2	11	7

Appendix Table C-10. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, summer 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
Species	M	U	L	M	L	M
Western brook lamprey	0	0	7	2	1	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	6	0
Chinook salmon	0	0	0	0	5	0
Cutthroat trout	0	9	6	10	27	98
Rainbow trout	0	0	0	0	14	7
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0
Speckled dace	5	0	2	0	0	0
Longnose dace	0	0	0	0	0	0
Largescale sucker	9	0	0	0	0	0
Threespine stickleback	18	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	46	1	225	31	79	58
Torrent sculpin	0	0	0	0	40	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	0	0	20	2	16	5

Appendix Table C-11. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, fall 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
Species	M	U	M	U	M	U
Western brook lamprey	3	15	0	0	17	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	6	21	8	0	22	0
Rainbow trout	0	0	0	0	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0
Speckled dace	0	0	0	0	0	0
Longnose dace	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	87	59	20	3	126	46
Torrent sculpin	0	0	0	0	0	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	0	0	0	1	18	0

Appendix Table C-12. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, fall 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
Species	M	U	L	M	L	M
Western brook lamprey	0	0	0	3	0	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0		0	5	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	0	7	1	5	26	68
Rainbow trout	0	0	0	0	3	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	1	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0
Speckled dace	1	0	0	0	0	0
Longnose dace	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	4	0	35	22	146	107
Torrent sculpin	0	0	0	0	41	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	1	0	3	0	5	3

Appendix Table C-13. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, winter 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
Species	M	U	M	U	M	U
Western brook lamprey	0	2	0	0	0	1
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	1	5	2	0	0	6
Rainbow trout	0	0	0	0	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0
Speckled dace	0	0	2	0	0	3
Longnose dace	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	25	12	12	0	11	16
Torrent sculpin	0	0	0	0	0	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	0	0	0	0	0	0

Appendix Table C-14. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, winter 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
Species	M	U	L	M	L	M
Western brook lamprey	0	0	1	0	0	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	5	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	0	5	1	1	17	44
Rainbow trout	0	0	0	0	2	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0
Speckled dace	2	0	0	0	1	0
Longnose dace	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Threespine stickleback	1	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	13	1	46	21	50	62
Torrent sculpin	0	0	0	0	19	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	0	0	0	0	2	0

Appendix Table C-15. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, spring 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
Species	M	U	M	U	M	U
Western brook lamprey	3	0	0	0	0	0
Unidentified lamprey	0	2	0	0	0	0
Coho salmon	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	9	2	1	0	5	0
Rainbow trout	0	0	0	0	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0
Speckled dace	0	0	0	0	6	0
Longnose dace	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	36	22	38	32	40	35
Torrent sculpin	0	0	0	0	0	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	1	2	0	4	13	2

Appendix Table C-16. Number of fish and crayfish collected in reaches of Tualatin River tributaries and upper Tualatin River, spring 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
Species	M	U	L	M	L	M
Western brook lamprey	4	0	47	1	1	0
Unidentified lamprey	0	0	0	0	0	0
Coho salmon	0	0	0	0	13	0
Chinook salmon	0	0	0	0	0	0
Cutthroat trout	0	0	0	1	12	68
Rainbow trout	0	0	0	0	0	0
Mountain whitefish	0	0	0	0	0	0
Unidentified salmonid	0	0	0	0	0	0
Northern pikeminnow	0	0	0	0	0	0
Redside shiner	14	0	0	0	0	0
Speckled dace	2	0	0	0	0	0
Longnose dace	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Threespine stickleback	2	0	0	0	0	0
Unidentified Lepomis	0	0	0	0	0	0
Reticulate sculpin	29	0	79	32	63	136
Torrent sculpin	0	0	0	0	32	0
Prickly sculpin	0	0	0	0	0	0
Crayfish	0	0	6	0	1	2

APPENDIX D

Water Quality Data

Appendix Table D-1. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, summer 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
	L	M	U	L	M	U
Turbidity (NTU)	4.0	1.4	0.6	9.5	9.1	1.5
Oxygen saturation (%)	64.7	106.1	110.9	93.5	59.5	119.5
Dissolved oxygen (mg/L)	7.1	11.4	13.1	10.1	6.4	13.2
Temperature (^{o}C)	11.2	12.3	7.9	11.6	12.2	9.5
Mean velocity (m/s)	1.0	1.1	3.2	3.4	0.6	1.8
Maximum velocity (m/s)	2.5	2.6	7.8	4.9	1.1	5.6
Conductivity (µS)	141.5	101.5	87.8	169.7	269.0	83.0
Total dissolved solids (mg/L)	67.4	48.2	41.6	81.0	129.3	39.3
Salinity (ppt)	0.1	0.1	0.0	0.1	0.1	0.0
pH	--	--	--	--	--	--

Appendix Table D-2. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, summer 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
	M	U	M	U	M	U
Turbidity (NTU)	6.1	3.7	16.7	5.7	1.8	2.9
Oxygen saturation (%)	98.3	105.5	98.2	78.9	97.6	107.0
Dissolved oxygen (mg/L)	10.5	11.8	10.3	9.3	10.5	11.9
Temperature (^{o}C)	12.4	10.4	9.4	8.5	11.8	11.3
Mean velocity (m/s)	1.3	1.3	0.0	2.2	10.2	2.1
Maximum velocity (m/s)	2.0	3.4	0.0	3.4	19.5	6.1
Conductivity (µS)	106.5	129.6	145.9	93.9	64.4	63.5
Total dissolved solids (mg/L)	50.5	61.7	69.5	44.5	30.4	29.9
Salinity (ppt)	0.1	0.1	0.1	0.0	0.0	0.0
pH	--	--	--	--	--	--

Appendix Table D-3. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, fall 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
	L[a]	M	U	L	M	U
Turbidity (NTU)	--	2.7	0.7	5.1	5.4	3.7
Oxygen saturation (%)	--	106.6	108.4	81.2	87.0	105.4
Dissolved oxygen (mg/L)	--	13.0	13.4	8.4	10.2	12.7
Temperature (^{o}C)	--	6.8	6.2	8.3	8.5	7.4
Mean velocity (m/s)	--	2.4	3.3	1.0	3.4	4.1
Maximum velocity (m/s)	--	4.1	7.5	1.5	3.6	9.6
Conductivity (µS)	--	99.0	88.2	162.8	100.0	82.3
Total dissolved solids (mg/L)	--	47.0	41.8	77.7	107.0	38.9
Salinity (ppt)	--	0.1	0.0	0.1	0.0	0.0
pH	--	7.8	--	--	7.4	--

[a]Measurements not taken due to high flows and turbidity.

Appendix Table D-4. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, fall 1999. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
	M	U	M	U	M	U
Turbidity (NTU)	--[a]	1.3	9.9	4.0	2.1	2.7
Oxygen saturation (%)	88.3	89.9	83.1	76.1	106.2	107.5
Dissolved oxygen (mg/L)	10.1	11.5	9.1	9.3	12.5	12.6
Temperature (^{o}C)	9.3	5.2	11.4	6.9	8.4	8.6
Mean velocity (m/s)	--[a]	1.0	0.6	1.4	8.3	6.3
Maximum velocity (m/s)	--[a]	2.2	0.8	2.6	16.7	13.2
Conductivity (µS)	109.2	113.5	112.7	88.2	65.7	66.8
Total dissolved solids (mg/L)	51.9	53.9	53.6	41.7	31.0	31.5
Salinity (ppt)	0.1	0.1	0.1	0.0	0.0	0.0
pH	--	--	7.0	--	--	--

[a]Measurements not taken due to equipment malfunction.

Appendix Table D-5. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, winter 1999-2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
	L[a]	M	U	L[a]	M[a]	U
Turbidity (NTU)	--	3.1	5.7	--	--	16.5
Oxygen saturation (%)	--	96.6	90.7	--	--	116.0
Dissolved oxygen (mg/L)	--	12.1	11.4	--	--	12.4
Temperature (^{o}C)	--	5.8	5.4	--	--	6.8
Mean velocity (m/s)	--	4.1	5.2	--	--	6.0
Maximum velocity (m/s)	--	5.9	7.5	--	--	7.2
Conductivity (µS)	--	65.0	64.4	--	--	33.0
Total dissolved solids (mg/L)	--	30.6	30.3	--	--	15.3
Salinity (ppt)	--	0.0	0.0	--	--	0.0
pH	--	7.4	7.5	--	--	--

[a]Measurements not taken due to high flows and turbidity.

Appendix Table D-6. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, winter 1999-2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
	M[a]	U	M[a]	U	M[a]	U
Turbidity (NTU)	--	4.7	--	12.0	--	2.9
Oxygen saturation (%)	--	93.3	--	92.7	--	94.8
Dissolved oxygen (mg/L)	--	11.4	--	11.3	--	12.2
Temperature (^oC)	--	6.7	--	6.8	--	4.9
Mean velocity (m/s)	--	5.3	--	4.4	--	5.2
Maximum velocity (m/s)	--	8.0	--	7.1	--	7.8
Conductivity (µS)	--	17.2	--	45.2	--	56.5
Total dissolved solids (mg/L)	--	7.7	--	21.1	--	26.6
Salinity (ppt)	--	0.0	--	0.0	--	0.0
pH	--	7.4	--	7.3	--	7.7

[a]Measurements not taken due to high flows and turbidity.

Appendix Table D-7. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, spring 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Gales			McKay		
	L	M	U	L	M	U
Turbidity (NTU)	11.3	2.0	1.7	11.3	8.9	3.4
Oxygen saturation (%)	106.6	108.1	106.8	97.8	92.6	106.0
Dissolved oxygen (mg/L)	10.4	11.7	12.3	9.6	9.6	12.9
Temperature (^oC)	16.4	11.7	8.5	16.2	15.1	6.9
Mean velocity (m/s)	1.8	2.7	2.0	0.9	0.9	1.5
Maximum velocity (m/s)	2.5	5.6	7.8	1.4	1.3	5.2
Conductivity (µS)	99.5	80.9	74.6	109.1	119.6	47.1
Total dissolved solids (mg/L)	47.2	38.2	35.2	51.8	56.9	22.0
Salinity (ppt)	0.0	0.0	0.0	0.1	0.1	0.0
pH	7.2	8.0	7.9	7.8	7.6	7.7

Appendix Table D-8. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, spring 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	W. Dairy		McFee		Tualatin R.	
	M	U	M	U	M	U
Turbidity (NTU)	5.6	2.9	9.4	7.1	5.5	1.6
Oxygen saturation (%)	94.2	102.7	93.9	103.0	108.0	113.3
Dissolved oxygen (mg/L)	9.3	11.8	10.2	12.3	11.0	12.5
Temperature (^{o}C)	15.6	9.8	11.7	12.1	11.6	10.9
Mean velocity (m/s)	0.9	1.2	2.0	2.0	6.0	3.6
Maximum velocity (m/s)	2.5	2.5	2.4	3.4	9.3	7.3
Conductivity (µS)	73.2	64.4	81.8	60.8	62.2	68.0
Total dissolved solids (mg/L)	34.5	30.3	38.7	28.6	29.3	32.1
Salinity (ppt)	0.0	0.0	0.0	0.1	0.0	0.0
pH	7.5	7.4	7.2	7.4	7.4	7.7

Appendix Table D-9. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, summer 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
	M	U	M	U	M	U
Turbidity (NTU)	6.6	5.4	16.5	18.7	14.6	7.3
Oxygen saturation (%)	93.3	114.7	94.3	110.3	10.1	84.3
Dissolved oxygen (mg/L)	11.0	13.2	10.7	11.9	10.1	9.5
Temperature (^{o}C)	9.2	8.4	9.8	12.1	15.3	10.6
Mean velocity (m/s)	0.6	0.5	1.6	0.8	0.1	1.3
Maximum velocity (m/s)	0.9	0.9	2.3	2.3	0.3	2.1
Conductivity (µS)	111.0	112.2	43.8	44.5	61.5	72.8
Total dissolved solids (mg/L)	52.8	53.3	20.5	20.8	28.9	34.4
Salinity (ppt)	0.1	0.1	0.0	0.0	0.0	0.0
pH	7.1	7.2	7.1	7.0	7.3	7.3

Appendix Table D-10. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, summer 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
	M	U	M	U	M	U
Turbidity (NTU)	32.5	8.5	8.1	7.4	3.8	9.5
Oxygen saturation (%)	18.6	106.1	88.0	85.0	91.7	86.3
Dissolved oxygen (mg/L)	2.1	11.8	10.1	9.6	10.6	9.5
Temperature (^{o}C)	11.7	11.2	9.2	9.9	9.7	11.0
Mean velocity (m/s)	0.0	0.0	0.5	0.8	3.7	1.4
Maximum velocity (m/s)	0.0	0.0	0.6	1.2	1.7	2.7
Conductivity (µS)	401.0	77.8	80.4	84.6	158.5	179.5
Total dissolved solids (mg/L)	193.4	36.8	38.0	10.0	75.6	56.8
Salinity (ppt)	0.2	0.0	0.0	0.0	0.1	0.1
pH	6.9	6.7	7.0	7.6	6.0	6.3

Appendix Table D-11. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, fall 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
	M	U	M	U	M	U
Turbidity (NTU)	5.3	2.7	16.5	7.3	3.2	7.6
Oxygen saturation (%)	74.0	84.9	56.7	72.8	84.5	81.5
Dissolved oxygen (mg/L)	8.4	9.8	6.5	8.4	10.0	10.0
Temperature (^{o}C)	9.7	9.0	8.9	7.5	7.2	6.5
Mean velocity (m/s)	1.5	0.0	0.0	0.7	0.7	1.4
Maximum velocity (m/s)	2.1	0.0	0.0	0.9	0.8	1.7
Conductivity (µS)	142.6	141.0	153.7	49.1	71.6	70.6
Total dissolved solids (mg/L)	67.9	67.2	73.3	23.0	33.8	33.3
Salinity (ppt)	0.1	0.1	0.1	0.0	0.0	0.0
pH	6.0	6.0	6.5	6.0	6.0	6.5

Appendix Table D-12. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, fall 2000. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
	M	U	M	U	M	U
Turbidity (NTU)	7.9	8.1	5.1	8.7	6.8	10.9
Oxygen saturation (%)	87.2	52.2	60.4	60.4	80.8	8.9
Dissolved oxygen (mg/L)	11.4	6.1	9.2	6.6	9.5	8.8
Temperature (^oC)	4.2	8.6	3.9	9.6	8.6	8.5
Mean velocity (m/s)	0.1	0.0	0.7	0.0	1.4	1.2
Maximum velocity (m/s)	0.2	0.0	1.1	0.0	2.2	2.6
Conductivity (µS)	200.0	97.2	87.0	89.8	153.7	119.0
Total dissolved solids (mg/L)	95.8	46.1	4.1	42.5	73.3	56.6
Salinity (ppt)	0.1	0.0	0.0	0.0	0.1	0.1
pH	7.0	6.5	6.0	6.5	6.0	6.5

Appendix Table D-13. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, winter 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
	M	U	M	U	M	U
Turbidity (NTU)	15.9	12.5	6.4	4.7	5.0	5.1
Oxygen saturation (%)	89.1	97.0	88.1	60.3	66.5	79.6
Dissolved oxygen (mg/L)	11.1	12.6	11.9	7.5	8.6	10.9
Temperature (^oC)	5.1	4.8	3.6	6.2	4.6	4.9
Mean velocity (m/s)	1.0	0.9	0.4	0.0	0.9	3.4
Maximum velocity (m/s)	3.1	3.1	0.8	0.0	1.6	5.5
Conductivity (µS)	136.6	134.7	43.7	202.0	55.0	56.0
Total dissolved solids (mg/L)	65.5	64.1	20.4	96.5	25.8	26.3
Salinity (ppt)	0.1	0.1	0.0	0.1	0.0	0.0
pH	7.9	7.8	8.5	8.4	8.4	9.4

Appendix Table D-14. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, winter 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
	M	U	M	U	M	U
Turbidity (NTU)	4.5	11.7	5.6	6.6	5.4	2.2
Oxygen saturation (%)	74.4	80.9	88.2	94.2	87.0	85.1
Dissolved oxygen (mg/L)	9.6	10.7	11.9	12.1	7.9	10.6
Temperature (^{o}C)	4.4	4.5	3.8	5.6	6.0	4.7
Mean velocity (m/s)	0.6	0.5	0.8	0.5	2.3	2.1
Maximum velocity (m/s)	0.9	0.9	1.7	1.5	3.7	4.4
Conductivity (µS)	121.7	83.6	58.1	58.1	84.6	84.3
Total dissolved solids (mg/L)	57.9	39.5	27.3	27.3	40.0	39.9
Salinity (ppt)	0.1	0.0	0.0	0.0	0.0	0.0
pH	7.7	7.8	8.9	8.7	8.1	9.1

Appendix Table D-15. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, spring 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Ayers		Baker		Burris	
	M	U	M	U	M	U
Turbidity (NTU)	9.5	6.1	5.4	13.0	5.4	21.7
Oxygen saturation (%)	103.0	97.8	91.9	104.0	91.1	95.3
Dissolved oxygen (mg/L)	10.3	9.8	10.0	10.8	10.4	10.8
Temperature (^{o}C)	15.0	15.1	11.6	23.3	9.4	9.6
Mean velocity (m/s)	0.0	0.0	0.0	1.3	0.3	2.3
Maximum velocity (m/s)	0.0	0.0	0.0	1.3	0.3	5.1
Conductivity (µS)	146.5	145.8	56.0	46.9	297.0	292.0
Total dissolved solids (mg/L)	69.8	69.5	26.2	21.9	142.6	140.2
Salinity (ppt)	0.1	0.1	0.0	0.0	0.1	0.1
pH	7.8	7.6	7.2	7.3	8.0	8.0

Appendix Table D-16. Water quality measurements in reaches of Tualatin River tributaries and upper Tualatin River, spring 2001. L = lower reach, M = middle reach, and U = upper reach.

	Stream					
	Christensen		Heaton		Roaring	
	M	U	M	U	M	U
Turbidity (NTU)	47.5	8.1	6.8	4.7	5.0	8.3
Oxygen saturation (%)	6.9	95.9	83.8	92.0	95.4	92.8
Dissolved oxygen (mg/L)	0.7	10.0	8.9	9.7	11.2	10.1
Temperature (°C)	13.8	12.8	12.6	13.1	8.3	11.3
Mean velocity (m/s)	0.0	0.7	0.6	0.0	1.0	3.4
Maximum velocity (m/s)	0.0	1.1	0.8	0.0	2.3	3.6
Conductivity (μS)	409.0	82.1	83.9	81.1	93.4	81.3
Total dissolved solids (mg/L)	197.3	38.8	39.7	38.3	44.3	38.4
Salinity (ppt)	0.2	0.0	0.0	0.0	0.0	0.0
pH	7.3	6.8	7.1	6.9	8.3	7.7