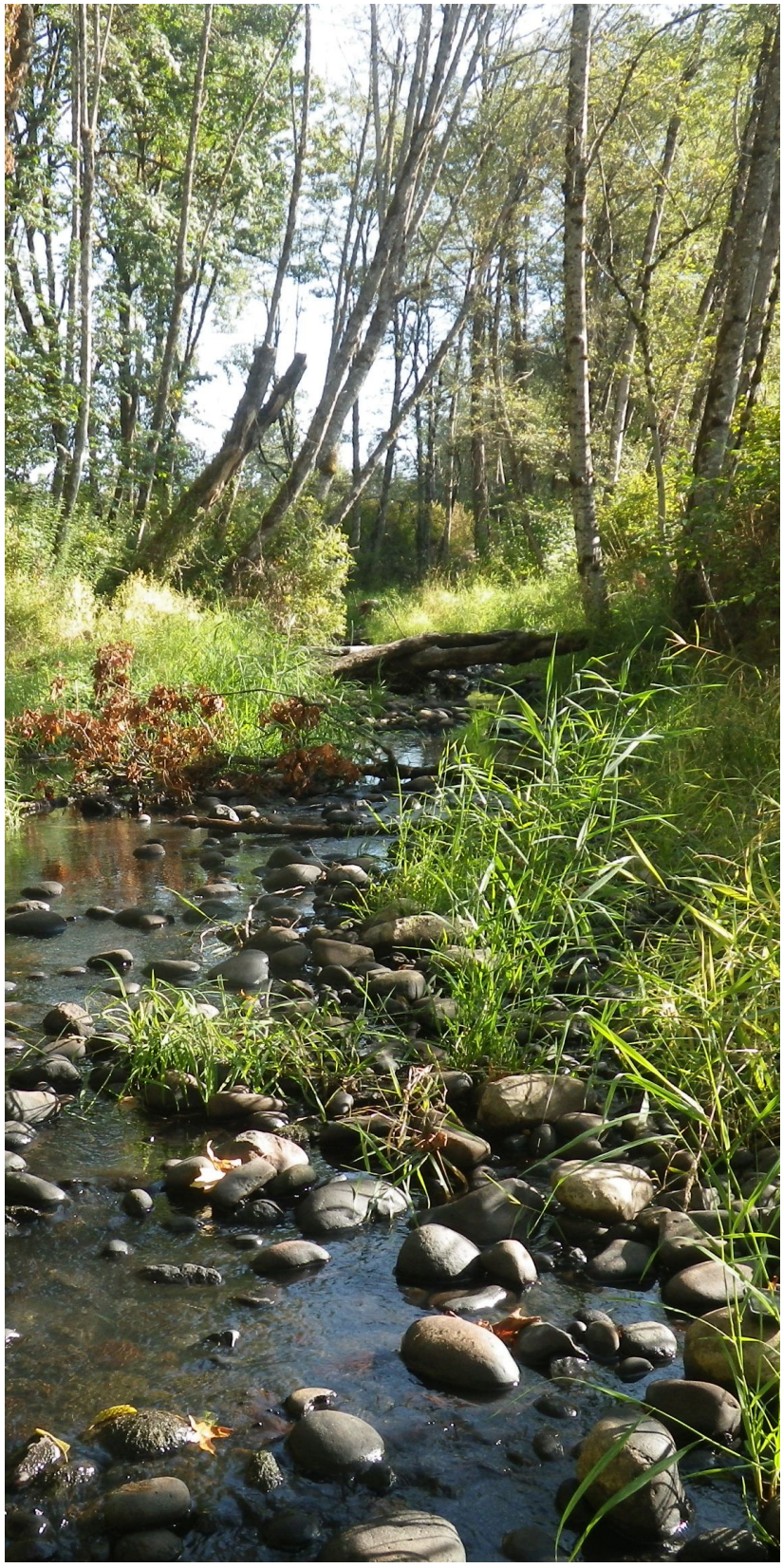
2018

CLACKAMAS SOIL & WATER CONSERVATION DISTRICT STREAM BENTHIC MACROINVERTEBRATE ASSESSMENT



FINAL REPORT

Prepared for

Clackamas Soil & Water Conservation District
Oregon City, Oregon

By

Michael B. Cole, Ph.D.
&
Christopher T. Burtch
Cole Ecological, Inc.

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EXECUTIVE SUMMARY

- The Clackamas Soil and Water Conservation District contracted an assessment of macroinvertebrate communities in fall 2018 to determine current ecological conditions in Doane, North Fork Deep, Noyer, and Tickle creeks. These streams were previously sampled by the SWCD in 2012 and 2016. Two reaches on Doane Creek and one reach on each of the other three creeks were sampled. Tickle Creek was again selected to represent least-disturbed or reference conditions against which to compare conditions from the other four reaches.
- Macroinvertebrate communities, physical habitat, and water chemistry were sampled from the five survey reaches on September 18 and 19, 2018. Macroinvertebrates were collected using the Oregon Department of Environmental Quality's (DEQ) Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams. Multimetric analysis, the Marine Western Coastal Forest (MWCF) Predictive Model, and Oregon DEQ temperature and fine sediment stressor models were used to analyze the macroinvertebrate data.
- Macroinvertebrate community conditions measured in 2018 were very similar to those measured in 2012 and 2016. DEQ multimetric scores of sampled macroinvertebrate communities ranged from 12 to 30, indicating that macroinvertebrate community conditions ranged from severely to slightly disturbed across the survey reaches. The Tickle Creek reference site received the only multimetric index score corresponding to only a slightly disturbed classification. The Deep, Noyer, and upper Doane Creek samples once again received multimetric scores that indicated severely disturbed biological conditions.
- MWCF predictive model O/E scores also suggested severe disturbance across all study reaches that had been classified as severely disturbed by the multimetric index. O/E scores the four test sites ranged narrowly from 0.291 to 0.533. In contrast, the Tickle Creek reference reach received an O/E score of 1.067, corresponding to a "least disturbed" condition class.

- Fine-sediment stressor model results suggested that macroinvertebrate communities from the North Fork Deep and both Doane sample reaches were likely showing fine-sediment-induced stress. Temperature stressor model results suggested that macroinvertebrate communities in four of the five reaches were likely showing elevated temperature stress. Only the Noyer Creek reach received an inferred temperature stressor score lower than the Willamette Valley threshold of 18.4 °C.
- Results from Noyer Creek are particularly noteworthy, as the benthic community in the sample reach is heavily disturbed, yet temperature and sediment stressor models to do not implicate either. Furthermore, the abundance of the tolerant and rapid-recolonizer mayfly, *Baetis tricaudatus* complex, suggests possible acute toxicity events in Noyer Creek. No other mayflies were present, and the pesticide imidacloprid has been detected in this reach at concentrations known to be toxic to mayflies.
- The macroinvertebrate communities of the creeks assessed by the Clackamas County SWCD stand to benefit from improved stormwater and/or agricultural runoff management. One of the primary goals of the SWCD macroinvertebrate monitoring program is to assess the effects of agricultural runoff on the biology of area creeks. These data serve as a baseline against which to evaluate improvements to the macroinvertebrate community in response to the SWCD's efforts to curtail agricultural runoff into receiving waters and improve the quality of runoff entering into local creeks. Long-term biological monitoring of these streams should serve as an effective measure of the future success of these efforts.

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INTRODUCTION

As Portland, Oregon's popularity and population increase, so do the demands on regional and local resource managers to maintain and improve aquatic resource conditions, functions and values. The Clackamas County Soil and Water Conservation District (SWCD) is an agency whose mission is to help landowners become better stewards of the natural resources they use and manage. Since 2012, the SWCD has conducted periodic monitoring of macroinvertebrate communities in five stream reaches on public and private lands throughout the Distinct (Haxton and Cole 2012, Cole 2016). The information and data obtained from the program are used to help track trends in ecological conditions of area streams, determine the success of water resource management efforts, and to help inform future planning and management of these resources. The SWCD conducted a third year of monitoring in 2018, repeating sampling in the same five reaches previously sampled in 2012 and 2016. This report provides a detailed description of the methods, results, and interpretation of the assessment conducted in 2018.

STUDY AREA

The streams included in this study all occur in the lower Clackamas River basin in northern Clackamas County. All reaches occur within the Willamette Valley Ecoregion, a region dominated by wide and low-gradient stream and river valleys. Doane and Deep creeks each flow in a generally southwesterly direction towards the Clackamas River. The upper reaches of each of these systems occur on this wide valley floor. The lower reaches have cut deeply into the valley floor deposits along their course to the Clackamas River, creating v-shaped valleys that are presently forested. Noyer Creek, a small tributary to Doane Creek, flows southwesterly across the valley floor. Upper Tickle Creek occurs farthest east and at the highest elevation among the four study streams. The area encompassing these four drainages is dominated by agriculture, but also includes urban and forested land uses.

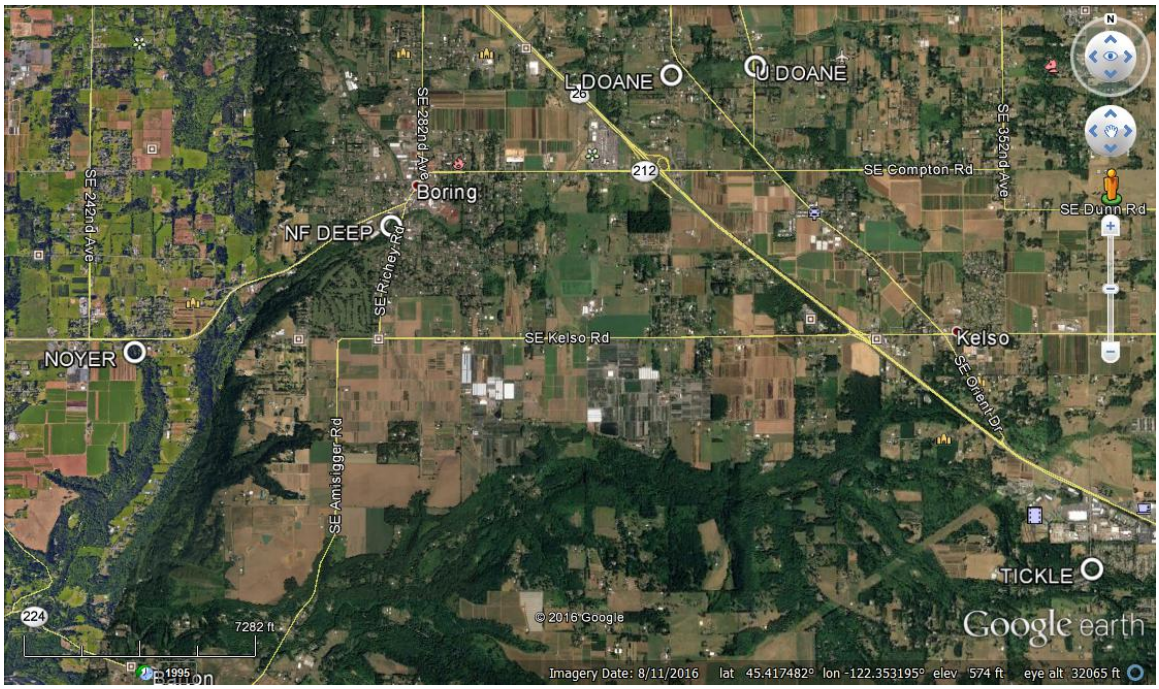

Figure 1. 2018 Clackamas Soil & Water Conservation District macroinvertebrate sample reaches.

METHODS

SAMPLE SITE SELECTION

The Clackamas County SWCD works with various landowners, public and private, in an effort to promote natural resource conservation. Five stream reaches were initially selected for sampling within the Clackamas County SWCD study area in 2012, when the first year of sampling was performed. A reach on Tickle Creek site was pre-determined to represent a least-disturbed or reference condition, as it is within Tickle Creek Park and its immediate riparian area is protected from development. The other four reaches were selected based on ease of accessibility and proximity to road crossings (Table 1). These same five reaches were sampled in 2016 and 2018.

MACROINVERTEBRATE ASSESSMENT

Macroinvertebrate communities, physical habitat, and water chemistry were sampled from the 5 survey reaches on September 18 and 19, 2018 by Michael Cole and Chris Burtch of Cole Ecological, Inc. First, each survey reach was marked and the reach length was measured to approximate the same length of reach surveyed in previous years.

Waypoints were acquired for the start and end of each reach using a GPS unit and the reach length was measured.

Table 1. Stream reaches sampled for macroinvertebrates, physical habitat, and water chemistry in the Clackamas Soil & Water Conservation District, Oregon, in the fall 2018.

Site ID	Stream	Location Description	Latitude	Longitude
LOWER DOANE	Doane Creek	DS side of SE 312th Ave.	45.441	-122.3429
UPPER DOANE	Doane Creek	US side of SE Revenue Rd.	45.44173	-122.3316
NF DEEP	Deep Creek	DS side of SE Richey Rd.	45.42797	-122.37645
NOYER	Noyer Creek	DS side of Hwy 212	45.41662	-122.40798
TICKLE	Tickle Creek	DS side of 362nd Dr.	45.39824	-122.2909

INSTREAM PHYSICAL HABITAT AND RIPARIAN ASSESSMENT

Habitat surveys were performed in the reaches following a modified Rapid Stream Assessment Technique (RSAT) which consisted of data collection from individual channel habitat units, three channel cross sections, and from the adjacent riparian zone (Table 2). First, the valley type within each survey reach 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 habitat 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 in each reach. The following definitions were adapted from the Oregon Department of Fish and Wildlife's (ODFW) 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 upstream and downstream.

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.

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

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

The following attributes were then measured or visually estimated in each channel unit. Substrate composition was visually estimated in each unit using substrate size classes adapted from the United States Environmental Protection Agency's (USEPA) Environmental Monitoring & Assessment Protocols (EMAP) protocols for wadeable streams (USEPA 2000). 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. Additionally, all woody debris measuring at least 15 cm in diameter and 2 m in length was tallied for each sampled unit and the configuration, type, location, and size of root wads and pieces of wood were recorded. Overhead cover was visually estimated with a spherical densiometer in four directions (upstream, downstream, right, and left) from the center of the stream at evenly spaced intervals along the length of the reach. Habitat features such as beaver activity, culverts, and potential fish passage barriers were noted by habitat unit.

Cross-section Surveys

Channel dimensions were measured at three transects occurring within each 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 (i.e. 10% of the reach length) 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 (BFHmax), 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 and 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), 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. Embeddedness is defined is the degree to which fine sediments surround coarse sediments on the streambed surface.

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

Table 2. Environmental parameters measured in the field to characterize stream reaches in the Clackamas Soil & Water Conservation District, Oregon, in the fall 2018.

Variable	Quantitative or Categorical	Visual Estimate or Measured Variable
Reach length (m)	Q	M
Valley type	C	V
Channel unit gradient (%)	Q	M
Wetted width (m)	Q	M
Bankfull width (m)	Q	M
Bankfull height (m)	Q	M
Mean water depth (cm)	Q	M
Rapids (% of reach length)	Q	M
Riffles (% of reach length)	Q	M
Glides (% of reach length)	Q	M
Pools (% of reach length)	Q	M
Substrate composition	Q	M
Substrate embeddedness (%)	Q	M
Large wood tally	Q	M
Overhead canopy cover (%)	Q	M
Reach embeddedness (%)	Q	V
Eroding banks (%)	Q	V
Undercut banks (%)	Q	V
Mean riparian buffer width (m)	Q	V
Riparian zone tree cover (%)	Q	V
Non-native riparian vegetation cover (%)	Q	V
Dominant adjacent land use	C	V
Water temperature (°C)	Q	M
pH (pH units)	Q	M
Specific conductance (µS/cm)	Q	M
Dissolved oxygen (mg/L)	Q	M

type(s) (riparian forest, 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.

MACROINVERTEBRATE COMMUNITY ASSESSMENT

Field Sampling

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 reaches that had sufficient riffle habitat; glides were sampled 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 was placed into one or more 1-L polyethylene wide-mouth bottles, 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, macroinvertebrates were identified to the level of taxonomic resolution established for Pacific Northwest macroinvertebrate samples (PNAMP 2015).

DATA ANALYSIS

A number of analytical tools are available for assessing and quantifying macroinvertebrate community conditions in western Oregon streams. These tools include a multimetric index, predictive models, and several stressor models, as further described below. The existing tools employed by Oregon DEQ for analysis of macroinvertebrate data in western Oregon have been developed from and therefore are most appropriate for the assessment of assemblages collected from coarse substrates in riffle habitats. One of the five study reaches, lower Doane Creek, did not exhibit these characteristics deemed necessary for appropriate application of these tools, but for purposes of maintaining consistency in analysis and reporting among sites, we analyzed the data from this reach in the same manner as were the data from the other reaches.

Both multimetric analysis and the Marine Western Coastal Forest (MWCF) Predictive Model were used to analyze the macroinvertebrate data. Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that has been shown to be associated with one or more types of pollution or habitat degradation. Each community metric is converted to a standardized score; standardized scores of all metrics are then summed to produce a single multimetric score that is an index of overall biological integrity. Reference condition data are required to develop and use this type of assessment tool. Metric sets and standardized metric scoring criteria are developed and calibrated for specific community types, based on both geographic location and stream/habitat type. 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).

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). 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 disturbance based on these total scores.

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 commonly occurring (>50% probability of occurrence) at reference reaches. The expected taxa, therefore, are taxa that are expected to have at least a 50% probability of occurring within a reach in the absence of disturbance. Biological condition is determined by comparing the O/E score 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 more accurately assess condition over this wide range of natural environmental gradients. 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 then used in the resulting model to predict macroinvertebrate community composition in the absence of disturbance. The model assigns a probability of class membership of each test site to the different classes of test sites specified in the model based on the environmental predictor variables that are input into the model.

Once predictor variables and taxonomic data have been input into the model, the probability of occurrence of each taxon at a given test site (in the absence of disturbance) is calculated based on the frequency of occurrence of each taxon in each class of site weighted by the probability that the site belongs in each class. With this information, the model calculates the O/E score for each site. Using the MWCF biological condition thresholds (Hubler 2008), 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 Identification

Weighted-average inference models were developed to reveal shifts in assemblage composition that implicate either substrate degradation (i.e. fine sediment pollution) or temperature pollution. These weighted-average inference models for temperature and sediment are to be used as screening tools to detect stress 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 90th 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 and sediment levels in each study reach. The DEQ's thresholds of 18.4 °C for

temperature and 19% of fine sediment (90th percentile of the distribution of DEQ Willamette Valley reference site scores) were used to determine whether each was functioning as a potential stressor in each sample reach (Huff et al. 2006).

Table 3. Metric set and scoring criteria (WQIW 1999) used to assess condition of macroinvertebrate communities in Clackamas SWCD assessment streams.

	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

RESULTS

PHYSICAL HABITAT CONDITIONS

Four of the five stream reaches included in this study were characterized as higher-gradient reaches that supported a significant proportion of riffle habitat and a predominance of coarse substrate bed material (Table 4 and Figure 2). Upper Doane (UDOANE), North Fork Deep Creek (NFDEEP), Noyer (NOYER) and Tickle Creek (TICKLE) supported riffle habitat ranging from 17% to 54% of the total reach length. Riffles within these reaches were heavily dominated by coarse substrates ranging from gravels to boulders (Table 4 and Figure 2). Gravel and cobble were the dominant substrates in upper Doane, NF Deep and Tickle Creek riffles; while Noyer Creek riffles included boulders in addition to gravel and cobble. Riffle substrate embeddedness in these four reaches was generally low, ranging from 12.1 to 16.8%. One reach, lower

Doane Creek (LDOANE), had a channel gradient of significantly less than 1%, supported primarily glide and pool habitat, and was dominated by hardpan and fine substrates.

Across all reaches, wetted channel widths in 2018 ranged from 1.8 to 4.6 m, which is considerably smaller than the range measured in 2016 (5.0 to 13.7 m), but similar to that measured in 2012 (1.7 m to 6.2 m). This disparity in wetted channel dimensions between 2016 and 2012/2018 results primarily from the 2016 sampling event occurring during high flows immediately following a significant rain event. Bankfull widths in 2018 ranged from 2.5 to 7.4 m, again considerably more similar those measured in 2012 (3.4 m to 9.5 m) than in 2016 (8.7 to 28.0 m). In this case, however, these differences are likely attributable to differences in how different crews interpreted and measured bankfull channel dimensions. Because the 2018 and 2012 values are similar, the 2016 values appear to be outliers and should be flagged as such, as actual changes in channel dimensions among the sampling years did not occur as the data would suggest (and are not evident in the 2016 site photos).

Streambank erosion in 2018 averaged 50% of the total streambank length among all five reaches and was highest in the two Doane Creek reaches at 89.7% (UDOANE) and 70.4 % (LDOANE) eroding banks. Riparian buffer zones are narrowest at both of the Doane Creek reaches and at the Deep Creek reach, as visual estimates ranged from 3.5 m at lower Doane Creek to 15 m at North Fork Deep Creek. Collectively, the field data and photos suggest that riparian conditions have remained largely unchanged in each sample reach since 2012, when this sampling was initiated. Forested riparian buffers remain most intact at Tickle Creek and Noyer Creek, with mean estimated buffer widths of 27.5 m and 62.5 m, respectively. Both upper Doane and NF Deep Creek reaches support narrow riparian buffers on one side, resulting in average buffer widths of 13.5 m and 15 m, respectively. The lower Doane Creek reach most conspicuously lacks a forested riparian buffer, particularly on its river-left side, resulting in mean buffer width of 3.5 m. Percent tree cover in 2018 remains highest at Noyer, as the presence of mature trees provided 98% canopy cover. By comparison, canopy cover in 2018 at the other sites ranged from 66% at lower Doane to 93% at Tickle.

MACROINVERTEBRATE COMMUNITY CONDITIONS

DEQ multimetric index scores of macroinvertebrate communities sampled in 2018 ranged from 12 to 30, indicating that macroinvertebrate community conditions vary from slightly to severely disturbed among the survey reaches (Table 5). The Tickle Creek reference site (TICKLE) received the only multimetric index score corresponding to only slight disturbance to the macroinvertebrate community. The upper Doane, NF Deep, and Noyer samples received multimetric scores of 16, 18 and 12, respectively. All three of these scores indicate severely disturbed biological conditions. These results are wholly consistent with those obtained in 2012 and 2016, and suggest that biological conditions in these reaches have remained significantly impacted (Table 5).

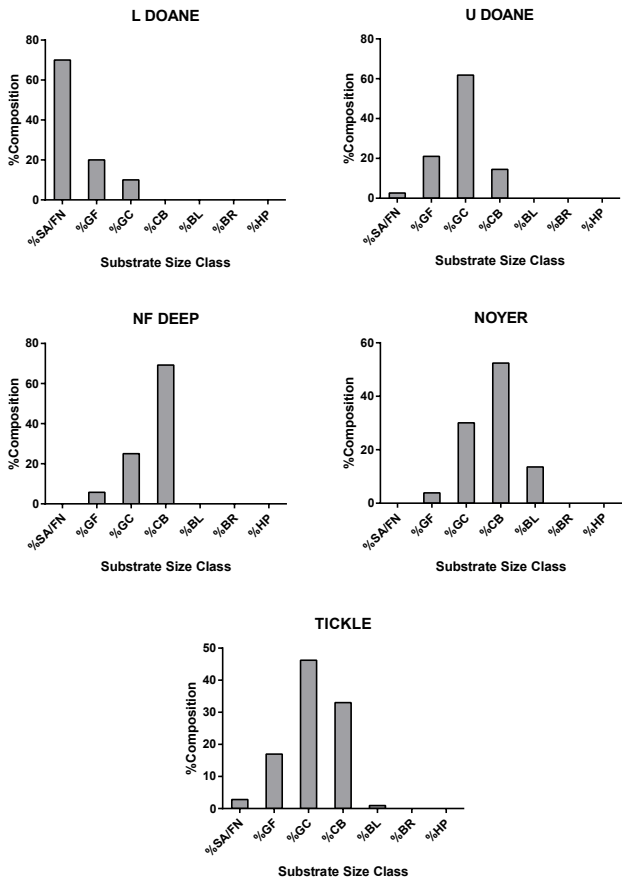

Figure 2. Substrate composition in habitats sampled for macroinvertebrates from five stream reaches in the Clackamas Soil & Water Conservation District, Oregon, in fall 2018.

Table 4. Environmental conditions of five stream reaches sampled in the Clackamas Soil & Water Conservation District, Oregon, in fall 2018.

Environmental parameter	L DOANE	UP DOANE	NF DEEP	NOYER	TICKLE	Summary Statistics			
						Mean	**SD**	**Min**	**Max**
Channel slope (%)	0.5	1.0	0.9	2.5	1.4	**1.3**	**0.8**	**0.5**	**2.5**
Wetted width (m)	1.8	1.8	4.6	3.7	3.3	**3.0**	**1.2**	**1.8**	**4.6**
Bankfull width (m)	3.0	2.5	7.2	7.4	6.7	**5.3**	**2.4**	**2.5**	**7.4**
Percent pools	75.3	41.7	35.4	31.5	36.0	**44.2**	**17.9**	**31.5**	**75.3**
Percent glides/runs	22.1	41.7	9.8	13.0	25.3	**22.6**	**13.0**	**9.8**	**42.9**
Percent riffles	2.6	16.7	54.9	55.4	38.7	**33.7**	**23.4**	**2.6**	**55.4**
Percent other	0.0	0.0	0.0	0.0	0.0	**0.0**	**0.0**	**0.0**	**0.0**
Percent coarse substrate	30.0	97.4	100.0	100.0	97.2	**84.9**	**30.7**	**30.0**	**100.0**
Percent fine substrate	70.0	2.6	0.0	0.0	2.8	**15.1**	**30.7**	**0.0**	**70.0**
Substrate embeddedness	91.0	16.7	12.3	16.8	12.1	**29.8**	**34.3**	**12.1**	**91.0**
Eroding banks	70.4	89.7	5.2	37.4	51.6	**50.9**	**32.2**	**5.2**	**89.7**
Undercut banks	0.0	0.0	0.0	0.0	2.4	**0.5**	**1.1**	**0.0**	**2.4**
Large wood tally (#/m)	1.3	0.0	8.5	1.1	14.7	**5.1**	**6.3**	**0.0**	**14.7**
Overhead cover (%)	66.5	76.0	66.5	98.2	93.0	**80.1**	**14.8**	**66.5**	**98.2**
Mean riparian width (m)	3.5	13.5	15.0	62.5	27.5	**24.4**	**22.9**	**3.5**	**62.5**
Riparian zone tree cover (%)	7.5	45.0	57.5	80.0	72.5	**52.5**	**28.6**	**7.5**	**80.0**
Riparian zone non-native Veg. Cover (%)	30.0	45.0	40.0	22.5	7.5	**29.0**	**14.9**	**7.5**	**45.0**
Water temperature (°C)	12.2	12.3	12.5	12.2	11.1	**12.1**	**0.5**	**11.1**	**12.5**
Dissolved oxygen (%)	76.5	80.9	92.8	95.7	97.8	**88.7**	**9.5**	**76.5**	**97.8**
Dissolved oxygen (mg/L)	8.2	8.7	9.9	10.3	10.7	**9.5**	**1.1**	**8.2**	**10.7**
Specific conductance (µS/cm)	225	245.0	202	152.0	68.0	**178.4**	**70.8**	**68.0**	**245.0**
pH	6.9	7.2	7.12	7.2	7.2	**7.1**	**0.1**	**6.9**	**7.2**

Table 5. Macroinvertebrate community multimetric scores and PREDATOR MWCF O/E scores from samples collected from five stream reaches in the Clackamas Soil & Water Conservation District, Oregon, in the fall 2012, 2016, and 2018.

Site	MMI Score			PREDATOR MWCF O/E Score		
	2012	2016	2018	2012	2016	2018
LOWER DOANE	12	14	20	0.485	0.291	0.291
UPPER DOANE	10	14	16	0.485	0.291	0.533
NF DEEP	18	18	18	0.437	0.485	0.485
NOYER	12	10	12	0.243	0.291	0.339
TICKLE	36	38	30	0.776	0.970	1.067

MMI Disturbance classes:	None	Slight	Moderate	Severe
PREDATOR Disturbance classes:	Least		Moderate	Most

Individual community metrics calculated for the multimetric index differed widely between the Tickle reference sample and the four test-reach samples. Among the four test reaches, total taxa richness ranged from 12 in Noyer Creek to 24 in NF Deep Creek, while 38 taxa were sampled from Tickle Creek (Figure 3). Mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) richness was also similar among the four test-reach samples, ranging from 1 to 6. These three insect orders, collectively referred to as "EPT taxa," are generally regarded as sensitive to disturbance and pollution. In contrast, the Tickle Creek reference reach supported 17 EPT taxa, the highest number among the study sites by a large margin.

As in 2012, the Noyer Creek reach once again supported the highest percentage of sediment tolerant taxa (33.5%, Figure 3), followed closely by the North Fork Deep Creek site (32.3%). Tolerant individuals represented nearly half of the total macroinvertebrate abundance in both the Tickle Creek and the Upper Doane Creek reaches, and more than a third of the total abundance in the NF Deep and Noyer reaches (Figure 3). While this metric scored favorably for the lower Doane Creek reach, the result was highly influenced by the high abundance of Ostracoda micro-crustaceans in the sample. While this taxon is not presently coded as "tolerant" by OR DEQ, its high HBI value of 8 indicates that it should be, and would result in the percent tolerance increasing to nearly 50%.

Also consistent with 2012 and 2016 results, MWCF predictive model O/E scores once again suggested severe disturbance across all four of the test reaches. Scores at these four sites ranged narrowly from 0.291 to 0.533, suggesting significant impacts to ecological conditions across these four reaches (Table 5). The Tickle Creek reference reach scored considerably higher than the four test sites and received a "least disturbed" classification (Table 5).

Fine-sediment stressor (FSS) model results suggested that macroinvertebrate communities from three of the four test reaches were likely showing fine-sediment-induced stress (Table 6). These reaches received an inferred fine sediment score higher than the Willamette Valley threshold of 19%, corresponding to "poor" community conditions in relation to sensitivity to elevated sediment loads. While the lower Doane site was not assigned a fine-sediment-stress condition class (because the sample was collected from a glide and not a riffle), this reach's overall bank and substrate characteristics strongly suggest that fine sediment is a stressor to the macroinvertebrate community in the reach. Both Noyer and Tickle Creek reaches received FSS scores between 15 and 19, corresponding to a "fair" condition class relative to sediment-induced stress (Table 6). These results suggest that fine sediment is not acting as a stressor in the Noyer and Tickle reaches to the extent that it likely is in the other three reaches.

Temperature stressor model results suggested that macroinvertebrate communities in four of the five reaches are likely showing elevated temperature stress (Table 6), as macroinvertebrate assemblages from each of these reaches received inferred temperature stressor scores higher than the Willamette Valley threshold of 18.4 °C (Huff et al. 2006). Interestingly, only the Noyer Creek reach received a sufficiently low temperature stressor score to suggest that temperature is not currently a significant stressor in the reach.

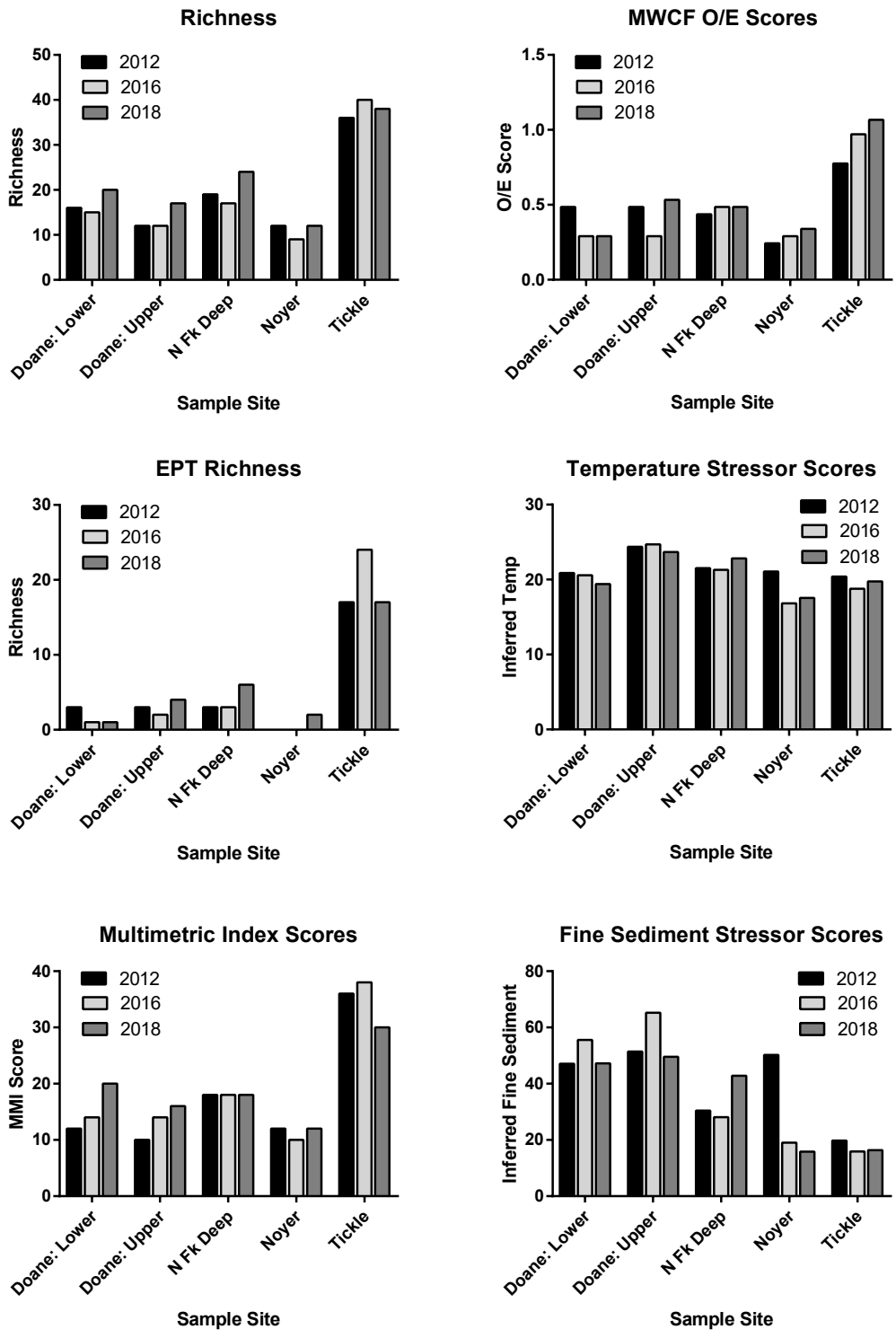

Figure 3. Summary of select metrics, multimetric scores, PREDATOR O/E scores, and temperature and sediment stressor model scores from five macroinvertebrate samples collected in the Clackamas Soil & Water Conservation District in fall 2012, 2016, and 2018.

Table 6. Macroinvertebrate community stressor model results from samples collected from five stream reaches in the Clackamas Soil & Water Conservation District, Oregon, in fall 2012, 2016, and 2018.

	Inferred % Fine Sediment				Inferred Temperature			
Site	2012	2016	2018	2018 FSS Class	2012	2016	2018	2018 Condition
LOWER DOANE	47.1	55.6	47.2	Glide (NA)	20.9	25.5	19.4	Glide (NA)
UPPER DOANE	51.4	65.2	49.6	Poor	24.4	32.1	23.7	Poor
NF DEEP	30.4	28.1	42.9	Poor	21.5	22.7	22.8	Poor
NOYER	50.3	19	15.8	Fair	21.1	17.1	17.6	Good
TICKLE	19.8	15.9	16.4	Fair	20.4	19.3	19.8	Poor

REACH DESCRIPTIONS

LOWER DOANE CREEK (LDOANE)

The lower survey reach on Doane Creek is located upstream of SE 312th Avenue. This small, lower-gradient channel exhibits a morphology dominated by slow-moving glides and pool habitat. This reach runs along the edge of a pasture and appears to have historically been straightened. In 2018, active bank erosion was observed along 70% of the survey reach. Large woody debris is scarce in the reach, which further destabilizes bank and channel conditions and deteriorates habitat quality for aquatic life.

Instream physical habitat consisted of 97% glides and pools in 2018, and reach-wide bed substrate conditions were dominated by fine sediment. Riffle habitat was scarce in this reach in 2018, necessitating the collection of the macroinvertebrate sample from glide habitat. The lower Doane Creek reach channel gradient was the lowest among the five reaches surveyed. Measured at only 0.5% in 2018, it is likely that this reach has historically lacked sufficient quantities of coarse substrate necessary for the development of significant riffle habitat. The riparian area adjacent to the reach is very narrow and is dominated by blackberry thickets and small alders. The riparian zone was the narrowest among the five survey reaches, averaging only 3.5 m between the two banks.

The macroinvertebrate community in this reach received a western Oregon multimetric index score of 20, and a MWCF model O/E score of 0.291. Because the sample was collected from glide habitat, condition classes should be assigned tentatively. Nevertheless, these assessment results clearly suggest a stressed condition. DEQ stressor model results indicate that macroinvertebrate communities show compositional signatures of stress induced by both elevated water temperatures and elevated fine sediment deposition. Based on these results and field substrate data, both stream temperature and fine sediment are likely stressors to aquatic biological communities in this reach. Because glide habitat was sampled in this reach, condition classifications and stressor results should be interpreted with caution.

UPPER DOANE CREEK (UDOANE)

The upper survey reach on Doane Creek is located along a private driveway, upstream of SE Revenue Road. The channel in this survey reach is narrow, incised, and predominantly straight. In 2018, instream physical habitat in this reach consisted primarily of glide and pools (83% of the reach length) and included 17% riffle habitat. The dominant bed condition throughout is coarse gravel and cobble with accumulations of fine sediment. Riffle substrate in 2018 was comprised primarily of gravels (83.0%) and cobble (14.5%). These coarser riffle substrate were 16.7% embedded by fine materials. Overhead cover averaged 76% through the reach. The riparian area along the left bank (facing downstream) of the survey reach is limited to a small strip of short vegetation and a few small trees. The right-bank riparian zone is wider and supports a higher tree density.

Results of macroinvertebrate sampling in this reach from 2012 to 2018 have consistently indicated a severely disturbed condition. The macroinvertebrate sample collected in this reach in 2018 was classified as severely disturbed with a western Oregon multimetric index score of 16. The reach received a similar classification of “most disturbed” using the MWCF PREDATOR. DEQ stressor model results indicated that macroinvertebrate communities show compositional indications of stress induced by both

elevated water temperatures and elevated sediment deposition. Based on these results and field substrate data from the physical habitat survey, both stream temperature and sediment were classified as likely stressors to aquatic communities in this reach.

NORTH FORK DEEP CREEK (NFDEEP)

The survey reach on North Fork Deep Creek is located downstream of SE Richey Road in Boring, OR. The channel gradient in this reach is approximately 1%. This reach and the Noyer Creek reach are the largest streams in the study, with average bankfull channel widths exceeding 7 m. The NF Deep Creek reach supports heterogeneous habitat with erosional and depositional types present in nearly even proportions (Table 4). Riffle substrate consisted entirely of coarse material, with no substrate smaller than fine gravel measured in pebble counts. Substrate embeddedness was low at 12.1% in 2012 and 12.3 in 2018. Active bank erosion was present but minimal in 2018, averaging only 5% of the bank length throughout the reach. The riparian canopy was dominated by alder and maples species, with a mean overhead canopy cover of 66%. The 2018 mean estimated riparian buffer width was 15 m, limited by the narrow buffer on the left-bank side in this reach.

Twenty-four macroinvertebrate taxa were sampled from this reach in 2018, the second-highest taxa richness observed among the SWCD reaches, yet a substantially lower total richness than supported by the Tickle Creek reach. A multimetric score of 18 and a MWCF O/E score of 0.485 suggest a biological community under significant duress. While 2018 substrate embeddedness values from this reach were relatively low, stressor model results implicate both elevated water temperature and sediment loads as potential stressors to aquatic life in this reach of North Fork Deep Creek.

NOYER CREEK (NOYER)

The survey reach on Noyer Creek is located in a broad, steep valley located downstream of OR Highway 212 (Clackamas-Boring Highway). This higher-gradient stream is dominated by riffle habitat (55%) and secondarily by small pools. A lack of in-

channel large wood, likely owing to the culverted road crossing immediately upstream of the reach, has reduced habitat complexity. Areas of moderate erosion were observed along both banks. Substrate conditions in riffles within the reach were dominated in 2018 by large gravel and cobble with embeddedness (the degree to which fine sediment surrounds larger substrate) in these areas estimated at 16.7%. While habitat conditions are generally favorable in this reach, a lack of large wood in the face of scouring stormflows and resulting bedload movement are potential periodic stressors to the benthic community in this reach. The riparian zone width averaged 63 m in 2018; an abundance of mature trees on both banks provides overhead cover averaging 98% throughout the reach. This coverage was the highest among all of the survey reaches.

The 2018 macroinvertebrate sample from this reach received a multimetric score of 12, corresponding to a severely disturbed condition, and a MWCF model score of 0.339, corresponding to a "most disturbed" biological condition. Only two EPT taxa were sampled from Noyer Creek in 2018, the first of the three sampling years that any EPT taxa have been sampled from this reach. In both 2012 and 2018 Noyer Creek was the only sample in the study to lack EPT taxa, despite generally favorable habitat conditions. The two EPT taxa sampled in 2018 – *Baetis tricaudatus* complex mayflies and a single *Cheumatopsyche* sp. caddisfly specimen – are both known to be generally tolerant to disturbance. The caddisfly Cheumatopsyche is known to be highly tolerant of warm water and nutrient enrichment. The *Baetis tricaudatus* complex of mayflies is also regarded as a generally tolerant taxon, and is perhaps among the most tolerant of lotic mayflies. *B. tricaudatus* complex mayflies are also capable of rapidly recolonizing stream habitats that have recently been denuded of aquatic fauna by physical disturbance or acute toxicity events (Wisseman, 2017, unpublished). This taxon represented *45% of the total organism abundance* sampled in the Noyer Creek reach, suggesting that a potentially severe physical disturbance or toxicity event had recently occurred. DEQ stressor models suggested that the macroinvertebrate community in this reach is not currently stressed by elevated water temperatures or fine sediment, lending further support to the possibility that toxicity from pesticides or physical disturbance from storm events may be impacting the benthic community in this reach.

TICKLE CREEK (TICKLE)

The survey reach on Tickle Creek is located upstream of Duncan Road, along the western end of the Tickle Creek Trail in Sandy. The stream runs through a parcel of public park land, which has the least streamside development among the five study sites. For these reasons, this reach was selected to represent a "least disturbed" or "reference" site for comparison with the other reaches in the assessment. Tickle Creek's channel is among the largest across the study sites (2018: WW= 3.3 m, BFW = 6.7 m). Channel gradient was 1.4% in the reach, and the reach supported a relatively heterogeneous habitat composition, with 39% riffle habitat, 36% pool habitat and 25% glide habitat measured in 2018. Bank erosion was observed along approximately half of the total bank length throughout the reach in 2018. Substrate within the sampled riffles was heavily dominated by coarse substrates (2018: 46% coarse gravel, 33% cobble and 17% fine gravel). Pebble count embeddedness in 2018 was 12.1%, once again the lowest among the surveyed reaches.

The riparian-zone buffer width along this reach was estimated at 27.5 m in 2018. Overhead canopy cover averaged 93% and the riparian vegetation was dominated by a variety of native trees and dense understory. Non-native vegetation occurs in the riparian zone here in the lowest abundance among the five survey reaches.

Thirty-eight macroinvertebrate taxa wee sampled from Tickle Creek in 2018, the highest taxa richness observed among the SWCD reaches. Seventeen EPT taxa were observed including 6 mayfly taxa, 5 stonefly taxa, and 6 caddisfly taxa. Unlike in previous years, no taxa classified as "sensitive" were sampled from this reach in 2018. Only the Tickle Creek sample supported sensitive taxa in 2016. Their absence from the 2018 sample does not necessarily indicate that they are now absent from the reach; only that their relative abundance has decreased sufficiently that they did not occur in the 500-organism subsample.

Overall, the macroinvertebrate community was classified as slightly disturbed by the western Oregon multimetric index, and was classified as "least disturbed" using the

MWCF model. These results suggest that Tickle Creek's current condition largely remains unchanged from 2016. DEQ stressor models suggested that the macroinvertebrate community in this reach is likely stressed by elevated water temperatures, but less likely by elevated fine sediment loading. This was particularly evident for fine sediment, as the inferred value for this reach was 16.4% relative to an average of 44% among the Doane and Deep Creek sites. Given the relatively low fine sediment stressor score and the results of the physical habitat surveys, fine sediment is unlikely to be exerting a significant stress on the macroinvertebrate communities in this section of Tickle Creek. This result is largely consistent with the 2012 and 2018 results.

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DISCUSSION

Other than the Tickle Creek reference reach, streams sampled in this study continue to support degraded macroinvertebrate communities, as evaluated by both the multimetric index and the MWCF predictive model. As in 2012 and 2016, samples from test sites supported no taxa classified as sensitive to disturbance, while all supported numerous taxa that are able to tolerate elevated sediment loads, increased water temperatures, periods of sustained high or low flows, and other perturbations. Mayflies, stoneflies, and caddisflies were poorly represented from samples collected from the four test sites.

Study results from the Noyer Creek reach were once again particularly noteworthy and were consistent with results obtained in 2012 and 2016. Environmental conditions observed and measured at this study reach suggest physical habitat conditions largely capable of supporting a macroinvertebrate community considerably less stressed than that measured. These results warrant further investigation to identify the cause(s) of this measured biological stress. Other water quality parameters that were not addressed with this assessment may need to be explored in order to identify factors contributing to the degraded macroinvertebrate community condition. Among pollutants entering streams through stormwater, pesticides are only starting to receive their deserved attention with respect to understanding their effects on the ecology of receiving surface waters. Recent work in Clackamas County, Oregon found that several indicators of macroinvertebrate

community condition were strongly negatively correlated with streambed sediment concentrations of the pyrethroid insecticide bifenthrin, now widely used in some urban areas (Carpenter et al. 2016). Carpenter et al.'s work suggests that pesticides carried by stormwater may play an important role in the degradation of aquatic communities in some areas, but much more work is necessary on this front.

In an effort to better manage the responsible use of pesticides in Clackamas County, the Clackamas Basin Pesticide Stewardship Partnership (https://conservationdistrict.org/programs/pesticide-stewardship-partnership) was formed to provide water quality monitoring, resources, and training for landowners and managers to enable more efficient and effective pesticide use that reduces unintended ecological effects. Since 2000, monitoring of local streams has detected pesticides in Clackamas River tributaries that exceed benchmarks to protect fish and invertebrates. Pesticides sampling has occurred in both Noyer and NF Deep Creeks, and results reveal that some pesticides are occurring at levels potentially deleterious to aquatic life. Most notably, concentrations of the pesticide imidacloprid were measured in Noyer Creek at concentrations as high as ~0.25 µg/L, relative to the 0.01 µg/L threshold for protecting aquatic life. Alarmingly, even this threshold may be inadequate to protect aquatic life, as recent toxicological testing results suggest that mayflies may be particularly sensitive to imidacloprid with chronic No Observed Effect Concentrations in the *nanogram per liter range* (Smit et al. 2015). The paucity of mayflies in Noyer Creek may be resulting from pesticide toxicity, but more work will be necessary to implicate imidacloprid or other compounds with any certainty.

Prior to initiating this program in 2012, Noyer Creek was last sampled in 2003 (Cole 2004), when reaches in the upper, middle, and lower portions of the creek were sampled. Results in the upper creek were similar to those obtained under the present monitoring program, as the upper creek received a multimetric score of 12 (Cole 2004). However, downstream conditions improved significantly in the 2003 study, as multimetric scores improved from 12 in the upper reach to 22 in the middle reach to 32 in the lower reach. The 2003 results suggest significant abatement of the stressor(s) along the length of the reach. ***Further study could determine whether this longitudinal trend of improving***

conditions still exists and could help identify and isolate potential stressors through a more comprehensive water quality assessment.

North Fork Deep Creek was also sampled in 2003 (Cole 2004). The uppermost site location in the 2003 study closely corresponded to the 2012/2016 study site on this creek. In both studies (2003 and again 2012/2016), this reach was classified by the multimetric index as severely disturbed. In the 2003 study, conditions improved to moderately disturbed in the mid-reaches of North Fork Deep Creek, suggesting an impairment of similar nature and as well as a similar longitudinal trend in improvement as measured in Noyer Creek in 2003 (Cole 2004). ***Once again, further investigation would be necessary to determine whether these same trends occur to this day and to identify the probable cause(s) of the measured degradation.***

Results from lower Doane Creek should be interpreted with caution because this section of Doane Creek potentially never provided riffle habitat with coarse substrate necessary for proper application of the assessment tools employed in this study. This section of Doane Creek occurs in a wide, low-gradient valley, where a highly sinuous channel potentially dominated by organic and fine inorganic material was the naturally occurring condition. Macroinvertebrate assemblages in such habitats, even under undisturbed conditions, would be expected to differ significantly from those occurring in riffles of higher-gradient reaches, the habitat type currently targeted in benthic bioassessment studies in Oregon. Consequently, the condition classes assigned by the assessment tools may not accurately reflect current conditions relative to a true reference condition for this stream type. Nonetheless, the quantitative results of the tools are helpful for tracking trends in conditions at the lower Doane reach over time.

Recovery of macroinvertebrate communities is dependent on identifying and improving stream conditions and functions that are currently compromised. Riparian-zone improvements and protection are among the most beneficial stream restoration approaches available. Because riparian zones provide a number of important functions, including sediment and pollutant retention, shading, food sources, bank stability, and large wood inputs, streams and the biological communities they support derive many

benefits from these areas. The two reaches assessed on Doane Creek are examples of areas where riparian improvement could prove beneficial.

The macroinvertebrate communities of the creeks assessed within the Clackamas SWCD, like those in many urban, suburban and rural streams also stand to benefit from improved stormwater and/or agricultural runoff management. One of the primary goals of the SWCD macroinvertebrate monitoring program is to assess the effects of agricultural runoff on the biology of area creeks. These data serve as a baseline against which to evaluate improvements to the macroinvertebrate community in response to the SWCD's efforts to curtail agricultural runoff into receiving waters and to improve the quality of runoff entering into local creeks. Continued monitoring of these area creeks should serve as an effective measure of the long-term success of these efforts.

LITERATURE CITED

Armantrout, N. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, MD.

Caton L. 1991. Improved subsampling methods for the EPA "Rapid Bioassessment" benthic protocols. Bulletin of the North American Benthological Society 8:317-319.

Carpenter, K.D., K. Kuivila, M. Hladik,T. Haluska, & M. B. Cole. 2016. Storm-event-transport of urban-use pesticides to streams likely impairs invertebrate assemblages. Environmental Monitoring and Assessment, 188:345

Cole, M. 2002. Assessment of macroinvertebrate communities in relation to land use, physical habitat, and water quality in the Tualatin River Basin, Oregon. Unpublished report prepared for Clean Water Services, Hillsboro, Oregon 38 pp.

Cole, M. B. 2004. Baseline Assessment of Stream Habitat and Macroinvertebrate Communities in and Adjacent to the Damascus Area Urban Growth Boundary Expansion, Oregon. Unpublished report prepared for Metro, Portland, Oregon.

Department of Environmental Quality (DEQ). 2003. Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams. Unpublished methods manual. Oregon Department of Environmental Quality, Portland, OR.

Hawkins, C. P., J. L. Kershner, P. A. Bisson, M. D. Bryant, L. M. Decker, S. V. Gregory, D. A. McCullough, C. K. Overton, G. H. Reeves, R. J. Steedman, and M. K. Young. 1993. A hierarchical approach to classifying stream habitat features at the channel unit scale. Fisheries 18 (6): 3-12.

Hawkins, C. P., R. H. Norris, J. L. Hogue, and J. W. Feminella. 2000. Development and evaluation of predictive models for measuring the biological integrity of streams. Ecological Applications 10(5): 1456-1477.

Haxton, N., and M. Cole. 2012. 2012 Stream Benthic Macroinvertebrate Assessment for the Clackamas SWCD. Unpublished report prepared by ABR, Inc. Forest Grove, OR.

Hilsenhoff, W. L. 1982. Using a biotic index to evaluate water quality in streams. Technical Bulletin No. 132. Department of Natural Resources, Madison, WI.

Hubler, S. 2008. PREDATOR: Development and use of RIVPACS-type macroinvertebrate models to assess the biotic condition of wadeable Oregon streams. Unpublished report prepared by the Oregon Department of Environmental Quality, Watershed Assessment Section. 51 pp.

Huff, D. D., S. L. Hubler, Y. Pan, and D. L. Drake. 2006. Detecting shifts in macroinvertebrate assemblage requirements: Implicating causes of impairment in streams. Oregon Department of Environmental Quality. DEQ06-LAB-0068-TR Version 1.1 37 pp.

Lemke, J.L., M. B. Cole, and J. Dvorsky. 2012a. Assessment of Benthic Macroinvertebrate Communities and Geomorphic Conditions in Streams of Clackamas County Service District No. 1, Clackamas County, OR. Unpublished report prepared for Clackamas Water Environment Services, Clackamas, OR.

Lemke, J.L., M. B. Cole, and J. Dvorsky. 2012b. Assessment of Benthic Macroinvertebrate Communities and Geomorphic Conditions in Streams of the Surface Water Management Agency of Clackamas County, OR. Unpublished report prepared for Clackamas Water Environment Services, Clackamas, OR.

Oregon Department of Fish and Wildlife (ODFW). 2002. Methods for Stream Habitat Surveys. Unpublished technical document by the Oregon Department of Fish and Wildlife, Salem, OR.

PNAMP. 2015. Draft Standard Taxonomic Effort for Pacific Northwest Macroinvertebrates. Unpublished file prepared for the Pacific Northwest Aquatic Monitoring Partnership. August 2015.

Rosgen, D. 1996. Applied River Morphology. Wildlands Hydrology. Pagosa Springs, Colorado.

Smit, C. E.,C. J. A. M. Posthuma-Doodeman,P. L. A. van Vlaardingen &F. M. W. de Jong. 2015. Ecotoxicity of Imidacloprid to Aquatic Organisms: Derivation of Water

Quality Standards for Peak and Long-Term Exposure. Human and Ecological Risk Assessment: An International Journal. Volume - Issue 6, pages 1608-1630.

U.S. Environmental Protection Agency (USEPA). 2000. Western Pilot Study Field Operations

Manual for Wadeable Streams. U.S. Environmental Protection Agency, Regional Ecology Branch, Western Ecology Division, Corvallis, Oregon. May 2000.

Water Quality Interagency Workgroup (WQIW). 1999. Chapter 12: Stream macroinvertebrate protocol, Oregon plan for salmon and watersheds. Water Quality Monitoring Guide Book, Version 1.03. Water Quality Interagency Workgroup for the Oregon Plan.

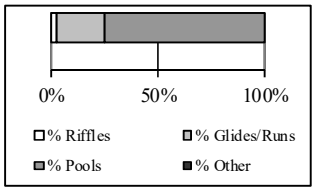
Reach Assessment Summary

Stream Name:	**Lower Doane Creek**	Site ID:	LDOANE
Location:	DS side of SE 312th Ave.		
County, State:	Clackamas, Oregon	Latitude:	45.441
Date sampled:	9/18/2018	Longitude:	-122.3429
Field Personnel:	MBC/CTB	Reach Length:	77 m

Physical and Chemical Conditions Summary

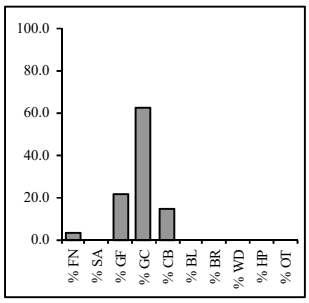
Instream Physical Characteristics

Reach Gradient (%)	0.5
Wetted Width (m)	1.8
Bankfull Width (m)	3.0
% Riffles	2.6
% Glides/Runs	22.1
% Pools	75.3
% Other	0.0



Substrate

% Fines (FN)	2.6
% Sand (SA)	0.0
% Gravel, Fine (GF)	21.1
% Gravel, Coarse (GC)	61.8
% Cobble (CB)	14.5
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	91.0
Large Wood Tally (pieces/100 m)	1.30
Eroding Banks (%)	70.39
Undercut Banks (%)	0



Embeddedness

Riparian Zone Characteristics

Overhead Cover (%)	67
Riparian Buffer Width (m)	4
Riparian Zone Tree Cover (%)	8
Riparian Zone Non-Native Cover (%)	30
Dom Adjacent Land Use	

Canopy Cover

Chemical Characteristics

Time of measurement	
Water Temperature (°C)	12.18
Dissolved Oxygen (%)	76.5
Dissolved Oxygen (mg/L)	8.21
Specific Cond. (µS/cm)	225
pH	6.9

Reach Location

Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

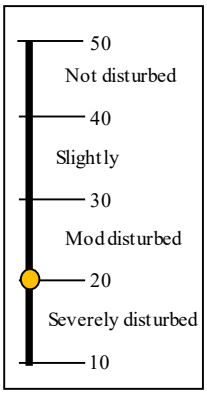
CE Sample ID: 18-127-06

Habitat(s) Sampled: Glides

Sample Method: OR DEQ 8-kick composite

Total Density: 4175 #/m2

DEQ Metric Scores	Raw	Stand.
Richness	20	3
Mayfly Richness	0	1
Stonefly Richness	0	1
Caddisfly	1	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	7.2	1
% Tolerant Taxa	4.8	5
% Sed Tol Taxa	4.2	5
% Dominant (1)	48.0	1
TOTAL		**20**



Stressor Scores		
Temperature Stress:	19.4	*>18.4 = stressed*
Fine Sediment Stress:	47.2	*>19 = stressed*

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Disturbance
2012/R	0.485	MOST
2016/R	0.291	MOST
2018/R	0.291	MOST

DEQ Multimetric Scores

Yr/Habitat	MM Score	Disturbance
2012/R	12	SEVERE
2016/R	14	SEVERE
2018/R	20	MOD

5 MOST ABUNDANT TAXA

Taxon	Count
Ostracoda	272
Procladius sp.	54
Tanytarsus sp.	50
Sphaeriidae	42
Paratanytarsus sp.	27

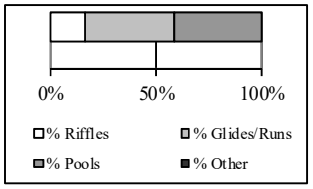
Reach Assessment Summary

Stream Name:	**Upper Doane Creek**	Site ID:	UDOANE
Location:	US side of SE Revenue Rd.		
County, State:	Clackamas, Oregon	Latitude:	45.44173
Date sampled:	9/19/2018	Longitude:	-122.3316
Field Personnel:	MBC/CTB	Reach Length:	35 m

Physical and Chemical Conditions Summary

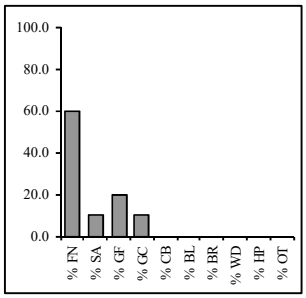
Instream Physical Characteristics

Reach Gradient (%)	1.0
Wetted Width (m)	1.8
Bankfull Width (m)	2.5
% Riffles	17.1
% Glides/Runs	42.9
% Pools	42.9
% Other	0.0



Substrate

% Fines (FN)	60.0
% Sand (SA)	10.0
% Gravel, Fine (GF)	20.0
% Gravel, Coarse (GC)	10.0
% Cobble (CB)	0.0
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	16.7
Large Wood Tally (pieces/100 m)	0.00
Eroding Banks (%)	89.714
Undercut Banks (%)	0



Embeddedness

Riparian Zone Characteristics

Overhead Cover (%)	76
Riparian Buffer Width (m)	14
Riparian Zone Tree Cover (%)	45
Riparian Zone Non-Native Cover (%)	45
Dom Adjacent Land Use	

Canopy Cover

Chemical Characteristics

Time of measurement	
Water Temperature (°C)	12.32
Dissolved Oxygen (%)	80.9
Dissolved Oxygen (mg/L)	8.66
Specific Cond. (µS/cm)	245
pH	7.18

Reach Location

Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

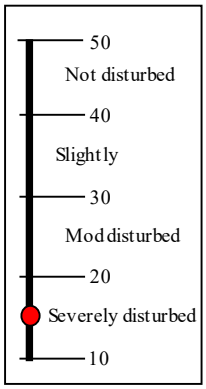
CE Sample ID: 18-127-05

Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

Total Density: 2688 #/m2

DEQ Metric Scores	Raw	Stand.
Richness	17	1
Mayfly Richness	2	1
Stonefly Richness	0	1
Caddisfly	2	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	6.2	1
% Tolerant Taxa	49.2	1
% Sed Tol Taxa	7.3	5
% Dominant (1)	39.5	3
TOTAL		**16**



Stressor Scores		
Temperature Stress:	23.7	*>18.4 = stressed*
Fine Sediment Stress:	49.6	*>19 = stressed*

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Disturbance
2012/R	0.485	MOST
2016/R	0.291	MOST
2018/R	0.533	MOST

DEQ Multimetric Scores

Yr/Habitat	MM Score	Disturbance
2012/R	10	SEVERE
2016/R	14	SEVERE
2018/R	16	SEVERE

5 MOST ABUNDANT TAXA

Taxon	Count
Cheumatopsyche sp.	210
Sphaeriidae	136
Baetis tricaudatus cmplx.	68
Juga sp.	28
Thienemannimyia grp.	18

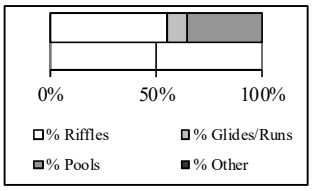
Reach Assessment Summary

Stream Name:	**North Fork Deep Creek**	Site ID:	NFDEEP
Location:	DS side of SE Richey Rd.		
County, State:	Clackamas, Oregon	Latitude:	45.42797
Date sampled:	9/18/2018	Longitude:	-122.37645
Field Personnel:	MBC/CTB	Reach Length:	82 m

Physical and Chemical Conditions Summary

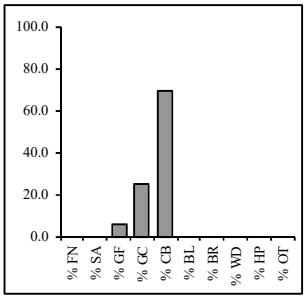
Instream Physical Characteristics

Reach Gradient (%)	0.9
Wetted Width (m)	4.6
Bankfull Width (m)	7.2
% Riffles	54.9
% Glides/Runs	9.8
% Pools	35.4
% Other	0.0



Substrate

% Fines (FN)	0.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	5.8
% Gravel, Coarse (GC)	25.0
% Cobble (CB)	69.2
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	12.3
Large Wood Tally (pieces/100 m)	8.50
Eroding Banks (%)	5.1829
Undercut Banks (%)	0



Embeddedness

Riparian Zone Characteristics

Overhead Cover (%)	67
Riparian Buffer Width (m)	15
Riparian Zone Tree Cover (%)	58
Riparian Zone Non-Native Cover (%)	40
Dom Adjacent Land Use	

Canopy Cover

Chemical Characteristics

Time of measurement	
Water Temperature (°C)	12.54
Dissolved Oxygen (%)	92.8
Dissolved Oxygen (mg/L)	9.87
Specific Cond. (µS/cm)	202
pH	7.12

Reach Location

Survey start, facing upstream

Survey end, facing downstream

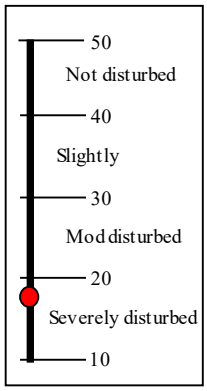
Biological Conditions Summary

CE Sample ID: 18-127-02 & 18-127-03 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

Total Density: 2062 #/m2

DEQ Metric Scores	Raw	Stand.
Richness	24	3
Mayfly Richness	3	1
Stonefly Richness	0	1
Caddisfly	3	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	1	3
Modified HBI	6.6	1
% Tolerant Taxa	37.9	3
% Sed Tol Taxa	32.3	1
% Dominant (1)	28.9	3
TOTAL		**18**



Stressor Scores		
Temperature Stress:	22.8	*>18.4 = stressed*
Fine Sediment Stress:	42.9	*>19 = stressed*

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Disturbance
2012/R	0.437	MOST
2016/R	0.485	MOST
2018/R	0.485	MOST

DEQ Multimetric Scores

Yr/Habitat	MM Score	Disturbance
2012/R	18	SEVERE
2016/R	18	SEVERE
2018/R	18	SEVERE

5 MOST ABUNDANT TAXA

Taxon	Count
Sphaeriidae	162
Juga sp.	97
Naidinae	48
Baetis tricaudatus comple	44
Thienemannimyia grp.	39

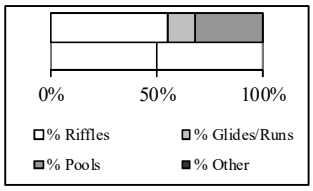
Reach Assessment Summary

Stream Name:	**Noyer Creek**	Site ID:	NOYER
Location:	DS side of Hwy 212		
County, State:	Clackamas, Oregon	Latitude:	45.41662
Date sampled:	9/19/2018	Longitude:	-122.40798
Field Personnel:	MBC/CTB	Reach Length:	92 m

Physical and Chemical Conditions Summary

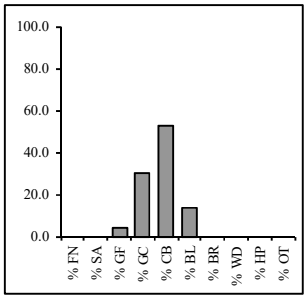
Instream Physical Characteristics

Reach Gradient (%)	2.5
Wetted Width (m)	3.7
Bankfull Width (m)	7.4
% Riffles	55.4
% Glides/Runs	13.0
% Pools	31.5
% Other	0.0



Substrate

% Fines (FN)	0.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	3.9
% Gravel, Coarse (GC)	30.1
% Cobble (CB)	52.4
% Boulder (BL)	13.6
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	16.8
Large Wood Tally (pieces/100 m)	1.10
Eroding Banks (%)	37.391
Undercut Banks (%)	0



Embeddedness

Riparian Zone Characteristics

Overhead Cover (%)	98
Riparian Buffer Width (m)	63
Riparian Zone Tree Cover (%)	80
Riparian Zone Non-Native Cover (%)	23
Dom Adjacent Land Use	

Canopy Cover

Chemical Characteristics

Time of measurement	
Water Temperature (°C)	12.17
Dissolved Oxygen (%)	95.7
Dissolved Oxygen (mg/L)	10.26
Specific Cond. (µS/cm)	152
pH	7.24

Reach Location

Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

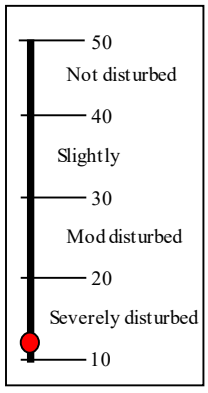
CE Sample ID: 18-127-01

Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

Total Density: 1606 #/m2

DEQ Metric Scores	Raw	Stand.
Richness	12	1
Mayfly Richness	1	1
Stonefly Richness	0	1
Caddisfly	1	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.9	1
% Tolerant Taxa	33.9	3
% Sed Tol Taxa	33.5	1
% Dominant (1)	45.4	1
TOTAL		**12**



Stressor Scores		
Temperature Stress:	17.6	*>18.4 = stressed*
Fine Sediment Stress:	15.8	*>19 = stressed*

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Disturbance
2012/R	0.243	MOST
2016/R	0.291	MOST
2018/R	0.339	MOST

DEQ Multimetric Scores

Yr/Habitat	MM Score	Disturbance
2012/R	12	SEVERE
2016/R	10	SEVERE
2018/R	12	SEVERE

5 MOST ABUNDANT TAXA

Taxon	Count
Baetis tricaudatus cmplx.	252
Naidinae	129
Lumbriculidae	55
Simulium sp.	41
Nemata	38

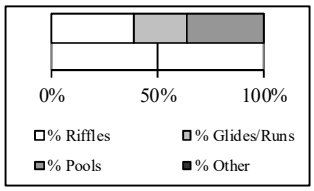
Reach Assessment Summary

Stream Name:	**Tickle Creek**	Site ID:	TICKLE
Location:	DS side of 362nd Dr.		
County, State:	Clackamas, Oregon	Latitude:	45.39824
Date sampled:	9/18/2018	Longitude:	-122.2909
Field Personnel:	MBC/CTB	Reach Length:	75 m

Physical and Chemical Conditions Summary

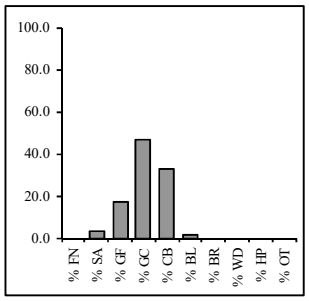
Instream Physical Characteristics

Reach Gradient (%)	1.4
Wetted Width (m)	3.3
Bankfull Width (m)	6.7
% Riffles	38.7
% Glides/Runs	25.3
% Pools	36.0
% Other	0.0



Substrate

% Fines (FN)	0.0
% Sand (SA)	2.8
% Gravel, Fine (GF)	17.0
% Gravel, Coarse (GC)	46.2
% Cobble (CB)	33.0
% Boulder (BL)	0.9
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	12.1
Large Wood Tally (pieces/100 m)	14.70
Eroding Banks (%)	51.6
Undercut Banks (%)	2.4



Embeddedness

Riparian Zone Characteristics

Overhead Cover (%)	93
Riparian Buffer Width (m)	28
Riparian Zone Tree Cover (%)	73
Riparian Zone Non-Native Cover (%)	8
Dom Adjacent Land Use	

Canopy Cover

Chemical Characteristics

Time of measurement	
Water Temperature (°C)	11.13
Dissolved Oxygen (%)	97.8
Dissolved Oxygen (mg/L)	10.74
Specific Cond. (µS/cm)	68
pH	7.15

Reach Location

Survey start, facing upstream

Survey end, facing downstream

Biological Conditions Summary

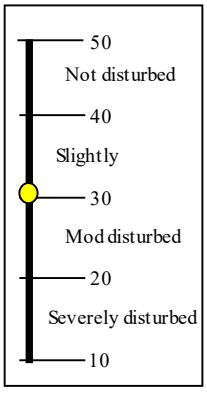
CE Sample ID: 18-127-04

Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

Total Density: 1030 #/m2

DEQ Metric Scores	Raw	Stand.
Richness	38	5
Mayfly Richness	6	3
Stonefly Richness	5	3
Caddisfly	6	3
# Sensitive Taxa	0	1
# Sed Sens Taxa	3	5
Modified HBI	4.1	3
% Tolerant Taxa	47.6	1
% Sed Tol Taxa	12.5	3
% Dominant (1)	25.3	3
TOTAL		**30**



Stressor Scores		
Temperature Stress:	19.8	*>18.4 = stressed*
Fine Sediment Stress:	16.4	*>19 = stressed*

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Disturbance
2012/R	0.776	MOST
2016/R	0.970	LEAST
2018/R	1.067	LEAST

DEQ Multimetric Scores

Yr/Habitat	MM Score	Disturbance
2012/R	36	SLIGHT
2016/R	38	SLIGHT
2018/R	30	SLIGHT

5 MOST ABUNDANT TAXA

Taxon	Count
Hydropsyche sp.	135
Lumbriculidae	46
Baetis tricaudatus comple	39
Polypedilum sp.	36
Optioservus sp.	28