2005-2006 ASSESSMENT OF FISH AND MACROINVERTEBRATE COMMUNITIES OF THE TUALATIN RIVER BASIN, OREGON

FINAL REPORT

Prepared for

Clean Water Services
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EXECUTIVE SUMMARY

- Biological monitoring with fish and macroinvertebrate communities is widely used to determine the ecological integrity of surface waters. Such surveys directly assess the status of surface waters relative to the primary goal of the Clean Water Act and provide information valuable to water quality planning and management. As such, fish and macroinvertebrate communities are periodically assessed by Clean Water Services to assist with water quality management in the Tualatin River basin. Fish and macroinvertebrate communities, physical habitat, and water chemistry were sampled in streams throughout the Tualatin River basin in fall 2005 to determine current ecological conditions of streams within the watershed. Fish communities were sampled again in spring 2006 to examine seasonal changes in fish community conditions. Sampling sites were selected to correspond with sites sampled in previous fish and macroinvertebrate surveys performed between 1999 and 2001. In fall 2005, fish communities were assessed in 64 stream reaches, while macroinvertebrate communities were assessed in 63 reaches. Fish and macroinvertebrate sampling occurred in the same reach at 29 locations.
- Depending on stream type and habitat sampled, macroinvertebrate data were analyzed either with both multimetric analysis and predictive models known as RIVPACS models (in the case of high-gradient streams from which riffles were sampled) or with only the RIVPACS model (in the case of low-gradient streams from which glides were sampled). Fish community data were analyzed with the Index of Biotic Integrity (IBI) developed by the USEPA and modified by ODFW for use in Tualatin River basin streams. Scoring systems of these three approaches occur on different scales, but in all cases higher scores represent higher ecological integrity.
- Macroinvertebrate community conditions ranged widely among high-gradient stream reaches as indicated by both RIVPACS O/E scores and DEQ multimetric scores. RIVPACS O/E scores from high-gradient reaches ranged from 0.24 to 1.05 and averaged 0.72, while multimetric scores ranged from 11 to 46 and averaged 27.9. The two approaches produced similar impairment-class groupings, as almost half of the high-gradient-reach macroinvertebrate communities that scored as unimpaired according to O/E scores also received unimpaired multimetric scores. Upper Gales Creek received both the highest O/E and multimetric scores of 1.05 and 46, respectively. Three sites received “fair” O/E scores ranging from 0.779 to 0.877. These sites scored as slightly or moderately impaired according to multimetric scores. Fourteen high-gradient reaches received “poor” O/E scores; five of these sites also received severely impaired multimetric scores. These most impaired streams occurred in areas with higher urban and agricultural land use intensities. Multimetric scores and O/E scores were significantly correlated with a number of environmental variables, including percent urban land use, percent forested land use, effective impervious area, percent total urban and agricultural land use, water temperature, conductivity, and dissolved oxygen, and several measures of streambed substrate conditions. Although significant, these relationships are only correlative and do not establish cause-and-effect relationships between environmental conditions and instream biological conditions.
- Across all high-gradient reaches, macroinvertebrate community conditions were similar to those reported in 2001 (Cole 2002). Reaches sampled in both years ($n = 24$) averaged multimetric scores of 28.9 in 2005 compared to 27.7 in 2001. A two-sample paired t-test performed to examine the data for a change in average conditions between the two years was not significant ($p = 0.502$).
- Biological integrity of macroinvertebrate communities varied less among low-gradient reaches and generally scored lower than in high-gradient reaches. Four reaches selected as representing least-impaired low-gradient conditions in the Tualatin River basin received O/E scores ranging from 0.340 to 0.726. The

mean of these four scores (0.557) was used as the threshold for determining impairment of low-gradient reaches. Based on this benchmark, only one of 36 sample reaches (excluding the reference reaches), the lower East Fork of Dairy Creek, was classified as unimpaired with an O/E score of 0.574. The remaining 35 O/E scores calculated from low-gradient reaches ranged from 0.143 to 0.469. These communities generally exhibited a low taxa richness, few or no EPT taxa, high dominance by one or a few tolerant taxa, and a high community-wide tolerance to disturbance. O/E scores calculated from low-gradient reaches were negatively correlated with percent embeddedness and positively correlated with dissolved oxygen concentrations. Physical characteristics of low-gradient streams on the Tualatin Valley floor differ from those of higher-gradient streams located in areas of more topographic relief within the basin. Naturally occurring dominance by sand and silt substrates and slower water velocities would naturally yield different macroinvertebrate communities on valley floor streams. Because the RIVPACS model and DEQ multimetric scoring system have not yet been calibrated for use with such Tualatin Valley floor streams, we caution the use of these results from low-gradient streams for regulatory purposes, as current tools do not provide reliable separation of naturally occurring differences (between macroinvertebrate communities occurring in high and low-gradient streams) from changes produced by anthropogenic alteration of instream conditions.

- A total of 112 fish-community IBI scores were calculated from reaches surveyed during fall, 2005 and spring, 2006. The upper Tualatin River reach was the only site to score as in acceptable condition in each season. Most reaches received IBI scores less than 50 and corresponding severely impaired classifications. Approximately 30% of reaches received IBI scores from 51 to 74 and resulting marginally impaired designations. Changes in IBI scores from fall to spring were generally modest. Approximately half of the IBI scores generated from the 2001 ODFW study and the current study were similar, with IBI-score differences of less than 10 points. Statistically significant correlations occurred between IBI scores and five measured environmental variables, including percent riffle habitat, morning dissolved oxygen concentrations, percent sand and fines, afternoon water temperature, and conductivity ($p < 0.0001$; Figure 8).
- Collectively, our results suggest that biological conditions largely remain the same as those measured between 1999 and 2001, with exceptions as noted in this report. As these periodic monitoring efforts continue into the future, longer-term data sets should reveal trends in these conditions in relation to land use changes, water resource management programs, and restoration activities occurring in the Tualatin River basin.

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INTRODUCTION

Biological monitoring with fish and macroinvertebrate communities is widely used to determine the ecological integrity of surface waters. Such surveys directly assess the status of surface waters relative to the primary goal of the Clean Water Act and provide information valuable to water quality planning and management. Clean Water Services (the District) is a public utility committed to protecting water resources of the Tualatin River basin. As part of this commitment, the District periodically performs comprehensive assessments of the status of fish and macroinvertebrate communities in rivers and streams of the watershed to better inform water quality planning and management decision making. These assessments document current conditions, and, when viewed in relation to past assessments, define trends in these conditions. These efforts, and particularly the macroinvertebrate assessment, address all three categories of the District's routine monitoring objectives, as identified in their draft Watershed Monitoring Plan (CWS 2006). In addition to assisting with defining status and trends in watershed conditions, the data from these assessments will also help document the effectiveness of the District's actions aimed at improving watershed conditions and can be used to assess the effects of stormwater on aquatic biology to satisfy requirements of the District's MS4 permit.

Assessments of fish communities throughout the Tualatin River basin began in 1993 (Ward 1995) and were performed again from 1999 to 2001 (Leader et al. 2002), while similar assessments of macroinvertebrate communities were initiated in 2000 and were performed again in 2001 (Cole 2000, Cole 2002). This study builds on these previous efforts with an assessment of macroinvertebrate communities in fall 2005 and assessments of fish communities in fall 2005 and spring 2006. Physical habitat surveys and water quality studies were performed in concurrence with biological assessments of each surveyed reach in fall 2005. The objective of the study was to determine the current condition of biological communities in streams throughout the Tualatin River basin.

STUDY AREA

The Tualatin River Basin is located primarily in Washington County, Oregon, with small areas extending into Multnomah, Yamhill, and Clackamas counties. The basin generally drains in a southeasterly direction, with headwaters occurring as far west as the eastern slopes of the Oregon Coast Range. The basin is bound on the north and south sides by the Tualatin and Chehalem mountain ranges, respectively. The Tualatin River empties into the Willamette River just west of Oregon City. Along its course from the Coast Range to the Willamette River, the Tualatin River and its tributaries exhibit a number of physical and hydrologic changes. These changes are due, in part, to the naturally-occurring physiographic variation that occurs in the area, but have been exacerbated by human settlement in the basin.

Streams occurring farther east in the basin are generally characterized by low gradient, heavy sediment loading, seasonal flooding, temperature extremes, and low habitat heterogeneity (ODFW 1995). Streams on the east slopes of the Coast Range and in other areas of more topographic relief in the western portion of the basin are characterized by higher gradients, larger and more heterogeneous substrate, and more heterogeneous habitat.

METHODS

SAMPLE SITE SELECTION AND OVERALL SAMPLING DESIGN

Fish and macroinvertebrate sampling sites were selected to correspond with sites previously sampled in the last round of surveys for each assemblage type. In fall 2005, macroinvertebrate communities were assessed in 63 reaches (Table 1, Figure 1), and fish communities were assessed in 64 stream reaches (Table 2 and Figure 2). Fish and macroinvertebrate sampling occurred in the same reach at 29 locations. Physical habitat assessments and morning/afternoon water quality sampling occurred in each reach sampled for biological conditions as described below.

Table 1. Macroinvertebrate sampling locations in the Tualatin River basin, Oregon, fall 2005. Asterisks indicate reaches in which fish communities also were sampled.

Stream Name	Study Reach Code	Macroinvertebrate Sampling Location
Low-gradient Reaches		
Ash Creek (Lower)	ASM2	below Highway 217 (above SW North Dakota St)
Beaverton Creek (Lower)*	BCM1	above of Cornelius Pass Road
Beaverton Creek (Upper 1)	BUM1	above 185th Ave
Beaverton Creek (Upper 2)	BUM2	Tualatin Hills Nature Park
Bronson Creek (Middle)*	BRM2	Bronson Creek Park north of Cornell Road
Cedar Creek (Middle)*	CDM2	above Meineke Road
Cedar Creek (Upper)*	CDM1	below Rein Road
Cedar Mill Creek (Middle)	CMM1	above Jenkins Road on Nike campus
Chicken Creek (Lower)*	CNM3	upstream of mouth
Christensen Creek (Lower)*	CHM2	above 219 bridge
Council Creek (Middle)	CLM1	Oregon Roses property above pond
Dairy Creek (Lower E Fork)*	DYM3	above Roy Road
Dairy Creek (Middle W Fork)	DYM5	below highway 26
East Fork Dairy Creek Trib	DYM6	above NW Dairy Creek Rd & Meacham Rd intersection
Dawson Creek (Lower)*	DNM2	below Baseline Road
Dawson Creek (Upper)*	DNM1	above Airport Road
Fanno Creek (Middle)	FMM1	downstream (south) of Scholls Ferry Road
Fanno Creek (Upper 2)*	FUM2	OES property (upstream of Nicol Road)
Gales Creek (Lower)	GSM3	below Rt 47 in Forest Grove
Gales Creek (Middle)	GSM2	At access site of Gales Creek Road (same site as GSM2)
Heaton Creek (Middle)*	HTM1	above NE Mountain Home Road
Hedges Creek (Lower)*	HDM1	in Tualatin Hills Park along Boones Ferry Road
Johnson Creek (Lower South)*	JSM3	upstream of Route 8
Johnson Creek (Mid South)	JSM2	upstream of Trillium Road (N of Davis Road)
Johnson Creek (Middle North)	JNM1	1/6 mile upstream of Cedar Hills Blvd
Johnson Creek (Upper South)	JSM1	below 170th and Rigert intersection
McFee Creek (Lower)*	MFM2	below SW Hillsboro Hwy (219)
McKay Creek (Lower)*	MKM3	at mouth north of Baseline
McKay Creek (Middle)	MKM2REF	below Church Road
McKay Creek (reference)	MKM4	NW Collins Road (adjacent to Bamboo nursery)

Table 1. Continued.

Stream Name	Study Reach Code	Macroinvertebrate Sampling Location
Low-gradient Reaches		
Rock Creek (Lower)*	RLM1	below River Road
Rock Creek (Middle)	RMM1	park west of John Olsen Road (take Windstone Court)
Rock Creek (Upper 2)	RUM2	behind Rock Creek Tavern on D Silva property
Saum Creek (Lower)	SAM1	below Borland Road
Scoggins Creek (Lower)	SCM3	below Stimson Mill on Patton Valley Road
Scoggins Creek (Middle)	SCM2	below Hagg Lake on Mill Road
Summer Creek (Lower)*	SMM2	1/8 mile above mouth
Summer Creek (Upper 2)	SMM1	below 1st crossing under Schools Ferry
Sylvan Creek (Middle)	SVM1	off of Scholls Ferry Road @ flow station
Willow Creek (Lower)	WLM2	in Salix Park below Heritage Parkway
	High-gradient Reaches	
Ash Creek (Upper)*	ASM1	above Taylors Ferry Road
Ayers Creek (Upper)	AYM1	above 1st Road Xing along Dopp Road
Baker Creek (Upper)*	BKM1	above Kruger Road
Bannister Creek (Lower)	BAM1	above Laidlaw Rd above confluence with Bronson
Bronson Creek (Upper)	BRM1	above Saltzman
Burris Creek (Upper)	BIM1	above falls upstream of SW Stickney Road
Cedar Mill Creek (Upper)*	CMM2	upstream of 113th Street
Chicken Creek (Middle)*	CNM2	below Edy Road
Chicken Creek (Upper)*	CNM1	above Kruger Road
Christensen Creek (Upper)*	CHM1	above Dixon Mill Road (above pond)
Dairy Creek (Middle E Fork)	DYM2	½ mile below Meachum Road
Dairy Creek (Upper E Fork)*	DYM1	Little Bend Park
Dairy Creek (Upper W Fork)	DYM4	above 1st Nehalem Highway road crossing N of 26
Fanno Creek (Lower)*	FLM1	Durham City Park below bridge
Fanno Creek (Upper 1)*	FUM1	below 39th Street
Gales Creek (Middle)*	GSM2	at access site off of Gales Creek Road
Gales Creek (Upper)	GSM1	below Gales Creek Campground
Golf Creek (Upper)	GLM1	below Barnes Road Xing
McFee Creek (Upper)	MFM1	above Finnigan Hill Road
McKay Creek (Upper)	MKM1	below Northrup Road crossing
Roaring Creek (Middle)*	RGM1	along Roaring Creek Road

Table 1. Continued.

Stream Name	Study Reach Code	Macroinvertebrate Sampling Location
High-gradient Reaches		
Rock Creek (Upper 1)*	RUM1	along Rock Creek Road
Sain Creek (Lower)	SNM1	above Henry Hagg Lake
Scoggins Creek (Upper)	SCM1	below confluence with Parsons Creek
Tanner Creek (Lower)	TNM1	above Scoggins Valley Road Xing
Willow Creek Upper)	WLM1	below 143rd Ave

HABITAT ASSESSMENTS

Habitat surveys were performed in 100-meter reaches following modified Rapid Habitat Assessment Protocols (RSAT) and consisted of data collection from surveys of channel habitat units, three channel cross sections, and the adjacent riparian zone (Table 3). First, the valley type within which each study reach occurred was broadly classified as U-type, V-type, ponded, and floodplain. A plan view of the reach was sketched as the survey was performed. The physical data were then collected using the following procedures:

HABITAT UNITS SURVEY

The number, length, width, and maximum water depth of pools, glides, riffles, and rapids were recorded from each reach. The following definitions were adapted from ODFW's *Methods for Stream Habitat Surveys* (2002) and Armantrout (1998) and used for this study:

Pool: Water surface slope is usually zero. Normally deeper and wider than aquatic habitats immediately above and below.

Glide: There is a general lack of consensus of the definition of glides (Hawkins et al. 1993). For the purposes of this study, a glide was defined as an area with generally uniform depth and flow with no surface turbulence. Glides have a low-gradient water surface profile of 0–1% slope. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. Glides are generally deeper than riffles with few major flow obstructions and low habitat complexity.

Riffle: Fast, turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Riffles generally have a broad, uniform cross section and a low-to-moderate water surface gradient, usually 0.5–2.0% slope and rarely up to 6%.

Rapids: Swift, turbulent flow including chutes and some hydraulic jumps swirling around boulders. Rapids often contain exposed substrate features composed of individual bedrock or boulders, boulder clusters, and partial bars. Rapids are moderately high gradient habitat, usually 2.0–4.0% slope and occasionally 7.0–8.0%. Rapids also include swift, turbulent, "sheeting" flow over smooth bedrock.

The following attributes were then measured or visually estimated in each channel unit. Substrate composition was visually estimated in each unit using substrate size classes adapted from EPA's EMAP protocols for wadeable streams (USEPA 2000). Percent substrate embeddedness, percent actively eroding banks, and percent undercut banks (both banks, combined) were each visually

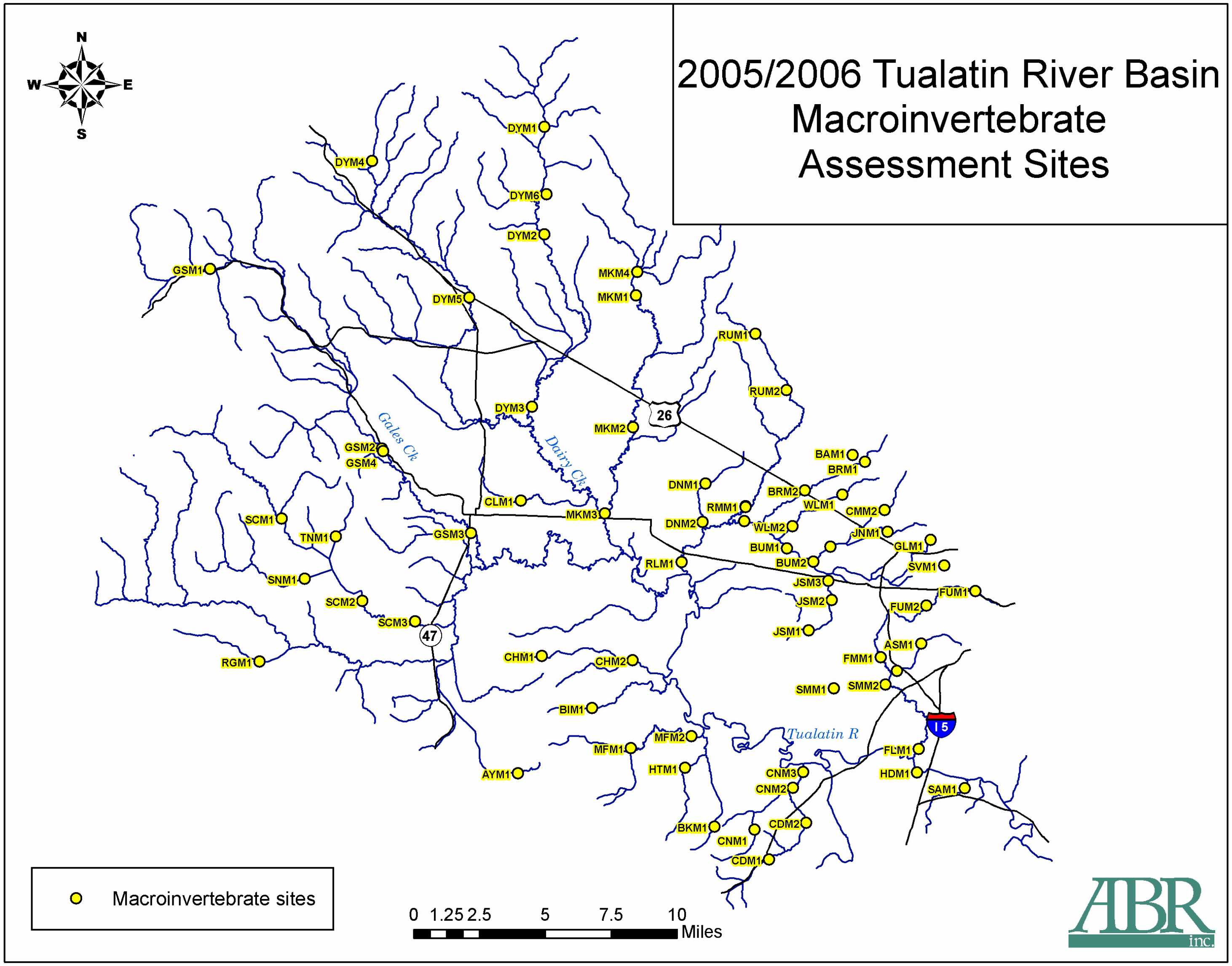

Figure 1. Locations of reaches sampled for macroinvertebrates in fall 2005 and for fish in fall 2005 and spring 2006 in the Tualatin River basin, Oregon.

Table 2. Fish sampling locations in the Tualatin River basin, Oregon, fall 2005 and spring 2006.

Stream	Reach	Location
Ash	ASL	Start 10 m above Greenburg Rd. bridge
	ASM	Start 10 m above Locust St. bridge
	ASU	Start above Taylor's Ferry Rd. @ intersection w/ 80th Ave.
Ayers	AYM	Start above old farm road culvert, road branches off Dopp Rd.
	AYU	Start 5 m above second Dopp Rd. crossing, rt side of road upstream
Baker	BKM	Below Mountain Creek Rd., downstream of barbed wire fence
	BKU	Start above SW Kruger Rd.
Beaverton	BVL	Upstream of Cornelius Pass Rd.
	BVM	Survey start between Pheasant Lanes
Bronson	BRL	Above pond @ Cornell Rd., next to church daycare
	BRM	End @ dam below Laidlaw Rd., follow fence down to start point
Burris	BUM	Below Stickney Dr. (gravel). Start where grass path crosses stream.
	BUU	Park @ Stickney Dr. crossing. Head upstream ~300m. Survey ends 75m below WF.
Butternut	BNL	Start downstream from River Rd. culvert
	BNM	Start 30 m above walking bridge @ Butternut Park
	BMU	Start above culvert @ Farmington Rd..
Cedar	CDM	Start above large pool @ Meineke Rd. culvert in city park.
	CDU	Start above Rein Rd. culvert
Cedar Mill	CMM	End @ Jay St. crossing, near Nike campus
	CMU	Start @ 113th St. crossing
Chicken	CNL	Start 10 m upstream of Tualatin confluence, park on Roy Rogers Rd.
	CNM	Start at Edy Rd. crossing (Beaver activity)
	CNU	Start at Kruger Rd., Permission to stay in stream only.
Christensen	CHM	Start at Highway 219
	CHU	Upstream of pond off SW Dixon Mill Rd.
Council	CLM	NW Martin Rd. to 100 meters downstream
	CLU	Start ~ 35m above Highway 47.
Dairy	DYM	Start @ Roy Rd.
	DYU	End just downstream of Little Bend Park (old park). Find retaining wall.
Dawson	DNL	End just below Baseline Rd. culvert
	DNM	Start 5 m above Brookwood Rd.
	DNU	Start above driveway culvert above Airport Rd.
Fanno	FLL	Park @ Durham City Park (off Rivendell Rd.) Across foot bridge
	FLM	Start ~25m above Nicols St. bridge
	FLU	End below culvert pool @ 39th St. off HWY 10
Gales	GSL	~300m upstream of confluence of Tualatin
	GSM	Enter @ Rippling Creek Park (pulloff on Gales Ck. Rd.)
	GSU	Behind Glenwood Store. Start just upstream of bridge.
Heaton	HNM	Siefert Rd. to upstream 75m. Private property @ 75m mark. End at fence.
	HNU	Start ~3m above NE Mountain Home Rd.
Hedges	HSL	Start above private drive culvert across from Martinazzi Ave.
	HSM	Start at Teton Rd. to 100 m upstream (pond)
	HSU	Start ~20m above 105th Ave crossing
McFee	MFM	End survey ~10m downstream of HWY 219 crossing.
	MFU	Start @ 17245 McKormick Hill Rd., above adjacent property driveway bridge.

Table 2. Continued.

Stream	Reach	Location
McKay	MKL	100 m above confluence w/ Dairy Ck. Enter from HWY 8. Walk just past RR bridge.
	MKM	Entrance to pond at South Ave. Enter @ private driveway above pond.
	MKU	Start at bridge crossing on Collins Rd.
N. Rock	RLL	Enter from River Rd. foot path near Treatment Plant.
	RMM	Start ~30 m upstream of Cornell Rd. crossing
	RUU	Start just above trib junction at Rock Creek Rd.
Roaring	RRL	Start ~10 m above confluence w/ Tualatin River.
	RRM	Start survey @ old Rd. crossing just above RR trib.
S. Johnson	JSM	Between Farmington Rd. and TV HWY. Access thru Valley Catholic HS.
	JSU	Start ~20m above 170th crossing.
S. Rock	SRM	Start at Highway 99W
	SRU	Start at Tualatin-Sherwood Rd.
Summer	SUL	End just downstream of walking bridge @ Fowler Junior High School
	SUM	Survey ends ~10m below 121st St.
	SUU	Start just upstream of 135th St. bridge
Tualatin R.	TUM	Start upstream of South Rd.
	TUU	Start ~25 m above Bridge crossing at Mt. Richmond Rd.
W. Dairy	WDM	Begin just above confluence w/ RR trip above HWY 6 Rd. crossing
	WDU	Start survey ~11 m upstream of HWY 47 crossing.

estimated. Water surface slope of each unit was measured with a clinometer and the value of woody debris to fish in each unit was rated on a scale from one to five, with one representing little or no wood, and five representing large amounts of wood creating abundant cover and refuge. Additionally, all woody debris measuring at least 15 centimeters in diameter (at estimated dbh) and 2 meters in length was tallied for each unit and the configuration, type, location, and size of root wads and pieces of wood were noted

Canopy cover was measured with a spherical densiometer in four directions (upstream, downstream, right, left) from the center of the stream at 0, 25, 50, 75, and 100 meters along the length of the reach. Habitat features such as beaver activity, culverts, and potential fish passage barriers were noted by habitat unit.

CROSS SECTION SURVEYS

Channel dimensions were measured at three transects occurring within each 100-meter sample reach. The three habitat units were selected according to the following guidelines:

1. Three separate riffles were sampled if three or more riffles occurred in the reach.
2. If two riffles occurred in the reach, both riffles and a representative glide or pool (least preferred) were sampled. If riffles were of sufficient length (10 meters or longer) then more than one set of cross-section measurements were made in the riffle to ensure that all measurements were taken from this habitat type.
3. If only one riffle occurred within the reach, two additional units that represented channel dimensions and substrate composition were sampled. If the riffle was longer than 20 meters, then all three sets of measurements were taken from the riffle.

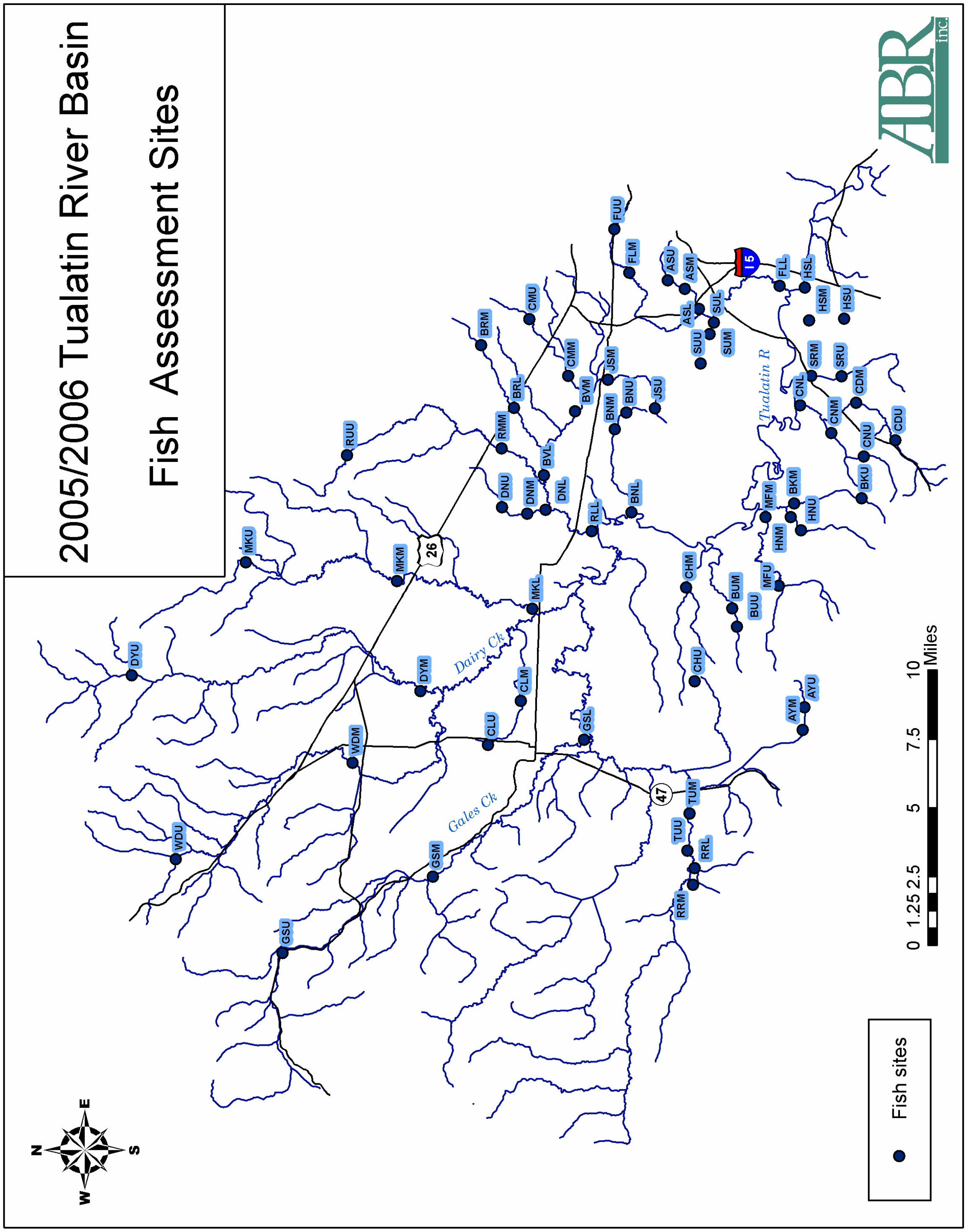

Figure 2. Locations of reaches sampled for fish in fall 2005 and spring 2006 in the Tualatin River basin, Oregon.

Table 3. Environmental variables collected in the field for characterizing streams in the Tualatin River basin, Oregon, fall 2005.

Variable	Quantitative or Categorical	Data Source (GIS or Field)	Visual Estimate, Measured, or Calculated Variable
Forest (%)	Q	G	M
Agriculture (%)	Q	G	M
Urban (%)	Q	G	M
Roads (%)	Q	G	M
Effective impervious area (EIA)	Q	G	M
Valley Type	C	F	V
Reach length	Q	F	M
Channel Habitat Units			
Max depth (m)	Q	F	M
Wetted width (m)	Q	F	M
Unit Length (m)	Q	F	M
Dominant Substrate	C	F	V
Percent embeddedness	Q	F	V
% Eroding bank	Q	F	V
% Undercut banks	Q	F	V
Large Wood Rating	Q	F	V
Overhead canopy cover	Q	F	M
Water Surface Slope (%)	Q	F	M
Percent riffles	Q	F	C
Percent glides	Q	F	C
Percent pools	Q	F	C
Large Wood Tally	Q	F	M
Channel Cross Sections			
Bankfull width (m)	Q	F	M
Width-to-depth ratio	Q	F	C
Entrenchment ratio	Q	F	C
Water Depth Profile	Q	F	M
Max bank height (m)	Q	F	M
L and R bank angle (deg)	Q	F	M
Substrate comp (Pebble Count)	Q	F	M
Discharge (cfs)	Q	F	M

Table 3. Continued.

Variable	Quantitative or Categorical	Data Source (GIS or Field)	Visual Estimate, Measured, or Calculated Variable
Riparian Condition			
Mean riparian buffer width (m)	Q	F	V
% Tree cover in riparian zone	Q	F	V
% Shrub cover in rip zone	Q	F	V
% Ground cover in rip zone	Q	F	V
% Nonnative riparian veg cover	Q	F	V
Plant Community Type	C	F	V
Dominant adjacent land use	C	F	V
AM/PM Water Chemistry			
Water temperature (^{o}C)	Q	F	M
pH	Q	F	M
Conductivity (µS/cm)	Q	F	M
Dissolved oxygen (mg/L)	Q	F	M
Oxygen Percent Saturation (%)	Q	F	C
Turbidity (NTU)	Q	F	M

4. If no riffles occurred in the reach, three units that were representative of the channel dimensions and substrate composition occurring within the reach were sampled.

At each of the three channel cross sections, wetted width (WW), bankfull width (BFW), maximum bankfull height (BFH_{max}), the bankfull height at 25%, 50%, and 75% across the distance of the bankfull channel, and the flood-prone width (FPW) were measured with a tape measure and survey rod. From these channel dimension data, width-to-depth and channel-entrenchment ratios were later calculated. Water depths were recorded at 10%, 30%, 50%, 70%, and 90% across the width of the wetted channel. Maximum bank height (L or R) and bank angles were visually estimated.

Pebble counts were performed in riffles when they represented an adequate amount of the stream channel area to allow measurement of at least 100 substrate particles along transects. If riffles occupied less than 10% of the total habitat area in the reach (e.g.,if macroinvertebrate samples were collected from glides in reaches where benthic sampling occurs), then pebble counts occurred in glides. Pebble counts were performed using the “heel-to-toe” method, starting at the bankfull edge on one side of the channel and walking heel-to-toe to the other edge (USEPA 2000). With each step, the surveyor looked away and touched the streambed at the tip of their toe. The size class and embeddedness of each piece of streambed substrate was estimated until at least 100 particles were counted.

A qualitative assessment of channel flow status was also performed in each reach in fall 2005. Channel flow broadly was classified as dry, no flow, flow too low to measure velocity at a channel cross section, or flow sufficient to measure velocity at one channel cross section station. If sufficient flow occurred, water velocity was measured at three locations (25, 50, and 75% of the way across the wetted channel) along the cross section with a Marsh-McBirney Flow Mate 2000 flow meter to produce a coarse estimate of stream discharge at the time of biological sampling.

RIPARIAN SURVEYS

Adjacent riparian conditions were characterized for left and right banks separately and according to a number of attributes. The dominant plant community type(s) (ash woodland, willow shrub scrub, upland forest, etc.) occurring in the riparian zone to the edge of human-dominated activity was classified and recorded and the approximate width of each of these community types was visually estimated. The percent vegetative cover of the canopy layer (>5-meter high), shrub layer (0.5 to 5-meter high), and groundcover layer (<0.5-meter high) was estimated, as well as the percent cover of invasive or nonnative species as a single estimate across all three vegetative layers. The dominant adjacent land use outside of the vegetated riparian zone buffer was noted, and then a cross-sectional diagram of the riparian zone was sketched.

WATER QUALITY SAMPLING

Water quality was sampled from each sample reach at peak stress times (before 9 am and after 4 pm) in fall 2005. Measured water quality parameters included temperature (°C), dissolved oxygen (mg/L), oxygen saturation (%), pH, conductivity (µS/cm), and turbidity (NTU). Water temperature, dissolved oxygen, and conductivity were measured in situ with a YSI Model 85 water chemistry meter. Turbidity was measured in the field with an Orbeco-Hellige portable turbidimeter or a HACH 2100P Turbidimeter. The pH was measured streamside with an Oakton pH Testr 3, hand-held pH meter. The pH was measured in a 200-milliliter sample of stream water with ionic strength adjuster added at a rate of 1 ml of adjuster per 100 ml of sample water. All equipment was calibrated according to the quality control plan assembled for the project and all calibration data were recorded and are available as raw field data.

MACROINVERTEBRATE COMMUNITY ASSESSMENTS

FIELD METHODS

Macroinvertebrates were collected using the Oregon Department of Environmental Quality's (DEQ) Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams (DEQ 2003). An 8-kick composite sample was collected from riffles or the best available habitat occurring in each reach. Instream sampling points were selected to apportion the eight kick samples among as many as four habitat units. Macroinvertebrates were collected with a D-frame kicknet (12-in wide, 500-µm mesh opening) from a 30 x 30 cm (1 x 1 ft) area at each sampling point. Larger pieces of substrate were first hand-washed inside the net and then placed outside of the sampled area. The area was then thoroughly disturbed by hand (or by foot in deeper water) to a depth of ~10 cm.

The eight samples from a reach were placed together into a 500-µm sieve and carefully washed to remove larger substrate and leaves after inspection for clinging macroinvertebrates. The composite sample then was placed into one or more 1-L polyethylene wide-mouth jars, labeled, and preserved with 80% ethyl alcohol for later sorting and identification at the laboratory.

LABORATORY METHODS

Samples were sorted to remove a 500-organism subsample from each preserved sample following the procedures described in DEQ's Level 3 protocols (WQIW 1999) and using a Caton gridded tray, as described by Caton (1991). Contents of the sample were first emptied onto the gridded tray and then floated with water to evenly distribute the sample material across the tray. Squares of material from the 30-square gridded tray were placed into a Petri dish which was then examined under a dissecting microscope at 7X magnification to sort aquatic macroinvertebrates from the sample matrix. Macroinvertebrates were removed from each sample until at least 500 organisms were counted or until the entire sample had been sorted.

Following sample sorting, all macroinvertebrates were identified to the level of taxonomic resolution recommended for Level 3 macroinvertebrate assessments (WQIW 1999).

Aquatic insects were keyed using Merritt and Cummins (1996), Wiggins (1995), Stewart and Stark (2002), and a number of regional and taxa-specific keys.

DATA ANALYSIS

Macroinvertebrate taxonomic data were analyzed using two approaches: multimetric analysis and predictive modeling. Both approaches were used because the multimetric analysis has been used in past years to assess the condition of macroinvertebrate communities sampled from riffles in higher-gradient (>1.5%) Tualatin basin streams, while the predictive model approach is a new tool recently developed by DEQ staff and researchers at Utah State University (Hawkins et al. 2000). This new approach, widely known as RIVPACS (River Invertebrate Prediction and Classification System) will likely become widely used in Oregon in the future. In its current form, each approach has limited applicability to Tualatin basin streams. Specifically, neither is calibrated for use with data from low-gradient, valley floor streams because an adequate number of suitable reference (or best attainable) locations has not been identified for streams of this type. As such, multimetric analyses were performed only on riffle-sample data collected from higher-gradient reaches, while the RIVPACS model was applied to both riffle and glide samples from higher and lower-gradient reaches, respectively. Because the RIVPACS model has not yet been calibrated for use with valley-floor, low-gradient reach macroinvertebrate data, an interim scoring system was selected for this study after consultation with DEQ and USGS staff. Each approach is described below.

Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that is known to be responsive to one or more types of pollution or habitat degradation. Each community metric is converted to a standardized score; standardized scores of all metrics are then summed to produce a single multimetric score that is an index of overall biological integrity. Reference condition data are required to develop and use this type of assessment tool. Metric sets and standardized metric scoring criteria are developed and calibrated for specific community types, based on both geographic location and stream/habitat type. DEQ has developed and currently employs a 10-metric set for use with riffle samples from higher-gradient streams in western Oregon (WQIW 1999).

The DEQ 10-metric set includes six positive metrics that score higher with better biological conditions, and four negative metrics that score lower with improved conditions (Table 4). The Modified Hilsenhoff Biotic Index (HBI), originally developed by Hilsenhoff (1982), computes an index to organic enrichment pollution based on the relative abundance of various taxa at a site. Values of the index range from 1 to 10; higher scores are interpreted as an indication of a more pollution tolerant macroinvertebrate community. Sensitive taxa are those that are intolerant of warm water temperatures, high sediment loads, and organic enrichment; tolerant taxa are adapted to persist under such adverse conditions. We used DEQ's taxa attribute coding system to assign these classifications to taxa in the data set (DEQ, unpublished information).

Metric values first were calculated for each riffle sample and then were converted to standardized scores using DEQ scoring criteria for riffle samples from western Oregon streams (Table 4). The standardized scores were summed to produce a multimetric score ranging between 10 and 50. Reaches were then assigned a level of impairment based on these total scores (Table 5).

RIVPACS is a predictive model that evaluates a site based on a comparison of observed (O) versus expected (E) taxa. The observed taxa are those that occurred at the site, whereas the expected taxa are those predicted to occur at the site in the absence of disturbance. Impairment is determined by comparing the O/E score to the distribution of reference site O/E scores. One major strength of RIVPACS over the IBI is that a single predictive model can be constructed to assess biological conditions over a wide range of environmental gradients such as stream slope, longitude, or elevation, whereas separate IBIs would have to be developed to make accurate impairment determinations (e.g., construct separate "high gradient" and "low gradient" IBIs). RIVPACS achieves this ability to predict taxonomic composition across a range of naturally occurring environmental gradients with discriminant functions models (DFMs). The model

Table 4. Metric set and scoring criteria (WQIW 1999) used to assess condition of macroinvertebrate communities in the Tualatin River basin, Oregon, fall 2001.

	Scoring Criteria		
Metric	5	3	1
POSITIVE METRICS			
Taxa richness	>35	19-35	<19
Mayfly richness	>8	4-8	<4
Stonefly richness	>5	3-5	<3
Caddisfly richness	>8	4-8	<4
Number sensitive taxa	>4	2-4	<2
# Sediment sensitive taxa	≥2	1	0
NEGATIVE METRICS			
Modified HBI[1]	<4.0	4.0-5.0	>5.0
% Tolerant taxa	<15	15-45	>45
% Sediment tolerant taxa	<10	10-25	>25
% Dominant	<20	20-40	>40

[1] Modified HBI = Modified Hilsenhoff Biotic Index

Table 5. Multimetric score ranges for assignment of macroinvertebrate community condition levels (WQIW 1999).

Level of Impairment	Score Range (scale of 10 - 50)
None	>39
Slight	30 – 39
Moderate	20 – 29
Severe	<20

assigns the probability of class membership of each test site to the different classes specified in the model based on the environmental variables that are input into the model. The model then determines the probability of occurrence of each taxon at a given test site (in the absence of disturbance) based on the frequency of occurrence of each taxon in each class of site weighted by the probability that the site belongs in each class. With this information, the O/E can then be calculated and compared to the frequency distribution of O/E scores of reference sites. Using the scoring criteria derived from the distribution of reference site scores for western Oregon, riffle-sample O/E scores in this study of less than 0.75 (>95th percentile of reference site scores) were classified as "poor" (severely impaired), between 0.75 and 0.90 (90–95th percentile of reference site scores) as "fair" (or slightly impaired), and greater than 0.90 (<90th percentile of reference site scores) as "good" (unimpaired).

The Marine Western Coastal Forest (MWCF) RIVPACS model was used for this analysis. Currently, the MWCF RIVPACS model uses date and longitude as predictor variables, as the model has been calibrated primarily with data collected from riffle-pool type streams. The current model and its corresponding impairment scoring criteria are likely not appropriate for evaluating low-gradient, Tualatin valley floor streams because the model can not adjust taxa predictions to the stream gradient or habitat type sampled. Consequently, any efforts at testing data from low-gradient sites could potentially result in biased results and over-classification of impairment. In the absence of a large set of low-gradient reference reaches with which to construct a new predictive model, we used the mean O/E score from the four "least impaired" low-gradient sites occurring in the 2005 Tualatin River basin macroinvertebrate data set as the threshold for determining impairment. Three low-gradient reach reference sites were sampled following a search for least disturbed conditions on west end of the valley floor in the McKay, Gales, and Dairy creek watersheds. A low-gradient sample reach on McKay Creek, MKM2, was included in the pool of low-gradient reference reaches because this reach also represented least-disturbed conditions based on instream and adjacent land use conditions. Additionally, owing to the scarcity of suitable reference sites, a Gales Creek reach, GSM2, that has in past years been analyzed as a high-gradient reach but shares characteristics intermediate of high and low-gradient reaches was selected as a low-gradient reference reach. Because none of these sites were unimpaired themselves, but only represent the least impaired conditions occurring on the Tualatin valley floor, the mean O/E score of these sites was set as the threshold for impairment rather than some lower score relative to the mean or overall distribution of scores from these least-impaired sites.

Following calculation of multimetric and O/E scores, relationships between these scores and selected environmental variables were examined using nonparametric correlation analysis (Spearman's Rho) to determine whether biological integrity is related to other measures of environmental conditions in the Tualatin River basin and to identify *potential* causative factors of impairment. Correlation analysis focused on variables known to correlate with macroinvertebrate community conditions (Cole 2002). To facilitate exploration of relationships between physical and biological conditions, several classes of variables such as percent urban, percent agriculture, and percent road land uses; percent coarse gravel, cobble, and boulder; and percent sand and fine substrate were summed to produce variables named "percent urban, roads, and ag," "percent coarse substrate," and "percent sand and fines." Land-use correlation analyses were run with land-use data calculated in 2001 in Arc/Info from 1990 land use/land cover data produced by the Pacific Northwest Ecosystem Research Consortium (Cole 2002). These data were produced by calculating the percent coverage of each land use type in a 2000-meter-long by 800-meter-wide (400-meter from each bank) buffer upstream of each macroinvertebrate sample reach.

FISH COMMUNITY ASSESSMENTS

FIELD SAMPLING

Fish communities were quantitatively sampled in fall 2005 and again in spring 2006 using survey techniques routinely employed to monitor fish communities of the Tualatin River basin (e.g., Leader 2002, Cole and Koehler 2005).

In each reach, block nets were first set up at the downstream and upstream end. A three-pass removal survey was performed with electrofishing equipment (Smith Root models LR 24 and 12B) to estimate abundance of each species occurring within each survey reach. If salmonids were not sampled in the first two electrofishing passes, a third pass was not conducted, as per the standard protocol (Leader 2002). After each pass, captured fish were counted and total length (TL; mm) of up to 50 individuals of each species was measured.

DATA ANALYSIS

Using the fish assessment data, an Index of Biotic Integrity (IBI; Hughes et al. 1998) was calculated to evaluate the condition of the fish community within each reach. The IBI consists of a numerical score calculated from biological data collected in the field. A set of scoring criteria based on fish assemblage attributes was used to calculate the biotic integrity score (Table 6). We followed an IBI modified by ODFW for urban streams in the Tualatin River watershed, adapted from the IBI developed and tested by Hughes et al. (1998) for wadeable streams in the Willamette River basin. We used the same 12 metrics employed in the 1999–2001 fish surveys (as per Leader 2002) to calculate a continuous IBI score for each study reach that ranged from 0–100 points.

IBI values were calculated for each season at each study site. Fish species were first classified by habitat preference, tolerance to disturbance, and trophic attributes. Raw attribute values were then calculated and converted to standardized metric scores using previously derived scoring criteria.

Table 6. Scoring criteria for Index of Biotic Integrity (IBI) metrics used for urban streams located in the Tualatin River watershed, modified from Hughes et al. (1998) and ODFW (Leader 2002).

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

1 Species that create nests in gravel or cobble substrates
2 Lunkers are relatively large individuals of the following species and sizes: 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)

Metric scores were then summed to produce an IBI value between 0 and 100. Following Hughes et al. (1998), sites scoring <75 are classified as acceptable, 51–74 as marginally impaired, and ≤50 as severely impaired. Metrics and ranges used to score fish assemblages were modified for Tualatin Valley streams by ODFW (Leader 2002). IBI scores from the current study were compared with IBI scores calculated from 1999–2001 ODFW surveys for the same season to identify any significant deviation of 2005–2006 IBI scores from 1999–2001 scores (fall and spring).

Relationships between fish IBI scores and selected environmental variables were examined using nonparametric correlation analysis (Spearman's Rho) to examine the data set for possible relationships between biological and environmental condition gradients. Correlation analysis focused on variables known to correlate with biological conditions (Cole 2002, Leader 2002). To facilitate exploration of relationships between physical and biological conditions, several classes of variables percent coarse gravel, cobble, and boulder; and percent sand and fine substrate were summed to produce variables named "percent coarse substrate," and "percent sand and fines."

RESULTS

PHYSICAL HABITAT AND WATER QUALITY

ENVIRONMENTAL CONDITIONS OF MACROINVERTEBRATE SURVEY REACHES

Streams sampled for macroinvertebrates in this study encompassed a wide range of land-use conditions, riparian and bank conditions, stream channel dimensions, and substrate characteristics (Table 7). Reaches were broadly classified into high and low-gradient classes for purposes of analyzing macroinvertebrate communities with appropriate assessments tools. Reaches with gradients exceeding 1.5% (as determined from clinometer measurements) and with riffle habitat exceeding 15% of the total surveyed reach length were classified as high-gradient reaches. High-gradient reaches were generally dominated by riffle-pool complex habitat and were usually contained within U- or V-shaped valleys in areas of more topographic relief along the periphery of the Coast, Tualatin, and Chehalem Mountain Ranges. Riparian zone conditions ranged from completely intact mature forest in forested areas to non-existent buffers and maintained lawns and parks to the top of the stream bank.

Low-gradient reaches were generally dominated by sand, silt, or hardpan substrates. Glide and pool habitat represented most, if not all, aquatic habitat in these low-gradient reaches; riffles were infrequent or absent. Riparian zone conditions ranged widely, but tended to be poorer (as determined by buffer width, % non-native vegetation, and % tree cover) than in high-gradient reaches, which generally occurred in less developed areas. Importantly, agricultural and urban land uses are higher in low-gradient reaches (mean = 84%, range = 37 to 99%) than in high-gradient reaches (mean = 47%, range 0 to 97%), which accounts for the lack of sufficient reference reaches for expressing undisturbed valley floor conditions.

Low-gradient reaches also tended to have more impaired water quality with lower dissolved oxygen concentrations and higher conductivities than did high-gradient reaches. Water temperatures also appear to be higher in low-gradient reach than in high-gradient reaches, based on the afternoon sampling performed for this study (Table 7).

ENVIRONMENTAL CONDITIONS OF FISH SURVEY REACHES

Fish survey reaches often overlapped with macroinvertebrate survey reaches; as such, a similarly wide range in stream channel dimensions, instream habitat characteristics, and riparian conditions was observed (Table 8). Reaches were broadly classified into lower, middle, and upper sites depending on the location of the reach within a particular stream, allowing for the comparison of reaches with generally similar geomorphic characteristics and topographic settings.

Upper reaches exhibited greater habitat heterogeneity with pool, glide, and riffle habitats more evenly apportioned (Table 8). Riffle-pool complexes were the most common habitat observed these upper-reach sites. These sites also had the highest percentage of coarse substrate and the lowest percentages of sand, fines, and hardpan substrates. Intact buffers were noted most

Table 7. Environmental conditions of low-gradient and high-gradient stream reaches from which macroinvertebrates were sampled in the Tualatin River basin, Oregon, fall 2005.

	Reach Type					
	Low-gradient			High-gradient		
Environmental Variable	Mean	Min	Max	Mean	Min	Max
Urban (%)	39.9	0.0	75.0	15.3	0.0	75.0
Agriculture (%)	33.8	2.0	94.0	24.4	0.0	94.0
Urban, Agri., Roads (%)	86.1	37.0	99.0	44.5	0.0	99.0
Forest (%)	13.5	1.0	57.0	55.5	2.0	35.0
Effective impervious area (%)	14.9	0.0	51.0	28.5	0.0	51.8
Wetted width (m)	5.2	1.4	15.2	3.0	0.8	8.3
Embeddedness (%)	88.1	16.3	100.0	41.5	2.0	100.0
Eroding Banks (%)	60.9	0.0	100.0	34.8	0.0	69.9
Undercut banks (%)	12.1	0.0	71.2	15.6	0.0	38.2
Large Wood Rating	1.7	0.7	3.9	1.2	0.8	2.7
Canopy cover (%)	63.9	0.0	99.7	89.9	58.5	0.0
Percent riffles	4.2	0.0	49.0	58.4	10.7	49.0
Percent glides/runs	50.7	0.0	100.0	12.2	0.0	100.0
Percent pools	45.0	0.0	93.0	24.0	0.0	93.0
Large Wood Tally	0.1	0.0	0.4	0.1	0.0	0.3
Percent coarse substrate	10.2	0.0	74.8	66.4	0.0	68.7
Percent sand and fines	68.6	0.0	100.0	18.4	0.0	100.0
Percent hardpan	6.6	0.0	50.0	1.2	0.0	11.8
Mean riparian buffer width (m)	33.0	2.5	100.0	59.6	0.0	100.0
Tree cover in riparian zone (%)	42.3	7.5	90.0	63.3	0.0	90.0
Rip nonnative veg cover (%)	56.1	5.0	95.0	37.7	0.0	75.0
PM Water temperature (^{o}C)	16.0	11.5	23.5	13.4	11.3	18.8
AM pH	7.4	7.0	8.1	7.6	6.9	8.1
Conductivity (µS/cm)	200.1	73.1	523.0	117.6	57.2	189.1
AM Dissolved oxygen (mg/L)	6.4	1.7	9.1	8.7	2.7	10.4
AM Dissolved oxygen (% sat)	57.9	15.0	87.7	79.8	24.6	100.0
Turbidity (NTU)	13.0	0.0	93.4	8.3	0.0	38.2

Table 8. Environmental conditions of stream reaches sampled for fish community conditions in the Tualatin River basin, Oregon, fall 2005 and spring 2006.

	Upper			Middle			Lower		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Wetted width (m)	3.4	0.8	16.8	5.3	1.7	16.1	5.0	2.3	10.5
Embeddedness (%)	62.4	7.1	100.0	84.9	33.0	100.0	85.7	18.4	100.0
Eroding Banks (%)	41.2	0.0	90.0	46.5	0.0	100.0	64.4	7.0	100.0
Undercut banks (%)	19.7	0.0	86.7	13.3	0.0	47.8	20.8	0.0	68.6
Large Wood Rating	1.4	1.0	2.9	1.6	1.0	4.1	1.9	1.0	3.9
Canopy cover (%)	46.7	0.0	90.0	39.6	0.0	90.0	48.0	5.0	90.0
Percent riffles	39.2	0.0	100.0	11.8	0.0	79.0	8.4	0.0	61.0
Percent glides/runs	23.5	0.0	100.0	28.0	0.0	100.0	37.2	7.7	70.0
Percent pools	37.1	0.0	100.0	59.5	0.0	100.0	54.7	12.7	88.9
Large Wood Tally	1.4	1.0	2.9	1.6	1.0	4.1	1.9	1.0	3.9
Percent coarse substrate	45.3	0.0	90.7	17.7	0.0	77.0	17.7	0.0	77.1
Percent sand and fines	38.2	0.0	100.0	67.2	9.0	100.0	53.9	0.0	100.0
Percent hardpan	1.0	0.0	11.8	3.0	0.0	45.5	7.1	0.0	50.0
Mean riparian buffer width (m)	35.0	0.0	100.0	34.0	2.0	100.0	29.4	5.0	67.5
Tree cover in riparian zone (%)	46.7	0.0	90.0	39.6	0.0	90.0	48.0	5.0	90.0
Rip nonnative Veg cover (%)	45.6	0.0	90.0	56.7	1.0	95.0	45.9	5.0	90.0
PM Water temperature (^{o}C)	15.1	10.7	26.3	16.5	11.1	29.0	16.2	12.3	20.2
AM pH	7.6	6.8	8.1	7.5	6.6	8.1	7.5	7.2	7.9
Conductivity (µS/cm)	155.3	57.2	604.0	193.7	55.5	803.5	246.9	142.6	523.0
AM Dissolved oxygen (mg/L)	7.96	3.3	10.85	5.2	1.7	9.9	6.3	1.9	9.8
AM Dissolved oxygen (% sat)	74.0	30.5	100.0	59.0	15.0	88.5	60.3	19.3	90.0
Turbidity (NTU)	5.8	0.0	33.2	13.7	0.0	55.5	10.9	1.9	47.4

frequently in these upper survey reaches as these areas tended to occur in more forested areas than did middle and lower reaches. Maintained lawns or agricultural land only occasionally occurred to the edge of the stream bank. Interestingly, this site class had the lowest average large woody debris rating among the three reach location classes (Table 8).

Middle reaches were dominated by pool habitat, while glide and riffle habitats were less common and sometimes absent (Table 8). These reaches were dominated by sand or silt substrates and, as such, tended to have a high degree of embeddedness. Canopy cover was generally lower relative to that occurring in the upper reaches; middle reaches also showed a higher percentage of invasive plant species within the riparian zone, as Himalayan blackberry and reed canary grass were frequently noted.

Overall environmental conditions in the lower reaches were similar to those observed within the middle reaches. These reaches were also dominated by pool habitat; sand, fine, and hardpan substrates; and a high degree of embeddedness. Lower sites had the narrowest mean buffer widths. Urban land use was the dominant adjacent land use as seventy-seven percent of the lower reaches occurred within the urban growth boundary. Interestingly, lower reaches had the highest average large woody debris rating (Table 8).

Lower and middle reaches tended to have impaired water quality conditions relative to upper reaches (Table 8). Afternoon water temperatures were warmer while dissolved oxygen concentrations tended to be lower at these sites. Lower and middle sites tended to have decreased water clarity as measured by turbidity and higher total dissolved solids as approximated by conductivity (Table 8).

MACROINVERTEBRATE COMMUNITIES

MACROINVERTEBRATE SURVEY EFFORT

Macroinvertebrate communities were sampled from 62 stream reaches between September 5 and October 29, 2005. Reaches were classified into high and low-gradient reach types based largely on the classifications assigned in 2001 (Cole 2002). 2001 classifications were based on overall stream gradient and prevalence of riffle habitat; reaches with gradients exceeding 1.5% (as determined from clinometer measurements) and with riffle habitat exceeding 15% of the total surveyed reach length were classified as high-gradient reaches. Riffle samples were collected from 27 stream reaches, including 23 reaches classified as high-gradient, and glide samples were collected from 40 stream reaches. Riffle and glide samples were both collected from four stream reaches that supported marginal riffle habitat, including lower Rock Creek, lower Summer Creek, lower Fanno Creek, and, middle Gales Creek. Two reaches sampled in 2001, Bannister Creek (BAM1) and upper Rock Creek (RUM2) were not sampled in this study because they were dry.

CONDITIONS IN HIGH-GRADIENT REACHES

Macroinvertebrate community conditions ranged widely among high-gradient Tualatin basin stream reaches as indicated by both RIVPACS O/E scores and DEQ multimetric scores. RIVPACS O/E scores from high-gradient reaches ranged from 0.24 to 1.05 and averaged 0.72 (Table 9), while multimetric scores ranged from 11 to 46 and averaged 27.9. The two approaches produced similar impairment-class groupings, as illustrated in Figure 3.

Almost half of the high-gradient-reach macroinvertebrate communities that scored as unimpaired according to O/E scores also received unimpaired multimetric scores, including upper Gales Creek, upper Burris Creek, upper Scoggins Creek, middle Roaring Creek, and upper West Fork Dairy Creek (Tables 9 & 10). These streams represent the least impaired stream conditions within the Tualatin River basin, and with the exception of upper Scoggins Creek, which scored eight multimetric points higher in 2005 than in 2001, these same streams also were identified as least impaired in the 2001 Tualatin basin macroinvertebrate assessment (Cole 2002). Additionally, the Upper East Fork of Dairy Creek, identified as one of the least-impaired stream reaches in 2001, received an unimpaired O/E score and a 2005 multimetric score of 39, only one point shy of being classified as unimpaired (Tables 9 & 10).

These reaches each support species-rich communities with high EPT richness and a collective sensitivity to habitat and water quality impairment. Upper Gales Creek received the both the highest O/E and multimetric scores of 1.05 and 46, respectively. Forty-seven taxa— five more taxa than the next highest sample richness—were sampled from upper Gales Creek, including ten mayfly taxa and eleven caddisfly taxa. Upper Gales Creek likely supports the richest assemblage of aquatic invertebrates among Tualatin River basin streams.

Other reaches receiving unimpaired O/E scores included middle Chicken Creek, upper McFee Creek, Sain Creek, and Tanner Creek. The former three sites all received slightly impaired multimetric scores, while Tanner Creek received a moderately impaired multimetric score of 26. Despite a modestly high taxa richness (26 total taxa), the Tanner Creek sample contained a large number of the pleurocerid snail, *Juga* (273 of 541 organisms sampled). Owing to the high tolerance of this taxon to disturbance, Tanner Creek received low metric scores for HBI, percent sediment-tolerant organisms, percent tolerant organisms, and percent dominance by one taxon, which accounted for the low multimetric score.

Three sites—upper McKay Creek, upper Bronson Creek, and upper Ayers Creek—received "fair" O/E scores ranging from 0.779 to 0.877 (Table 9). These sites scored as slightly or moderately impaired according to multimetric scores (Table 10).

Fourteen high-gradient reaches received "poor" O/E scores, suggesting that the communities in these reaches have been significantly altered by changes in physical,

Table 9. O/E scores and corresponding impairment classes of macroinvertebrate communities sampled from 27 high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005.

Reach Name	Reach Code	2005 O/E Score (P>0.5)
	UNIMPAIRED	
Gales Creek (Upper)	GSM1	1.054167
McFee Creek (Upper)	MFM1	1.021516
Burris Creek (Upper)	BIM1	1.0211
Chicken Creek (Middle)	CNM1	1.02065
Scoggins Creek (Upper)	SCM1	1.00678
Tanner Creek (Lower)	TNM1	1.00563
Roaring Creek (Middle)	RGM1	0.998617
Dairy Creek (Middle East Fork)	DYM1	0.950207
Dairy Creek (Upper West Fork)	DYM4	0.93322
Sain Creek (Lower)	SNM1	0.910252
FAIR		
McKay Creek (Upper)	MKM1	0.877299
Bronson Creek (Upper)	BRM1	0.874876
Ayers Creek (Upper)	AYM1	0.77987
POOR		
Baker Creek (Upper)	BKM1	0.729131
Chicken Creek (Upper)	CNM2	0.7283
Christensen Creek (Upper)	CHM1	0.682147
Dairy Creek (Upper East Fork)	DYM2	0.634865
Rock Creek (Upper 1)	RUM1	0.632239
Gales Creek (Middle)	GSM2	0.632186
Summer Creek (lower)	SMM2	0.340538
Fanno Creek (Upper 1)	FUM1	0.340363
Cedar Mill Creek (Upper)	CMM2	0.340337
Willow Creek Upper)	WLM1	0.339349
Golf Creek (Upper)	GLM1	0.339
Rock Creek (Lower)	RLM1	0.292873
Ash Creek (Upper)	ASM1	0.243628
Fanno Creek (Lower)	FLM1	0.242847

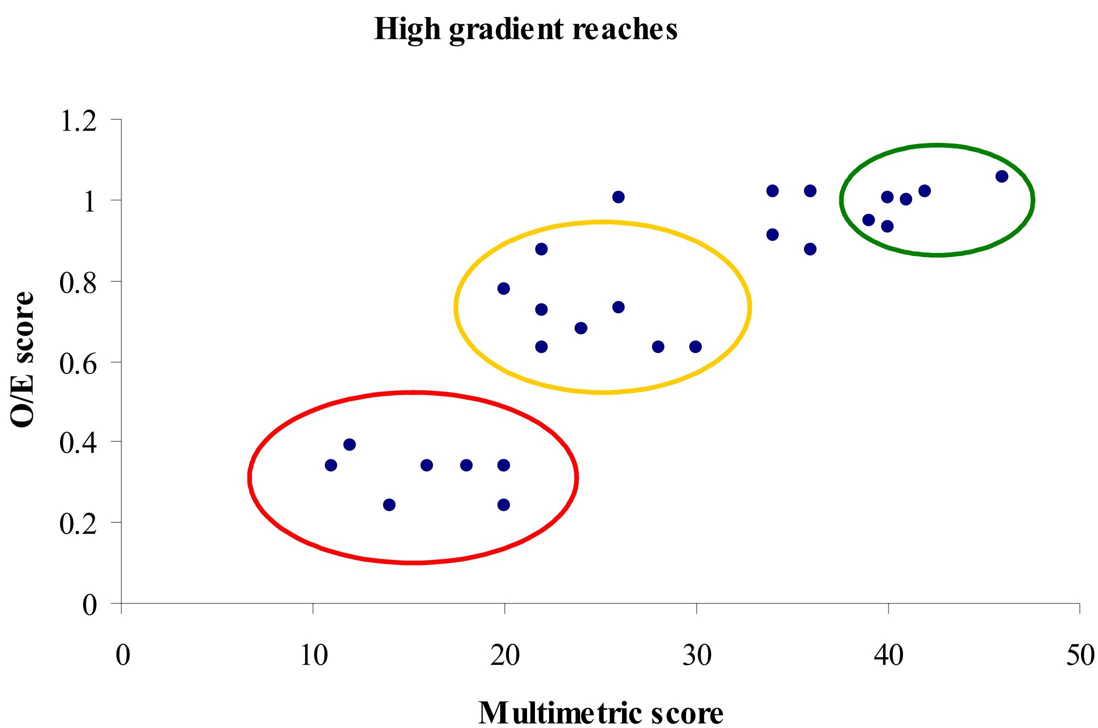

Figure 3. Relationship between O/E scores and IBI scores derived from macroinvertebrate community samples collected from high-gradient stream reaches in the Tualatin River basin, fall 2005. Circles represent groups of sites that received similar O/E and multimetric scores.

hydrologic, and/or chemical conditions (Table 9). O/E scores from these reaches revealed two groups of scores, with one group ranging from 0.632 to 0.729 and the second group ranging from 0.243 to 0.341 (Table 9, Figure 3). The former group of sites scored an average multimetric score of 26.0 with four moderately impaired and one slightly impaired site, while the latter group received an average multimetric score of 16.4 with five severely impaired multimetric scores and three moderately impaired multimetric scores (Table 10), again suggesting general agreement between the two analysis approaches.

Sites receiving both the lowest multimetric scores (less than 22) and "poor" O/E scores included upper Ash Creek, lower Summer Creek, upper Willow Creek, upper Golf Creek, upper Fanno, upper Cedar Mill Creek, and lower Rock Creek (Table 9). These streams scoring as severely impaired (multimetric scores) or poor (O/E scores) primarily occur in areas with higher urban and agricultural land use intensities. The communities occurring in these waters are characterized by low taxa richness, low EPT richness, and a high collective tolerance to disturbance.

Upper Ayers Creek, the reach receiving the lowest multimetric score in 2001 of 15 (average of duplicate samples), again received a low multimetric score of 20 in 2005. However, the reach received a "fair" O/E score of 0.77, resulting in discordant classifications by the two approaches. As was the case with Tanner Creek, Ayers Creek supported a relatively rich community of 29 taxa, yet the community was heavily dominated by *Juga* snails, resulting in low metric scores for HBI, percent sediment-tolerant organisms, percent tolerant taxa, and percent dominance by one taxon.

Across all high-gradient reaches, macroinvertebrate community conditions were similar to those reported in 2001 (Cole 2002). Reaches sampled in both years (n = 24) averaged multimetric scores of 28.9 in 2005 compared to 27.7 in 2001. A two-sample paired t-test performed to examine the data for a change in average

Table 10. Multimetric scores of macroinvertebrate communities sampled from 23 high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005. The fourth column represents the multimetric score change from 2001 to 2005.

Reach Name	Reach Code	2005 Multimetric Score	Change from 2001 Score
	UNIMPAIRED		
Gales Creek (Upper)	GSM1	46	**8**
Burris Creek (Upper)	BIM1	42	6
Roaring Creek (Middle)	RGM1	41	5
Dairy Creek (Upper West Fork)	DYM4	40	**8**
Scoggins Creek (Upper)	SCM1	40	2
	SLIGHTLY IMPAIRED		
Dairy Creek (Middle East Fork)	DYM1	39	1
Chicken Creek (Middle)	CNM1	36	2
McKay Creek (Upper)	MKM1	36	**10**
McFee Creek (Upper)	MFM1	34	5
Sain Creek (Lower)	SNM1	34	2
Gales Creek (Middle)	GSM2	30	**10**
	MODERATELY IMPAIRED		
Dairy Creek (Upper East Fork)	DYM2	28	-4
Baker Creek (Upper)	BKM1	26	-2
Tanner Creek (Lower)	TNM1	26	-4
Christensen Creek (Upper)	CHM1	24	**-10**
Bronson Creek (Upper)	BRM1	22	**-10**
Chicken Creek (Upper)	CNM2	22	-4
Rock Creek (Upper 1)	RUM1	22	2
Ayers Creek (Upper)	AYM1	20	5
Cedar Mill Creek (Upper)*	CMM2	20	
Fanno Creek (Lower)	FLM1	20	-2
Summer Creek (lower)	SMM2	20	-4
	SEVERELY IMPAIRED		
Willow Creek Upper)	WLM1	18	0
Fanno Creek (Upper 1)	FUM1	16	-2
Ash Creek (Lower)	ASM1	14	-4
Rock Creek (Lower)*	RLM1	12	
Golf Creek (Upper)	GLM1	11	-5

* Riffle samples were not collected from these reaches in 2001

conditions between the two years was not significant (p = 0.502).

Duplicate sampling in high-gradient reaches in 2005 resulted in an average difference of 3.6 multimetric points between duplicate pairs (n = 5) and ranged from 2 to 6. Based on these results and those obtained in 2001 (Cole 2002), only year-to-year changes larger than 6 multimetric points were flagged as temporal changes in biological conditions between the two years. Among individual reaches, upper McKay Creek and middle Gales Creek showed the largest improvement in multimetric scores from 2001 to 2005, each scoring 10 points higher in 2005 (Table 10). Similarly, upper Gales Creek and the upper West Fork of Dairy Creek each scored 8 points higher in 2005 than in 2001 (Table 10). Two sites, upper Christensen Creek and upper Bronson Creek, scored ten points lower in 2005 than in 2001, suggesting a decrease in biological integrity in these two reaches (Table 10).

Both multimetric scores and O/E scores were significantly correlated with a number of environmental variables (Table 11). Each set of scores was significantly correlated (p < 0.01) with percent urban land use, percent forested land use,

Table 11. Means, ranges, and correlation with multimetric and O/E scores of selected environmental variables measured at 23 high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005. Asterisks (*) aside p-values indicate significant correlation at alpha = 0.01.

			Multimetric Scores		O/E Scores	
Variable	Mean	Range	Spearman rho	P value	Spearman rho	P value
Urban (%)	15.3	0-80	-0.7599	**P<0.0001***	-0.7151	**P<0.0001***
Agriculture (%)	24.43	0-71	-0.2104	0.1676	-0.06858	0.3809
Forest (%)	55.52	2-100	0.7692	**P<0.0001***	0.6819	**0.0002**
Effective Imp Area (%)	9.957	0-46	-0.7613	**P<0.0001***	-0.7274	**P<0.0001***
Urban, Roads, and Ag (%)	46.46	0-98	-0.7693	**P<0.0001***	-0.6833	**0.0002***
Coarse substrate (%)	66.41	17-92	0.4997	**0.0089***	0.3123	0.0841
Sand and fines (%)	18.32	5-60	-0.5223	**0.0063***	-0.3504	0.0597
Embeddedness (%)	41.52	2-100	-0.2854	0.0934	-0.182	0.2088
Riparian Buffer Width (m)	59.67	0-100+	0.6505	**0.0007***	0.5867	**0.0033***
Riparian tree cover (%)	63.41	0-90	0.3901	0.0363	0.3277	0.0735
Nonnative riparian veg (%)	37.68	0-75	-0.487	0.0172	-0.3531	0.0753
Water temperature (^{o}C)	13.46	11.3-18.8	-0.6205	**0.0008***	-0.658	**0.0004***
Conductivity (µS/cm)	117.7	57-199	-0.627	**0.0007***	-0.4366	0.0211
Dissolved oxygen mg/L)	8.723	2.7-10.4	0.601	**0.0012***	0.6069	**0.0014***

effective impervious area, percent total urban and agricultural land use (Figure 4), water temperature, and dissolved oxygen (Table 11, Figure 5). Several measures of streambed substrate conditions were significantly correlated with multimetric scores but not with O/E scores (Table 11, Figure 6). Consistent with 2001 results, conductivity was significantly correlated with multimetric scores; however, conductivity was not significantly correlated with 2005 O/E scores (Table 11, Figure 5).

CONDITIONS IN LOW-GRADIENT REACHES

Biological integrity of macroinvertebrate communities varied less among low-gradient reaches and generally scored lower than in high-gradient reaches (Table 12). Four reaches selected as representing least impaired low-gradient conditions in the Tualatin River basin (based in instream habitat and adjacent and upstream land use)—an east Fork Dairy Creek tributary, two reaches on McKay Creek, and middle Gales Creek—received O/E scores ranging from 0.340 to 0.726. The mean of these four scores (0.557) was then used as the threshold for determining whether low-gradient reaches were impaired. Based on this cut-off, only one of 36 sample reaches (excluding the reference reaches), the lower East Fork of Dairy Creek, was classified as unimpaired with an O/E score of 0.574. The remaining 35 O/E scores calculated from low-gradient reaches ranged from 0.143 to 0.469 (Table 12). These communities generally exhibited a low taxa richness, few or no EPT taxa, high dominance by one or a few tolerant taxa, and a high community-wide tolerance to disturbance.

Three of four reaches within which both riffles and glides were sampled received similar O/E scores from the two habitat types. Lower Fanno Creek riffle and glide samples received O/E scores of 0.24 and 0.44, respectively; lower Rock Creek riffle and glide samples scored 0.29 and 0.39, respectively; and lower Summer Creek riffle and glide samples scored 0.34 and 0.29, respectively. Middle Gales Creek riffle samples scored almost twice as high (0.63) as glide samples (0.34) from the same reach. Results of this paired habitat sampling generally suggest that assemblages occurring in the infrequent riffles in impaired low-gradient reaches are similar to those occurring in glides, as O/E scores were comparable between the two habitat types when riffle community conditions scored poorly. This result suggests that sampling from riffles or glides should not significantly affect the outcome of impairment class determinations when the stream is degraded. In contrast, it appears that when conditions are less degraded, as is the case with the middle Gales Creek reach, riffles indeed score higher than glides owing to the expected differences in community composition between the two habitat types. Interestingly, in two of three cases where both habitat types were sampled from impaired low-gradient reaches, glide samples produced higher O/E scores than riffle samples.

O/E scores calculated from low-gradient reaches were negatively correlated ($p < 0.01$) with percent embeddedness and positively correlated with dissolved oxygen concentrations (Table 13, Figure 7). Figure 7 suggests that a relationship between low dissolved oxygen concentrations and poor macroinvertebrate community conditions may occur in low-gradient streams in the basin, as only macroinvertebrate assemblages receiving O/E scores of less than 0.4 were sampled from streams with AM dissolved oxygen concentrations of less than 6 mg/L.

FISH COMMUNITIES

FISH COMMUNITIES SURVEY EFFORT

Fish communities were sampled in the fall of 2005 as well as the spring of 2006. In the fall, fish communities were sampled in 64 stream reaches between August 16 and October 19, 2005. These sites included 13 lower, 27 middle, and 24 upper reaches within 28 creeks. Fish communities were again sampled in 51 of these same stream reaches between April 11 and June 16, 2006. Sampled reaches included 10 lower, 18 middle, and 23 upper reaches. Thirteen reaches were not sampled due to high water levels which prevented safe and/or effective sampling.

CATCH DATA

Among both seasons, 25 species from 10 families were sampled (Table 14). Neither sculpins nor lampreys were identified to species in this study, yet is it likely that more than one sculpin species and more than one lamprey species occur

HIGH-GRADIENT STREAMS

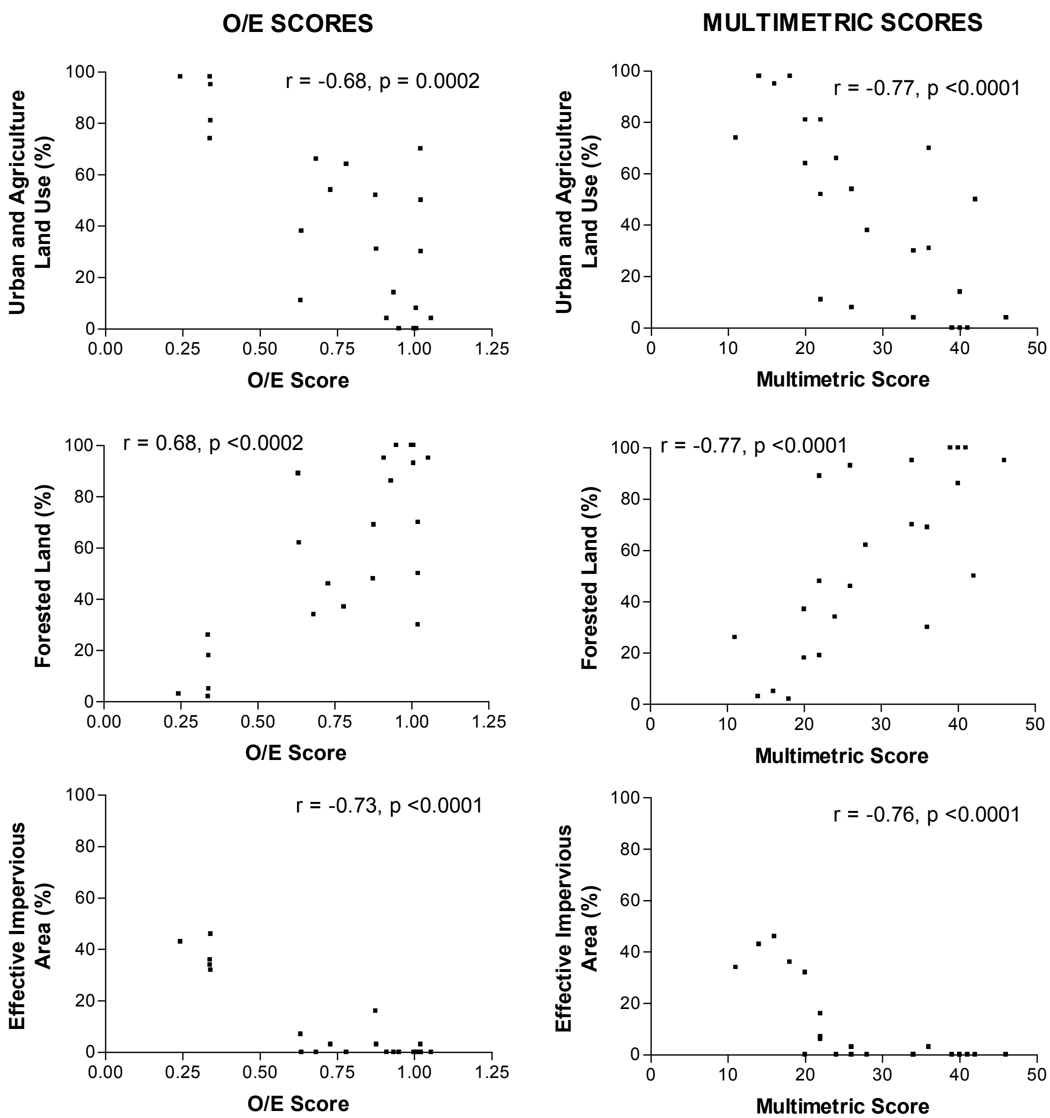

Figure 4. Relationship of macroinvertebrate community O/E scores (left column) and multimetric scores (right column) with land-use variables found to be significantly correlated with one or both response variables. Community scores are derived from macroinvertebrate samples from high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005. O/E scores >0.9 are classified as unimpaired, 0.75 to 0.9 as slightly impaired, and <0.05 severely impaired. Multimetric scores >39 are classified as unimpaired, 30–39 as slightly impaired, 20–29 as moderately impaired, and <20 as severely impaired.

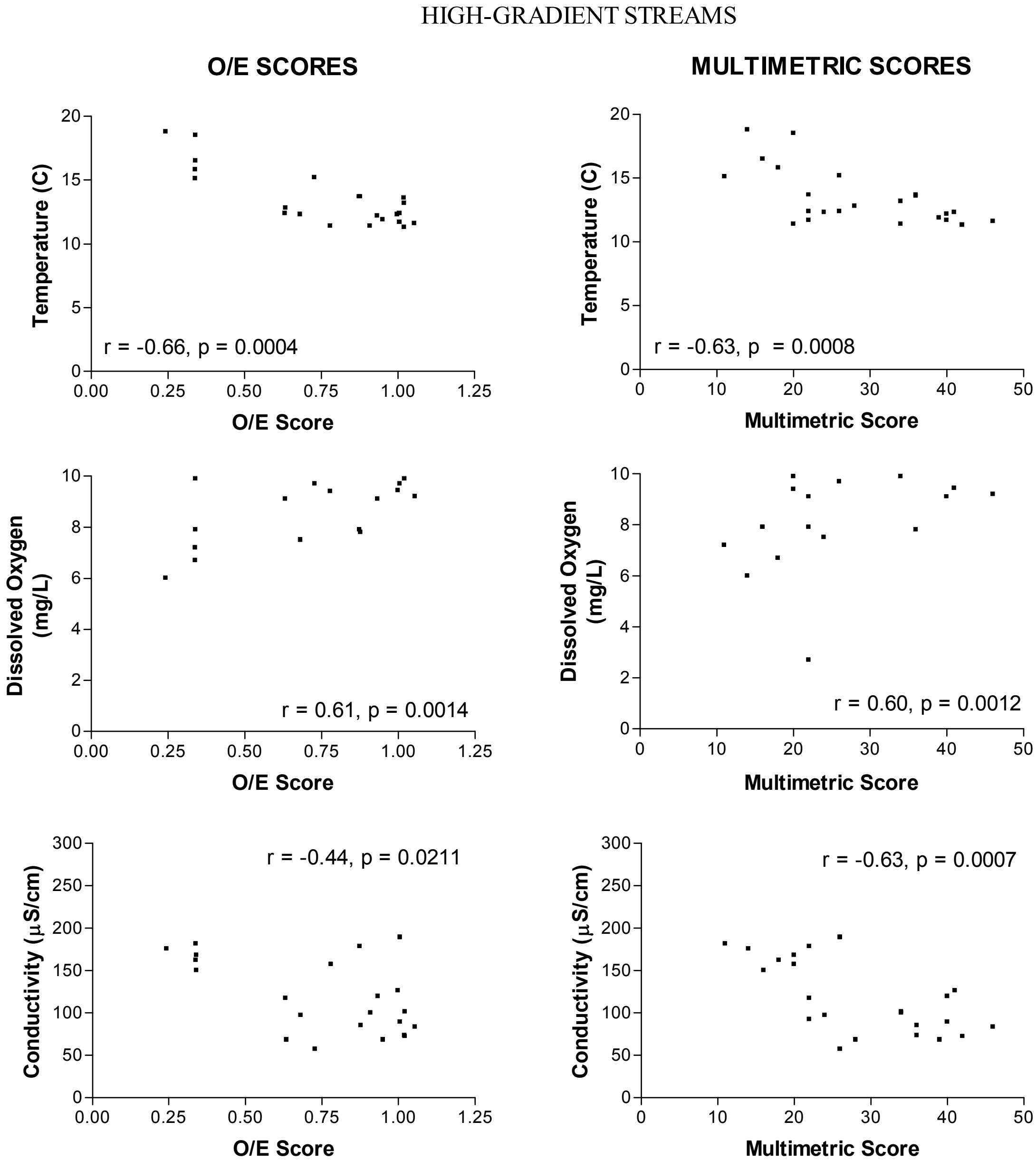

Figure 5. Relationship of macroinvertebrate community O/E scores (left column) and multimetric scores (right column) with water quality variables found to be significantly correlated with one or both response variables. Community scores are derived from macroinvertebrate samples from high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005. O/E scores >0.9 are classified as unimpaired, 0.75 to 0.9 as slightly impaired, and <0.05 severely impaired. Multimetric scores >39 are classified as unimpaired, 30–39 as slightly impaired, 20–29 as moderately impaired, and <20 as severely impaired.

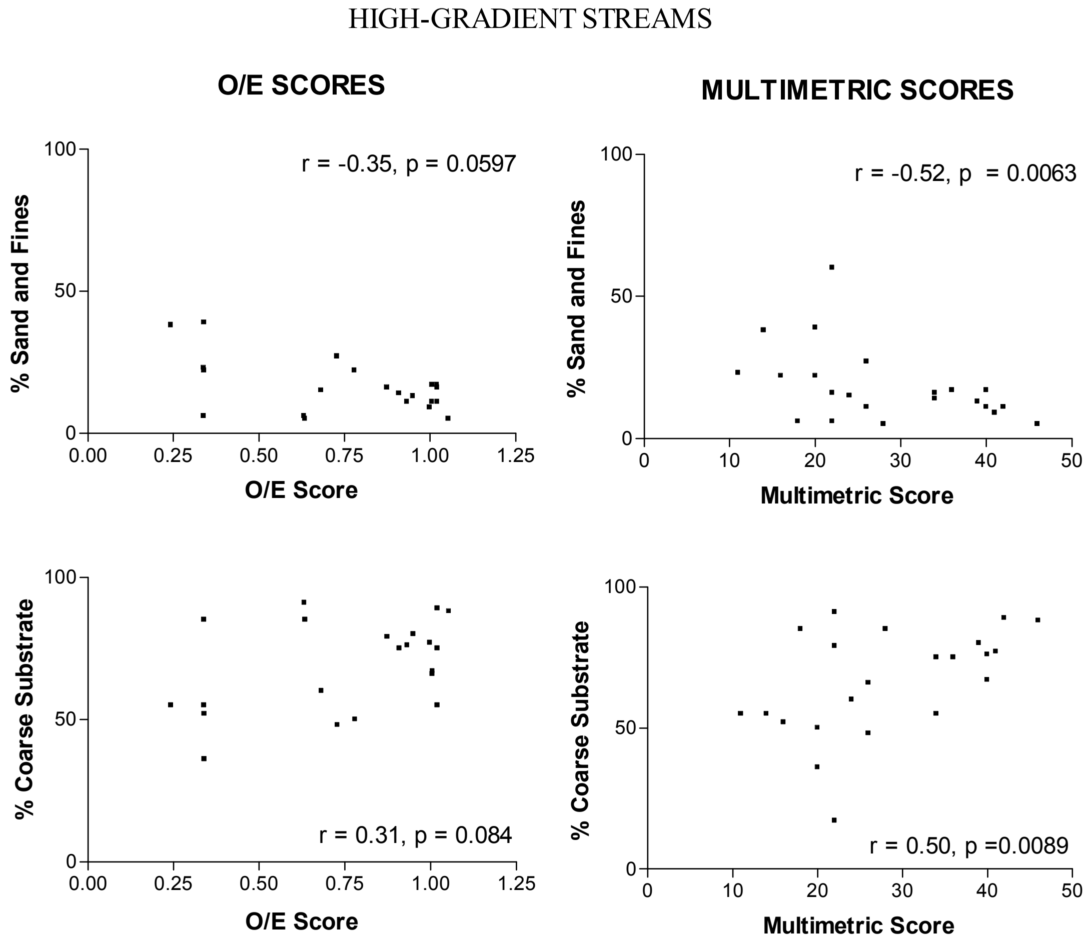

Figure 6. Relationship of macroinvertebrate community O/E scores (left column) and multimetric scores (right column) with stream substrate variables found to be significantly correlated with one or both response variables. Community scores are derived from macroinvertebrate samples from high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005. O/E scores >0.9 are classified as unimpaired, 0.75 to 0.9 as slightly impaired, and <0.05 severely impaired. Multimetric scores >39 are classified as unimpaired, 30–39 as slightly impaired, 20–29 as moderately impaired, and <20 as severely impaired.

in the study area. In surveys conducted in the same reaches in 2001, three cottid species (Reticulate sculpin, *Cottus perplexus*; Torrent sculpin, *Cottus rhotheus*; and Prickly sculpin, *Cottus asper*) and two lamprey species were identified (Western Brook lamprey, *Lampetra richardsoni* and Pacific lamprey, *Lampetra tridentate*; Leader 2002).

In the fall, cottids composed the greatest majority of the total catch (46.9%), followed closely by mosquitofish (35.3%), an introduced species. In the spring, cottids represented the majority of the catch (74.9%), while mosquitofish were rarely observed in large numbers (1.0%). Introduced species comprised 38.3% of the total catch in the fall and 2.6% of the total catch on the spring. Similarly, species tolerant of environmental stressors, which are primarily non-native species, composed 36.3% of the total catch in the fall, and 1.9% of the total catch in the spring. These seasonal compositional differences are primarily related to the observed differences in mosquitofish abundance. Salmonids and lamprey were the only sampled species that are classified as sensitive to environmental stressors. Salmonids composed

Table 12. O/E scores and corresponding impairment classes of macroinvertebrate communities sampled from 40 low-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005. Impairment was determined by evaluating O/E scores relative to the mean O/E score of the four reference locations. Sites receiving O/E scores lower than the mean O/E of the four reference sites (0.557) were classified as impaired.

Reach Name	Reach Code	2005 O/E Score (P>0.5)
	REFERENCE	
Dairy Creek (East Fork Ref)	DYM6	0.726513
McKay Creek Ref	MKM4	0.726317
McKay Creek (Middle)	MKM2REF	0.436253
Gales Creek (Middle)	GSM2	0.339823
UNIMPAIRED		
Dairy Creek (Lower E)	DYM3	0.573495
IMPAIRED		
Mckay Creek (Lower)	MKM3	0.468624
Scoggins Creek (Middle)	SCM2	0.439222
Fanno Creek (Lower)	FLM1	0.435102
Dairy Creek (Middle W)	DYM5	0.430678
Rock Creek (Lower)	RLM1	0.390498
Bronson Creek (Middle)	BRM2	0.389971
Chicken Creek (Lower)	CNM3	0.389325
Scoggins Creek (Lower)	SCM3	0.382304
Willow Creek (Lower)	WLM2	0.341605
Cedar Creek (Middle)	CDM2	0.341246
Cedar Mill Creek (Middle)	CMM1	0.341231
Gales Creek (Lower)	GSM3	0.341011
Rock Creek (Milddle)	RMM1	0.339644
Beaverton Creek (Lower)	BCM1	0.293029
Fanno Creek (Middle)	FMM1	0.292265
Johnson Ck. (Middle N)	JNM1	0.29196
Summer Creek (Lower)	SMM2	0.291889
Johnson South (Upper S)	JSM1	0.290876
Johnson Ck. (Middle S)	JSM2	0.290845
Sylvan Creek (Middle)	SVM1	0.290572
Dawson Creek (Lower)	DNM2	0.244521
Dawson Creek (Upper)	DNM1	0.24451
Beaverton Ck. (Upper 1)	BUM1	0.243811
Fanno Creek (Upper 2)	FUM2	0.243742

Table 12. Continued.

Reach Name	Reach Code	2005 O/E Score (P>0.5)
	REFERENCE	
IMPAIRED		
Hedges Creek (Lower)	HDM1	0.24363
Cedar Creek (Upper)	CDM1	0.243586
Johnson Creek (Lower S)	JSM3	0.242354
Saum Creek (Lower)	SAM1	0.242119
Summer Creek (Upper)	SMM1	0.195246
Beaverton Ck. (Upper 2)	BUM2	0.195
Ash Creek (Lower)	ASM2	0.194991
Christensen Ck. (Lower)	CHM2	0.194926
Heaton Creek (Middle)	HTM1	0.194777
McFee Creek (Middle)	MFM2	0.146105
Council Creek (Middle)	CLM1	0.143776

Table 13. Means, ranges, and correlation with O/E scores of selected environmental variables measured in low-gradient stream reaches in the Tualatin River basin, Oregon, fall 2005. Asterisks (*) aside p-values indicate significant correlation at alpha = 0.01.

Variable	Mean	Range	Spearman rho	P value
Urban (%)	39.92	0-80	-0.1315	0.2157
Agriculture (%)	33.84	0-71	0.2453	0.0688
Forest (%)	13.47	2-100	-0.1263	0.225
Effective Imp Area (%)	27.34	0-46	-0.01845	0.4562
Urban, Roads, and Ag (%)	46.46	0-46	0.139	0.2027
Coarse substrate (%)	8.45	17-91	0.01629	0.4603
Sand and fines (%)	66.83	5-60	-0.3499	0.0134
Embeddedness (%)	89.9	2-100	-0.3786	**0.0087***
Riparian Buffer Width (m)	33.18	0 - 100+	-0.03644	0.4117
Riparian tree cover (%)	42.43	0-90	0.2188	0.0966
Nonnative riparian veg (%)	56.24	0-75	-0.01472	0.4676
Water temperature (^{o}C)	15.91	11.3-18.8	0.03711	0.4125
Conductivity (µS/cm)	199.5	57-189	-0.1743	0.1476
Dissolved oxygen mg/L)	6.295	2.7-10.4	0.4192	**0.0049***

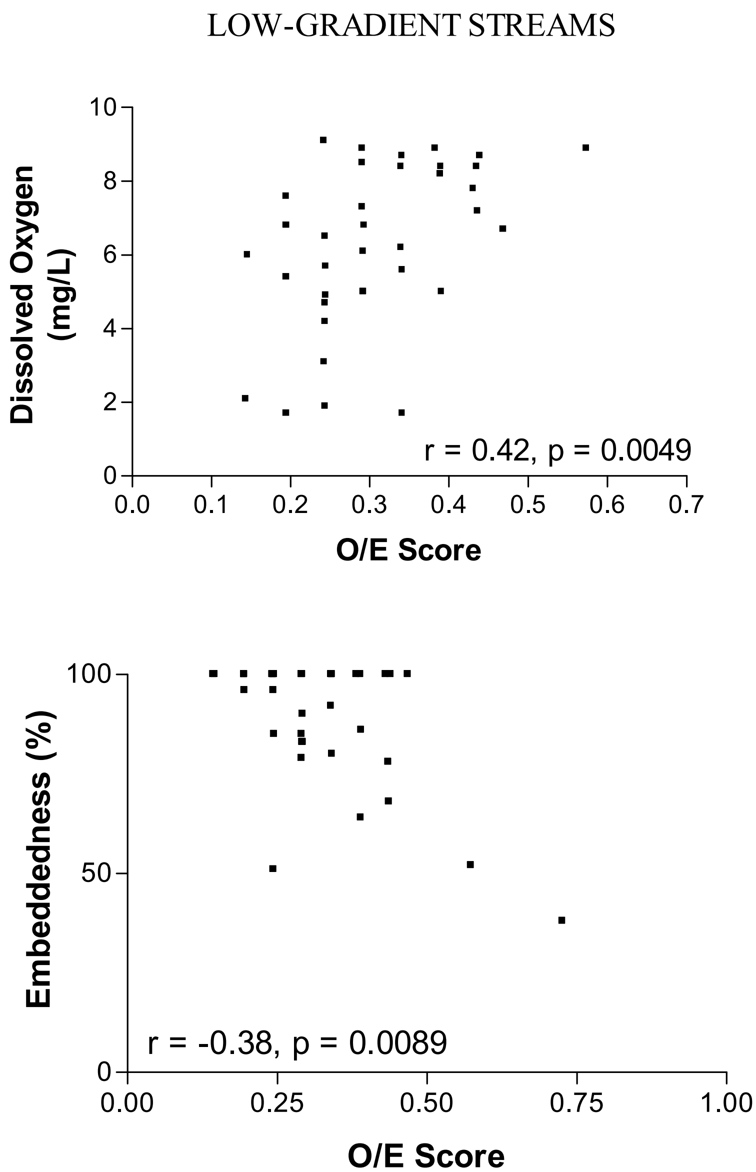

Figure 7. Relationship of macroinvertebrate community O/E scores from low-gradient Tualatin River basin streams with stream substrate variables found to be significantly correlated with O/E scores.

2.4% of the fall total catch and 4.3% of the spring total catch, while lamprey and ammocoetes composed 0.9% of the fall total catch and 2.2% of the spring total catch.

INDEX OF BIOTIC INTEGRITY

A total of 112 IBI scores were generated for the study reaches surveyed during fall 2005 and spring 2006 (Table 15). The highest IBI scores were reported for the upper Tualatin River reach (77 and 76 points for fall and spring respectively; Table 15). The upper Tualatin River reach was the only site to score as acceptable (≥75). The lower Roaring Creek reach (71 points) and the upper Gales Creek reach (68 points) received the third and fourth highest IBI scores, while the lowest IBI score of 12 was reported from middle Hedges Creek (Table 15). Most reaches received

Table 14. Fish species sampled in the fall of 2005 and spring of 2006 with percentage of total catch for each season, including the classifications used to calculate the Index of Biotic Integrity (IBI; Origin: N, native, I: introduced; Habitat: B = benthic, H = hider and W = water column; Relative tolerance: S = sensitive, I = intermediate, T = tolerant; Trophic group: F/S = filterer/specialist, O = omnivore, I = insectivore, T = Top carnivore; classifications from Hughes et al. 1998).

Common name	Origin	Habitat	Relative tolerance	Trophic group	% of total catch 2005	% of total catch 2006
Unidentified lamprey, *Lampetra* spp.	N	BH	S	F/S	0.65	1.43
Ammocoete	N	BH	S	F/S	0.24	0.77
Cuttroat trout, *Oncorhynchus clarkii*	N	WH	S	T	2.06	1.75
Rainbow trout, *Oncorhynchus mykiss*	N	WH	S	T	0.21	0.17
Coho salmon, *Oncorhynchus kisutch*	N	W	S	T	0.11	0.81
Unidentified salmonid, *Oncorhynchus* spp.	N	WH	S	T	0.01	0.04
Salmonid fry, *Oncorhynchus* spp.	N	WH/W	S	T	0.00	1.54
Redside shiner, *Richardsonius balteatus*	N	W	I	I	3.79	2.67
Speckled dace, *Rinichthys osculus*	N	BH	I	I	1.04	2.31
Goldfsh, *Carassius auratus*	I	B	T	O	0.02	0.12
Common carp, *Cyprinus carpio*	I	B	T	O	0.27	0.00
Peamouth, *Mylocheilus caurinus*	N	W	I	I	0.01	0.00
Fathead minnow, *Pimephales promelas*	I	B	T	O	0.02	0.07
Northern pikeminnow, *Ptychocheilus oregonensis*	N	W	I	T	0.01	0.00
Unkown minnow/shiner	I				0.25	1.27
Largescale sucker, *Catostomus macrocheilus*	N	B	I	O	0.35	0.16
Yellow bullhead, *Ameiurus natalis*	I	BH	T	O	0.17	0.16
Brown bullhead, *Ameiurus nebulosus*	I	BH	T	O	0.08	0.16
Channel catfish, *Ictalurus punctatus*	I	BH	T	O	0.02	0.00
Mosquitofish, *Gambusia affinis*	I	WH	T	O	35.33	0.98
Threespine stickleback, *Gasterosteus aculeatus*	N	WH	I	I	6.07	9.62
Bluegill, *Lepomis macrochirus*	I	W	T	I	0.34	0.48
Pumpkinseed, *Lepomis gibbosus*	I	W	I	I	1.78	0.49
Unknown *Lepomis* spp.	I	W		I	0.00	0.01
Warmouth, *Lepomis gulosus*	I	W	T	T	0.01	0.00
Smallmouth bass, *Micropterus dolomieu*	I	W	I	T	0.11	0.00
Largemouth bass, *Micropterus salmoides*	I	W	T	T	0.17	0.12
Yellow perch, *Perca flavescens*	I	W	I	T	0.00	0.01

Table 15. Index of biotic integrity (IBI) scores of fish communities sampled from stream reaches located in the Tualatin River watershed, Oregon, in fall 2005 and spring 2006. Stream reaches were considered acceptable, marginally impacted, or severely impacted when IBI scores were ≥75, 74–51 and ≤50, respectively (Hughes et al. 1998). L = lower reach, M = middle reach, and U = upper reach. NS = no survey, NA = not applicable.

Stream	Reach	Fall	Spring	Reach Mean	Stream Mean
Ash	L	30	34	32	
	M	37	30	33.5	
	U	38	37	37.5	34
Ayers	M	42	41	41.5	
	U	53	46	49.5	46
Baker	M	57	59	58	
	U	35	33	33	46
Beaverton	L	41	NS	NA	
	M	33	28	30.5	34
Bronson	L	32	46	39	
	M	47	48	47.5	43
Burris	M	58	58	58	
	U	40	52	46	52
Butternut	L	27	41	34	
	M	28	35	31.5	
	U	37	38	37.5	34
Cedar	M	31	35	33	
	U	59	53	56	45
Cedar Mills	M	49	35	42	
	U	52	54	53	48
Chicken	L	42	41	41.5	
	M	45	NS	NA	
	U	48	39	43.5	43
Christensen	M	45	37	41	42
	U	40	46	43	
Council	M	19	NS	NA	
	U	32	NS	NA	26
Dairy	M	40	NS	NA	
	U	61	59	60	53

Table 15. Continued.

Stream	Reach	Fall	Spring	Reach Mean	Stream Mean
Dawson	L	32	NS	NA	
	M	30	34	32	
	U	37	32	34.5	33
Fanno	L	19	55	37	
	M	34	58	46	
	U	43	54	48.5	44
Gales	L	38	NS	NA	
	M	52	NS	NA	
	U	61	68	64.5	55
Heaton	M	42	61	51.5	
	U	52	61	56.5	54
Hedges	L	21	29	25	
	M	12	12	12	
	U	44	46	45	27
McFee	M	53	NS	NA	
	U	66	60	63	60
McKay	L	49	NS	NA	
	M	54	NS	NA	
	U	35	52	43.5	48
North Rock	L	36	NS	NA	
	M	34	38	36	
	U	29	53	41	38
Roaring	L	71	66	68.5	
	M	43	50	46.5	58
South Johnson	M	20	22	21	
	U	23	35	29	25
South Rock	M	45	36	40.5	
	U	25	32	28.5	35
Summer	L	30	36	33	
	M	16	20	18	
	U	15	17	16	22
Tualatin	M	62	NS	NA	
	U	77	76	76.5	72
West Dairy	M	50	NS	NA	
	U	53	66	59.5	56

IBI scores ≤50 and resulting severely impaired classifications. Approximately 30% of reaches received IBI scores from 51 to 74 points and resulting marginally impaired designations. Changes in IBI scores from fall to spring were generally modest. Overall, spring IBI scores appear slightly higher than fall scores (Table 15). In general, upper reaches scored slightly higher than lower reaches, but no strong trend was evident.

Approximately 50% of the 2005 IBI scores were similar to 2001 IBI scores, with a difference ≤10 points between years. The smallest change in IBI scores across the two studies occurred in the middle Bronson Creek reach, which had decreased fall and spring IBI scores of 0.4 and 1.0, respectively, relative to 2001 study results (Table 16). The largest increases in fall IBI scores generally occurred in streams outside of the urban growth boundary, including middle and upper McFee Creek, middle Gales Creek, and lower Roaring Creek (Table 16), whereas the largest deceases in fall IBI scores from 2001 to 2005 generally occurred in reaches within the UGB, including lower and middle Summer Creek, lower Fanno Creek, and middle Hedges Creek (Table 16).

ENVIRONMENTAL CORRELATIONS

Statistically significant correlations occurred between fish community IBI scores and five measured environmental variables (Table 17). Fall IBI scores were found to be positively correlated with the percentage of the reach occupied by riffle habitat (p = 0.0006; Figure 8) and morning dissolved oxygen concentrations ($p < 0.0001$; Figure 9). Conversely, fall IBI scores were negatively correlated with percent sand and fines (p = 0.0137: Figure 10), afternoon water temperature ($p < 0.0001$; Figure 8), and conductivity ($p < 0.0001$; Figure 9).

DISCUSSION

The wide variation in biological conditions in Tualatin River basin streams, as indicated by both fish and macroinvertebrate communities, is related to natural variation in morphologic and hydrologic stream conditions as well as by degraded habitat and water quality and altered hydrology resulting from human activities. Results of correlation analyses between measured environmental variables and macroinvertebrate communities showed the strongest correlations occurred with variables that either directly reflect the degree of human alteration of the adjacent landscape (e.g., land use, EIA, and riparian zone conditions) and those that are heavily influenced by anthropogenic activities (e.g., water temperature, dissolved oxygen, substrate composition). Because many of these factors are correlated among themselves and likely with others not measured in this study, assigning causes of biological impairment to particular variables is beyond the design and scope of this study. These results are remarkably similar to those reported in the 2001 Tualatin River basin macroinvertebrate assessment (Cole 2002). Although only correlative, these consistent results provide compelling evidence that rural and urban development of the Tualatin River basin has had a measurable effect on physical habitat and water quality in basin streams, which in turn, have measurably impaired biological integrity.

One aspect of disturbance not measured directly in this study, yet known to significantly affect both the form and function of streams, is hydrologic modification by urban and agricultural land uses. Urban development, in particular, significantly alters stream hydrology. Physical data from Seattle-area watersheds indicate that effective impervious areas (EIA) of less than 10% can cause significant habitat degradation to sensitive waterbodies as a result of altered hydrology (Booth and Jackson 1997). Undoubtedly, development of the basin has altered the natural hydrologic regime of the watershed, likely reducing baseflows and increasing peak flows, which has contributed to degradation stream habitat and water quality.

This study used recently developed predictive models to examine macroinvertebrate community conditions in Tualatin basin streams for the first time. The results were similar to those obtained from the previously used multimetric approach. Despite general agreement in the overall scoring and impairment classification distribution, the two approaches produced several disparate results. Conceptually, the RIVPACS model works best when changes to the macroinvertebrate community are largely related to loss or replacement of taxa because the model does not assess the relative abundance of different taxa. Therefore, if community changes occur only in the relative

Table 16. Index of biotic integrity scores and comparisons between ODFW 1999–2001 surveys and ABR 2005–2006 surveys for stream reaches located in the Tualatin River watershed. Stream reaches were considered acceptable, marginally impacted, or severely impacted when IBI scores were ≥75, 74–51 and ≤50, respectively (Hughes et al. 1998). UGB = urban growth boundary, NS = no survey, NA = not applicable. Positive 'difference' scores reflect an increase in IBI scores for 2005–2006 compared to 1999–2001 data. Negative 'difference' scores reflect a decrease in IBI scores for 2005–2005 compared to 1999–2001 data.

Stream	Reach	Inside UGB	Outside UGB	Fall 1999	Fall 2005	Difference	Spring 2000	Spring 2006	Difference
Ash	Lower	1		25.2	30	4.8	29.2	34	4.8
Ash	Middle	1		32.2	37	4.8	32.2	30	-2.2
Ash	Upper	1		43.9	38	-5.9	43.9	37	-6.9
Ayers	Middle		1	37.7	42	4.3	48.7	41	-7.7
Ayers	Upper		1	51.8	53	1.2	49.8	46	-3.8
Baker	Middle		1	34.9	57	22.1	36.6	59	22.4
Baker	Upper		1	31.5	35	3.5	31.5	33	1.5
Beaverton	Lower	1		30.7	41	10.3	28.3	NS	NA
Beaverton	Middle	1		38.3	33	-5.3	47	28	-19
Bronson	Lower	1		37.1	32	-5.1	45.2	46	0.8
Bronson	Middle	1		47.4	47	-0.4	49	48	-1
Burris	Middle		1	54.1	58	3.9	39.8	58	18.2
Burris	Upper		1	28.1	40	11.9	28.1	52	23.9
Butternut	Lower	1		37.7	27	-10.7	44.2	41	-3.2
Butternut	Middle	1		34.9	28	-6.9	34.6	35	0.4
Butternut	Upper	1		35.6	37	1.4	29	38	9
Cedar	Middle	1		47.4	31	-16.4	21.7	35	13.3
Cedar	Upper	1		31.4	59	27.6	42.5	53	10.5
Cedar Mill	Middle	1		28.9	49	20.1	46.1	35	-11.1
Cedar Mill	Upper	1		33.9	52	18.1	32.3	54	21.7
Chicken	Lower	1		34.9	42	7.1	34	41	7
Chicken	Middle	1		50.1	45	-5.1	59.9	NS	NA
Chicken	Upper	1		51.8	48	-3.8	44.8	39	-5.8
Christensen	Middle		1	31.3	45	13.7	48.2	37	-11.2
Christensen	Upper		1	41.9	40	-1.9	0	46	46
Council	Middle	1		29.8	19	-10.8	23.8	NS	NA
Council	Upper	1		35.6	32	-3.6	39.7	NS	NA
Dairy	Middle	1		28.1	40	11.9	40.3	NS	NA
Dairy	Upper	1		50.4	61	10.6	58.3	59	0.7
Dawson	Lower	1		38.1	32	-6.1	38.1	NS	NA
Dawson	Middle	1		47.6	30	-17.6	45.7	34	-11.7
Dawson	Upper	1		29	37	8	53.9	32	-21.9

Table 16. Continued.

Stream	Reach	Inside UGB	Outside UGB	Fall 1999	Fall 2005	Difference	Spring 2000	Spring 2006	Difference
Fanno	Lower	1		30.7	19	-11.7	51.7	55	3.3
Fanno	Middle	1		37	34	-3	49.2	58	8.8
Fanno	Upper	1		40.6	43	2.4	50.2	54	3.8
Gales	Lower		1	NS	38	NA	42.8	NS	NA
Gales	Middle		1	37.8	52	14.2	52.7	NS	NA
Gales	Upper		1	53.3	61	7.7	37.9	68	30.1
Heaton	Middle		1	36.6	42	5.4	43.3	61	17.7
Heaton	Upper		1	43.4	52	8.6	45.8	61	15.2
Hedges	Lower	1		23.8	21	-2.8	34.4	29	-5.4
Hedges	Middle	1		23.8	12	-11.8	20.7	12	-8.7
Hedges	Upper	1		31.5	44	12.5	40.9	46	5.1
McFee	Middle		1	28.1	53	24.9	50.9	NS	NA
McFee	Upper		1	45.6	66	20.4	51.1	60	8.9
McKay	Lower		1	27.1	49	21.9	45.5	NS	NA
McKay	Middle		1	NS	54	NA	44.8	NS	NA
McKay	Upper		1	32.6	35	2.4	47.7	52	4.3
N. Rock	Lower	1		46.6	36	-10.6	38.5	NS	NA
N. Rock	Middle	1		NS	34	NA	41.4	38	-3.4
N. Rock	Upper	1		45.1	29	-16.1	36.7	53	16.3
Roaring	Lower		1	48.8	71	22.2	51.5	66	14.5
Roaring	Middle		1	30.8	43	12.2	36.6	50	13.4
S. Rock	Middle	1		35.9	45	9.1	48.7	36	-12.7
S. Rock	Upper	1		27.9	25	-2.9	20.7	32	11.3
S. Johnson	Middle	1		29.8	20	-9.8	21.1	22	0.9
S. Johnson	Upper	1		NS	23	NA	NS	35	NA
Summer	Lower	1		41.6	30	-11.6	40.2	36	-4.2
Summer	Middle	1		28	16	-12	15.6	20	4.4
Summer	Upper	1		20.5	15	-5.5	8.3	17	8.7
Tualatin R.	Middle		1	NS	62	NA	34.5	NS	NA
Tualatin R.	Upper		1	NS	77	NA	NS	76	NA
W. Dairy	Middle		1	NS	50	NA	53.4	NS	NA
W. Dairy	Upper		1	45.6	53	7.4	46.6	66	19.4

Table 17. Results of correlation analysis comparing fall index of biotic integrity (IBI) scores to instream characteristics, riparian canopy cover and condition, and water chemistry parameters measured on all stream reaches in the fall 2005.

Variable	Mean	Range	Fall IBI Scores	
			Spearman's rho	*P* value
Pools (%)	50.16	0-100	-0.26	0.0192
Glides (%)	28.16	0-100	-0.01	0.4781
Riffles (% of reach)	21.44	0-100	0.39	0.0006
Rapids (% of reach)	1.141	0-23	0.07	0.2968
Coarse substrate (%)	28.11	0-91	0.24	0.0272
Sand and fines (%)	53.61	0-100	-0.28	0.0137
Embeddedness (%)	70.77	13-100	-0.27	0.0155
Riparian Buffer Width (m)	33.64	0-100	0.10	0.2114
Riparian tree cover (%)	44.08	0-90	0.15	0.1196
Nonnative riparian veg (%)	50.44	0-95	-0.24	0.0418
Afternoon water temperature (^{o}C)	15.94	10.6-29.0	-0.65	P<0.0001
Conductivity (µS/cm)	190.1	56-804	-0.60	P<0.0001
Morning dissolved oxygen (mg/L)	6.838	1.7-10.85	0.53	P<0.0001

abundance of organisms without the loss of more sensitive taxa, then the model may under classify a site with respect to impairment. The multimetric model, which includes measures of the relative abundance of taxa of different ecological attributes, is more likely to discern among sites when the primary differences are those related to relative abundance.

Such community changes appear to have occurred in upper Bronson Creek (BRM1), upper Ayers Creek (AYM1), and lower Tanner Creek (TNM1), where taxa-richness measures suggest that conditions are minimally impaired, yet the high numbers of the disturbance-tolerant snail, *Juga*, produced low relative-abundance-related metric scores, including percent dominance by a single taxon, percent tolerant organisms, and Hilsenhoff Biotic Index scores, thereby resulting in low multimetric scores. In contrast, the O/E scores for these sites, based exclusively on the presence of taxa (not their relative abundance), were relatively high. It thus appears that the use of both tools may help identify community changes not detected with the use of only one. The Oregon DEQ is currently developing models that examine the condition of macroinvertebrate communities based on the relative abundance of taxa that differ in their sensitivity to particular environmental stressors—namely temperature and sediment—two variables that were correlated with macroinvertebrate conditions in this study. These models should prove useful as supporting tools used to augment the results of RIVPACS analyses and help identify causation in impairment to benthic communities (Dave Huff, OR DEQ, personal communication).

The close correspondence between 2001 and 2005 multimetric scores from high-gradient reaches suggests that overall benthic conditions in the basin have not markedly improved or declined over the four intervening years. It is also important to note that the average multimetric score of all sites does not represent the average condition throughout the basin because this study design did not use a randomized sampling design to select sites. Instead, sites were selected, in part, to

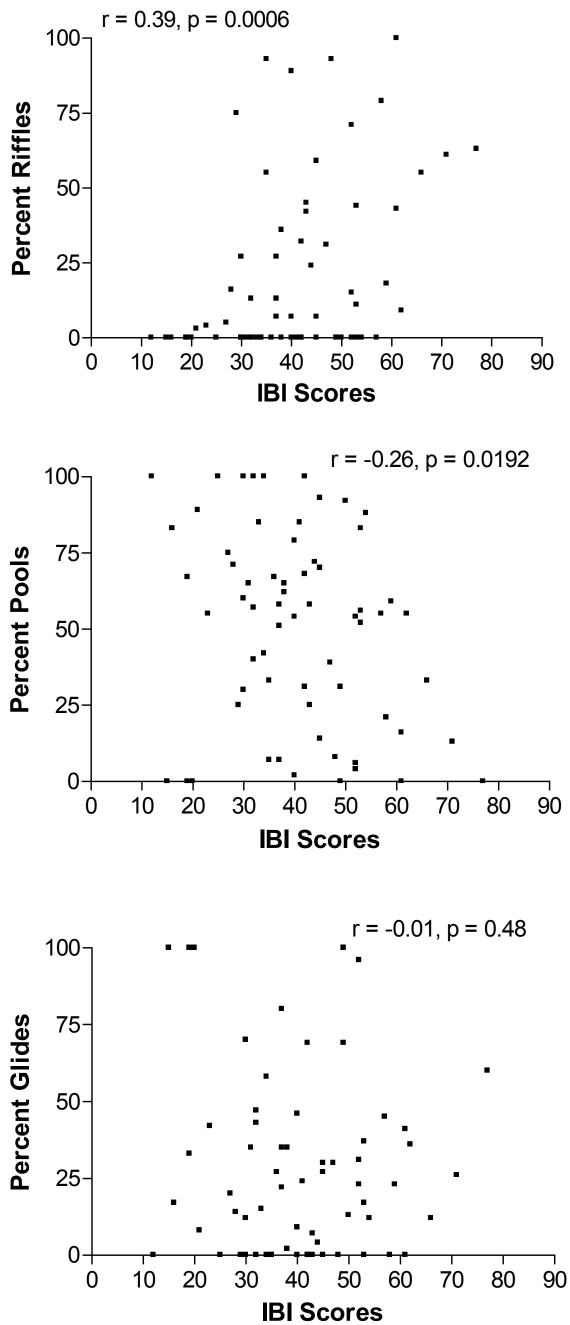

Figure 8. Relationships between fall 2005 IBI scores and selected instream habitat conditions measured during surveys of streams fish communities in the Tualatin River basin in fall 2005. IBI scores >75 were classified as acceptable, 51–75 as marginally impaired, and <50 as impaired.

represent a range of land use conditions across the basin, with a relatively even distribution of sites across land-use type and intensity. Sites were also sampled based on securing permission to access sites through private property and proximity to road crossings.

Several high-gradient reaches, including upper and middle Gales Creek, upper McKay Creek, and upper Dairy Creek scored considerably higher in 2005 than in 2001. Conversely, upper Christensen and upper Bronson creeks scored 10 points lower in 2005 than in 2001. We suggest that biological conditions in these reaches that declined substantially be assessed more frequently than every six years, as proposed in the draft Watershed Monitoring Plan (CWS 2006). Perhaps these sites could be sampled every two years along with the others already identified for more frequent monitoring in the draft Plan to identify with more confidence reaches that are declining or improving in biological condition.

RIVPACS results from this study suggested that low-gradient reaches throughout the Tualatin River basin are biologically impaired. Only one reach not used as a reference, the lower East Fork of Dairy Creek (DYM3), scored in the unimpaired O/E range. All thirty five low-gradient reaches scored as impaired. Macroinvertebrate community conditions in low-gradient reaches did not vary as much as they did among high-gradient reaches. Low-gradient reaches generally supported fewer taxa, fewer sensitive taxa, far fewer EPT taxa, and larger numbers of tolerant organisms. Although correlations between low-gradient O/E scores and environmental variables were generally not significant, dissolved oxygen concentrations were highly correlated with O/E scores. Although only correlative, these data suggest that benthic communities may be severely impaired by low dissolved oxygen concentrations occurring in some streams within the basin.

Although magnified by human development of the basin, macroinvertebrate community structure has always differed between valley floor streams and higher-gradient streams occurring in areas with more topographic relief, such as along the lower slopes of the Coast Range, Chehalem, and Tualatin mountain ranges. Naturally occurring differences in stream gradient, hydrology, streambed substrate, stream habitat types, and resulting stream microhabitat characteristics have undoubtedly produced different biological community types.

The Tualatin Valley floor, as is much of the northern Willamette Valley floor, is covered by sediment deposited by the Missoula floods. Missoula flood deposits consisting of clayey and very-fine sandy silts cover the Tualatin Valley floor to a average depth of 24 meters (Wilson 1998). These deposits occur at elevations of up to 75 meters above sea level, suggesting that streams at higher elevations within the watershed would not be cut through these same deposits, although other deposits from earlier periods are known to occur at higher elevations in other portions of the watershed, such as the Portland Hills (Wilson 19998). Moreover, the Tualatin River and its tributaries have maintained a low-gradient profile since the last flood materials were deposited almost 13,000 years ago because a shallow formation of Columbia River basalt creates a knickpoint at the lower end of the river near its confluence with the Willamette River, thereby preventing the river from headcutting and steepening beyond this point (Wilson 1998). This maintenance of a low-gradient profile through most of the length of a major Willamette River tributary is unique to the Tualatin River and has resulted in valley floor streams with physical templates very different from those of higher-elevation streams along the periphery of the valley.

These naturally occurring differences coupled with heavy human development of the Tualatin Valley floor create significant problems for identifying suitable valley floor reference reaches as the lack of low-gradient reference sites within the basin precludes characterization of unimpaired biological conditions using local field conditions. These lowland areas are almost entirely developed with agricultural or residential land use and as such, we do not currently know the expected community composition in undisturbed low-gradient streams, but we can nonetheless be confident that it would be inappropriate to apply unmodified assessment tools developed from high-gradient streams data to low-gradient reaches to assess biological impairment.

Prior to this year, the western Oregon multimetric index was the only assessment tool available for western Oregon streams. Developed

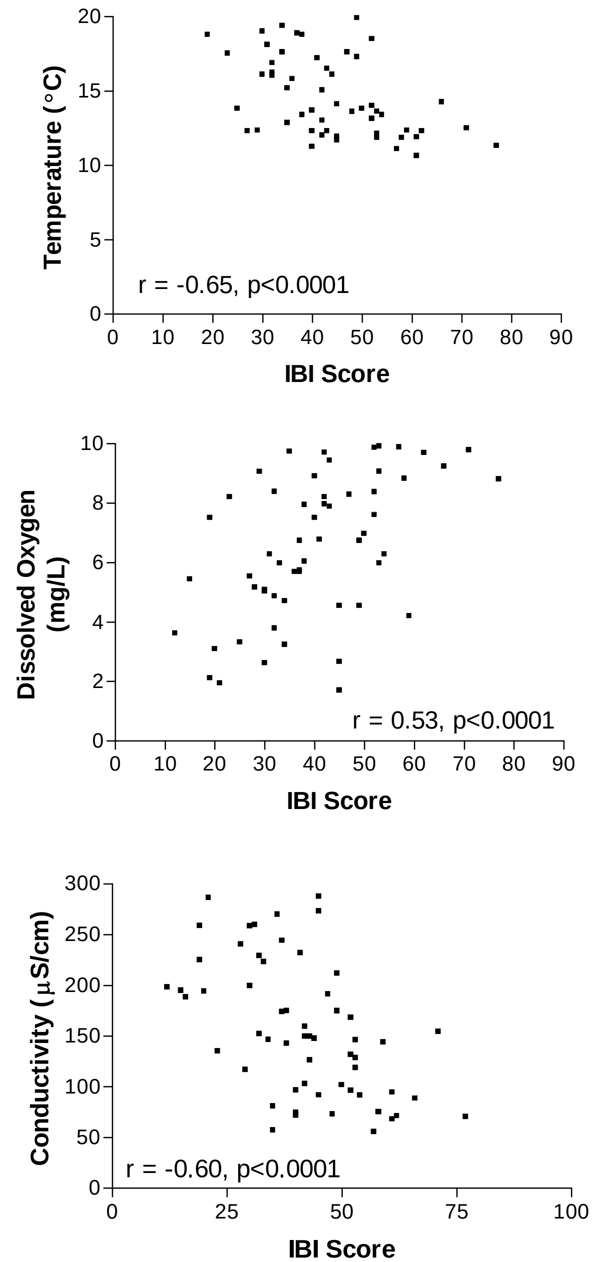

Figure 9. Relationships between fall 2005 IBI scores and water quality measured during surveys of streams fish communities in the Tualatin River basin in fall 2005. IBI scores >75 were classified as acceptable, 51–75 as marginally impaired, and <50 as impaired.

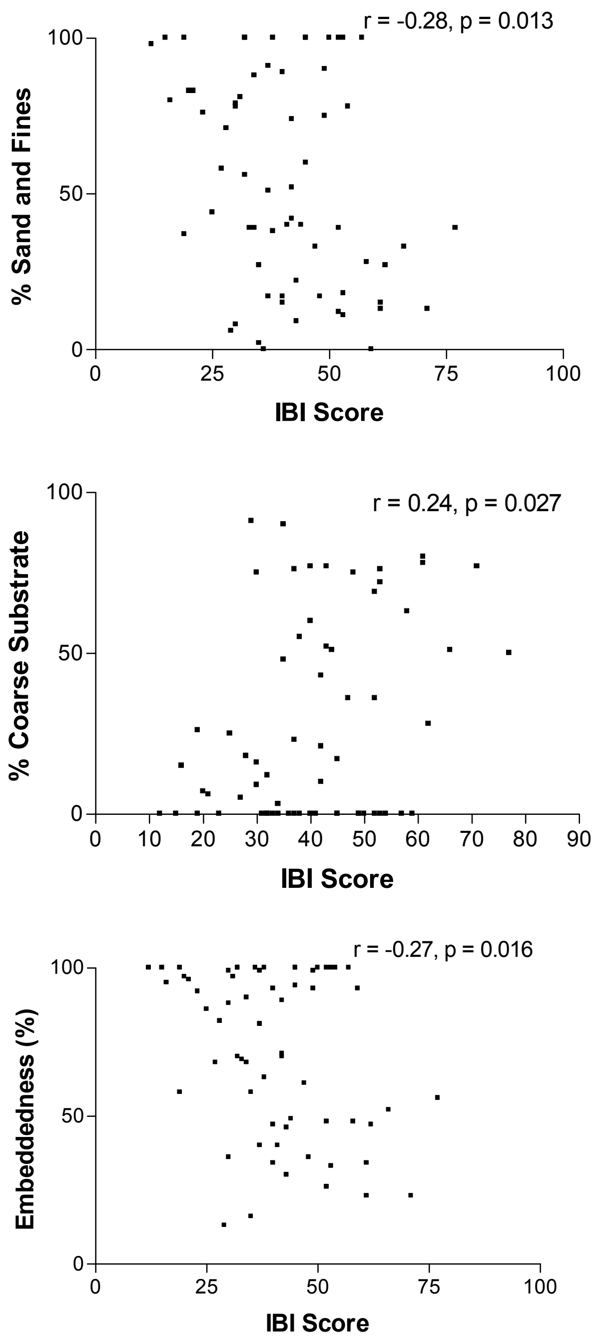

Figure 10. Relationships between fall 2005 IBI scores and stream substrate conditions measured during surveys of streams fish communities in the Tualatin River basin in fall 2005. IBI scores >75 were classified as acceptable, 51–75 as marginally impaired, and <50 as impaired.

using data only from high-gradient streams, the index was unsuitable for assigning impairment classes to benthic communities in low-gradient streams and therefore was modified for use with low-gradient streams data in 2001 (Cole 2002). Using this approach, the data were first summarized according to a number of community attributes (metrics) that (1) were known to be responsive to disturbance and (2) varied among low-gradient samples. Each site's metric values were then ranked relative to those received by all other low-gradient sites and then the ranks were averaged to produce an average rank (Cole 2002). The numerous shortcomings to this approach included the limitation that any impairment determination was precluded by the lack of least-disturbed low-gradient reference conditions. Furthermore, the final "scores" (rankings) could not be compared to any data other than those ranked. Therefore, the 2001 results can not be compared to results obtained in other years or studies without re-ranking all sites in relation to each other.

In contrast, the use of the RIVPACS model with 2005 data from low-gradient stream reaches allowed biological impairment to be coarsely classified in this study. The use of O/E scores from four "least impaired" low-gradient sites as the threshold for impairment provided an interim approach for broadly evaluating impairment in low-gradient streams. Although the RIVPACS model allowed sites to be scored rather than ranked, the model still requires calibration and testing to improve precision of impairment classifications of low-gradient reaches. As explained earlier, the MWCF RIVPACS model used in this study was developed using data primarily from higher-gradient streams. The model includes data from only a "handful" of low-gradient (<2%) reference streams from the foothills of the Willamette Valley rather than on the valley floor (Shannon Hubler, Oregon DEQ, personal communication).

As a short-term solution to the persistent problem with low-gradient reference conditions, the best attainable low-gradient-reach conditions were sought by field reconnaissance of the watershed. Four such reaches were identified and the average O/E score of these sites was used as a benchmark against which O/E scores from other sites were evaluated to determine whether impairment occurs. Despite thorough reconnaissance and familiarity of the basin by project staff, these four reference reaches neither represented undisturbed conditions, nor do they entirely represent the same geomorphic characteristics of most valley floor streams. This paucity of reference reaches in the Tualatin River basin emphasizes the need to seek additional and more appropriate reference locations outside of the basin. Such additional sites should be sought and included in future efforts to develop bioassessment tools for Tualatin valley streams. We anticipate that as more suitable reference reaches are identified, if even from elsewhere in the Willamette Valley, some of those reference reaches used for this study will be deemed less appropriate and no longer used. As such, this year's impairment classifications of low-gradient streams should be considered tentative until reference conditions are better characterized.

Conceptually, the approach of identifying less-than-unimpaired least-impaired conditions as a benchmark is similar to EPA's new Tiered Aquatic Life Use approach for bioassessment that is currently in development (USEPA 2005). This new approach explicitly recognizes that many geographic locales with surface waters assessed for biological integrity no longer support unimpaired reference conditions. As such, the tiered approach allows for evaluation of biological conditions with respect to "tiered down" reference conditions (Rick Hafele, ORDEQ, personal communication). In other words, regional waterbodies representing best attainable conditions, even if impaired themselves, are used as a benchmark for examining the relative condition of other waterbodies in the same region. This approach provides for the development of more precise aquatic life-use designations for waterbodies that have been extensively altered (USEPA 2005), such as many Tualatin River basin valley floor streams. Although still under development, this approach will likely be used in the future by DEQ to more precisely evaluate biological integrity throughout the Willamette Valley.

Although an improvement over the ranking of low-gradient macroinvertebrate communities in 2001, the precision of the RIVPACS model for use with low-gradient data could be improved if the model were calibrated with additional data that included those that represented "best-attainable" low-gradient conditions in the Willamette Valley floor. In its current form, we are unsure of the potential bias in expected taxa predictions for low-gradient streams generated by the MWCF RIVPACS model. A single model could be developed that is inclusive of both high and low-gradient stream types and predictor variables that include stream gradient to more precisely predict expected taxa. Such a model would improve our confidence in estimates of expected taxa predictions in low-gradient valley floor streams.

A model that included reference conditions represented by a wider range of stream types would also overcome the dilemma of coarsely and arbitrarily segregating streams according to continuous variables such as stream gradient and then developing separate assessment tools for each stream "type" (as is currently the case with respect to "high" and "low-gradient" stream types). A predictive model that weights the probability of occurrence of each taxon by the *probability* that a site belongs to each class of streams avoids the dilemma of having to assign each site to only one stream type (high or low gradient, for example), when, in fact, the site may have physical and biological characteristics intermediate of the types. This is one of the major strengths of predictive modeling and one reason why it stands to offer much to bioassessment efforts in the Tualatin Valley and elsewhere in the Willamette River basin.

However, the long-standing task of characterizing reference conditions in the Tualatin River valley must be surmounted to achieve the goal of developing this comprehensive model. If adequate data exist from what regional experts in aquatic ecology deem to be valley floor reference sites, a discriminant functions model that includes data from these reference sites could be constructed. In the absence of an adequate number of reference sites, the idea of "developing hypothetical low-gradient reference sites from regional and literature information" has been proposed (Ian Waite, USGS, personal communication) and would warrant discussion if adequate low-gradient reference reaches can not be identified. Ultimately, one of these two approaches for identifying reference conditions for Tualatin Valley streams should provide the data needed to develop a single comprehensive tool for more precisely assessing macroinvertebrate communities for impairment throughout the basin, irrespective of stream type.

Fish assemblages of the Tualatin River basin have changed little since previous surveys in 1999–2001. Sculpin remain the most abundant and widely distributed species within the Tualatin River Basin, as observed in a similar study conducted in the fall of 1999 and the spring of 2000 (Leader 2002). Sculpins were observed in 90.6% and 92.2% of the reaches sampled in the fall and spring respectively, and were observed in at least one reach of every sampled stream. Although sculpin were not identified to species in this study, it is likely that reticulate sculpin (*Cottus perplxus*) were the most commonly observed species, similar to previous studies. Reticulate sculpin are known to be of intermediate tolerance to environmental stress such as warm temperatures, thereby allowing them to persist across a range of disturbance conditions.

All of the reaches where salmonids were present in the fall also contained salmonids in the spring, with the exception of the middle Bronson Creek reach. Additionally, cutthroat trout were present in the upper reach of North Rock Creek in the spring but were not observed in the fall. The majority of the coho observed in this study were collected in Roaring Creek (not sampled in 1999/2000). In the lower Roaring Creek reach, coho fry accounted for 21% of the total catch, while accounting for 2% of the total catch in the Roaring Creek middle reach. Additionally, salmonid fry accounted for another 8.7% of the total catch in the lower Roaring Creek reach and 21.1% of the catch in the middle Roaring Creek reach, highlighting the importance of this stream as nursery and rearing habitat for juvenile salmonids. This is further evidenced by one of the highest average IBI scores when averaged among both Roaring Creek reaches and seasons. Creeks with similarly high average IBI scores include the west fork of Dairy Creek, McFee Creek, and the Tualatin River, all located outside of the urban growth boundary (UGB).

In general, streams outside of the UGB had higher IBI scores relative to those within the UGB. Furthermore, only a small percentage of the reaches where a decrease in the IBI was noted between 1999–2000 and 2005–2006 were located within the UGB (4% in the fall and 18% in the spring). Streams outside of the UGB tended to have higher dissolved oxygen concentrations and lower afternoon water temperatures which are necessary to support sensitive species such as salmonids. In fact, these water chemistry parameters strongly correlated with IBI scores. Other instream habitat features such as the percentage of various habitat units (pools, glides, riffles, and rapids), as well as sediment composition were also correlated with IBI scores. Following the recommendations of Leader (2002), we again recommended that stream reaches with the highest IBI scores receive the highest priority when planning conservation projects, while stream reaches with low IBI scores should receive priority for enhancement and restoration activities.

Collectively, our results suggest that biological conditions largely remain the same as those measured between 1999 and 2001, with exceptions as noted in this report. As these periodic monitoring efforts continue into the future, longer-term data sets should reveal trends in these conditions in relation to land use changes, water resource management programs, and restoration activities occurring in the Tualatin River basin.

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Appendix 1. Environmental variables measured from 63 stream reaches sampled for macroinvertebrate community conditions in the Tualatin River basin, Oregon, fall 2005. Coding is as follows: Valley Type: 1 = V shape, 2 = U shape, 3 = ponded, 4 = floodplain; Large Wood Tally: 1–5, 1 = provides no instream cover, 5 = provides abundant instream cover; Adjacent land use: 1 = residential, 2 = industrial/commercial, 3 = agricultural, 4 = undeveloped/forested. Embeddedness estimates were made from both pebble count data (these represent emdeddedness only of habitat types from which pebble counts were performed), denoted in the appendix by two asterisks (**), and from visual estimates of reach-wide embeddedness across all habitat types, denoted by one asterisk (*).

Site Code	Forest %	Agriculture %	Urban %	Roads %	EIA (%)	Valley Type	Wetted Width (m)	Embeddedness* (%)	Eroding Banks (%)	Undercut banks (%)	Large Wood Rating	Canopy Cover (%)	Percent Riffles	Percent Glides	Percent Pools	Large Wood Tally
ASM1	3%	2%	80%	16%	43	4	0.99	73	49	5	1.0	61	36%	2%	62%	0.00
ASM2	3%	7%	66%	24%	51	4	2.60	100	90	13	1.9	64	0%	63%	37%	0.08
AYM1	37%	62%	0%	2%	0	1	1.85	67	62	30	1.0	94	49%	0%	51%	0.05
BCM1	6%	17%	65%	12%	31	4	8.25	83	98	57	2.5	68	0%	24%	76%	0.15
BIM1	50%	50%	0%	0%	0	2	1.46	2	16	16	1.3	97	20%	0%	0%	0.09
BKM1	46%	54%	0%	0%	3	2	1.58	28	32	23	1.0	100	93%	0%	7%	0.08
BRM1	48%	34%	14%	4%	16	1	1.50	54	39	23	1.0	74	53%	12%	35%	0.02
BRM2	3%	16%	60%	21%	40	4	2.29	64	46	69	1.0	62	13%	47%	40%	0.02
BUM1	22%	2%	64%	12%	39	4	6.44	51	60	0	2.8	42	3%	62%	35%	0.25
BUM2	35%	11%	42%	12%	39	3	6.25	100	73	8	2.0	80	0%	55%	45%	0.12
CDM1	21%	63%	0%	16%	5	1	1.46	96	62	13	1.5	97	18%	23%	59%	0.23
CDM2	23%	35%	31%	11%	20	4	2.40	100	48	1	1.1	65	0%	35%	65%	0.03
CHM1	34%	64%	0%	2%	0	1	0.81	65	45	30	1.7	100	89%	9%	2%	0.05
CHM2	27%	68%	0%	5%	0	1	3.85	100	38	17	1.1	97	7%	0%	93%	0.06
CLM1	6%	46%	43%	5%	14	4	8.65	100	100	0	1.0	0	0%	100%	0%	0.06
CMM1	4%	11%	62%	22%	52	4	4.37	100	7	0	1.0	22	0%	44%	56%	0.00
CMM2	18%	5%	65%	11%	32	1	3.19	16	55	6	1.3	93	71%	23%	6%	0.05

Appendix 1. Continued.

Site Code	Forest %	Agriculture %	Urban %	Roads %	EIA (%)	Valley Type	Wetted Width (m)	Embeddedness* (%)	Eroding Banks (%)	Undercut banks (%)	Large Wood Rating	Canopy Cover (%)	Percent Riffles	Percent Glides	Percent Pools	Large Wood Tally
CNM1	30%	70%	0%	0%	3	2	1.48	38	34	11	2.0	95	93%	0%	8%	0.21
CNM2	19%	71%	6%	4%	6	4	2.00	100	70	20	1.0	90	59%	27%	14%	0.08
CNM3	11%	76%	7%	6%	6	4	3.19	100	76	34	1.6	95	0%	69%	31%	0.39
DNM1	1%	27%	66%	6%	50	4	1.39	85	55	1	1.2	62	7%	35%	58%	0.11
DNM2	10%	24%	55%	12%	33	4	4.68	100	53	3	2.6	52	0%	43%	57%	0.18
DYM1	100%	0%	0%	0%	0	2	8.30	25	13	9	1.2	88	43%	41%	16%	0.07
DYM2	62%	35%	0%	3%	0	4	7.58	39	37	12	1.0	98	31%	24%	45%	0.00
DYM3	1%	94%	0%	5%	2	4	6.10	52	85	3	2.0	81	0%	46%	54%	0.18
DYM4	86%	5%	0%	9%	0	1	1.84	39	27	21	1.6	97	11%	37%	52%	0.10
DYM5	2%	89%	0%	9%	1	4	5.90	100	49	0	1.0	70	0%	44%	56%	0.01
DYM6	--	--	--	--	--	4	1.73	16	8	2	0.7	91	49%	25%	26%	0.11
FLM1	9%	8%	67%	16%	52	1	6.24	78	74	13	1.7	67	0%	33%	67%	0.11
FMM1	1%	14%	66%	18%	51	1	3.00	90	90	10	1.0	26	0%	100%	0%	0.00
FUM1	5%	4%	63%	28%	46	1	2.16	77	57	31	1.3	97	42%	0%	58%	0.00
FUM2	3%	9%	73%	15%	44	2	3.35	100	89	21	1.7	99	0%	58%	42%	0.24
GLM1	26%	6%	56%	12%	34	2	2.27	36	14	1	1.0	99	95%	0%	5%	0.17
GSM1	95%	0%	0%	4%	0	2	4.86	23	20	5	2.7	85	73%	0%	6%	0.19
GSM2	26%	71%	0%	3%	0	3	15.20	92	47	20	2.8	1	15%	31%	54%	0.20
GSM3	5%	75%	12%	9%	18	1	9.00	100	30	0	2.3	72	0%	57%	43%	0.17
HDM1	6%	18%	61%	13%	46	4	2.31	100	42	6	1.3	83	3%	8%	89%	0.13
HTM1	22%	74%	0%	3%	0	1	3.60	100	85	71	2.9	79	0%	96%	4%	0.24
JNM1	18%	12%	52%	18%	33	1	2.19	100	72	17	1.7	83	0%	38%	62%	0.16
JSM1	14%	13%	61%	13%	30	4	4.67	85	17	2	1.2	74	0%	57%	43%	0.39
JSM2	7%	3%	59%	21%	43	4	4.33	79	69	12	1.0	27	0%	93%	7%	0.13
JSM3	2%	5%	75%	18%	43	4	3.23	100	0	0	1.0	1	0%	100%	0%	0.00

Appendix 1. Continued.

Site Code	Forest %	Agriculture %	Urban %	Roads %	EIA (%)	Valley Type	Wetted Width (m)	Embeddedness* (%)	Eroding Banks (%)	Undercut banks (%)	Large Wood Rating	Canopy Cover (%)	Percent Riffles	Percent Glides	Percent Pools	Large Wood Tally
MKM4	--	--	--	--	--	4	9.73	41	13	10	1.0	75	15%	57%	28%	0.08
MFM1	70%	30%	0%	0%	0	1	1.88	36	34	13	1.0	97	89%	0%	11%	0.02
MFM2	25%	72%	0%	4%	0	4	7.00	100	37	3	1.5	80	0%	17%	83%	0.08
MKM1	69%	31%	0%	0%	3	4	3.20	47	--	16	0.8	69	28%	31%	41%	0.00
MKM2REF	17%	81%	0%	2%	0	4	6.90	68	56	3	3.0	89	0%	32%	68%	0.17
MKM3	11%	59%	21%	8%	24	1	6.40	100	85	0	1.7	86	0%	69%	31%	0.29
RGM1	100%	0%	0%	0%	0	4	3.28	49	38	15	1.0	96	45%	7%	25%	0.26
RLM1	10%	15%	64%	11%	51	4	6.68	86	100	0	3.9	62	0%	27%	67%	0.20
RMM1	6%	24%	58%	13%	44	4	4.99	100	67	19	1.1	78	0%	47%	53%	0.26
RUM1	89%	11%	0%	0%	7	1	2.16	7	0	2	1.0	97	75%	0%	25%	0.04
SAM1	17%	24%	32%	27%	15	4	3.74	100	84	19	1.1	80	0%	44%	56%	0.31
SCM1	100%	0%	0%	0%	0	1	5.22	38	0	0	1.0	99	73%	27%	0%	0.00
SCM2	57%	33%	0%	4%	0	4	10.25	100	80	5	2.0	48	0%	100%	0%	0.14
SCM3	41%	52%	0%	7%	0	4	11.50	100	52	5	1.0	--	0%	100%	0%	0.06
SMM1	9%	11%	63%	18%	32	1	1.76	96	55	0	1.0	58	10%	26%	64%	0.00
SMM2	7%	10%	67%	15%	46	4	4.55	83	93	6	3.8	93	27%	12%	60%	0.14
SNM1	95%	4%	0%	0%	0	1	7.20	40	42	25	1.1	91	67%	23%	10%	0.11
SVM1	21%	7%	56%	16%	40	1	3.30	100	53	21	1.0	48	0%	93%	7%	0.07
TNM1	93%	6%	0%	2%	0	1	2.15	46	49	38	1.1	93	57%	11%	31%	0.07
WLM1	2%	18%	68%	12%	36	4	1.98	10	--	8	1.0	59	52%	7%	42%	0.24
WLM2	3%	10%	69%	18%	44	4	2.67	80	100	0	2.0	34	0%	16%	84%	0.07

Appendix 1. Environmental variables measured from 62 stream reaches.

Site Code	% Coarse Substrate	% Sand & Fines	% Hard Pan	Embeddedness** (%)	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	PM Temperature (C)	AM pH	Conductivity (µS/cm)	AM Dissolved Oxygen (mg/L)	Turbidity (NTU)	Dominant Adjacent Land Use	Riffle Sample Collected	Glide Sample Collected
ASM1	55	38	0	63.2	0	0	50	18.8	6.0	174.8	7.3	27.5	1	1	
ASM2	9	74	6	89.3	40	--	--	--	--	--	--	--	1		1
AYM1	50	22	0	50.1	55	70	38	11.4	9.4	157.4	7.6	38.2	4	1	
BCM1	0	40	50	39.6	60	43	65	17.2	6.8	231.8	7.7	7.5	1		1
BIM1	89	11	0	11.0	100	79	--	11.3	10.3	71.7	7.4	4.2	4	1	
BKM1	48	27	0	58.3	33	80	36	15.2	9.7	57.2	7.1	5.8	4	1	
BRM1	79	16	0	32.0	--	75	25	13.7	7.9	177.9	7.9	6.4	1	1	
BRM2	36	33	0	69.6	10	25	70	16.1	8.4	229.1	7.7	5.2	2		1
BUM1	42	33	0	62.0	33	39	40	17.4	6.5	232.1	7.7	6.1	1		1
BUM2	1	86	0	97.1	100	61	48	18.9	5.4	224.9	7.2	93.4	4		1
CDM1	0	0	3	92.8	3	33	18	12.4	4.2	143.8	7.0	33.2	4		1
CDM2	0	81	0	97.1	20	25	9	18.1	--	259.65	7.51	14.25	1		1
CHM1	60	15	3	46.7	100	76	--	12.3	7.5	96.7	7.9	12.2	4	1	
CHM2	0	100	0	100.0	7	58	45	12.0	1.7	287.4	7.1	49.9	1		1
CLM1	0	100	0	100.0	28	40	--	20.2	2.1	224.9	7.5	3.4	3		1
CMM1	0	96	0	99.2	30	55	90	17.3	5.6	213.9	7.3	11.2	2		1
CMM2	36	39	0	47.8	15	45	65	18.5	9.9	168.4	8.1	18.0	1	1	
CNM1	75	17	5	35.9	28	55	29	13.6	10.1	72.8	7.2	9.5	4	1	
CNM2	17	60	0	93.6	3	65	70	11.7	2.7	91.5	6.9	21.8	3	1	

Appendix 1. Continued.

Site Code	% Coarse Substrate	% Sand & Fines	% Hard Pan	Embeddedness** (%)	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	PM Temperature (C)	AM pH	Conductivity (µS/cm)	AM Dissolved Oxygen (mg/L)	Turbidity (NTU)	Dominant Adjacent Land Use	Riffle Sample Collected	Glide Sample Collected
CNM3	21	52	13	70.8	5	25	83	15.1	8.2	159.3	7.9	6.6	3		1
DNM1	0	91	0	99.0	4	10	70	21.0	5.7	505.5	7.5	5.4	2		1
DNM2	0	100	0	100.0	35	41	25	16.9	4.9	523.0	7.2	4.9	1		1
DYM1	80	13	0	23.4	100	83	14	11.9	10.3	68.1	8.1	0.0	4	1	
DYM2	85	5	0	13.8	5	50	40	12.8	10.2	67.6	7.7	N/A	3	1	
DYM3	0	89	0	93.1	20	--	--	13.7	8.9	74.7	7.5	0.0	3		1
DYM4	76	11	0	33.0	100	68	45	12.2	9.1	118.6	7.5	1.4	4	1	
DYM5	0	100	0	100.0	10	43	60	14.3	7.8	101.7	7.3	11.5	3		1
DYM6	15	48	0	71.9	53	55	13	--	--	--	--	--	4		1
FLM1	26	37	0	57.6	15	70	50	18.8	--	258.6	7.8	3.8	1	1	1
FMM1	0	60	40	100.0	20	8	55	15.9	5.0	235.4	7.5	8.2	1		1
FUM1	52	22	12	45.8	30	90	75	16.5	7.9	149.7	7.7	9.7	1	1	
FUM2	0	39	46	64.7	13	80	60	17.6	4.7	146.4	7.6	14.3	1		1
GLM1	55	23	0	39.7	73	68	68	15.1	7.2	181.1	7.2	2.8	1	1	
GSM1	88	5	0	22.4	100	70	--	11.6	9.2	82.6	7.7	1.6	4	1	
GSM2	69	12	0	25.8	82	18	79	14.0	8.4	131.7	7.8	1.7	4	1	1
GSM3	0	100	0	100.0	40	58	--	13.1	8.7	139.0	7.3	3.3	3		1
HDM1	6	83	0	95.5	27	33	90	20.2	1.9	286.1	7.5	15.4	1		1
HTM1	0	100	0	100.0	10	30	50	13.2	7.6	96.3	7.4	8.3	1		1
JNM1	0	100	0	100.0	43	43	62	14.2	6.1	212.1	7.3	22.2	1		1
JSM1	3	77	11	81.6	13	18	83	13.7	8.5	102.1	7.3	10.6	1		1
JSM2	1	83	0	93.6	18	10	95	15.7	7.3	128.7	7.2	10.4	1		1
JSM3	7	83	0	97.4	100	38	73	23.5	3.1	193.9	7.4	12.3	1		1

Appendix 1. Continued.

Site Code	% Coarse Substrate	% Sand & Fines	% Hard Pan	Embeddedness** (%)	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	PM Temperature (C)	AM pH	Conductivity (µS/cm)	AM Dissolved Oxygen (mg/L)	Turbidity (NTU)	Dominant Adjacent Land Use	Riffle Sample Collected	Glide Sample Collected
MKM4	57	25	0	49.6	65	71	48	--	--	--	--	--	4		1
MFM1	55	16	0	35.2	53	73	30	13.2	9.9	101.2	7.3	5.3	1	1	
MFM2	0	100	0	100.0	30	40	--	11.9	6.0	128.6	7.3	9.4	3		1
MKM1	--	--	--	--	--	--	--	13.7	7.8	84.6	7.6	2.2	--	1	
MKM2REF	9	32	32	64.5	13	80	--	13.8	7.2	108.2	7.3	7.1	3		1
MKM3	0	75	0	92.7	53	73	38	17.3	6.7	174.7	7.3	7.2	3		1
RGM1	77	9	0	30.2	100	86	20	12.3	9.435	126.05	7.8	1.91	2	1	
RLM1	0	100	10	100.0	25	--	--	15.8	--	270.0	7.5	4.5	1	1	1
RMM1	0	75	6	86.2	33	33	68	14.8	6.2	219.1	7.2	9.3	1		1
RUM1	91	6	0	13.4	58	71	15	12.4	9.1	116.9	7.8	5.0	4	1	
SAM1	0	75	0	88.1	65	40	63	11.5	9.1	142.0	8.1	5.8	1		1
SCM1	67	17	0	39.7	100	85	10	11.7	10.4	88.8	7.9	1.7	4	1	
SCM2	25	48	0	92.7	10	20	70	15.6	8.7	74.1	7.6	4.5	2		1
SCM3	0	90	0	94.5	55	74	39	15.3	8.9	73.1	7.2	3.8	1		1
SMM1	8	83	0	95.4	28	24	45	17.0	6.8	229.7	7.4	1.7	1		1
SMM2	75	8	0	35.8	8	90	5	16.1	5.0	199.4	7.2	47.4	2	1	1
SNM1	75	14	0	30.4	100	83	21	11.4	10.2	99.7	8.1	1.6	4	1	
SVM1	0	88	0	96.7	78	23	82	14.0	8.9	208.1	7.2	9.7	1		1
TNM1	66	11	6	28.9	100	23	65	12.4	9.7	189.1	8.0	2.0	4	1	
WLM1	85	6	0	6.4	0	0	0	15.8	6.7	162.4	7.2	5.1	1	1	
WLM2	0	50	50	100.0	25	43	65	17.4	--	233.3	7.2	9.6	1		1

Appendix 2. Metrics (and standardized scores) calculated from macroinvertebrate communities from 32 stream reaches in the Tualatin River basin, Oregon, fall 2005.

Site	Taxa Richness	Mayfly Richness	Stonefly Richness	Caddisfly Richness	Number of Sensitive Taxa	Number Sediment Sens Taxa	Modified HBI	% Tolerant	% Sediment Tol	% Dominant (single taxon)	Multimetric Score
ASM1	14 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	5.9 (1)	33.1 (3)	32.1 (1)	30.7 (3)	14
AYM1	29 (3)	4 (3)	3 (3)	5 (3)	0 (1)	1 (3)	6.5 (1)	86.5 (1)	80.5 (1)	79.3 (1)	20
BKM1	34 (3)	3 (1)	6 (5)	6 (3)	2 (3)	0 (1)	5.9 (1)	21.2 (3)	18.4 (3)	29.9 (3)	26
BRM1	34 (3)	4 (3)	4 (3)	4 (3)	1 (1)	0 (1)	5.6 (1)	42.6 (3)	40.5 (1)	29.5 (3)	22
BIM1	39 (5)	6 (3)	7 (5)	7 (3)	2 (3)	2 (5)	3.0 (5)	11.2 (5)	4.1 (5)	38.6 (3)	42
CHM1	28 (3)	4 (3)	5 (3)	3 (1)	2 (3)	2 (5)	6.2 (1)	46.0 (1)	43.5 (1)	37.7 (3)	24
CMM2	18 (1)	1 (1)	0 (1)	1 (1)	0 (1)	0 (1)	5.8 (1)	8.3 (5)	8.3 (5)	25.3 (3)	20
CNM1	35 (3)	6 (3)	6 (5)	8 (3)	1 (1)	2 (5)	4.4 (3)	34.9 (3)	15.6 (3)	13.9 (5)	34
CNM1	37 (5)	7 (3)	6 (5)	8 (3)	2 (3)	2 (5)	4.5 (3)	40.1 (3)	16.2 (3)	11.0 (5)	38
CNM2	25 (3)	4 (3)	2 (1)	3 (1)	0 (1)	0 (1)	5.9 (1)	22.3 (3)	22.7 (3)	18.1 (5)	22
DYM1	36 (5)	7 (3)	6 (5)	9 (5)	4 (3)	3 (5)	4.6 (3)	16.2 (3)	1.9 (5)	26.4 (3)	40
DYM1	39 (5)	7 (3)	5 (3)	12 (5)	3 (3)	3 (5)	4.5 (3)	15.6 (3)	3.2 (5)	29.2 (3)	38
DYM2	30 (3)	5 (3)	5 (3)	7 (3)	0 (1)	1 (3)	4.7 (3)	20.9 (3)	10.7 (3)	27.1 (3)	28
DYM4	37 (5)	(3)	5 (3)	10 (5)	1 (1)	2 (5)	3.7 (5)	25.9 (3)	19.7 (3)	17.0 (5)	38
DYM4	39 (5)	9 (5)	6 (5)	7 (3)	6 (5)	1 (3)	3.4 (5)	20.0 (3)	10.6 (3)	18.9 (5)	42
FNM1	16 (1)	1 (1)	0 (1)	1 (1)	0 (1)	0 (1)	5.6 (1)	0.8 (5)	0.6 (5)	30.4 (3)	20
FUM1	19 (3)	2 (1)	0 (1)	0 (1)	1 (1)	0 (1)	5.9 (1)	31.6 (3)	26.1 (1)	25.1 (3)	16
GLM1	13 (1)	1 (1)	0 (1)	0 (1)	0 (1)	0 (1)	5.7 (1)	55.1 (1)	54.0 (1)	54.0 (1)	10
GLM1	13 (1)	1 (1)	0 (1)	0 (1)	0 (1)	0 (1)	5.3 (1)	42.3 (3)	41.5 (1)	41.3 (1)	12
GSM1	47 (5)	10 (5)	7 (5)	11 (5)	4 (3)	3 (5)	4.3 (3)	11.5 (5)	3.9 (5)	18.2 (5)	46
GSM2	27 (3)	5 (3)	7 (5)	2 (1)	1 (1)	1 (3)	3.3 (5)	21.9 (3)	5.7 (5)	61.8 (1)	30
MFM1	27 (3)	8 (3)	7 (5)	8 (3)	1 (1)	2 (5)	4.3 (5)	18.8 (3)	8.6 (5)	24.7 (3)	34
MKM1	26 (3)	4 (3)	4 (3)	5 (3)	0 (1)	2 (5)	3.7 (5)	14.5 (5)	8.5 (5)	25.2 (3)	36
RGM1	34 (3)	8 (3)	6 (5)	5 (3)	1 (1)	1 (3)	3.3 (5)	15.5 (5)	9.7 (5)	19.5 (5)	38
RGM1	42 (5)	9 (5)	6 (5)	8 (3)	5 (5)	2 (5)	3.8 (5)	29.4 (3)	14.1 (3)	15.1 (5)	44
RLM1	14 (1)	1 (1)	0 (1)	1 (1)	0 (1)	0 (1)	6.0 (1)	86.0 (1)	21.9 (3)	62.6 (1)	12
RUM1	32 (3)	1 (1)	0 (1)	6 (3)	0 (1)	1 (3)	5.6 (1)	20.4 (3)	16.2 (3)	27.9 (3)	22
SCM1	42 (5)	7 (3)	8 (5)	11 (5)	5 (5)	3 (5)	4.6 (3)	19.1 (3)	15.8 (3)	31.7 (3)	40
SMM2	17 (1)	1 (1)	0 (1)	1 (1)	0 (1)	0 (1)	6.1 (1)	13.6 (5)	6.6 (5)	29.2 (3)	20
SNM1	33 (3)	6 (3)	6 (5)	6 (3)	2 (3)	3 (5)	4.6 (3)	17.4 (3)	11.4 (3)	20.3 (3)	34
TNM1	34 (3)	6 (3)	7 (5)	7 (3)	3 (3)	2 (5)	5.4 (1)	53.0 (1)	51.6 (1)	50.5 (1)	26
WLM1	15 (1)	0 (1)	0 (1)	1 (1)	0 (1)	0 (1)	6.0 (1)	1.8 (5)	0.6 (5)	72.4 (1)	18

Appendix 3. Environmental variables measured from 64 stream reaches sampled for fish community conditions in the Tualatin River basin, Oregon, fall 2005. Coding is as follows: Valley Type: 1 = V shape, 2 = U shape, 3 = ponded, 4 = floodplain; Large Wood Tally: 1–5, 1 = provides no instream cover, 5 = provides abundant instream cover; Adjacent land use: 1 = residential, 2 = industrial/commercial, 3 = agricultural, 4 = undeveloped/forested. Embeddedness estimates were made from both pebble count data (these represent emdeddedness only of habitat types from which pebble counts were performed), denoted in the appendix by two asterisks (**), and from visual estimates of reach-wide embeddedness across all habitat types, denoted by one asterisk (*).

Lower Reaches

Site Code	Dominant Adjacent Land Use	Wetted Width (m)	Embeddedness* (%)	Eroding Banks (%)	Undercut banks (%)	Large Wood Rating	Canopy Cover (%)	Percent Riffles	Percent Glides	Percent Pools	Large Wood Tally
ASL	1	2.40	100	94	56	1.11	49	0	70	30	0.09
BNL	1	2.87	97	19	14	1.17	83	5	20	75	0.19
BRL	2	2.29	64	46	69	1.00	62	13	47	40	0.02
BVL	1	8.25	88	98	58	2.56	68	0	24	85	0.15
CNL	3	3.19	100	76	34	1.59	95	0	69	31	0.39
DNL	1	4.68	100	53	3	2.65	52	0	43	57	0.18
FLL	1	6.24	78	74	13	1.69	67	0	33	67	0.11
GSL	3	10.50	100	50	10	1.65	36	0	35	65	0.10
HSL	1	2.31	100	42	6	1.32	83	3	8	89	0.13
MKL	3	6.40	100	85	0	1.69	86	0	69	31	0.29
RLL	1	6.68	86	100	0	3.91	62	0	27	67	0.20
RRL	2	4.87	18	7	1	1.19	97	61	26	13	0.05
SUL	2	4.55	83	93	6	3.76	93	27	12	60	0.14

Appendix 3. Continued.

Middle Reaches

Site Code	Dominant Adjacent Land Use	Wetted Width (m)	Embeddedness* (%)	Eroding Banks (%)	Undercut banks (%)	Large Wood Rating	Canopy Cover (%)	Percent Riffles	Percent Glides	Percent Pools	Large Wood Tally
ASM	1	2.57	33	33	3	1.00	88	27	22	51	0.01
AYM	3	1.68	73	56	32	1.00	96	32	0	68	0.01
BKM	1	2.70	100	16	9	2.25	53	0	45	55	0.34
BNM	1		92	56	24	1.00	48	16	14	71	0.00
BRM	1	2.44	33	60	48	1.00	91	31	30	39	0.05
BUM	1	2.70	50	43	35	1.00	97	79	0	21	0.09
BVM	1	7.50	84	69	15	2.40	77	0	15	85	0.46
CDM	1	2.40	100	48	1	1.13	65	0	35	65	0.03
CHM	1	3.85	100	38	17	1.07	97	7	0	93	0.06
CLM	3	8.65	100	100	0	1.00	0	0	100	0	0.06
CMM	2	7.00	100	5	0	1.00	4	0	100	0	0.03
CNM	3	2.00	100	70	20	1.00	90	59	27	14	0.08
DNM	1		100	10	13	1.34	47	0	0	100	0.26
DYM	3	6.10	52	85	3	2.03	81	0	46	54	0.18
FLM	1	3.35	100	89	21	1.66	99	0	58	42	0.24
GSM	4	15.20	92	47	20	2.78	1	15	31	54	0.20
HNM	1	4.98	100	73	27	1.38	87	0	0	100	0.44
HSM	2	16.05	100	3	0	1.00	0	0	0	100	0.00
JSM	1	3.23	100	0	0	1.00	1	0	100	0	0.00
MFM	3	7.00	100	37	3	1.50	80	0	17	83	0.08
MKM	1	7.60	99	40	1	4.11	83	0	12	88	0.46
RMM	1		100	41	37	2.99	70	0	0	100	0.35
RRM	2	3.28	49	38	15	1.00	96	45	7	25	0.26
SRM	3	1.90	100	38	3	1.31	7	0	30	70	0.00
SUM	1	3.24	100	70	8	2.00	79	0	17	83	0.08
TUM	3	5.74	37	19	2	1.00	49	9	36	55	0.30
WDM	3	6.13	100	72	0	3.20	59	0	13	92	0.24

Appendix 3. Continued.

Upper Reaches

Site Code	Dominant Adjacent Land Use	Wetted Width (m)	Embeddedness* (%)	Eroding Banks (%)	Undercut banks (%)	Large Wood Rating	Canopy Cover (%)	Percent Riffles	Percent Glides	Percent Pools	Large Wood Tally
ASU	1	0.99	73	49	5	1.00	61	36	2	62	0.00
AYU	4	2.18	48	31	24	1.00	96	44	0	56	0.09
BKU	4	1.58	28	32	23	1.00	100	93	0	7	0.08
BNU	1	1.26	94	82	87	1.00	55	13	80	7	0.02
BUU	4	2.54	85	15	7	2.79	95	7	0	79	0.27
CDU	4	1.46	96	62	13	1.50	97	18	23	59	0.23
CHU	4	0.81	65	45	30	1.68	100	89	9	2	0.05
CLU	1	6.57	100	90	10	1.00	0	0	0	100	0.00
CMU	1	3.19	16	55	6	1.32	93	71	23	6	0.05
CNU	4	1.48	38	34	11	2.00	95	93	0	8	0.21
DNU	2	1.39	85	55	1	1.16	62	7	35	58	0.11
DYU	4	8.30	25	13	9	1.16	88	43	41	16	0.07
FLU	1	2.16	77	57	31	1.33	97	42	0	58	0.00
GSU	4	7.30	40	10	10	2.00	66	100	0	0	0.01
HNU	1	3.60	100	85	71	2.92	79	0	96	4	0.24
HSU	1	1.55	68	79	11	2.06	94	24	4	72	0.27
JSU	1	0.80	98	61	22	1.03	98	4	42	55	0.11
MFU	3	2.38	63	29	0	1.00	86	55	12	33	0.03
MKU	4	6.20	35	17	17	1.40	89	55	0	33	0.04
RUU	4	2.16	7	0	2	0.96	97	75	0	25	0.04
SRU	2	2.07	72	10	9	1.00	21	0	0	100	0.01
SUU	1		100	25	25	1.50	2	0	100	0	0.10
TUU	1	16.75	46	26	29	1.23	83	63	60	0	0.08
WDU	4	1.84	39	27	21	1.58	97	11	37	52	0.10

Appendix 3. Continued.

Lower Reaches

Site Code	% Coarse Substrate	% Sand & Fines	% Hard Pan	Embeddedness** (%)	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	PM Temperature (C)	AM pH	AM Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Turbidity (NTU)
ASL	9	79	0	99	15	25	55	19	7.15	2.62	258.4	23.2
BNL	5	58	22	68	54	74	10	12	7.46	5.54	322.5	11.6
BRL	12	56	0	70	10	25	70	16	7.67	8.39	229.1	5.2
BVL	0	40	50	40	60	43	65	17	7.73	6.78	231.8	7.5
CNL	21	52	13	71	5	25	83	15	7.90	8.21	159.3	6.6
DNL	0	100	0	100	35	41	25	17	7.25	4.87	523.0	4.9
FLL	26	37	0	58	15	70	50	19	7.79	ND	258.6	3.8
GSL	0	100	0	100	10	5	ND	13	7.54	7.95	142.6	3.0
HSL	6	83	0	96	27	33	90	20	7.46	1.94	286.1	15.4
MKL	0	75	0	93	53	73	38	17	7.28	6.74	174.7	7.2
RLL	0	0		100	25	ND	ND	16	7.45	ND	270.0	4.5
RRL	77	13	0	23	68	74	15	13	7.74	9.79	154.1	1.9
SUL	75	8	0	36	8	90	5	16	7.18	5.04	199.4	47.4

Appendix 3. Continued.

Middle Reaches

Site Code	% Coarse Substrate	% Sand & Fines	% Hard Pan	Embeddedness** (%)	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	PM Temperature (C)	AM pH	AM Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Turbidity (NTU)
ASM	76	17	0	40	5	55	50	19	7.96	6.74	244.2	12.6
AYM	43	42	2	70	53	55	30	13	7.69	9.71	149.5	6.2
BKM	0	100	0	100	10	10	90	11	8.08	9.89	55.5	4.3
BNM	18	71	0	82	10	9	80	22	7.76	5.17	240.5	30.2
BRM	36	33	0	61	5	35	40	18	7.78	8.29	191.1	7.6
BUM	63	28	0	48	100	73	1	12	7.85	8.83	75.2	2.7
BVM	0	39	0	69	8	20	70	20	7.39	ND	223.0	10.4
CDM	0	81	0	97	20	25	9	18	7.51	ND	259.7	14.3
CHM	0	100	0	100	7	58	45	12	7.14	1.70	287.4	49.9
CLM	0	100	0	100	28	40	ND	20	7.48	2.11	224.9	3.4
CMM	0	90	0	99	68	14	83	20	7.31	ND	211.6	55.5
CNM	17	60	0	94	3	65	70	12	6.90	2.66	91.5	21.8
DNM	16	78	0	88	38	36	94	23	7.06	5.08	803.5	7.5
DYM	0	89	0	93	20	ND	ND	14	7.55	8.91	74.7	0.0
FLM	0	39	46	68	13	80	60	18	7.57	4.71	146.4	14.3
GSM	69	12	0	26	82	18	79	14	7.82	8.38	131.7	1.7
HNM	10	74	3	89	40	90	28	12	7.15	7.97	102.9	7.8
HSM	0	98	0	100	9	0	95	21	7.81	3.62	198.2	8.5
JSM	7	83	0	97	100	38	73	24	7.44	3.10	193.9	12.3
MFM	0	100	0	100	30	40	ND	12	7.28	5.98	128.6	9.4
MKM	0	78	0	100	53	36	25	13	7.36	6.28	91.4	6.9
RMM	3	88	0	90	70	48	73	19	7.50	3.24	345.6	7.5
RRM	77	9	0	30	100	86	20	12	7.80	9.44	126.1	1.9
SRM	0	100	0	100	2	0	95	14	6.65	4.55	272.9	25.0
SUM	15	80	0	95	25	29	48	29	7.54	ND	188.5	40.0
TUM	28	27	30	47	10	20	50	12	7.67	9.70	71.1	2.5
WDM	0	100	0	100	15	50	ND	14	7.38	6.97	101.9	6.9

Appendix 3. Continued.

Upper Reaches

Site Code	% Coarse Substrate	% Sand & Fines	% Hard Pan	Embeddedness** (%)	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	PM Temperature (C)	AM pH	AM Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Turbidity (NTU)
ASU	55	38	0	63	0	0	50	19	7.33	6.04	174.8	27.5
AYU	72	18	0	33	73	45	20	14	7.83	9.92	146.1	8.4
BKU	48	27	0	58	33	80	36	15	7.08	9.74	57.2	5.8
BNU	23	51	0	81	4	3	90	21	7.66	5.74	173.8	17.3
BUU	77	17	0	34	100	60	ND	11	7.38	10.30	71.7	4.2
CDU	0	0	3	93	3	33	18	12	7.03	4.20	143.8	33.2
CHU	60	15	3	47	100	76	ND	12	7.89	7.51	96.7	12.2
CLU	0	100	0	100	0	0	0	16	7.43	3.79	152.1	0.0
CMU	36	39	0	48	15	45	65	19	8.13	9.87	168.4	18.0
CNU	75	17	5	36	28	55	29	14	7.16	10.06	72.8	9.5
DNU	0	91	0	99	4	10	70	21	7.52	5.69	505.5	5.4
DYU	80	13	0	23	100	83	14	12	8.05	10.30	68.1	0.0
FLU	52	22	12	46	30	90	75	17	7.70	7.89	149.7	9.7
GSU	78	15	0	34	7	63	5	11	8.11	10.85	94.6	1.1
HNU	0	100	0	100	10	30	50	13	7.39	7.61	96.3	8.3
HSU	51	40	0	49	19	50	63	16	7.70	ND	147.6	4.2
JSU	0	76	0	92	23	70	70	18	7.34	8.21	135.1	13.6
MFU	51	33	0	52	3	5	80	14	7.65	9.24	88.7	4.2
MKU	90	2	0	16	34	63	ND	13	7.95	10.38	80.8	1.4
RUU	91	6	0	13	58	71	15	12	7.76	9.06	116.9	5.0
SRU	25	44	0	86	3	15	83	14	6.77	3.32	604.0	23.9
SUU	0	100	0	100	30	23	50	26	7.47	5.44	194.9	22.2
TUU	50	39	1	56	67	87	32	11	7.75	8.81	70.4	1.8
WDU	76	11	0	33	100	68	45	12	7.49	9.07	118.6	1.4

Appendix 4. Number of fish and crayfish collected in reaches of Tualatin River tributaries, fall 2005 and spring 2006. L = lower reach, M = middle reach, and U = upper reach.

	Stream									
	Ash						Ayers			
	Fall			Spring			Fall		Spring	
Species	L	M	U	L	M	U	M	U	M	U
Unidentified lamprey	0	0	0	0	0	0	7	2	3	7
Ammocoete	0	0	0	0	0	0	0	0	1	0
Cutthroat trout	0	0	0	0	0	0	0	11	0	1
Rainbow trout	0	0	0	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0	0	0
Redside shiner	107	8	16	1	17	4	0	0	0	0
Speckled dace	0	0	0	0	0	0	0	0	0	0
Goldfish	2	0	0	0	9	0	0	0	0	0
Common carp	0	0	0	0	0	0	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	0	0	0	0	0	0
Largescale sucker	6	0	0	1	1	0	0	0	0	0
Unknown sucker	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0	0	0
Mosquitofish	70	0	0	0	0	0	0	0	0	0
Threespine stickleback	64	0	0	29	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	1	0	0	0	2	0	0	0	0	0
Warmouth	0	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Cottid	114	138	51	208	248	142	172	49	95	134
Northern pikeminnow	0	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0	0
Crayfish	1	6	2	8	27	4	3	3	3	0
Bullfrog tadpoles	0	0	0	0	0	0	0	0	0	0

Appendix 4. Continued.

	Stream										
	Baker				Beaverton			Bronson			
	Fall		Spring		Fall		Spring	Fall		Spring	
Species	M	U	M	U	L	M	M	L	M	L	M
Unidentified lamprey	9	0	5	0	1	0	0	0	6	2	33
Ammocoete	0	0	1	0	0	0	0	0	0	0	5
Cutthroat trout	9	0	5	0	0	0	0	0	3	0	0
Rainbow trout	0	0	0	0	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	13	0	0	0	0	0
Speckled dace	9	0	8	0	0	0	0	3	1	0	0
Goldfish	0	0	0	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	0	0	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	0	0	0	0	0	1	0
Largescale sucker	0	0	0	0	0	0	0	0	0	0	0
Unknown sucker	0	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	3	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0	0	0	0
Mosquitofish	0	0	0	0	0	2	0	1	0	0	0
Threespine stickleback	0	0	0	0	0	2	0	42	0	8	0
Bluegill	0	0	0	0	0	0	0	14	0	0	0
Pumpkinseed	0	0	0	0	2	0	0	0	0	1	0
Warmouth	0	0	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	2	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0	0
Cottid	306	71	181	200	74	63	92	270	302	274	164
Northern pikeminnow	0	0	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0	0	0
Crayfish	43	4	14	13	10	6	0	44	43	7	22
Bullfrog tadpoles	0	0	0	0	0	0	0	0	0	0	0

Appendix 4. Continued.

	Stream									
	Burris				Butternut					
	Fall		Spring		Fall			Spring		
Species	M	U	M	U	L	M	U	L	M	U
Unidentified lamprey	1	0	33	0	4	0	0	0	0	0
Ammocoete	2	0	1	2	0	0	0	0	0	0
Cutthroat trout	9	19	2	2	0	0	0	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	2	9	0	0	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0	0	0
Redside shiner	0	0	0	0	11	6	0	63	23	0
Speckled dace	1	0	0	0	0	13	23	12	47	96
Goldfish	0	0	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	1	0	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0	1	0
Unknown minnow/shiner	0	0	0	0	0	0	0	3	0	0
Largescale sucker	0	0	0	0	0	0	0	0	0	0
Unknown sucker	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	1	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0	0	0
Mosquitofish	0	0	0	0	30	32	0	0	0	0
Threespine stickleback	0	0	0	0	0	18	14	12	45	6
Bluegill	0	0	0	0	2	0	0	1	0	0
Pumpkinseed	0	0	0	0	1	0	0	2	0	0
Warmouth	0	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	1	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Cottid	54	88	152	146	177	114	6	249	55	0
Northern pikeminnow	0	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0	0
Crayfish	5	11	6	11	11	9	0	11	8	0
Bullfrog tadpoles	0	0	0	0	0	0	0	7	0	0

Appendix 4. Continued.

	Stream														
	Cedar				Cedar Mill				Chicken					
	Fall		Spring		Fall		Spring		Fall			Spring	
Species	M	U	M	U	M	U	M	U	L	M	U	L	U
Unidentified lamprey	0	3	0	1	1	1	0	1	1	1	1	0	0
Ammocoete	0	0	0	3	1	0	0	3	7	1	0	0	0
Cutthroat trout	0	5	0	1	0	14	0	1	1	0	14	0	0
Rainbow trout	0	0	0	0	0	0	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0	0	0	0	0	4
Redside shiner	7	15	2	48	24	0	2	48	11	24	0	3	0
Speckled dace	0	0	0	0	4	0	0	0	0	4	0	0	0
Goldfish	0	0	0	0	0	0	0	0	0	0	0	2	0
Common carp	0	0	0	0	0	0	0	0	22	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown minnow/shiner	22	0	0	0	0	0	0	0	0	0	0	0	0
Largescale sucker	0	0	0	4	0	0	0	0	0	0	0	0	0
Unknown sucker	0	2	0	0	0	0	0	4	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0	2	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0	0	0	0	1	0
Channel catfish	0	0	0	0	0	0	0	0	0	0	0	0	0
Mosquitofish	0	0	0	0	0	0	0	0	0	0	0	0	0
Threespine stickleback	396	4	10	19	0	0	10	19	0	0	0	5	0
Bluegill	0	0	0	0	0	0	0	0	4	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	6	0	0	16	0
Warmouth	0	0	0	0	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0	1	0	0	1	0
Smallmouth bass	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0	0	0	0
Cottid	409	131	168	194	181	86	168	194	107	181	86	349	13
Northern pikeminnow	0	0	0	0	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0	0	0	0	0
Crayfish	14	3	12	11	9	8	15	8	36	14	13	31	5
Bullfrog tadpoles	0	0	0	0	0	0	8	0	0	0	0	7	0

Appendix 4. Continued.

	Stream								
	Christensen				Council		Dairy		
	Fall		Spring		Fall		Fall		Spring
Species	M	U	M	U	M	U	M	U	U
Unidentified lamprey	0	0	0	0	0	0	1	5	2
Ammocoete	0	0	0	0	0	0	0	0	2
Cutthroat trout	0	13	0	1	0	0	0	37	10
Rainbow trout	0	0	0	0	0	0	0	11	3
Coho salmon	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	40	0	0	0	0	7
Unknown salmonid	0	0	0	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	9	0	0	0
Speckled dace	4	0	7	0	0	1	0	0	0
Goldfish	0	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0	0	0	0
Unknown sucker	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	5	0	0	0
Brown bullhead	0	0	0	0	0	10	0	0	0
Channel catfish	0	0	0	0	0	0	0	0	0
Mosquitofish	0	0	0	0	45	1370	0	0	0
Threespine stickleback	23	0	16	0	0	0	0	0	0
Bluegill	0	0	0	0	16	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0
Warmouth	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	1	0	13	0	0	0	0
Smallmouth bass	0	0	0	0	13	3	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0
Cottid	398	0	196	0	0	2	67	162	187
Northern pikeminnow	0	0	0	0	0	0	0	0	0
Peamouth	2	0	0	0	0	0	0	0	0
Crayfish	7	5	1	4	0	0	28	27	26
Bullfrog tadpoles	0	0	3	0	0	0	0	0	0

Appendix 4. Continued.

	Stream										
	Dawson					Fanno					
	Fall			Spring		Fall			Spring		
Species	L	M	U	M	U	L	M	U	L	M	U
Unidentified lamprey	0	0	0	0	0	0	0	0	2	0	5
Ammocoete	0	0	0	0	0	0	0	0	2	1	2
Cutthroat trout	0	0	0	0	0	0	1	12	0	1	2
Rainbow trout	0	0	0	0	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0	0	1	0
Unknown salmonid	0	0	0	0	0	0	0	0	0	0	0
Redside shiner	2	32	3	53	8	0	33	0	1	16	0
Speckled dace	0	0	13	1	10	2	0	0	0	1	0
Goldfish	0	0	1	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	0	0	0	0	0	0
Unknown minnow/shiner	0	0	2	0	0	0	0	0	14	95	0
Largescale sucker	0	0	0	0	0	0	0	0	0	0	0
Unknown sucker	0	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0	0	1	0
Brown bullhead	0	0	0	0	0	0	0	0	1	0	0
Channel catfish	0	0	0	0	0	3	0	0	0	0	0
Mosquitofish	0	19	0	4	0	11	10	0	0	0	0
Threespine stickleback	1	6	172	210	47	0	0	0	0	0	0
Bluegill	2	0	0	6	1	0	0	0	2	0	0
Pumpkinseed	10	0	1	0	1	0	0	0	1	0	0
Warmouth	0	0	0	0	0	0	0	0	0	0	0
Largemouth bass	1	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0	0
Cottid	4	170	204	534	367	87	130	76	219	233	192
Northern pikeminnow	0	0	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0	0	0
Crayfish	0	10	8	0	0	71	9	4	24	8	10
Bullfrog tadpoles	0	0	0	0	0	0	0	0	2	0	0

Appendix 4. Continued.

	Stream							
	Gales				Heaton			
	Fall			Spring	Fall		Spring	
Species	L	M	U	U	M	U	M	U
Unidentified lamprey	0	3	1	5	0	1	8	17
Ammocoete	0	5	0	1	0	0	0	12
Cutthroat trout	0	0	27	11	1	5	15	3
Rainbow trout	0	4	9	3	0	0	0	0
Coho salmon	0	0	0	3	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0
Redside shiner	10	135	0	0	0	0	0	0
Speckled dace	1	51	0	0	4	0	10	0
Goldfish	0	0	0	0	0	0	0	0
Common carp	1	0	0	0	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	0	0	0	0
Largescale sucker	1	35	0	0	4	0	2	0
Unknown sucker	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0
Mosquitofish	0	0	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Warmouth	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Cottid	89	284	456	361	85	60	134	182
Northern pikeminnow	0	1	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0
Crayfish	5	24	10	1	23	7	24	3
Bullfrog tadpoles	0	0	0	0	0	0	0	0

Appendix 4. Continued.

	Stream								
	Hedges						McFee		
	Fall			Spring			Fall		Spring
Species	L	M	U	L	M	U	M	U	U
Unidentified lamprey	0	0	1	0	0	0	3	19	10
Ammocoete	0	0	0	0	0	4	0	0	2
Cutthroat trout	0	0	0	0	0	0	0	11	9
Rainbow trout	0	0	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0	15
Unknown salmonid	0	0	0	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0	0	0	0
Speckled dace	0	0	0	0	0	0	1	15	44
Goldfish	0	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	0	0	0	0
Fathead minnow	0	0	0	1	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0	0	2	2
Unknown sucker	0	0	0	0	0	0	0	0	1
Yellow bullhead	0	3	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	1	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0	0
Mosquitofish	285	1062	0	2	1	0	0	0	0
Threespine stickleback	24	0	0	142	0	0	0	0	0
Bluegill	0	0	0	0	5	0	0	0	0
Pumpkinseed	0	93	0	2	13	0	0	0	0
Warmouth	0	0	0	0	0	0	0	0	0
Largemouth bass	0	1	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0
Cottid	35	0	70	95	0	69	11	121	287
Northern pikeminnow	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0
Crayfish	4	0	2	4	0	4	3	9	12
Bullfrog tadpoles	0	0	0	5	83	0	0	0	0

Appendix 4. Continued.

	Stream								
	McKay				N. Rock				
	Fall			Spring	Fall			Spring	
Species	L	M	U	U	L	M	U	M	U
Unidentified lamprey	9	2	0	2	1	0	0	0	1
Ammocoete	0	0	0	2	0	0	0	0	0
Cutthroat trout	0	2	0	16	0	0	0	0	2
Rainbow trout	0	0	0	0	2	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0	0
Redside shiner	0	45	32	0	0	1	0	1	0
Speckled dace	0	0	0	0	0	0	0	0	0
Goldfish	0	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	15	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	0	0	0	0	0
Largescale sucker	1	4	4	0	0	0	0	0	0
Unknown sucker	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0	0
Mosquitofish	0	0	0	0	0	0	0	0	0
Threespine stickleback	2	0	0	0	0	0	0	0	0
Bluegill	0	1	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	1	0	0	0	0
Warmouth	0	0	0	0	1	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0	0	0
Cottid	64	116	96	204	171	174	8	190	40
Northern pikeminnow	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0
Crayfish	5	10	18	12	17	26	3	12	4
Bullfrog tadpoles	0	0	0	0	0	0	0	0	0

Appendix 4. Continued.

	Stream							
	Roaring				S. Johnson			
	Fall		Spring		Fall		Spring	
Species	L	M	L	M	M	U	M	U
Unidentified lamprey	3	0	4	0	0	0	0	0
Ammocoete	3	0	0	0	0	0	0	0
Cutthroat trout	18	73	31	55	0	0	0	0
Rainbow trout	3	0	4	0	0	0	0	0
Coho salmon	2	0	47	5	0	0	0	0
Salmonid fry	0	0	19	44	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0	10	0
Speckled dace	0	0	0	0	0	13	0	10
Goldfish	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	0	0	0
Fathead minnow	0	0	0	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	1	0	0	0
Largescale sucker	0	0	0	0	0	0	1	0
Unknown sucker	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0
Mosquitofish	0	0	0	0	987	36	87	0
Threespine stickleback	0	0	0	0	22	3	418	0
Bluegill	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	1	0	3	0
Warmouth	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	2	0	10	0
Smallmouth bass	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Cottid	44	60	114	104	7	1	70	1
Northern pikeminnow	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0
Crayfish	0	5	17	10	4	1	6	0
Bullfrog tadpoles	0	0	0	0	0	0	188	0

Appendix 4. Continued.

	Stream									
	S. Rock				Summer					
	Fall		Spring		Fall			Spring		
Species	M	U	M	U	L	M	U	L	M	U
Unidentified lamprey	3	0	2	0	0	0	0	0	0	0
Ammocoete	0	0	0	0	0	0	0	1	0	0
Cutthroat trout	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0	0	0	0
Salmonid fry	0	0	0	0	0	0	0	0	0	0
Unknown salmonid	0	0	0	0	0	0	0	0	0	0
Redside shiner	1	0	0	1	10	4	123	16	9	1
Speckled dace	1	0	0	0	0	0	0	0	0	0
Goldfish	0	0	0	0	0	0	0	0	1	0
Common carp	0	0	0	0	0	2	0	0	0	0
Fathead minnow	0	0	0	0	0	1	0	0	1	4
Unknown minnow/shiner	0	0	2	0	0	4	0	0	23	0
Largescale sucker	0	0	0	0	0	0	0	5	1	0
Unknown sucker	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	14	0	0	10	0
Brown bullhead	1	0	2	0	1	0	0	1	0	2
Channel catfish	0	0	0	0	0	0	0	0	0	0
Mosquitofish	5	0	1	0	0	815	653	1	0	10
Threespine stickleback	128	29	44	30	0	0	0	0	0	0
Bluegill	0	0	9	0	1	12	0	10	14	1
Pumpkinseed	0	0	0	0	2	9	0	6	2	2
Warmouth	0	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	1	0	0
Smallmouth bass	0	0	0	0	0	0	1	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Cottid	296	0	360	38	49	0	0	137	6	0
Northern pikeminnow	0	0	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0	0	0
Crayfish	10	0	3	0	24	0	0	122	1	3
Bullfrog tadpoles	0	0	3	0	0	0	0	0	0	2

Appendix 4. Continued.

	Stream					
	Tualatin			West Dairy		
	Fall		Spring	Fall		Spring
Species	M	U	U	M	U	U
Unidentified lamprey	1	2	0	6	2	12
Ammocoete	2	18	10	0	0	3
Cutthroat trout	1	5	7	2	14	7
Rainbow trout	0	4	5	0	0	1
Coho salmon	4	11	33	0	0	0
Salmonid fry	0	0	5	0	0	0
Unknown salmonid	0	1	0	0	0	0
Redside shiner	0	0	0	3	3	1
Speckled dace	2	2	1	0	0	0
Goldfish	0	0	0	0	0	0
Common carp	0	0	0	1	0	0
Fathead minnow	0	0	0	0	0	0
Unknown minnow/shiner	0	0	0	0	0	0
Largescale sucker	0	0	0	0	0	0
Unknown sucker	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0
Mosquitofish	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0
Bluegill	0	0	0	2	0	0
Pumpkinseed	0	0	0	0	0	0
Warmouth	0	0	0	0	0	0
Largemouth bass	0	0	0	5	0	0
Smallmouth bass	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0
Cottid	114	294	128	69	92	213
Northern pikeminnow	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0
Crayfish	4	44	17	2	0	0
Bullfrog tadpoles	0	0	0	0	0	0