CLACKAMAS COUNTY NPDES MS4 CO-PERMITTEES
2013 COORDINATED MACROINVERTEBRATE ASSESSMENT

Clackamas County, Oregon

FINAL REPORT

Prepared for

City of Gladstone
City of Lake Oswego
City of Milwaukie
City of Oregon City
City of West Linn
City of Wilsonville

By

Michael B. Cole, Ph.D.
Cole Ecological, Inc.

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EXECUTIVE SUMMARY

In 2013, six Clackamas County jurisdictions, including the cities of Gladstone, Lake Oswego, Milwaukie, Oregon City, West Linn, and Wilsonville, participated in biological monitoring as required during the 2012-2017 NPDES MS4 permit period. Cole Ecological, Inc. sampled macroinvertebrate communities, stream physical habitat, and water chemistry from seventeen stream reaches across these six jurisdictions in the fall of 2013. The objectives of the study were to assess the current status of chemical, physical, and biological conditions in these waters, and as applicable, determine whether noticeable trends in improvement or decline in biological conditions are occurring.

Multimetric Index (MMI) scores and PREDATOR Marine Western Coastal Forest O/E scores indicated biological conditions generally similar to those measured in 2009 across the ten Lake Oswego study reaches. MMI scores ranged among the ten Lake Oswego reaches from 10 to 24, and eight of the ten sites scored lower than 20, corresponding to "severely disturbed" biological conditions. Only the Springbrook Creek restoration reach (MMI score = 20) and the Tryon Creek reach (MMI score = 24) scored outside of the "severely disturbed" range. PREDATOR O/E scores ranged from 0.194 to 0.437, occurring exclusively in the "most disturbed" condition class. The lower Springbrook Creek reach's MMI score of 20 represented the largest difference from 2009 scores, when this reach received the lowest possible MMI score of 10. Tryon Creek notwithstanding, only the Springbrook Creek restoration reach MMI score occurred outside its 2004-2009 range. Temperature stressor (TS) scores indicate that compositional shifts in macroinvertebrate communities have occurred in seven of the ten Lake Oswego stream reaches. Only lower Lost Dog Creek, East Lost Dog Creek, and Nettle Creek appear to support macroinvertebrate communities unaffected by elevated water temperatures. Fine sediment stressor (FSS) scores from all nine Lake Oswego samples collected from riffle habitats (i.e., all reaches other than Carter Creek) indicated likely sediment-induced stress on macroinvertebrate communities in these reaches.

MMI scores ranged from 14 to 36 among the seven reaches assessed by the other five co-permittees. Coffee Creek received the highest MMI score of 36, corresponding to a slightly disturbed biological condition. Singer Creek scored a 30, corresponding to slightly/moderately disturbed. Boeckman Creek received an MMI score of 20, indicating moderately/severely disturbed conditions. Minthorn and Tanner creeks both scored in the severely disturbed range. PREDATOR O/E scores ranged from 0.242 to 0.630, exclusively within the "most disturbed" condition class among the seven co-permittee reaches. Rinearson Creek received the lowest MMI and O/E scores among the seven co-permittee reaches; however, riffles were nearly absent from this reach, necessitating sampling macroinvertebrates from sand-dominated glide habitat. As such, condition classes were not assigned to the community scores calculated for this reach. Among the seventeen study reaches, only Rinearson Creek and Lost Dog Creek at Lake Front Road samples failed to support any EPT taxa. Temperature stressor (TS) scores indicate temperature-stress-induced shifts in macroinvertebrate communities have likely occurred in four of the seven co-permittee reaches, including Boeckman, Minthorn, Rinearson, and

Trillium creeks. Fine sediment stressor (FSS) scores indicate FS-induced stress in all six reaches from which riffle samples were collected. Generally high embeddedness values across all study reaches corroborate this finding.

Recovery of biological communities in these area streams is dependent on identifying and improving stream conditions and functions that are currently impaired. While additional water quality data would further elucidate likely cause-effect relationships, stressor model results, combined with the results of physical habitat assessments, are suggestive of multiple stressors co-occurring in most streams assessed in this study. This phenomenon, known as "urban stream syndrome" or "multiple stress syndrome" is well documented among urban streams (Walsh et al. 2005). Mechanisms driving the syndrome are complex, yet stream hydro-modification from efficient stormwater delivery into receiving waters is largely responsible for the various perturbations observed and measured in this and other studies. Protection of area streams should focus on maximizing riparian buffer protection, minimizing total effective impervious areas, and improving stormwater retention and drainage patterns to minimize the hydrologic effects of storm events on stream channel conditions. As stormwater best management practices and other restoration activities are undertaken, these data will assist with determining the success of these actions relative to their intended benefits to aquatic life.

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INTRODUCTION

As a condition of the Clackamas County National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit, Clackamas County co-permittees have developed a comprehensive NPDES MS4 stormwater monitoring program (Brown and Caldwell 2012). This NPDES stormwater monitoring program includes biological monitoring throughout the Clackamas MS4 permit area that is intended to address the following objectives:

- Evaluate status and long-term trends in receiving waters associated with MS4 stormwater discharges; and
- Assess the chemical, biological, and physical effects of MS4 stormwater discharges on receiving waters

Specifically, the comprehensive monitoring plan states that monitoring activities will attempt to address the following questions (Brown and Caldwell 2012):

- What are the biological conditions of receiving waters?
- Based on historic macroinvertebrate sampling efforts (as applicable), are there noticeable trends of improvement or impairment in receiving waters?

In 2013, six Clackamas County jurisdictions, including the cities of Gladstone, Lake Oswego, Milwaukie, Oregon City, West Linn, and Wilsonville, participated in biological monitoring as required during the 2012-2017 NPDES MS4 permit period. Among these jurisdictions, only the City of Lake Oswego performs regular biological monitoring of their receiving waters, having assessed macroinvertebrate communities in 2004, 2007, and 2009 (Lemke & Cole 2009). The City of Wilsonville last performed a macroinvertebrate assessment in 2003 (Cole 2003). The 2013 assessment represented the first biological assessment by the other jurisdictions of their receiving waters.

In the present study, Cole Ecological (CE), Inc. sampled macroinvertebrate communities, stream physical habitat, and water chemistry from seventeen stream reaches across these six jurisdictions in the fall of 2013. As stated above the objectives of the study were to assess the current status of chemical, physical, and biological conditions in these waters, and as applicable, determine whether noticeable trends in improvement or decline in biological conditions are occurring.

METHODS

SAMPLE SITE SELECTION

Sample sites were selected for the cities of Lake Oswego and Wilsonville to correspond with previously assessed locations in order to determine whether trends or

changes in biological conditions have occurred as compared to prior sampling efforts (Table 1 and Figure 1). Sample sites within the City of Lake Oswego were selected in 2004 and 2007 (Cole & Harris 2004; Lemke & Cole 2007) to provide representative coverage of perennial streams within the city. Six reaches were initially selected and sampled in 2004 (Table 1). In 2007, an additional five reaches were added to the previously surveyed reaches, while the Blue Heron Creek reach was dropped from sampling. These same ten stream reaches were sampled for the City of Lake Oswego in 2009 and 2013.

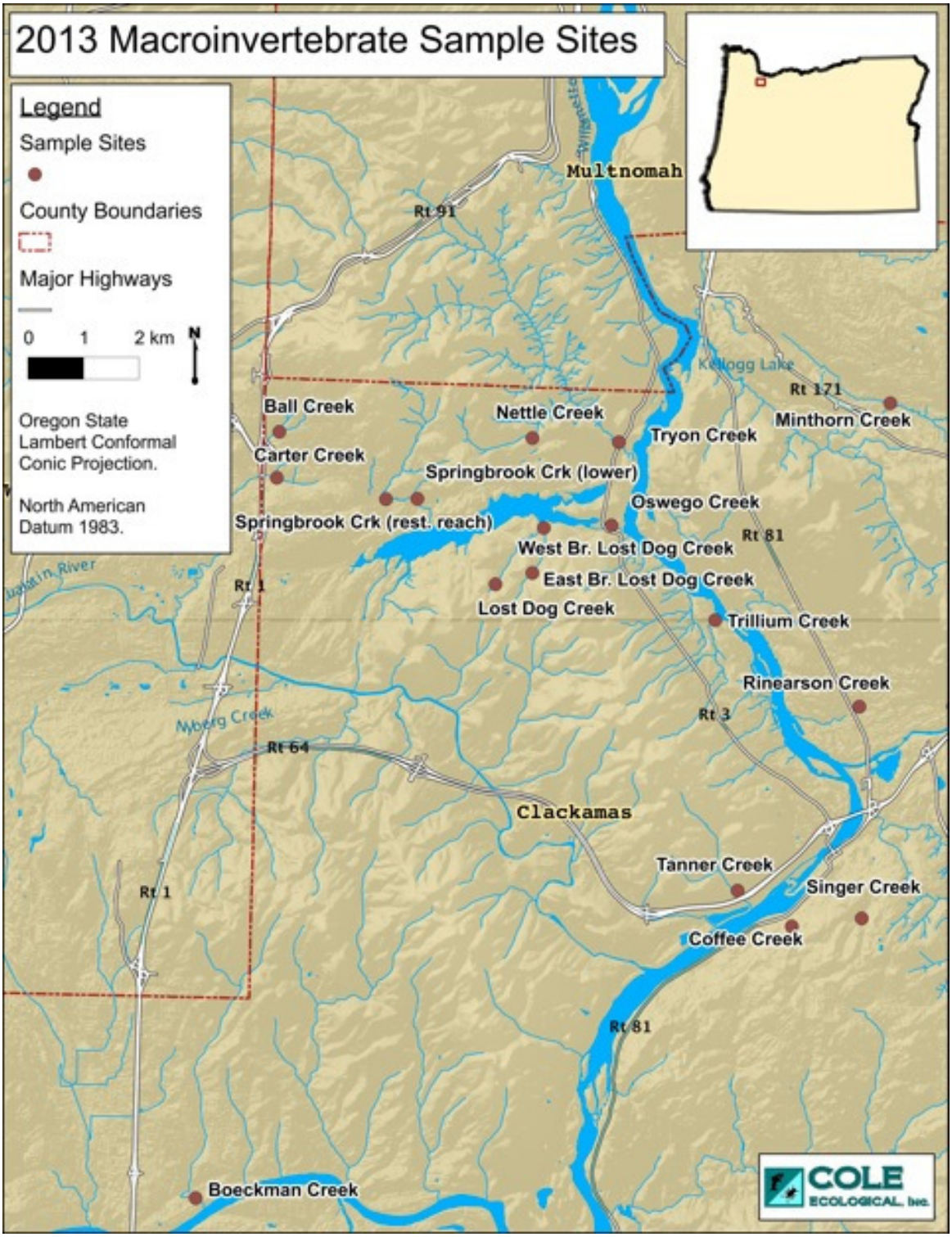
The City of Wilsonville performed a comprehensive biological assessment of eleven reaches in Boeckman Creek, Coffee Lake Creek, and Mill Creek in 2003 (Cole 2004). One reach in Boeckman Creek, presently also used as a water quality monitoring station by the City, was re-assessed in the present study.

The cities of Gladstone, Milwaukie, Oregon City, and West Linn have not previously performed macroinvertebrate sampling. Macroinvertebrate sample sites within these jurisdictions were co-located with current water quality and pesticide monitoring sites in order to provide greater opportunity for examining relationships between water quality and biological conditions (Brown and Caldwell 2012).

Sample Site	Location	Jurisdiction	Habitat Sampled	Lat	Long	Past Assessments
Rinearson Creek	Outfall at Risley Rd	Gladstone	Glide	45.3822	-122.6038	
Ball Creek	Ball Crk at Kruse Oaks	Lake Oswego	Riffle	45.4245	-122.7403	04, 07, 09
Carter Creek	Carter Crk at Bangy	Lake Oswego	Glide	45.4170	-122.7406	07, 09
East Br. Lost Dog Creek	@ Stafford Rd	Lake Oswego	Riffle	45.4026	-122.6806	07, 09
Lost Dog Creek	@ Lake Front Dr	Lake Oswego	Riffle	45.4006	-122.6891	04, 07, 09
Nettle Creek	at Iron Mtn Blvd	Lake Oswego	Riffle	45.4246	-122.6814	04, 07, 09
Oswego Creek	downstream of Hwy 43)	Lake Oswego	Riffle	45.4107	-122.6625	07, 09
Springbrook Crk (lower)	at Iron Mtn Park	Lake Oswego	Riffle	45.4142	-122.7078	04, 07, 09
Springbrook Crk (rest.)	upstream of Boones Way	Lake Oswego	Riffle	45.4140	-122.7151	04, 07, 09
Tryon Creek	Upstream of Hwy 43	Lake Oswego	Riffle	45.4243	-122.6613	07, 09
West Br. Lost Dog Creek	Lake O. Golf Course	Lake Oswego	Riffle	45.4100	-122.6782	07, 09
Minthorn Creek	SE Lake Road	Milwaukie	Riffle	45.4318	-122.5984	
Coffee Creek	Lower Coffee Creek	Oregon City	Riffle	45.3461	-122.6182	
Singer Creek	Singer Creek Park	Oregon City	Riffle	45.3477	-122.6020	
Tanner Creek	Imperial Drive	West Linn	Riffle	45.3517	-122.6310	
Trillium Creek	Caloroga Rd	West Linn	Riffle	45.3957	-122.6378	
Boeckman Creek	Downstream of Rose Ln	Wilsonville	Riffle	45.2992	-122.7549	03

Table 1. List of 2013 Clackamas County MS4 co-permittee macroinvertebrates sample sites.

Figure 1. 2013 Clackamas County NPDES co-permittees macroinvertebrate sample sites.



FIELD DATA COLLECTION

Macroinvertebrate communities, physical habitat, and water chemistry were sampled at the seventeen study reaches between 14 and 22 September, 2013. First, each study reach was marked and the reach length was measured. Each sample reach measured approximately 75 m, unless the sample reach was obstructed by a culvert, heavy vegetation, or other impediments.

HABITAT ASSESSMENTS

Habitat surveys were performed in the reaches following modified Rapid Stream Assessment Technique (RSAT) protocols (adapted from Clean Water Services 2000) 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 following procedures:

HABITAT UNITS SURVEY

The number, length, width, maximum water depth, and gradient 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. Pools are 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%.

Rapid: 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.

Variable	Quantitative or Categorical	Visual Estimate or Measured Variable
Wetted Width	Q	M
Bankfull Width	Q	M
Bankfull Height	Q	M
Mean Water Depth	Q	M
Pools (% of reach length)	Q	M
Glides (% of reach length)	Q	M
Riffles (% of reach length)	Q	M
Rapids (% of reach length)	Q	M
Cascades (% reach length)	Q	M
Reach Embeddedness (%)	Q	V
Eroding Banks (%)	Q	V
Undercut Banks (%)	Q	V
Substrate Composition	Q	M
Substrate Embeddedness (%)	Q	M
Large Wood Rating	Q	M
Overhead Canopy Cover (%)	Q	M
Riparian Buffer Width	Q	V
Riparian Zone Tree Cover (%)	Q	V
Non-native Riparian Veg. Cover (%)	Q	V
Dominant Adjacent Land Use	C	V
Water Temperature (^{o}C)	Q	M
Specific Conductance (µS/cm)	Q	M
Dissolved Oxygen (mg/L)	Q	M

Table 2. Environmental variables measured in the field for characterizing stream reaches sampled for macroinvertebrates in Clackamas County, fall 2013.

Cascade: Fast, turbulent flow with many hydraulic jumps and strong chutes and eddies, 30–80% white water. Gradients approaching or exceeding 10.0%.

The following attributes were then measured or visually estimated in each channel unit. Dominant substrate was visually estimated in each unit using substrate size classes adapted from EPA's Environmental Monitoring & Assessment Program (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 cm in diameter (at estimated diameter breast height) and 2 m in length was tallied for each unit and the configuration, type, location, and size of root wads and pieces of wood were noted. Overhead cover was measured with a spherical densiometer in four directions (upstream, downstream, right, left) from the center of the stream at evenly spaced intervals along the length of the reach (usually every 15 m). 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 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 m 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 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 beyond the 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 m high), shrub layer (0.5 to 5 m high), and groundcover layer (<0.5 m high) was estimated, as well as the percent cover of invasive or non-native species as a single estimate across all three vegetative layers. The dominant adjacent land use outside of the vegetated riparian 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 prior to collecting macroinvertebrates and performing the reach habitat assessment. Measured water quality parameters included temperature (°C), dissolved oxygen (mg/L), oxygen saturation (%), conductivity (µS/cm), and specific conductance (µS/cm). Water temperature, dissolved oxygen, conductivity, and specific conductance were measured in situ with a YSI Model 85 water chemistry meter. The YSI was re-calibrated for dissolved oxygen saturation at each sample site according the manufacturer's instructions.

MACROINVERTEBRATE SAMPLE COLLECTION

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 in higher-gradient reaches that supported sufficient riffle habitat; glides were sampled from lower-gradient reaches that lacked riffle 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 (30 cm wide, 500 µm mesh opening) from a 30 x 30 cm (1 x 1 ft) area at each sampling point. Larger pieces of substrate, when encountered, were first hand-washed inside the net, and then placed outside of the sampled area. Then the area was thoroughly disturbed by hand (or by foot in deeper water) to a depth of ~10 cm.

The eight samples from the reach were composited and carefully washed through a 500 µm sieve to strain fine sediment and hand 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% denatured ethanol for later sorting and identification at the laboratory.

SAMPLE SORTING AND MACROINVERTEBRATE IDENTIFICATION

Samples were sorted to remove a 500-organism subsample from each preserved sample following the procedures described in the DEQ Level 3 protocols (Water Quality Interagency Workgroup [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 transferred to a Petri dish, which was examined under a dissecting microscope at 7–10X 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 generally identified to the level of taxonomic resolution recommended for Level 3 macroinvertebrate assessments by the Northwest Biological Assessment Working Group (NBAWG 2002).

DATA ANALYSIS

A number of standard analytical approaches exist for assessing the condition of macroinvertebrate communities in western Oregon. These approaches can be broadly classified as multimetric indexes and predictive models. Existing tools for analysis of macroinvertebrate data in western Oregon have been developed from, and therefore are only appropriate for, assessment of assemblages collected from coarse substrates (gravels and cobble) in riffle habitat. Consequently, the use of existing bioassessment tools and their attendant condition thresholds is inappropriate for assessing the condition of benthic communities from low-gradient (generally <1.5% slope) streams dominated by fine substrates and glide/pool habitat. Analysis of glide samples collected from these streams with existing bioassessment tools would result in artificially lower index scores and classification of condition. In the present study, two of the seventeen sample sites supported only glide habitat and fine substrates, a condition likely naturally occurring in each system. Accordingly, these two sites were not assigned condition classifications following data analysis.

MULTIMETRIC INDEX ANALYSIS

Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that has been shown 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. Metric sets and

standardized metric scoring criteria are developed and calibrated for specific stream types and geographic locales. The DEQ has developed and currently employs a 10-metric set for use with riffle samples from higher-gradient streams in western Oregon (WQIW 1999). Owing to the lack of reference conditions for low-gradient, glide-dominated valley-floor streams, no multimetric index currently exists for such stream types in this region.

The DEQ 10-metric set includes six positive metrics that score higher with improved biological conditions, and four negative metrics that score lower with improved conditions (Table 3). Mayflies (order Ephemeroptera), stoneflies (order Plecoptera), and caddisflies (order Trichoptera) are widely regarded among the aquatic insect orders as the most sensitive to water pollution and habitat degradation; accordingly, three metrics in the index summarize taxonomic richness within these three insect orders. These three orders of insects are collectively referred to as the "EPT" taxa, derived from the first letter in each of the order names.

	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 3. Multi-metric set and scoring criteria (WQIW 1999) used to assess the condition of macroinvertebrate communities from Clackamas County streams in fall 2013.

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 reach. Values of the index range from 1 to 10; higher scores are interpreted as an indication of a macroinvertebrate community more tolerant to fluctuations in water temperature, fine sediment inputs, and organic enrichment. 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.

The DEQ taxa attribute coding system was used 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).

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

Table 4. Multimetric score ranges for assignment of macroinvertebrate community condition levels (WQIW 1999).

PREDATOR MWCF MODEL

PREDATOR is a predictive model that evaluates macroinvertebrate community conditions based on a comparison of observed (O) to expected (E) taxa (Hawkins et al. 2000, Hubler 2008). The observed taxa are those that occurred at the reach, whereas the expected taxa are those expected to occur (>50% probability of occurrence) in the reach in the absence of disturbance. Biological condition is determined by comparing the O/E score at the test site to the distribution of reference reach O/E scores in the model. One major strength of PREDATOR over the multimetric approach 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 multimetric tools would have to be developed to make accurately assess condition. PREDATOR is able to predict taxonomic composition across a range of naturally occurring environmental gradients with discriminant functions models (DFMs). Discriminant functions analysis is used during the model building phase to identify the environmental variables that are statistically related to natural gradients in macroinvertebrate community composition (Hawkins et al. 2000). These "predictor variables" are 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.

Several geographically specific PREDATOR models are currently in use in Oregon. The Marine Western Coastal Forest (MWCF) model includes the Willamette Valley and lower western foothills of the Cascades. Accordingly, this model was used for the present study. Predictor variables and taxonomic data were input into the model, which

calculated the probability of occurrence of each taxon at each study site (in the absence of disturbance). With this information, the model calculates the O/E score for each site. Using the MWCF biological condition thresholds (Hubler 2008), higher-gradient streams with O/E scores ≤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."

STRESSOR MODELS

Weighted-average (WA) inference models were developed by DEQ (Huff et al. 2006) to reveal shifts in macroinvertebrate assemblage composition that implicate either substrate degradation (i.e. fine sediment pollution) or temperature pollution. These WA inference models for temperature and sediment are to be used as screening tools to assist with detecting the source(s) of stress to biological communities in wadeable Oregon streams. Inferred values at a test site are compared to conditions observed at regional reference sites to determine if there is a difference in assemblage-level preferences for temperature or fine sediment (Huff et al. 2006). The 75th percentile of the distribution of inferred temperature and fine-sediment values from regional reference sites is used to determine whether a particular site is potentially stressed by one or both of these attributes.

In the analysis for this study, temperature stress and fine-sediment stress weighted-average inference models were first run to derive estimates of inferred water temperatures (temperature scores, or TS) and sediment levels (fine sediment scores, or FSS) in each study reach. Both temperature and fine-sediment models were applied to riffle data, while only the temperature model was applied to glide data. Glide data were not run through the fine-sediment model because fine sediment levels would be expected to differ significantly between the higher- and lower-gradient reach types. For riffle samples, DEQ's thresholds of 18.2ºC for temperature and 15% of fine sediment (75th percentile of the distribution of DEQ Willamette Valley reference site scores) were used to determine whether each was a potential stressor in each sample reach (Huff et al. 2006). In lower-gradient reaches that supported only glide and pool habitats, DEQ's 90th percentile temperature value of 18.4^{o}C was used to initially assess temperature as a potential stressor in this reach type (DEQ, unpublished data).

RESULTS

ENVIRONMENTAL CONDITIONS

LAKE OSWEGO STREAM REACHES

Land use adjacent to the ten previously assessed Lake Oswego study reaches did not change significantly from 2009 to 2013. Study reaches primarily occurred in areas dominated by moderate density residential land use within Lake Oswego's city limits. Reaches were represented by a range of stream channel and riparian conditions (Table 5). Across most sites, stream habitat was co-dominated by riffle and pool habitats; riffle habitat averaged 42% across all study reaches, while pool habitat averaged 46% (Table 5). Carter (14.7% riffle habitat) and West Lost Dog (16.2% riffle habitat) creeks supported the lowest frequency of riffle habitat. In 2013, it was noted that Carter Creek's "riffle" habitat was limited to a short section of creek in the middle of the reach that contained cobble-sized fill material used to bury a water or sewer line. Because no naturally occurring riffle habitat occurred in this section of Carter, only a glide sample was collected from this reach in 2013.

Streambed substrate within Lake Oswego study reaches primarily comprised coarse materials, which represented an average of 69% (2009: 69%; 2007: 58%) of streambed material across all study reaches (Table 5 and Figure 2). Bedrock was absent from all reaches, excepting Nettle Creek, where it represented 1% of the stream substrate within sampled riffle habitats. Substrate embeddedness derived from pebble counts was generally high and was similar between 2013 and 2009, averaging 45.5 and 49.1, respectively. Carter Creek again had the highest reach-wide substrate embeddedness of 98% in 2013 (versus 83% in 2007 and 82% in 2009), where sand and fines were the predominant substrates. Pebble count substrate embeddedness (which are collected in the habitat from which macroinvertebrates are collected) values were far higher in Carter Creek in 2013 than in 2009 because macroinvertebrates were sampled from glides rather than from the "artificial" riffle in Carter Creek in 2013.

Forested riparian zone widths are generally narrow across the Lake Oswego study reaches, as buffer widths ranged from 5 to 65 m and average 25 m. Mature forested riparian zones also occurred along most Lake Oswego study reaches (excluding Carter Creek), providing overhead cover ranging from 68 to 99%. Carter Creek, where sampled, flowed through a reed canary grass-dominated meadow which provided 28% overhead cover (38% in 2009 and 27% in 2007). Riparian conditions in the Springbrook Creek restoration reach continue to improve as a result of willow plantings in the early 2000s. Willows in the riparian area of the Springbrook Creek restoration reach have continued to grow, resulting in further increases in canopy cover to 93% in 2013 from 80% in 2009 and 55% in 2007.

	Other Co-Permittees (n = 7)				Lake Oswego (n = 10)			
Variable	Mean	SD	Min	Max	Mean	SD	Min	Max
Wetted width (m)	1.5	0.4	1.0	2.0	2.0	1.4	0.7	4.8
Bankfull width (m)	2.8	0.8	1.8	3.8	4.6	3.1	1.1	10.2
% Pool	29.3	18.7	0.0	50.7	46.0	14.4	32.0	70.7
% Glide	17.8	35.7	0.0	94.7	8.1	8.5	0.0	24.7
% Riffle	45.2	26.7	5.3	80.0	42.3	17.6	14.7	66.3
% Rapid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Cascade	7.8	16.5	0.0	44.3	3.6	8.1	0.0	25.3
% Embeddedness (reach visual est)	35.4	29.4	15.8	100.0	30.9	24.6	12.0	97.5
% Eroding Banks	53.9	24.3	19.9	73.8	52.1	31.9	0.0	98.2
% Undercut Banks	2.8	3.5	0.0	8.5	2.8	3.4	0.0	9.0
% Coarse substrate	69.0	32.8	0.0	94.4	70.2	29.1	10.0	98.3
% Sand and fines	16.0	37.2	0.0	100.0	10.7	21.4	0.0	70.0
% Hardpan	1.5	2.6	0.0	6.9	2.5	6.0	0.0	19.3
Embeddedness (pebble count)	56.5	23.8	25.6	100.0	45.5	17.4	23.9	86.4
LWD rating	0.6	0.9	0.0	1.9	0.6	0.6	0.0	1.7
Overhead Cover	73.2	32.6	6.9	98.2	86.0	22.0	28.7	99.3
Riparian Buffer Width (m)	15.0	12.1	2.0	28.0	25.3	18.4	5.0	65.0
% Tree Cover	42.7	26.4	5.0	78.0	60.4	19.6	33.0	88.0
% Non-Native Veg	47.7	16.0	30.0	73.0	36.1	22.3	0.0	68.0
Water Temperature (^{o}C)	16.4	1.8	14.1	19.1	15.1	2.4	13.0	21.2
Dissolved Oxygen (% sat)	83.7	13.2	60.7	94.2	84.1	11.0	61.0	94.0
Dissolved Oxygen (mg/L)	8.2	1.5	5.7	9.4	8.5	1.3	6.0	9.9
Conductivity (µS/cm)	117.2	51.6	36.3	165.7	122.6	30.7	93.7	190.6
Specific Conductance (µS/cm)	127.2	55.1	40.0	175.2	135.4	33.1	106.1	208.4

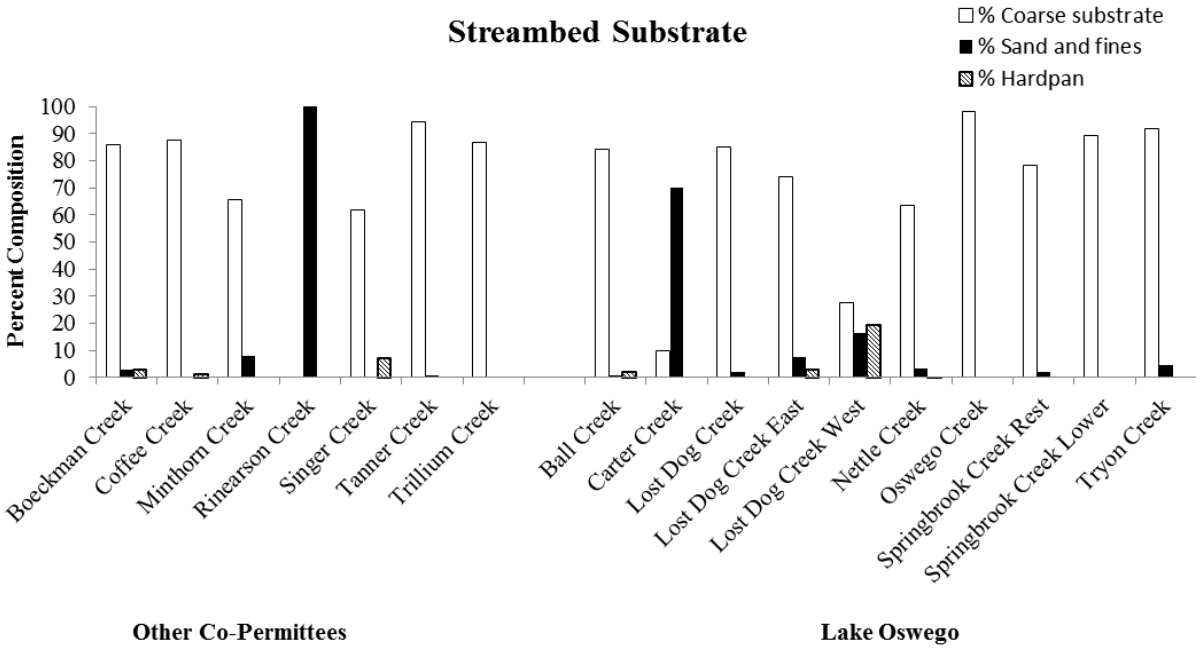
Table 5. Environmental conditions measured in Clackamas County MS4 co-permittee stream reaches sampled for macroinvertebrates in fall 2013.

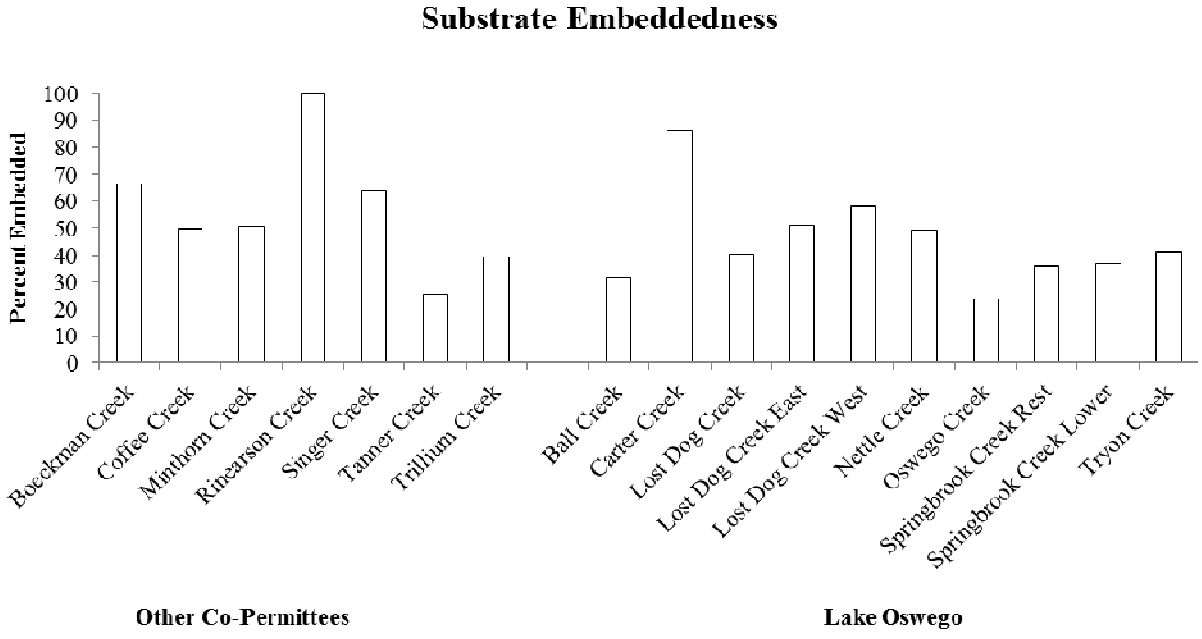
Limited water quality sampling during macroinvertebrate sampling in 2013 suggested potential low dissolved oxygen issues in several Lake Oswego stream reaches. While dissolved oxygen concentrations exceeded 8 mg/L in most reaches (measurements taken at various times of the day and not necessarily during peak stress early AM hours), Carter Creek dissolved oxygen was 6.0 mg/L (collected at 1330), the lowest among Lake Oswego study reaches, suggesting likely periodic low-DO-induced stress in this reach.

CO-PERMITTEE STREAM REACHES

Land use adjacent to the seven co-permittee reaches was variable, ranging from moderate density residential to commercial/industrial. All streams were smaller first or second-order tributaries; bankfull widths averaged 2.8 m and ranged from 1.8 to 3.8 m, while wetted channel widths averaged 1.5 m and ranged from 1.0 to 2.0 m (Table 5). Riffle habitat ranged from 5.3 to 80%. Six of seven reaches supported sufficient riffle area to sample macroinvertebrates from this habitat type; among the seven reaches, only Rinearson Creek lacked sufficient riffle habitat.

Figure 2. Substrate composition and embeddedness from pebble counts performed in 17 Clackamas County MS4 co-permittee streams sampled for determining conditions of macroinvertebrate communities in September 2013.





Streambed substrate in sampled habitats was dominated by coarse materials in six of the seven co-permittee reaches (Figure 2). In contrast, Rinearson Creek lacked substrates larger than fine gravels and was heavily dominated by sand and fines (Figure 2). Embeddedness varied among sites, but was generally high, ranging from 26% to 100% (Table 5). Substrate embeddedness from habitats sampled for macroinvertebrate was less than 50% in only Tanner and Trillium creeks (Figure 2).

Riparian buffer widths were generally narrow among the seven co-permittee reaches, averaging 15 m and ranging from 2 to 33 m. Overhead canopy cover exceeded 80% in five of the seven reaches; overhead cover was only 6% along the Minthorn Creek reach and 56% along the Rinearson Creek reach. Riparian tree cover was lacking in both of these reaches, averaging 5% along Minthorn Creek and 15% along Rinearson Creek.

Limited water quality sampling indicated potential low dissolved oxygen problems in both Rinearson (5.7 mg/L) and Minthorn (6.5 mg/L) creeks. Dissolved oxygen concentrations from the other five reaches approached or exceeded 9 mg/L.

MACROINVERTEBRATE COMMUNITY CONDITIONS

LAKE OSWEGO STREAM REACHES

Multimetric Index (MMI) scores and PREDATOR MWCF O/E scores indicated biological conditions generally similar to those measured in 2009 (Table 6, Table 7, and Figure 3). MMI scores ranged among the ten Lake Oswego reaches from 10 to 24, and eight of the ten sites scored lower than 20, corresponding to "severely disturbed" biological conditions. Only the Springbrook Creek restoration reach and the Tryon Creek reach MMI scores occurred outside their 2004-2009 ranges. Moreover, only the Springbrook Creek restoration reach (MMI score = 20) and the Tryon Creek reach (MMI score = 24) scored outside of the "severely disturbed" range, and only marginally. In fact, the Tryon Creek duplicate sample received an MMI score of 18, suggesting that conditions are likely on the threshold between severely and moderately disturbed in this reach. PREDATOR O/E scores ranged from 0.194 to 0.437, occurring exclusively in the "most disturbed" condition class (equivalent to the MMI "severely disturbed" class).

The lower Springbrook Creek reach's MMI score of 20 represents the largest difference from 2009 scores, when this reach received the lowest possible MMI score of 10. For the first time since initiating sampling in 2004, three mayfly taxa (Baetis tricaudatus, *Paraleptophlebia debilis*, and *Cinygma* sp.) were sampled from the reach; while *Baetis tricaudatus* has been sampled from the reach in each sampling year, *Cinygma* sp. has been sampled only once before, and *Paraleptophlebia debilis* had never previously been sampled. Furthermore, for the first time since the inception of routine sampling in 2004, two caddisfly taxa (*Cheumatopsyche* sp. and *Lepidostoma* sp.) were

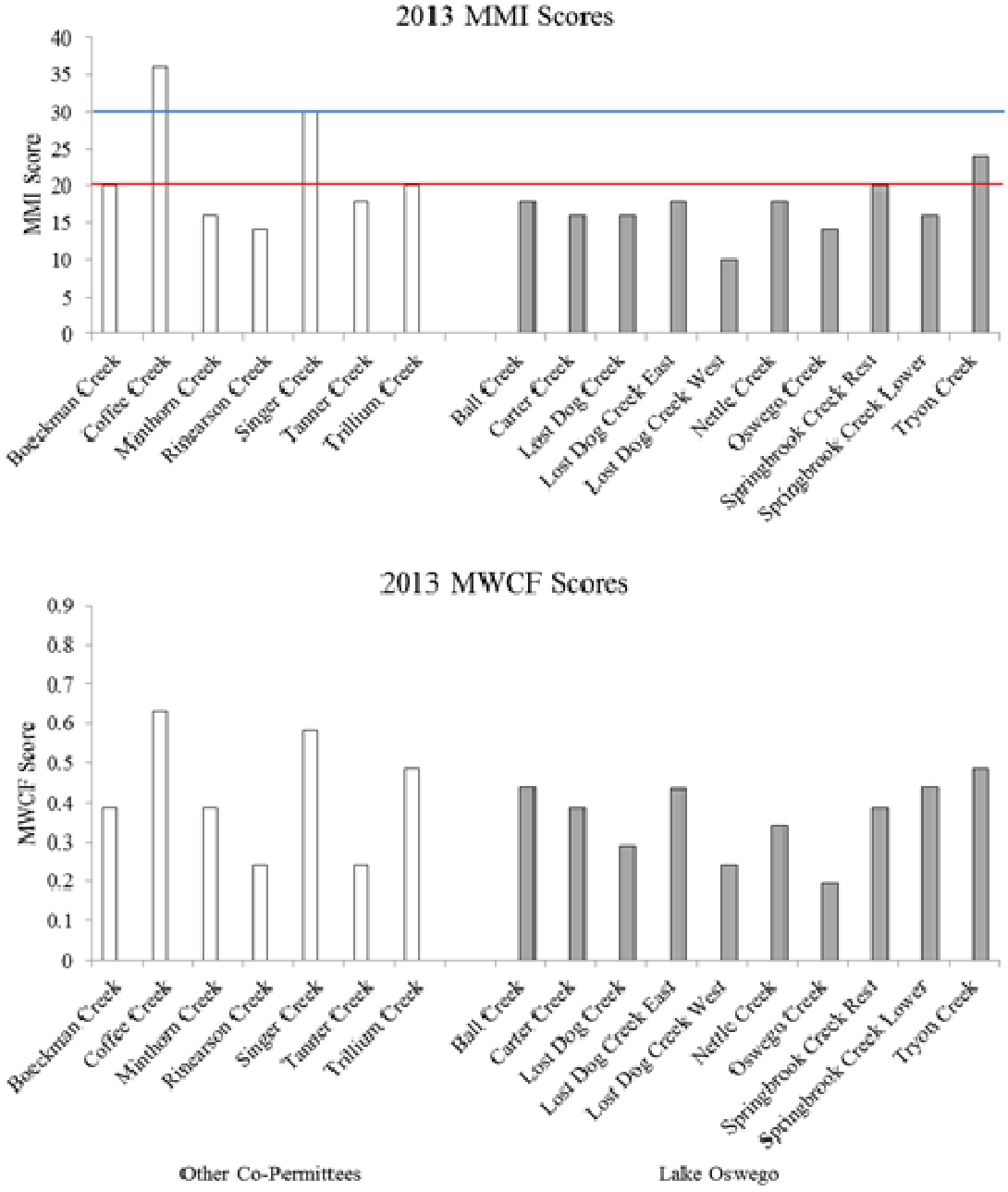
sampled from the reach. Neither had previously been sampled from the Springbrook Creek restoration reach.

Waterbody	Habitat Sampled	MMI Score	Disturbance Class	O/E Score	Disturbance Class	TS	FSS
Boeckman Creek	Riffle	20	Mod/Severe	0.388	Most	22.9	30.6
Coffee Creek	Riffle	36	Slight	0.630	Most	17.2	22.1
Minthorn Creek	Riffle	16	Severe	0.388	Most	23.4	51.2
Rinearson Creek	Glide	14		0.242		21.0	
Singer Creek	Riffle	30	Slight/Mod	0.581	Most	16.2	24.0
Tanner Creek	Riffle	18	Severe	0.242	Most	16.1	18.2
Trillium Creek	Riffle	20	Mod/Severe	0.485	Most	20.0	23.7
Ball Creek	Riffle	18	Severe	0.437	Most	20.6	42.8
Carter Creek	Glide	16		0.388		21.9	
Lost Dog Creek	Riffle	16	Severe	0.291	Most	15.9	32.3
Lost Dog Creek East	Riffle	18	Severe	0.436	Most	16.8	49.5
Lost Dog Creek West	Riffle	10	Severe	0.242	Most	19.3	43.3
Nettle Creek	Riffle	18	Severe	0.339	Most	16.8	21.5
Oswego Creek	Riffle	14	Severe	0.194	Most	26.3	54.2
Springbrook Crk Rest	Riffle	20	Mod/Severe	0.388	Most	21.2	36.8
Springbrook Crk Lower	Riffle	16	Severe	0.437	Most	22.1	38.6
Tryon Creek	Riffle	24	Moderate	0.485	Most	21.2	18.1

Table 6. Summary of Multimetric Index (MMI) scores, PREDATOR MWCF model O/E scores, and temperature (TS) and fine sediment (FSS) stressor model scores calculated from macroinvertebrate samples collected from 17 Clackamas County MS4 co-permittee streams in September 2013. Highlighted TS and FSS scores indicate values that exceed DEQ inferred stressor thresholds of 18.2°C and 15% fine sediment.

Temperature stressor (TS) scores indicate that compositional shifts in macroinvertebrate communities have occurred in seven of the ten Lake Oswego stream reaches (Table 6). Only lower Lost Dog Creek, East Lost Dog Creek, and Nettle Creek appear to support macroinvertebrate communities unaffected by elevated water temperatures. Among those seven reaches indicating temperature-induced stress, Oswego Creek's community showed the largest shift likely induced by temperature, as the inferred temperature score was 26.3°C, more than 4°C higher than the second highest score (Table 6).

Figure 3. Multimetric index (MMI) and Marine Western Coastal Forest (MWCF) PREDATOR model scores calculated from 17 macroinvertebrate samples collected from Clackamas County MS4 co-permittee streams in September 2013.



Fine sediment stressor (FSS) scores from all nine Lake Oswego samples collected from riffle habitats (i.e., all reaches other than Carter Creek) indicated likely sediment-induced stress on macroinvertebrate communities in these reaches. All nine samples exceeded the threshold FSS score of 15, and only two of the nine reaches scored lower than 30 (Table 6).

	DEQ Multimetric Index Scores					PREDATOR O/E Scores				
Sample Site	2004	2007	2009	2013	09-13	2004	2007	2009	2013	09-13
Ball Creek	20	12	12	18	6	0.243	0.339	0.243	0.437	0.194
Carter Creek		16	14	16	2		0.388	0.388	0.388	0.000
Lost Dog Creek	18	16	16	16	0	0.242	0.291	0.339	0.291	-0.048
Lost Dog Creek East		16	18	18	0		0.291	0.436	0.436	0.000
Lost Dog Creek West		14	10	10	0		0.242	0.194	0.232	0.038
Nettle Creek	18	14	12	18	6	0.436	0.533	0.388	0.339	-0.049
Oswego Creek		18	12	14	2		0.436	0.194	0.194	0.000
Springbrook Creek Lower	14	12	10	20	10	0.242	0.388	0.339	0.388	0.049
Springbrook Restoration	16	14	12	16	4	0.339	0.436	0.291	0.437	0.146
Tryon Creek		14	18	24	6		0.532	0.388	0.485	0.097

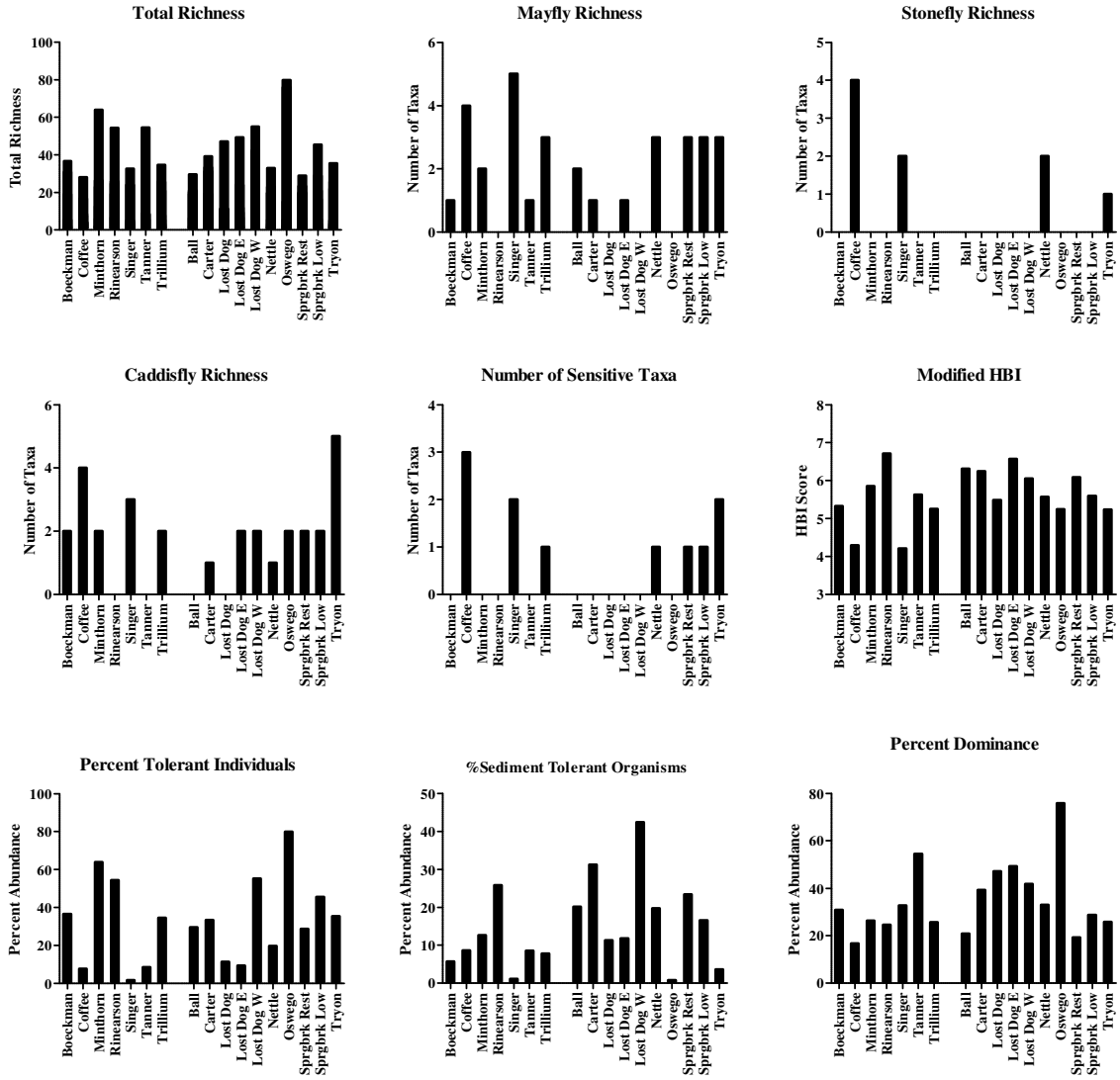
Table 7. Multimetric Index scores and PREDATOR MWCF model O/E scores from stream reaches sampled in and adjacent to the City of Lake Oswego, Oregon, fall 2004, 2007, 2009, and 2013. DEQ score corresponding levels of impairment: <20 = severe, 20–29 = moderate, 30–39 = slight, >39 = none. O/E score corresponding levels of impairment: <0.75 = poor/severely impaired, 0.75–0.90 = fair/slightly impaired, >0.90 = good/unimpaired.

CO-PERMITTEE STREAM REACHES

MMI scores ranged from 14 to 36 among the seven co-permittee reaches (Table 6). Coffee Creek received the highest MMI score of 36, corresponding to a slightly disturbed biological condition. Singer Creek scored a 30, corresponding to slightly/moderately disturbed. Boeckman Creek received an MMI score of 20, indicating moderately/severely disturbed conditions. Minthorn and Tanner creeks both scored in the severely disturbed range (Table 6). PREDATOR O/E scores ranged from 0.242 to 0.630, exclusively within the "most disturbed" condition class among the seven co-permittee reaches (Table 6). Rinearson Creek was not assigned a condition class based on either assessment tool because only glides were sampled from this reach.

Among the seven reaches, macroinvertebrate total taxa richness was highest in Coffee Creek, as 28 taxa were sampled (Figure 4). This richness included 12 EPT taxa (mayfly, stonefly, and caddisfly), the highest richness in these generally disturbance-intolerant orders among all seventeen reaches sampled in this study. Coffee Creek's EPT richness included three taxa classified as sensitive to disturbance and water pollution,

Figure 4. Individual community metric values calculated from macroinvertebrate samples collected from 17 Clackamas County MS4 co-permittee streams in September 2013.



including the mayfly *Cinygma* sp., the stonefly *Despaxia augusta*, and the caddisfly *Rhyacophila grandis* Gr.

Singer Creek supported 24 total taxa, including ten EPT taxa, five of which were mayfly taxa (Figure 4). Furthermore, Singer Creek's modified HBI score, percent tolerant individuals, and percent sediment tolerant individuals were the lowest among all seventeen study sites (Figure 4), indicating a macroinvertebrate community most sensitive to disturbance among all reaches sampled.

The Trillium Creek sample supported five EPT taxa (Figure 4), and included one sensitive taxon, *Cinygma* sp., while the Boeckman Creek sample supported three EPT

taxa and no taxa classified as sensitive. Boeckman Creek's 2013 macroinvertebrate sample MMI score of 20 was similar to the 2003 sample score of 16, suggesting similar benthic community conditions. In each year, three EPT taxa were sampled from this reach, and all other individual metrics were similar (Table 8).

Metric	2003	2013
Taxa Richness	17	19
Mayfly Richness	2	1
Stonefly Richness	0	0
Caddisfly Richness	1	2
# Sensitive Taxa	1	0
# Sediment Sensitive Taxa	0	0
Modified HBI	5.5	5.3
% Tolerant Taxa	25	37
% Sediment Tolerant	4	5.7
% Dominant (1 taxon)	40	30.8
MMI Score	16	20

Table 8. Macroinvertebrate community metrics calculated from samples collected from Boeckman Creek below Rose Lane, Wilsonville, Oregon in 2003 and again in 2013.

Among co-permittee reaches from which riffles were sampled, Tanner and Minthorn creeks received the lowest MMI and O/E scores (Table 6). The Tanner Creek sample supported the lowest total taxa richness among all seventeen study reaches (Figure 4). HBI scores from these two reaches were highest among the six co-permittee reaches from which riffle samples were collected (Figure 4).

Rinearson Creek received the lowest MMI and O/E scores among the seven co-permittee reaches; however, riffles were nearly absent from this reach, necessitating sampling macroinvertebrates from sand-dominated glide habitat. As such, condition classes were not assigned to the community scores calculated for this reach. Among the seventeen study reaches, only Rinearson and Lost Dog creek (Lost Dog at Lake Front Road) samples failed to support any EPT taxa.

Temperature stressor (TS) scores indicate temperature-stress-induced shifts in macroinvertebrate communities have likely occurred in four of the seven co-permittee reaches, including Boeckman, Minthorn, Rinearson, and Trillium creeks (Table 6). Fine sediment stressor (FSS) scores indicate FS-induced stress in all six reaches from which riffle samples were collected. Generally high embeddedness values across all study reaches corroborate this finding (Figure 2).

DISCUSSION

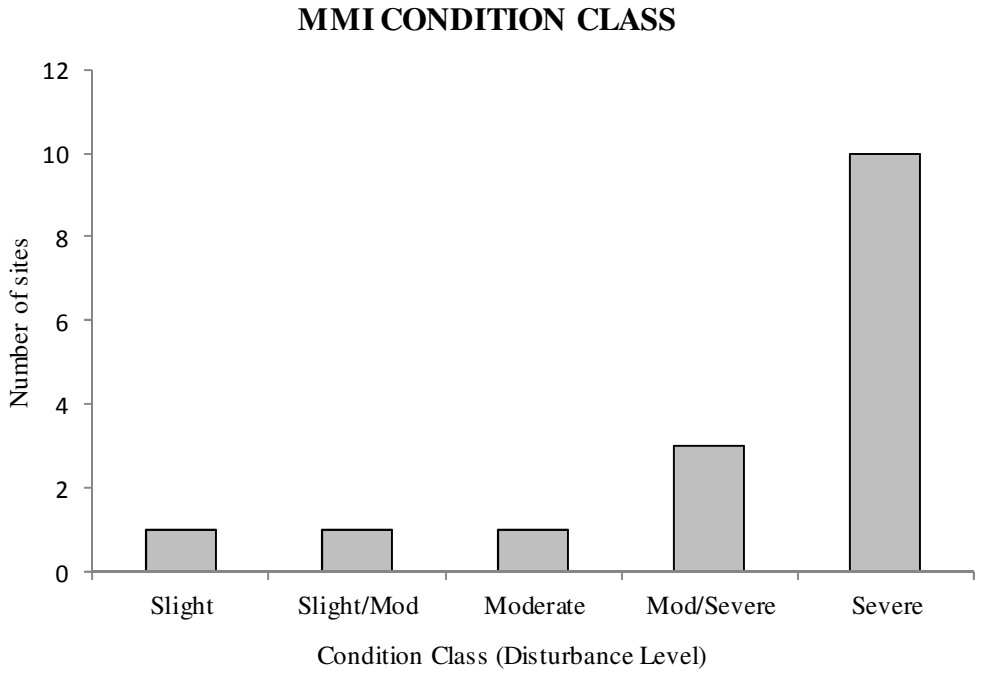
Owing to the extent of urban development within the study area, results indicating that biological conditions are severely disturbed in most local streams (Figure 5) are not unexpected. The results of this study are consistent with the results of other studies of macroinvertebrate communities in Clackamas County urban/suburban settings. Clackamas Water Environment Services most recently sampled macroinvertebrates in the Mt. Scott and Kellogg Creek drainages in 2011; among seven riffle samples collected from these two drainages in the 2011 study, five received "severely disturbed" and two received "moderately disturbed" MMI scores (Lemke et al. 2012).

In the present study, while PREDATOR O/E scores correspond well with MMI scores ($r^2 = 0.693$), condition classes do not align between the two sets of scores (Figure 6). Importantly, DEQ currently uses the PREDATOR models to evaluate biological condition of Oregon's streams; by that measure, all reaches evaluated in this study are deemed to be in a most disturbed condition relative to regional reference conditions (Figure 6). However, the MMI scores and corresponding condition classes better and more tangibly reflect the range of conditions that currently exist among these small streams sampled in this study. Higher MMI scores result directly from higher taxonomic richness, including that of generally more sensitive groups such as mayflies, stoneflies, and caddisflies.

Recognizing this range of biological conditions across these study reaches is instructive to understanding and setting potential biological recovery targets; the highest quality reaches such as Coffee and Singer Creeks represent locally realistic least-disturbed and therefore potentially best attainable conditions for these small streams in local urban and suburban settings. A closer examination of the drainages supporting these reaches may reveal what physical and chemical conditions are necessary to support these locally least-disturbed biological conditions as measured in Coffee and Singer creeks. Further quantification of potential stressors in these and the other systems, including water temperature regime and diel patterns of dissolved oxygen concentrations during peak-stress periods may further reveal potentially causative agents producing the observed biological conditions. Temperature and fine sediment stressor modelling results suggested nearly ubiquitous fine sediment stress across study reaches, and potential temperature-induced stress in most reaches. Coffee and Singer creeks were among the few reaches supporting macroinvertebrate communities not exhibiting temperature-induced compositional shifts.

While the dissolved oxygen data collected for this study are of limited use for relating observed biological conditions to environmental gradients, the data nonetheless suggest potential dissolved oxygen issues in several systems, including Minthorn, Rinearson, and Carter Creeks. Importantly, dissolved oxygen data were collected at the

Figure 5. Distribution of macroinvertebrate community condition classes from 15 Clackamas County MS4 co-permittee streams sampled in September 2013, as determined from multimetric index (MMI) scores. Rinearson and Carter Creeks are not included in these results, as glides were sampled from each of these two reaches, thereby precluding the assignment of condition classes.



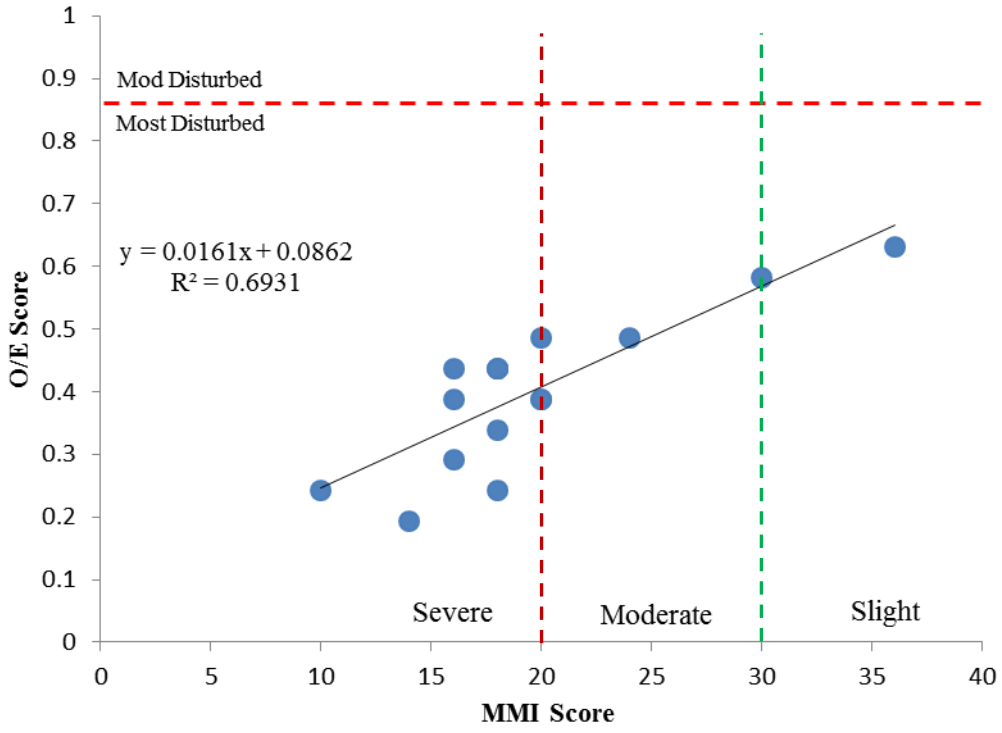
time of macroinvertebrate sampling from each reach, so times varied across reaches and occurred only in the early AM hours from a handful of reaches. Continuous or synoptic temperature and dissolved oxygen monitoring is recommended from these reaches to produce more robust water quality data sets that would better implicate causes of the measured biological disturbance.

Noteworthy findings in this study include the potential recovery of benthic communities in the Springbrook Creek restoration reach. EPT richness was notably higher in this reach than had ever been sampled, and riparian conditions apparently continue to improve. While conditions still score in the moderately-to-severely impaired range, the presence of these EPT taxa suggests improvement. Future sampling will reveal whether this change in 2013 is a more permanent result of restoration work or simply climate/weather-induced year-to-year variation.

Because riffle habitats were lacking in both the Rinearson and Carter creek reaches, both were excluded from comparative assessments among sites. Identifying alternative reaches supporting riffle habitat and coarse substrates is recommended for future sampling from these systems. If such reaches cannot be found, omitting these systems from future biological monitoring should be considered.

For the first time since biological sampling was initiated in Lake Oswego streams in 2004, no EPT taxa were sampled from lower Lost Dog Creek. However, both MMI and O/E scores have remained similar among the four years of sampling from this reach. Nonetheless, the absence of any EPT taxa from the sample warrants further attention to this reach during future sampling events, as persistence of this change would suggest further degradation of the lower reaches of Lost Dog Creek.

Figure 6. Relationship between MMI and O/E scores.



The Boeckman Creek reach below the Rose Lane culvert replacement project had not been assessed since 2003, or three years prior to the culvert being replaced with a foot bridge. Macroinvertebrate community conditions were similar between the 2003 and 2013 sampling events, suggesting recovery of the community following any short-term disturbance that may have resulted from the culvert replacement work. While habitat sampling protocols differed slightly between the 2003 and 2013 sampling events, the data are suggestive of similar habitat conditions with respect to bank stability, habitat types, and riparian conditions. As a result of the culvert removal, a larger amount of coarse substrate appeared to be in the stream channel immediately above and below the bridge.

Recovery of biological communities in these MS4 co-permittee area streams is dependent on identifying and improving stream conditions and functions that are currently impaired. While additional water quality data would further elucidate likely cause-effect relationships, stressor model results, combined with the results of physical

habitat assessments, are suggestive of multiple stressors co-occurring in most streams assessed in this study. This phenomenon, known as "urban stream syndrome" or "multiple stress syndrome" is well documented among urban streams (Walsh et al. 2005). Mechanisms driving the syndrome are complex, yet stream hydro-modification from efficient stormwater delivery into receiving waters is largely responsible for the various perturbations observed and measured in this and other studies. These highly modified hydrologic patterns destabilize streamflows and alter seasonal high and low flows, pollutant concentrations, temperature and dissolved oxygen extremes, sediment inputs, and channel morphology. These numerous perturbations ultimately result in significant impact to biological communities such as those measured in this study.

Protection of area streams should focus on maximizing riparian buffer protection, minimizing total effective impervious areas, and improving stormwater retention and drainage patterns to minimize the hydrologic effects of storm events on stream channel conditions. Research has shown that the hydraulic efficiency of stormwater drainage influences the relationship between catchment imperviousness and receiving water biology (Walsh 2005). As such, widespread installation and retrofitting with innovative approaches to drainage design will be necessary to achieve the conservation and restoration of streams in Clackamas County urban environments. Further development within Clackamas County will necessitate careful attention to these and other measures intended to preserve and enhance stream conditions and functions. As such stormwater best management practices and other restoration activities are undertaken, these data will assist with determining the success of these actions relative to their intended benefits to aquatic life.

RECOMMENDATIONS

- Continue periodic biological monitoring to produce robust data sets of biological condition status and trends

- Establish continuous temperature monitoring (and potentially regular DO monitoring) at water quality/biological monitoring stations. These data will offer better opportunities for identifying potential causative agents in producing observed biological conditions

- Further characterize and quantify physical, chemical, and hydrologic conditions in study area drainages to understand potential causation in observed variation in biological conditions among streams

- Identify alternative sampling reaches in Carter and Rinearson creeks or consider omission from biological sampling.

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Appendix 1. Environmental conditions measured from 17 Clackamas County NPDES MS4 co-permittee stream reaches, fall 2013.

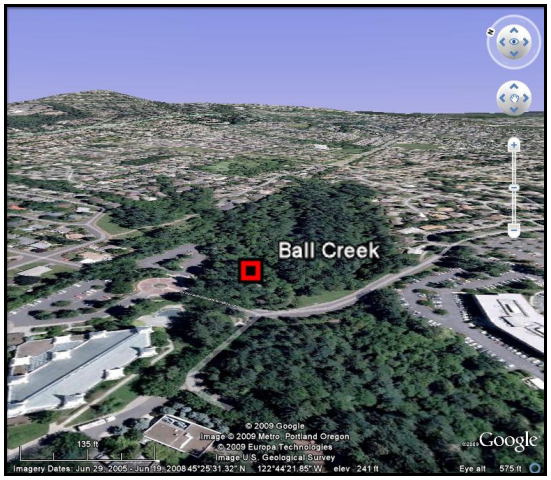
Variable	Ball Creek	Carter Creek	Lost Dog Creek	Lost Dog East	Lost Dog W	Nettle Creek	Oswego Creek	Springbrook Rest.	Springbrook Lower	Tryon Creek	Boeckman Creek	Coffee Creek	Minthorn Creek	Rinearson Creek	Singer Creek	Tanner Creek	Trillium Creek
Reach length (m)	75	75	75	50	75	80	75	75	84	80	100	50	45	75	75	75	75
Wetted width (m)	1.4	1.6	1.1	1.0	0.7	1.2	4.8	1.7	1.9	4.5	1.9	1.2	1.2	1.2	1.0	1.9	2.0
Bankfull width (m)	5.0	7.9	3.5	1.3	1.1	2.8	10.2	2.9	2.9	8.0	3.4	2.4	2.1	3.4	1.8	3.0	3.8
% Pool	32.0	70.7	42.7	45.1	70.3	33.8	53.3	34.7	42.9	34.6	45.0	10.0	42.2	0.0	29.9	27.1	50.7
% Glide	9.3	14.7	5.3	0.0	13.5	0.0	0.0	13.3	0.0	24.7	30.0	0.0	0.0	94.7	0.0	0.0	0.0
% Riffle	50.7	14.7	26.7	54.9	16.2	66.3	46.7	49.3	57.1	40.7	25.0	80.0	57.8	5.3	70.1	28.6	49.3
% Rapid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Cascade	8.0	0.0	25.3	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	10.0	0.0	0.0	0.0	44.3	0.0
% Embeddedness (Reach Est)	15.5	97.5	23.5	32.2	23.9	36.6	12.0	17.7	20.7	29.8	15.8	22.1	30.0	100.0	36.6	24.9	18.3
% Eroding Banks	92.0	27.7	21.6	98.2	73.8	46.9	0.0	68.7	59.3	33.0	85.3	73.8	46.0	55.1	69.7	19.9	27.9
% Undercut Banks	0.0	7.3	0.4	9.0	0.0	1.3	0.0	4.5	5.1	0.0	6.4	0.0	0.0	0.0	1.2	3.6	8.5
% Coarse substrate	84.2	10.0	85.0	74.3	27.5	63.7	98.3	78.3	89.2	91.7	86.1	87.7	65.8	0.0	61.8	94.4	86.9
% Sand and fines	0.9	70.0	2.0	7.6	16.5	3.2	0.0	1.9	0.0	4.6	3.0	0.0	8.1	100.0	0.0	0.9	0.0
% Hardpan	1.8	0.0	0.0	2.9	19.3	0.8	0.0	0.0	0.0	0.0	3.0	0.9	0.0	0.0	6.9	0.0	0.0
Embeddedness (Pebble Count)	31.8	86.4	40.3	51.4	58.0	49.0	23.9	36.0	36.7	41.2	66.6	49.4	50.2	100.0	64.0	25.6	39.4
Overhead Cover	97.8	28.7	90.4	91.7	99.3	98.9	68.4	93.4	96.7	94.5	90.9	81.6	6.9	55.9	98.2	81.3	97.4
LWD rating	0.9	0.0	0.3	0.0	0.0	1.7	0.0	0.9	0.8	1.2	1.7	1.9	0.0	0.0	0.2	0.0	0.2
Riparian Buffer Width (m)	65.0	38.0	13.0	18.0	13.0	23.0	43.0	10.0	5.0	25.0	33.0	28.0	2.0	4.0	10.0	8.0	20.0
% Tree Cover	50.0	33.0	55.0	38.0	88.0	88.0	68.0	58.0	48.0	78.0	65.0	38.0	5.0	15.0	40.0	58.0	78.0
% Non-Native Veg	18.0	57.0	35.0	48.0	45.0	10.0	0.0	25.0	55.0	68.0	48.0	73.0	35.0	60.0	55.0	33.0	30.0
Water Temperature (^{o}C)	14.2	16.1	14.7	13.1	14.4	13.7	21.2	15.0	15.7	13.0	14.1	15.6	19.1	18.1	14.8	16.1	17.1
Dissolved Oxygen (% sat)	92.5	61.0	81.1	94.0	68.9	85.7	85.6	91.4	87.2	93.5	89.0	94.2	69.7	60.7	87.0	92.6	93.0
Dissolved Oxygen (mg/L)	9.5	6.0	8.2	9.9	7.1	8.9	7.6	9.2	8.7	9.9	9.2	9.4	6.5	5.7	8.8	9.1	9.0
Conductivity (µS/cm)	128.1	190.6	105.1	93.7	99.4	130.4	138.7	96.0	98.0	145.6	156.9	36.3	165.7	159.6	63.8	98.4	139.4
Specific Conductance (µS/cm)	143.2	208.4	116.8	106.1	111.0	146.5	143.5	106.4	107.5	164.9	175.5	40.0	175.2	170.6	70.9	107.6	150.5

Appendix 2. Western Oregon multimetric index individual metric scores calculated from macroinvertebrate communities sampled from 17 Clackamas County NPDES MS4 co-permittee stream reaches in fall 2013.

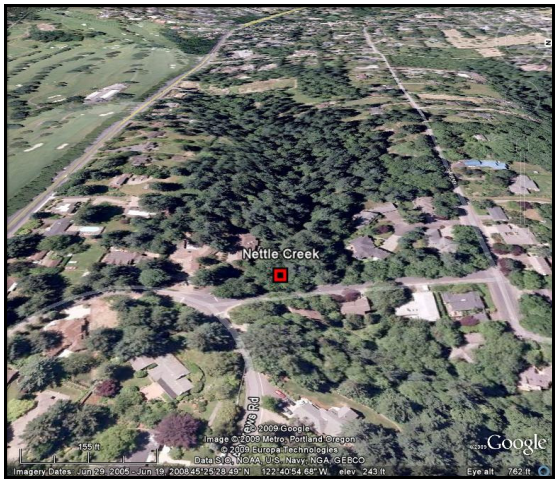
Metric	Ball Creek	Carter Creek	Lost Dog Creek	Lost Dog Creek East	Lost Dog Creek West	Nettle Creek	Oswego Creek	Springbrook Creek Rest	Springbrook Creek Lower	Tryon Creek	Tryon Creek (Dup sample)	Boeckman Creek	Coffee Creek	Minthorn Creek	Rinearson Creek	Singer Creek	Tanner Creek	Trillium Creek
Richness	19	19	11	24	12	23	15	20	21	22	21	19	28	23	19	24	8	21
Mayfly Richness	2	1	0	1	0	3	0	3	3	3	3	1	4	2	0	5	1	3
Stonefly Richness	0	0	0	0	0	2	0	0	0	1	1	0	4	0	0	2	0	0
Caddisfly Richness	0	1	0	2	2	1	2	2	2	5	3	2	4	2	0	3	0	2
Number Sensitive Taxa	0	0	0	0	0	1	0	1	1	2	0	0	3	0	0	2	0	1
# Sediment Sensitive Taxa	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Modified HBI1	6.3	6.2	5.5	6.6	6.0	5.6	5.2	6.1	5.6	5.2	5.4	5.3	4.3	5.9	6.7	4.2	5.6	5.3
% Tolerant Taxa	29.6	33.3	11.3	9.3	55.1	19.7	79.9	28.8	45.5	35.4	37.8	36.6	7.7	64.0	54.4	1.7	8.5	34.5
% Sediment Tolerant Taxa	20.1	31.3	11.3	11.8	42.4	19.7	0.7	23.4	16.5	3.6	12.3	5.7	8.6	12.6	25.8	1.1	8.5	7.8
% Dominant	20.9	39.2	47.2	49.4	41.8	33.0	75.9	19.3	28.8	25.8	22.2	30.9	16.7	26.4	24.7	32.7	54.5	25.6

Appendix 3. Google Earth images depicting locations of 2013 Clackamas County NPDES MS4 co-permittees macroinvertebrate sample sites.

Carter Creek



Ball Creek



Nettle Creek

Tryon Creek

Oswego Creek

Springbrook Creek – Restoration Reach

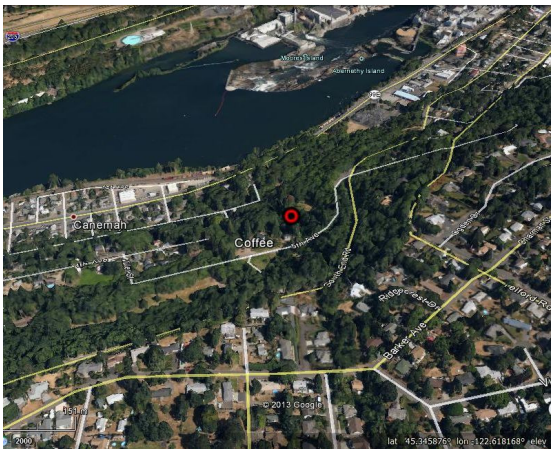
West Branch Lost Dog Creek

Lower Springbrook Creek

East Branch Lost Dog Creek

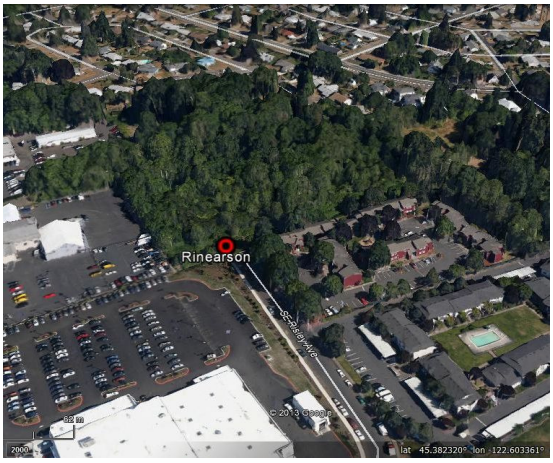
Lower Lost Dog Creek

Boeckman Creek

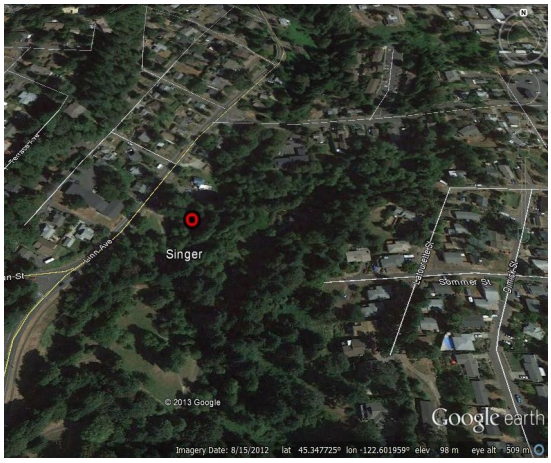


Coffee Creek

Minthorn Creek

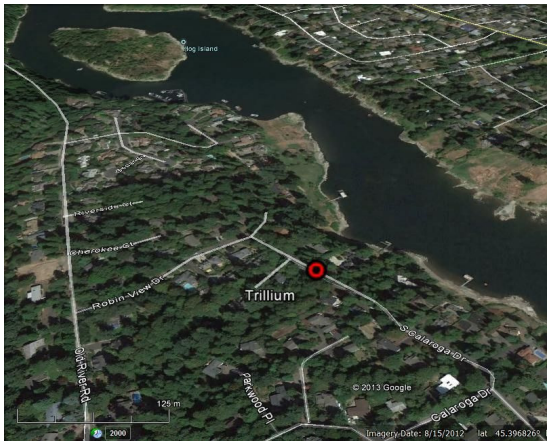


Rinearson Creek



Singer Creek

Tanner Creek



Trillium Creek

Appendix 4. Reach Assessment Summary Sheets

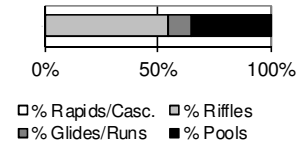
Reach Assessment Summary

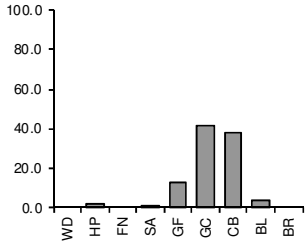
Stream Name:	**Ball Creek**		
Location:	~70 m upstream of Kruse Oaks Blvd	Latitude:	45.42452
County, State:	Clackamas, Oregon	Longitude:	-122.74031
Date sampled:		Reach Length:	75 m
Personnel:	M. Cole and A. Miller		

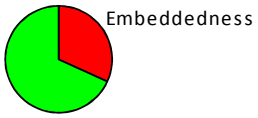
Physical and Chemical Conditions Summary

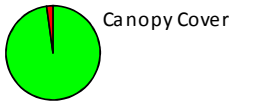
Instream Physical Characteristics

Wetted Width (m)		1.4
Bankfull Width (m)		5.0
% Rapids/Casc.		0.0
% Riffles		50.7
% Glides/Runs		9.3
% Pools		32.0
Substrate		
% Wood	WD	0.0
% Hardpan	HP	2.0
% Fines	FN	0.0
% Sand	SA	1.0
% Fine Gravel	GF	13.0
% Crse Gravel	GC	42.0
% Cobble	CB	38.0
% Bulder	BL	4.0
% Bedrock	BR	0.0
% Embeddedness		31.8
Large Wood Rating		0.92
Eroding Banks (%)		92
Undercut Banks (%)		0









Survey start, facing upstream

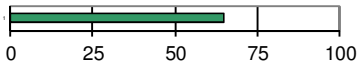
Survey end, facing downstream

Riparian Zone Characteristics

Canopy Cover (%)	97.8
Riparian Buffer Width (m)	65
Rip Zone Tree Cover (%)	80
Rip Non-Native Cover (%)	18

Chemical Characteristics

Water Temperature (°C)	14.2
Specific Cond (µS/cm)	143
Dissolved Oxygen (% sat)	92.5
Time of Measurement	820

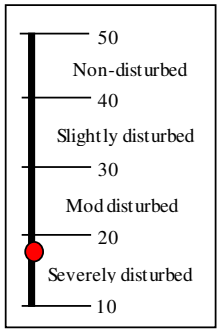


Biological Conditions Summary

CE Sample ID: 13-121-01
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ Metric Scores

	Raw	Stand.
Richness	19	3
Mayfly	2	1
Stonefly	0	1
Caddisfly	1	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	6.3	1
% Tolerant Taxa	29.6	3
% Sed Tol Taxa	20.1	3
% Dominant (1)	20.8	3
TOTAL MMI SCORE		**18**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.437	Most

Stressor Scores

Temperature Stress:	20.6
Fine Sediment Stress:	42.8

Reach Assessment Summary

Stream Name: **Carter Creek**
Location: Carter Crk at Bangy
County, State: Clackamas, Oregon
Date sampled: 9/20/2013
Personnel: M. Cole and A. Miller

Latitude: 45.42452
Longitude: -122.74031
Reach Length: 75 m

Physical and Chemical Conditions Summary

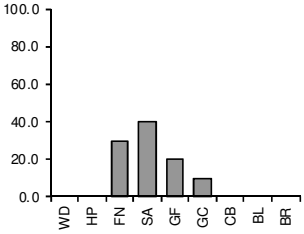
Instream Physical Characteristics

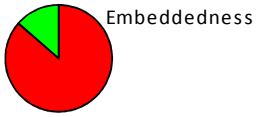
Wetted Width (m)	1.6
Bankfull Width (m)	7.9
% Rapids/Casc.	0.0
% Riffles	14.7
% Glides/Runs	14.7
% Pools	70.7

Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	30.0
% Sand	SA	40.0
% Fine Gravel	GF	20.0
% Crse Gravel	GC	10.0
% Cobble	CB	0.0
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		86.4
Large Wood Rating		0
Eroding Banks (%)		27.7333
Undercut Banks (%)		7.33333

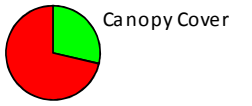




Survey end, facing downstream

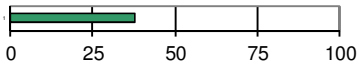
Riparian Zone Characteristics

Canopy Cover (%)	28.6765
Riparian Buffer Width (m)	38
Rip Zone Tree Cover (%)	33
Rip Non-Native Cover (%)	57



Chemical Characteristics

Water Temperature (°C)	16.1
Specific Cond (µS/cm)	208.4
Dissolved Oxygen (% sat)	61
Time of Measurement	1330

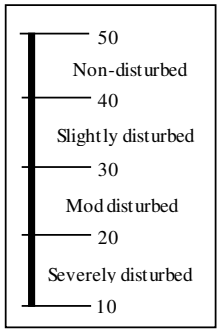


Biological Conditions Summary

CE Sample ID: 13-121-02
Sample Method: OR 8-kick
Target Habitat: Glide

DEQ METRIC SCORES

	Raw	Stand
Richness	19	
Mayfly	1	
Stonefly	0	
Caddisfly	1	
# Sensitive Taxa	0	
# Sed Sens Taxa	0	
Modified HBI	6.24	
% Tolerant Taxa	33.3	
% Sed Tol Taxa	31.25	
% Dominant (1)	39.2	
TOTAL MMI SCORE		**16**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.388	NA

Stressor Scores

Temperature Stress:	21.9
Fine Sediment Stress:	NA

Reach Assessment Summary

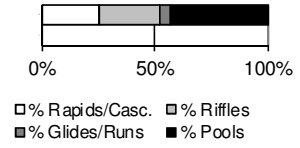
Stream Name: **Lost Dog Creek**
Location: Lost Dog @ Lake Front Dr
County, State: Clackamas, Oregon
Date sampled: 9/20/2013
Personnel: M. Cole and A. Miller

Latitude: 45.40064
Longitude: -122.6891
Reach Length: 75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

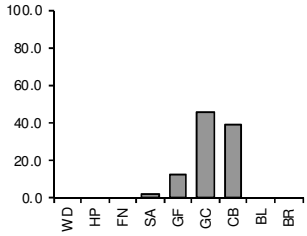
Wetted Width (m)	1.1
Bankfull Width (m)	3.5
% Rapids/Casc.	25.3
% Riffles	26.7
% Glides/Runs	5.3
% Pools	42.7

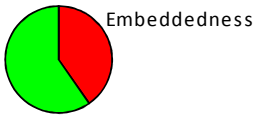


Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.0
% Sand	SA	2.0
% Fine Gravel	GF	13.0
% Crse Gravel	GC	46.0
% Cobble	CB	39.0
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		40.3
Large Wood Rating		0.32
Eroding Banks (%)		21.6
Undercut Banks (%)		0.4

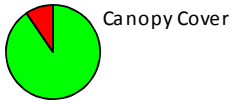




Survey end, facing downstream

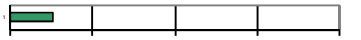
Riparian Zone Characteristics

Canopy Cover (%)	90.4412
Riparian Buffer Width (m)	13
Rip Zone Tree Cover (%)	55
Rip Non-Native Cover (%)	35



Chemical Characteristics

Water Temperature (°C)	14.7
Specific Cond (µS/cm)	116.8
Dissolved Oxygen (% sat)	81.1
Time of Measurement	1115

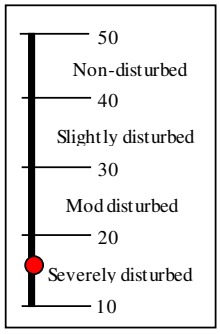


Biological Conditions Summary

CE Sample ID: 13-121-03
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES

	Raw	Stand
Richness	11	1
Mayfly	0	1
Stonefly	0	1
Caddisfly	0	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.5	1
% Tolerant Taxa	11.3	5
% Sed Tol Taxa	11.3	3
% Dominant (1)	47.2	1
TOTAL MMI SCORE		16



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.291	Most

Stressor Scores

Temperature Stress:	15.9
Fine Sediment Stress:	32.3

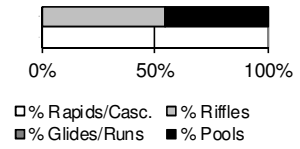
Reach Assessment Summary

Stream Name:	**Lost Dog Creek East**		
Location:	Lost Dog @ Stafford Rd	Latitude:	45.4026
County, State:	Clackamas, Oregon	Longitude:	-122.68057
Date sampled:	9/20/2013	Reach Length:	50 m
Personnel:	M. Cole and A. Miller		

Physical and Chemical Conditions Summary

Instream Physical Characteristics

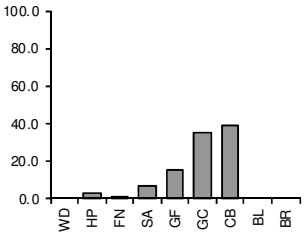
Wetted Width (m)	1.0
Bankfull Width (m)	1.3
% Rapids/Casc.	0.0
% Riffles	54.9
% Glides/Runs	0.0
% Pools	45.1



Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	2.9
% Fines	FN	1.0
% Sand	SA	6.7
% Fine Gravel	GF	15.2
% Crse Gravel	GC	35.2
% Cobble	CB	39.0
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		51.4
Large Wood Rating		0
Eroding Banks (%)		98.2353
Undercut Banks (%)		9.01961



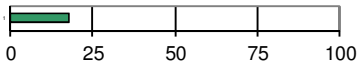
Survey end, facing downstream

Riparian Zone Characteristics

Canopy Cover (%)	91.6667
Riparian Buffer Width (m)	18
Rip Zone Tree Cover (%)	38
Rip Non-Native Cover (%)	48

Chemical Characteristics

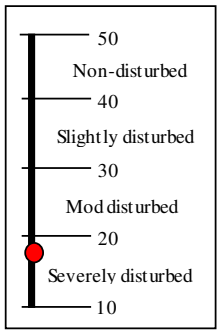
Water Temperature (°C)	13.1
Specific Cond (µS/cm)	106.1
Dissolved Oxygen (% sat)	94
Time of Measurement	1005



Biological Conditions Summary

CE Sample ID: 13-121-04
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	24	3
Mayfly	1	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	6.6	1
% Tolerant Taxa	9.3	5
% Sed Tol Taxa	11.8	3
% Dominant (1)	49.4	1
TOTAL MMI SCORE		**18**



PREDATOR O/E Score		
Year	Score	Disturbance Level
2013	0.436	Most

Stressor Scores	
Temperature Stress:	16.8
Fine Sediment Stress:	49.5

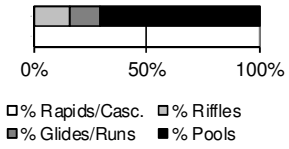
Reach Assessment Summary

Stream Name:	**Lost Dog Creek West**		
Location:	Lost Dog @ Golf Course	Latitude:	45.40999
County, State:	Clackamas, Oregon	Longitude:	-122.67819
Date sampled:	9/20/2013	Reach Length:	75 m
Personnel:	M. Cole and A. Miller		

Physical and Chemical Conditions Summary

Instream Physical Characteristics

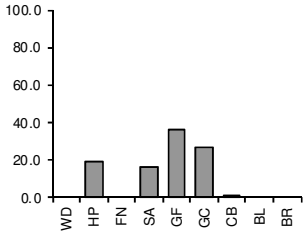
Wetted Width (m)	0.7
Bankfull Width (m)	1.1
% Rapids/Casc.	0.0
% Riffles	16.2
% Glides/Runs	13.5
% Pools	70.3

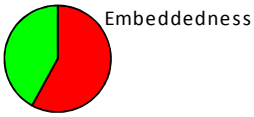


Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	19.3
% Fines	FN	0.0
% Sand	SA	16.5
% Fine Gravel	GF	36.7
% Crse Gravel	GC	26.6
% Cobble	CB	0.9
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		58.0
Large Wood Rating		0
Eroding Banks (%)		73.7838
Undercut Banks (%)		0

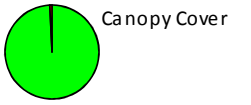




Survey end, facing downstream

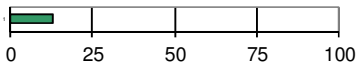
Riparian Zone Characteristics

Canopy Cover (%)	99.2647
Riparian Buffer Width (m)	13
Rip Zone Tree Cover (%)	88
Rip Non-Native Cover (%)	45



Chemical Characteristics

Water Temperature (°C)	14.4
Specific Cond (µS/cm)	111
Dissolved Oxygen (% sat)	68.9
Time of Measurement	845

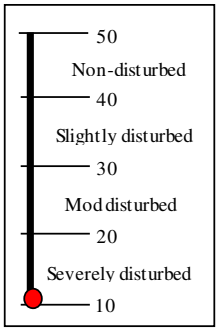


Biological Conditions Summary

CE Sample ID: 13-121-05
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES

	Raw	Stand.
Richness	12	1
Mayfly	0	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	6.0	1
% Tolerant Taxa	55.1	1
% Sed Tol Taxa	42.4	1
% Dominant (1)	41.8	1
TOTAL MMI SCORE		**10**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.242	Most

Stressor Scores

Temperature Stress:	19.3
Fine Sediment Stress:	43.3

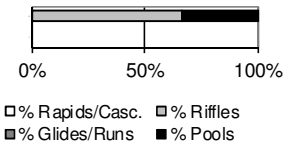
Reach Assessment Summary

Stream Name:	**Nettle Creek**		
Location:	Nettle Creek at Iron Mtn Rd	Latitude:	45.42461
County, State:	Clackamas, Oregon	Longitude:	-122.68137
Date sampled:	9/19/2013	Reach Length:	80 m
Personnel:	M. Cole and A. Miller		

Physical and Chemical Conditions Summary

Instream Physical Characteristics

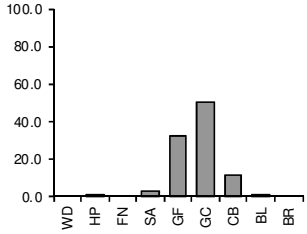
Wetted Width (m)	1.2
Bankfull Width (m)	2.8
% Rapids/Casc.	0.0
% Riffles	66.3
% Glides/Runs	0.0
% Pools	33.8



Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	0.8
% Fines	FN	0.0
% Sand	SA	3.2
% Fine Gravel	GF	32.3
% Crse Gravel	GC	50.8
% Cobble	CB	12.1
% Bulder	BL	0.8
% Bedrock	BR	0.0
% Embeddedness		49.0
Large Wood Rating		1.7
Eroding Banks (%)		46.875
Undercut Banks (%)		1.25



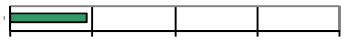
Survey end, facing downstream

Riparian Zone Characteristics

Canopy Cover (%)	98.8971
Riparian Buffer Width (m)	23
Rip Zone Tree Cover (%)	88
Rip Non-Native Cover (%)	10

Chemical Characteristics

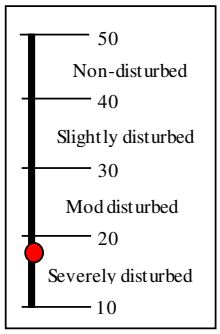
Water Temperature (°C)	13.7
Specific Cond (µS/cm)	146.5
Dissolved Oxygen (% sat)	85.7
Time of Measurement	1100



Biological Conditions Summary

CE Sample ID: 13-121-06
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	23	3
Mayfly	3	1
Stonefly	2	1
Caddisfly	1	1
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	5.6	1
% Tolerant Taxa	19.7	3
% Sed Tol Taxa	19.7	3
% Dominant (1)	33.0	3
TOTAL MMI SCORE		**18**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.339	Most

Stressor Scores	
Temperature Stress:	16.8
Fine Sediment Stress:	21.5

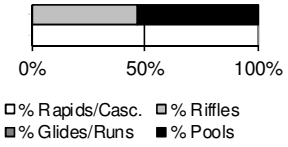
Reach Assessment Summary

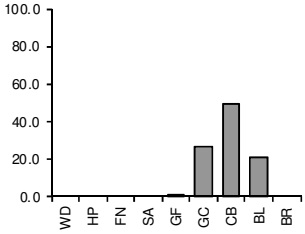
Stream Name:	**Oswego Creek**		
Location:	Oswego Creek (ds Hwy 43)	Latitude:	45.41073
County, State:	Clackamas, Oregon	Longitude:	-122.66248
Date sampled:	9/19/2013	Reach Length:	75 m
Personnel:	M. Cole and A. Miller		

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)		4.8
Bankfull Width (m)		10.2
% Rapids/Casc.		0.0
% Riffles		46.7
% Glides/Runs		0.0
% Pools		53.3
Substrate		
% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.0
% Sand	SA	0.0
% Fine Gravel	GF	1.7
% Crse Gravel	GC	27.3
% Cobble	CB	49.6
% Bulder	BL	21.5
% Bedrock	BR	0.0
% Embeddedness		23.9
Large Wood Rating		0
Eroding Banks (%)		0
Undercut Banks (%)		0



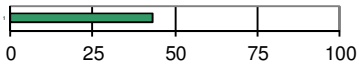


Riparian Zone Characteristics

Canopy Cover (%)	68.3824
Riparian Buffer Width (m)	43
Rip Zone Tree Cover (%)	68
Rip Non-Native Cover (%)	0

Chemical Characteristics

Water Temperature (°C)	21.2
Specific Cond (µS/cm)	143.5
Dissolved Oxygen (% sat)	85.6
Time of Measurement	1535



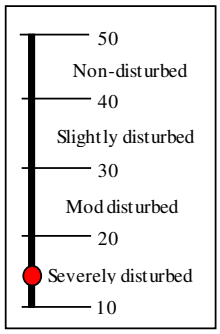
Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

CE Sample ID: 13-121-07
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	15	1
Mayfly	0	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.2	1
% Tolerant Taxa	79.9	1
% Sed Tol Taxa	0.7	5
% Dominant (1)	75.9	1
TOTAL MMI SCORE		**14**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.194	Most

Stressor Scores	
Temperature Stress:	26.3
Fine Sediment Stress:	54.2

Reach Assessment Summary

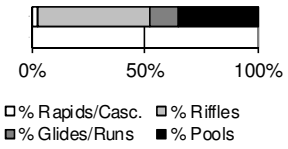
Stream Name: **Springbrook Creek Restoration Reach**
Location: Springbrook Creek at Boones Way
County, State: Clackamas, Oregon
Date sampled: 9/19/2013
Personnel: M. Cole and A. Miller

Latitude: 45.41403
Longitude: -122.71512
Reach Length: 75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

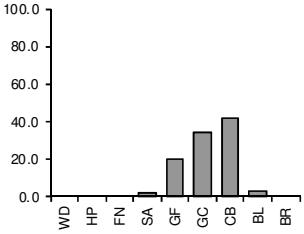
Wetted Width (m)	1.7
Bankfull Width (m)	2.9
% Rapids/Casc.	2.7
% Riffles	49.3
% Glides/Runs	13.3
% Pools	34.7

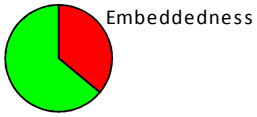


Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.0
% Sand	SA	1.9
% Fine Gravel	GF	19.8
% Crse Gravel	GC	34.0
% Cobble	CB	41.5
% Bulder	BL	2.8
% Bedrock	BR	0.0
% Embeddedness		36.0
Large Wood Rating		0.88
Eroding Banks (%)		68.6667
Undercut Banks (%)		4.53333

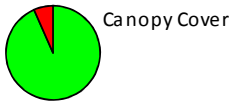




Survey end, facing downstream

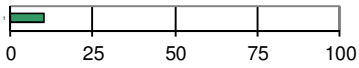
Riparian Zone Characteristics

Canopy Cover (%)	93.3824
Riparian Buffer Width (m)	10
Rip Zone Tree Cover (%)	58
Rip Non-Native Cover (%)	25



Chemical Characteristics

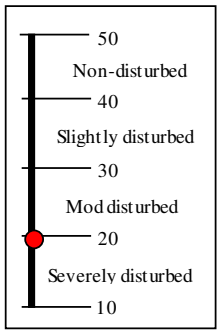
Water Temperature (°C)	15
Specific Cond (µS/cm)	106.4
Dissolved Oxygen (% sat)	91.4
Time of Measurement	1245



Biological Conditions Summary

CE Sample ID: 13-121-08
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	20	3
Mayfly	3	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	6.1	1
% Tolerant Taxa	28.8	3
% Sed Tol Taxa	23.4	3
% Dominant (1)	19.3	5
TOTAL MMI SCORE		**20**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.388	Most

Stressor Scores

Temperature Stress:	21.2
Fine Sediment Stress:	36.8

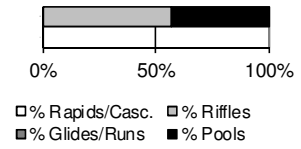
Reach Assessment Summary

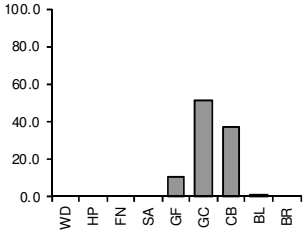
Stream Name:	**Springbrook Creek Lower**		
Location:	Springbrook Creek at Iron Mtn Park	Latitude:	45.41421
County, State:	Clackamas, Oregon	Longitude:	-122.70775
Date sampled:	9/19/2013	Reach Length:	84 m
Personnel:	M. Cole and A. Miller		

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)		1.9
Bankfull Width (m)		2.9
% Rapids/Casc.		0.0
% Riffles		57.1
% Glides/Runs		0.0
% Pools		42.9
Substrate		
% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.0
% Sand	SA	0.0
% Fine Gravel	GF	10.8
% Crse Gravel	GC	51.4
% Cobble	CB	36.9
% Bulder	BL	0.9
% Bedrock	BR	0.0
% Embeddedness		36.7
Large Wood Rating		0.77381
Eroding Banks (%)		59.2857
Undercut Banks (%)		5.05952



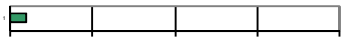


Riparian Zone Characteristics

Canopy Cover (%)	96.6912
Riparian Buffer Width (m)	5
Rip Zone Tree Cover (%)	48
Rip Non-Native Cover (%)	55

Chemical Characteristics

Water Temperature (°C)	15.7
Specific Cond (µS/cm)	107.5
Dissolved Oxygen (% sat)	87.2
Time of Measurement	1430



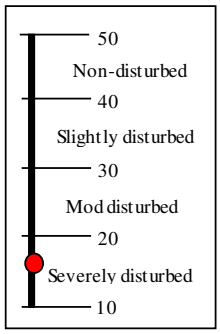
Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

CE Sample ID: 13-121-09
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	21	3
Mayfly	3	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	5.6	1
% Tolerant Taxa	45.5	1
% Sed Tol Taxa	16.5	3
% Dominant (1)	28.8	3
TOTAL MMI SCORE		**16**



PREDATOR O/E Score		
Year	Score	Disturbance Level
2013	0.437	Most

Stressor Scores	
Temperature Stress:	22.1
Fine Sediment Stress:	38.6

Reach Assessment Summary

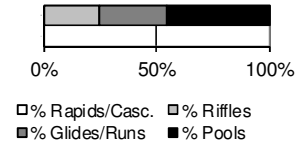
Stream Name: **Boeckman Creek**
Location: Boeckman Creek DS Rose Ln
County, State: Clackamas, Oregon
Date sampled: 9/22/2013
Personnel: M. Cole and A. Miller

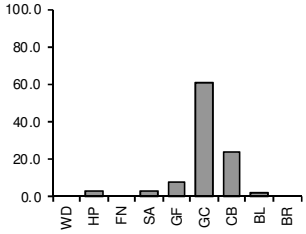
Latitude: 45.29917142
Longitude: -122.754864
Reach Length: 100 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)		1.9
Bankfull Width (m)		3.4
% Rapids/Casc.		0.0
% Riffles		25.0
% Glides/Runs		30.0
% Pools		45.0
Substrate		
% Wood	WD	0.0
% Hardpan	HP	3.0
% Fines	FN	0.0
% Sand	SA	3.0
% Fine Gravel	GF	7.9
% Crse Gravel	GC	60.4
% Cobble	CB	23.8
% Bulder	BL	2.0
% Bedrock	BR	0.0
% Embeddedness		66.6
Large Wood Rating		1.74
Eroding Banks (%)		85.3
Undercut Banks (%)		6.4



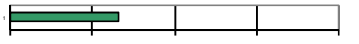


Riparian Zone Characteristics

Canopy Cover (%)	90.8824
Riparian Buffer Width (m)	33
Rip Zone Tree Cover (%)	65
Rip Non-Native Cover (%)	48

Chemical Characteristics

Water Temperature (°C)	14.1
Specific Cond (µS/cm)	175.5
Dissolved Oxygen (% sat)	89
Time of Measurement	1040



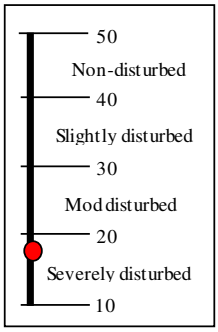
Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

CE Sample ID: 13-121-12
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	19	3
Mayfly	1	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.3	1
% Tolerant Taxa	36.6	3
% Sed Tol Taxa	5.7	5
% Dominant (1)	30.9	3
TOTAL MMI SCORE		**20**



PREDATOR O/E Score		
Year	Score	Disturbance Level
2013	0.388	Most

Stressor Scores	
Temperature Stress:	22.9
Fine Sediment Stress:	30.6

Reach Assessment Summary

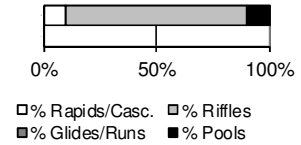
Stream Name: **Coffee Creek**
Location: Lower Coffee Creek
County, State: Clackamas, Oregon
Date sampled: 9/16/2013
Personnel: M. Cole and A. Miller

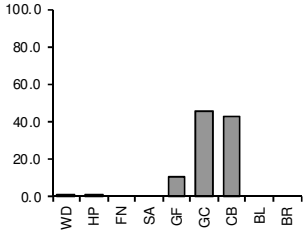
Latitude: 45.34613529
Longitude: -122.618168
Reach Length: 50 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)		1.2
Bankfull Width (m)		2.4
% Rapids/Casc.		10.0
% Riffles		80.0
% Glides/Runs		0.0
% Pools		10.0
Substrate		
% Wood	WD	0.9
% Hardpan	HP	0.9
% Fines	FN	0.0
% Sand	SA	0.0
% Fine Gravel	GF	10.4
% Crse Gravel	GC	45.3
% Cobble	CB	42.5
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		49.4
Large Wood Rating		1.92
Eroding Banks (%)		73.8
Undercut Banks (%)		0



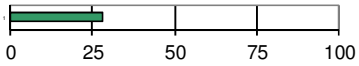


Riparian Zone Characteristics

Canopy Cover (%)	81.6176
Riparian Buffer Width (m)	28
Rip Zone Tree Cover (%)	38
Rip Non-Native Cover (%)	73

Chemical Characteristics

Water Temperature (°C)	15.6
Specific Cond (µS/cm)	40
Dissolved Oxygen (% sat)	94.2
Time of Measurement	850



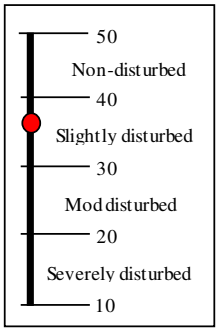
Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

CE Sample ID: 13-121-13
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	28	3
Mayfly	4	3
Stonefly	4	3
Caddisfly	4	3
# Sensitive Taxa	3	3
# Sed Sens Taxa	1	3
Modified HBI	4.3	3
% Tolerant Taxa	7.7	5
% Sed Tol Taxa	8.6	5
% Dominant (1)	16.7	5
TOTAL MMI SCORE		**36**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.63	Most

Stressor Scores

Temperature Stress:	17.2
Fine Sediment Stress:	22.1

Reach Assessment Summary

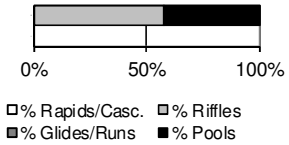
Stream Name: **Minthorn Creek**
Location: Box Culvet at SE Lake Road
County, State: Clackamas, Oregon
Date sampled: 9/14/2013
Personnel: M. Cole and A. Miller

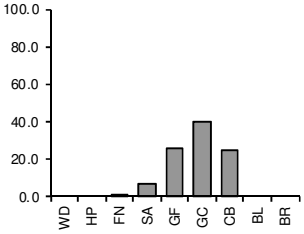
Latitude: 45.43181479
Longitude: -122.598378
Reach Length: 45 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)		1.2
Bankfull Width (m)		2.1
% Rapids/Casc.		0.0
% Riffles		57.8
% Glides/Runs		0.0
% Pools		42.2
Substrate		
% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.9
% Sand	SA	7.2
% Fine Gravel	GF	26.1
% Crse Gravel	GC	40.5
% Cobble	CB	25.2
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		50.2
Large Wood Rating		0
Eroding Banks (%)		46
Undercut Banks (%)		0



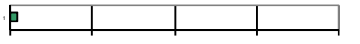


Riparian Zone Characteristics

Canopy Cover (%)	6.86275
Riparian Buffer Width (m)	2
Rip Zone Tree Cover (%)	5
Rip Non-Native Cover (%)	35

Chemical Characteristics

Water Temperature (°C)	19.1
Specific Cond (µS/cm)	175.2
Dissolved Oxygen (% sat)	69.7
Time of Measurement	940



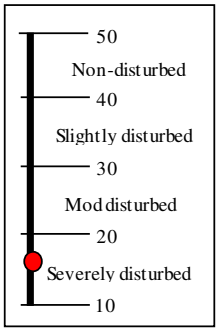
Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

CE Sample ID: 13-121-14
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	23	3
Mayfly	2	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.9	1
% Tolerant Taxa	64.0	1
% Sed Tol Taxa	12.6	3
% Dominant (1)	26.4	3
TOTAL MMI SCORE		**16**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.388	Most

Stressor Scores

Temperature Stress:	23.4
Fine Sediment Stress:	51.2

Reach Assessment Summary

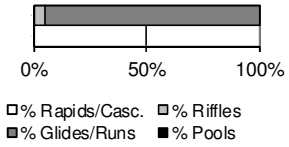
Stream Name: **Rinearson Creek**
Location: Outfall at Risley Rd
County, State: Clackamas, Oregon
Date sampled: 9/16/2013
Personnel: M. Cole and A. Miller

Latitude: 45.38215896
Longitude: -122.60383
Reach Length: 75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

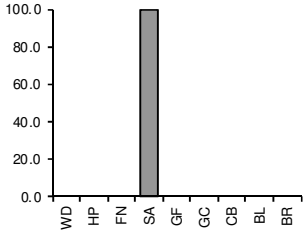
Wetted Width (m)	1.2
Bankfull Width (m)	3.4
% Rapids/Casc.	0.0
% Riffles	5.3
% Glides/Runs	94.7
% Pools	0.0

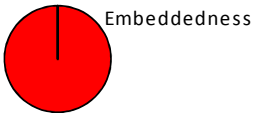


Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.0
% Sand	SA	100.0
% Fine Gravel	GF	0.0
% Crse Gravel	GC	0.0
% Cobble	CB	0.0
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		100.0
Large Wood Rating		0
Eroding Banks (%)		55.0667
Undercut Banks (%)		0

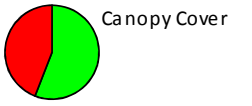




Survey end, facing downstream

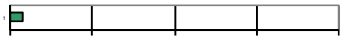
Riparian Zone Characteristics

Canopy Cover (%)	55.8824
Riparian Buffer Width (m)	4
Rip Zone Tree Cover (%)	15
Rip Non-Native Cover (%)	60



Chemical Characteristics

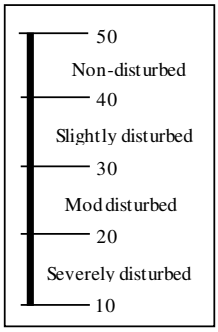
Water Temperature (°C)	18.1
Specific Cond (µS/cm)	170.6
Dissolved Oxygen (% sat)	60.7
Time of Measurement	1350



Biological Conditions Summary

CE Sample ID: 13-121-15
Sample Method: OR 8-kick
Target Habitat: Glide

DEQ METRIC SCORES	Raw	Stand.
Richness	19	3
Mayfly	0	1
Stonefly	0	1
Caddisfly	0	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	6.7	1
% Tolerant Taxa	54.4	1
% Sed Tol Taxa	25.8	1
% Dominant (1)	24.7	3
TOTAL MMI SCORE		**14**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.242	NA

Stressor Scores

Temperature Stress:	21
Fine Sediment Stress:	NA

Reach Assessment Summary

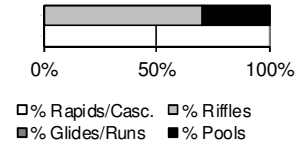
Stream Name: **Singer Creek**
Location: Singer Creek at Singer Creek Park
County, State: Clackamas, Oregon
Date sampled: 9/16/2013
Personnel: M. Cole and A. Miller

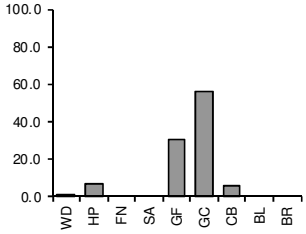
Latitude: 45.34771701
Longitude: -122.601959
Reach Length: 75 m

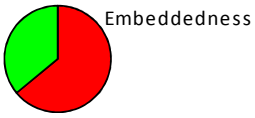
Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)		1.0
Bankfull Width (m)		1.8
% Rapids/Casc.		0.0
% Riffles		70.1
% Glides/Runs		0.0
% Pools		29.9
Substrate		
% Wood	WD	1.0
% Hardpan	HP	6.9
% Fines	FN	0.0
% Sand	SA	0.0
% Fine Gravel	GF	30.4
% Crse Gravel	GC	55.9
% Cobble	CB	5.9
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		64.0
Large Wood Rating		0.24675
Eroding Banks (%)		69.7403
Undercut Banks (%)		1.16883

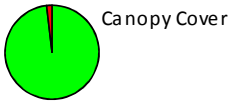






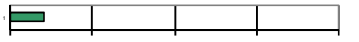
Riparian Zone Characteristics

Canopy Cover (%)	98.1618
Riparian Buffer Width (m)	10
Rip Zone Tree Cover (%)	40
Rip Non-Native Cover (%)	55



Chemical Characteristics

Water Temperature (°C)	14.8
Specific Cond (µS/cm)	70.9
Dissolved Oxygen (% sat)	87
Time of Measurement	950



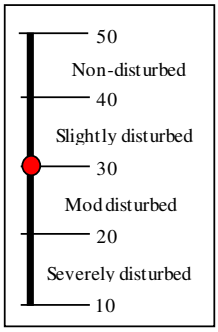
Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

CE Sample ID: 13-121-16
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	24	3
Mayfly	5	3
Stonefly	2	1
Caddisfly	3	1
# Sensitive Taxa	2	3
# Sed Sens Taxa	1	3
Modified HBI	4.2	3
% Tolerant Taxa	1.7	5
% Sed Tol Taxa	1.1	5
% Dominant (1)	32.7	3
TOTAL MMI SCORE		**30**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.582	Most

Stressor Scores

Temperature Stress:	16.2
Fine Sediment Stress:	24

Reach Assessment Summary

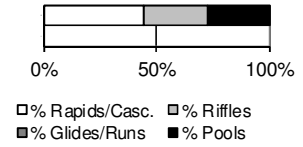
Stream Name: **Tanner Creek**
Location: Imperial Drive
County, State: Clackamas, Oregon
Date sampled: 9/16/2013
Personnel: M. Cole and A. Miller

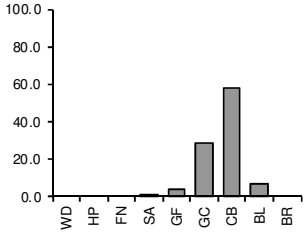
Latitude: 45.3516544
Longitude: -122.630998
Reach Length: 75 m

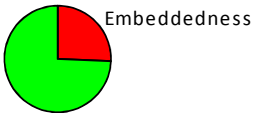
Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)		1.9
Bankfull Width (m)		3.0
% Rapids/Casc.		44.3
% Riffles		28.6
% Glides/Runs		0.0
% Pools		27.1
Substrate		
% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.0
% Sand	SA	0.9
% Fine Gravel	GF	4.6
% Crse Gravel	GC	28.7
% Cobble	CB	58.3
% Bulder	BL	7.4
% Bedrock	BR	0.0
% Embeddedness		25.6
Large Wood Rating		0
Eroding Banks (%)		19.8571
Undercut Banks (%)		3.57143

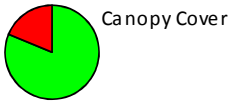






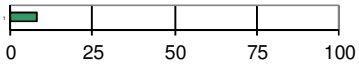
Riparian Zone Characteristics

Canopy Cover (%)	81.25
Riparian Buffer Width (m)	8
Rip Zone Tree Cover (%)	58
Rip Non-Native Cover (%)	33



Chemical Characteristics

Water Temperature (°C)	16.1
Specific Cond (µS/cm)	107.6
Dissolved Oxygen (% sat)	92.6
Time of Measurement	1130



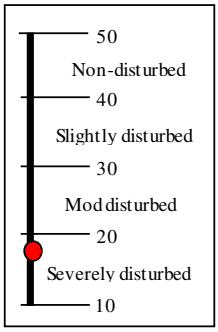
Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

CE Sample ID: 13-121-17
Sample Method: OR 8-kick
Target Habitat: Riffle

DEQ METRIC SCORES	Raw	Stand.
Richness	8	1
Mayfly	1	1
Stonefly	0	1
Caddisfly	0	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.6	1
% Tolerant Taxa	8.5	5
% Sed Tol Taxa	8.5	5
% Dominant (1)	54.5	1
TOTAL MMI SCORE		**18**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.242	Most

Stressor Scores

Temperature Stress:	16.1
Fine Sediment Stress:	18.2

Reach Assessment Summary

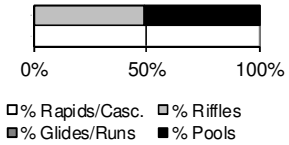
Stream Name: **Trillium Creek**
Location: Caloroga Rd
County, State: Clackamas, Oregon
Date sampled: 9/14/2013
Personnel: M. Cole and A. Miller

Latitude: 45.39573241
Longitude: -122.637776
Reach Length: 75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

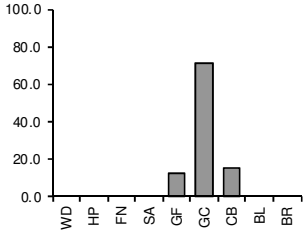
Wetted Width (m)	2.0
Bankfull Width (m)	3.8
% Rapids/Casc.	0.0
% Riffles	49.3
% Glides/Runs	0.0
% Pools	50.7

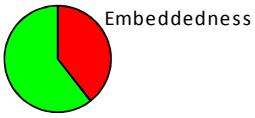


Survey start, facing upstream

Substrate

% Wood	WD	0.0
% Hardpan	HP	0.0
% Fines	FN	0.0
% Sand	SA	0.0
% Fine Gravel	GF	13.1
% Crse Gravel	GC	71.0
% Cobble	CB	15.9
% Bulder	BL	0.0
% Bedrock	BR	0.0
% Embeddedness		39.4
Large Wood Rating		0.16
Eroding Banks (%)		27.8667
Undercut Banks (%)		8.53333

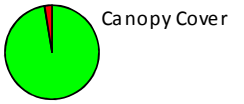




Survey end, facing downstream

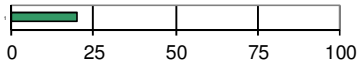
Riparian Zone Characteristics

Canopy Cover (%)	97.4265
Riparian Buffer Width (m)	20
Rip Zone Tree Cover (%)	78
Rip Non-Native Cover (%)	30



Chemical Characteristics

Water Temperature (°C)	17.1
Specific Cond (µS/cm)	150.5
Dissolved Oxygen (% sat)	93
Time of Measurement	1110

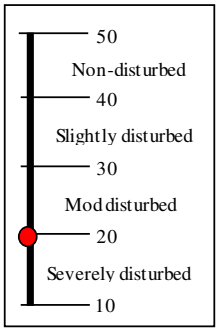


CE Sample ID: 13-121-18
Sample Method: OR 8-kick
Target Habitat: Riffle

Biological Conditions Summary

DEQ METRIC SCORES

	Raw	Stand.
Richness	21	3
Mayfly	3	1
Stonefly	0	1
Caddisfly	2	1
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	5.3	1
% Tolerant Taxa	34.5	3
% Sed Tol Taxa	7.8	5
% Dominant (1)	25.6	3
TOTAL MMI SCORE		**20**



PREDATOR O/E Score

Year	Score	Disturbance Level
2013	0.485	Most

Stressor Scores

Temperature Stress:	20
Fine Sediment Stress:	23.7