Report

High Level Indicators of Oregon's Forested Streams

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Introduction

In January of 2007 the Oregon Board of Forestry endorsed the "Oregon Indicators of Sustainable Forest Management" (OISFM; Oregon Department of Forestry, 2007). The document outlines seven environmental, economic, and social strategies for measuring and discussing sustainable forestry management in Oregon. Each of the seven strategies has a set of endorsed indicators that will be used by the Board of Forestry and other Oregonians to evaluate Oregon's progress towards sustainable forest management.

This report provides information on two indicators outlined in OISFM "Strategy D: Protect, maintain, and enhance the soil and water resources of Oregon's forests." The Oregon Water Quality Index (OWQI) is used to evaluate objective "D.a. Water quality of forest streams". The Predictive Assessment Tool for Oregon (PREDATOR), a biological index using benthic macroinvertebrates, is used to assess objective "D.b. Biological integrity of forest streams". Both tools were developed by the Oregon Department of Environmental Quality (ODEQ) to evaluate the status and trends of water quality and biological condition. The other indicator for Strategy D, "Forest road risks to soil and water resources", is not covered in this assessment.

The information presented in this report may also be used to inform some of the objectives outlined in the "Statement of Forest Principles" adopted at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro 1992. Following the UNCED meeting, international experts from the United States and 11 other countries convened in Montreal and developed indicators of sustainable forest management. Known as "The Montreal Process", seven environmental, economic, and social criteria were outlined. The indicators addressed in this report may be used to help assess "Criterion 4: Conservation and maintenance of soil and water resources. Part 4.3: Water" (Montreal Process Working Group 2007).

Objectives

The purpose of this report is to assess the status of water quality and macroinvertebrates on forested lands in Oregon. Reporting on these conditions is at two geographic scales--state wide and 3rd field Hydrologic Unit Codes--and across four ownership classes--federal, state, private industrial, and private non-industrial. The intent is to provide the Board of Forestry and the public with information that will be useful in determining if Oregon is achieving Strategy D in the Forestry Program for Oregon (2003).

Executive Summary

Maintaining and improving the condition of the water resources on Oregon's forest lands is one of seven strategies adopted by the Board of Forestry to measure Oregon's progress towards sustainable forest management. This report does not address the effectiveness of the Forest Practices Act or federal forest management, but rather it provides the Board and the public with and overview of the status of water quality and aquatic biological conditions of forest lands. We hope that the information provided in this report will be used to inform Oregon sustainable forestry objectives, as well as identify future monitoring and assessment needs for forest management in Oregon.

Basins or HUCs?

Our main reporting unit is at the 3rd field Hydrologic Unit Code (HUC) level.

There are fifteen 3rd field HUCs in Oregon. Three of these HUCs are actually basins: Deschutes, John Day, and Willamette.

The other HUCs are a collection of smaller basins.

In this report we assess the condition of water resources on forested lands in Oregon. We limited our assessments to those data collected in the last ten years so that the results presented would be contemporary with most recent management activities on forest lands. We also limited our analyses to sites with a high percentage of forest at the local scale and the watershed scale. Our intent was to report on conditions due to natural forest ecosystem dynamics and forest land management activities, rather than non-forestry activities (e.g., urban or agriculture). Where sufficient sample sizes existed, we assessed conditions of forest lands at two spatial scales: statewide and 3rd-field hydrological unit codes (HUCs). We also assessed conditions among four ownership classes: federal, state, private industrial, and private non-industrial.

Water quality conditions were assessed using the Oregon Water Quality Index (OWQI). This index combines seven sub-indices of various water quality parameters into one measure of overall water quality. Biological conditions were assessed using one index as a measure of overall condition of macroinvertebrate assemblages (PREDATOR) and two indices to measure preferences for temperature and fine sediments. PREDATOR predicts the kinds of stream macroinvertebrates expected to occur at a site, assuming the site had low levels of human disturbances.

Oregon Water Quality Index

The OWQI represents general water quality conditions at a site at the time of the visit. The index combines information from multiple water quality parameters into a single score.

Sites are categorized into one of five condition classes, ranging from excellent to very poor.

It does not represent any information on toxic pollutants.

PREDictive Assessment Tool for ORegon

PREDATOR measures overall biological condition at a site. Macroinvertebrates observed at a site are compared to a set of expected macroinvertebrates. Comparisons are made to reference sites, which show the least amount of human activities in any particular region.

Sites are categorized into one of four condition classes, ranging from least disturbed to most disturbed.

Stream temperature and fine sediments at a site were modeled using macroinvertebrates alone. These two indices were used to compare environmental conditions observed among HUCs and ownership classes, as well as to establish a baseline of current environmental conditions on forest lands for comparisons with future studies.

At the state scale, over ninety percent of the sites on forest lands showed OWQI in good or excellent condition and the remaining sites in fair or lower condition. Two water quality measures that are included in the OWQI, the biochemical oxygen demand (BOD) and total solids sub-indices, showed the lowest percentages of sites in excellent condition. These two sub-indices showed the same trend across all reporting units and ownership classes. Previous studies by ODEQ have shown high total solids to be a significant risk to stream biota. High BOD and total solids can prove to be harmful to drinking water.

The index measuring overall biological condition (PREDATOR) showed just over half of forested sites in Oregon in least disturbed condition and approximately one-quarter of sites in most disturbed conditions. Approximately one-third of sites had macroinvertebrate assemblages representative of the coldest stream conditions. At fourteen percent of sites, macroinvertebrate communities were more tolerant of warmer stream conditions. Over two-thirds of forested sites in Oregon had macroinvertebrate assemblages indicating fine sediments at levels that are considered supportive of salmonids (< 10% fines).

At the HUC scale, water quality and biological conditions were highest in the Willamette, Middle Columbia, and Lower Columbia. Overall water quality and biological conditions in the North Coast were intermediate compared to the other HUCs assessed, but the macroinvertebrate assemblages showed higher temperature and fine sediment tolerances than nearly all other HUCs. The South Coast showed the lowest overall water quality and biological conditions, with higher temperature preferences and intermediate fine sediment preferences. Water quality and biological condition are typically considered to be a major issue in several of the HUCs assessed (e.g., the Willamette). However, it's important to remember that these results are reflective of conditions of forested lands only.

Differences in stream conditions among ownership classes were assessed at the state scale and for three HUCs. Ownership class was determined by identifying the ownership in the immediate vicinity of the sample points and did not consider ownership in the upstream drainage area. Through this analysis, federal lands made up the majority of sites in our datasets (623 sites), followed by private industrial lands (171 sites). Water quality among ownership classes was only assessed at the state scale. Federal lands showed the highest percent of sites with OWQI in excellent condition and state lands showed the next highest percentage. Water quality on privately owned lands showed lower conditions. Private industrial lands had two-thirds

Disturbance

The term disturbance in this report refers to both natural and human disturbances.

The reference sites used in the PREDATOR model were screened to include those with the lowest levels of human disturbances. Naturally disturbed sites were included in the model.

A site classified as "most disturbed" by PREDATOR could be disturbed naturally (fires, landslides, disease, etc.) or by human activities (roads, harvest, pesticide application, etc.).

The next step in reporting the conditions of forested streams in Oregon should include a determination of whether a site identified as disturbed by PREDATOR is different from most reference sites due to natural or human disturbances.

of sites in excellent condition, while private non-industrial lands had a slightly lower percent of sites in excellent condition.

Overall biological conditions (PREDATOR) on federal lands were similar to conditions observed on private industrial lands. However, macroinvertebrates on private industrial lands consistently showed higher temperature and fine sediments preferences than observed on federal lands. These differences in macroinvertebrate assemblage preferences, especially in the South Coast and Willamette, may be due to federal lands occupying higher elevations and a higher proportion of sites in the Cascades ecoregion. Further study is needed to determine if differences observed in water quality and biological condition were related to different management practices between ownership classes or because of other natural factors such as geology, elevation, upstream drainage area, etc.

Private non-industrial lands had the lowest water quality and biological conditions for all indicators and at all reporting scales where this ownership was included. There were only 80 private non-industrial sites statewide, with more than half of the sites in the North and South Coast HUCs. Private non-industrial lands in the South Coast shared very similar natural characteristics (elevation, watershed area, gradient, and precipitation) with private industrial lands. However, private non-industrial lands showed lower water and biological conditions than private industrial lands. This result warrants further investigation in future analyses of the conditions of forest lands.

State owned forest lands also had a low sample size, with 69 statewide and two-thirds of those in the North Coast HUC. Biological conditions for PREDATOR showed greater disturbance than was observed on federal and private industrial lands in the North Coast. However, temperature and fine sediments preferences for State lands in the North Coast were substantially lower than observed on all other ownership classes in this HUC.

Data Limitations

The data assembled for this report were collected by ODEQ staff and others for a variety of different projects over the last ten years. This increases the value of information collected from a variety of projects with varying objectives. However, it is important to understand the limitations of the data when interpreting the results.

This report analyzed water quality and biological condition at the statewide and 3rd-field HUC scale. It does not directly assess the adequacy of the Oregon Forest Practices Act, federal Northwest Forest Plan, or other forest management strategies to meet water quality standards and total maximum daily load allocations.

Most of these data were collected on a single site visit. Consequently, the data do not represent the daily, seasonal, or annual variability of the conditions at a location. It is a snapshot of one period in time and the associated disturbances (natural and anthropogenic). However, when aggregated with hundreds of other sites to describe a larger spatial scale, using the site results as a sample that describes the larger spatial scale represents some of the daily, seasonal and yearly variability.

These data also represent conditions during the summer months. In most cases, the information was collected between the middle of June and the end of September. It is not representative of water quality conditions during fall, winter and spring when freshets may increase turbidity, nutrients, bacteria, toxic run- off, and changes in other parameters that have known detrimental effects on water quality and biological conditions.

In addition, while much of the data in this report were collected for projects that used a random site selection process, the combined data set does not represent a random sample of forest lands in Oregon. There may be biases associated with geography, land

Data sources used in this report:

State

Oregon Plan for Salmon and Watersheds (ODEQ and ODFW)

Ambient Water Quality Monitoring Network (ODEQ)

Total Maximum Daily Load (TMDL) (ODEQ)

Federal

Environmental Monitoring and Assessment Program (EMAP) (USEPA)

Interior Columbia Basin Ecosystem Management Project (ICBEMP) (USFS and BLM)

Reference Site Identification (USEPA Star Grant)

Watershed Councils

Rogue Basin Coordinating Council

Yamhill Watershed Council

use, or other factors that influence the generalization of the results.

Next Steps/Future work

Following are several recommendations that would potentially improve our assessments of forest streams and rivers:

1) Future monitoring to fill in the data gaps. Increase monitoring in reporting areas and ownership classes with low sample sizes.
2) Continued monitoring to assess trends in water and biological conditions in Oregon's forests.
3) A random sampling design for future monitoring would provide multiple benefits. We could improve our ability to describe forest lands, while reducing potential sources of bias. Additionally, it would lower costs by requiring fewer samples than a census of all forested streams. Coordinated probabilistic monitoring allows for additional cost savings by incorporating information from other management agencies and monitoring groups utilizing the same sampling design.
4) A long term reference monitoring strategy would help to understand how natural systems vary through time. Ongoing monitoring at reference sites helps us to understand how target conditions vary due to natural conditions or global disturbance and provides useful insights for assessing other locations.
5) A common, map based, framework for evaluating and discussing land use and ownership classes. Ownership classification and its relationship to stream conditions is complex and needs further refinement. Future work should include an understanding of all ownership classifications--forested and non-forested.
6) Improving the screening of natural or human disturbances identified by the PREDATOR model would provide a better tool for understanding which management activities are the most effective at protecting or enhancing watershed conditions.
7) Reference benchmarks should be incorporated into the temperature and fine sediment stressor identification models. These benchmarks would make it easier to assess differences related to natural conditions or management actions.
8) Reference benchmarks should be incorporated into the assessment of water quality. While the OWQI is a useful tool, it is not likely to be as discriminating as using the range of conditions observed at regionally appropriate reference sites.
9) Indicators of roads and the risk to stream condition should be included in future analyses of Oregon's forested streams, as identified in the Oregon Indicators of Sustainable Forest Management report.
10) Understanding toxic pollutants, their sources, and their effects on beneficial uses will be an important monitoring theme in the future.

Methods

There were two types of sites used in the assessment of water quality conditions on forested lands. Sites of the first type were sampled as part of biomonitoring programs within ODEQ, other agencies, universities, and volunteer monitoring groups. Most of the biomonitoring sites analyzed for this report were collected as part of probabilistic monitoring projects (e.g., Oregon Plan for Salmon and Watersheds, Environmental Monitoring and Assessment Program). The remaining biomonitoring sites were part of targeted sampling plans (e.g., Total Maximum Daily Load assessments, actively searching for reference conditions, etc.). Biomonitoring sites were typically sampled during the low flow summer period (June – September). These sites were mostly wadeable, 1st - 3rd order streams. Some sites were visited multiple times during the 10-year time period, however, most sites were visited once.

Defining forest lands

Local scale

- **300 m buffer around sampling point**
- **at least 70% forest**

Watershed scale

- **pour-point watershed or 6th field HUC**

ODEQ's Ambient River Network made up the second type of sites assessed in this report. Ambient sites were targeted sites located on non-wadeable 4th-5th order streams and rivers. These sites are part of ODEQ's long-term river monitoring program. They were sampled bi-monthly (six times a year) throughout the 10-year sample period, using the Water Monitoring and Assessment Mode of Operations Manual (MOM's) methods for collection (ODEQ 2007).

We limited the information included in this report to data collected from 1998 – 2007. We felt it was important to focus on more recent conditions of forest lands, rather than past conditions. None of the monitoring programs mentioned above were intended to specifically assess forest land conditions. Since the projects generally covered the range of forest lands across Oregon, we felt that they could be used in an assessment of forest streams.

Identifying forest lands in Oregon

One of the most critical components of our work was to clearly, objectively, and accurately identify forest lands in Oregon. Because our main objective was to report on conditions of forest lands, we attempted to factor out other land use activities as much as possible. To do so, we utilized land cover information at the local scale and watershed scale. The body of literature examining landscape effects on macroinvertebrates and water quality suggest that both scales play an important role in shaping the chemical, physical, and biological compositions of streams and rivers (Martel et al. 2007, Townsend et al. 2003, Potter et al. 2004).

For the local scale, a 300 m diameter buffer was established around the coordinates of each sampling site using geographic information systems (GIS; ESRI ArcGIS9.3). For biomonitoring sites from random sampling designs, the coordinates were located at the random x-site, which was typically located at the bottom of a sampling reach equal to 40x the wetted width. For ambient sites, the coordinates were located at the water chemistry sampling location.

For the watershed field scale, our first choice was to use pour-point watersheds upstream from the sampling coordinates. Pour-point watersheds are defined as the entire upslope area draining to the sampling point. Delineating watersheds is time and resource intensive. Approximately half of the sites in our dataset with macroinvertebrate and/or water chemistry data did not have delineations completed. Where this was the case, we used the delineated 6th field hydrologic unit (HUC) containing the site. Understanding that this could potentially provide significant errors in our determination of forested lands, we checked on the error rates of the percent forest identified at the HUC scales, compared to the percent forest identified at the watershed scale. Of 572 sites with percent forest identified at both HUC and watershed scales, we found 33 sites with less than 70% forest in the HUC, but at least 70% forest in the watershed. This means that 6% of these sites would be misclassified as non-forest, when actually they should be included. Only 7 sites (1%) had at least 70% forest in the HUC, but less than 70% in the watershed. These sites would have been erroneously classified as forest if the watershed information was not available. Given these results, we felt justified in having a higher rejection rate of forested lands, compared to a lower rate of including non-forest landuses in our analyses.

We used the Interagency Mapping and Assessment Project (IMAP) GIS coverage to calculate the percentage of forest lands for both the local and watershed scale. Percent forest was calculated for candidate sites by summing the percentages of the vegetation classes considered to be indicative of forest lands (see Appendix I). We used satellite imagery from Google Earth to visually inspect the classifications of percent forest by the IMAP coverage. We used the list of sites where percent forest was calculated for the catchment and at least 70% forest was identified in the buffer (586 sites). Ten percent of sites east of the Cascades crest (15 sites) and 10% west of the Cascades crest (43 sites) were inspected for misclassification of land use types. Only one of the 58 sites (1.7%) appeared to actually have less than 70% forest in the buffer, as identified by IMAP. Additionally, 10% of the sites within each HUC were inspected for misclassifications of land uses. We again found a low misclassification rate of forest lands, with only one of 62 sites (1.6%) showing less than 70% forest in the buffer based on Google Earth satellite imagery.

Based on these observations, we settled on two benchmarks for inclusion in identifying forest lands in Oregon: 1) ≥ 70% forest at the local scale (300m diameter buffer) <u>and</u> 2) ≥ 70% forest at the pour-point watershed or 6th field HUC. Using the two benchmarks provided a cleaner dataset with results more clearly related to forest land uses. It also ensured that we included land use activities at the local and watershed scales, both of which may be important drivers of macroinvertebrates and water chemistry at a site. The inclusion of percent forest at the HUC, where watershed information was missing, resulted in a minor inclusion of non-forest lands in our analyses. The inclusion of HUC information also nearly doubled the number of available macroinvertebrate samples. This made assessments at smaller geographic and ownership scales more robust.

Identifying land ownership

We examined the conditions of forest lands in four different ownership classes: federal, state, private industrial, and private non-industrial. Ownership was only determined at the local scale (300m diameter buffer around the sampling location). To fall into one of these categories, at least 70% of the buffer area had to be identified as one of the four ownership classes. While we understand that watershed scale ownership information may provide important insight into results at a given site, we felt applying both local and watershed scale inclusion criteria would result in sample sizes too low for adequate representation.

We used geographic information systems (GIS; ESRI, ArcGIS 9.3) to determine ownership within the 300m buffers. All sites and GIS coverages were projected in the NAD83 Oregon Lambert (feet) projection. We used the forest ownership layer utilized by the Oregon Department of Forestry (Oregon Department of Forestry 2009). The original nine ownership classes were reclassified to five (federal, state, private industrial, private non-industrial, and other). Federal ownership represents a merging of United States Forest Service (USFS), Bureau of Land Management (BLM), and National Parks Service (NPS) into a single class. The layer was dissolved for faster processing and converted from a polygon vector file to a raster grid. The cell size was set to 30 ft. The buffer shapefile and landownership raster were loaded in ArcView 3.1. USEPA Analytical Tools Interface for Landscape Assessments (ATtILA) extension (USEPA 2004) was activated in order to determine the proportion of land ownership types in each buffer. The output was an ATtILA created shapefile that contained the percentages of each ownership class within the buffer. For the analyses of conditions on forest lands across ownership classes, we excluded sites within both tribal and mixed ownership. Only a small number of sites were identified as tribal lands. Because the sample size of mixed ownership was only large enough to be reported at a few geographic scales, plus the uncertainty of interpreting results, conditions of forest lands with mixed ownership was not reported. The locations of sites in each of the ownership classes assessed in this report are shown in Figure 1.

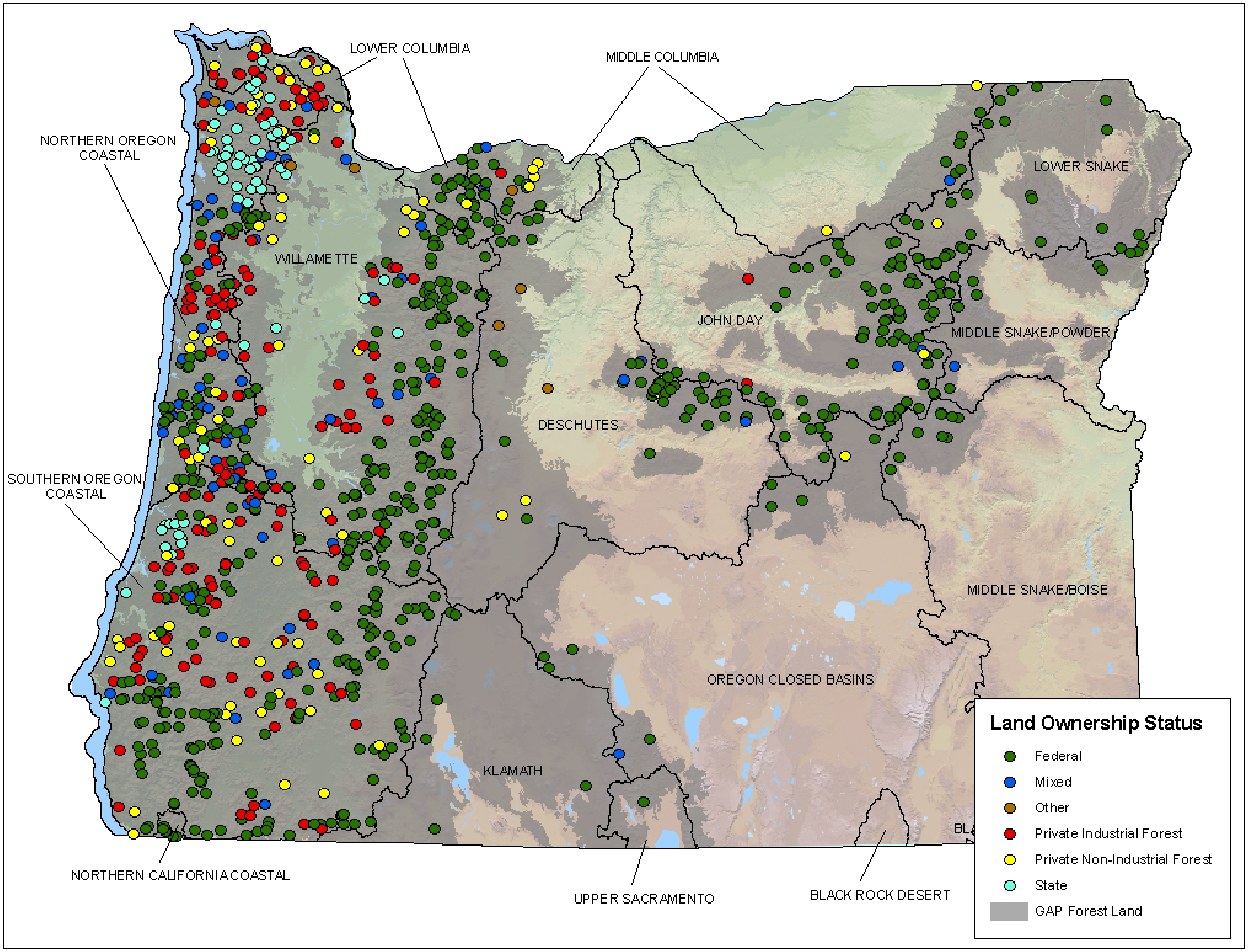


Figure 1. Site locations and ownership classes of sites used to assess conditions of forest lands in Oregon. The dark grey areas are regions identified as forest lands by the Gap Analysis Program (GAP).

Oregon Water Quality Index

ODEQ uses the OWQI to describe water quality in a consistent manner across streams (Cude 2001). The OWQI is useful for describing temporal and spatial water quality conditions. Water chemistry samples were collected by following ODEQ's Mode of Operations Manual v3.1. (ODEQ 2004a), which outlines methods required to produce accurate and representative samples. Parameters that required laboratory analyses were analyzed following ODEQ's Laboratory Quality Manual (ODEQ 2004b). The bulk of forested sites assessed by the OWQI were biomonitoring sites (414). Another 10 sites from the Ambient Network also met the forest lands criteria, making a total of 424 sites assessed by the OWQI (Figure 2).

The water quality parameters used to calculate the OWQI are shown in Table 1. The OWQI calculation used in this report is a modification of the original (Cude 2001). The modified calculation removes the bacteria sub-index from the OWQI score and reduces the number of sub-indices by one. Logistics prevented bacteria (*E. coli*), a parameter normally needed to calculate the OWQI, from being collected on the majority of the samples. Sub-Index categories were examined separately to determine individual water quality parameter scores for each site. Sub-Index scores included: Temperature, Dissolved Oxygen, BOD-5, pH, Total Solids, Nitrogen, and Total Phosphate.

Table 1. Water quality parameters used in the Oregon Water Quality Index.

Parameter	**Units**
Temperature	^{o}C
Dissolved Oxygen	mg/l
Dissolved Oxygen Percent Saturation	%
Biochemical Oxygen Demand (BOD-5)	mg/l
pH	SU
Total Solids	mg/l
Ammonia	mg/l
Nitrate + Nitrite	mg/l
Total Phosphate	mg/l

OWQI scores for biomonitoring sites sampled more than once were averaged into a single OWQI. OWQI scores for the ten Ambient sites were parsed out seasonally to obtain an average summer score and a Fall/Winter/Spring (FWS) score. OWQI scores with a sample date between June and September were considered Summer Scores, while sample scores with dates between October and May were considered FWS scores. The OWQI scores were then averaged to create a final OWQI Summer and final OWQI FWS score for each Ambient Network site.

Scoring the OWQI

A benchmark classification scheme was derived for the OWQI to describe general water quality conditions (Cude 2001). The range of possible scores for the OWQI varies from 10 (worst case) to 100 (best case). OWQI scores that are less than 60 are very poor, 60-79 = poor; 80-84 = fair, 85-90 = good, and 90-100 = excellent.

Traditionally these classification categories were only applied to the final OWQI score. The sub-indices that make up the OWQI are also scaled from 10-100. This report assigned the same classification scheme to the sub-indices. By examining the sub-indices, we can investigate the water quality parameters that were responsible for lower quality OWQI values. The sub-indices classifications allowed us to examine patterns of water quality issues across forested landscapes.

Limitations of the OWQI

The OWQI was developed to provide a simple and concise method of evaluating water quality information. OWQI only includes conventional water quality data and therefore cannot evaluate all hazards (toxics, bacteria, metals, etc). The water quality samples are also collected as a 'snapshot' at one particular time. Sampling at different times of the day may produce different results, especially for temperature, pH, and Dissolved Oxygen which all have diel cycles.

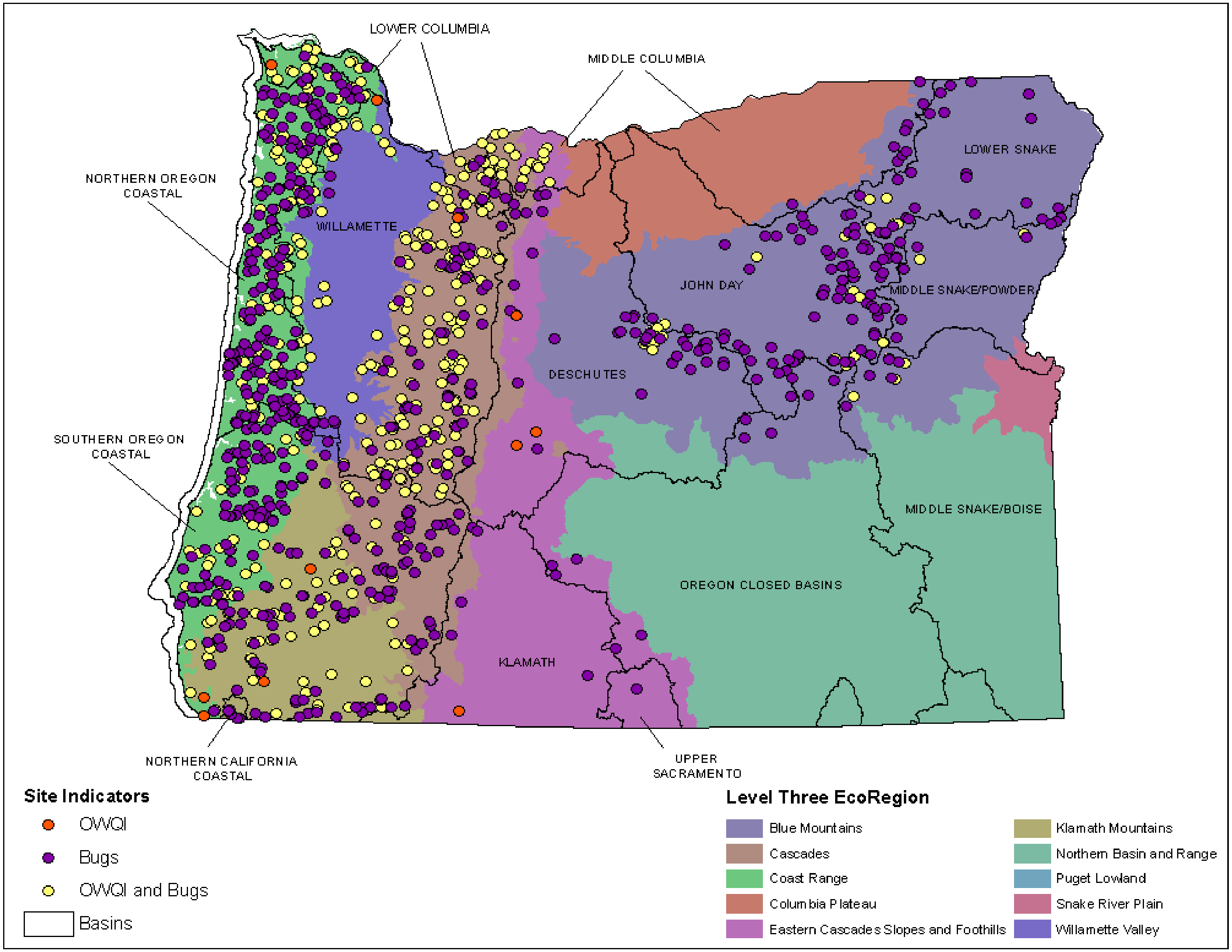


Figure 2. Site locations for water quality (OWQI) and macroinvertebrate (Bugs) samples.

Macroinvertebrate bioassessment tools

Macroinvertebrates are an important component of stream ecosystems. They actively link the bottom of the food chain (bacteria, algae, riparian inputs) to the top of the food chain (fishes and amphibians). Macroinvertebrates have shown to be sensitive to a wide range of human caused stressors, such as organic pollution, increased temperature, habitat alteration, and increased suspended and bedded sediment (Rosenberg and Resh 1993). Monitoring changes in macroinvertebrates relative to minimally impaired reference condition streams provides a sensitivity in assessing stream condition that evaluating chemical water quality alone cannot provide (Wright 2000).

It would be better to make assessments of stream conditions using multiple biological assemblages (e.g., including fish, algae, and macroinvertebrates) because each assemblage may show varying responses to different stressors. However, the central position of macroinvertebrates in the ecosystem allow for a good overall view of biological condition within a stream. Also, the data availability and assessment tools for macroinvertebrates are much more widely available than other assemblages. We assessed conditions of Oregon's forested streams using the results of three tools designed to summarize the quality and environmental tolerances of macroinvertebrate assemblages. A total of 1025 sites were assessed for macroinvertebrate condition (Figure 2).

Macroinvertebrate sampling methods

Macroinvertebrate samples were collected from the fastest flowing habitat available in the study streams. Typically this resulted in samples collected from riffle habitat, but on low-gradient streams samples were collected from either run/glide habitat (second choice) or pool habitat (third choice). Samples were collected using a D-frame kicknet with 500 µm mesh. Samples consisted of eight 1-ft^2 kicks from separate riffles (where available) composited into a single sample. Following field collection, samples were preserved with 95% denatured ethanol. In the laboratory, samples were randomly sub-sampled and sorted at 10x magnification until a target of 500 individuals was reached. These sub-samples were then identified to standard taxonomic levels, typically genus/species. For complete details of macroinvertebrate sampling and processing, see ODEQ (2004).

Assemblage or Community?

An assemblage refers to one group of organisms in an ecosystem. In this case, all macroinvertebrates (insects, crustaceans, snails, worms, etc.).

A community represents all of the assemblages within an ecosystem (fish, amphibians, macroinvertebrates, algae, bacteria, etc.)

Defining "taxa"

A taxon refers to a single, unique type of macroinvertebrate. In some instances it refers to a species. In other cases it may refer to a genus, or family of macroinvertebrates. Taxa is the plural of taxon.

Our biological indices use varying taxonomic levels because certain macroinvertebrates are easier to identify than others to lower levels (genus or species).

Reference condition

In order to assess stream condition, we must apply some benchmark by which to judge a given stream. ODEQ uses the reference condition approach (RCA; Stoddard et al. 2007). ODEQ's reference selection process (Drake 2004) seeks to identify those streams or stream segments with the least amount of human activities. We do not assume that we can find streams that have not been altered or affected by human activities, but instead seek out the "best of what's left" or "most natural" streams. We do not exclude sites due to high levels of natural disturbances (e.g., fires, landslides, disease, etc.). Sites with natural disturbances are included in developing our assessment benchmarks. We use GIS screens of forest harvest, road density, and urban and agriculture land use at the watershed. We also identify human activities at the reach scale by noting the presence and proximity of logging, roads, grazing, recreation, etc. We identify as reference those sites that rank among the lowest for reach and watershed disturbances in each Level III ecoregion (Omernik 2004). Ecoregions combine elements of geology, elevation, climate, and vegetative and wildlife communities, providing a basis for establishing natural expectations.

PREDictive Assessment Tool for ORegon (PREDATOR)

The PREDATOR tool is a multivariate predictive model used to assess the integrity of an aquatic macroinvertebrate assemblage. Predictive modeling estimates the expected occurrence of macroinvertebrate taxa at a sample location. This is accomplished by developing a list of macroinvertebrates that commonly occur at least disturbed, or reference, locations that have similar natural characteristics to the sample locations. The list of species generated from the reference locations is known as the "Expected" taxa list or "E". This list is compared to the captured macroinvertebrates, or "Observed" taxa ("O"), at an assessment site. The predictive model output is the observed to expected (O/E) taxa ratio. Scores less than 1.0 have fewer taxa at a site than were predicted by the model. Scores greater than 1.0 show more reference taxa were collected than predicted to occur at a site. For a detailed description of ODEQ's PREDATOR models, see Hubler (2008).

Samples from forest lands were assessed using one of two PREDATOR models. For sites in the Coast Range and Willamette Valley ecoregions (Figure 2), they were assessed using the Marine Western Coastal Forest model. Sites in the Cascades, Klamath Mountains, East Cascades, Blue Mountains, and Columbia Plateau ecoregions (Figure 2) were assessed using the Western Cordillera and Columbia Plateau model. Based on differing precision and accuracy between the models, different benchmarks were used to classify the samples into one of four biological condition classes: least disturbed (few reference taxa missing; similar to reference condition), enriched (many more reference taxa than expected), moderately disturbed, and most disturbed (many reference taxa missing; different from reference) (Hubler 2008).

Limitations of PREDATOR

Accurate predictions of the types of reference taxa that are expected to occur at a site depend on several factors. First, we need to adequately cover the landscape, making sure to include sites that reflect Oregon's naturally diverse landscapes. This includes sites in different ecoregions, and at different elevations, geologies, and climates. We need to balance this coverage of natural diversity with the need for quality reference sites. Some areas have higher levels of human activities than others. The intent of PREDATOR is to predict which taxa would be present if the site was in least disturbed (by humans) reference condition. Thus, in certain areas it is necessary to use fewer reference sites to ensure that as little human disturbances are included in our predictions as possible.

The PREDATOR models work well across the majority of the landscape (Table 2), but we understand that the models are not always accurate--if they were, then O/E for reference sites would always be 1.0. This is not the case, as some reference sites score poorly. These are typically sites with unique characteristics. (For example, our one reference site in the Kalmiopsis wilderness scores poorly. This is likely due to the unique geology and climate in this region. Future versions of PREDATOR will attempt to model sites in this region more accurately.)

Given these modeling limitations, a site scored by PREDATOR as "most disturbed" should be validated by further screening to determine its actual levels of disturbance. There are four likely scenarios: 1) low O/E is related to high levels of human disturbances, 2) low O/E is related to high levels of natural disturbances, 3) the site has minimal disturbance and is scored poorly due to errors associated with modeling a type of site that was underrepresented or not previously included in the model, or 4) low O/E is related to field sampling errors due to a heterogeneous environment.

Table 2. PREDATOR 2005 model performance statistics. Model performance is shown for reference sites in level III ecoregions used to build the respective predictive models. "n" = sample size, "O/E" = observed/expected, and "SD" = standard deviation of O/E scores.

Model	N	Mean O/E	SD
Marine Western Coastal Forest	**38**	**0.99**	**0.12**
Coast Range	28	0.98	0.12
Willamette Valley	10	1.04	0.14
Western Cordillera + Columbia Plateau	**167**	1.01	0.15
Cascades	101	1.01	0.17
East Cascades	11	0.97	0.17
Klamath Mountains	10	0.99	0.13
Blue Mountains	39	1.02	0.12
Columbia Plateau	6	1.12	0.10

Stressor Identification (Stressor ID)

Unlike the PREDATOR models, the Stressor ID models were not created with reference sites. Any sites with macroinvertebrate assemblage data as well as temperature and/or fine sediment data were used to construct the models. Macroinvertebrate taxa present in a sample were used to infer a macroinvertebrate assemblage preference for temperature and fine sediments. The indices use weighted-averaging statistical methods to calculate scores. A total of 320 sites were used for substrate model calibration and 269 sites were used for temperature model calibration (Huff et al. 2006).

The relationship between macroinvertebrate taxa abundances and environmental variables were used to model the optimum temperature and fine sediment values for each taxon. For temperature, taxa abundances were compared to the average daily maximum temperatures for the warmest seven-day period of the season based on data from continuous data loggers. For fine sediments, taxa abundances were compared to fine sediment values, based on 105 systematically random pebble counts throughout the reach.

Optima were then used to infer the temperature (°C) and fine sediments (%) of any site using a macroinvertebrate sample alone. Inferred values were calculated by weighing the optimum of each modeled taxon collected in a sample by its relative abundance within the sample. These weighted optima were then summed across all taxa in the sample for a weighted-average temperature score (TS) and fine sediment score (FSS).

Optima

Optima represent the environmental conditions where taxa thrive, or show their highest abundances.

Optima were determined by relating abundances to the environmental variable.

Inferences

TS and FSS are inferred values based entirely on the abundances of the macroinvertebrates found at a site. They are not physical measurements of the variables.

Assessing temperature and fine sediment stress

TS values were placed into one of four categories (Table 3). These categories were chosen because they align with ODEQ's temperature standards and these 2 °C increments also correspond to the error associated with the TS model (Table 4). Additionally, each site was compared to ODEQ's temperature standard for the appropriate stream segment in which it was located (Boyd and Sturdevant 1997). A site was identified as meeting the standard if the TS was below or equal to the appropriate summer temperature standard. TS above the standard were identified as above the appropriate summer temperature standard.

FSS values were also placed into one of four categories (Table 3). These categories correspond to the error associated with the FSS model (Table 4). They also correspond with the benchmarks used in the assessment of macroinvertebrates for the Coastal Coho ESU (ODEQ 2005). However, recent data suggests that in mountain streams in Oregon fine sediment values above 10% may not be protective of aquatic vertebrate assemblages (Bryce et al. 2008). We combined the percent of sites in the last three categories (FSS > 10%) to show the percent of sites above this 10% threshold.

Table 3.Categories used for assessing temperature stress and fine sediment stress on the macroinvertebrate assemblages of forested streams in Oregon.

Temperature Stressor (TS)	<16.0 °C	16–17.9 °C	18.0–19.9 °C	≥20.0 °C
Fine Sediment Score (FSS)	0 – 10 %	11 – 20 %	21 - 30 %	> 30 %

Uses and Limitations of the Stressor Identification tools

While they can be used to infer directly the summer maximum temperatures and fine sediments in a stream, they are more effective at providing a view of patterns across the landscape. However, with repeated sampling at a single site, they could provide a more robust inference of actual instream values. Model errors for TS range from 1.8–2.5 °C and for FSS range from 2–14% fines (Table 4). For more information on model performances, see Huff et al. 2006.

The Stressor Identification models should be considered as screening tools. In this report we use them to look for patterns across HUCs or ownership classes. Where we see these patterns it is suggestive that the macroinvertebrates are experiencing different environmental conditions. Just as with PREDATOR where we still need to verify if a site labeled most disturbed is due to natural or human disturbances, so to with the Stressor Identification models do we need to determine if a TS or FSS fits with or is outside of natural expectations for a given ecoregion. So far, we do not have enough information on all ecoregions to develop these natural expectations based on reference sites. Future developments of the Stressor ID tools should include these regional models.

We can also use the models as a baseline of the percent of sites in each temperature or fine sediment category. If in five years we have another assessment of the conditions of forest lands, we should be able to look at these percentages and see if we are maintaining as many cold and cool water areas as we were five years ago. With temperature, this could become a useful and cost-effective monitoring tool of the local affects of global climate change.

Table 4. Model errors for the two Stressor Identification models. RMSE = root mean squared error.

	Temperature Score (°C)	Fine Sediment Score (%)
Training RMSE	1.8	2
Jackknifed RMSE	2.0	3
Independent Validation RMSE	2.5	14

Reporting units

We limited reporting units to those HUCs with a sample size greater than twenty. We included assessments of ownership classes if more than two of the four ownerships had sample sizes greater than twenty. For macroinvertebrates, we were able to report at the state scale and eight HUCs. Additionally, for three of those HUCs we were able to report on ownership classes. For water quality, we were able to report on conditions of forest lands at the state scale and five HUCs. We were able to report on ownership classes for water quality only at the state scale.

Graphical representations (boxplots) of four natural environmental variables (elevation, gradient, precipitation, and watershed area) are shown in Appendix III. This information could be useful in explaining differences among reporting units or ownership classes.

Oregon

A total of 1,036 sites were included in the analysis of the conditions of forest lands in Oregon. Elevations in our dataset ranged from near sea level in the west (10') to 7,789' in the Wallowa Mountains of Northeastern Oregon. Stream slopes ranged from near 0 to 44.6%, with a median of 3.3% (mean = 5.4%). Precipitation ranged from 11 inches in the Deschutes, to 165 inches in both the North Coast and South Coast. Federal lands made up 61% of the sites included in this assessment. Private industrial lands were the next highest ownership class (17%), followed by private non-industrial (8%) and state lands (6%).

North Coast

We included data from 230 North Coast sites. These sites were on average the lowest in elevation (mean = 591') and ranged from near sea level (13') to 1,860'. Stream slopes were predominantly low to moderate (median = 1.9%, mean = 3.1%), but there were steeper sites (max 24.8%). Precipitation was highest in the North Coast, with a mean of 92 inches, and a maximum of 165 inches. Federal lands made up 30% of the samples in the North Coast, followed by private industrial (25%), state (20%), and private non-industrial (10%). The North Coast contains a single Level III ecoregion (Coast Range).

South Coast

We included data from 293 North Coast sites. Because the South Coast includes three Level III ecoregions (Coast Range, Klamath Mountains, and Cascades), there were large ranges in natural variables within the dataset. Elevations ranged from 13' in the Coast Range to 5,200' in the Cascades. Stream slopes ranged from 0.2% to 43%, with a median of 3.4% (mean 6.2%). (Only 40% of South Coast sites had accompanying stream slope information.) Precipitation in the South Coast was quite variable, but overall the lowest of any western Oregon HUC and higher than observed in eastern Oregon (range = 23 – 165 inches, median = 57 inches). Federal lands made up 57% of the samples in the South Coast, followed by private industrial (24%), private non-industrial (9%), and state lands (4%).

Willamette

We included data from 218 sites in the Willamette. The Willamette includes three Level III ecoregions (Coast Range, Willamette Valley, and Cascades), but 82% of the sites in this HUC were located in the Cascades ecoregion. Elevations ranged from 190’ to 4823’. Stream slopes ranged from 0.2% to 44%, with a median of 3.4% (mean 6.2%). (Stream slope data was missing from 24% of sites in this HUC.) Precipitation in the Willamette ranged from 41 – 105 inches, with a median of 67 inches. Federal lands made up 67% of the samples, followed by private industrial (13%), private non-industrial (7%), and state lands (4%).

Lower Columbia

We included data from 43 sites in the Lower Columbia. The Lower Columbia includes three Level III ecoregions (Coast Range, Willamette Valley, and Cascades), but no sites used in this study were located in the Willamette Valley ecoregion. Elevations ranged from 16’ to 3691’. Stream slopes ranged from 0.6% to 16%, with a median of 3.8% (mean 4.8%). (Stream slope data was missing from nine sites.) Precipitation ranged from 57 – 145 inches, with a median of 85 inches. Due to low sample sizes, we did not report on ownership classes in this HUC.

Middle Columbia

Thirty-one forest sites in the Middle Columbia were spread nearly evenly across three Level III ecoregions (Cascades, Eastern Cascades Slopes and Foothills, and Blue Mountains). Elevations ranged from 351’ to 4839’. Stream slopes ranged from 1% to 17%, with a median of 3.3% (mean 4.4%). (Stream slope data was missing from six sites.) Precipitation ranged from 23 – 113 inches, with a median of 47 inches. Due to low sample sizes, we did not report on ownership classes in this HUC.

Lower Snake

A total of 31 sites in the Lower Snake were identified as forest lands. Sites in the Lower Snake were all within the Blue Mountains ecoregion. Elevations ranged from 2038’ to 7789’. Stream slope data was missing from 25 sites, leaving too few to summarize the conditions in the Lower Snake. Precipitation ranged from 17 – 67 inches, with a median of 29 inches. Due to low sample sizes, we did not report on the OWQI or ownership classes in this HUC.

Deschutes

In the Deschutes, 52 sites were identified as forest lands. Approximately 77% of sites in the Deschutes were located in the Blue Mountains ecoregion. The remaining sites were predominately located in the Eastern Cascades Slopes and Foothills (13 sites), but two sites were located in the Cascades. Elevations ranged from 2287’ to 5450’. Stream slope data was missing from nearly all sites (45), leaving too few to summarize the conditions in the Deschutes. Precipitation ranged from 11 – 53 inches, with a median of 19 inches. Due to low sample sizes, we did not report on the OWQI or ownership classes in this HUC.

John Day

In the John Day, 90 sites were identified as forest lands. All sites in the John Day were located in the Blue Mountains ecoregion. Elevations ranged from 2664' to 6870'. Stream slopes ranged from 0.2% to 17%, with a median of 3.6% (mean 5.0%). (Stream slope data was missing from 23 sites, or 25%.) Precipitation ranged from 15 – 45 inches, with a median of 23 inches. Because federal lands made up 94% of the sites in the John Day, we did not report on ownership classes in this HUC.

Table 5. Reporting units (state and 3rd-field HUCs), which assessment tools were used, and whether or not ownership was assessed.

Reporting Unit	Water Quality	Biological	Ownership
Oregon	√	√	√
North Coast	√	√	√
South Coast	√	√	√
Willamette	√	√	√
Lower Columbia	√	√	
Middle Columbia	√	√	
Lower Snake		√	
Deschutes		√	
John Day		√	
Klamath	No forest sites		
Oregon Closed Basins	No forest sites		
Middle Snake/Boise	No forest sites		
Middle Snake/Powder	No forest sites		

Results

Statewide scale

PREDATOR

The majority of forested sites (53%) showed macroinvertebrate assemblages in least disturbed conditions (Figure 3). Sites with many more reference taxa than expected were classified as enriched, representing 3% of forested sites in Oregon. Another 16% of forested sites were in moderately disturbed condition. Almost one-quarter of sites (24%) were in most disturbed conditions, meaning a significant percentage of expected reference taxa were not present. O/E values were not available for 4% of forested sites.

Macroinvertebrate Inferred Temperature and Fine Sediment Scores

Macroinvertebrate temperature scores (TS) were less than 16 ^{o}C at 32% of forested sites throughout Oregon (Figure 3). TS were between 16.0 – 17.9 ^{o}C for 30% of forested streams. TS were between 18.0 – 19.9 ^{o}C at 24% of sites and greater than 20 ^{o}C at 14% of sites. We compared TS to the applicable summer temperature standard for each site. TS at 41% of forested streams in Oregon were meeting the standard, while 59% of TS were above the standard.

Just over two-thirds of forest sites (69%) had FSS between 0 - 10% (Figure 3). Twenty one percent of forested sites had FSS between 11 – 20%. 7% of sites had FSS between 21 – 30%. Three percent of forested sites had FSS > 30%. FSS were not available for 4% of sites. With FSS > 10 as a benchmark, 31% of macroinvertebrate assemblages on forested sites throughout Oregon would be in poor condition.

Biological conditions among ownership classes

Across Oregon, overall biological condition (PREDATOR) was closer to reference condition on private industrial and federally owned forest sites. These ownership classes had the highest percent of sites (58% and 55%, respectively) in least disturbed condition and lowest percent of sites (25% and 20%) in most disturbed condition (Figure 3). Private non-industrial sites showed the lowest overall biological condition, with 35% of forest sites in least disturbed and 44% of sites in most disturbed.

Federal and state forest sites showed macroinvertebrate assemblages preferring colder water and fewer fines than observed on private sites (Figure 3). Private industrial sites had a higher percentage of sites with TS ≥ 18 ^{o}C (50%) and FSS > 10 (44%) than observed on federal (32% and 23%) and state sites (29% and 29%). Macroinvertebrates showed the highest temperature and fine sediment preferences on private non-industrial sites (TS ≥18 = 68% and FSS > 10 = 57%).

Federal and state sites also had the highest percent of sites with TS meeting the summer temperature standard (46% and 45%, respectively). Private industrial sites followed, with 39% of sites meeting the standard. Private non-industrial sites had the lowest percent of sites with TS meeting the standard (21%).

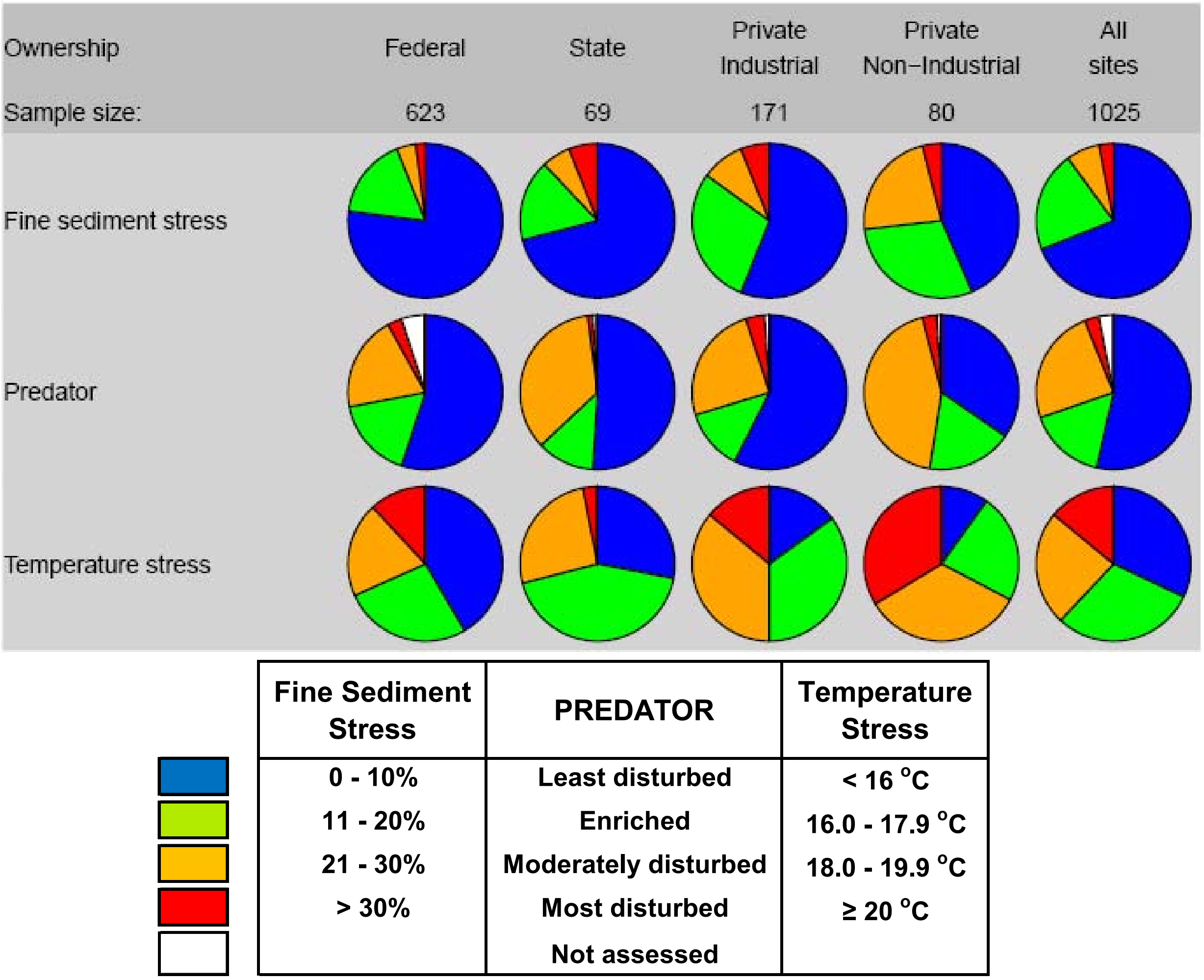


Figure 3. Conditions of macroinvertebrate assemblages for three biological indices on forested sites across Oregon.

Oregon Water Quality Index

Water quality on forested sites across Oregon was in excellent condition for 77% of sites (Figure 4). Fourteen percent of sites were in good condition. Nine percent of sites were in fair or worse condition. Five percent of sites were in poor or worse condition.

OWQI Sub-Indices

Two sub-indices, pH and temperature, resulted in nearly all forested streams in excellent condition (95% and 90%, respectively) (Figure 4). The percent of sites in good or better condition was 98% for pH and 96% for temperature. Dissolved oxygen also showed a high percent of sites in excellent condition (87%) and good or better condition (94%). Nutrient conditions on forested sites were also good or better for the majority of sites. For nitrogen, 87% of sites were in excellent condition and 94% of sites were in good or better condition. Phosphorus results showed slightly lower condition than nitrogen, with 76% of sites in excellent condition and 89% in good or better condition.

Two sub-indices, biochemical oxygen demand (BOD) and total solids (solids) scored lower than other indices on forested sites across Oregon. Just under two-thirds of forested streams (64%) showed BOD in excellent condition. The percent of sites with good or better conditions was 79%. Eleven percent of sites were in poor or worse conditions. Solids showed lower conditions. Fifty-eight percent of sites across Oregon were in excellent condition and 70% were in good or better condition. Twenty percent of sites were in poor or worse conditions.

Water quality conditions among ownership classes

Overall water quality was highest for federal sites, with 86% of sites in excellent condition and 97% in good or better conditions (Figure 4). State sites showed the next highest OWQI scores, with 75% in excellent condition and 89% in good or better conditions. Private industrial sites had 66% of OWQI scores in excellent condition and 87% in good or better conditions. Private non-industrial sites showed the lowest water quality, with 59% in excellent condition and 77% in good or better conditions.

Sub-indices scores across ownership classes showed BOD and solids in lower condition than nutrients and physical chemistry (Figure 4). Few sites showed pH in less than good conditions (they were all on federal sites). Temperature was in excellent condition for over 90% of sites for all ownerships except private non-industrial (80%). Dissolved oxygen showed state and private industrial sites with 93% and 90% of sites (respectively) in excellent condition, followed by federal sites (87%), and private non-industrial (76%).

Nutrient conditions showed some differences across ownership classes, as well as across the two nutrients themselves. State sites showed the highest percent of sites (86%) in excellent condition for phosphorus, but the lowest (61%) in excellent condition for nitrogen. Private industrial and non-industrial sites both showed 80% of sites in excellent condition for nitrogen, but 68% and 63% (respectively) in excellent condition for phosphorus.

BOD and solids again showed the lowest condition of any sub-index. Federal sites showed the highest percent of sites in good or better conditions, with 84% for BOD and 82% for solids. State (60%) and private non-industrial sites (61%) showed the lowest percentages of sites in good or better condition for BOD. Private industrial (53%) and private non-industrial (55%) showed the lowest percentages of sites in good or better condition for solids.

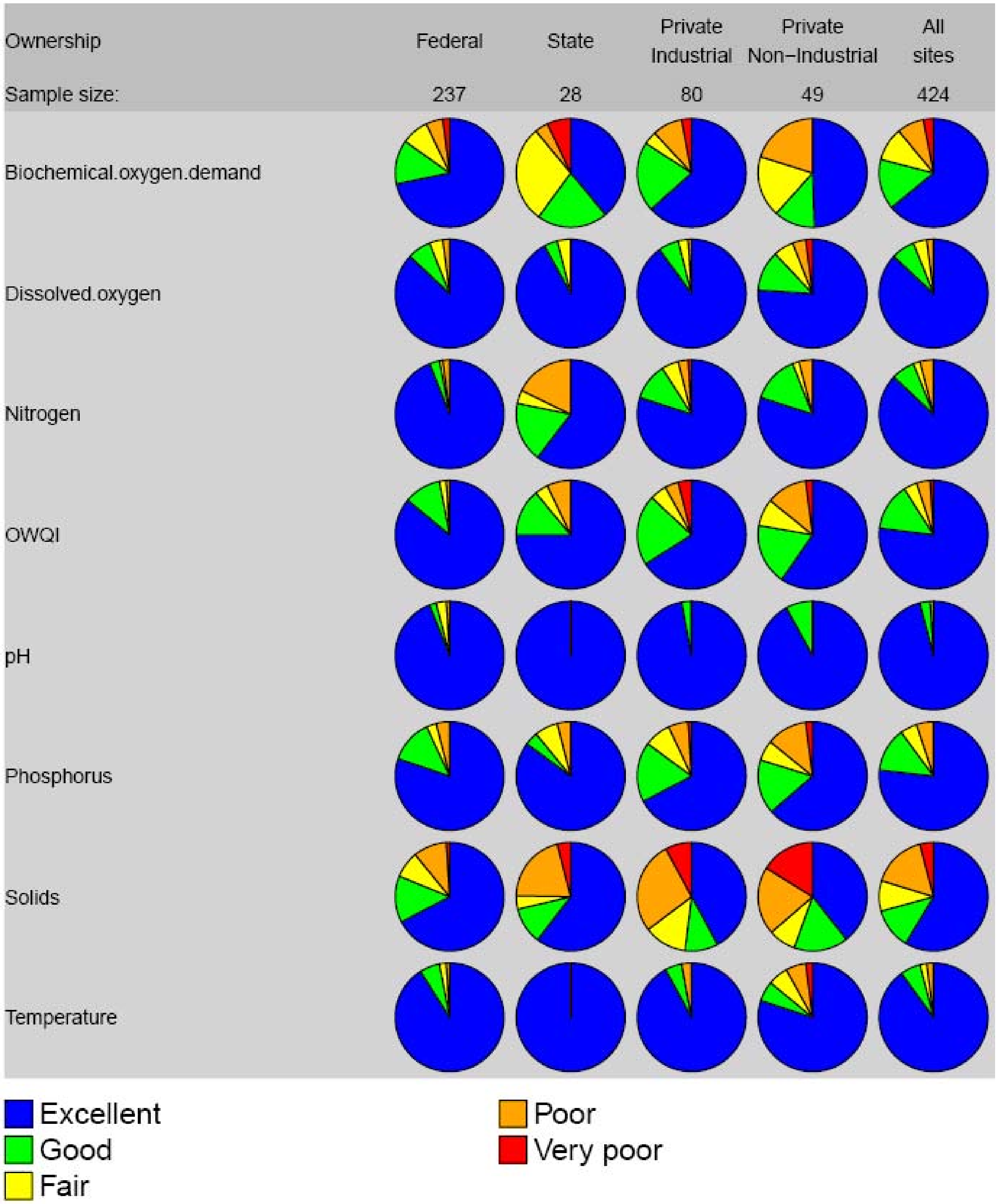


Figure 4. Conditions of water chemistry for forested sites across Oregon. OWQI = Oregon Water Quality Index.

North Coast

PREDATOR

The majority of forested sites (59%) showed macroinvertebrate assemblages in least disturbed conditions (Figure 5). Sites with many more reference taxa than expected were classified as enriched, representing 3% of forested sites in the North Coast. Thirteen percent of forested sites were in moderately disturbed condition. Just over one-quarter of sites (26%) were in most disturbed conditions, meaning they had a significant percentage of expected reference taxa missing.

Temperature and Fine Sediment Scores

Macroinvertebrate TS in the North Coast were less than 16 ^{o}C at 14% of forested sites, which was less than half of what was observed at the statewide scale (32%). TS were between 16.0 – 17.9 ^{o}C for 38% of forested streams. TS were between 18.0 – 19.9 ^{o}C at 36% of sites and greater than 20 ^{o}C at 12% of sites. Forty-eight percent of forested sites showed TS ≥ 18.0 ^{o}C. We compared TS to the applicable summer temperature standard for each site. TS at 29% of forested streams in the North Coast were "meeting" the standard, while 71% of TS were above the standard.

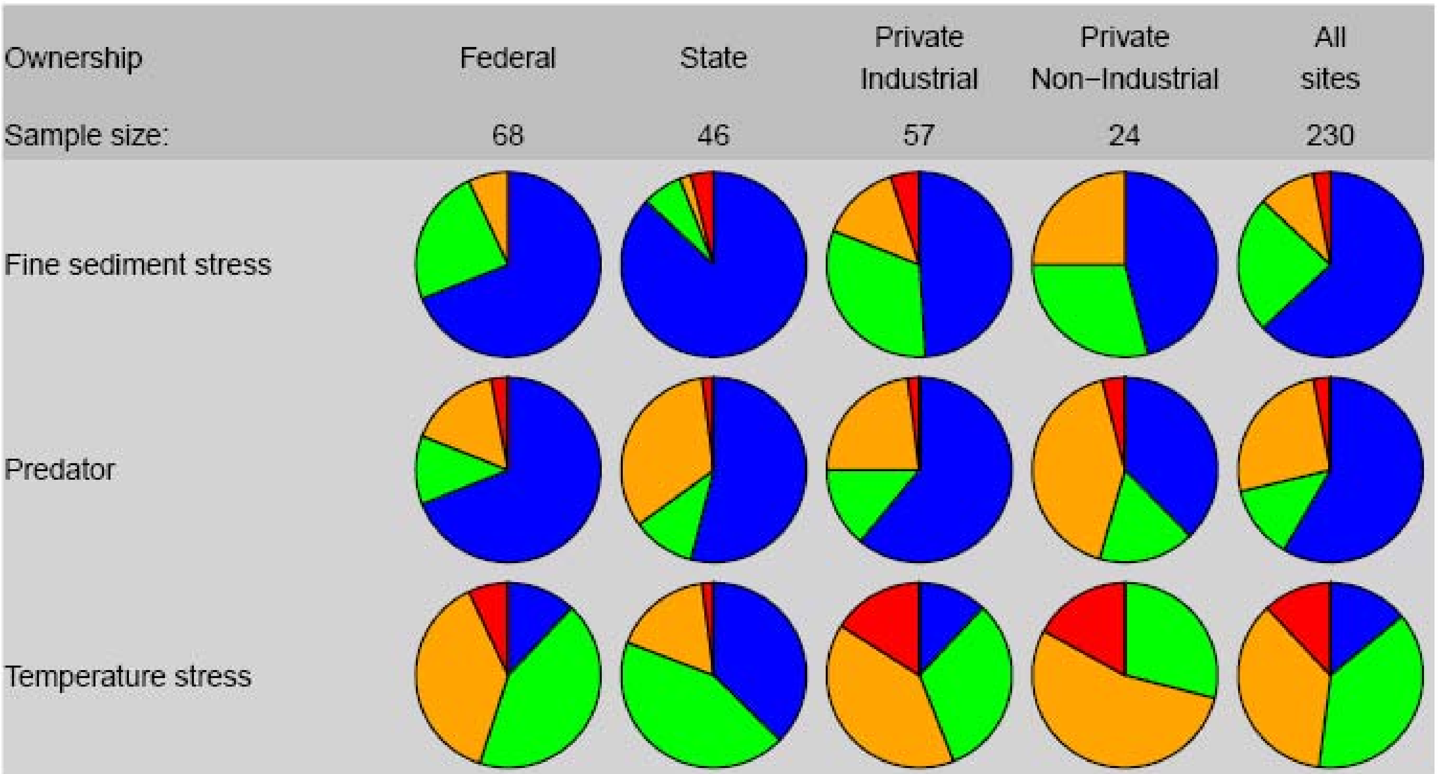
Slightly less than two-thirds of forest sites (63%) had FSS between 0 - 10%. Twenty four percent of forested sites had FSS between 11 – 20%. Ten percent of forested North Coast sites had FSS between 21 – 30%. Three percent of forested sites had FSS > 30%. With FSS > 10 as a benchmark, 37% of macroinvertebrate assemblages on forested sites throughout the North Coast would be in poor condition.

Biological conditions among ownership classes

Overall biological condition (PREDATOR) in the North Coast was better on federally and private industrial owned forest sites with the highest percent of sites in least disturbed condition (69% and 61%, respectively) and lowest percent of sites (16% and 23%, respectively) in most disturbed condition (Figure 5). Private non-industrial sites showed the lowest overall biological condition, with 38% of forest sites in least disturbed and 42% of sites in most disturbed.

State forest sites in the North Coast showed macroinvertebrate assemblages preferring colder water and fewer fines than observed on other ownership classes (Figure 5). Nineteen percent of state owned forest sites had TS ≥ 18.0 ^{o}C and 13% of sites had FSS > 10%. Federal and private industrial sites showed similar percentages of sites with TS ≥ 18.0 ^{o}C (45% and 46%, respectively), but federal sites showed lower FSS than private industrial sites (31% and 51% of sites, respectively). Private non-industrial sites had 71% of sites with TS ≥ 18 ^{o}C and no sites with TS < 16.0 ^{o}C. Fifty-four percent of private non-industrial sites had FSS > 10.

State sites also had the highest percent of sites with TS meeting the summer temperature standard (43%). Federal sites in the North Coast had 35% of sites with TS meeting the temperature standard. Private industrial sites followed, with 28% of sites meeting the standard. Private non-industrial sites had no sites with TS meeting the standard (0%).



Fine Sediment Stress	PREDATOR	Temperature Stress
0 - 10%	Least disturbed	< 16 °C
11 - 20%	Enriched	16.0 - 17.9 °C
21 - 30%	Moderately disturbed	18.0 - 19.9 °C
> 30%	Most disturbed	≥ 20 °C
	Not assessed	

Figure 5.Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the North Coast.

Oregon Water Quality Index

Water quality on forested sites across the North Coast was in excellent condition for 73% of sites (Figure 6). Nineteen percent of sites were in good condition. Eight percent of sites were in fair or worse condition. Four percent of sites were in poor or worse condition.

OWQI Sub-Indices

One sub-index, pH, showed all forested streams in excellent condition (Figure 6).Dissolved oxygen showed a high percent of sites in excellent condition (92%) and good or better condition (97%). Temperature showed a lower percent of sites (84%) in excellent condition, but the same amount in good or better condition (97%). Nutrient conditions on forested sites were also good or better for the majority of sites, although nitrogen conditions were the lowest compared to any other HUC. Phosphorus sub-index scores showed 79% of sites in excellent condition and 91% in good or better condition. For nitrogen, 63% of sites were in excellent condition and 79% of sites were in good or better condition.

As at the state scale, biochemical oxygen demand (BOD) and total solids (solids) showed the lowest conditions on forested sites across the North Coast. Just over half of forested streams (53%) showed BOD in excellent condition. The percent of sites with good or better conditions was 72%. Seventeen percent of sites were in poor or worse conditions. Solids showed nearly the same conditions. Fifty-six percent of sites across the North Coast were in excellent condition and 72% were in good or better condition. Seventeen percent of sites were in poor or worse conditions.

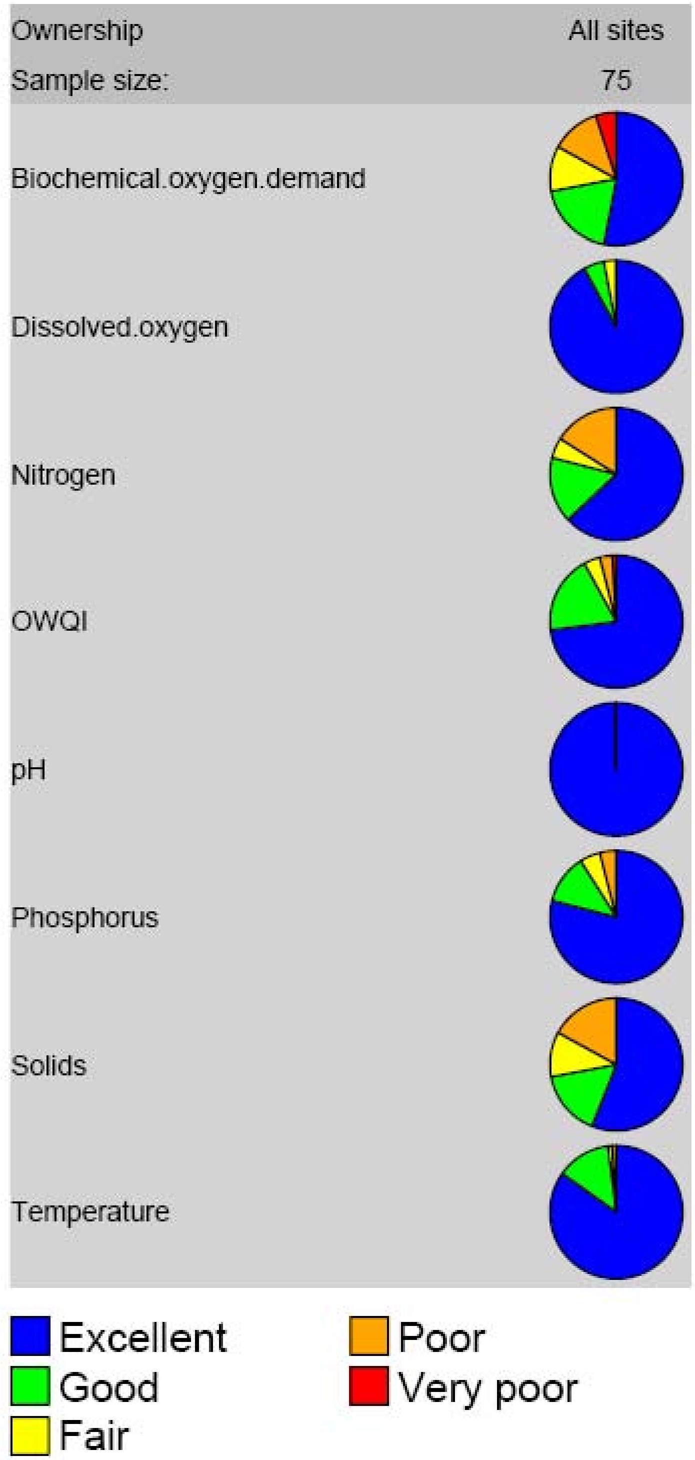


Figure 6. Conditions of water chemistry for forested sites in the North Coast. OWQI = Oregon Water Quality Index.

South Coast

PREDATOR

Less than half of sites (42%) showed macroinvertebrate assemblages in least disturbed conditions (Figure 7). Fifteen percent of forested sites were in moderately disturbed condition. One-third of South Coast sites (33%) were in most disturbed conditions, meaning they had lost a significant percentage of expected reference taxa.

Temperature and Fine Sediment Scores

Macroinvertebrate TS in the South Coast were less than 16 °C at 26% of forested sites (Figure 7). TS were between 16.0 – 17.9 °C for 28% of forested streams. TS were between 18.0 – 19.9 °C at 28% of sites and greater than 20 °C at 18% of sites. Forty-six percent of forested sites had a TS ≥ 18.0. We compared TS to the applicable summer temperature standard for each site. TS at 45% of forested streams in the South Coast were "meeting" the standard, while 55% of TS were above the standard.

More than two-thirds of forest sites (67%) had FSS between 0 - 10% (Figure 7). Twenty two percent of forested sites had FSS between 11 – 20%. Six percent of forested North Coast sites had FSS between 21 – 30%. Four percent of forested sites had FSS > 30%. With FSS > 10 as a benchmark, 33% of macroinvertebrate assemblages on forested sites throughout the South Coast would be in poor condition.

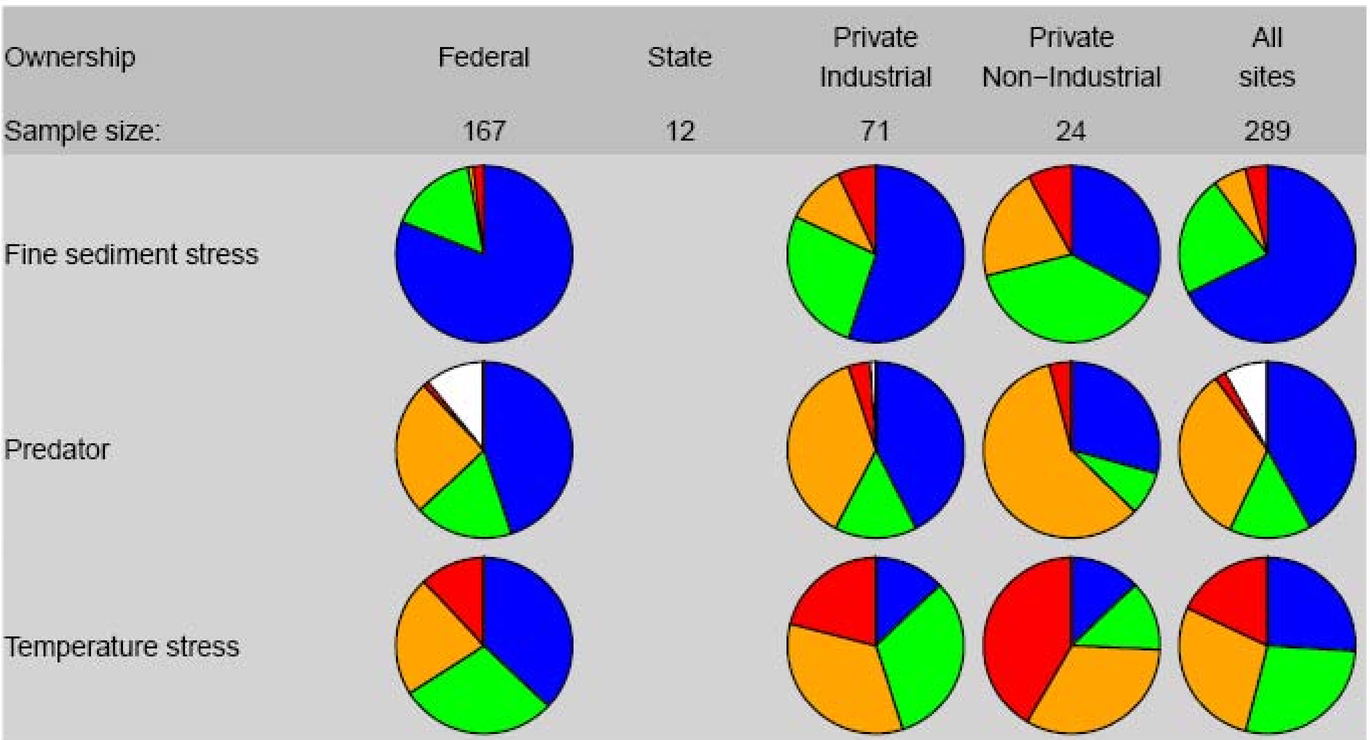
Biological conditions among ownership classes

Overall biological condition (PREDATOR) in the South Coast was better on federal forest sites with the highest percent of sites in least disturbed condition (45%) and lowest percent of sites (25%) in most disturbed condition (Figure 7). Conditions on private industrial sites were similar for least disturbed (42% of sites), but higher for most disturbed (37%). Private non-industrial sites showed the lowest overall biological condition, with 29% of forest sites in least disturbed and 58% of sites in most disturbed. Due to a small sample size (n = 12), conditions on state-owned sites were not assessed. A relatively high percent of sites in the South Coast (11%) were not assessed for PREDATOR, due to missing GIS information necessary to make predictions of expected taxa.

Federal forest sites in the South Coast showed macroinvertebrate assemblages preferring colder water than observed on other ownership classes (Figure 7). Federal sites showed 37% percent of sites with TS less than 16.0 °C and 34% of sites with TS greater than or equal to 18.0 °C. Both private ownership classes had the same percent of sites with TS less than 16.0 °C, but a substantially higher percentage of sites with TS greater than 18.0 °C was observed for private non-industrial (75%) than private industrial (55%).

Most sites on federal sites in the South Coast had TS meeting the temperature standard (54%). Private industrial sites followed, with 39% of sites meeting the standard. Private non-industrial sites had one-quarter of sites with TS meeting the standard (25%).

The same patterns were observed for fine sediment preferences that were observed for temperature preferences. Federal forest sites in the South Coast showed macroinvertebrate assemblages less tolerant to higher amounts of fine sediments than observed on private sites (Figure 7). Federal sites showed 81% percent of sites with FSS between 0 – 10%. Private industrial sites had a little more than half (55%) of sites with FSS between 0 – 10%. Private non-industrial sites had one-third (33%) of sites with FSS between 0 – 10%.



Fine Sediment Stress	PREDATOR	Temperature Stress
0 - 10%	Least disturbed	< 16 °C
11 - 20%	Enriched	16.0 - 17.9 °C
21 - 30%	Moderately disturbed	18.0 - 19.9 °C
> 30%	Most disturbed	≥ 20 °C
	Not assessed	

Figure 7. Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the South Coast.

Oregon Water Quality Index

Water quality on forested sites in the South Coast was lowest for any HUC. Less than two-thirds (66%) of OWQI scores were in excellent condition (Figure 8). Fifteen percent of sites were in good condition. Twenty percent of sites were in fair or worse condition. Twelve percent of sites were in poor or worse condition.

OWQI Sub-Indices

The pH sub-index showed the highest overall condition, with 94% of sites in excellent condition and 99% in good or better condition (Figure 8). Temperature showed a high percent of sites in excellent condition (89%) and good or better condition (95%). Dissolved oxygen showed a similar, but lower, percent of sites (82%) in excellent condition and in good or better condition (91%). Nutrient conditions on forested sites in the South Coast were also good or better for the majority of sites. The phosphorus sub-index showed 80% of sites in excellent condition and 89% in good or better condition. Nitrogen conditions were even better, with 94% of sites in excellent condition and 99% of sites were in good or better condition.

The BOD and solids indices, again, showed the lowest conditions. Two-thirds (66%) of forested streams showed BOD in excellent condition. The percent of sites with good or better conditions was 82%. Ten percent of sites were in poor or worse conditions. Solids conditions in the South Coast were the lowest of any sub-index for any HUC (Figure 8). Thirty-one percent of sites were in excellent condition and 47% were in good or better condition. Poor or worse conditions were observed at 43% percent of sites in the South Coast.

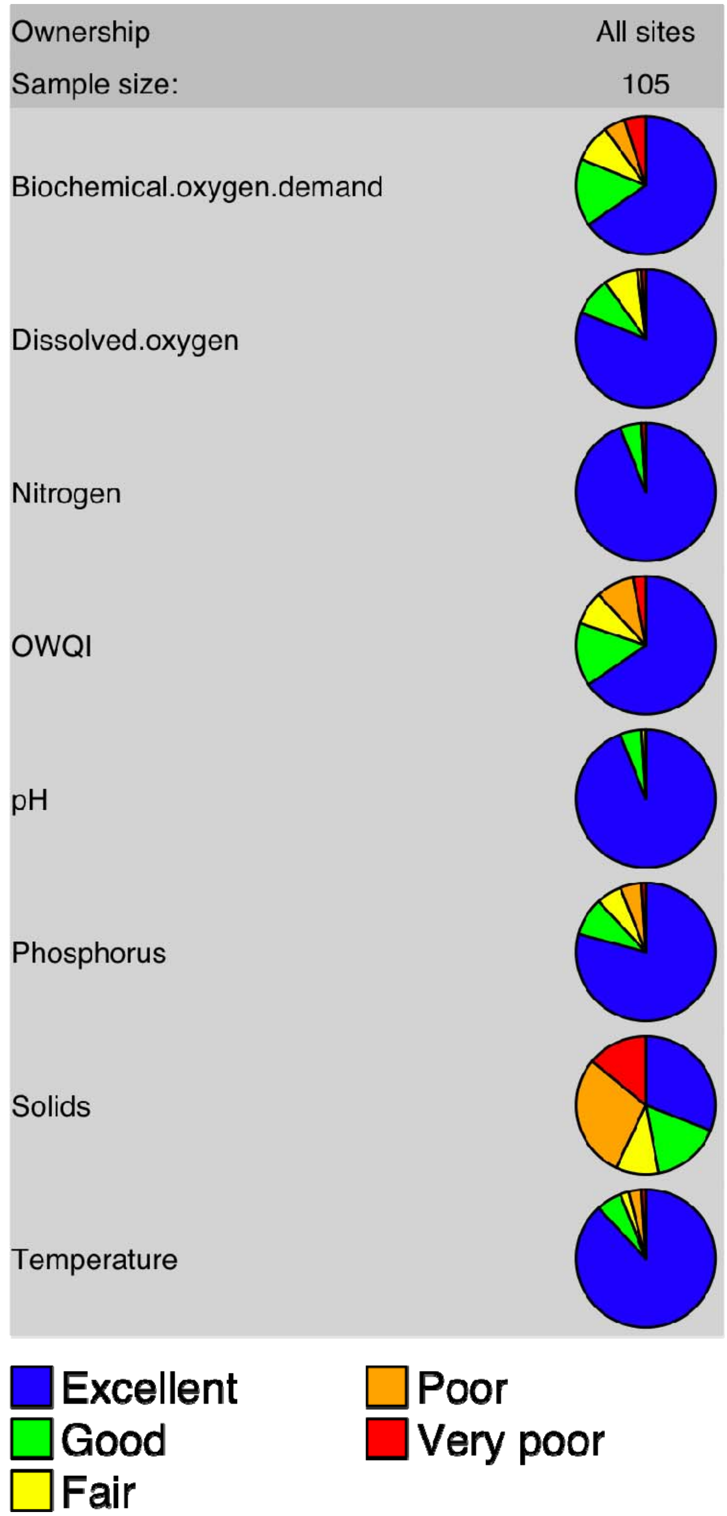


Figure 8. Conditions of water chemistry for forested lands in the South Coast. OWQI = Oregon Water Quality Index.

Willamette

PREDATOR

Almost two-thirds of sites in the Willamette (63%) showed macroinvertebrate assemblages in least disturbed conditions (Figure 9). Sixteen percent of forested sites were in moderately disturbed condition. Thirteen percent of Willamette sites were in most disturbed conditions. Twelve percent of sites were considered enriched, or having more reference taxa than expected.

Overall biological conditions in the Willamette were higher than conditions observed at the state scale (53% least disturbed, 24% most disturbed), North Coast (59% least disturbed, 26% most disturbed), and South Coast (42% least disturbed, 33% most disturbed).

Temperature and Fine Sediment Scores

Macroinvertebrate TS for forested sites in the Willamette were less than 16 ^{o}C at 46% of sites (Figure 9). TS were between 16.0 – 17.9 ^{o}C for 36% of forested streams. TS were between 18.0 – 19.9 ^{o}C at 14% of sites and greater than 20 ^{o}C at 4% of sites. Eighteen percent of forested sites had TS greater than or equal to 18.0 ^{o}C. The Willamette was one of only three HUCs with the majority of TS meeting the temperature standard for each site. TS at 53% of forested streams in the Willamette were "meeting" the standard, while 47% of TS were above the standard.

More than three-quarters of forest sites (82%) had FSS between 0 - 10% (Figure 9). Fourteen percent of forested sites had FSS between 11 – 20%. Two percent of forested Willamette sites had FSS between 21 – 30%. Only 1% of forested sites had FSS greater than 30%. With FSS greater than 10 as a benchmark, 18% of forested sites in the Willamette had macroinvertebrate assemblages that would be in poor condition.

Biological conditions among ownership classes

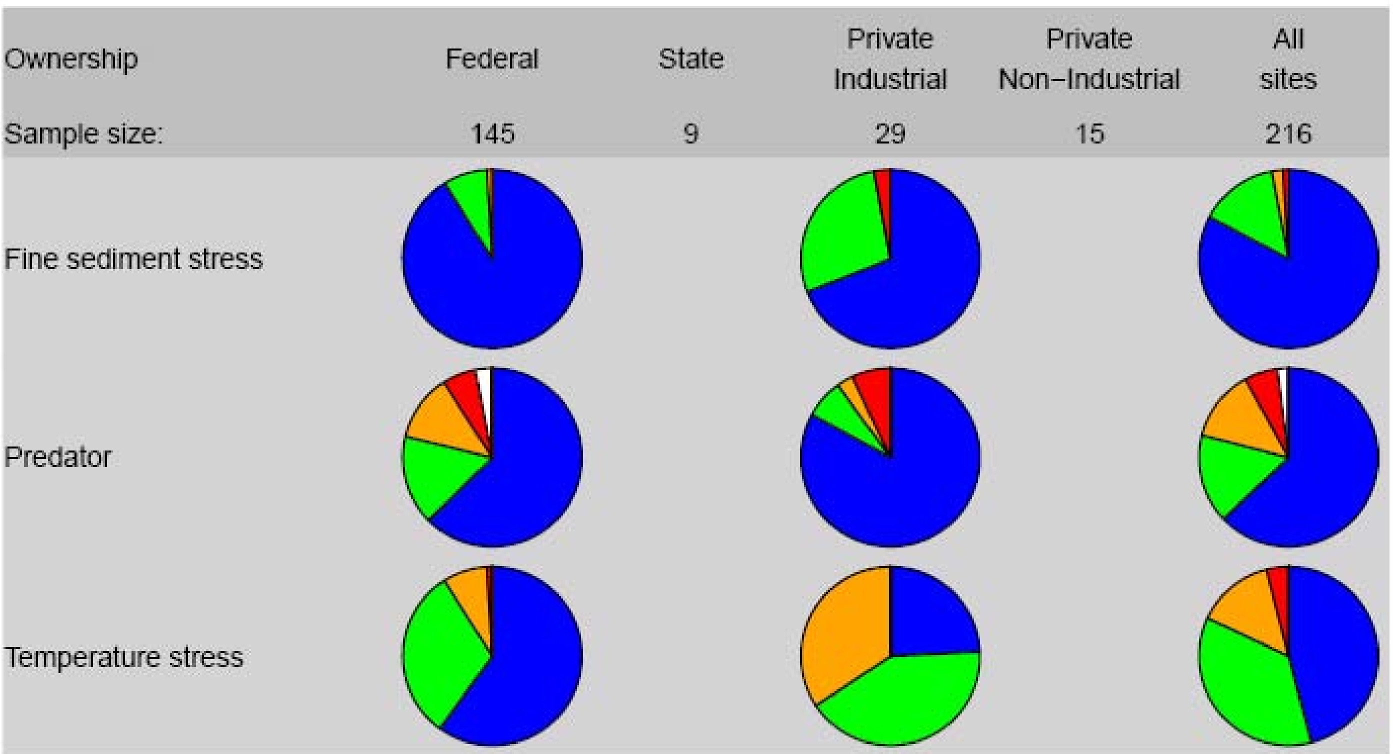
Due to small samples sizes, state sites (n = 9) and private non-industrial sites (n = 15) were not assessed.

Private industrial sites showed the highest percent of sites in least disturbed condition (83%) and three percent of sites in most disturbed condition (Figure 9). Almost two-thirds (62%) of federal forest sites were in least disturbed condition and 12% of sites were in most disturbed condition.

Federal forest sites in the Willamette showed macroinvertebrate assemblages preferring colder water and lower levels of fine sediments than observed on private industrial sites (Figure 9). Federal sites showed 60% percent of sites with TS less than 16.0 ^{o}C and 9% of sites with TS greater than 18.0 ^{o}C. Private industrial sites had nearly one-quarter the percent of sites (24%) with TS less than 16.0 ^{o}C. TS greater than or equal to 20.0 °C were very rare on federal and private industrial sites, with only one occurrence.

Federal sites in the Willamette had 57% of sites with TS meeting the temperature standard. Private industrial sites had 45% of sites meeting the summer temperature standard.

The same patterns were observed for fine sediment preferences that were observed for temperature preferences. Federal forest sites in the Willamette showed macroinvertebrate assemblages less tolerant to higher amounts of fine sediments than observed on private industrial sites (Figure 9). Federal sites showed 92% percent of sites with FSS between 0 – 10%. Private industrial sites had 69% of sites with FSS between 0 – 10%.



Fine Sediment Stress	PREDATOR	Temperature Stress
0 - 10%	Least disturbed	< 16 °C
11 - 20%	Enriched	16.0 - 17.9 °C
21 - 30%	Moderately disturbed	18.0 - 19.9 °C
> 30%	Most disturbed	≥ 20 °C
	Not assessed	

Figure 9. Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the Willamette.

Oregon Water Quality Index

Water quality on forested sites for forested streams in the Willamette was in excellent condition for 88% of sites (Figure 10). Seven percent of sites were in good condition. Five percent of sites were in fair or worse condition. Two percent of sites were in poor or worse condition.

OWQI Sub-Indices

The pH sub-index showed 97% forested streams in excellent condition (Figure 10). Dissolved oxygen and temperature showed a high percent of sites in excellent condition (94% and 95%, respectively) and good or better condition (97% each). Nutrient conditions on forested sites were also good or better for the majority of sites, although nitrogen conditions were higher than phosphorus for forested streams in the Willamette. Phosphorus sub-index scores showed 81% of sites in excellent condition and 91% in good or better condition. For nitrogen, 91% of sites were in excellent condition and 97% of sites were in good or better condition.

The BOD and solids indices showed the lowest conditions on forested sites across the Willamette, but were the highest of any other HUC (Figure 10). Seventy-two percent of sites showed BOD in excellent condition. The percent of sites with good or better conditions was 84%. Eight percent of sites were in poor or worse conditions for BOD. Solids showed nearly the same conditions, with 74% of sites in excellent condition and 82% were in good or better condition. Ten percent of sites were in poor or worse conditions.

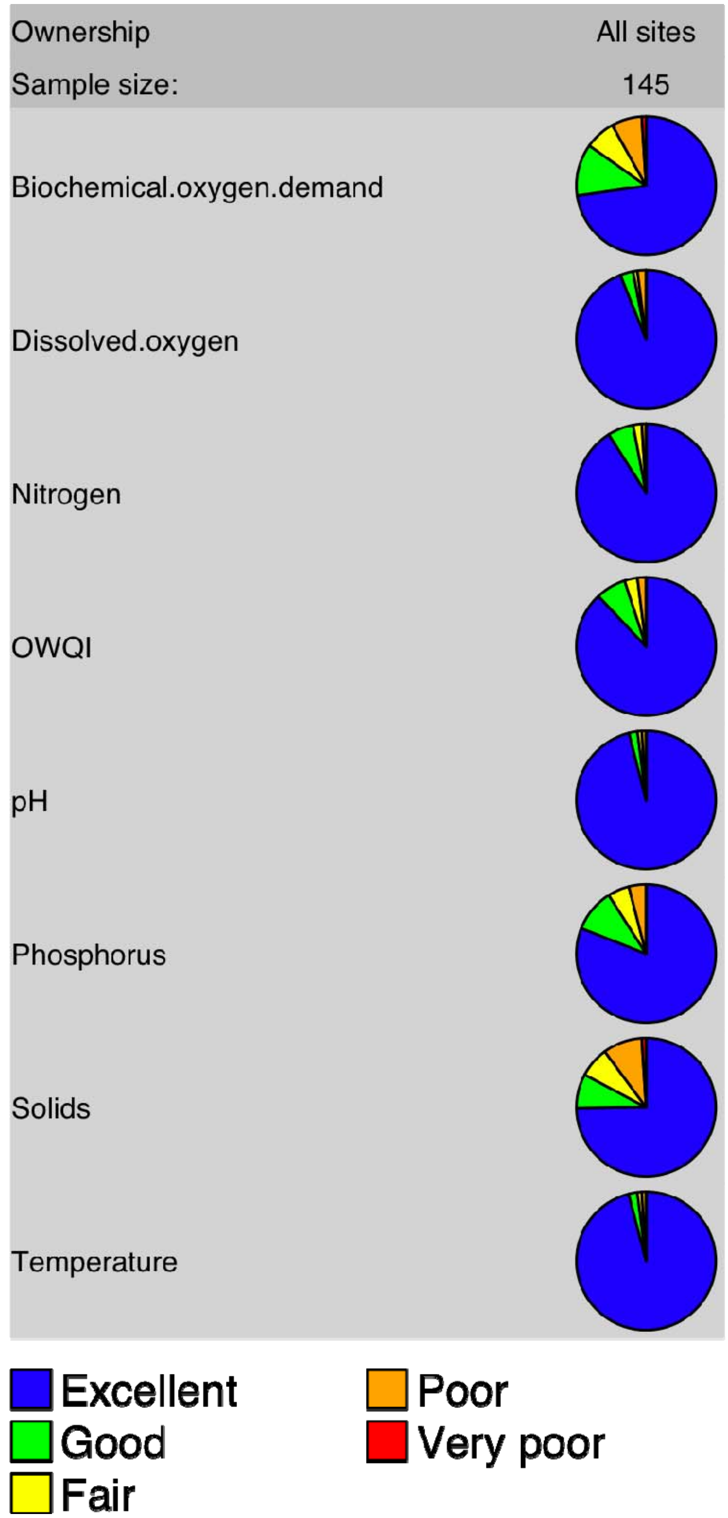


Figure 10. Conditions of water chemistry for forested sites in the Willamette. OWQI = Oregon Water Quality Index.

Lower Columbia

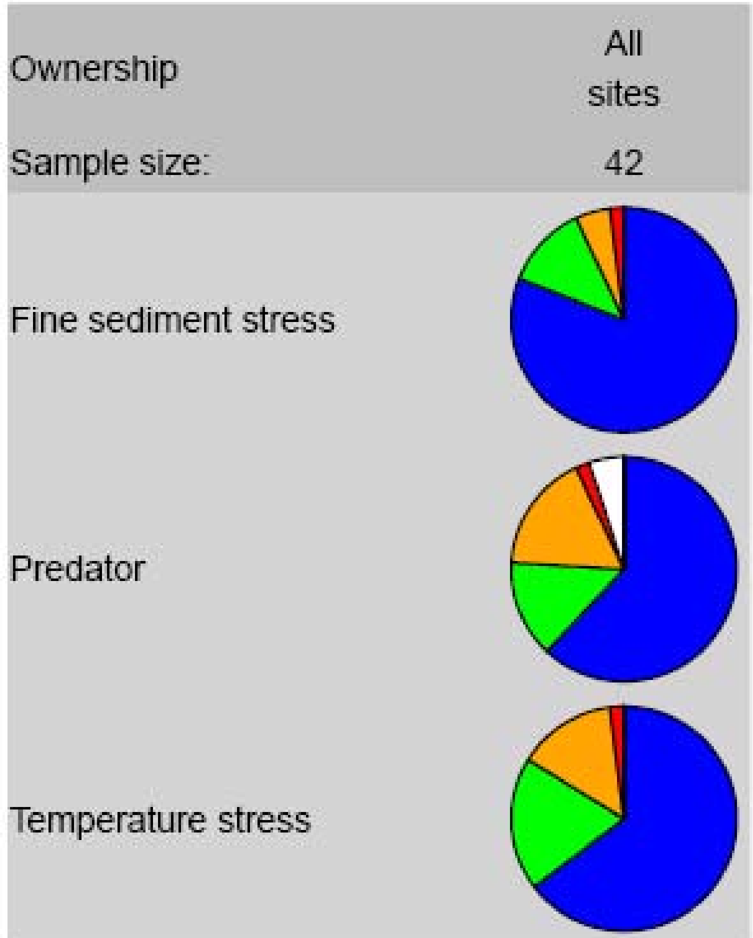
PREDATOR

Almost two-thirds of sites in the Lower Columbia (62%) showed macroinvertebrate assemblages in least disturbed conditions (Figure 11). Fourteen percent of forested sites were in moderately disturbed condition. Seventeen percent of Lower Columbia sites were in most disturbed conditions. Two percent of sites were considered enriched, or having more reference taxa than expected. Five percent of sites were not assessed.

Temperature and Fine Sediment Scores

Macroinvertebrate TS for forested sites in the Lower Columbia were less than 16 °C at 64% of sites (Figure 11). TS were between 16.0 – 17.9 °C for 19% of forested streams. Combining the last two TS categories, 16% of forested sites had TS values greater than or equal to 18.0 °C. TS in the Lower Columbia had the highest percentage of sites (83%) meeting the appropriate temperature standard for each site. Seventeen percent of sites had TS above the temperature standard.

Forested sites in the Lower Columbia showed 81% of sites with FSS between 0 - 10% (Figure 11). With FSS greater than 10% as a benchmark, 19% of forested sites in the Lower Columbia had macroinvertebrate assemblages that would be in poor condition for fine sediment.



Fine Sediment Stress	PREDATOR	Temperature Stress
0 - 10%	Least disturbed	< 16 °C
11 - 20%	Enriched	16.0 - 17.9 °C
21 - 30%	Moderately disturbed	18.0 - 19.9 °C
> 30%	Most disturbed	≥ 20 °C
	Not assessed	

Figure 11. Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the Lower Columbia.

Oregon Water Quality Index

Water quality on forested sites across the Lower Columbia was in excellent condition for 78% of sites (Figure 12). Thirteen percent of sites were in good condition. Nine percent of sites were in fair or worse condition. Six percent of sites were in poor or worse condition.

OWQI Sub-Indices

The pH sub-index showed 97% forested streams in excellent condition (Figure 12). Temperature showed a high percent of sites in excellent condition (97%) and all sites were in good or better condition. Dissolved oxygen showed 94% of sites in excellent condition and 97% of sites in good or better condition. Nutrient conditions on forested sites were also good or better for the majority of sites in the Lower Columbia. Phosphorus sub-index scores showed 75% of sites in excellent condition and 88% in good or better condition. For nitrogen, 75% of sites were in excellent condition and 91% of sites were in good or better condition.

BOD and solids showed the lowest conditions on forested sites across the Lower Columbia. Just over half of forested streams (53%) showed BOD in excellent condition. The percent of sites with good or better conditions was 69%. Nine percent of sites were in poor or worse conditions. While the solids sub-index showed a relatively high percent of sites (72%) in excellent condition, 22% percent of sites were in poor or worse conditions.

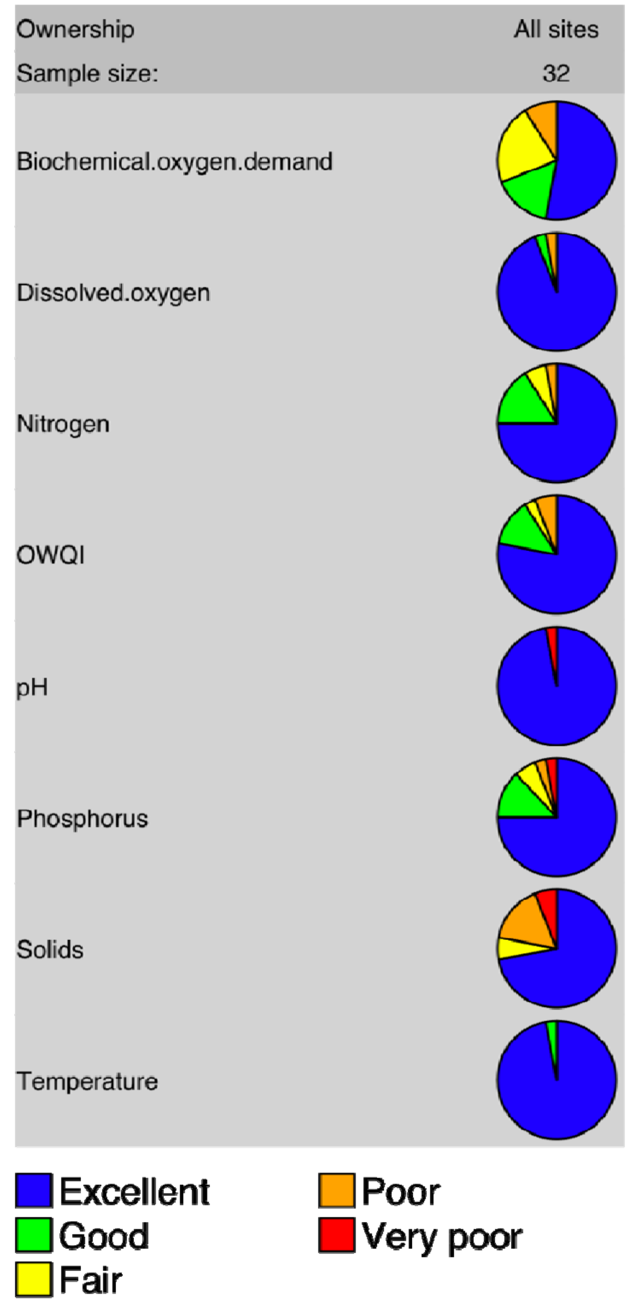


Figure 12. Conditions of water chemistry for forested sites in the Lower Columbia. OWQI = Oregon Water Quality Index.

Middle Columbia

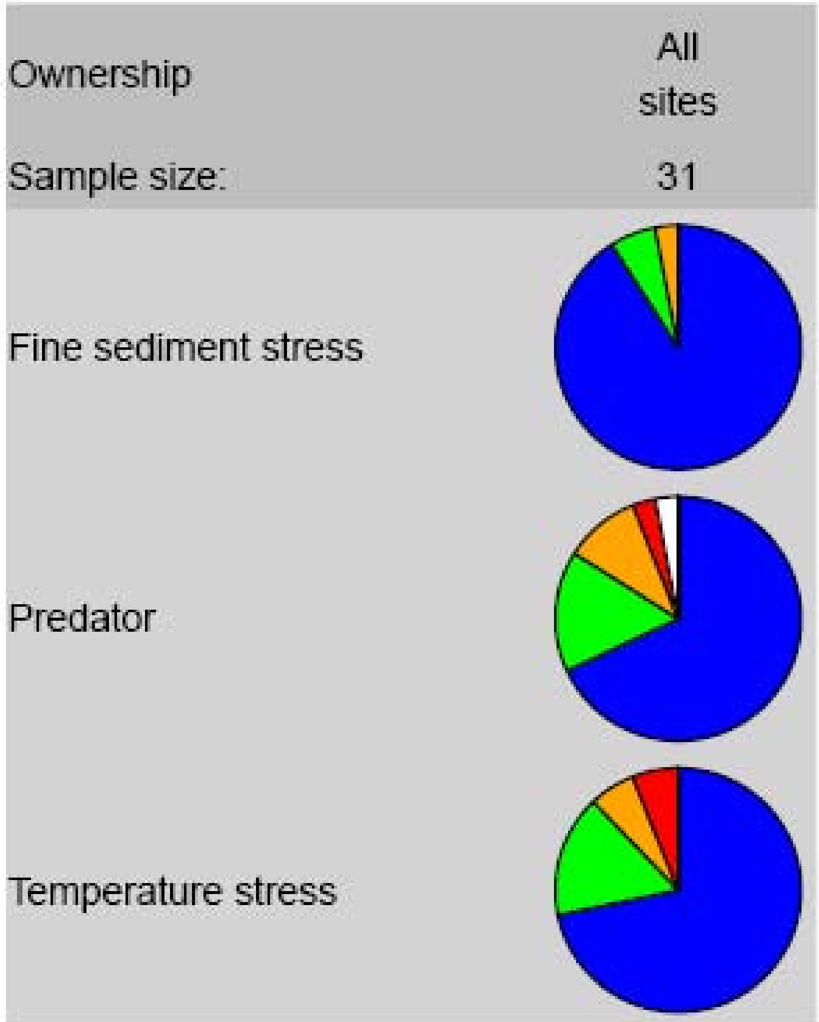
PREDATOR

More than two-thirds of sites in the Middle Columbia (68%) showed macroinvertebrate assemblages in least disturbed conditions (Figure 13). Sixteen percent of forested sites were in moderately disturbed condition. Ten percent of Middle Columbia sites were in most disturbed conditions. Three percent of sites were considered enriched and three percent of sites were not assessed.

Temperature and Fine Sediment Scores

Macroinvertebrate TS for forested sites in the Middle Columbia were less than 16 °C at 71% of sites (Figure 13). TS were between 16.0 – 17.9 °C for 16% of forested streams surveyed. Combining the last two TS categories, 12% of forested sites had TS greater than or equal to 18.0 °C. The Middle Columbia had the second highest percent of sites meeting the appropriate temperature standard (65%). Thirty-five percent of sites had TS above the temperature standard.

Forested sites in the Middle Columbia showed 90% of sites with FSS between 0 - 10% (Figure 13). With FSS greater than 10% as a benchmark, 9% of forested sites in the Lower Columbia had macroinvertebrate assemblages that would be in poor condition for fine sediment.



	Fine Sediment Stress	PREDATOR	Temperature Stress
(blue)	0 - 10%	Least disturbed	< 16 °C
(green)	11 - 20%	Enriched	16.0 - 17.9 °C
(orange)	21 - 30%	Moderately disturbed	18.0 - 19.9 °C
(red)	> 30%	Most disturbed	≥ 20 °C
(white)		Not assessed	

Figure 13. Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the Middle Columbia.

Oregon Water Quality Index

Water quality on forested sites across the Middle Columbia was in excellent condition for 80% of sites (Figure 14). Twenty percent of sites were in good condition. No sites were in fair or worse condition.

OWQI Sub-Indices

The temperature sub-index showed all forested streams in excellent condition (Figure 14). Dissolved oxygen and pH both showed 95% of sites in excellent condition. Nutrient conditions on forested sites were the highest compared to any other HUC. Phosphorus sub-index scores showed 85% of sites in excellent condition and 95% in good or better condition. For nitrogen, 100% of sites were in excellent condition.

The BOD and solids sub-indices showed the lowest conditions on forested sites across the Middle Columbia. Seventy percent of sites showed BOD in excellent condition, which was higher than observed in most other HUCs. The percent of sites with good or better conditions for BOD was 80%. No sites were in poor or worse conditions. The solids sub-index showed a low percent of sites (40%) in excellent condition, but 70% percent of sites were in good or better conditions. One-quarter of sites (25%) were in poor condition.

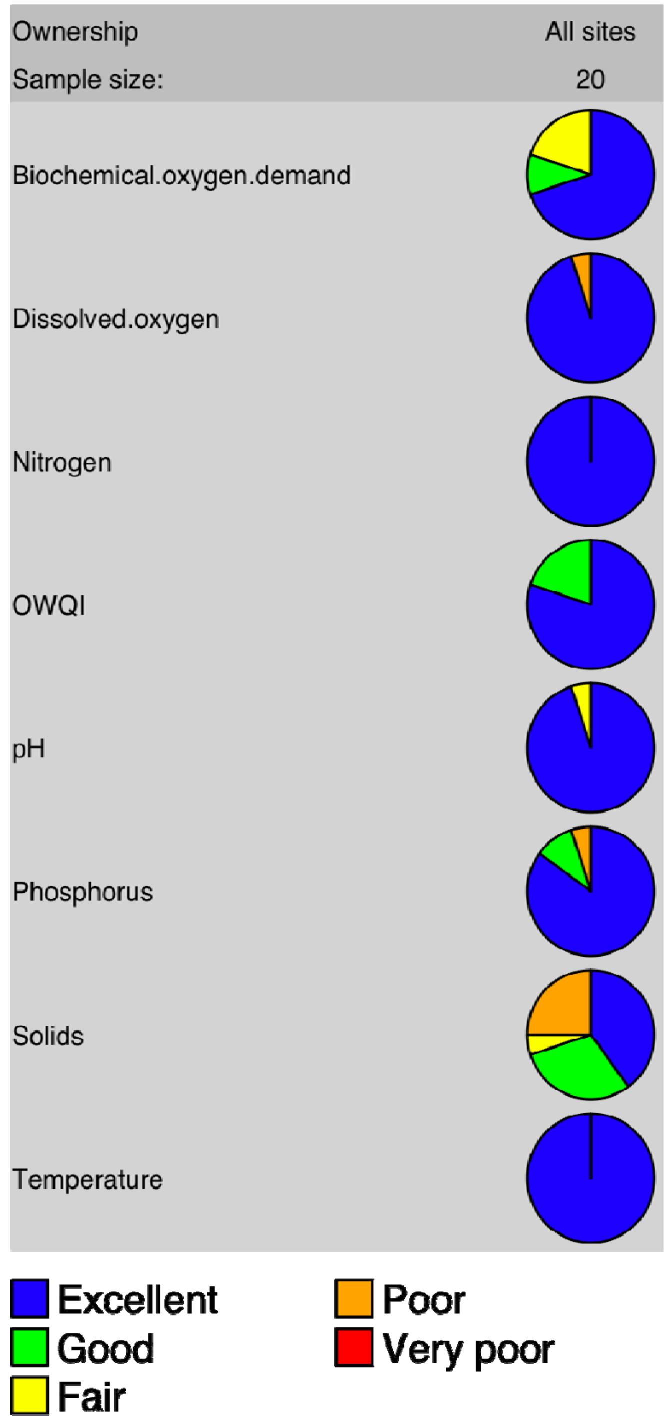


Figure 14. Conditions of water chemistry for forested sites in the Middle Columbia. OWQI = Oregon Water Quality Index.

Lower Snake

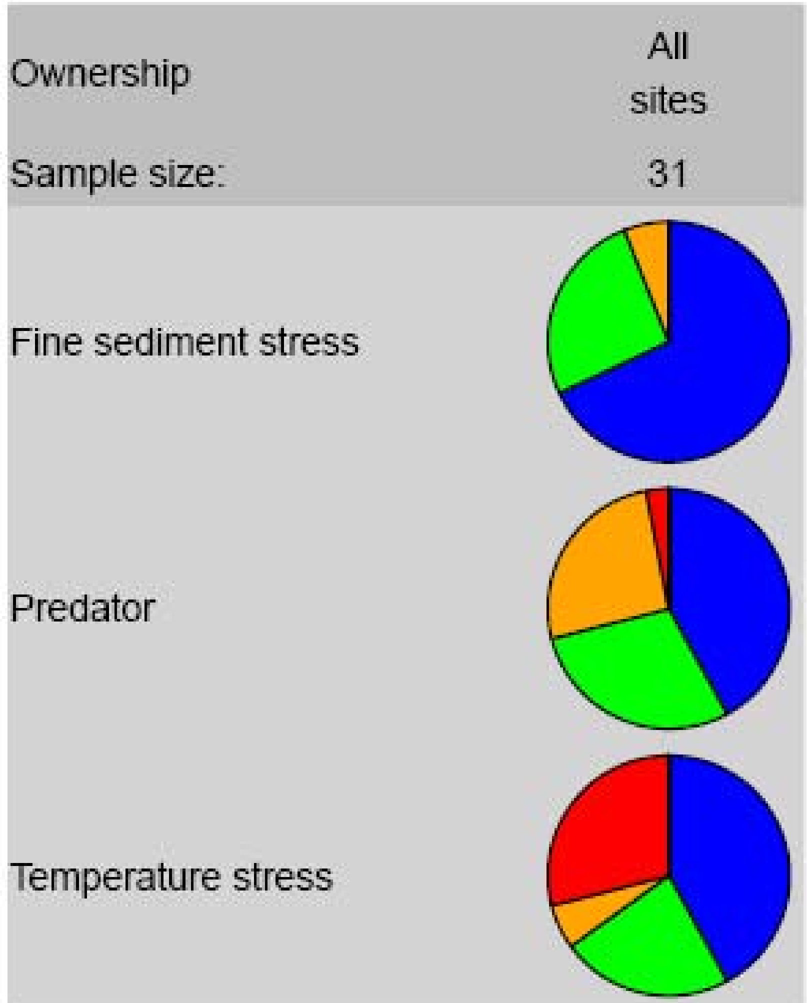
PREDATOR

Less than half of sites (42%) in the Lower Snake showed macroinvertebrate assemblages in least disturbed conditions (Figure 15). Twenty-nine percent of forested sites were in moderately disturbed condition. Most disturbed conditions were observed for 26% of sites. Two percent of sites were considered enriched and five percent of sites were not assessed.

Temperature and Fine Sediment Scores

Macroinvertebrate TS for forested sites in the Lower Snake were less than 16 °C at 42% of sites (Figure 15). TS were between 16.0 – 17.9 °C for 23% of forested streams surveyed. Thirty-five percent of Lower Snake sites had TS greater than or equal to 18.0 °C. The Lower Snake had the lowest percent of sites meeting the appropriate temperature standard (6%). Nearly all sites (94%) had TS above the temperature standard.

Forested sites in the Lower Snake showed 68% of sites with FSS between 0 - 10% (Figure 15). With FSS greater than 10% as a benchmark, 32% of forested sites in the Lower Snake had macroinvertebrate assemblages that would be in poor condition for fine sediment.



Fine Sediment Stress	PREDATOR	Temperature Stress
0 - 10%	Least disturbed	< 16 °C
11 - 20%	Enriched	16.0 - 17.9 °C
21 - 30%	Moderately disturbed	18.0 - 19.9 °C
> 30%	Most disturbed	≥ 20 °C
	Not assessed	

Figure 15. Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the Lower Snake.

Deschutes

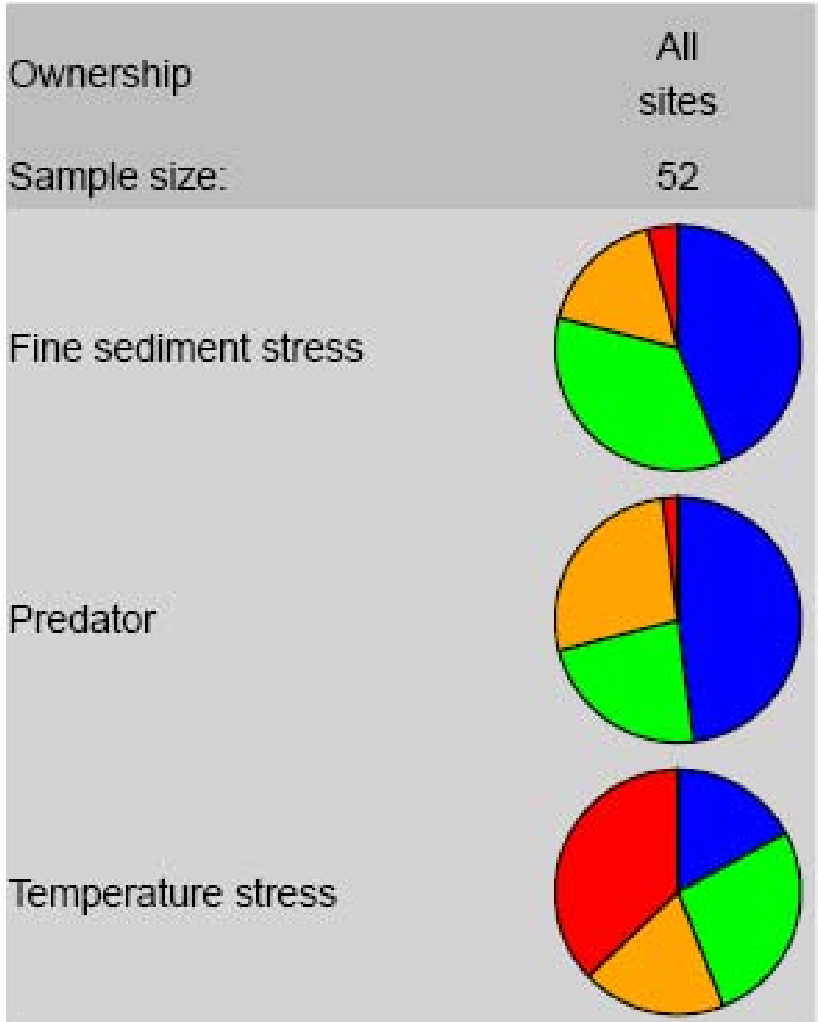
PREDATOR

Slightly less than half of sites (48%) in the Deschutes showed macroinvertebrate assemblages in least disturbed conditions (Figure 16). Twenty-three percent of forested sites were in moderately disturbed condition. Most disturbed conditions were observed for 27% of Deschutes sites. Two percent of sites were considered enriched.

Temperature and Fine Sediment Scores

Macroinvertebrate TS for forested sites in the Deschutes were less than 16 °C at 17% of sites (Figure 16). TS were between 16.0 – 17.9 °C for 27% of forested streams surveyed. Fifty-five percent of Deschutes sites had TS greater than or equal to 18.0 °C). Forty percent of sites in the Deschutes had TS meeting the temperature standard and 60% of sites were above temperature standard.

Forested sites in the Deschutes showed 44% of sites with FSS between 0 - 10% (Figure 16). With FSS greater than 10% as a benchmark, 56% of forested sites in the Deschutes had macroinvertebrate assemblages that would be in poor condition for fine sediment.



Fine Sediment Stress	PREDATOR	Temperature Stress
0 - 10%	Least disturbed	< 16 °C
11 - 20%	Enriched	16.0 - 17.9 °C
21 - 30%	Moderately disturbed	18.0 - 19.9 °C
> 30%	Most disturbed	≥ 20 °C
	Not assessed	

Figure 16. Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the Deschutes.

John Day

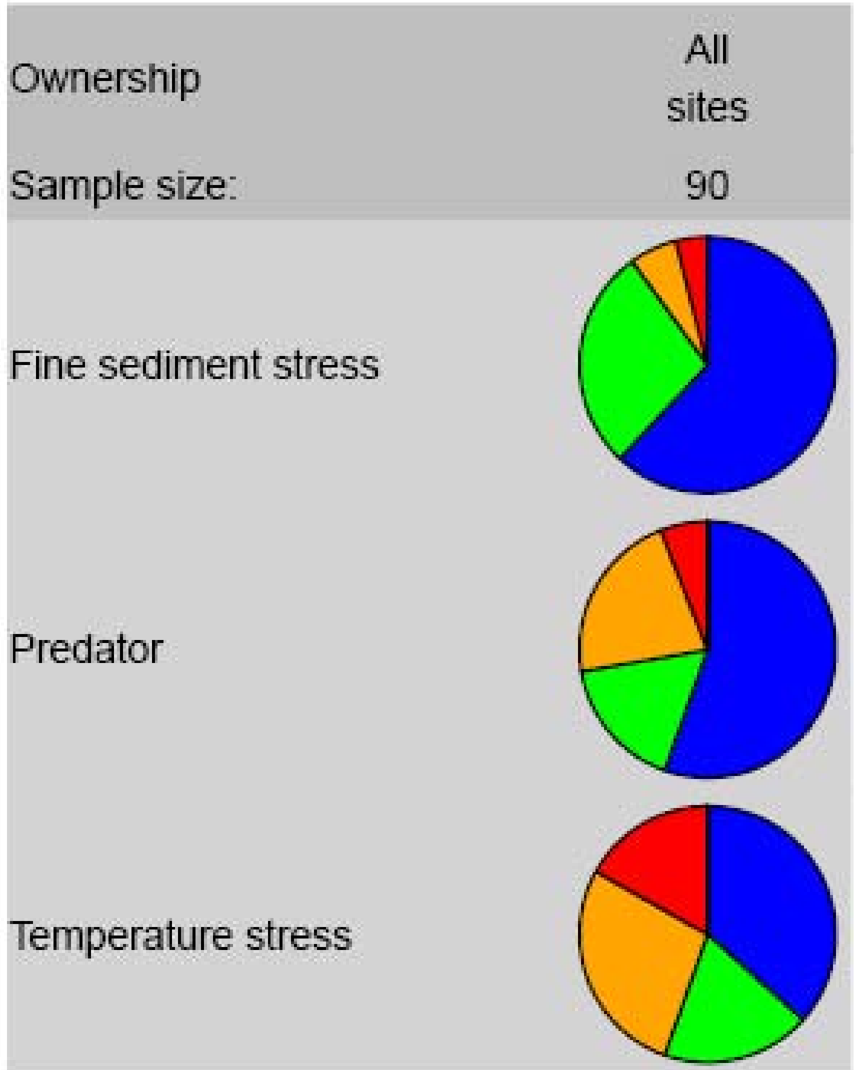
PREDATOR

A little more than half of forested sites (56%) in the John Day showed macroinvertebrate assemblages in least disturbed conditions (Figure 17). Seventeen percent of sites were in moderately disturbed condition. Most disturbed conditions were observed for 22% of Deschutes sites. Six percent of sites were considered enriched.

Temperature and Fine Sediment Scores

Macroinvertebrate TS for forested sites in the John Day were less than 16 °C at 37% of sites (Figure 17). TS were between 16.0 – 17.9 °C for 19% of forested streams surveyed. Combining the last two TS categories, 45% of sites in the John Day had TS greater than or equal to 18.0 °C. The John Day had the second lowest percent of sites meeting the appropriate temperature standard (22%), with 78% of sites above the temperature standard.

Forested sites in the John Day showed 62% of sites with FSS between 0 - 10% (Figure 17). With FSS greater than 10% as a benchmark, 38% of forested sites in the John Day had macroinvertebrate assemblages that would be in poor condition for fine sediment.



	Fine Sediment Stress	PREDATOR	Temperature Stress
Blue	0 - 10%	Least disturbed	< 16 °C
Green	11 - 20%	Enriched	16.0 - 17.9 °C
Orange	21 - 30%	Moderately disturbed	18.0 - 19.9 °C
Red	> 30%	Most disturbed	≥ 20 °C
White		Not assessed	

Figure 17. Conditions of macroinvertebrate assemblages for three biological indices on forested sites in the John Day.

Discussion

Biases in the datasets

The results presented in this report are biased towards conditions of forest sites on smaller streams, on federal sites, in western Oregon. Our restrictions on percent forest at both the local and watershed scales (≥ 70% forest at both scales) forced the majority of sites to be 1st through 3rd order streams, away from other land uses typical of lower elevations (e.g., agriculture and urban). Sample sizes east of the Cascades were much lower than west of the Cascades (Figure 1). Except for the North Coast and Lower Columbia, the number of sites on federal lands far outnumbered other ownership classes (Figure 1).

Very few of these sites were sampled outside of the summer low-flow period, and most were sampled only one time. This makes accurate characterizations of single sites difficult, especially for water chemistry data where yearly, seasonal, or even daily fluctuations may be dramatic. For biological assemblage data this is less problematic. The composition of biological assemblages reflect the conditions within streams over time, making them more suited to representing a site with a single sampling event.

The data used to characterize forest sites in this report came from a variety of projects—the majority included random site selection methods, while others used targeted site selection. If all sites were chosen randomly, we could have incorporated error bars into our estimates of forest sites conditions. Since this was not possible, we need to rely on sample sizes and adequate coverage of forest sites within the reporting units as our measure of confidence in the results. We chose 20 sites as a minimum sample size for each reporting unit or land ownership class. However, even 20 sites is still a small sample size, and results presented in this report with lower sample sizes should be interpreted with caution. Even in the Deschutes, which had 52 forested sites, the results in this report are biased towards the conditions in the Crooked River sub-basin (eastern part of the HUC) and against the upper Deschutes sub-basin (south-western part of the HUC) where there were few sites (Figure 1). Only in the North Coast, South Coast, and Willamette did we achieve both high sample sizes and relatively even coverage of forested sites to feel confident that the results presented in this report are reflective of the true forest conditions across the entire reporting unit (Figure 1).

State scale

At the state scale, over half of forested sites were in the best overall condition class for PREDATOR (53% least disturbed) and FSS (69% of sites between 0-10% fines). For TS, the percent of sites in the best overall condition class was substantially lower (32% of sites < 16 °C). We observed similar percentages of sites in the lowest condition classes for the two stressor models (38% of sites with TS ≥ 18.0°C and 31% of sites with FSS > 10% fines).

Water quality conditions across Oregon's forest sites showed a higher percentage of sites in best overall condition (77% excellent) for the OWQI. Nine percent of sites had OWQI scores that were in fair, poor, or very poor condition. Except for BOD and Solids, the sub-indices of the OWQI generally showed the same or better trend. Both BOD and Solids resulted in less than two-thirds of Oregon's forest sites in excellent condition. These two sub-indices consistently showed poorer performance than the other sub-indices across all HUCs and ownership classes.

HUC assessments

Comparisons among HUCs were made by ranking the percent of sites in each HUC within the lowest quality condition classes (Table 4). The lowest biological condition classes were most disturbed for PREDATOR, ≥ 18.0°C for TS, and > 10% fines for FSS.

Table 6. Relative rankings of biological and water quality conditions among the HUCs with at least 20 forested sites. The Hydrologic Unit Code (HUC) with the lowest percent of sites in the least desired condition received the lowest rank (1). The higher the rank, the higher the percent of sites in the least desired condition class.

Reporting Unit	**PREDATOR** *Most disturbed*	**Temperature Score** *≥18.0 °C*	**Fine Sediment Score** *> 10% fines*	**Oregon Water Quality Index** *Poor + Very Poor*
Middle Columbia	1	1	1	1
Willamette	2	3	2	2
Lower Columbia	3	2	3	4
North Coast	5	7	6	3
John Day	4	5	7	--
Deschutes	7	8	8	--
Lower Snake	5	4	4	--
South Coast	8	6	4	5

Middle Columbia

Due to the low sample size in the Middle Columbia, we should interpret these results carefully.

The best biological conditions of any of the HUCs assessed in this report were observed in the Middle Columbia. It ranked first for the smallest percent of sites in lowest condition for all three biological indices (Table 4). The Middle Columbia had the lowest (out of five HUCs) percent of sites with OWQI scores rated as poor or very poor. There are two regionally distinct populations represented in the Middle Columbia (Figure 18). The western sites were located in the Hood River basin, or nearby direct tributaries to the Columbia River. The eastern sites were located in the upper reaches of the Umatilla and Walla Walla basins. The forested sites in the west showed lower O/E than the western sites, but again, sample sizes were very small.

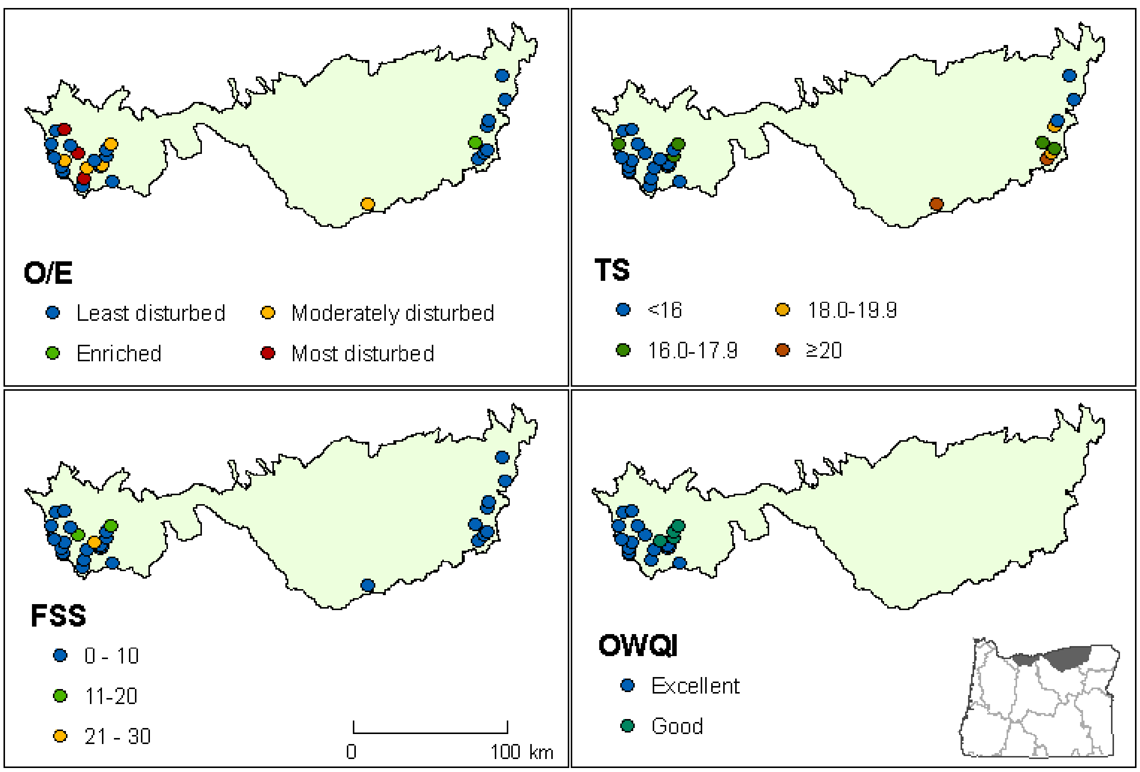


Figure 18. Biological and water quality conditions in the Middle Columbia.

Willamette

The Willamette ranked second for PREDATOR and FSS, and third for TS (Table 4). There were spatial differences in TS and FSS in the Willamette (Figure 19). Sites in the higher elevations of the Cascades ecoregion (sites further east in the HUC) primarily had TS < 16 °C and FSS between 0-10% fines. As elevations decreased in the Cascades and down into the Willamette Valley ecoregion (moving from east to west), the number of sites with higher TS and FSS increased. PREDATOR, however, did not show the same spatial differences, suggesting that the differences in temperature and fine sediment preferences in the macroinvertebrate assemblages may be representing natural gradients in the ecoregions. To test this hypothesis, though, it would be best to relate TS and FSS to regional reference conditions, rather than the same benchmarks applied across the entire state. Water quality in the Willamette ranked second, with only 2% of sites in poor or very poor condition (Table 4). Solids and BOD showed the lowest percent of sites in excellent condition, compared to the other sub-indices; but they did show the highest percent of sites in excellent condition compared to any other HUC.

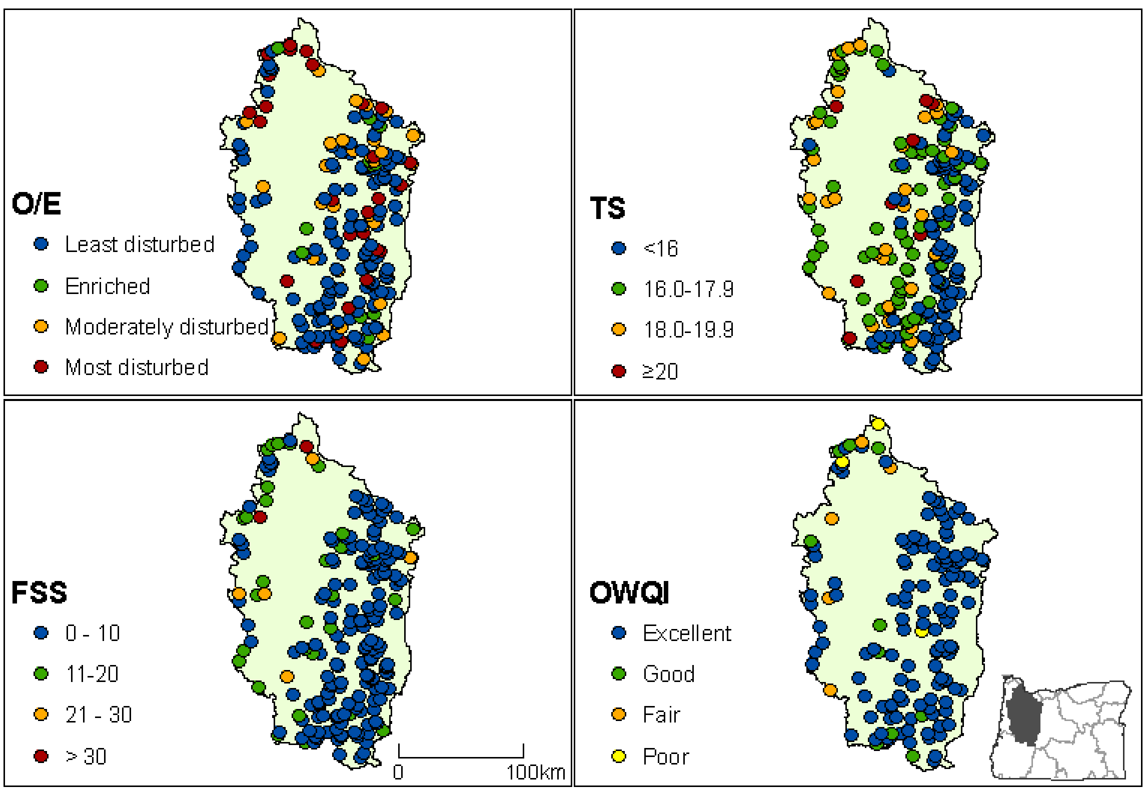


Figure 19. Biological and water quality conditions in the Willamette.

Lower Columbia

The lower sample size in the Lower Columbia (n = 42) suggests we should interpret these results with caution, however, this HUC is small compared to other HUCs and the coverage of forest sites appears to be decent in the Lower Columbia (Figure 1).

The Lower Columbia ranked third for PREDATOR and FSS, and second for TS (Table 4). There were some spatial differences in the biological indices within the Lower Columbia (Figure 20). The sites in the southeastern section of the HUC, located in the Sandy River basin and Columbia River Gorge, had lower TS and FSS than sites in the northwestern portion of the HUC. Some of this spatial variability may be explained by ecoregional differences. The Sandy basin and Columbia Gorge sites were located in the Cascades ecoregion, while the remaining sites were located in the Coast Range ecoregion. Stream temperatures in the Cascades naturally tend to be lower than in the Coast Range due to higher snowpack and glacial runoff. Also, lithologies between the two ecoregions are different, with the Coast Range showing regions with more erodible soils than in the Cascades. OWQI scores in poor or very poor condition in the Lower Columbia ranked fourth (Table 4). This appeared to be mostly due to the BOD sub-index, which showed 53% of sites in excellent condition.

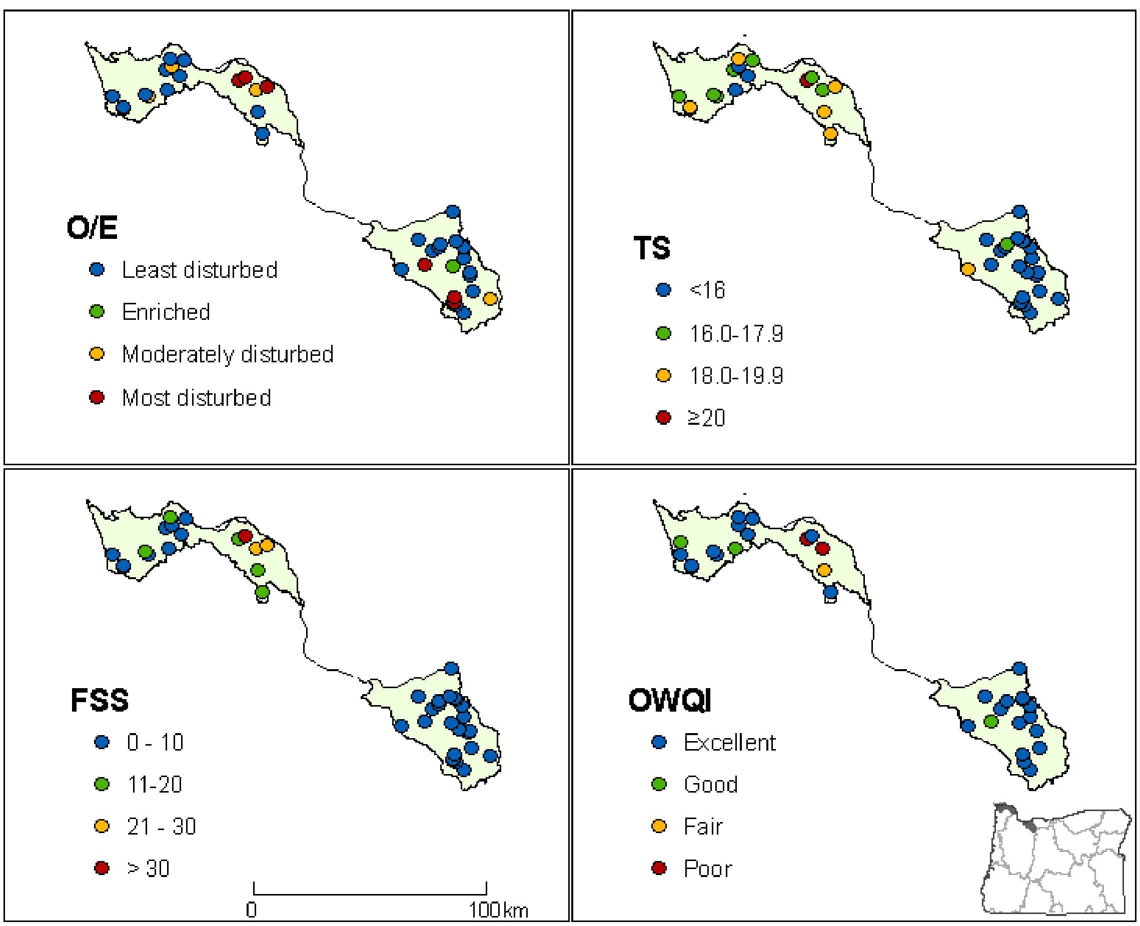


Figure 20. Biological and water quality conditions in the Lower Columbia.

North Coast

Ranked biological conditions in the North Coast were highly variable (Table 4). The North Coast was ranked5thfor the percent of sites in most disturbed condition for PREDATOR. TS rankings were among the poorest in the North Coast. It had the 7th rank due to the second highest percent of sites for TS ≥18.0°C. Partly the low TS rankings were due to the highest percentages in the middle TS condition classes (16.0 – 17.9 °C and 18.0 – 19.9 °C). FSS rankings in the North Coast (6th) were also among the lowest rankings of all the HUCs. The North Coast was ranked 3rd (out of five) for the percent of sites with OWQI in poor or very poor condition. This was due to lower quality of the BOD, Solids, and Nitrogen sub-indices.

There were some spatial patterns evident in the biological indices in the North Coast. In this HUC, higher TS and FSS were observed in the northeastern (upper Nehalem River basin) and southern portions (Alsea River and Siuslaw River basins) (Figure 21). The single Level III ecoregion in the North Coast HUC (Coast Range) doesn't explain these localized patterns of higher macroinvertebrate temperature and fine sediment preferences. The differences in FSS between these two regions may be explained by looking at Level IV ecoregions, where the upper Nehalem basin falls in the Wilapa Hills and the Siuslaw basin falls in the Mid-Coastal Sedimentary. Both of these Level IV ecoregions have geologies more prone to erosion, compared to the other Level IV ecoregions in the Coast Range.

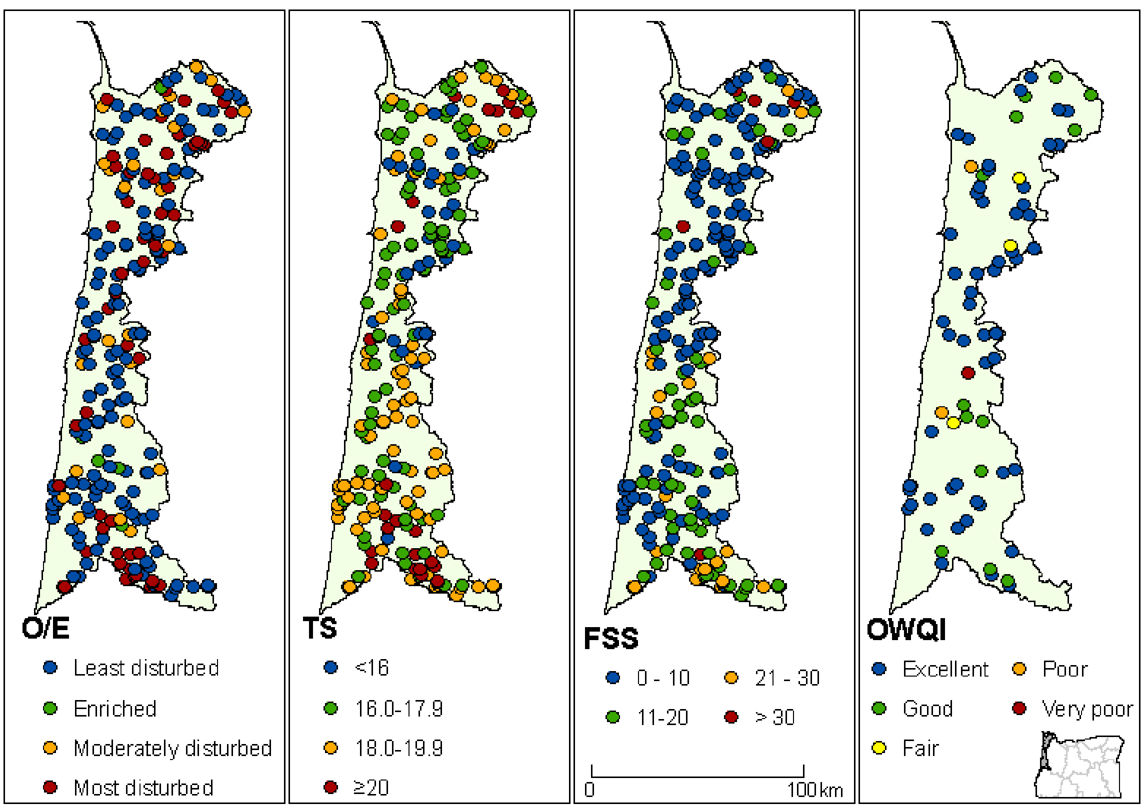


Figure 21. Biological and water quality conditions in the North Coast.

John Day

The John Day showed intermediate to lower rankings for biological conditions (Table 4). It ranked 4th for the percent of stream miles in most disturbed condition for PREDATOR. It ranked 5th for percent of stream miles with TS ≥18.0°C. FSS conditions in the John Day were lower, ranking 7th for percent of sites > 10% fines. Sites in the North Fork and Middle Fork sub-basins (northeastern part of the HUC) showed lower PREDATOR values and higher TS values than observed in the other sub-basins (Figure 22). The North Fork of the John Day had ten of 32 sites and the Middle Fork had six of 20 sites in most disturbed PREDATOR condition. By comparison, the Upper John Day (including the upper mainstem and South Fork sub-basins) had two of 34 sites in most disturbed condition for O/E. Of 15 sites with TS ≥ 20.0 °C, all but one were in the North Fork or Middle Fork sub-basins.

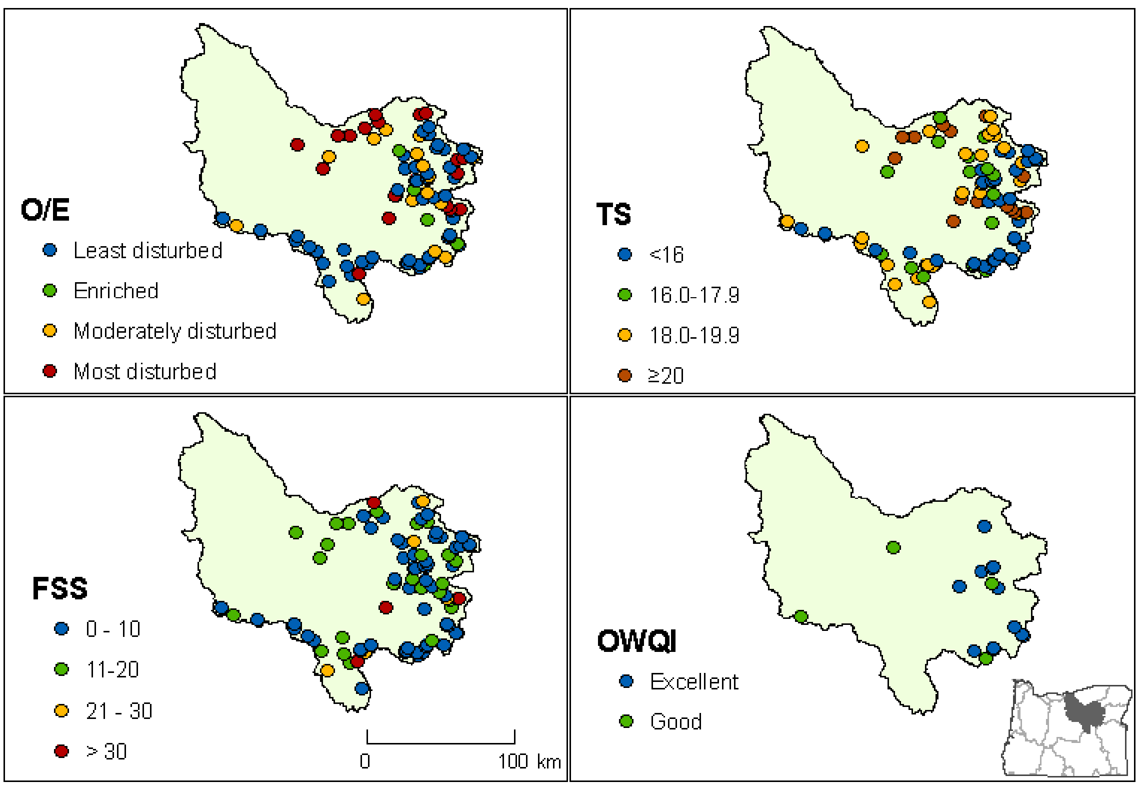


Figure 22. Biological and water quality conditions in the John Day.

Deschutes

The Deschutes ranked near last for PREDATOR (7th) and last (8th) for TS and FSS (Table 4). PREDATOR conditions on forest sites were lower in the Crooked River sub-basin (eastern portion of the HUC) than conditions observed in the rest of the HUC (Figure 23). One-third of sites in the Crooked River sub-basin (12 of 36) were in most disturbed condition for PREDATOR. The lower PREDATOR conditions in the Crooked River sub-basin may be related to higher TS and FSS values. But the differences in macroinvertebrate assemblage preferences could also be due to natural conditions, as the Crooked River sub-basin falls into a different Level III ecoregion (Blue Mountains) than sites in the rest of the basin (Cascades and Eastern Cascades Slopes and Foothills). Given that sample size in the Crooked River sub-basin was only 36--and yet that was more than twice sample size of the rest of the HUC--these differences should be interpreted with caution.

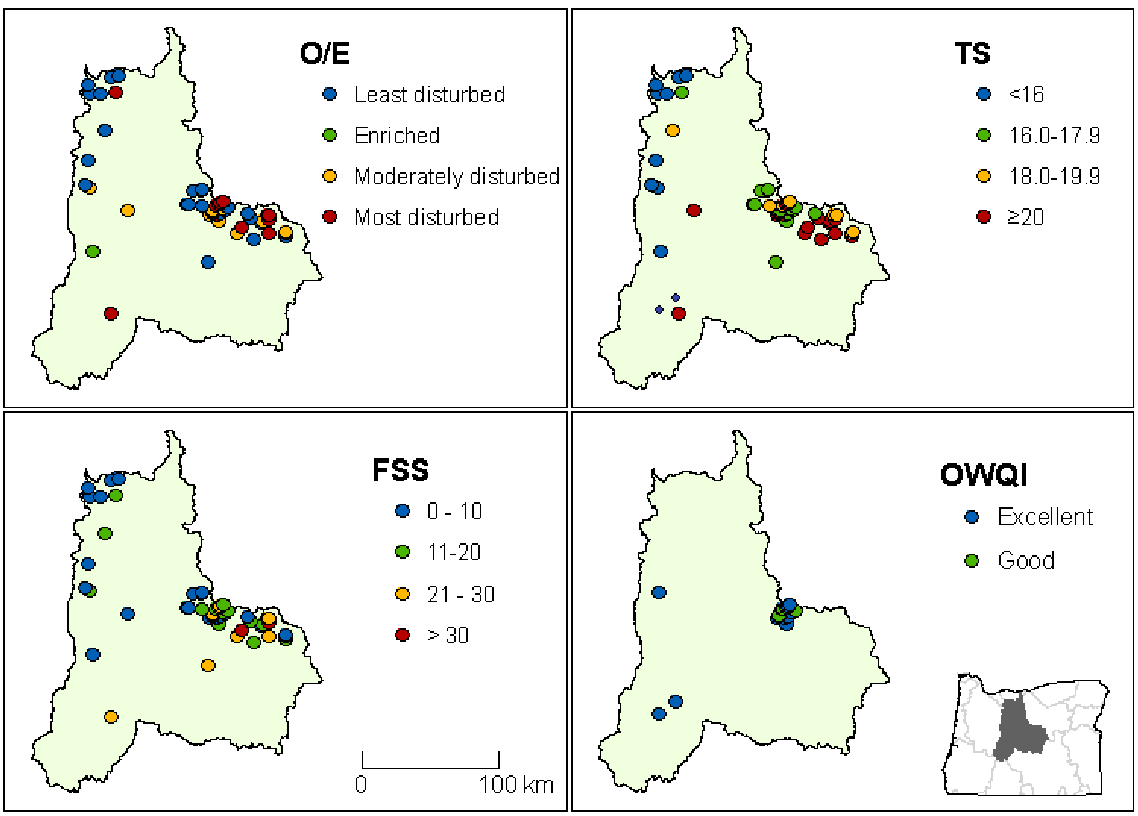


Figure 23. Biological and water quality conditions in the Deschutes.

Lower Snake

The Lower Snake ranked 5th for the highest percentage of sites in most disturbed condition for PREDATOR (Table 4). TS and FSS conditions were slightly better, ranking fourth for both condition classes. Within the HUC, there were more sites in the upper Grande Ronde River basin (southwest portion of the HUC) showing most disturbed O/E conditions and higher TS and FSS conditions (Figure 24).

Again, with a sample size of only 31, these results should be interpreted with caution.

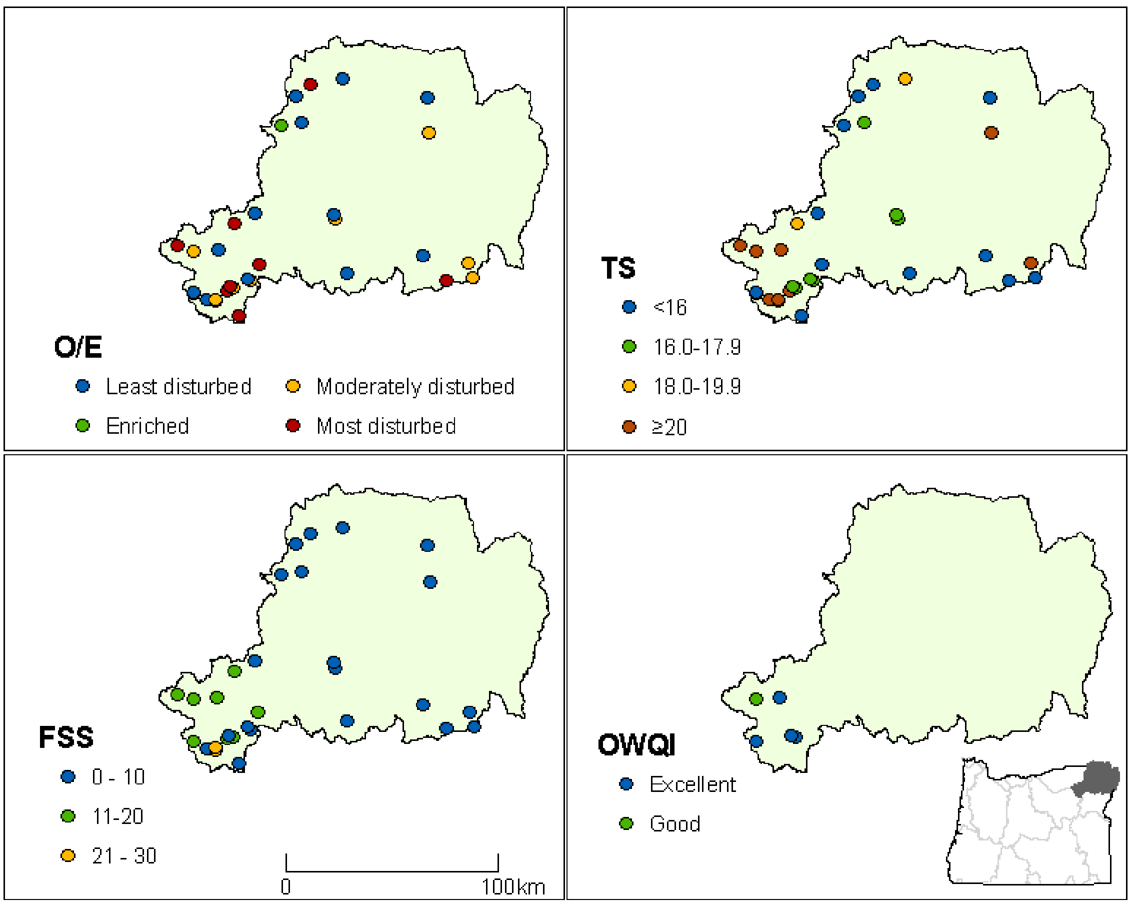


Figure 24. Biological and water quality conditions in the Lower Snake.

South Coast

The South Coast HUC ranked last in percent of sites in most disturbed condition for PREDATOR (Table 4). It ranked 6th for TS and ranked 4th for the percent of sites with FSS > 10% fines. The South Coast also had the lowest ranked HUC (fifth out of five) for percent of sites in poor or very poor OWQI condition (12%). Higher FSS were observed in the northwestern portion of the HUC (Figure 25), primarily consisting of sites in the lower Umpqua river basin.

Water quality was most often limited by BOD and especially Solids, which had 31% of sites in excellent condition. The dissolved oxygen sub-index was also the lowest in the South Coast. The relationship between lowest O/E condition and lowest Solids sub-index scores are potentially correlated. Other studies by ODEQ staff (ODEQ 2005, Hubler 2007) showed a strong risk to biological assemblages when total solids at a site exceed reference benchmarks.

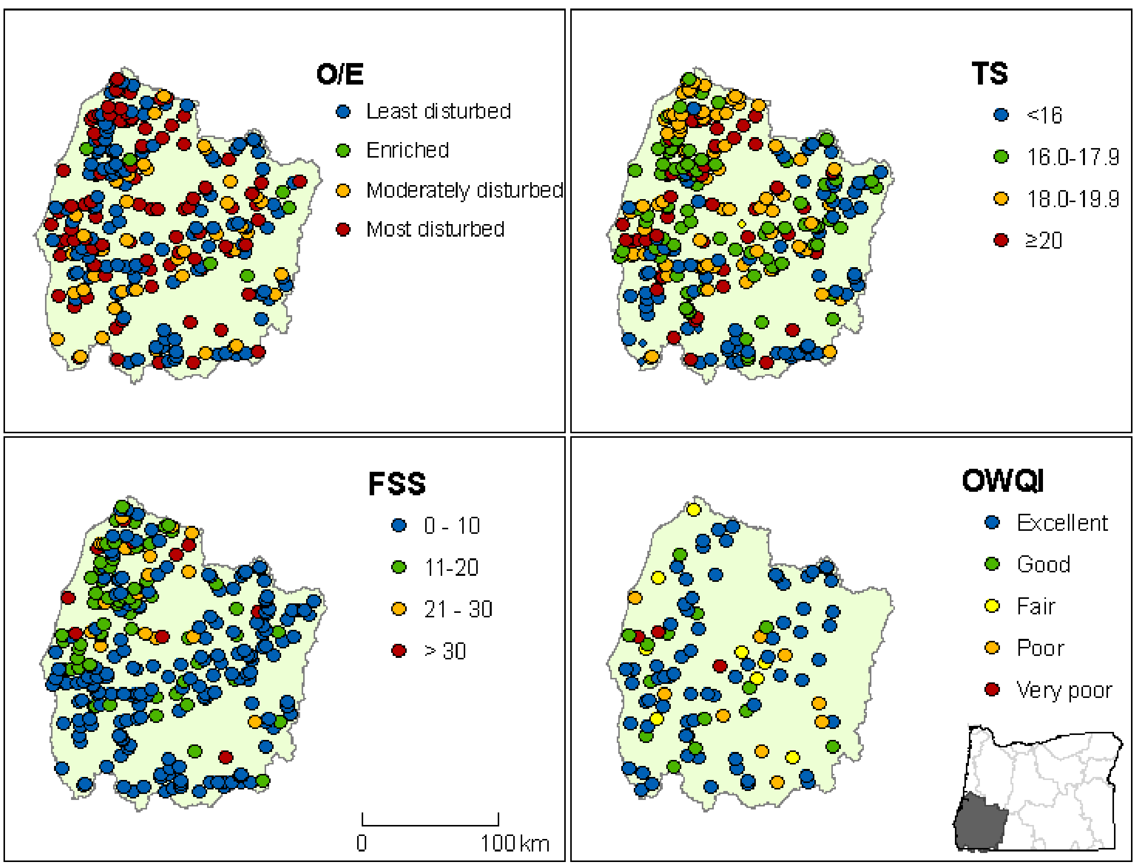


Figure 25. Biological and water quality conditions in the South Coast.

Ownership classes

The sample size of federal sites, in all cases except for the North Coast, was much higher than any of the other ownership classes. State sites were concentrated mainly in the northern third of the North Coast (Tillamook State Forest), and a secondary minor concentration in the northern part of the South Coast (Elliot State Forest) (Figure 1). Private sites were better represented in western than eastern Oregon.

Private industrial sites were nearly identical to federal sites and in higher quality than state sites for overall biological condition. At the same time, assemblages on private industrial sites preferred higher temperatures and fine sediments than both public ownership classes. The majority of private industrial sites were in the North Coast and South Coast HUCs, which tended to have higher TS and FSS compared to other HUCs. Additionally, federal sites dominated the sites located in the Cascades ecoregion (Figure 1), which has colder water temperatures naturally due to higher elevations and snowpack, and lower sedimentation due to more resistant geology. It would be useful to put the TS and FSS indices into context with natural regional expectations, establishing reference benchmarks for Level III ecoregions. By doing so, we may understand if these differences in TS and FSS are simply due to differences in location (different proportions of ownership classes among ecoregions).

For all three scales at which it was assessed, the private non-industrial ownership class had the lowest water quality and biological quality (Figures 3, 4, and 5). Private non-industrial sites showed the lowest biological condition for PREDATOR, as well as the highest TS and FSS values. The sample size for private non-industrial sites was relatively low (n = 80), and the majority of sites were located in the North Coast and South Coast HUCs. Private non-industrial sites shared similar elevations, slopes, and climate to private industrial sites, yet much lower overall biological condition and higher preferences for temperature and fine sediment. Given the similarities in natural factors (especially in the South Coast), we would expect similar biological conditions. Is it possible that different management practices between the two private ownership classes are linked to the differences in biological conditions? Or are there other natural factors that are responsible? Future assessments of forest sites should investigate these results more fully, with a carefully planned out study design to limit potentially confounding factors.

In this report, state sites could only be assessed at the state and North Coast scales. Given the highly regionalized nature and small sample size (compared to other ownerships), results at the state scale should be interpreted with caution. In the North Coast, state sites showed slightly lower biological condition (compared to federal and private industrial), yet overall the macroinvertebrates on state sites showed much lower preferences for temperature and fine sediments. One possible interpretation is that causes of lower overall biological condition (O/E) on state sites in the North Coast are due to factors other than temperature and fine sediments. This would lead to the question: Besides temperature and fine sediments, what are the other potential stressors on forest sites that might be more pronounced on state sites in the North Coast than the other land ownership classes? These stressors could be human induced (e.g., splash damming, mining, pesticide applications, historic large woody debris removal), or they could be natural stressors (e.g., fires, landslides, disease) that were not modeled well by the PREDATOR models.

Interpreting TS and FSS

It is difficult to state definitively what the reasons are for some of the regional differences we saw between water quality and biological conditions on forest sites. The PREDATOR models assess biological condition by making comparisons to the most appropriate reference sites, based on a few environmental predictors. Because of these comparisons to regionally appropriate reference sites, differences in O/E can be assumed to be due to either truly different biological condition or model errors.

The TS and FSS models, however, do not have benchmarks based on reference conditions. For this report, we used the same TS and FSS benchmarks to categorize all sites. Optimally, we would compare TS and FSS at a site to benchmarks established for the ecoregion in which it was located. Ecoregions take into account many natural factors that shape biological assemblages (e.g., climate, geology, vegetation, etc.). They provide a baseline of what we might expect to see for natural environmental factors such as temperature and sediments. Ecoregion benchmarks would allow us to better interpret differences like were observed in the Willamette where private industrial sites showed higher PREDATOR condition and yet assemblages with higher temperature and fine sediment preferences. With ecoregion benchmarks, we would have a better sense of whether the TS and FSS differences were due to location (natural differences), or if they actually represented an altered biological condition (not meeting local expectations).

There appears to be a discrepancy between the temperature sub-index of the OWQI and the Stressor Identification model for temperature (TS). The temperature sub-index of the OWQI routinely showed the vast majority of sites to be in excellent condition for temperature—the lowest percent of sites in excellent condition for any HUC or ownership class was 80% (private non-industrial sites across Oregon), with a mean of 92% of sites. By contrast, the highest percent of sites with TS less than 16.0 ^{o}C was 71% (Middle Columbia), with a mean of 30% of sites. The main reason for these differences is the types of measurements involved. The OWQI temperature sub-index is based on one-time grab samples. A single sample, taken early in the day (as is often done) could miss higher temperatures that occur later in the day. TS, on the other hand, are inferences of season maximum temperatures. Maximum temperatures are much more likely to have an impact on biological condition than an instantaneous measure of temperature.

Comparisons to other land uses

The results presented in this report were based on forested streams throughout Oregon. ODEQ has completed or is near completing other reports that examine the conditions of water and biological quality on forest, agricultural, and urban sites.

A report on the conditions of streams in the Oregon Coastal Coho ESU (ODEQ 2005) showed macroinvertebrate to be in better conditions on forest sites than in agricultural sites. (Sample sizes were too low for urban sites to be assessed.) In that report, PREDATOR scores were best on federal forest sites followed by state forest sites, private industrial forest, private non-industrial forest and agriculture. Most water quality parameters showed the same general trend, where public forest sites (federal and state) had fewer stream miles exceeding reference benchmarks for water chemistry than private industrial. Private non-industrial sites showed the highest percent of stream miles exceeding reference benchmarks of any other forestry ownership class, but these values were still lower than the percent of stream miles exceeding benchmarks on agricultural sites.

An assessment of conditions in the Willamette River basin (ODEQ, *in prep*) also showed the same trends. Forest sites showed a significantly lower percent of stream miles in poor or most disturbed conditions compared to agricultural and urban land uses. This was true for both macroinvertebrate and vertebrate (fish and amphibians) assemblages. Approximately 80% of stream miles in agricultural and urban sites were in most disturbed conditions for macroinvertebrates (PREDATOR), compared to less than 20% of stream miles on forest sites. For vertebrate assemblages, urban sites showed greater than 30% of stream miles and agricultural sites showed greater than 60% of stream miles in poor condition, compared to just over ten percent of stream miles on forest sites. The results of the Willamette report also show similarities to forest ownership patterns observed in this report on forest sites. Biological condition (both vertebrates and macroinvertebrates) was equivalent on public forest sites (dominated by federal ownership) and private industrial sites. Private non-industrial sites, again, showed higher percentages of stream miles in poor or most disturbed conditions.

A summary of water quality conditions based on Oregon's Ambient Monitoring Network showed forest sites to have better water quality than observed on other land uses (Cude 2002). The determination of land use was coarser in the Cude paper, looking at dominant land use (> 50%) in a five mile radius from the sampling locations, plus the sites in this monitoring network tended to be much larger on average than what was reported in this forests only report. Cude found approximately 50% of sites dominated by forest land use in good or excellent condition and approximately 20% in poor or very poor condition for the OWQI. In contrast, agricultural sites showed 20% of sites in good or excellent condition and almost 60% o sites in poor or very poor condition. Range sites showed 20% of sites in good (and 0% in excellent) condition and approximately 70% of sites in poor or very poor condition. For urban sites, 100% of OWQI scores were in poor or very poor condition.

In all of the above studies, water quality and/or biological quality of forested sites were in a higher condition than observed on agricultural, range, or urban sites. One factor contributing to these results is position in the landscape. Forest sites, for the most part, occupy the upper parts of watersheds and basins and drain onto sites occupied by other land uses. So, while conditions are typically of higher quality on forest sites, any reduction of stream conditions has the opportunity to affect conditions on downstream land uses. This report and others suggest that forest landuses have the potential to improve or contribute to the lower water quality and biological index scores observed in the portions of basins dominated by other landuses.

Future Work

We reported on biological and water quality conditions on forest sites across the state and within eight different 6-digit HUCs. Sample sizes were low for several of the HUCs. Also there were large areas within some HUCs that were not covered by the samples included in this report. More data should be incorporated from outside data sources for forest sites in the western portion of the Deschutes (East Cascades), for all regions of the Klamath, and streams outside of the upper Grande Ronde in the Lower Snake HUC.

Future monitoring plans should incorporate probabilistic monitoring designs so as to maximize the amount of information collected, while minimizing costs. The biggest advantages of probabilistic monitoring designs are that they help to reduce bias in the datasets and allow an estimation of error in the results. Incorporating a long-term monitoring strategy in these designs would allow us to examine trends of forest conditions throughout time.

Including a plan to establish new and monitor existing reference sites through time is also a critical exercise. Including reference sites that are representative of the diverse landscapes of Oregon allow for more accurate and fair assessments of stream conditions. Including more reference sites in our water quality and biological assessments also improves our understanding of variability in the context of natural and human disturbances. Stream ecosystems are not static, including reference sites. Long-term monitoring of reference sites is essential to make sure that we are fairly assessing sites through time. This is especially important in the context of global climate change, where we can expect environmental conditions (and in response, biological conditions) at sites in the most natural state to change.

The next step in the analyses of these data should relate biological and water quality conditions to the amount of forest sites within all watersheds. Rather than limiting our datasets to only those sites with high percent forest at the local and watershed scales, we should look at the continuous relationship between the percent of forest sites and water resources conditions. Are there regions where the amount of forest at the local scale is more important to the stream conditions than the watershed scale? Is there a minimum percent of forest sites before stream conditions show significant decline? Or are there differences in the biological and water quality condition that depend upon the type and extent of different land management in a given watershed? We should also examine the ownership patterns for potential errors, or misclassification of ownership types.

In addition to water chemistry and macroinvertebrate assemblages, we have the ability to assess physical habitat (instream and riparian) and aquatic vertebrate assemblages on forest sites (especially in western Oregon). The physical habitat data could aid in interpreting patterns observed in the biological and water quality conditions observed in this report. The addition of another biological assemblage may show conditions are more or less supportive for vertebrates than they are for macroinvertebrates. These two assemblages respond similarly to certain stressors, but differently to others (ODEQ 2005).

The relationships among stream condition and disturbance gradients should also be examined. Specifically, where we see differences in stream condition among reporting units or ownership classes, can these differences be related to either natural disturbances or human disturbances? As mentioned above, incorporating reference condition into the stressor identification models would go a long way towards helping answer this question. If we were able to isolate the factors that control temperatures and fine sediments, we would have a better understanding of the potential remaining stressors affecting stream conditions.

Future assessments of the conditions of Oregon's forest streams should also include indicators that assess the relationships between roads on forest sites and water quality and biological condition. In addition, conditions of streams from forest sites that are also drinking water sources should be examined.

Acknowledgements

This report was funded from a grant provided by the Oregon Department of Forestry. Many people and organizations provided input that helped shape the direction and focus of this report. The following participated in pre-project planning: Kirsten Gallo of the United States Forest Service; Paul Measels of the Oregon Department of Agriculture; Greg Sieglitz of the Oregon Watershed Enhancement Board; Jeremy Groom and David Morman of the Oregon Department of Forestry; Steve Mrazik, Koto Kishida, and Joshua Seeds of the Department of Environmental Quality. Peter Leinenbach of Region 10 United States Environmental Protection Agency provided significant GIS analyses and training that allowed us to determine our target population and land ownership. Chris Parker with Portland State University graciously developed R-code to print the summary pie charts. The following provided thoughtful and critical reviews of this report: David Morman, Jeremy Groom, and Andrew Yost (ODF); Joshua Seeds, Doug Drake, Mike Mulvey, Jessica Vogt, and Koto Kishida (ODEQ).

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Appendix I. Methods for calculating percent forest at the watershed scale.

Memorandum **December 1, 2008**

To: Robin Leferink, Aaron Borisenko

From: Peter Leinenbach, USEPA Region 10

Subject: Sampling of the "Vegetation Classification" dataset from the GNNPAC – Pacific States Forest Vegetation Mapping (www.fsl.orst.edu/lemma/gnnpac/index.php) along with the 2001 National Landcover dataset (www.mrlc.gov/nlcd_multizone_map.php).

Datasets -

Sampling Zone – Buffer - Using the "buffer" tool in ArcGIS, created a 300m buffer surrounding the x/y coordinates for 1495 biological sampling locations in Oregon. The site list was obtained from ODEQ, and contained unique identification information, such as "Station" and "Site_id". These buffers were used to define sampling boundaries for the GIS data.

Sampling Zone – Catchment - Using the "join" function in ArcGIS, selected 761 catchment areas which had similar "Station" unique identification information (An attempt was done to develop a "join" based on "Site_id" but there were no additional matches created by this effort.). The catchment areas were obtained from ODEQ and represent the upstream contributing area associated with each sampling location. These catchments were used to define sampling boundaries for the GIS data.

Forest Vegetation Dataset - The GNN "Species-Size Model" grid dataset was downloaded for the seven ecoregions associated with Oregon. Because data was presented as a "floating point", the data was converted to an "integer" through the following process in ArcInfo Command Line:

Outgrid = int(Ingrid.<value> + 0.5)

During this processing, the "Setwindow" was set on an ArcInfo "coverage of "Oregon" and the snap grid was set to one of the original datasets. This dataset was not "projected" from its original projection.

Numerous attributes were available for this dataset. The "vegetation class" attribute was sampled because it integrates several models (i.e., Forest Vegetation Canopy Cover (CANCOV), Hardwood Basil Area (BAH), and size class (QMDA_DOM)). "Nonforest" areas were 'masked' using an ancillary map of "Ecological Systems" developed for the Gap Analysis Program (GAP). The specific components associated with "vegetation class" are presented in **Table 1** and illustrated in **Figure 1**.

Forest Landcover Dataset - The 2001 National Landcover Dataset was obtained from the USGS ftp site - http://www.mrlc.gov/nlcd_multizone_map.php. The following steps were used to process the data –

- The dataset was clipped to the 30 kilometer buffer of the state of Oregon using the "clip" tool in ArcGIS (The "analysis extent" was set to 30 km buffered grid, and the "snapgrid" and cell size were set to itself.).
- The "clipped" grid was projected to OGIC using the "Project Raster" tool in ArcGIS (The "nearest" sampling method was used, and the cell size and "snapgrid" were set to the projected DEM dataset.)

Attributes associated with the NLCD dataset are presented in **Table 2** and illustrated on **Figure 2**.

Sampling

Sampling of the two GIS datasets was implemented using the "Tabulate Area" tool associated with the "Spatial Analyst" extension in ArcView (**Figure 3**). It is important to note that the ArcGIS version of this tool created spurious results because it did not compute values correctly for "nested" sampling zones. There are many "nested" sampling zones associated with both the "300 buffer" and the "catchment" sampling zones.

Results

Results of the sampling are presented in four "excel" spreadsheets which are included in this "zipped" file (One file for each of the four sampling efforts: (1) "Vegetation Class" – 300m buffer, (2) "Vegetation Class" – Catchment, (3) "Landcover" – 300m buffer, and (4) "Landcover" – Catchment.). Each "excel" spreadsheet has multiple sheets which present the numerous steps used to convert sampled values to percent conditions. Sampling results are illustrated in **Figure 4**.

General Findings/Descriptions

1) *"Forested" conditions in the "Vegetation Class" dataset include "Sparse" and "Open" categories.*
2) *The NLCD "landcover" dataset incorrectly categorized many "forested" areas as non-forest conditions (i.e. grassland or shrubland for recently harvested areas). (These are the same areas which are often categorized as "Sparse" and "Open" in the "Vegetation Class" dataset.)*
3) *Roads are included in both datasets as "non-forest". (It appears that these areas were "burned" into these datasets.).*

Table 1. Description of the Vegetation Classification attribute associated with the GNN "Species-Size Model".

Vegetation class based on CANCOV, BAH_PROP, QMDA_DOM (used in GNNFIRE, Ohmann et al (in press, EcoApp))	
1	Sparse (CANCOV <10)
2	Open (CANCOV 10-39)
3	Broadleaf, sap/pole, mod/closed (CANCOV >=40, BAH_PROP >=0.65, QMDA_DOM <25 cm)
4	Broadleaf, sm/med/lg, mod/closed (CANCOV >=40, BAH_PROP >=0.65, QMDA_DOM >25 cm)
5	Mixed, sap/pole, mod/closed (CANCOV >=40, BAH_PROP 0.20-0.64, QMDA_DOM <25 cm)
6	Mixed, sm/med, mod/closed (CANCOV >=40, BAH_PROP 0.20-0.64, QMDA_DOM 25-50 cm)
7	Mixed, large+giant, mod/closed (CANCOV >=40, BAH_PROP 0.20-0.64, QMDA_DOM >50 cm)
8	Conifer, sap/pole, mod/closed (CANCOV >=40, BAH_PROP <0.20, QMDA_DOM <25 cm)
9	Conifer, sm/med, mod/closed (CANCOV >=40, BAH_PROP <0.20, QMDA_DOM 25-50 cm)
10	Conifer, large, mod/closed (CANCOV >=40, BAH_PROP <0.20, QMDA_DOM 50-75 cm)
11	Conifer, giant, mod/closed (CANCOV >=40, BAH_PROP <0.20, QMDA_DOM >75 cm)

Figure 1. Illustration of the Vegetation Classification attribute associated with the GNN "Species-Size Model"

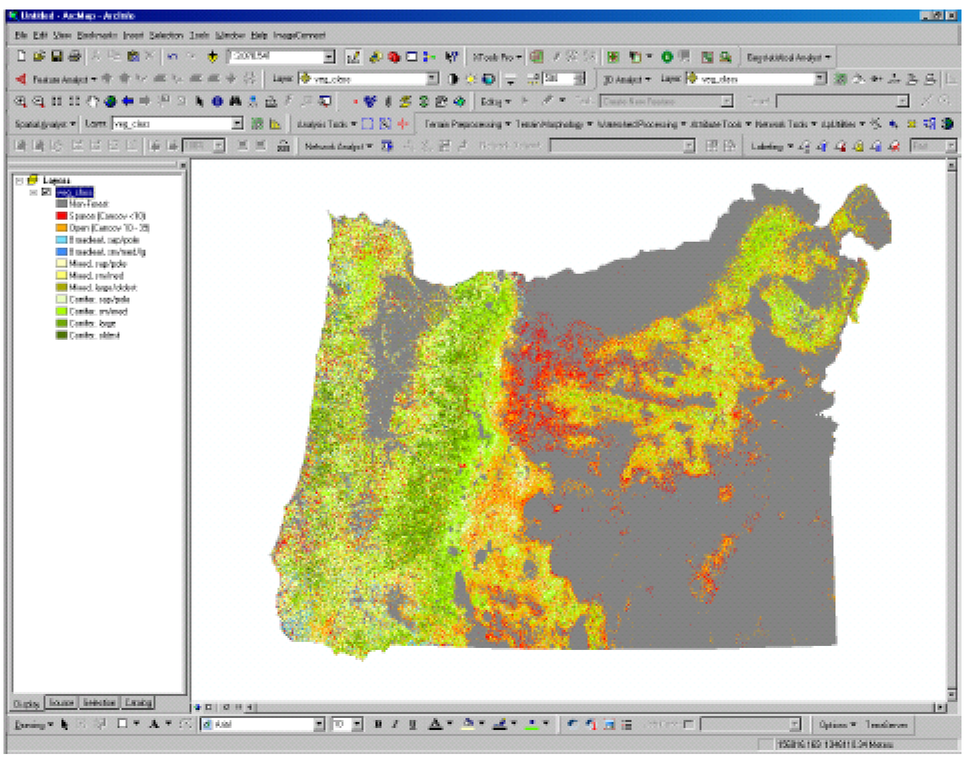


Table 2. Description of "Landcover" associated with the NLCD 2001 Dataset

11. Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.
12. Perennial Ice/Snow - All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.
21. Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes
22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
23. Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
24. Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.
31. Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
41. Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
42. Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
43. Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
52. Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
71. Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
95. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Figure 2. Illustration of "Landcover" associated with the NLCD 2001 Dataset.

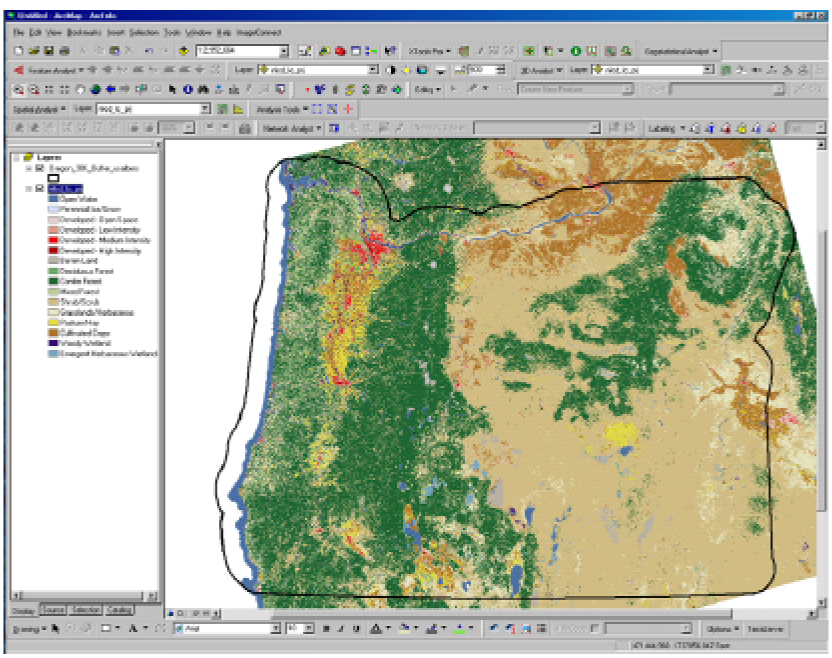


Figure 3. Illustration of the "Tabulate Area" GIS Sampling Tool.

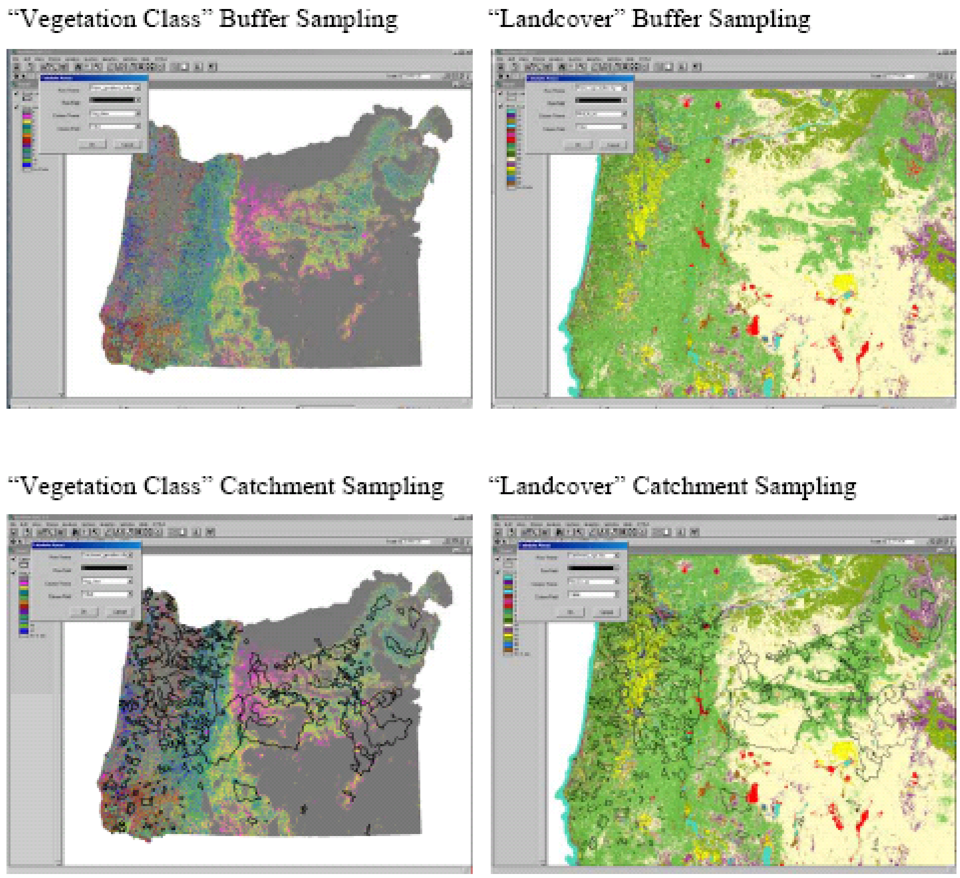


Figure 4. Example Illustration - Results for Station 21809 "Gravel Creek at RM 0.34".

Percent Forest calculated from "Vegetation Class" for 300 Buffer and Catchment

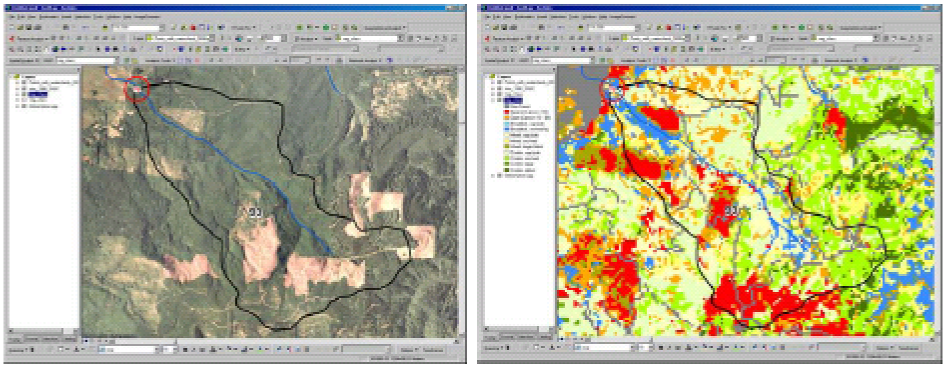


Illustration of "Vegetation Class" Distribution – 300m Buffer

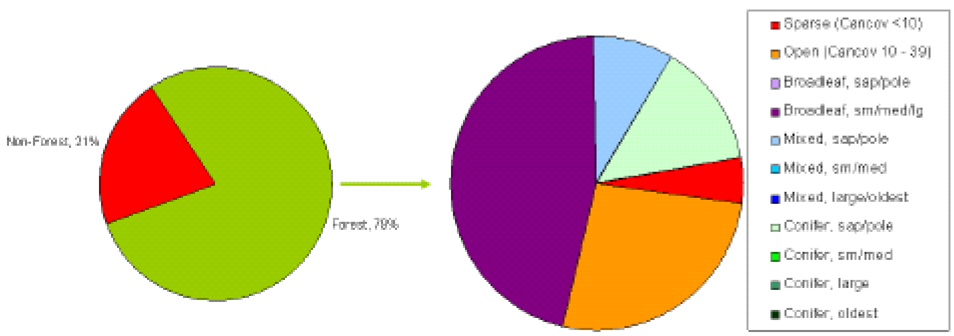


Illustration of "Vegetation Class" Distribution – Catchment

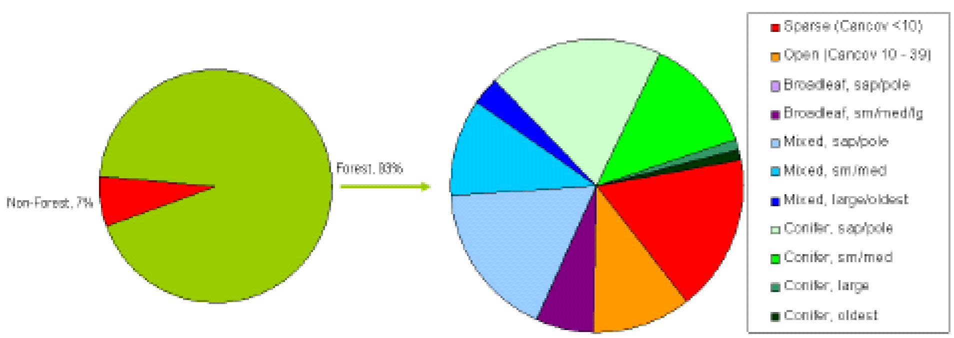


Figure 4 (cont). Example Illustration - Results for Station 21809 "Gravel Creek at RM 0.34".

Percent Forest calculated from "Landcover" for 300 Buffer and Catchment

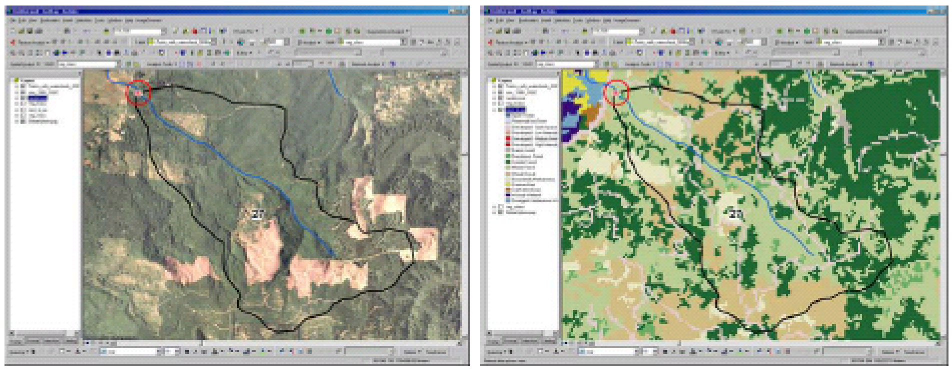


Illustration of "Landcover" Distribution – 300m Buffer

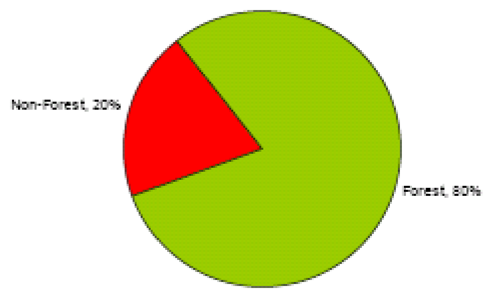
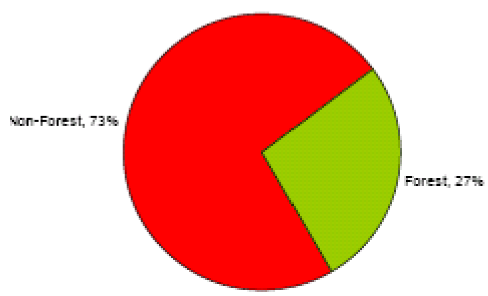


Illustration of "Landcover" Distribution – Catchment



Appendix II. Summary results of biological and water quality indices across HUCs and ownership classes.

Table II.1. Percent of forest lands sites in various condition classes for three biological indices. Summary results were not determined for HUCs or ownership classes with a sample size less than 20.

		PREDATOR O/E					Temperature Stress				Fine Sediment Stress			
	Sample size	Least Disturbed	Enriched	Moderately Disturbed	Most Disturbed	Not assessed	< 16	16.0 - 17.9	18.0 - 19.9	>= 20	0 - 10	11 - 20	21 - 30	> 30
Oregon	1025	53	3	16	24	3	32	30	24	14	69	21	7	3
Federal	623	55	3	17	20	5	42	27	20	12	77	17	4	2
State	69	51	1	12	35	1	28	43	26	3	71	17	6	6
Private Industrial	171	58	4	13	25	1	15	35	36	14	56	29	9	6
Private Non-industrial	80	35	3	18	44	1	10	23	34	34	44	30	23	4
Northern Oregon Coastal	230	59	3	13	26	0	14	38	36	12	63	24	10	3
Federal	68	69	3	12	16	0	12	43	38	7	69	24	7	0
State	46	54	2	11	33	0	37	43	17	2	87	7	2	4
Private Industrial	57	61	2	14	23	0	12	32	40	16	49	32	14	5
Private Non-industrial	24	38	4	17	42	0	0	29	54	17	46	29	25	0
Southern Oregon Coastal	289	42	2	15	33	8	26	28	28	18	67	22	6	4
Federal	167	45	1	18	25	11	37	29	22	12	81	16	1	2
State	12	--	--	--	--	--	--	--	--	--	--	--	--	--
Private Industrial	71	42	4	15	37	1	13	32	34	21	55	27	11	7
Private Non-industrial	24	29	4	8	58	0	13	13	33	42	33	38	21	8
Willamette	216	63	6	16	13	2	46	36	14	4	82	14	2	1
Federal	145	62	6	16	12	3	60	31	8	1	92	8	1	0
State	9	--	--	--	--	--	--	--	--	--	--	--	--	--
Private Industrial	29	83	7	7	3	0	24	41	34	0	69	28	0	3
Private Non-industrial	15	--	--	--	--	--	--	--	--	--	--	--	--	--
Lower Columbia	42	62	2	14	17	5	64	19	14	2	81	12	5	2
Middle Columbia	31	68	3	16	10	3	71	16	6	6	90	6	3	0
Lower Snake	31	42	3	29	26	0	42	23	6	29	68	26	6	0
Deschutes	52	48	2	23	27	0	17	27	19	37	44	35	17	4
John Day	90	56	6	17	22	0	37	19	28	17	62	28	6	4

Table II.2. Percent of forest lands sites in various condition classes for three biological indices. Summary results were not determined for HUCs or ownership classes with a sample size less than 20.

		BOD					DO					N					pH					P					Solids					Temperature					OWQI				
	n	E	G	F	P	VP	E	G	F	P	VP	E	G	F	P	VP	E	G	F	P	VP	E	G	F	P	VP	E	G	F	P	VP	E	G	F	P	VP	E	G	F	P	VP
OR	424	64	15	10	8	3	87	7	4	2	0 (<1)	87	7	2	4	0 (<1)	95	3	1	0 (<1)	0 (<1)	76	13	5	5	0 (<1)	58	12	9	16	4	90	6	2	2	0 (<1)	77	14	4	4	1
Fed	237	71	13	8	5	2	87	7	4	2	0	95	3	1	2	0	94	2	3	1	0 (<1)	81	13	3	4	0	68	14	8	10	1	91	6	2	1	0	86	11	2	1	0
State	28	39	21	29	4	7	93	4	4	0	0	61	18	4	18	0	100	0	0	0	0	86	4	7	4	0	61	11	4	21	4	100	0	0	0	0	75	14	4	7	0
PI	80	64	21	4	9	3	90	6	3	1	0	80	11	5	3	1	98	3	0	0	0	68	18	8	6	1	43	10	13	28	8	93	5	0	3	0	66	21	5	4	4
PNI	49	49	12	18	20	0	76	12	6	4	2	80	14	2	4	0	92	8	0	0	0	63	16	6	12	2	39	16	8	20	16	80	6	6	6	2	59	18	8	12	2
NC	75	53	19	11	12	5	92	5	3	0	0	63	16	5	16	0	100	0	0	0	0	79	12	5	4	0	56	16	11	17	0	84	13	1	1	0	73	19	4	3	1
SC	105	66	16	9	5	5	82	9	8	1	1	94	5	0	0	1	94	5	1	0	0	80	9	6	5	1	31	16	10	29	14	89	6	2	3	1	66	15	8	9	3
Will	145	72	12	7	7	1	94	3	1	2	0	91	6	2	1	0	97	2	1	1	0	81	10	5	4	0	74	8	7	9	1	95	2	1	1	0	88	7	3	2	0
LC	32	53	16	22	9	0	94	3	0	3	0	75	16	6	3	0	97	0	0	0	3	75	13	6	3	3	72	0	6	16	6	97	3	0	0	0	78	13	3	6	0
MC	20	70	10	20	0	0	95	0	0	5	0	100	0	0	0	0	95	0	5	0	0	85	10	0	5	0	40	30	5	25	0	100	0	0	0	0	80	20	0	0	0

OR = Oregon
Fed = Federal
PI = Private Industrial
PNI = Private Non-Industrial
NC = North Coast
SC = South Coast
Will = Willamette
LC = Lower Columbia
MC = Middle Columbia

Appendix III. Boxplots of environmental variables for HUCs and ownership classes.

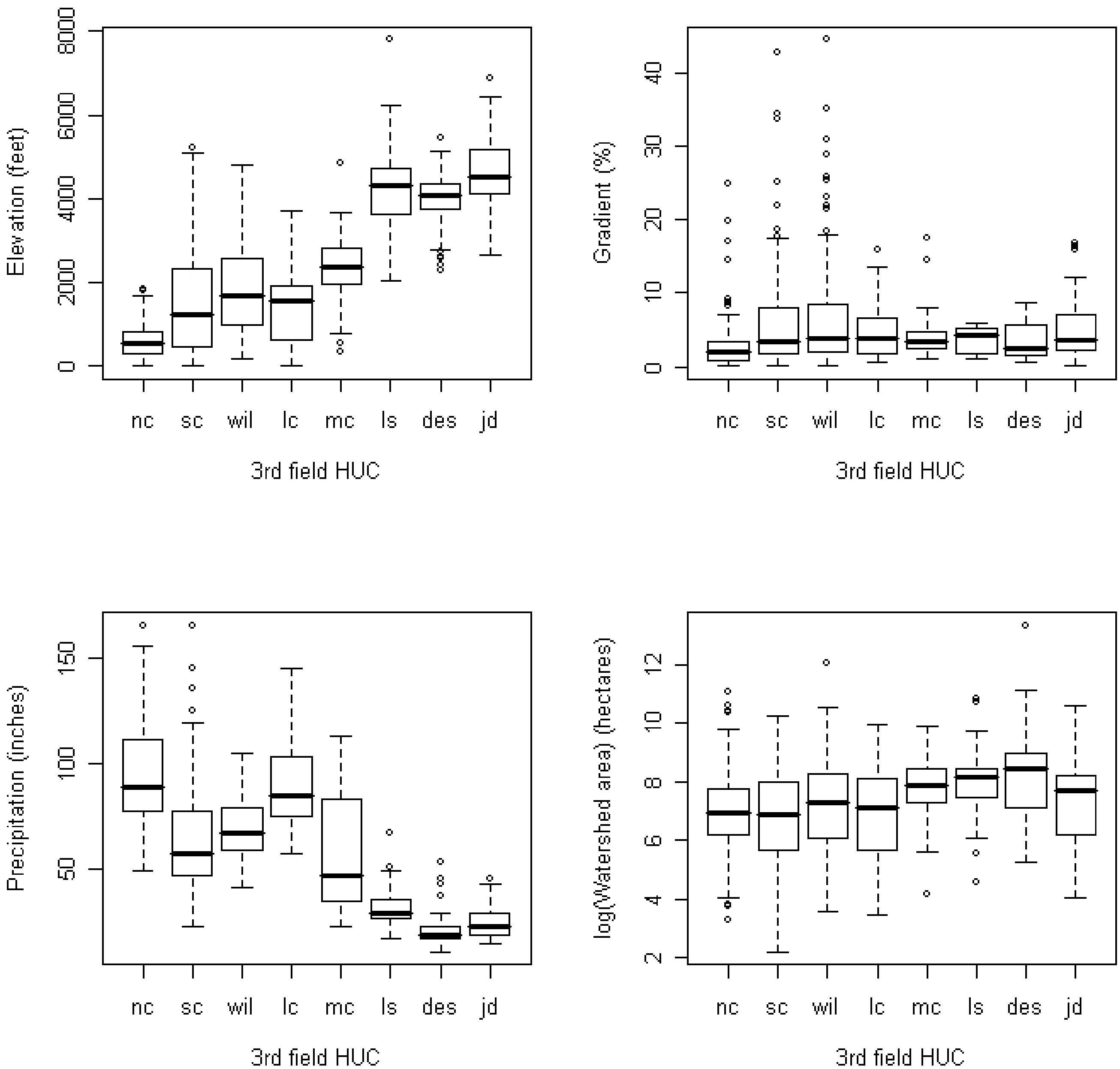


Figure III.1. Summary boxplots of environmental variables for all forest sites in each HUC. Dark horizontal bars = medians, boxes = 25th (bottom) and 75th (top) percentiles, vertical dashed bars = minimums (bottom) and maximums (top), open circles = outliers. nc = North Coast, sc = South Coast, wil = Willamette, lc = Lower Columbia, mc = Middle Columbia, ls = Lower Snake, des = Deschutes, jd = John Day.

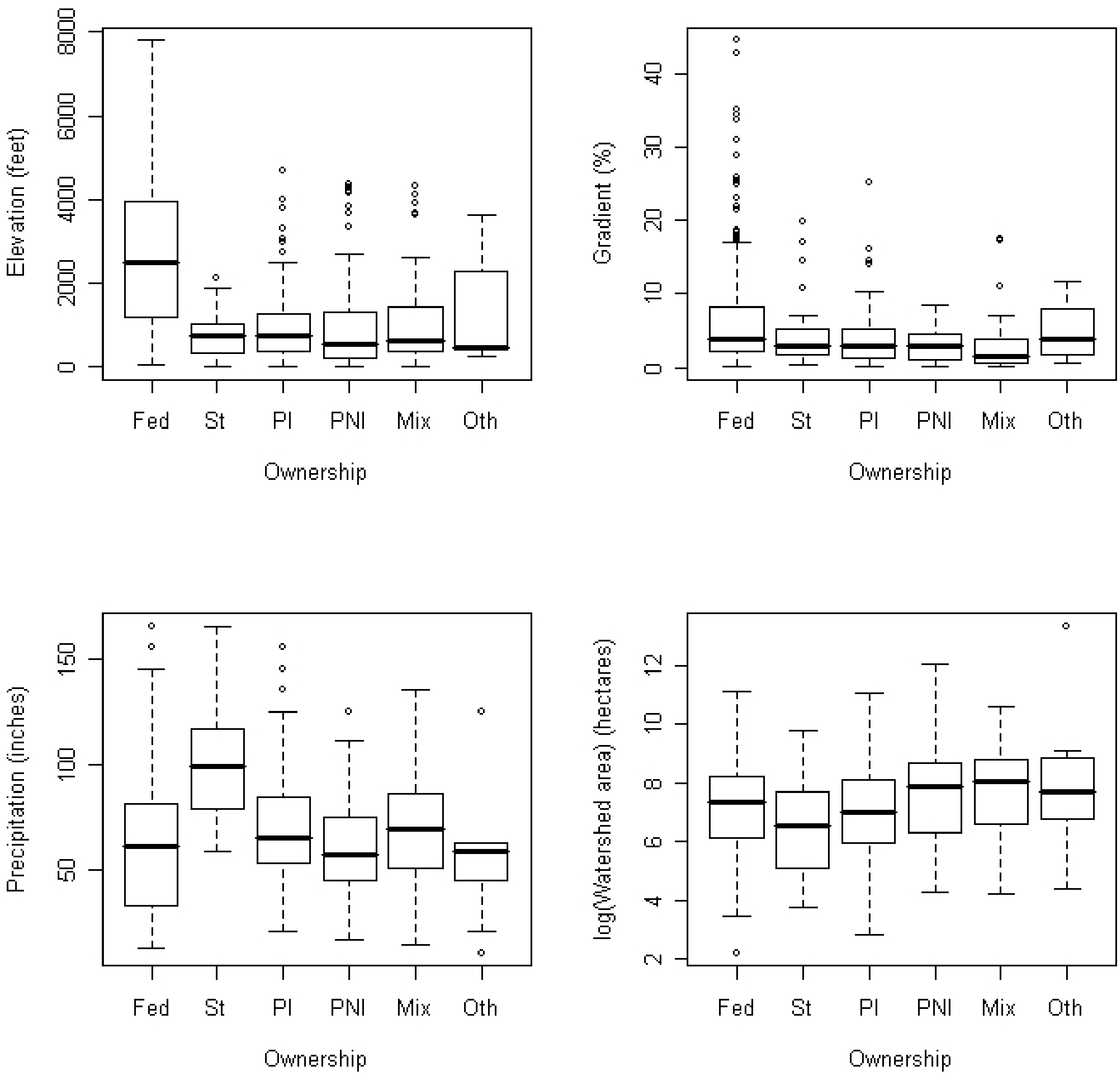


Figure III.2. Summary boxplots of environmental variables for all forest sites in each of six ownership classes. Dark horizontal bars = medians, boxes = 25th (bottom) and 75th (top) percentiles, vertical dashed bars = minimums (bottom) and maximums (top), open circles = outliers. Fed = Federal, St = State, PI = Private Industrial, PNI = Private Non-Industrial, Mix = Mixed, Oth = Other.

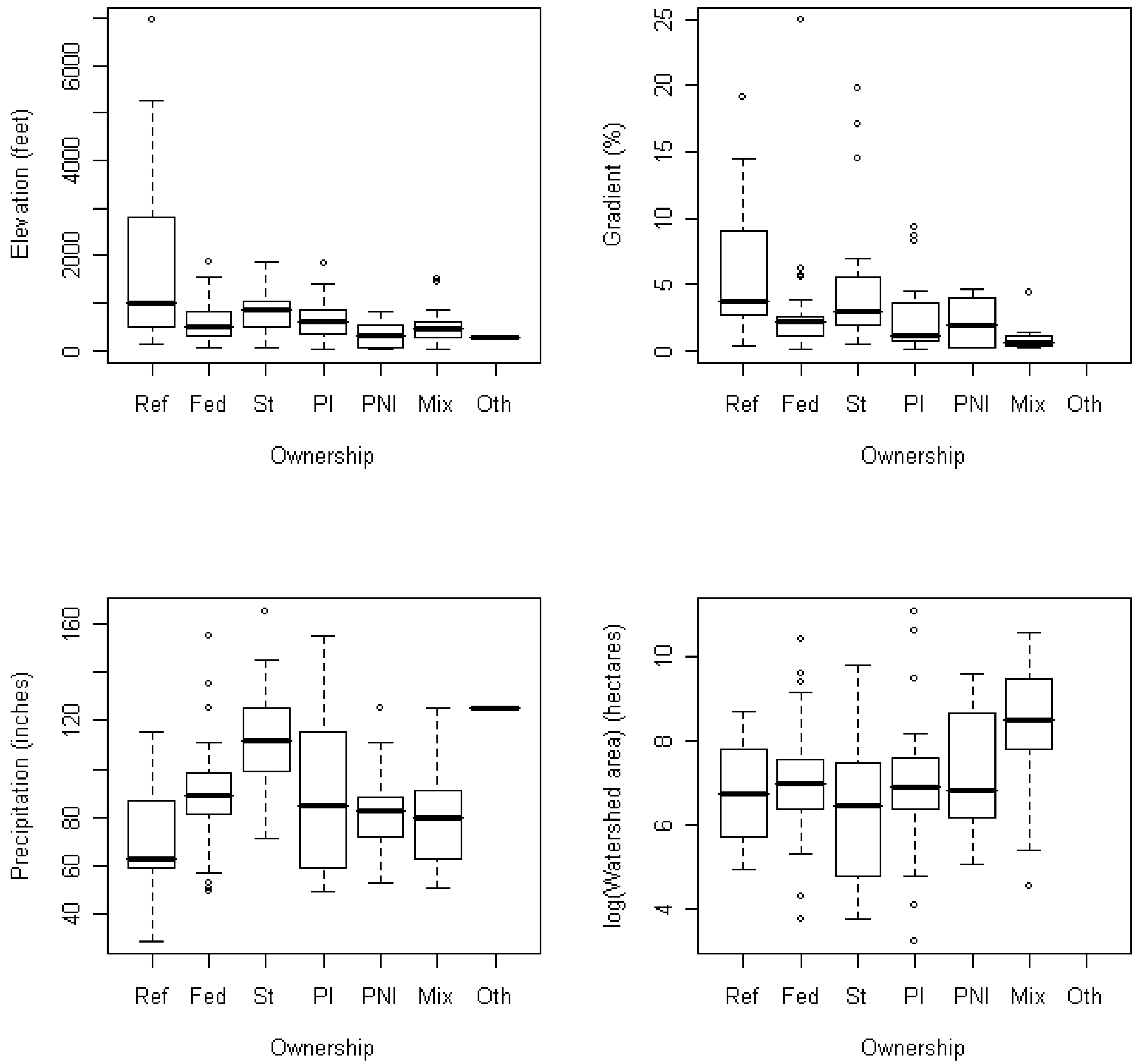


Figure III.3. Summary boxplots of environmental variables for all forest sites in each of six ownership classes in the North Coast. Dark horizontal bars = medians, boxes = 25th (bottom) and 75th (top) percentiles, vertical dashed bars = minimums (bottom) and maximums (top), open circles = outliers. Ref = reference sites, Fed = Federal, St = State, PI = Private Industrial, PNI = Private Non-Industrial, Mix = Mixed, Oth = Other.

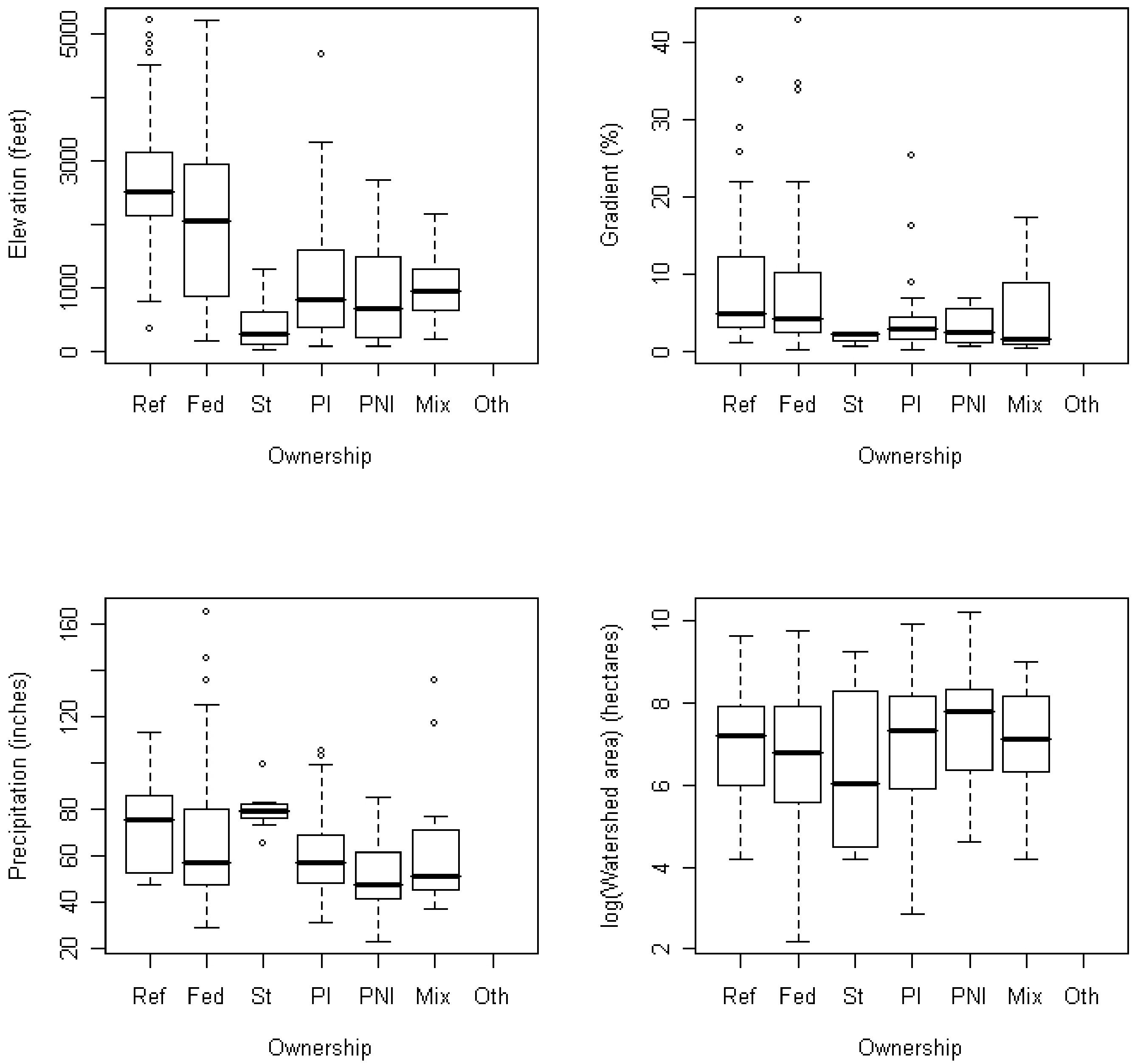


Figure III.4. Summary boxplots of environmental variables for all forest sites in each of six ownership classes in the South Coast. Dark horizontal bars = medians, boxes = 25th (bottom) and 75th (top) percentiles, vertical dashed bars = minimums (bottom) and maximums (top), open circles = outliers. Ref = reference sites, Fed = Federal, St = State, PI = Private Industrial, PNI = Private Non-Industrial, Mix = Mixed, Oth = Other.

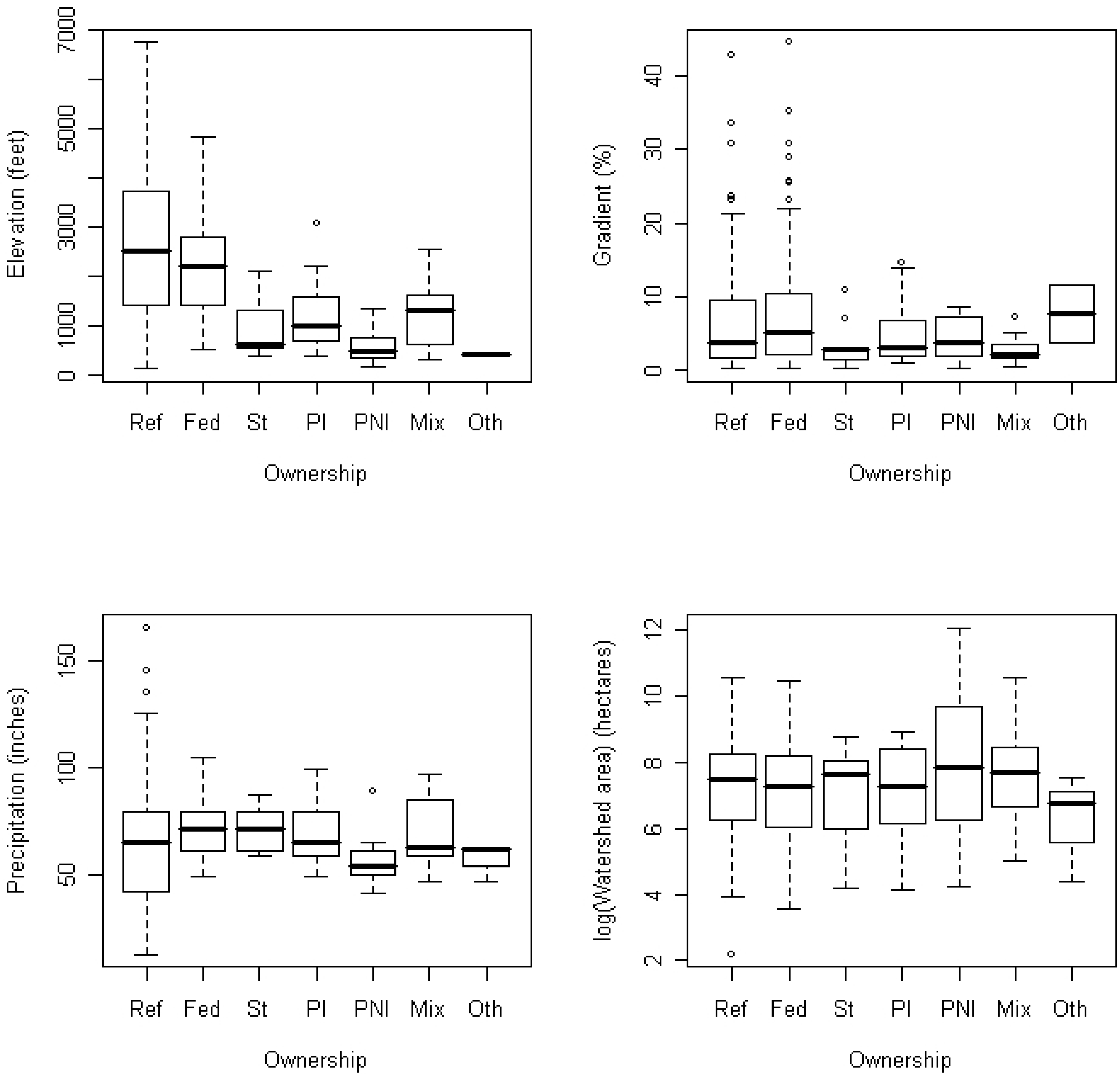


Figure III.5. Summary boxplots of environmental variables for all forest sites in each of six ownership classes in the Willamette. Dark horizontal bars = medians, boxes = 25th (bottom) and 75th (top) percentiles, vertical dashed bars = minimums (bottom) and maximums (top), open circles = outliers. Ref = reference sites, Fed = Federal, St = State, PI = Private Industrial, PNI = Private Non-Industrial, Mix = Mixed, Oth = Other.