FINAL REPORT

2007 ASSESSMENT OF MACROINVERTEBRATE COMMUNITIES OF THE TUALATIN RIVER BASIN, OREGON

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PREPARED FOR

CLEAN WATER SERVICES
HILLSBORO, OREGON

PREPARED BY

ABR, INC.–ENVIRONMENTAL RESEARCH & SERVICES
FOREST GROVE, OREGON

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EXECUTIVE SUMMARY

- Clean Water Services (District) is committed to protecting water resources of the Tualatin River basin. As part of this commitment, the District periodically performs assessments of the status of macroinvertebrate communities in rivers and streams of the watershed to better inform water quality planning and management decision making. In 2007, the District began performing bi-annual macroinvertebrate assessments at approximately 20 monitoring stations. This monitoring is in support of the District 's efforts to track long-term trends in benthic community conditions in more than 60 stream and river reaches that have been monitored since 2001 (Clean Water Services 2006). The objective of the present study was to determine the current condition of macroinvertebrate communities in 20 stream reaches within the Tualatin River basin and compare these present conditions to those measured in previous investigations of these reaches. Study sites included 12 low-gradient reaches and 8 high-gradient reaches.
- Macroinvertebrate assemblage data were analyzed using two approaches: multimetric analysis and predictive modeling. The predictive model approach is known as PREDATOR (PREDictive Assessment Tool for ORegon) in Oregon. Three PREDATOR models are currently used in Oregon; one of these three models—the Marine Western Coastal Forest (MWCF) model—encompasses the Willamette Valley and Coast Range ecoregions. Currently, both the MWCF model and multimetric analysis have limited applicability to Tualatin basin streams, as neither is calibrated for use with data from low-gradient, valley floor streams. As such, multimetric analyses were performed only on riffle-sample data collected from higher-gradient reaches, while the MWCF model was used on both low and high-gradient data, but biological condition thresholds were modified for evaluating macroinvertebrate assemblages in low-gradient reaches.
- Macroinvertebrate community conditions ranged widely among high-gradient Tualatin basin stream reaches, as indicated by both O/E scores and DEQ multimetric scores. O/E scores from high-gradient reaches ranged from 0.43 to 0.81 and averaged 0.68, while 2005 O/E scores from these sites ranged from 0.34 to 0.83 and averaged 0.65. Using updated O/E condition thresholds, 2007 O/E scores occur exclusively in the "most disturbed" range. Using condition thresholds that were used in the 2005 assessment, but that have since been superseded, 3 of the 8 high-gradient reaches scored as "fair" rather than "poor". Multimetric scores ranged from 18 to 40 and averaged 27.3, while in 2005, the range of scores was 20 to 38 and averaged 25.7. Impairment classes in 2007 derived from MMS scores ranged from unimpaired (1 site) to severe impairment (1 site); most sites were slightly (3 sites) to moderately impaired (3 sites). In comparison, 2005 multimetric scores indicated that 2 sites were slightly impaired and 5 sites were moderately impaired (one high gradient reach, BAM1 not sampled in 2005). Only Christensen Creek (CHM1) received an unimpaired multimetric score in 2007, while Bronson Creek (BRM1), Gales Creek (GSM2), and McKay Creek (MKM4) received slightly impaired classifications based on multimetric scores.
- O/E scores from 12 low-gradient reaches ranged from 0.195 to 0.488 and averaged 0.344. Using biological condition thresholds adjusted for valley-floor streams, these 12 reaches scored exclusively in the "more impacted" range. Individual metrics calculated from macroinvertebrate assemblages collected in low-gradient reaches varied among reaches. Taxa richness ranged from 11 to 22 taxa and averaged 16 taxa. EPT richness ranged from 0 to 7 and averaged 1 taxon. No EPT taxa were sampled from 6 of the 12 sites, including lower Ash Creek (ASM2), lower Beaverton Creek (BCM1), upper Fanno Creek (FUM2), lower McFee Creek (MFM2), lower McKay Creek (MKM3), and middle Rock Creek (RMM1). These reaches generally exhibited low taxa richness, high dominance by one or a few

tolerant taxa, and a high community-wide tolerance to disturbance.

- In three sampling years (2001, 2005, and 2007), less variation was observed in both multimetric and O/E scores at the lower end of the range of scores (i.e. with sites with moderate to severe levels of impairment or those with "most impacted" community condition). Conversely, at the higher end of the range of scores, more variability was noted in both multimetric and O/E scores over the three years in which macroinvertebrate communities were sampled. Low-gradient reaches generally supported fewer taxa, fewer sensitive taxa, far fewer EPT taxa, and larger numbers of tolerant organisms than did the higher-gradient reaches. While these differences between low and high-gradient streams are likely exacerbated by human activities on the valley floor, bioassessment activities are currently unable to separate human-induced changes to valley floor macroinvertebrate assemblages from naturally occurring differences in community composition.
- O/E and multimetric scores were highly correlated, but there was little agreement in biological condition classes between the two approaches. The MWCF model consistently produced lower (or equal) condition classes than did the multimetric tool. Importantly, DEQ uses the MWCF model to assess biological conditions in wadeable streams, so assessments should include the use of this tool.
- Collectively, our results suggest that biological conditions in reaches that have previously been classified as moderately to severely-impaired sites have largely remained unchanged. Conversely, sites that have previously scored within the upper range of multimetric and O/E scores tend to have more annual variation in community condition. In order to better quantify community conditions in these streams that exhibit wider temporal variability, we recommend collecting triplicate samples at these sites to produce statistical measures of confidence in estimates of average condition. Such estimates will better inform these monitoring efforts to detect trends in community conditions over time 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 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 “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” They also provide information valuable to water quality planning and management. Clean Water Services (District) is a public utility committed to protecting water resources of the Tualatin River basin. As part of this commitment, the District periodically performs assessments of the status of macroinvertebrate communities in rivers and streams of the watershed to better inform water quality planning and management decision making. Specifically, this biological monitoring program is designed to support the District’s monitoring objectives of 1) defining status and trends, 2) documenting effectiveness of District actions, and 3) performing regulatory monitoring for stormwater (Clean Water Services 2006). In 2007, the District began performing bi-annual macroinvertebrate assessments at approximately 20 monitoring stations. This monitoring is in support of the District ’s efforts to track long-term trends in benthic community conditions in more than 60 stream and river reaches that have been monitored since 2001 (Clean Water Services 2006). The objective of the present study was to determine the current condition of macroinvertebrate communities in 20 stream reaches within the Tualatin River basin and compare these present conditions to those measured in previous investigations of these reaches.

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 at river mile 28.5 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 within the Tualatin River basin are variable in slope, substrate, and habitat characteristics. These characteristics are largely a function of valley shape, slope, and confinement. Streams occurring on the valley bottom 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 are characterized by higher gradients, larger and more heterogeneous substrate, and more heterogeneous habitat. Valley bottom streams are typically dominated by glide and pool habitats, and lack riffle habitat necessary for sampling using standard targeted-habitat sampling techniques; consequently, valley-bottom macroinvertebrate samples are typically collected from glides and the data are analyzed using modified approaches, as described below.

METHODS

SAMPLE SITE SELECTION AND OVERALL SAMPLING DESIGN

Twenty macroinvertebrate sampling sites were selected to provide a representative subsample of overall stream conditions within the Tualatin River basin, including 12 low-gradient sites and 8 high-gradient sites (Table 1). Reaches were broadly classified into high and low-gradient classes for purposes of analyzing macroinvertebrate communities with appropriate assessments tools (applying the multimetric index, in particular). 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. These designations, assigned in 2001 were also used for the 2007 sampling. Macroinvertebrate

Table 1. Macroinvertebrate sampling locations in low- and high-gradient reaches in the Tualatin River basin, Oregon, fall 2007. Habitats sampled at each were glides (G) or riffles (R).

Stream name	Study reach code	Macroinvertebrate sampling location	Habitat Sampled
Low-gradient reaches			
Ash Creek (Lower)	ASM2	Upstream of Greenburg Road	G
Beaverton Creek (Lower)	BCM1	Upstream of Cornell Road in Bronson Creek Park	G
Bronson Creek (Middle)	BRM2	Bronson Creek Park north of Cornell Road	G
Fanno Creek (Lower)	FLM1	Durham City Park, downstream of pedestrian bridge	G
Fanno Creek (Upper)	FUM2	Upstream of Nicol Road, (OES property)	G
Gales Creek (Lower)	GSM3	Downstream of B Street, Forest Grove	G
Gales Creek (Reference)	GSM4	Downstream of Roderick Road bridge	G
McFee Creek (Lower)	MFM2	Downstream of SW Hillsboro Highway (219)	G
McKay Creek (Middle)	MKM2	Downstream of NW Old Scotch Church Road	G
McKay Creek (Lower)	MKM3	Upstream of the confluence with Dairy Creek	G
Rock Creek (Lower)	RLM1	Downstream of River Road	G
Rock Creek (Middle)	RMM1	Off of the west end of NW Windstone Court	G
High-gradient reaches			
Bannister Creek (Lower)	BAM1	Upstream of Laidlaw Road	R
Bronson Creek (Upper)	BRM1	Upstream of Saltzman Road	R
Cedar Mill Creek (Upper)	CMM2	Upstream of 113th Street	R
Chicken Creek (Middle)	CNM2	Downstream of Edy Road	R
Christensen Creek (Upper)	CHM1	Upstream of Dixon Mill Road (above pond)	R
EF Dairy Creek Trib	DYM6	Upstream of Dairy Creek Road & Meacham Road intersection	G
Gales Creek (Middle)	GSM2	At access site off of Gales Creek Road (same site as GSM4)	R
McKay Creek	MKM4	NW Collins Road; adjacent to Bamboo nursery	G

communities were sampled from these stream reaches between September 11 and September 24, 2007. Physical habitat assessments and morning/afternoon water quality sampling occurred in each reach sampled for biological conditions as described below.

HABITAT ASSESSMENTS

Habitat surveys were performed in 100-m 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 2). First, the valley type within which each study reach occurred was broadly classified as U-type, V-type, ponded, or floodplain. A plan view of the reach was sketched as the survey was performed. The physical data were then collected using the procedures documented below.

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 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,

Table 2. Environmental parameters measured in the field to characterize streams in the Tualatin River basin, Oregon, fall 2007.

Variable	Quantitative or Categorical	Visual Estimate, Measured, or Calculated Variable
Valley type	C	V
Reach length	Q	M
Channel habitat units		
Maximum depth (m)	Q	M
Wetted width (m)	Q	M
Unit length (m)	Q	M
Dominant substrate	C	V
Percent embeddedness	Q	V
% Eroding banks	Q	V
% Undercut banks	Q	V
Large wood rating	Q	V
Overhead canopy cover	Q	M
Water surface slope (%)	Q	M
Percent riffles	Q	C
Percent glides	Q	C
Percent pools	Q	C
Large wood tally	Q	M
Channel cross sections		
Bankfull width (m)	Q	M
Max bank height (m)	Q	M
L and R bank angle (degrees)	Q	M
Substrate comp (Pebble Count)	Q	M
Riparian condition		
Mean riparian buffer width (m)	Q	V
% Tree cover in riparian zone	Q	V
% Shrub cover in riparian zone	Q	V
% Ground cover in riparian zone	Q	V
% Nonnative riparian vegetation	Q	V
Plant community type	C	V
Dominant adjacent land use	C	V
AM/PM water chemistry		
Water temperature (^{o}C)	Q	M
pH	Q	M
Specific conductance (µS/cm)	Q	M
Dissolved oxygen (mg/L)	Q	M
Dissolved oxygen saturation (%)	Q	C
Turbidity (NTU)	Q	M

then all three sets of measurements were taken from the riffle.

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 (left or right) 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.

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-meters high), shrub layer (0.5 to 5-meters 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 2007. 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 an 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 when necessary. All equipment was calibrated according to the quality control plan assembled for the project.

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. The best available habitat in low-gradient reaches was almost exclusively glide habitat. 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 × 30 cm (1 × 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 7× 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, Cummins, and Berg (2007), Wiggins (1995), Stewart and Stark (2002), and a number of regional and taxa-specific keys.

DATA ANALYSIS

Overall Approach

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, known as PREDATOR (PREDictive Assessment Tool for ORegon), is now being widely used for determination of biological conditions in Oregon rivers and streams. Three PREDATOR models are currently in use in Oregon; one of these three models—the Marine Western Coastal Forest (MWCF) Predictive Model—covers the Willamette Valley and Coast Range ecoregions (Hubler 2008). Currently, both the MWCF model and multimetric analysis have 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 MWCF model was used on both low and high-gradient data, but biological condition thresholds were modified for evaluating macroinvertebrate assemblages in low-gradient reaches.

In its present form, the MWCF model has limited applicability to streams in the Willamette Valley ecoregion, particularly those that occur on the valley floor whose natural character is significantly different from streams occurring in higher-elevation areas with more topographic relief. Owing to a paucity of reference sites on the Willamette Valley floor, the MWCF model has been calibrated with only two streams from the valley floor. Consequently, biological condition thresholds currently used with the MWCF model would not be appropriate for application to low-gradient streams and were not used to assess low-gradient reaches in this study. Instead, we evaluated conditions in low-gradient, valley-floor reaches by developing a coarse biological condition classification using data from the 10 least-disturbed Willamette Valley Prairie Terrace (i.e., valley floor) Ecoregion sites.

Multimetric Analyses

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 3). 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 3). 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 4).

MWCF Analysis

The MWCF model 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. The predictive model approach is an improvement over the IBI in 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. Because reference sites are lacking on the Willamette Valley Floor, neither tool has been developed to allow

Table 3. Metric set and scoring criteria (WQIW 1999) used to assess condition of macroinvertebrate communities in the Tualatin River basin, Oregon, fall 2007.

Metric	Scoring Criteria 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

Table 4. 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

accurate assessment of biological conditions of Willamette Valley floor streams that naturally lack coarse substrate and support little or no riffle habitat.

Discriminant functions analysis (DFA) is used to build predictive models that can predict taxonomic composition across a range of naturally occurring environmental gradients. DFA is used during the model building phase to identify the environmental variables that are statistically related to natural gradients in macroinvertebrate community composition. These "predictor variables" are then used in the resulting model to predict macroinvertebrate community composition in the absence of disturbance. The model assigns a probability of class membership of each test site to the different classes of test sites specified in the model based on the environmental predictor variables that are input into the model. In its current form the MWCF model uses longitude and sampling date as predictor variables; other variables likely to influence macroinvertebrate community composition in the Willamette Valley ecoregion, such as stream size, elevation, or channel slope, did not increase predictive power of the MWCF model, which explains the absence of these variables model in its current form. These other variables such as slope and elevation likely did not improve model performance because longitude accounted for variation in their values, resulting in their apparent omission from the final model. Therefore, these variables weren't omitted because they aren't important determinants of macroinvertebrate community composition, but because they had already been indirectly accounted for in the model with the inclusion of the variable, "longitude".

Once predictor variables and taxonomic data have been input into the model, the probability of occurrence of each taxon at a given test site (in the absence of disturbance) is calculated 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 model calculates the O/E score for each site. Using the MWCF biological condition thresholds (Hubler 2008), high gradient streams with O/E scores less than ≤0.85 (≤10th percentile of reference site scores) were classified as "most disturbed", 0.86 to 0.91 (>10th to 25th percentile) as "moderately disturbed," and 0.92 to 1.24 (25th to 95th percentile) as "least disturbed" (Table 5). The median score of 10 least-disturbed Willamette Valley Prairie Terrace Ecoregion sites (O/E = 0.68) was used as to classify biological conditions in low-gradient streams. Low-gradient streams with scores <0.68 were deemed "more impacted" the assessment, while streams scoring ≥0.68 were deemed "less impacted".

Following calculation of multimetric and O/E scores, relationships between O/E scores and selected environmental variables were examined among high-gradient and low-gradient sites separately 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. To facilitate exploration of relationships between physical and biological conditions, several classes of variables such as 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."

Table 5. O/E benchmarks for the Oregon Marine Western Coastal Forest (MWCF) predictive model (DEQ 2008).

Distribution Percentile	MWCF model reference score	Biological Condition Class
≤10th	≤0.85	Most Disturbed
>10th to 25th	0.86 - 0.91	Moderately Disturbed
>25th to 95th	0.92 - 1.24	Least Disturbed
>95th	>1.24	Enriched

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 6). High-gradient reaches were generally dominated by riffle-pool complex habitat, had a high percentage of coarse substrates, had a lower percentage of eroding banks, 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. Low-gradient reaches were generally dominated by slow moving glide and pool habitat; riffles were infrequent or completely absent. Substrate was predominately comprised of clay, silt, and sand. Banks in low-gradient reaches were less stable on average in comparison to high-gradient sites.

MACROINVERTEBRATE COMMUNITIES

MACROINVERTEBRATE SURVEY EFFORT

Macroinvertebrate communities were sampled from 20 stream reaches between September 11 and September 24, 2007. Reaches were classified into high and low-gradient reach types based largely on the classifications assigned in 2005 (Cole et al 2006). Classifications in 2005 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 6 high-gradient reaches and glide samples were collected from 12 low-gradient and two high-gradient stream reaches. While in previous years, the lower Fanno Creek site, FLM1, was classified as a high-gradient reach, an absence of riffles from the reach in 2007 resulted in reassigning this reach to the low-gradient reaches group. Also, the McKay Creek reach, MKM4, and the East Fork Dairy Creek tributary reach, DYM6, were reassigned to the high-gradient reach group after further consideration of their habitat characteristics, particularly the prevalence of riffle habitat and coarse substrates in each reach. Bannister Creek (BAM1), which was dry in 2005, was sampled in 2007. High flows in Scoggins Creek precluded safe and effective sampling in 2007.

CONDITIONS IN HIGH-GRADIENT REACHES

Macroinvertebrate community conditions ranged widely among high-gradient Tualatin basin stream reaches, as indicated by both O/E scores and DEQ multimetric scores. O/E scores from high-gradient reaches ranged from 0.43 to 0.81 and averaged 0.68, while 2005 O/E scores from these sites ranged from 0.34 to 0.83 and averaged 0.65 (Table 7). Using updated O/E condition thresholds (Hubler 2008), 2007 O/E scores occur exclusively in the “most disturbed” range. Using condition thresholds that were used in the 2005 assessment, but that have since been since superseded, 3 of the

Table 6. Environmental conditions of low-gradient and high-gradient stream reaches from which macroinvertebrates were sampled in the Tualatin River basin, Oregon, fall 2007.

	Reach Type					
	Low-gradient			High-gradient		
Environmental Variable	Mean	Min	Max	Mean	Min	Max
Wetted width (m)	7.0	2.4	17.8	4.4	1.2	17.8
Embeddedness (%)	92.9	69.4	100.0	53.7	31.0	86.8
Eroding banks (%)	63.0	8.5	99.6	42.3	14.6	83.4
Undercut banks (%)	13.9	0.0	54.0	18.9	0.0	59.0
Large wood rating	1.8	0.0	4.0	0.5	0.0	1.6
Overhead canopy cover (%)	76.9	20.9	96.5	87.3	20.9	99.1
Percent rapids	0.0	0.0	0.0	4.0	0.0	31.6
Percent riffles	1.7	0.0	17.0	40.5	17.0	64.7
Percent glides/runs	51.0	13.1	100.0	33.9	7.7	72.5
Percent pools	47.2	0.0	86.9	21.6	2.8	55.9
Large wood tally	0.1	0.0	0.3	0.0	0.0	0.1
Percent coarse substrate	19.1	0.0	83.1	55.7	2.7	83.1
Percent sand and fines	60.9	0.8	100.0	23.5	0.8	68.2
Percent hardpan	3.9	0.0	20.0	0.0	0.0	0.0
Mean riparian buffer width (m)	28.0	5.0	87.5	23.6	3.0	52.5
Tree cover in riparian zone (%)	51.5	5.0	80.0	56.9	5.0	75.0
Rip non-native veg cover (%)	62.0	37.5	87.5	51.6	12.5	87.5
PM Water temperature (^oC)	15.8	13.9	17.5	14.6	12.1	17.7
AM pH	7.4	7.3	7.6	7.5	6.9	7.9
Specific Conductance (µS/cm)	189.0	97.0	273.0	115.7	48.6	183.5
AM Dissolved oxygen (mg/L)	6.1	2.6	8.2	9.0	7.5	10.7
AM Dissolved oxygen (% sat)	60.6	26.5	78.4	83.5	72.2	95.9
Turbidity (NTU)	6.4	1.8	13.5	4.3	1.8	9.3

8 high-gradient reaches scored as “fair” rather than “poor”. Multimetric scores ranged from 18 to 40 and averaged 27.3, while in 2005, the range of scores was 20 to 38 and averaged 25.7 (Table 8). 2007 impairment classes derived from MMS scores ranged from unimpaired (1 site) to severe impairment (1 site); most sites were slightly (3 sites) to moderately impaired (3 sites). In comparison, 2005 multimetric scores indicated that 2 sites were slightly impaired and 5 sites were moderately impaired (one high gradient reach, BAM1 not sampled in 2005). Only Christensen Creek (CHM1) received an unimpaired multimetric score in 2007, while Bronson Creek (BRM1), Gales Creek (GSM2), and McKay Creek (MKM4) received slightly impaired classifications based on multimetric scores (Table 8). These four stream reaches represent least impaired conditions among streams sampled in 2007. These reaches support species-rich communities with high EPT richness and a collective sensitivity to habitat and water quality impairment. Thirty-eight taxa, including four mayfly taxa, seven stonefly taxa, and four caddisfly taxa were sampled in Christensen Creek, which received the highest multimetric score (40).

Sites receiving both the lowest multimetric scores (less than 20) and O/E scores included lower

Table 7. O/E scores and corresponding 2007 impairment classes of macroinvertebrate communities sampled from 8 high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2007. MWCF impairment classes include both current classes and those superseded by the current classes (for comparison with past reporting of 2005 conditions).

		MWCF O/E Scores and Condition Classes					
		2007 Samples			2005 Samples		
Reach Name	Reach Code	O/E Score	Current	Superseded	O/E Score	Current	Superseded
Gales Creek (Middle)	GSM2	0.814	Most disturbed	Fair	0.632	Most disturbed	Poor
Christensen Creek (Upper)	CHM1	0.782	Most disturbed	Fair	0.682	Most disturbed	Poor
Bronson Creek (Upper)	BRM1	0.778	Most disturbed	Fair	0.827	Most disturbed	Fair
Dairy Creek Trib (DYM6)	DYM6	0.732	Most Disturbed	Poor	0.727	Most disturbed	Poor
McKay Creek (MKM4)	MKM4	0.731	Most Disturbed	Poor	0.678	Most disturbed	Poor
Bannister Creek (Lower)*	BAM1	0.631	Most disturbed	Poor	--	--	
Chicken Creek (Middle)	CNM2	0.535	Most disturbed	Poor	0.680	Most disturbed	Poor
Cedar Mill Creek (Upper)	CMM2	0.438	Most disturbed	Poor	0.340	Most disturbed	Poor

Table 8. Multimetric scores and corresponding impairment classes of macroinvertebrate communities sampled from 8 high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2007. The right-hand columns represent 2001 and 2005 multimetric scores. Multimetric score corresponding levels of impairment: <20 = severe, 20-29 = moderate, 30-39 = slight, >39 = unimpaired.

		2007		2005		2001	
Reach Name	Reach Code	Multimetric Score	Impairment class	Multimetric Score	Impairment class	Multimetric Score	Impairment class
Christensen Creek (Upper)	CHM1	40	Unimpaired	24	Moderate	34	Slight
Gales Creek (Middle)	GSM2	32	Slight	30	Slight	20	Moderate
Bronson Creek (Upper)	BRM1	30	Slight	22	Moderate	32	Slight
McKay Creek (MKM4)	MKM4	30	Slight	38	Slight	--	--
Dairy Creek Trib (DYM6)	DYM6	28	Moderate	24	Moderate	--	--
Cedar Mill Creek (Upper)*	CMM2	20	Moderate	20	Moderate	--	--
Chicken Creek (Middle)	CNM2	20	Moderate	22	Moderate	20	Moderate
Bannister Creek (Lower)**	BAM1	18	Severe	--	--	18	Severe

Bannister Creek (BAM1), middle Chicken Creek (CNM2), and upper Cedar Mill Creek (CMM2) (Tables 7 & 8). The communities occurring in these waters are characterized by low taxa richness, low EPT richness, and a high collective tolerance to disturbance. Upper Christensen Creek showed the largest improvement in multimetric scores from 2005 to 2007, scoring 16 points higher in 2007 (Table 8). In 2005 Christensen Creek supported a relatively rich community of 28 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. In 2007, 38 taxa were sampled in the same reach and only 23 individual *Juga* snails were sampled. The upper Bronson Creek reach scored 8 points higher in 2007 in comparison to 2005, resulting in a change from a moderately impaired classification to a slightly impaired classification. A decrease of ten points was previously noted for this reach between 2001 and 2005, suggesting a decrease in biological integrity had occurred (Table 7).

While high-gradient-reach O/E scores were statistically correlated with those produced by the multimetric index ($r^2 = 0.650$, $p = 0.008$; Figure 1), biological condition classes were not in agreement between the two approaches. Of eight high-gradient sites, four were classified as severely to moderately impaired using multimetric scoring. These three sites received a “most-disturbed” classification using O/E scores. Middle Gales Creek (GSM2), upper Christensen Creek (CHM1), upper Bronson Creek (BRM1), and McKay Creek (MKM4) reaches scored in the “unimpaired” or “slight impairment” range (Table 8), while O/E scores from all four of these reaches were in the “most disturbed” range (Table 7).

CONDITIONS IN LOW-GRADIENT REACHES

O/E scores from 12 low-gradient reaches ranged from 0.195 to 0.488 and averaged 0.344 (Table 9). Using biological condition thresholds adjusted for valley-floor streams as described earlier, these 12 reaches scored exclusively in the “more impacted” range. O/E scores from each of

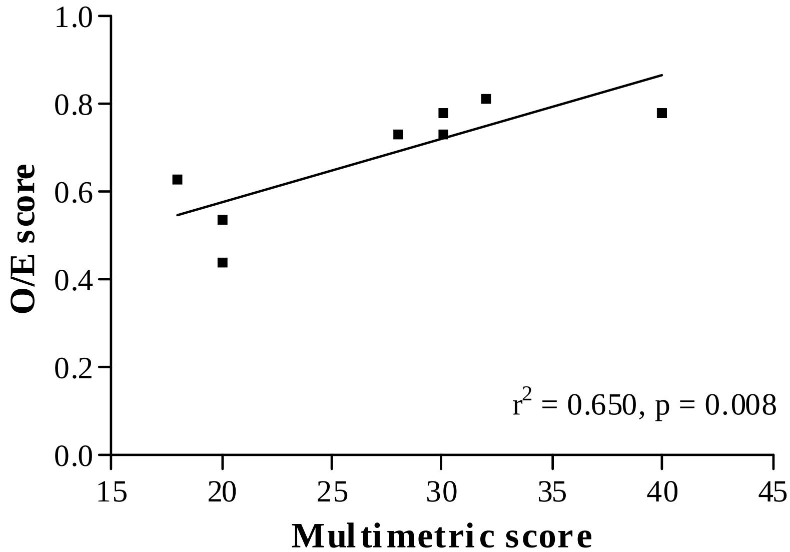

Figure 1. Relationship between O/E scores and multimetric scores derived from macroinvertebrate community samples collected from high-gradient stream reaches in the Tualatin River basin, fall 2007.

Table 9. MWCF model O/E scores from 12 low-gradient stream reaches in the Tualatin River basin, Oregon, fall 2007.

		2007		2005	
Reach Name	Reach Code	O/E Score	WV Floor Condition	O/E Score	Impairment class
McKay Creek (Middle)	MKM2	0.488	More Impacted	0.436	More Impacted
Gales Creek (Middle)	GSM4	0.431	More Impacted	0.243	More Impacted
McKay Creek (Lower)	MKM3	0.293	More Impacted	0.469	More Impacted
Rock Creek (Lower)	RLM1	0.292	More Impacted	0.343	More Impacted
Bronson Creek (Middle)	BRM2	0.390	More Impacted	0.390	More Impacted
Fanno Creek (Lower)	FLM1	0.389	More Impacted	0.387	More Impacted
Gales Creek (Lower)	GSM3	0.382	More Impacted	0.390	More Impacted
Rock Creek (Middle)	RMM1	0.341	More Impacted	0.340	More Impacted
McFee Creek (Lower)	MFM2	0.341	More Impacted	0.146	More Impacted
Fanno Creek (Upper 2)	FUM2	0.340	More Impacted	0.195	More Impacted
Ash Creek (Lower)	ASM2	0.243	More Impacted	0.244	More Impacted
Beaverton Creek (Lower)	BCM1	0.195	More Impacted	0.293	More Impacted

the 12 sites were lower than 0.68, using an interim threshold (more impacted/less impacted) established to determine biological conditions in Tualatin Valley floor streams.

Individual metrics calculated from macroinvertebrate communities collected in low-gradient reaches varied widely (Table 10). Taxa richness ranged from 11 to 22 taxa and averaged 16 taxa. EPT richness—the number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera caddisfly) taxa found in a given reach—ranged from 0 to 7 and averaged 1 taxon. No EPT taxa were sampled from 6 of the 12 sites, including lower Ash Creek (ASM2), lower Beaverton Creek (BCM1), upper Fanno Creek (FUM2), lower McFee Creek (MFM2), lower McKay Creek (MKM3), and middle Rock Creek (RMM1). Such reaches generally exhibited low taxa richness, high dominance by one or a few tolerant taxa, and a high community-wide tolerance to disturbance.

ENVIRONMENTAL CORRELATIONS

Among measured environmental variables, O/E scores for high-gradient ($n = 8$) sites were significantly correlated only with substrate embeddedness and percent sand and fine substrates (Table 11). Unlike previous studies, scores were not statistically correlated ($p > 0.05$)with measures of water quality including temperature, dissolved oxygen concentration, and specific conductance (Table 11). The small sample size for this study likely resulted in fewer statistically significant correlations than have been reported in past years (e.g., Cole et al. 2006).

DISCUSSION

As in previous assessments (performed in 2001 and 2005) of macroinvertebrate communities of Tualatin River basin streams, macroinvertebrate community conditions varied widely among stream reaches sampled during 2007. This range in community conditions reflects both the natural variation in stream types and characteristics, as well as the wide range of anthropogenic effects on area streams. In the three sampling years, less variation was observed in both multimetric and O/E scores at the lower end of the range of scores (i.e., with sites with moderate to severe levels of impairment or those with “poor” community condition). Conversely, at the higher end of the range of scores, more variability was noted in both multimetric and O/E scores over the three years in which macroinvertebrate communities were sampled.

In 2005, middle Gales Creek (GSM2) scored considerably higher than in 2001, with multimetric scores of 30 and 20 respectively. The reach scored another two points higher in 2007 and was the only high-gradient site where an increase in multimetric scores was noted over the three sampling years. Upper Christensen Creek (CHM1) and upper Bronson Creek (BRM1) each scored 10 points lower in 2005 than in 2001. In 2007, multimetric scores from these sites increased by 16 and 12 points, respectively. While smaller differences in metric values have been shown to result from spatial variation and sampling error, larger differences of eight or more points are more likely attributable to real temporal changes occurring to the benthic community. For example, among three recently completed macroinvertebrate assessments in the area, the difference between duplicate samples averaged 2.5 multimetric points and ranged from 0 to 6 points ($n = 12$; Cole 2002, Cole et al. 2006, Lemke & Cole 2007), suggesting that the amount of variability that sampling error and spatial variability can introduce into multimetric-score calculations is generally limited to this range of values. The lower scores observed for Christensen Creek and Bronson Creek in 2005 were likely due to the large number of tolerant *Juga* snails observed in the samples, comprising 37.7% and 29.5% of the organisms sampled at Christensen and Bronson Creeks, respectively. In comparison, *Juga* snails only comprised 4.7% and 15.1% of the organisms sampled in 2007.

Low-gradient reaches generally supported fewer taxa, fewer sensitive taxa, many fewer EPT taxa, and larger numbers of tolerant organisms than did the higher-gradient reaches. While these differences between low and high-gradient streams are likely exacerbated by human activities on the valley floor, bioassessment activities are currently unable to separate human-induced changes to valley floor macroinvertebrate assemblages from naturally occurring differences in community composition.

Table 10. Individual metrics calculated from macroinvertebrate communities sampled from 13 low-gradient stream reaches in the Tualatin River basin, Oregon, fall 2007.

Stream Reach	High/Low Gradient	Riffle/Glide Sample	Site code	Richness	Mayfly Richness	Stonefly Richness	Caddisfly Richness	Number Sensitive Taxa	# Sediment Sensitive Taxa	Modified HBI	% Tolerant Taxa	% Sediment Tolerant Taxa	% Dominant
Ash Creek (Lower)	L	G	ASM2	17	0	0	0	0	0	5.9	49.9	42.0	31.9
Beaverton Creek (Lower)	L	G	BCM1	12	0	0	0	0	0	6.4	51.2	47.5	41.9
Bronson Creek (Middle)	L	G	BRM2	20	1	0	1	0	0	5.7	34.2	32.0	42.2
Fanno Creek (Lower)	L	G	FLM1	16	1	0	1	0	0	5.7	41.7	24.9	48.6
Fanno Creek (Upper)	L	G	FUM2	16	0	0	0	0	0	6.6	17.2	17.0	39.6
Gales Creek (Lower)	L	G	GSM3	20	1	1	0	0	0	6.2	56.5	44.2	32.7
Gales Creek (Reference)	L	G	GSM4	17	5	0	2	0	0	4.6	91.1	71.2	66.7
McFee Creek (Lower)	L	G	MFM2	13	0	0	0	1	0	6.1	49.8	47.7	44.9
McKay Creek (Middle)	L	G	MKM2	22	1	0	2	0	0	6.4	33.1	27.4	25.1
McKay Creek (Lower)	L	G	MKM3	15	0	0	0	0	0	6.8	45.0	41.6	34.9
Rock Creek (Lower)	L	G	RLM1	16	1	0	0	0	0	6.2	78.7	36.1	38.7
Rock Creek (Middle)	L	G	RMM1	11	0	0	0	0	0	6.2	54.1	54.1	50.5
Bannister Creek (Lower)	H	R	BAM1	30	2	3	2	1	1	5.6	55.2	51.9	25.9
Bronson Creek (Upper)	H	R	BRM1	32	5	3	5	2	1	4.7	25.2	18.5	21.2
Cedar Mill Creek (Upper)	H	R	CMM2	22	2	0	2	0	0	5.8	18.4	10.1	18.1
Chicken Creek (Middle)	H	R	CNM2	21	3	2	2	2	0	6.1	22.3	6.4	23.2
Christensen Creek (Upper)	H	R	CHM1	38	4	7	4	4	2	4.2	13.0	16.2	34.2
EF Dairy Creek Trib	H	G	DYM6	35	9	7	3	3	0	5.2	26.1	24.6	23.1
Gales Creek (Middle)	H	R	GSM2	27	9	6	2	0	1	3.7	21.7	10.1	34.8
McKay Creek	H	G	MKM4	36	7	5	7	1	2	0.0	45.9	26.2	22.5

Table 11. Means, ranges, and correlation with O/E scores of selected environmental variables measured at 8 high-gradient stream reaches in the Tualatin River basin, Oregon, fall 2007. Asterisks (*) beside p-values indicate significant correlation at alpha = 0.05.

			O/E Scores	
Variable	Mean	Range	Spearman rho	*p* value
Coarse substrate (%)	56	3–83	0.251	0.268
Sand and fines (%)	23	1–68	-0.738	**0.023***
Embeddedness (%)	37	4–75	-0.857	**0.005***
Riparian buffer width (m)	24	3–53	0.071	0.441
Riparian tree cover (%)	57	5–75	-0.443	0.134
Non-native riparian vegetation (%)	52	13–88	-0.228	0.291
PM water temperature (^{o}C)	14.6	12.1–17.7	-0.167	0.352
Specific conductance (µS/cm)	115.7	48.6–183.5	-0.347	0.195
AM dissolved oxygen (mg/L)	9.0	7.5–10.7	0.191	0.332

O/E and multimetric scores were highly correlated, but there was little agreement in biological condition classes between the two approaches. The MWCF model consistently produced lower (or equal) condition classes than did the multimetric tool. Importantly, DEQ uses the MWCF model to assess biological conditions in wadeable streams, so any assessments should include the use of this tool.

Collectively, our results suggest that biological conditions in sites that have previously been classified as moderately to severely-impaired sites have largely remained unchanged. Conversely, sites that have previously scored in the upper range of multimetric and O/E scores exhibit more annual variation. In order to better quantify community conditions in these streams that exhibit wider temporal variability, we recommend collecting triplicate samples at these sites showing a wider range of scores to produce statistical measures of confidence in estimates of average condition. Such estimates will better inform these monitoring efforts to detect trends in community conditions over time in relation to land use changes, water resource management programs, and restoration activities occurring in the Tualatin River basin.

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