

WILLAMETTE BASIN RIVERS & STREAMS ASSESSMENT

**OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY:
*Laboratory and Environmental Assessment Division,
Watershed Assessment Section.***

3150 NW 229th Street, Suite 150,
Hillsboro, Oregon 97124

June 30, 2009

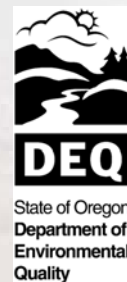
An Oregon Plan for Salmon & Watersheds report funded through
Oregon Watershed Enhancement Board grant # 206-932

Prepared by:

Michael Mulvey

Robin Leferink

Aaron Borisenko



This is a blank page.

Table of Contents

Acknowledgements	7
How to use this report	8
Introduction.....	8
Executive Summary	10
Project Scope and Design	13
Randomly Selected Sites	13
Site Weighting Factors	13
Reference Condition	14
Data Sources	15
Spatial Scales.....	18
Land use	18
Subbasins	19
Indicator Descriptions	19
Indicators of Biological Condition	19
Aquatic Macroinvertebrates	20
Aquatic Vertebrates	20
Indicators of Water Quality Stress	21
Temperature	22
Nitrogen and Phosphorus Nutrients	22
Dissolved Oxygen	23
We measured dissolved oxygen in the field using a Winkler titration on a single sample typically collected during the mid-morning.	23
Biochemical Oxygen Demand	23
pH	23
Water Column Fine Sediment: Total Solids and Turbidity	24
Indicators of Physical Habitat Stress	24
Streambed Condition	Error! Bookmark not defined.
Riparian Condition	26

Fish Habitat Condition.....	26
Introduction to Condition Assessment Sections	28
Spatial Scales.....	28
Confidence Intervals, Statistical Significance and Sample Size.....	28
Condition of Willamette Basin Rivers and Streams.....	29
Biological Health	29
Water Quality.....	29
Habitat Condition	29
Conditions of Willamette Basin Rivers and Streams by Land Use	32
Biological Health	32
Water Quality.....	32
Habitat Condition	32
Condition of Willamette Basin Rivers and Streams by Subbasin.....	41
The Cascades Subbasins.....	42
Clackamas Subbasin	42
North Santiam Subbasin	42
McKenzie Subbasin	43
Middle Fork Willamette Subbasin.....	43
The Coast Range Subbasins.....	44
Tualatin Subbasin	44
Yamhill Subbasin	44
Upper Willamette Subbasin	45
Coast Fork Willamette Subbasin	45
Valley Floor Subbasins	46
Lower Willamette Subbasin	46
Mid Willamette Subbasin.....	46
Molalla/Pudding Subbasin	47
South Santiam Subbasin.....	48
References	63

Appendix A: Benchmarks	64
Appendix B: Sample Size	67
Appendix C: Relative Risk: evaluating stressor importance	68

List of Figures

Figure 1. Extent of impairment and biological risk.	10
Figure 2. Map of Willamette Basin with land use and subbasins.	11
Figure 3. Biological condition of Willamette Basin rivers and streams by major land use class.	12
Figure 4. Locations of randomly selected streams and river sites in the Willamette Basin.	13
Figure 5. Locations of ecoregional reference sites.	14
Figure 6. Data collection 1994-2007.	15
Figure 7. Number of sites by project.....	16
Figure 8. Number of data sets by project.	16
Figure 9. Number of random samples by data type.	16
Figure 10. Map of Willamette Basin land uses and subbasins.....	18
Figure 11. Stream length proportions of land use classes.....	19
Figure 12. Macroinvertebrate sampling.	20
Figure 13. Backpack electrofishing.....	21
Figure 14. Raft electrofishing.	21
Figure 15. Length measurement of a cutthroat trout.....	21
Figure 16. Water quality sample processing.....	22
Figure 17. Habitat survey.	25
Figure 18. Survey reach transects.....	25
Figure 19. Extent of impairment in Willamette Basin rivers and streams.	29
Figure 20. Biological and habitat conditions of Willamette Basin rivers and streams.	30
Figure 21. Water quality conditions of Willamette Basin rivers and streams.	31
Figure 22. Extent of stressor impairment of land use classes.....	33
Figure 23. Biological condition of land use classes.	34
Figure 24. Water quality conditions of land use classes: dissolved oxygen, biochemical oxygen demand, pH.....	35
Figure 25. Water quality conditions of land use classes: Oregon Water Quality Index, total solids, total suspended solids.	36
Figure 26. Water quality conditions of land use classes: temperature, total phosphorus, total nitrogen.....	37
Figure 27. Habitat conditions of land use classes: canopy cover, riparian vegetation, riparian human disturbance.	38
Figure 28. Habitat conditions of land use classes: streambed stability, percent sand and fine sediment, percent fine sediment.....	39
Figure 29. Habitat conditions of land use classes: fish cover and large woody debris.....	40

Figure 30. Biological disturbance of subbasins.	41
Figure 31. Biological conditions of subbasins: ATI and PREDATOR.	49
Figure 32. Biological conditions of subbasins: ATI and PREDATOR, continued.	50
Figure 33. Water quality conditions of subbasins: dissolved oxygen, biochemical oxygen demand, pH.	51
Figure 34. Water quality conditions of subbasins: dissolved oxygen, biochemical oxygen demand, pH, continued.	52
Figure 35. Water quality conditions of subbasins: Oregon Water Quality Index, total solids, total suspended solids.	53
Figure 36. Water quality conditions of subbasins: Oregon Water Quality Index, total solids, total suspended solids, continued.	54
Figure 37. Water quality conditions of subbasins: temperature, total phosphorus, total nitrogen. .	55
Figure 38. Water quality conditions of subbasins: temperature, total phosphorus, total nitrogen, continued.	56
Figure 39. Water quality conditions of subbasins: streambed stability, percent sand and fine sediment, percent fine sediment.	57
Figure 40. Water quality conditions of subbasins: streambed stability, percent sand and fine sediment, percent fine sediment, continued.	58
Figure 41. Habitat conditions of subbasins: canopy cover, riparian vegetation, riparian human disturbance.	59
Figure 42. Habitat conditions of subbasins: canopy cover, riparian vegetation, riparian human disturbance, continued.	60
Figure 43. Habitat conditions of subbasins: fish cover, large woody debris.	61
Figure 44. habitat conditions of subbasins: fish cover, large woody debris, continued.	62

List of Tables

Table 1. Data sources by project.	17
Table 2. Land use classes.	18
Table 3. Subbasins.	18
Table 4. Water quality indicators.	22
Table 5. Habitat indicators.	24
Table 6. Cascade Range subbasins percent stream land use.	43
Table 7. Coast Range subbasins percent stream land use.	45
Table 8. Valley floor subbasins percent stream land use.	47

Acknowledgements

This assessment was made possible by an unusually high level of collaboration in sharing stream and river monitoring data. We gathered data from state and federal agencies, city governments, university researchers and a watershed council to answer basic questions about the condition of Willamette Basin rivers and streams.

The authors of this assessment thank the data contributors.

Robert Hughes, Oregon State University
Allen Herlihy, Oregon State University
Charles Hawkins, Utah State University
Ken Roley, City of Salem
Chris Prescott, City of Portland
Cindy Thieman, Long Tom Watershed Council

We received a tremendous amount of assistance over many years in sampling design, monitoring protocols and data analysis from people at the Environmental Protection Agency's National Health and Environmental Effects Research Laboratory in Corvallis, Oregon, and from faculty at Oregon State University.

Donald L. Stevens Jr., Department of Statistics, Oregon State University
Anthony Olson, EPA
Phil Larson, EPA
John Van Sickle, EPA
Robert Hughes, Department of Fisheries and Wildlife, Oregon State University
Thomas Whittier, Department of Fisheries and Wildlife, Oregon State University
David Peck, EPA
Phil Kaufmann, EPA
William Gaeuman, Department of Statistics, Oregon State University
Curt Seeliger
Marlys Capert

We also thank the Oregon Department of Environmental Quality reviewers of earlier drafts of this report: Rick Hafele, Doug Drake, Avis Newell, and Jared Rubin. We also thank Shannon Hubler, DEQ, with help with the macroinvertebrate analysis.

Finally, we gratefully acknowledge the contribution of many unnamed field survey crew members whose careful, diligent work helps us better understand the health of the rivers and streams of the Willamette Basin.

How to use this report

This report was written as a resource for water quality managers, watershed councils, municipalities and citizens to help understand the status of watershed conditions in the Willamette Basin. Our interpretations are based on chemical, physical and biological indicators at three different spatial scales: the basin scale, the subbasin scale and by land use categories. The data in this report were collected at randomly selected locations. Like a political poll, these locations represent the population of rivers and streams as a whole. It is not appropriate to interpret the information on an individual site basis. However, individual site data may be used for other purposes, such as indicating when water quality standards or other benchmarks are not met.

The bar charts in this report typically divide the information into “good”, “fair” and “poor” categories. These categories were chosen to maintain consistency with similar reports. Where we have water quality standards, the categories were based on the standard.. If a site did not meet the standard it was placed in the “poor” category. For other parameters, we evaluated the data based on the conditions found at hand-picked reference or least impaired sites with similar conditions. On each bar you will see a 95% confidence interval. The confidence intervals are based on the number of samples we had at each spatial scale. We included all available data that were collected using the random site selection process but for some parameter-spatial scale combinations the sample sizes were quite small. In these cases there is a risk that we have not adequately characterized the conditions. We flagged results based on fewer than 15 samples because caution is required when interpreting these findings.

The indicator groups – chemical water quality, physical habitat and biological may be interpreted together to help understand the relationships among the parameters. This will provide insights into watershed health that might otherwise be missed.

Introduction

Oregon’s Willamette basin is the hub of the state’s population and economy with 70% of the state’s population, 75% of the state’s employment, and 12% of the state’s land area. The basin contains some of the state’s most challenging water quality issues. In recent years more than a dozen stream and river surveys have monitored approximately 650 randomly selected sites on streams and rivers in the Willamette basin using US EPA’s Generalized Random Sampling Design (GRTS) and Environmental Monitoring and Assessment Program (EMAP) protocols. Monitoring was conducted by municipal, state and federal governments; university researchers, and local watershed councils. The Oregon Department of Environmental Quality has aggregated these various compatible data sets to evaluate stream and river status for the entire basin, for land use types and for 12 subbasins using a range of biological, water quality and physical habitat condition indicators. Randomly selected sites are compared with least human impaired reference sites to evaluate the role of natural conditions and human activity to the current stream and river status.

The Oregon Department of Environment Quality (DEQ) is required by law to develop a list of state waters that do not meet applicable water quality standards (Clean Water Act Section 303(d) (1) (A)). The standards are adopted to protect aquatic life, recreational uses, public water supplies and other identified beneficial uses. The 2004-2006 303d list submitted to the Environmental Protection Agency (EPA) identified water quality impairments for water temperature, bacteria and mercury in the Willamette Basin (<http://www.deq.state.or.us/WQ/TMDLs/TMDLs.htm>). For each pollutant, DEQ identified the relative contributions of point sources and non-point sources to the impaired receiving waters and allocated the pollution reductions that were necessary to come into compliance with water quality standards (Total Maximum Daily Load or TMDL).

On September 12, 2006 DEQ issued the Willamette Basin TMDL as an order. The order covered 12 subbasins (4th field Hydrologic Unit Codes) in the Willamette. The Tualatin, Yamhill and Molalla-Pudding subbasins are also covered under separate TMDL's which include additional pollutants such as pesticides, metals and low dissolved oxygen.

The TMDL's are implemented through water quality permits and by designated management agencies (DMA's) that include local government agencies and state and federal agencies. DMA's are required to submit a Water Quality Management Plan (WQMP) outlining actions that will be taken to reduce pollutants in order to comply with the TMDL limits set forth ((OAR) 340-042-0080(3)). Over 40 WQMP's have been reviewed and approved by DEQ basin coordinators in the Willamette Basin. More than 20 additional plans have been submitted and are either pending approval or need minor changes to meet the implementation requirements. A few other DMA's have not submitted plans and DEQ basin coordinators are working with them to move forward.

While plans are being written, finalized, reviewed and implemented, actions are being taken on the ground to improve water quality and watershed health conditions in the Willamette Basin. DEQ's Non-point Source Pollution Program (319) administers over one million dollars annually in grants aimed at reducing sources of non-point source pollution runoff to streams and rivers that have water quality impairments (TMDL's), drinking water sources and groundwater management needs. DEQ also administers the Clean Water State Revolving Fund (CWSRF) loan program which loans money to cities, counties, sanitary districts, Soil and Water Conservation Districts (SWCD's), and irrigation districts for water pollution control activities. In 2009, approximately \$45 million will be loaned out for water quality improvements.

In addition, the Oregon Watershed Enhancement Board (OWEB) provides funding for watershed councils, municipalities, landowners, SWCD's and private parties to help improve habitat for threatened salmon runs in the Willamette Basin and in other parts of Oregon. Many of the actions being implemented are directed at salmon recovery but should help to reduce stream temperatures, sediment runoff, nutrients, bacteria and mercury.

The ongoing commitment of Oregonians to maintaining and improving water quality and salmon habitat are essential for protecting the rivers and streams in the Willamette Basin. It is also important that we strive to understand the effectiveness of the management practices,

technologies and actions that are being used to protect and enhance our water quality so we can adapt to changing conditions and identify emerging issues. Monitoring of specific best management practices and best available technologies will help us understand what is working and what isn't at the project scale. But perhaps even more important and challenging is trying to understand the cumulative effects of the various activities that are being taken at the basin, subbasin and land use scales.

This report provides a status assessment of the water quality, biological and physical habitat conditions at the basin, subbasin and land use scales. These spatial scales are ecologically relevant and useful for understanding cumulative management effects. While this report does not address all the water quality parameters listed in the Willamette Basin TMDL, it does include many parameters that are useful surrogates for understanding potential loading pathways for bacteria and mercury. It also includes a variety of parameters that are not listed in the Willamette TMDL that may warrant careful consideration for future management activities

Executive Summary

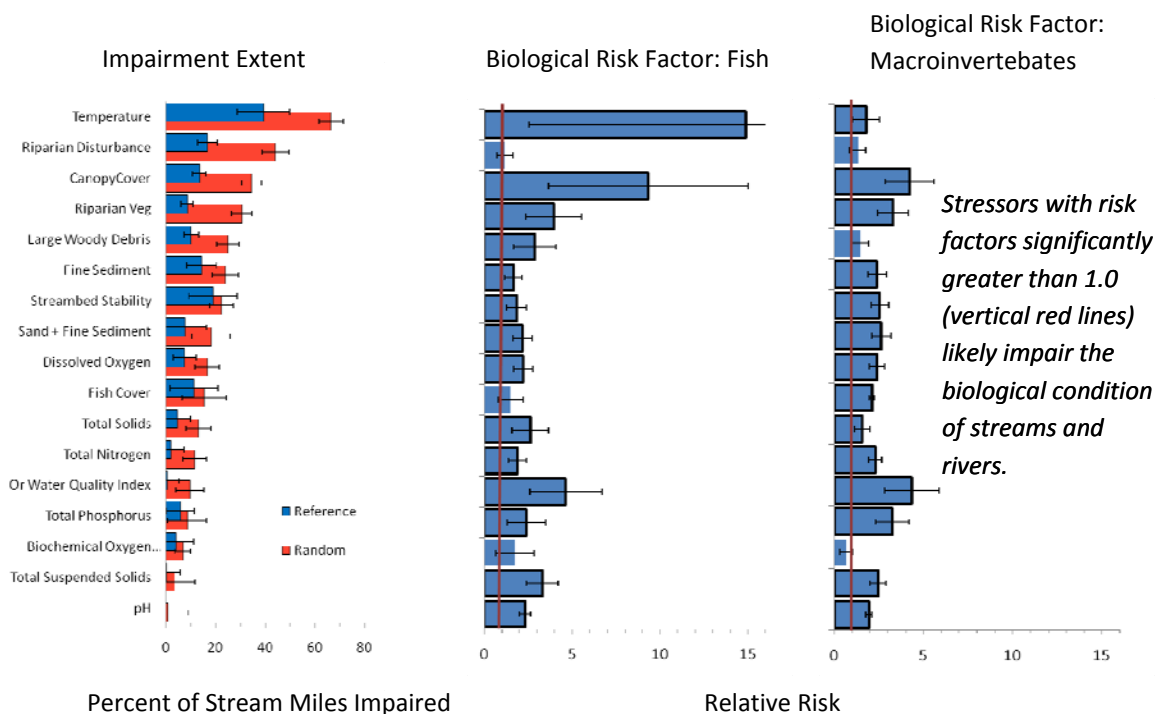


Figure 1. Extent of impairment and biological risk.

- Warm water is the single most extensive impairment in the Willamette basin. Nearly 70% of the stream and river extent in the basin violates the temperature criteria for protecting sensitive cold water fish like salmon and trout. Streams with temperature violations were nearly twice as likely to have impaired macroinvertebrate biological condition and 14 times

more likely to have impaired fish and amphibian biological condition.

Riparian human disturbance, sparse canopy cover and degraded riparian vegetation are also extensive impairing between 30 and 44% of the stream extent.

- The extensive riparian vegetation impairment is most likely responsible for the extensive warm water impairment as well as the cause of impairment from low levels of large woody debris (25%), poor streambed stability (19%) and high fine sediment (24%).
- Impairment for random sites was significantly worse than for the natural reference condition for the five most extensive stressors: water temperature, riparian human disturbance, canopy cover, riparian vegetation condition and large woody debris
- Although impairment from very poor Oregon Water Quality Index scores and poor levels of total phosphorus were relatively rare impairing less than 10% of the stream miles, these stressors were a significant risk to the biological condition of streams. Streams with very poor OWQI scores were more than four times more likely to have impaired biological condition than streams with excellent water quality.

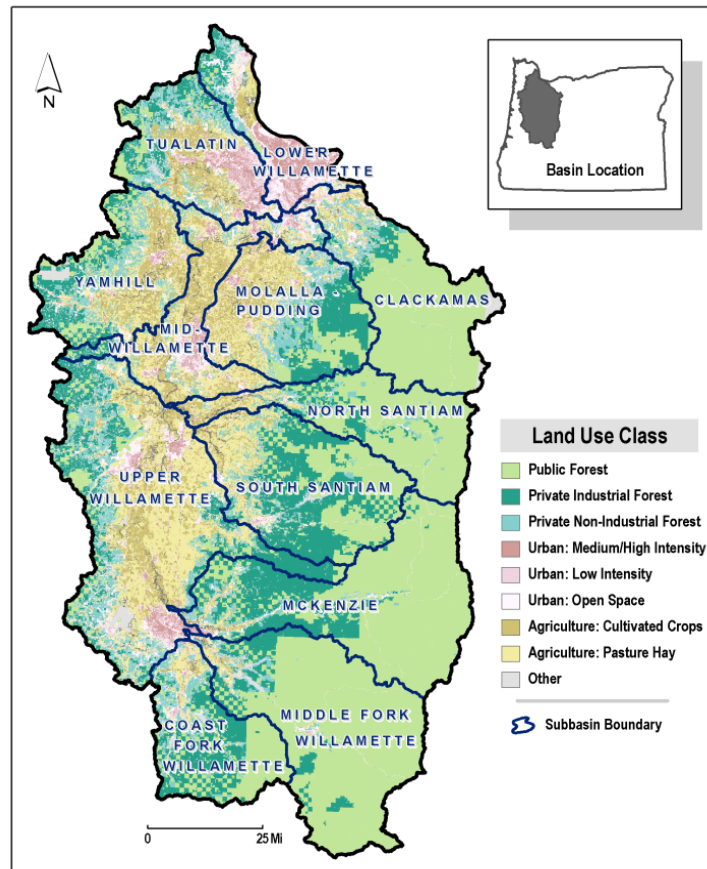


Figure 2. Map of Willamette Basin with land use and subbasins.

Sources: Oregon Department of Land Conservation and Development, Oregon Zoning. Oregon Department of Forestry, 2009, Resource Planning Program, Draft Land Ownership/Allocation. Oregon GIS Service Center, public Ownership. US Geologic Survey, 2007, NLDC 2001 Land Cover.

- The least impaired subbasins had a greater proportion of streams in forest land uses.
- More than 80% of the stream extent in agricultural and urban land uses is in most disturbed biological condition.
- Forestry has comparatively low extent of disturbance with about 13% of the stream extent biologically impaired.
- The extent of disturbance in forest streams is significantly less than in urban and agricultural streams.

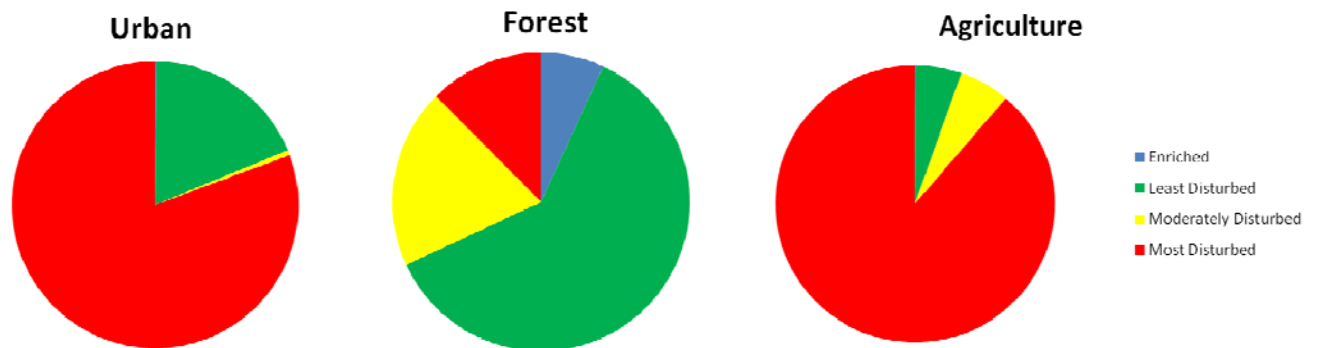


Figure 3. Biological condition of Willamette Basin rivers and streams by major land use class.

Project Scope and Design

Randomly Selected Sites

The Clean Water Act requires states to report on the condition of *all* waters in their state. There are two ways to describe a large, extensive population like streams and rivers in a basin: take a complete census or conduct a probability survey.

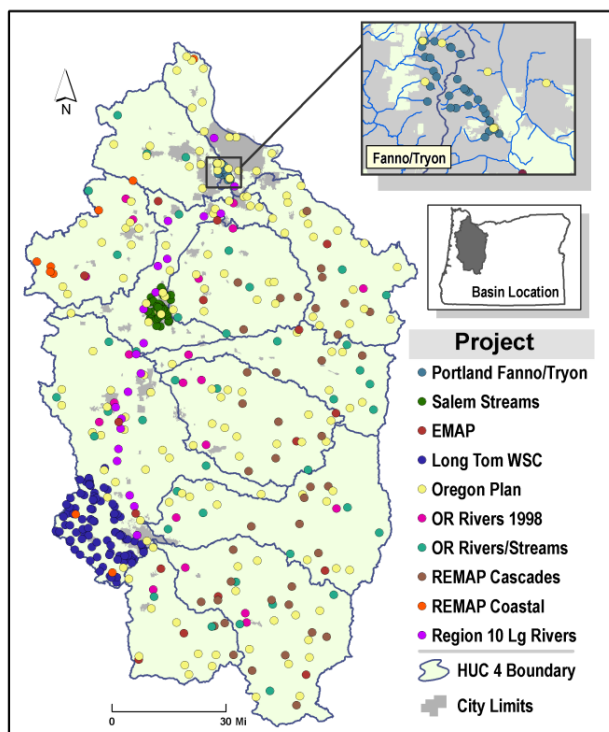


Figure 4. Locations of randomly selected streams and river sites in the Willamette Basin.

In a census, all river and stream segments would be visited and data on the stream condition collected. This would be a very expensive task in the Willamette with more than 15,000 miles of streams and rivers in the basin. A probability survey is like a public opinion poll where a relatively small, randomly selected sample is visited and analyzed. Compared to conducting a stream census, probability surveys are a cost effective and

scientifically valid approach to describing all the water of the Willamette basin with a known level of statistical confidence.

Site Weighting Factors

In this assessment we are using 450 randomly selected sites compiled from a dozen probabilistic monitoring programs in the basin (Figure 4). Individually, these programs looked at streams in a variety of spatial sampling frames. These included looking at stream and river conditions in subbasins, within the borders of a city, ecoregion, size, land use and salmon and steelhead habitat. These various sampling frames present some challenges in combining the data sources into a single probabilistic assessment.

One thing obvious in the map of randomly selected sites in Figure 4 is that there are three dense clusters of sites from surveys by the Long Tom Watershed Council and the Cities of Portland and Salem. Another less obvious problem that affects the ‘randomness’ of the sample is our ability to gain permission to sample from some types of private land owners. Overall, we had less success in gaining access permission from rural, non-corporate landowners than from urban or corporate private landowners.

Fortunately, these potential sources of bias are easily addressed by differential site weighting factors. Site weights are the stream miles that each site in our poll represents in the basin as a whole. Site weights were calculated for each site by land use category and by monitoring project cluster. Sites that were part of a dense cluster have a proportionally lower site weight than a similar site that is not part of a cluster. Differential site weighting allows us to easily combine projects of very different sampling

frames and correct for biases introduced by landowner access problems.

Reference Condition

In addition to randomly selected sites used to describe regional conditions we used data from about 240 reference sites to evaluate natural background conditions. Reference sites represent the least human impaired sites we can find. We selected reference sites by identifying basins with lower levels of human activity on the map and then visiting the candidate sites to conduct a human disturbance evaluation of the stream reach and basin (Drake 2004).

The reference condition approach is an important component of this assessment. We use reference sites in two ways. First, we use reference sites to set good-fair-poor benchmarks for habitat, water quality and biological condition indicators that do not yet have numeric water quality criteria. Second, we use the distribution of reference condition to estimate to what extent conditions are due to natural background conditions and what extent conditions are the results of human activity. Besides describing the extent of water quality and habitat stressors at randomly selected sites we also want to estimate what natural, relatively unimpaired conditions would look like. Comparing conditions at the random sites and estimated reference condition helps us to understand the effect of human activity on stream and river condition.

We feel it is important to use as many reference sites as possible in order to better represent the range and distribution of natural conditions, and to better incorporate the influence natural disturbances. We have included reference sites outside of the Willamette basin but are in

regions of similar ecological potential with similar geology, soil, climate, topography, potential vegetation, in-stream habitat, water quality and biological condition (Figure 5). The ecoregions delineated in Figure 5 have been widely used in water quality assessments in Oregon (Thorsen, et al 2003).

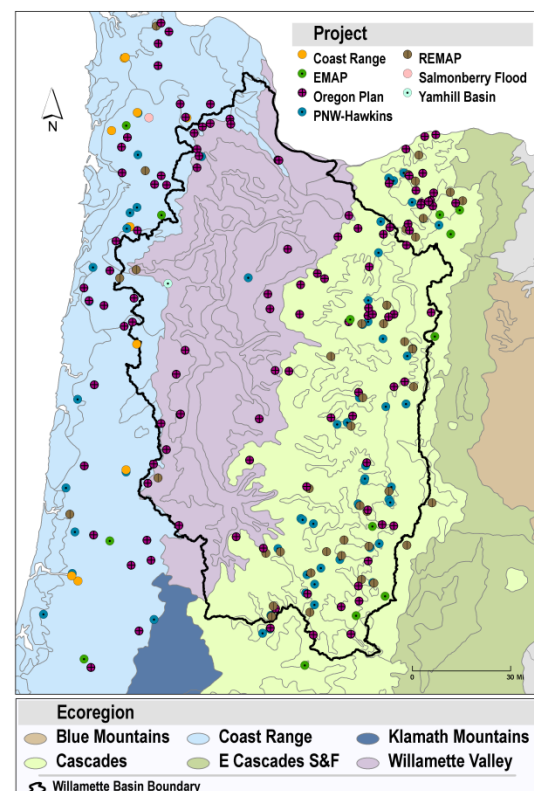


Figure 5. Locations of ecoregional reference sites.

The Willamette basin has three major (level three) ecoregions: the Coast Range, Willamette Valley, and the Cascades. We chose not to use reference sites that were in level four sub-ecoregions along the Pacific Ocean or south of 43.3° north latitude. We felt that these sites may be too strongly influenced by the Pacific Ocean or too far south to be representative of Willamette basin reference conditions.

Figure 5 shows clearly that reference site representation is not proportional across the

three ecoregions in the basin. The Coast Range is a relatively small component of the basin compared to the Willamette Valley ecoregion yet the Valley ecoregion has far fewer reference sites. These differences reflect the pattern of human land use. Relatively unimpaired Willamette Valley stream reaches are far more difficult to locate than Cascade or Coast Range sites. The whole basin and 12 subbasins all have differing proportions of streams in the Coast Range, Willamette Valley and Coast Range ecoregions. Estimating the reference conditions for each different spatial scale requires a different set of site weights. The site weights are the length of stream kilometers a site represents in the area being described. Ecoregional reference sites are weighted proportional to the extent of that ecoregion in each spatial scale ensures a reasonable reference condition appropriate for each subbasin.

It is important to keep in mind is that reference sites are not pristine or unimpaired by human activity. While smaller streams at higher elevations may be in basins minimally impaired by human activity, larger streams and rivers, and streams at lower elevation will have considerable alteration from human activities. Often these reference streams represent local stream reaches in relatively better condition than most streams in the area. The reference condition is not intended to be a model of basin conditions at some historical point in time, such as pre European-American settlement of Oregon. It estimates what the biological, water quality and habitat condition of the basin would look like if all streams were in the condition of the best streams we can find today.

Appendix A of this assessment has more information on reference sites and benchmarks.

Data Sources

Between 1994 and 2007, 451 randomly selected sites and 238 hand-selected reference sites were surveyed between late June and late September (Figure 6). Forty-four random sites were also reference sites.

These sites were surveyed as part of more than a dozen different monitoring projects. These monitoring projects and source data types are summarized in Table 1.

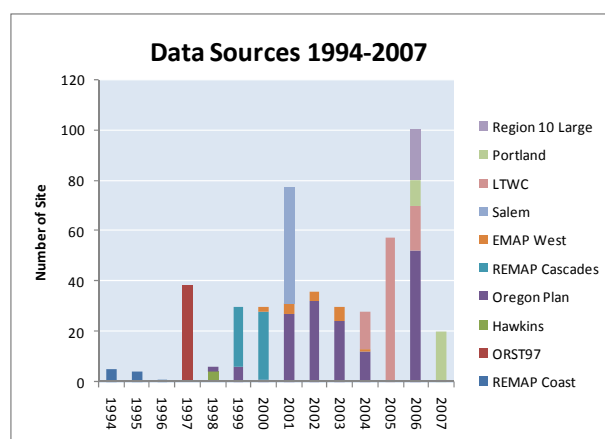


Figure 6. Data collection 1994-2007.

Figures 7 – 9 further summarize information about the data sources and amount of data for the five different types of data (macroinvertebrates, vertebrates, chemical water quality, habitat and temperature).

Approximately half of the sites were surveyed by DEQ field crews in various random and reference site monitoring projects with about one third of the sites surveyed as part of DEQ's Oregon Plan for Salmon and Watersheds (Figure 7). Approximately one quarter of the sites were surveyed in monitoring programs conducted by the EPA/OSU laboratory in Corvallis, Oregon, and one quarter were surveyed by watershed councils or municipalities.

Since not all monitoring projects collected all types of data the data sources by project graph looks a little different from the sites graph (Figure 8). About three quarters of the data sets come from DEQ monitoring projects with half coming from Oregon Plan monitoring. Approximately one quarter of the data sets come from sources outside of DEQ.

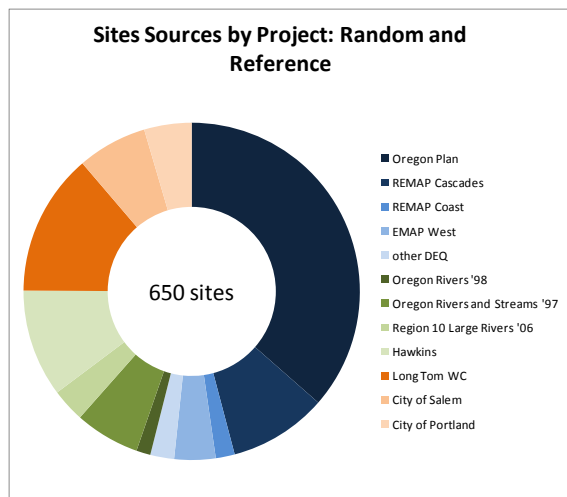


Figure 7. Number of sites by project.

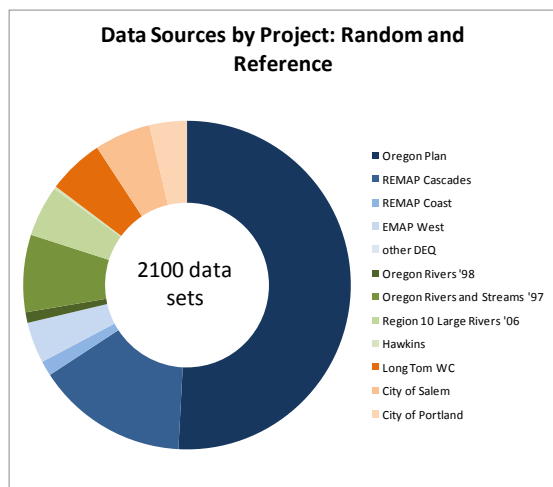


Figure 8. Number of data sets by project.

Figure 9 shows that macroinvertebrate samples represent the largest data set in the assessment with nearly 400 sites with data. Temperature data are the smallest data set with about 100 records.

With data from multiple sources being compiled into a single assessment, it was critical that standardized field and laboratory protocols

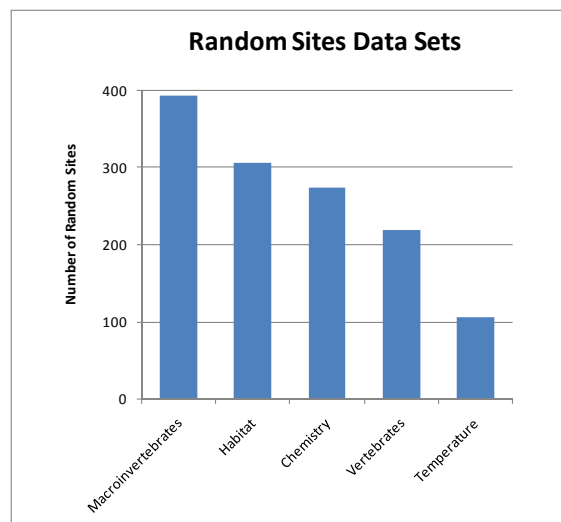


Figure 9. Number of random samples by data type.

were used by all the various monitoring programs. We have been very fortunate in this assessment that that the EPA's Environmental Monitoring and Assessment Program's methods for assessing streams and rivers have been so widely used in Oregon. Due to the cooperative approach of monitoring staff at the EPA's laboratory in Corvallis, Oregon, DEQ's Watershed Assessment Section, and others, there has been coordinated field crew training, methodology sharing and data analysis assistance for all of the monitoring programs that generated data used in this assessment.

Table 1. Data sources by project.

Data Source	Contact	#sites	Random	Reference	Macroinvertebrates	Habitat	Chemistry	Vertebrates	Temperature
City of Portland	Chris Prescott	13	X		X				
City of Salem	Ken Roley	44			X	X			
Coast Range Ecoregion Reference Condition Study	Michael Mulvey, DEQ	11		X	X		X		
EMAP	Shannon Hubler, DEQ Robert Hughes, OSU	25	X	X	X	X	X	X	X
Long Tom Basin Study	Cindy Thieman, LTWC	90	X		X				
Oregon Plan for Salmon and Watersheds	Michael Mulvey, DEQ	236	X	X	X	X	X	X	X
Oregon Rivers 98	Robert Hughes, OSU Allen Herlihy, OSU	9	X			X	X		
Oregon Rivers and Streams 97	Robert Hughes, OSU Allen Herlihy, OSU	41	X			X	X	X	
Pacific Northwest Reference Condition Study	Charles Hawkins, USU	60		X	X				
Region 10 Large Rivers Study	Robert Hughes, OSU Allen Herlihy, OSU	21	X		X				
REMAP Cascades	Shannon Hubler, DEQ	62	X	X					
REMAP Coast Range	Michael Mulvey, DEQ	12				X	X	X	
REMAP Deschutes	Shannon Hubler, DEQ	2		X	X	X	X	X	
Salmonberry River Study	Michael Mulvey, DEQ	1		X	X				
Yamhill Watershed Council		1		X		X	X		X
Total		645	451	238	572	410	381	329	203

Abbreviations used in Table 1: DEQ= Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Division; EMAP=Environmental Monitoring and Assessment Program; LTWC=Long Tom Watershed Council; OSU=Oregon State University; USU=Utah State University; REMAP=Regional Environmental Monitoring and Assessment.

Spatial Scales

In this assessment we examined the condition of Willamette Basin rivers and streams for the entire basin and for a number of different land use and hydrologic spatial scales.

Table 2. Land use classes.

- Urban
 - High/medium intensity
 - Low intensity
 - Open space
- Agriculture
 - Cultivated crops
 - Pasture/hay
- Forest
 - Public forest
 - Private forest
 - Private industrial forest
 - Private non-industrial forest

Table 3. Subbasins.

- Clackamas
- Coast Fork Willamette
- Lower Willamette
- McKenzie
- Middle Fork Willamette
- Mid Willamette
- Molalla-Pudding
- North Santiam
- South Santiam
- Tualatin
- Upper Willamette
- Yamhill

Land use

Table 2 and Figure 10 show the land use categories we assigned with ArcMap 9.2 geographic information system to classify the land use of streams and sites using a

combination of zoning, land ownership information and satellite land cover data. The land predominant land use was determined using a 300 meter diameter circle centered on the site latitude and longitude. The land use designations are for what the use is at the site and does not consider what is occurring in the basin up stream of the site. The Technical Appendix provides the land use designation methods in more detail.

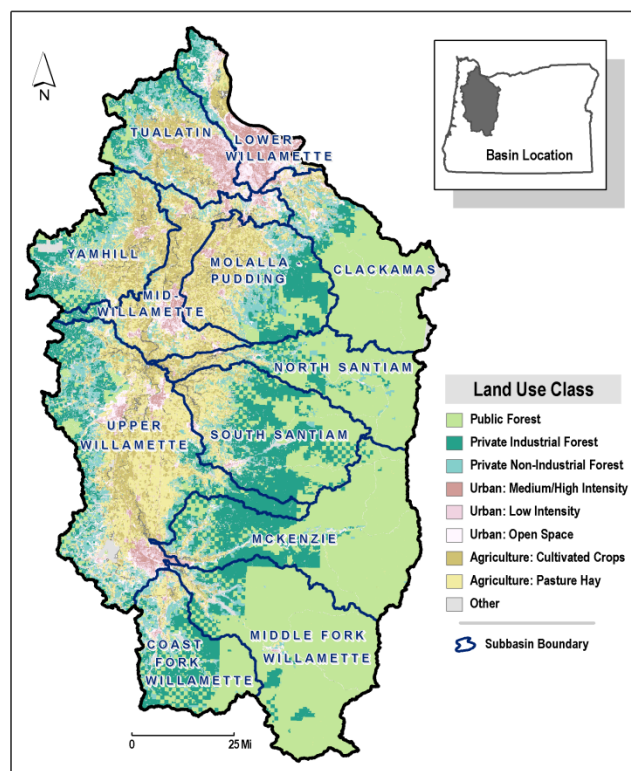


Figure 10. Map of Willamette Basin land uses and subbasins.

We felt that looking at stream conditions for different land uses was important since types of point source and non-point source stresses to water quality vary with human land use and activity. Management practices to address non point source water quality problems are typically specific to the land use activity involved.

The predominant land use surrounding Willamette streams and rivers is forest with approximately 60% of the stream length. Public forest is largest single class of land use in the basin. Approximately a third of the stream miles are in agricultural land use and approximately 10 % are in urban areas (Figure 11).

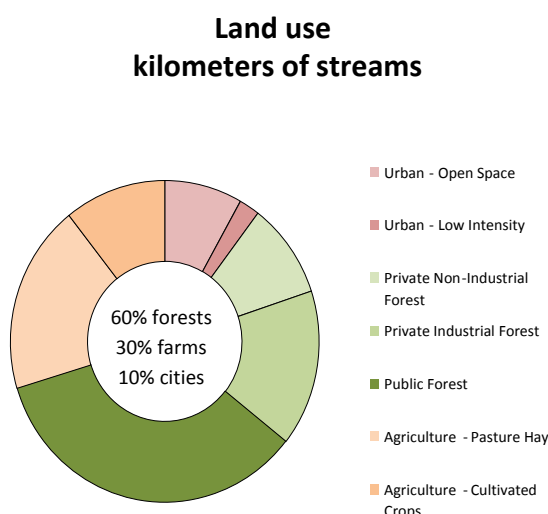


Figure 11. Stream length proportions of land use classes.

Subbasins

The 12 subbasins listed in Table 2 are the 4th field US Geologic Survey Hydrologic Units. They are the spatial scale most often used by DEQ for conducting intensive water quality assessments and for determining waste load allocations for water quality limited water bodies as required by the Clean Water Act in the Total Maximum Daily Load (TMDL) process.

Indicator Descriptions

In this assessment we looked at the overall ecological health or integrity of Willamette Basin rivers and streams. There is no one single

definition or indicator of stream ‘health’. By evaluating an array of biological, water quality and physical habitat indicators that are affected by human activity we get a picture of the overall stream condition.

In the following sections we list the various indicators, briefly describe why they are important, and provide a very brief description of the sample collection methods. More information on sample collection and analysis methods is provided in the Technical Appendix and in the cited references.

Indicators of Biological Condition

Using biological indicators of stream health is useful for a number of reasons. Since the aquatic organisms live in the water for extended periods of time, they are indicators of not just the current conditions but also the cumulative effect of a wide range of stressors over time. Organisms evolve to use habitats with specific characteristics. Changes in these characteristics due to human disturbance can result in changes in the species composition of a stream relative to what would be found under unimpaired conditions. This is something difficult to capture with a typical water quality “grab” sample that is collected at one point in time and analyzed for a relatively small number of chemicals. The stressor that caused the impairment may not be present at the time of the sample collection, or the sample may not be analyzed for the appropriate stressor. Finally, the federal Clean Water Act sets the nation’s goal “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” Biological indicators of stream health are a direct measure of the extent to which waters achieve this goal of Clean Water Act (33 USC § 1251).

In this assessment we look at two different biological assemblages: the macroinvertebrates that live on the stream bottom and the fish and amphibians of the streams. There are benefits to looking at more than one group. Different groups respond to stressors differently. Macroinvertebrates live in all waters from the largest to the smallest, including some that naturally do not have fish. Macroinvertebrates are the foundation of the animal food chain in streams. They graze on algae, leaves and wood, and in turn are a source of food for fish. Fish are eaten by other wildlife and humans.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates are a diverse group mostly made up of insects but also clams, mussels, crustaceans, worms and other types of creatures. They are animals that are large enough to see without a microscope and do not have an internal skeleton. A single stream sample can have dozens of different species, and the possible list of species a stream could have may change at different locations or time.

In wadeable streams macroinvertebrate samples were collected using fine mesh net from riffle habitat distributed throughout the survey reach. In wadeable streams without riffle habitat samples were collected in the fastest water habitat available. In non-wadeable rivers or from streams without fast water habitat macroinvertebrate samples were collected at transects evenly spaced throughout the survey reach (DEQ 2009).

We evaluate the biological health of a stream's macroinvertebrate assemblage using a species loss model. The list of species we observe (O) at a site is compared to the species expected (E) to be present at good condition reference condition streams in the area at about the same time of year. The site macroinvertebrate score is a ratio of the observed to the expected

species (O/E). O/E scores range from 0 meaning no species predicted in the reference condition model were found to more than 1.0 meaning



Figure 12. Macroinvertebrate sampling.

that all of the species predicted were found. An O/E score of 0.75 means that 25% of the species predicted at reference sites have been lost. O/E scores greater than 1.0 represent a species enriched condition. Species enrichment over what would be expected in reference condition streams may represent a slightly disturbed stream condition (Hubler 2008).

Aquatic Vertebrates

The aquatic vertebrates are the second species assemblage we used as an indicator of biologic health. Typically, western streams have fewer than a dozen species of fish and amphibians although larger rivers have more species. As with aquatic macroinvertebrates, different vertebrate species have evolved to survive in differing habitats and conditions. Some are tolerant to poor water quality or habitat conditions while others are not.

Fish and amphibians were collected using a single pass with an electrofisher. Stunned individuals were collected in nets, identified, length measured and released. In wadeable streams the field crew used a backpack electrofisher. In non-wadeable rivers the field crew used a raft or boat mounted electrofisher.

Electrofishing was conducted over the entire survey reach. The goal of the electrofishing survey is to collect a representative sample of the most abundant species present and not conduct a census of all individual present in the survey reach.



Figure 13. Backpack electrofishing.



Figure 14. Raft electrofishing.

To assess the condition of the aquatic vertebrates we used the vertebrate Assemblage Tolerance Index (ATI), an overall indicator of the species assemblage's tolerance to a broad range of human disturbances. The index is a weighted average of individual taxon tolerance values created from habitat, water quality and species presence data from the western United States (Whittier. et al. 2007).



Figure 15. Length measurement of a cutthroat trout.

Indicators of Water Quality Stress

Various water quality and physical habitat measurements occur over a range of values. Human activity and natural conditions both affect the values we measure in a stream or river. Since aquatic life has evolved to adapt to a range of stream conditions, the ecological health of streams can be impaired when those conditions are altered beyond the natural ranges. In this section we look at a relatively short list of water quality and habitat indicators that have been found to be important to the ecological health of aquatic systems and are affected by human activity. It is not a complete list of all important stressors. For example, it does not include toxic chemicals in the water. Nor does it include water quality stressors that may be present during winter time high stream flow conditions.

In this assessment a single set of water quality samples were collected at each site from a well mixed location in the mid channel of the stream near the downstream end of the survey reach. Samples were typically collected mid morning before any other survey work had been performed at the stream. Some analysis was performed in the field while other samples were returned to the laboratory for further analysis.

Table 4. Water quality indicators.

- Temperature
- Nitrogen
- Phosphorus
- Dissolved Oxygen
- Biochemical Oxygen Demand
- pH
- Total Solids
- Total Suspended Solids



Figure 16. Water quality sample processing.

Temperature

Water temperature is an important factor in determining the distribution and survival of aquatic species. Temperature is especially important to the survival of cold water adapted species like salmon and trout. When water temperatures become too warm, cold water species suffer a variety of effects including decreased ability to compete for food, avoid predators or fight diseases. This could lead to decreased spawning success or death. Warm water holds less oxygen dissolved in solution than cold water. The single major factor effecting water temperature that human

activities in a watershed contribute to is canopy cover. Removing shading vegetation from small and medium sized streams leads to increased water heating from radiant solar energy.

Temperature was measured using a thermistor that recorded temperature at half hour intervals. Thermistor accuracy was checked with a reference thermometer of known accuracy before the devices were deployed and again after they were retrieved. Thermistors were deployed in a well mixed, mid channel location in the stream in the spring and retrieved in the fall in order to capture the warmest time period during the summer.

The highest 7 day average of daily maximum temperature (7DAM) was calculated for each site and compared to the water quality standard. The standard applicable at a particular site varies depending on the fish use at that location (see Appendix A of this assessment). In the categorical graphs the sites with 7DAM below the standard are 'good' and sites with 7DAM above the temperature standard are 'poor'.

Nitrogen and Phosphorus Nutrients

The biological productivity of streams depends on a combination of nutrients and energy. Nutrients can enter the stream dissolved in groundwater and surface water runoff. Nutrients can also enter the stream through the decomposition of solid material such as terrestrial plant leaves and wood falling into the stream and animal bodies, such as salmon carcasses. Human activity in a basin often increases nutrient input to a stream over the normal levels through fertilization of agricultural and residential land, animal and human wastes, and increased soil erosion. Conversely, human activity also leads to decreased stream nutrients in some areas, such as in higher elevation, forested streams, when

there is a decrease in decomposing salmon carcasses due to reduced salmon populations.

The primary impact of nutrients is on the growth of aquatic plant and algal communities. Algae, like all plants, require nutrients for normal growth. Most of these nutrients are available in aquatic systems in excess of the algal nutritional requirements. Nitrogen and phosphorus are exceptions in that the availability of these nutrients frequently limits algal growth in lakes and streams. In most natural waters the availability of phosphorus limits algae growth. When extra phosphorus is added the next nutrient to become limiting is nitrogen. The growth of algae feeds insects that are eaten by fish and other organisms. Nutrient availability is a matter of balance. Too little nitrogen and phosphorus may mean a reduced food supply for juvenile salmonids and overall reduced stream productivity. Too much nitrogen and phosphorus leads to excess algal growth causing pH and dissolved oxygen problems unhealthy to salmonids and other species.

Dissolved Oxygen

Dissolved oxygen is essential to all life that depends on aerobic respiration, including fish, amphibians and aquatic macroinvertebrates. The amount of oxygen in water is determined by a number of factors. First, the solubility of oxygen in water decreases as water temperature increases. Second, the amount of oxygen dissolvable in water decreases with decreasing barometric pressure. Barometric pressure decreases with increasing elevation and changes with the weather.

In many waters the biological activity in the water has a tremendous influence on the dissolved oxygen. Photosynthesis by algae and aquatic plants releases oxygen into the water and takes up carbon dioxide. In very

productive, eutrophic systems photosynthesis temporarily creates super-saturated levels of oxygen over 100%. In a similar way, aerobic respiration can deplete the dissolved oxygen to lethally low levels in nutrient rich waters when photosynthesis stops due to darkness. Also high levels of un-decomposed organic material causing high levels of biochemical oxygen demand will deplete dissolved oxygen when the organic material is broken down by bacteria and fungi. Dissolved oxygen can vary daily and seasonally as photosynthesis, respiration and water temperature vary. Turbulent, fast-moving water can restore depleted dissolved oxygen through aeration.

We measured dissolved oxygen in the field using a Winkler titration on a single sample typically collected during the mid-morning.

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen consumed by microorganisms when breaking down the organic materials in the water under standardized laboratory conditions in 5 days. Waters polluted with untreated sewage or that have high levels of fine organic sediment from soil erosion will have high BOD. BOD can vary a lot naturally. Leaves and other organic material collect in depositional areas, contributing to the BOD of a stream. Anthropogenic influences include untreated manure and sewage, wood waste, leachate from landfills and sediments from erosion.

pH

pH is a measure of the acidity of waters and is an important and frequently measured water quality parameter critical to the growth and survival of aquatic life. It affects the toxicity of heavy metals and ammonia. Like dissolved oxygen and temperature, pH often varies daily and seasonally with variations in photosynthesis

and respiration due to changes in available sunlight. In most waters pH is determined by dissolved carbon dioxide gas, which forms carbonic acid, a weak acid. Algal photosynthesis and respiration in areas with abundant algal growth decrease dissolved carbon dioxide and increase the pH. At night pH in those same waters decreases as a result of carbon dioxide excretion during respiration. Such daily swings in pH can be very stressful to salmon and other aquatic life.

We measured pH in the field, typically around mid-morning, on freshly collected water samples using a meter with a glass pH electrode.

Water Column Fine Sediment: Total Solids and Turbidity

The detrimental effects of excess fine sediment on juvenile salmon and other aquatic life are well known. Fine sediment can clog spaces between gravel and cobble smothering salmon eggs and emerging fry. Excess fine sediment in the water column interferes with gill function and the ability of young fish to forage for food. Human activities near streams and rivers such as road building, logging and agriculture that disturb the ground surface or remove stabilizing vegetation can lead to increased fine sediment in streams.

Fine sediment in the water is measured in two different ways in this assessment: total solids, total suspended solids and turbidity. Total solids and total suspended solids are determined by evaporating a known volume of water sample and then weighing the remaining residue for a filtered and unfiltered sample. Total and suspended solids have units of milligrams solid material per liter of water.

Like many other water quality parameters, these measures of water column sediment can vary widely depending on flow conditions. A

single sample collected during summer low-flow conditions may not adequately capture water quality sediment problems for many streams.

Indicators of Physical Habitat Stress

The habitat data used in this assessment were collected and analyzed using the EPA's Environmental Monitoring and Assessment Program's protocols for wadeable and non-wadeable streams (Peck et al 2005 and Peck et al 2006). Stream and river habitat data were collected from a length of stream that varied with size. Most wadeable streams had a sample length of 200 to 500 meters with a 150 meter minimum while larger rivers could have a sample length of more than a kilometer. Measurements of stream channel morphology, substrate, canopy cover, and riparian characteristics evaluations were conducted by the field crew at regularly spaced transects while other measurements were collected at intervals between transects.

Table 5. Habitat indicators.

- **Streambed Condition**
 - Streambed Stability
 - Fine Sediment
 - Sand and Fine Sediment
- **Riparian Condition**
 - Canopy cover
 - Riparian Vegetation
 - Riparian Human Disturbance
- **Fish Habitat Condition**
 - Fish Cover Extent
 - Large Woody Debris

A field habitat crew of 2 people could usually conduct a habitat survey on a smaller wadeable site in 2 to 3 hours while a larger, more complex site might require several hours. Although the specific field method may have been adapted for wadeable and non-wadeable water bodies,

the habitat stressors assessed were the same. Non-wadeable water bodies were surveyed by raft or boat. Field crews complete about 40 pages of forms with raw physical habitat data at each site. Field crews re-sampled 10% of the sites for quality assurance.

The eight habitat indicators that we selected for this assessment were developed by the EPA and have been used in stream assessments in Oregon and across the country (Kaufmann et al 1999). They are important to fish and other aquatic life and are affected by human activity in the riparian area along the stream channel and in the drainage basin. Three stressors look at the condition of the streambed (streambed stability, percent fine



Figure 17. Habitat survey.

sediment, and percent sand and fine sediment), three stressors look at the condition of the riparian area (canopy cover, riparian vegetation condition, and riparian human disturbance) and

two look at the condition of fish habitat (extent of fish cover and large woody debris habitat).

Streambed Condition

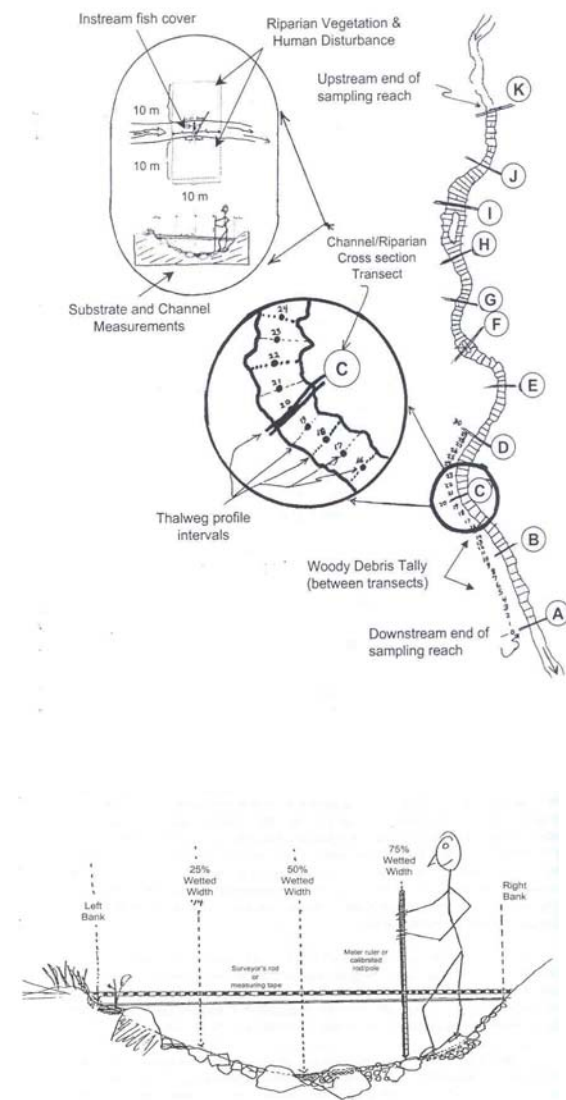


Figure 18. Survey reach transects.

(From the EPA's Environmental Monitoring and Assessment Program, Peck, et al, 2005)

Many human activities affect the characteristics of streambeds, particularly the amount of small sized particles in the streambed. Frequently, excessive erosion leads to increasing the amount of small sized sediment in streambeds. Excess fine sediment fills in the spaces between

boulders and cobbles reducing habitat space for fish and macroinvertebrates. Accumulations of fine sediment in salmon spawning gravel can smother and kill salmon eggs.

The evaluation of impairment from excess fine sediment needs to be done carefully. Simply measuring the amount of fine sediment in a streambed alone is not adequate to evaluate impairment. Not only is the amount of fine sediment affected by human disturbance but it also varies naturally with basin geology and soils, stream size, channel gradient, and streambed roughness. Larger, steeper streams in areas of erosion resistant soils and geology will naturally have less fine sediment than smaller, low gradient streams in areas with more erodible soils and geology.

The streambed stability indicator is a value that models the expected mean substrate size for a stream reach based on the natural factors that affect streambed substrate size and compares it to the observed mean particle size. Expectations for good, fair and poor streambed stability were calibrated based on ecoregions that have soils and geology as a component.

We used two measures of fine sediment in this assessment. The first, percent fine sediment, is defined as silt, clay and muck material that feels slick between the fingers and not gritty (<0.06 mm diameter). The second, percent sand and fines, is the proportion of particles less than 2.0 mm in diameter. Both forms of fine sediment were included to be consistent with earlier DEQ reports. Substrate data were collected at evenly spaced transects along the survey reach.

Riparian Condition

The riparian area is a corridor of land along a stream or river. An intact, well-vegetated riparian area along streams and rivers will act like a buffer against human disturbance in the watershed. It can reduce nutrient and sediment

runoff from nearby land, reduce erosion from unstable stream banks, provide shading vegetation to reduce stream temperature, provide fish and amphibian habitat in the form of large woody debris, and provide leaf litter food for aquatic life.

Canopy cover is a direct measure of the vegetation and topography over the stream channel. It was measured using a densiometer, a gridded spherical mirror that reflects the vegetation over the stream channel. Canopy cover measurements were taken at evenly spaced transects along the survey reach either at the center of the channel for wadeable streams or at the wet edge at the stream bank for non-wadeable streams.

Riparian vegetation condition was evaluated at 10 meter square plots on evenly spaced transects. Vegetation density estimates were made for the ground cover (<0.5 m high), mid layer (0.5 to 5.0 meters high) and canopy (>5 meters high). The riparian vegetation condition is the sum of the woody plant density in all three layers.

Field crews recorded the presence and proximity of eleven types of human land use or disturbance at riparian plots along the survey reach. Human disturbances were evaluated as occurring on the stream bank, within 10 meters, present in the watershed but beyond 10 meters or completely absent. Riparian human disturbance score is proximity weighted indicator of general human stress on the stream.

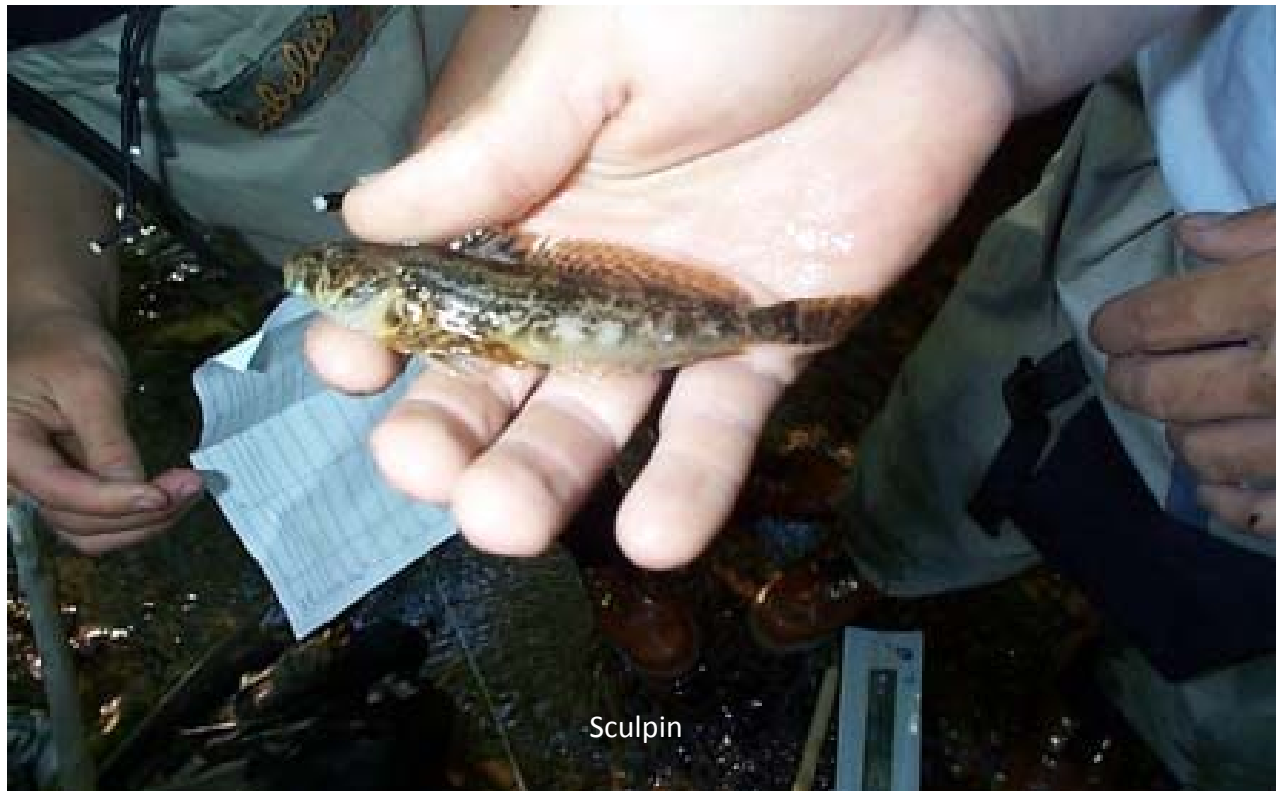
Fish Habitat Condition

More diverse fish and amphibian assemblages are found in streams and rivers with complex habitat elements: boulders, undercut banks, large submerged logs. These structures provide spaces to rest, avoid strong currents, hide from predators, and wait for prey organisms. In-

stream large wood is especially important because it creates complex habitat, such as pools and high water refugia, for juvenile salmonids. Habitat complexity also benefits macroinvertebrates, an important food source for salmonids, and wood provides habitat for some macroinvertebrate species. Human activity can simplify this habitat through channel straightening, loss of large woody

debris from the riparian area and destabilization of stream banks.

The fish cover indicator is the sum of the areal presence of all types of fish cover observed in sections of stream at 11 evenly spaced transects. The large woody debris indicator is the volume of wood pieces within or above the active stream channel based on a tally by size category taken along the entire stream reach.



Introduction to Condition Assessment Sections

Spatial Scales

In the sections that follow we look at the biological, water quality and habitat condition of streams and rivers for the entire basin; for agricultural, forest and urban land use classes; and for the 12 subbasins in the Willamette. We also compare the condition at randomly selected sites with the modeled reference condition for the entire Willamette basin and for the 12 subbasins. Reference condition represents our estimate of natural background conditions and is based on the least human-impaired sites we can find. A statistically significant difference between the random and reference extent of impairment indicates problems caused by human activity and not due to natural conditions.

Confidence Intervals, Statistical Significance and Sample Size

Data from probabilistic surveys are usually presented with information about the confidence of the estimates. The thin lines at the ends of the bars in the charts of this report are a measure of the statistical confidence or certainty of the information presented. The lines are the range of the 95% confidence interval, meaning that there is a 95% change that the real value falls within that range and a 5% chance that the true value is outside that range. Two values are said to be statistically significantly different if their confidence intervals do not overlap. A small, narrow confidence interval range is better than a wide confidence interval but more expensive to

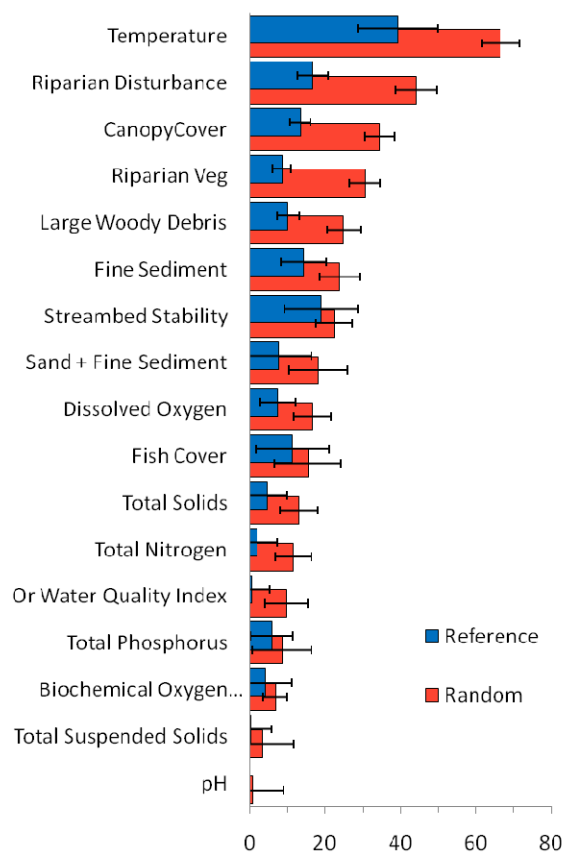
create since it involves sampling a larger number of streams.

The number of streams sampled is a major determinant of the confidence interval size. When the sample size is small the confidence interval will be big. For example, in the Willamette basin, with a sample size of 395 randomly selected sites for macroinvertebrates, 37.3% of the extent of streams and rivers has least impaired biological condition for macroinvertebrates with a confidence interval of plus or minus (\pm) 5.4%. This means that we are 95% certain that the true value of the proportion of least impaired stream extent is somewhere between 31.9% and 42.7%. In the Clackamas subbasin, with a sample size of only 23 randomly selected sites, the proportion of stream extent with least disturbed macroinvertebrate communities was $47.4\% \pm 17.5\%$. We are 95% certain that the true proportion of least impaired Clackamas basin streams is between 29.9% and 64.9%.

For a number of spatial scales and data sets presented in this assessment the sample sizes are small, resulting in confidence intervals that are larger than ideal. We have included warnings in the charts for using some of the results where the sample size was less than 15, causing very large confidence intervals. For example, the temperature data set was the smallest in this assessment and tended to have more spatial scales with very low sample size warnings. The private non-industrial forest land use also had a rather small sample size. It is important for the reader to pay attention to the confidence intervals when interpreting these results and making decisions based on these data. Appendix B of this report has more information on sample sizes for the various spatial scales.

Condition of Willamette Basin Rivers and Streams

Willamette Basin Impairments



Percent of Stream Miles Impaired

Figure 19. Extent of impairment in Willamette Basin rivers and streams.

Biological Health

As summarized in Figure 20, the biological condition of the macroinvertebrate community was most disturbed at 46% of the Willamette basin streams and rivers, compared to only 23% for basin reference condition. The extent of streams with impaired aquatic vertebrate communities was about 30% of the stream extent. The extent of streams with impaired vertebrate communities was about 20% greater than reference conditions.

These differences between random and reference conditions were statistically significant.

Water Quality

Warm water temperature was the single most extensive water quality stressor in the Willamette basin (Figures 19 and 20). More than 66% of the stream and river length exceeded the temperature standard to protect sensitive fish. Under modeled reference conditions only 39% of the streams and rivers were impaired by temperature over the standard.

Other water quality stressors were less extensive with less than 20% of the stream network impaired. All other water quality stressors impaired a greater extent of stream length than the estimated reference condition, but the differences between random and reference condition were not statistically significant at the 95% confidence interval.

Habitat Condition

Human disturbance in the riparian area was the greatest source of habitat impairment in the basin (Figures 19 and 20). Reduced levels of canopy cover from canopy cover impaired 34% of the stream extent and sparse riparian vegetation impaired about 30% of the stream extent in the basin. Low levels of in-stream large woody debris impaired 25% of the stream extent. More than 40% of the stream extent had high levels of human disturbance in the riparian area. The extent of impairment from these habitat stressors was significantly greater at the randomly selected sites than at the reference condition. The extensive riparian impairment was most likely the cause of the extensive warm water impairment in the basin.

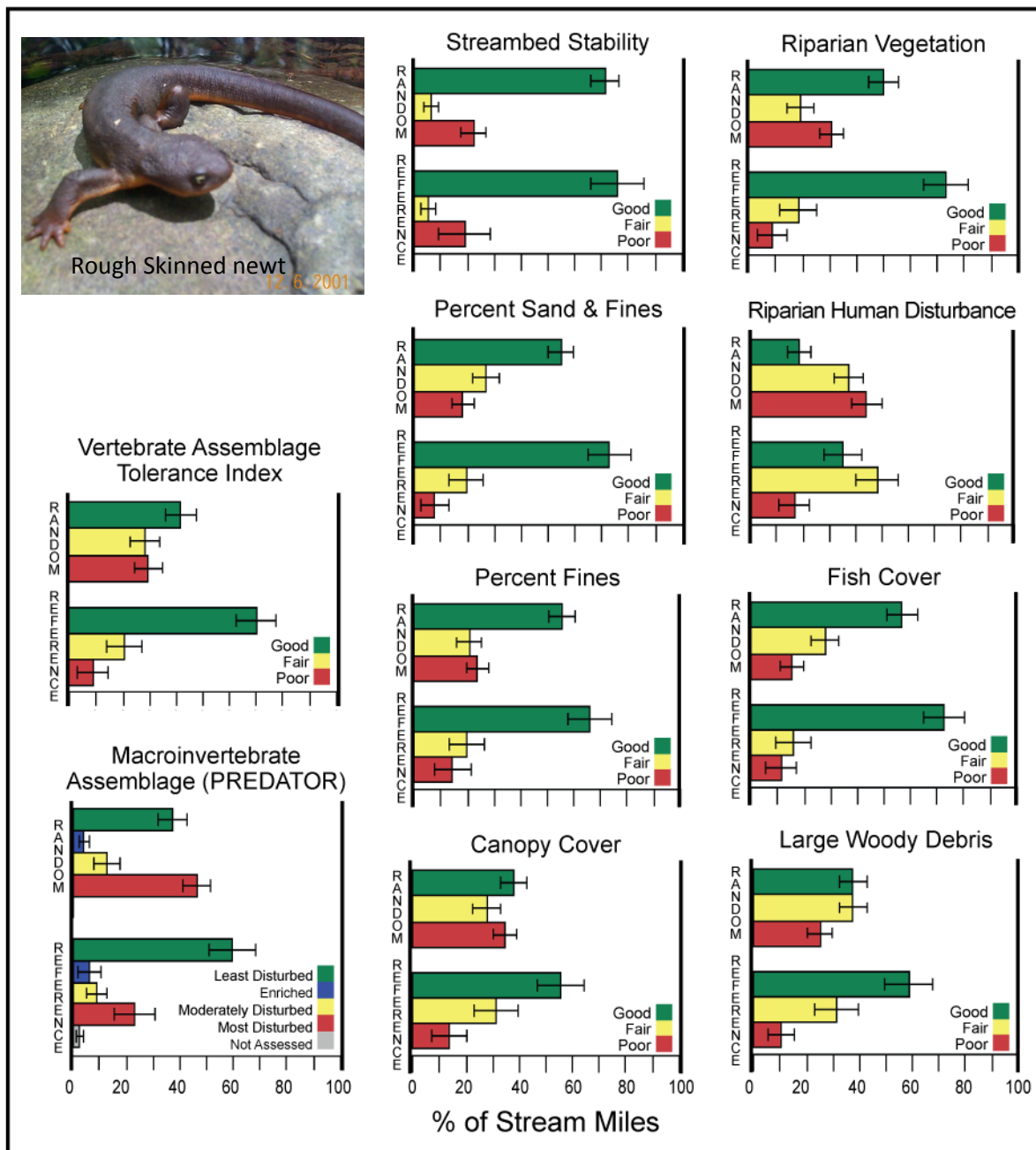


Figure 20. Biological and habitat conditions of Willamette Basin rivers and streams.

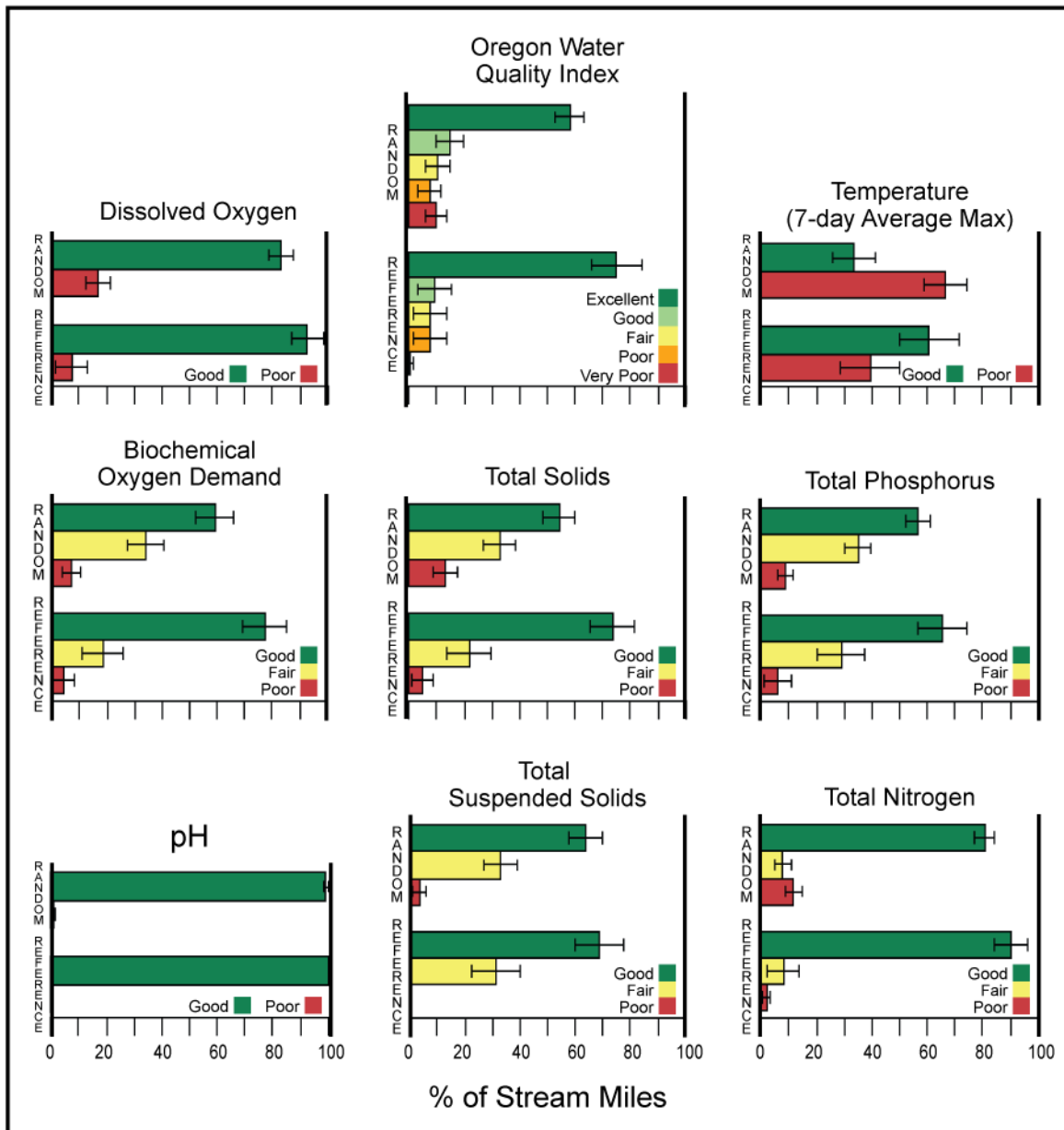


Figure 21. Water quality conditions of Willamette Basin rivers and streams.

Conditions of Willamette Basin Rivers and Streams by Land Use

Although we had adequate sample sizes for the three major land use classes (agriculture, forest and urban), land use sub-class results should be interpreted with caution since the 95% confidence intervals tend to be large due to low sample sizes. While it appears that private non-industrial forest and higher intensity urban land use have streams with greater overall impairment, these differences are not significantly different than the larger general land use groups.

Biological Health

The land use categories that showed the greatest impairment in the macroinvertebrate communities were agriculture with 89% of the stream miles most disturbed and urban with 81% of streams impaired. Forestry had streams in the least impaired macroinvertebrate communities with 12% of streams and rivers most disturbed, 19% moderately disturbed, and 61% least disturbed. Sub divided land use categories are presented in Figure 23 but these results should be interpreted with caution since the 95% confidence intervals tend to be large due to low sample sizes. It appears that private non-industrial forest was in poorer biological condition than other forest types.

Water Quality

Figures 24, 25 and 26 summarize the water quality of the land use classes and sub-classes. Of the three major land use classes, both agricultural and urban land uses had high proportions of streams above the temperature standard (88% and 82%). Forestry overall had the lowest

proportion of temperature impaired streams with 54% above the temperature standard. Public and private forest lands showed significantly different temperature patterns with 39% of public forest streams temperature impaired compared to more than 75% impaired on private forest land.

The continuous temperature data set was the smallest of the data sets used in this report. This resulted in very large 95% confidence intervals for the smaller, more specific land use sub-classes. The results for those classes are not summarized here but are presented in Figures 24, 25, 26.

Low dissolved oxygen impaired about 30% of agricultural and urban stream extent but impaired less than 6% of all forest stream extent.

Nitrogen and phosphorus enrichment were more extensive in agricultural and urban streams than in forest streams. Less than 5% of forest streams had high levels of nitrogen and phosphorus while 36% of urban streams had high nitrogen levels and 22% had high phosphorus. In agricultural streams 16% had high nitrogen and 11 had high phosphorus levels.

Habitat Condition

Overall, urban streams had the greatest impairment from unstable streambeds and excess fine sediment with 61% of the urban stream extent impaired by unstable streambed compared to more than 30% of agricultural streams and only 9% of forest streams.

The riparian areas of urban and agricultural streams had greater extent of streams in poor condition compared to forest streams and rivers. About 82% of agricultural streams and 30% of urban streams had impaired canopy cover while the level of impairment of forest streams was about 12%.

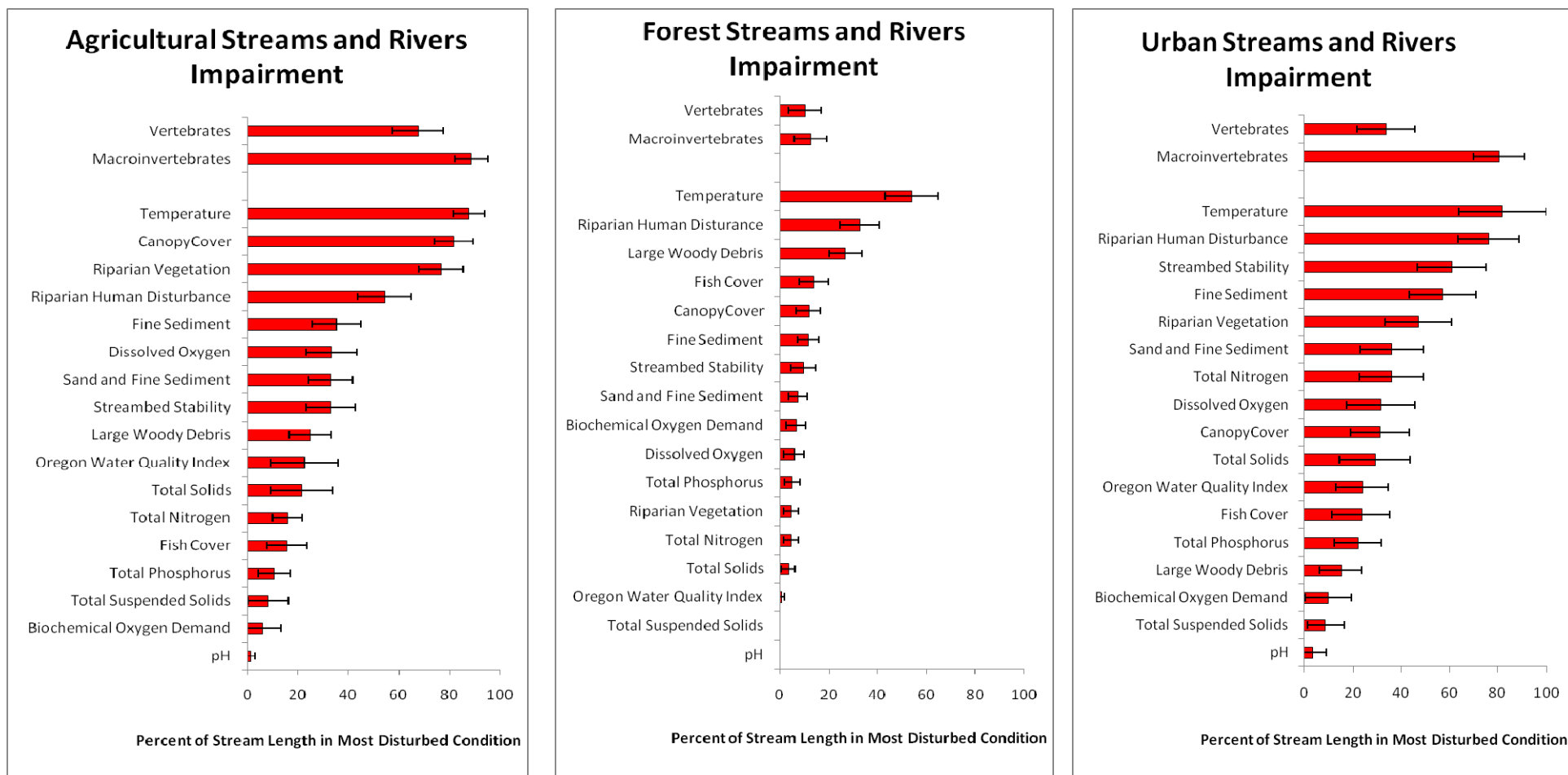


Figure 22. Extent of stressor impairment of land use classes.

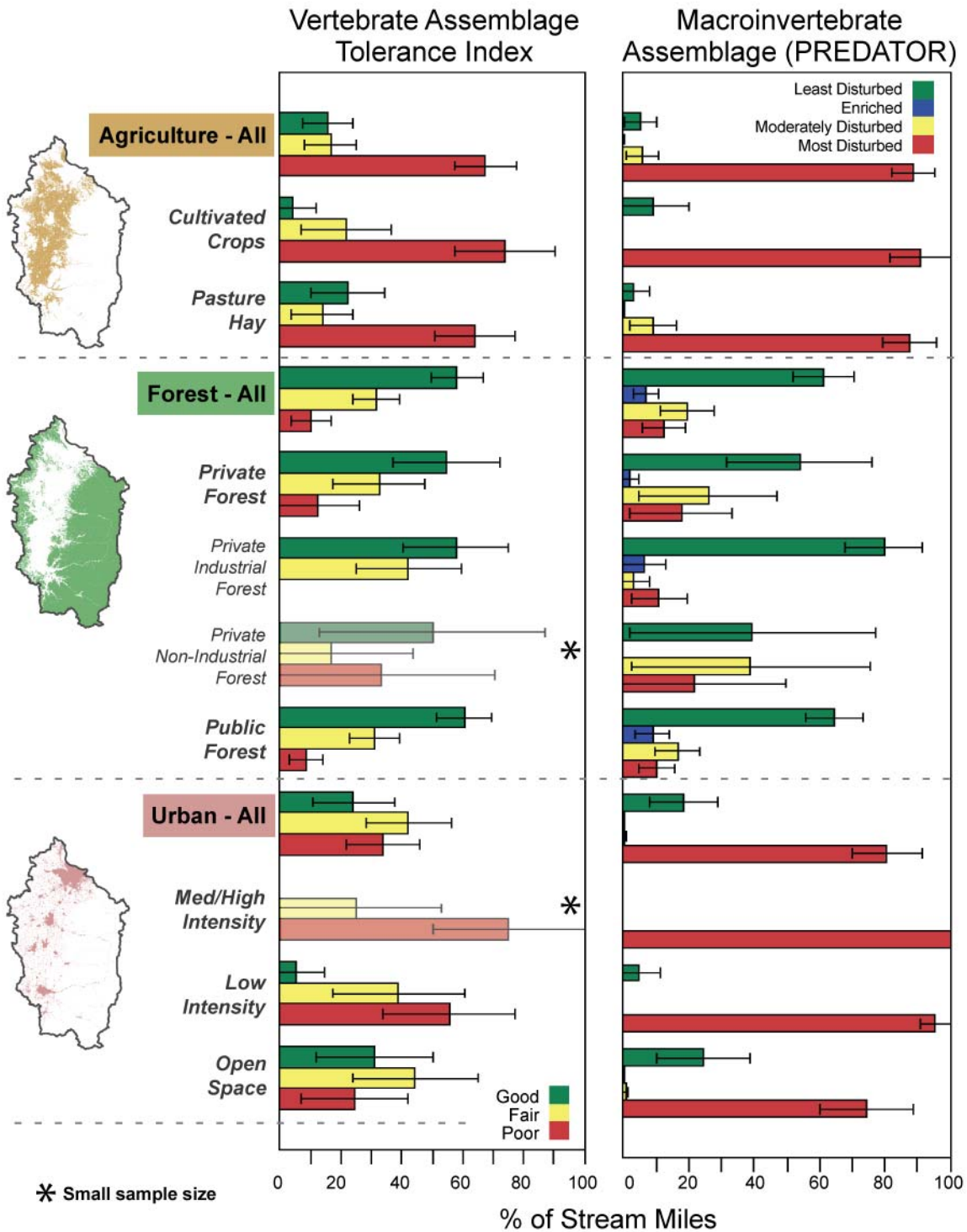


Figure 23. Biological condition of land use classes.

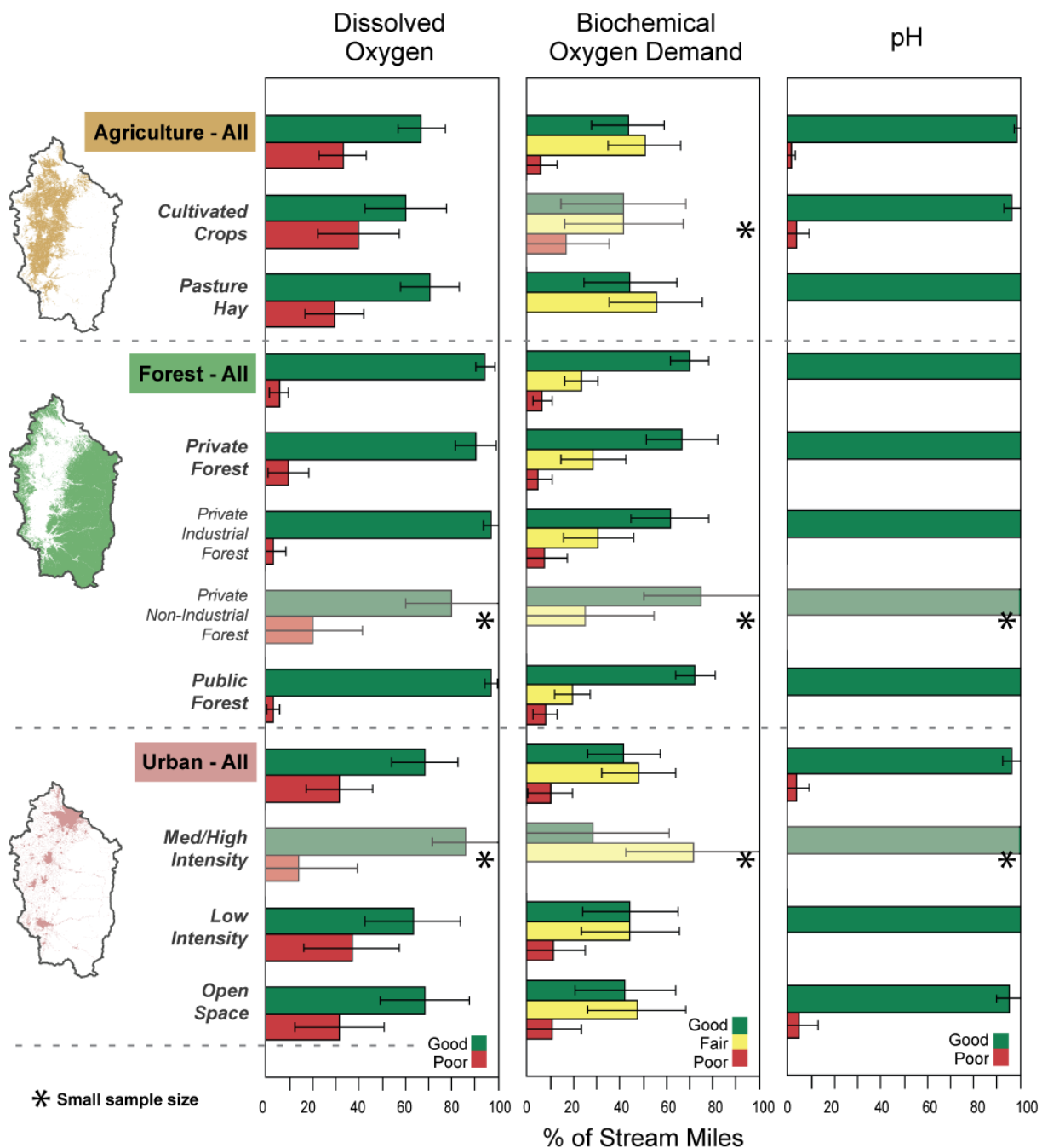


Figure 24. Water quality conditions of land use classes: dissolved oxygen, biochemical oxygen demand, pH.

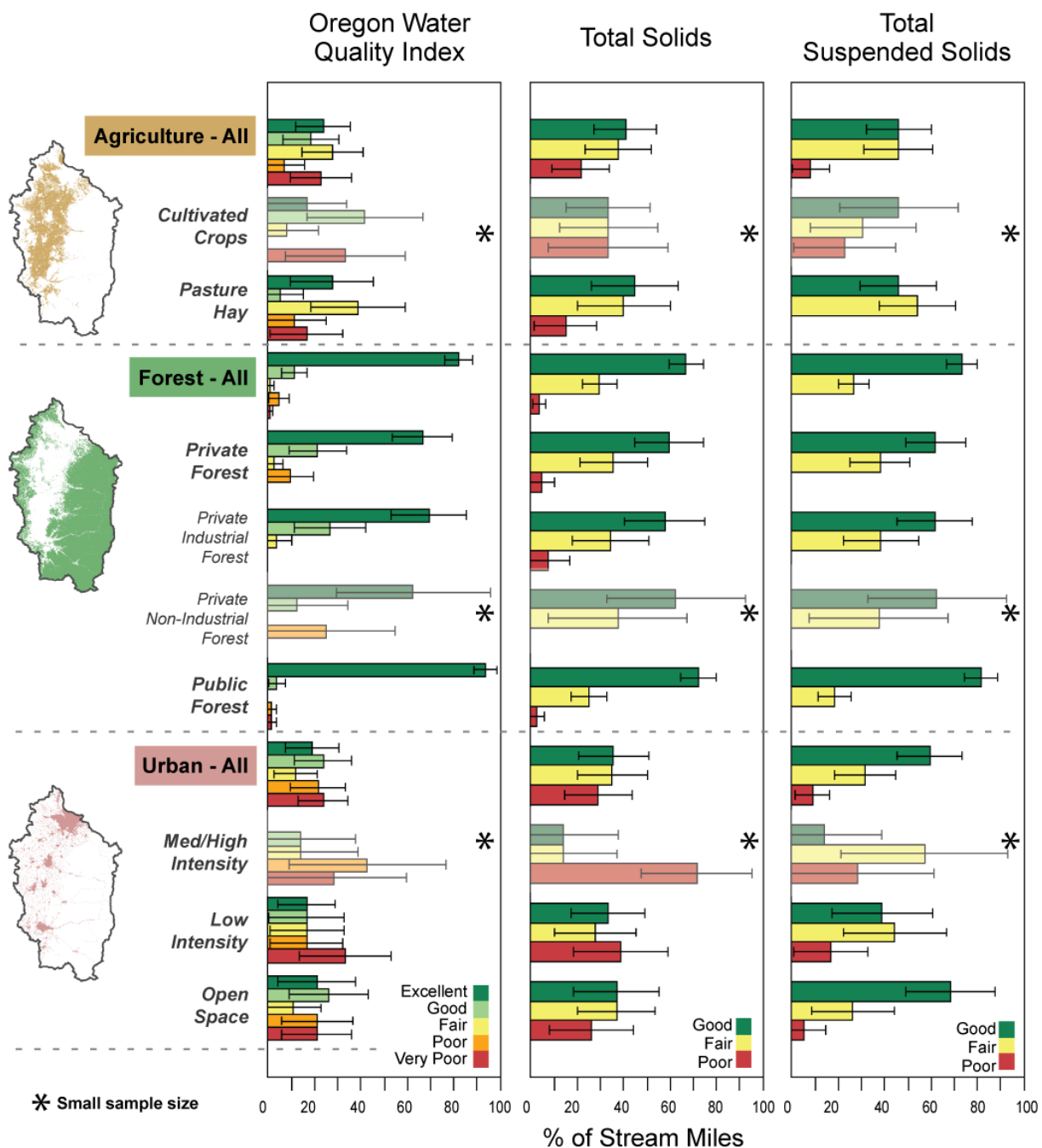


Figure 25. Water quality conditions of land use classes: Oregon Water Quality Index, total solids, total suspended solids.

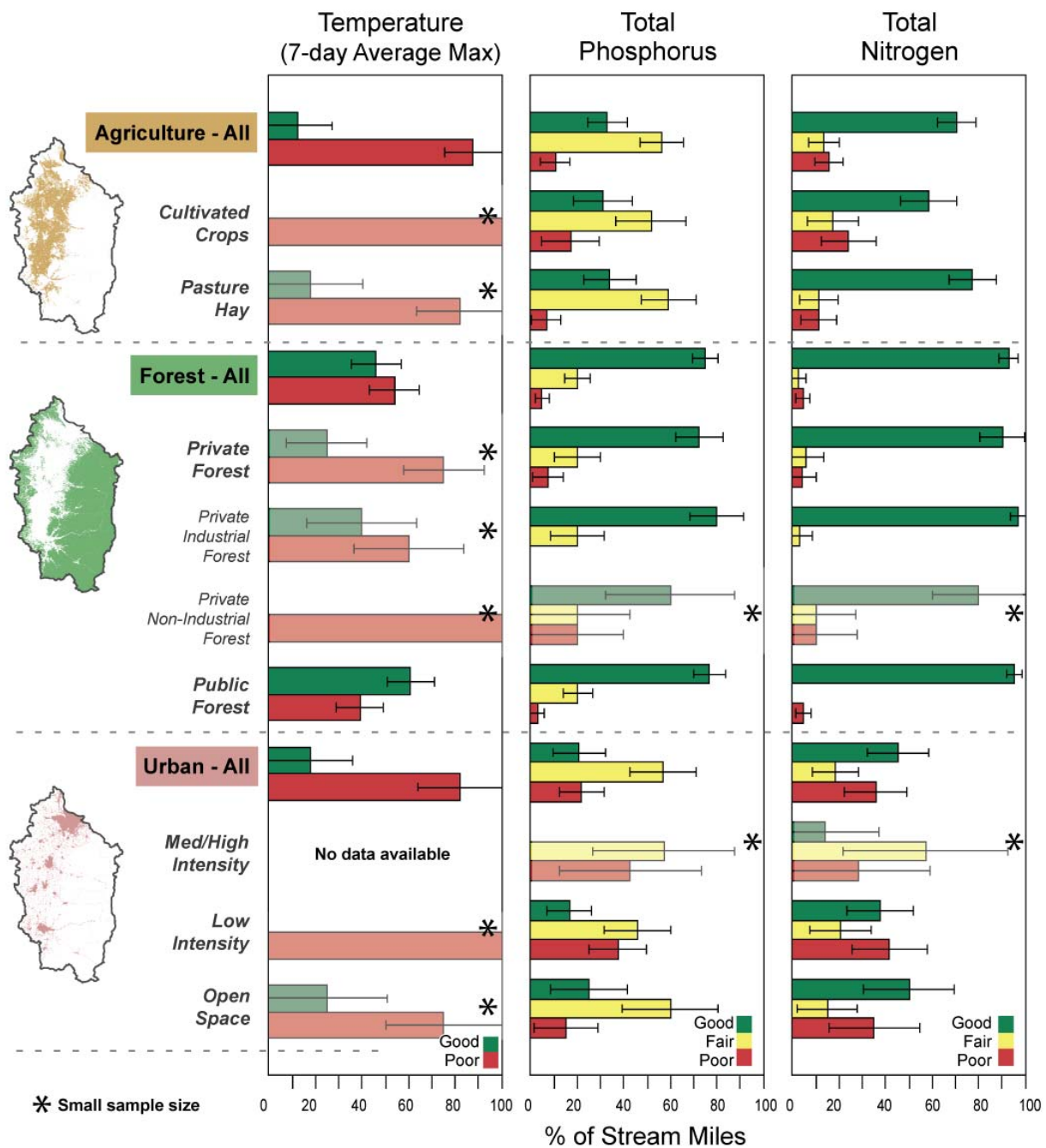


Figure 26. Water quality conditions of land use classes: temperature, total phosphorus, total nitrogen.

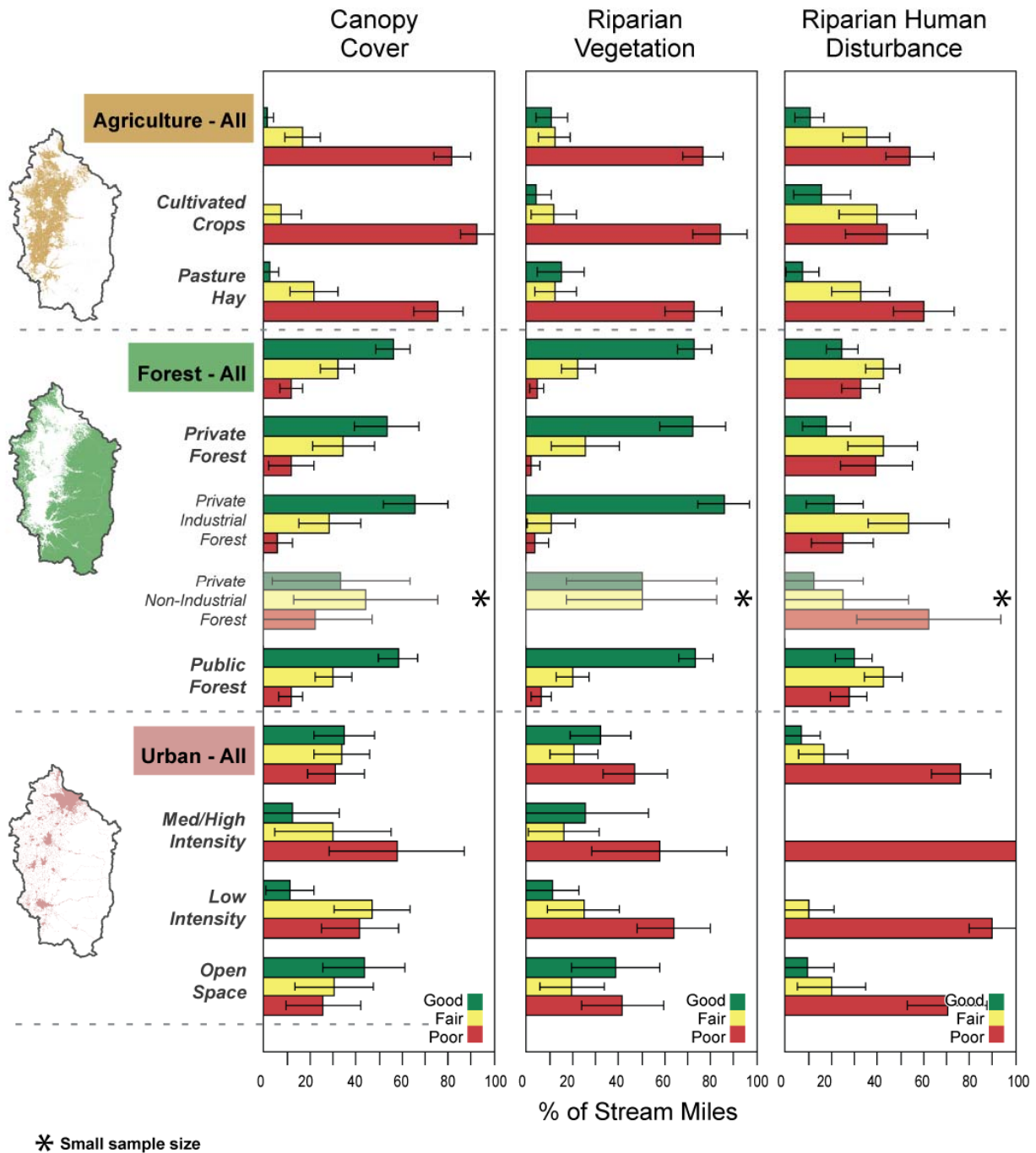


Figure 27. Habitat conditions of land use classes: canopy cover, riparian vegetation, riparian human disturbance.

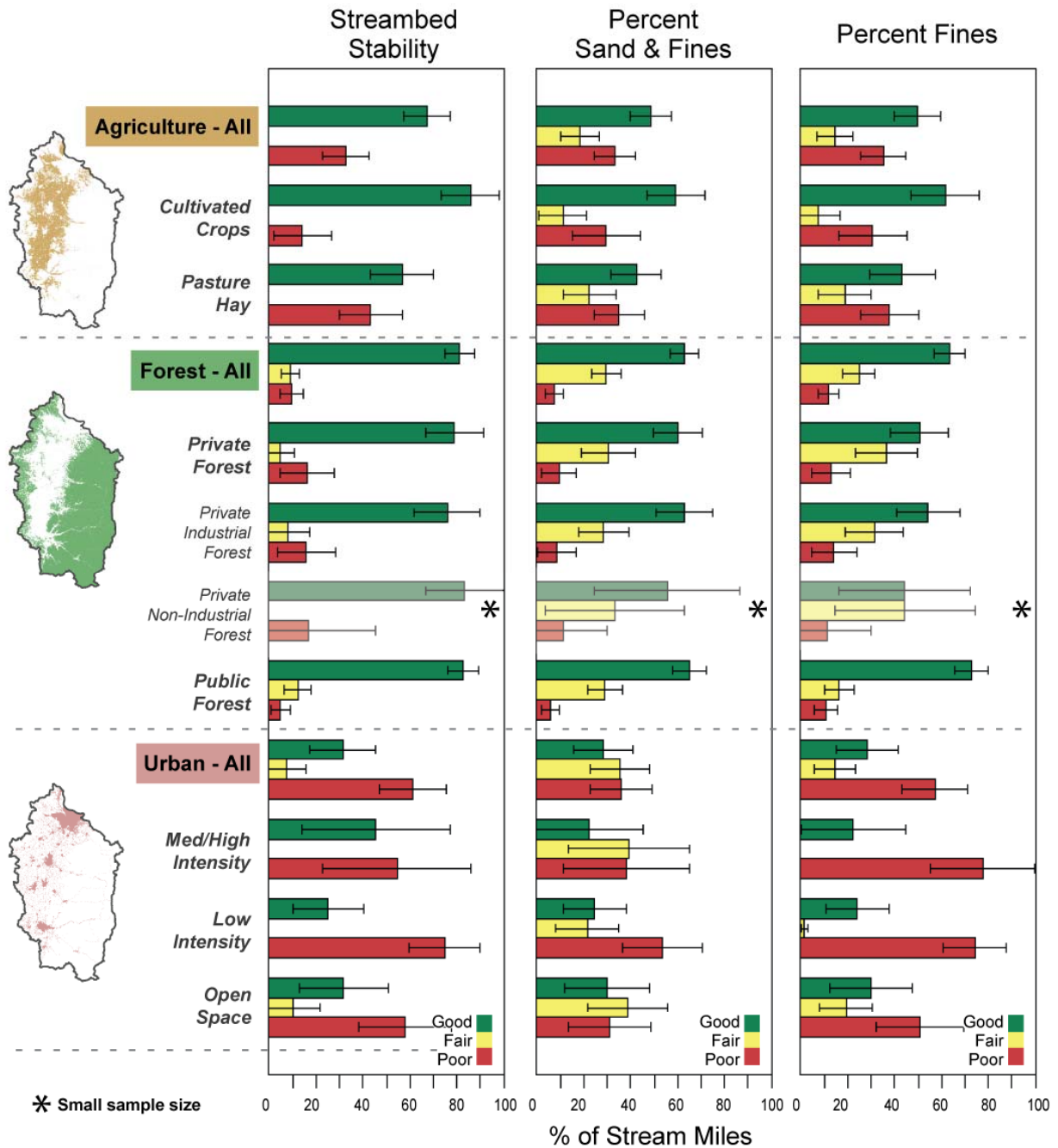


Figure 28. Habitat conditions of land use classes: streambed stability, percent sand and fine sediment, percent fine sediment.

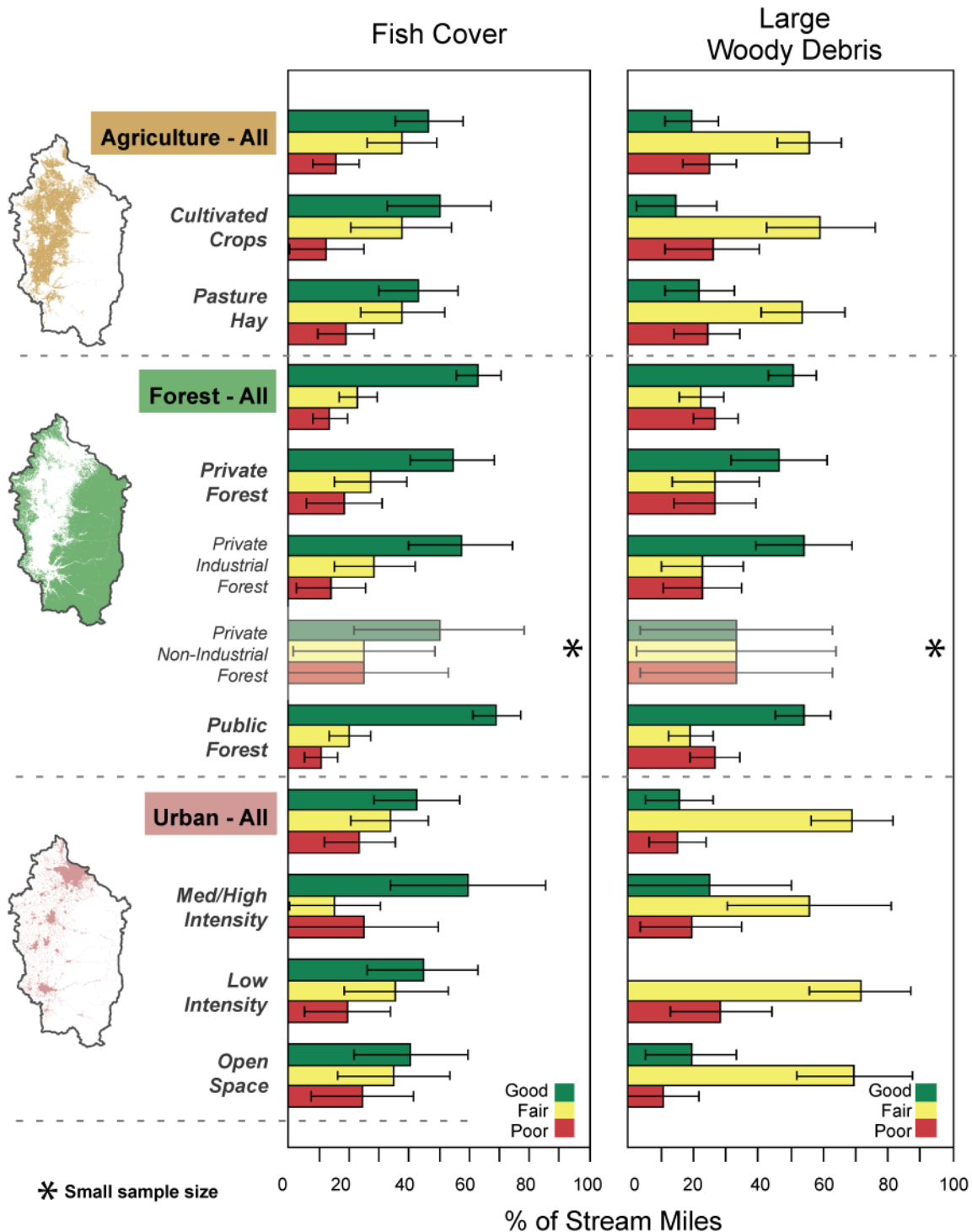


Figure 29. Habitat conditions of land use classes: fish cover and large woody debris.

Condition of Willamette Basin Rivers and Streams by Subbasin

In the previous section of this report we presented results for the entire Willamette basin and for basin-wide land use types. In this section we present results for the 12 subbasins in the Willamette basin. The results are presented in a similar format as before. Figure 30 summarizes the biological impairment of the macroinvertebrate community of the 12 subbasins with the estimated reference condition impairment. Figures 31 and 32 are graphs of the indicators of vertebrate and macroinvertebrate biological health, Figures 33 to 38 present the water quality conditions, and Figures 39 to 44 present the habitat conditions.

We have also presented the reference condition for each subbasin. The reference condition graphs are an estimate of what the subbasins would look like if all the stream miles were in as good a condition as the least impaired conditions we can find today. The analysis we present in this section discusses the highlights of these results.

We remind the reader again to pay attention to the confidence intervals when interpreting these results. Temperature data is the smallest data set in this assessment and often has a small sample size at most subbasin scales. In addition, land use sub-classes often have small sample sizes. See Appendix B in this assessment for more information on sample sizes used in this assessment.

Subbasins Biological Impairment

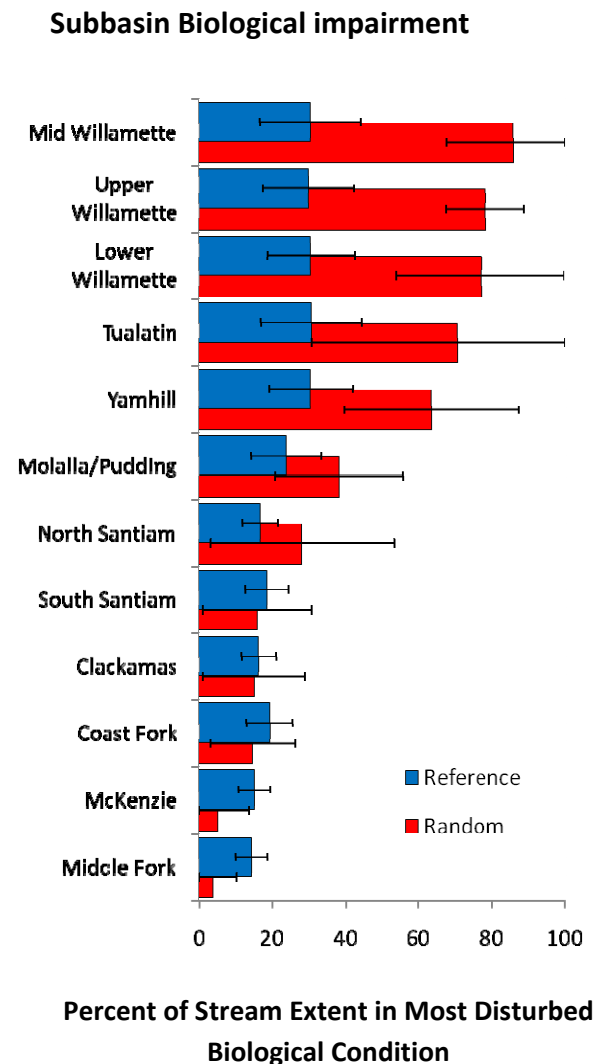


Figure 30. Biological disturbance of subbasins.

The most biologically impaired subbasins in the Willamette basin were the Mid Willamette, Upper Willamette and Lower Willamette with approximately 80% of the stream extent severely disturbed (Figure 30). The extent of disturbance was significantly worse at the random sites than at the reference sites.

The least impaired subbasins were the Middle Fork Willamette, McKenzie, Coast Fork Willamette and Clackamas with less than 20%

of the stream extent severely disturbed. The randomly selected sites in these subbasins had a lower extent of biological disturbance than the estimated reference condition although the difference in disturbance extent between random and reference condition was not significant.

The most disturbed subbasins had greater proportions of streams in agricultural and urban land uses. The least impaired subbasins had their headwaters in the Cascade Range and had greater proportions of forest land use.

The Cascades Subbasins

There were four subbasins in the Willamette basin that had their headwaters on the west slope of the Cascades Range: Clackamas, North Santiam, McKenzie and the Middle Fork Willamette. In the Cascades summer stream flow is fed from snow melt at higher elevations. Most of these subbasins had extensive forests with public forest being the most extensive land use and agriculture and urban land use less extensive than in other subbasins in the Willamette basin (Table 6).

Clackamas Subbasin

The Clackamas subbasin had the highest proportion of stream length in good biological condition for aquatic vertebrates (74%) but the 7th highest proportion in good condition for macroinvertebrates (44%) among the 12 subbasins.

The extent of poor habitat conditions was fairly low for the stressors we evaluated and not significantly different than the reference condition. The riparian human disturbance (34% poor) and fine sediment (20% poor) were the most extensive stressors in the basin but

were not significantly worse than reference condition.

The overall chemical water quality was generally good with 94% of the stream extent with excellent OWQI scores. The extent of streams with nitrogen and phosphorus enrichment was among the lowest of the 12 subbasins, however impairment from warm water temperatures was fairly extensive with 50% of the stream length impaired with warm water compared to only 29% for the reference condition.

North Santiam Subbasin

The North Santiam subbasin had the third highest proportion of stream length in good biological condition for aquatic vertebrates (56%) and the 5th highest proportion in least disturbed condition for aquatic macroinvertebrates (57%) among the 12 subbasins.

Leading habitat stressor in the North Santiam basin were low levels of large woody debris, riparian human disturbance and sparse riparian vegetation condition (approximately one third of the stream length in poor condition for these indicators). Levels of fine sediment and streambed stability were good (approximately 6% or less in poor condition). The extent of stream length impaired by habitat stressors was not significantly different than reference condition.

Overall water quality of the North Santiam subbasin was generally good with the highest proportion of streams with excellent OWQI scores of the 12 subbasins. The most extensive water quality stressor was warm water temperatures (31%) although the extent of stream length impaired was not significantly different than reference condition.

McKenzie Subbasin

Among the Cascades subbasins, the McKenzie subbasin had a fairly large extent of streams with fair to poor biological condition for aquatic vertebrates (50%) compared to reference condition (27%). The subbasin had the 3rd highest proportion of stream length in good biological condition for aquatic macroinvertebrates (68%).

The leading habitat stressors were high levels of riparian human disturbance (21% of the stream length), low riparian canopy density (19%) and sparse riparian vegetation (15%), although the extent impaired was not significantly different from reference condition.

The overall water quality in the McKenzie subbasin was very good with 94% of the stream length with excellent OWQI scores, the second highest extent in excellent condition of the 12 subbasins. Surprisingly, the extent of stream length impaired by warm water temperatures was high (66% of stream length failing the temperature criteria to protect salmon and bull trout). This was a significantly greater extent than the modeled reference condition for the McKenzie subbasin (27%).

Middle Fork Willamette Subbasin

The Middle Fork Willamette subbasin had the greatest proportion of stream length in good biological condition for aquatic macroinvertebrates (72%) and the 4th greatest extent of streams in good biological condition for aquatic vertebrates (54%) of the 12 subbasins.

The overall condition of stream habitat in the Middle Fork Willamette subbasin was good for all indicators and comparable to reference. The most extensive stressor was riparian human disturbance for approximately 30% of the

stream extent. The Middle Fork Willamette subbasin had the 5th greatest extent of streams impaired by low levels of large woody debris (28%) and low levels of fish cover of all types (16%).

The overall water quality condition in the Middle Fork Willamette subbasin was good: with 86% of the stream length had excellent OWQI scores. The leading water quality stressor in the subbasin was warm water temperatures (50%).

Table 6. Cascade Range subbasins percent stream land use.

	Clackamas	N Santiam	McKenzie	MF Willamette
Agriculture (Total)	4.8	15.2	5.7	3.1
Cultivated Crops	1.8	6.7	2.9	1.4
Pasture/Hay	3.0	8.5	2.9	1.7
Forest (Total)	88.6	80.6	89.0	94.7
Public	72.7	67.4	64.2	85.1
Private	15.9	13.1	24.8	9.6
Industrial	5.4	6.4	20.1	7.6
Non-industrial	10.5	6.7	4.7	2.0
Urban (Total)	6.6	4.2	5.2	2.2
High/Medium	0.3	0.2	0.1	0.0
Low	0.4	0.9	0.2	0.1
Open Space	5.9	3.2	5.0	2.0

The Coast Range Subbasins

There are four subbasins in the west side of the Willamette basin with headwaters in the Coast Range: Tualatin, Yamhill, Upper Willamette, and Coast Fork Willamette. Stream flow in these subbasins is fed more from rainfall rather than snow melt as in the Cascade subbasins. The Tualatin, Yamhill and Upper Willamette subbasins have extensive areas of agricultural and urban land use and less extensive area in forest. The Coast Fork Willamette subbasin has more extensive forest land use than the other three subbasins.

Tualatin Subbasin

The Tualatin subbasin is the second most urbanized subbasin in the Willamette basin with nearly 27% of the stream length in urban land use (Table 7). The Tualatin subbasin contains a portion of the greater Portland metropolitan region including all or part of the cities of Beaverton, Hillsboro, Forest Grove, Tigard, Tualatin, and Lake Oswego.

The Tualatin subbasin had the 4th highest extent of stream length in disturbed biological condition for both aquatic vertebrates (37%) and aquatic macroinvertebrates (71%).

The overall stream habitat condition of the Tualatin subbasin indicated extensive stream length in undesirable condition for supporting aquatic life with undesirably high levels of fine sediment and low fish habitat complexity being the leading habitat stressors. The Tualatin subbasin ranked first among the 12 subbasins with the greatest extent of stream length disturbed by unstable streambeds (96%), excess fine sediment (81%) and riparian human disturbance (78%). The Tualatin subbasin also

had the greatest extent of stream length impaired by low levels of large woody debris habitat (50%) and had the second greatest extent of stream with low quality fish cover (35%).

We also found extensive water quality impairment in the Tualatin subbasin. The Tualatin subbasin had the greatest extent of stream length with poor to very poor OWQI scores, indicating overall impaired water quality condition for the subbasin. Leading water quality stressors included warm water temperatures, nutrient enrichment, and high total solids. Of the 12 subbasins, the Tualatin subbasin had the highest proportion of stream length impaired by low dissolved oxygen in the basin (41%), and the second highest extent of impairment for high levels of total solids (46%) and nutrient enrichment (more than 35%).

Yamhill Subbasin

The Yamhill subbasin had a moderate level of stream extent with impaired biological condition for aquatic vertebrates (17% in poor condition) and aquatic macroinvertebrates (63% in most disturbed condition).

Our survey indicated a moderately high level of habitat impairment. The Yamhill subbasin ranked second in greatest extent of stream length impaired by sparse riparian vegetation (53%) and third in impairment from unstable stream bottoms (49%) and low canopy (38%), and fourth for high levels of fine sediment (43%).

The Yamhill subbasin had a moderate level of water quality impairment compared to the 12 other subbasins with approximately 40% of the stream extent with excellent OWQI scores. Warm water temperature was the leading stressor impairing 37% of the stream extent in

the subbasin. The Yamhill subbasin ranked third in the extent of streams that passed the water quality temperature standard.

Upper Willamette Subbasin

The Upper Willamette subbasin has extensive agricultural land use (57% of the stream mile) as well as containing most of the Eugene-Springfield metropolitan area, Oregon's 3rd largest urban area (Proehl 2009).

The Upper Willamette subbasin had the second greatest extent of streams with most disturbed biological condition for both aquatic macroinvertebrates (78%) and aquatic vertebrates (50%), indicating a generally high level of stream overall impairment in the subbasin.

Sparse riparian vegetation and high levels of fine sediment were leading habitat stressors in the subbasin. Poor riparian vegetation conditions and low levels of stream shading affected 47% of the stream extent. Unstable stream bottoms and high levels of fine sediment affected 44% of the stream extent. The Upper Willamette subbasin had the second highest extent of streams with poor levels of canopy cover of the 12 Willamette subbasins.

Nearly one quarter of the stream miles in the Upper Willamette subbasin had poor to very poor OWQI scores indicating generally extensive water quality impairment. The overall water quality of Upper Willamette subbasin ranked the 4th worse of the 12 subbasins. Leading water quality stressors were excessively warm water temperatures (65%), low dissolved oxygen (32%) and high total solids (19%). Among the 12 subbasins, the Upper Willamette ranked the third most impaired for low dissolved oxygen and phosphorus enrichment (16%) and fourth for total solids.

Coast Fork Willamette Subbasin

The overall biological condition of the Coast Fork Willamette subbasin streams was good in comparison to the 12 Willamette subbasins. The Coast Fork Willamette ranked second in extent of streams in least impaired biological condition for aquatic macroinvertebrates (70%) and aquatic vertebrates (64%).

Table 7. Coast Range subbasins percent stream land use.

	Tualatin	Yamhill	U Willamette	CF Willamette
Agriculture (Total)	35.2	48.0	57.1	13.7
Cultivated Crops	18.6	18.6	16.4	2.9
Pasture/Hay	16.6	29.4	40.6	10.8
Forest (Total)	38.2	43.6	30.1	79.4
Public	8.0	10.4	5.5	36.3
Private	30.2	33.2	24.6	14.0
Industrial	10.7	19.7	15.6	31.7
Non-industrial	19.5	13.5	9.0	11.4
Urban (Total)	26.6	8.3	12.8	7.0
High/Medium	2.0	0.1	0.9	0.3
Low	7.1	0.8	3.4	0.7
Open Space	17.5	7.5	8.5	6.0

The general habitat quality was good in the Coast Fork Willamette subbasin. Leading stressors were low levels of large woody debris (28%) and low fish habitat complexity (15%). Although undesirably low levels of large woody

debris habitat were one of the leading habitat stressors, the Coast Fork Willamette ranked third in extent of streams with good levels of large woody debris in among the 12 subbasins. The Coast Fork Willamette subbasin had the largest proportion of stream extent with good levels of streambed stability (93%), riparian vegetation (79%) and stream canopy (62%) of the 12 subbasins.

The Coast Fork Willamette subbasin had fairly good overall chemical water quality with 92% of the stream extent with excellent to good OWQI scores, ranking fifth among the subbasins in extent of stream length in excellent to good water quality condition. High levels of total solids were the leading water quality stressor with 78% of the stream extent with poor to fair condition for total solids.

Valley Floor Subbasins

The four valley floor subbasins are more heavily urbanized and have more extensive agriculture than the other subbasins (Table 8). Some of the largest cities in Oregon are in these subbasins. The subbasins are at lower elevation, and have lower overall stream gradients than most of the other subbasins in this assessment. Unlike the other Willamette subbasins the Lower and Mid Willamette subbasins are not true watersheds where all precipitation that falls in the basin has the potential to pass through a single confluence.

Lower Willamette Subbasin

The Lower Willamette subbasin is the most downstream portion of the Willamette basin. It is the most extensively urbanized subbasin in this assessment with 51% in urban land use. Most of the greater Portland metropolitan region is in this subbasin. Portland, home to 570,000 people, is the largest city in the state

with 2.2 million people in the greater Portland metropolitan area (Proehl 2009).

The Lower Willamette subbasin had the third highest proportion of stream extent with most disturbed condition for aquatic macroinvertebrates (77%) and aquatic vertebrates (41%). Only the Mid and Upper Willamette subbasins exceeded the Lower Willamette in the extent of biologically impaired streams.

High fine sediment and poor quality fish habitat were the leading habitat impairments in the subbasin. The Lower Willamette subbasin ranked second of the 12 subbasins for extent of streams with unstable streambeds (62%) and high fine sediments (50%). It ranked third for extent of streams with high riparian human disturbance (60%) and highest for extent of stream length with low quality fish cover (39%).

The overall water quality in the Lower Willamette subbasin ranks second worse after the Tualatin subbasin in extent of stream length with poor to very poor OWQI scores. Temperature was the leading source of water quality impairment with 82% of the stream extent over temperature standard. Nutrient enrichment was also a major stressor in the subbasin with 50% of the stream extent with high total phosphorus and 22% with high total nitrogen. Impairment with high levels of total solids (24%) was also fairly extensive.

Mid Willamette Subbasin

The Mid Willamette subbasin is the most agricultural subbasin in the Willamette with 60% of the streams and river extent in agriculture, and the least forested with only 15% of the stream length in forested land uses. The subbasin is the third most urban in the Willamette basin and contains the City of

Salem, the state capitol and the second largest metropolitan area in the state.

Table 8. Valley floor subbasins percent stream land use.

	L Willamette	Mid Willamette	Molalla/Pudding	S Santiam
Agriculture (Total)	21.0	60.4	44.6	24.6
Cultivated Crops	10.2	20.6	16.1	9.7
Pasture/Hay	10.8	39.8	28.5	14.9
Forest (Total)	27.8	14.8	49.1	72.2
Public	5.8	1.3	12.1	29.1
Private	22.0	13.5	37.0	43.0
Industrial	10.8	3.7	19.0	37.3
Non-industrial	11.2	9.8	18.0	5.8
Urban (Total)	51.2	24.8	6.3	3.2
High/Medium	3.4	2.0	0.4	0.1
Low	7.8	5.9	1.4	0.5
Open Space	40.0	16.9	4.5	2.6

The Mid Willamette subbasin had the highest proportion of most disturbed stream length for aquatic macroinvertebrate condition (86%) and aquatic vertebrate condition (77%), indicating generally unhealthy streams for this subbasin.

Leading habitat impairments in the subbasin included the highest proportion of stream extent impaired by sparse riparian vegetation

(76%) and low stream canopy cover (65%). Low levels of large woody debris habitat impaired about 40% of the stream length. The Mid Willamette subbasin had the second highest proportion of stream length with poor riparian human disturbance (63%) of the 12 subbasins.

The overall water quality in the Mid Willamette subbasin was the third worse in terms of extent of stream length with poor to very poor OWQI scores. No randomly selected sites were found to have OWQI scores in the excellent category, the only subbasin where that occurred. Impairment from warm water temperatures was extensive with all of the random sites surveyed in the subbasin exceeding the temperature standard. The Mid Willamette subbasin had the highest extent of stream length impaired by total solids (46%). Nutrient enrichment was also a problem in the subbasin. Fair to poor levels of phosphorus occurred at 94% of the stream length and of nitrogen at 61% of the stream extent.

Molalla/Pudding Subbasin

The Molalla/Pudding subbasin ranked in the bottom half of the 12 subbasins for extent of streams with good biological condition for aquatic vertebrates (42%) and near the middle for extent of streams with good biological condition for aquatic macroinvertebrates (56%).

The most extensive water quality stressors in the Molalla/Pudding subbasin were warm water temperatures (87% poor), nitrogen enrichment (71% poor) and low dissolved oxygen (33% poor). The extent of streams impaired by these three stressors were significantly worse than at the estimated reference condition for the subbasin and among the most extensive of the 12 subbasins. Overall water quality for the Molalla/Pudding subbasin ranked near the

middle of the 12 subbasins with 52% of the stream length with excellent OWQI scores.

The overall extent of poor habitat conditions was fairly high in the Molalla/Pudding subbasin with 43% of the stream extent with poor riparian human disturbance. The most extensive impairment was from low levels of canopy cover (36%) and poor riparian vegetation condition (44%). Approximately 30% of the streams had high levels of fine sediment and 14% had poor streambed stability.

South Santiam Subbasin

The biological condition of the South Santiam subbasin ranked near the middle of the 12 subbasins with 46% of the stream extent in unimpaired condition for aquatic vertebrates and 50% in unimpaired condition for aquatic macroinvertebrates.

The most extensive stressors for habitat were low levels of large woody debris habitat (42%), low stream canopy cover (26%) and sparse riparian vegetation (17%). Human Disturbance Index scores for the South Santiam subbasin indicates that 84% of the stream extent had fair to poor levels of human disturbed riparian areas.

Overall water quality conditions in the South Santiam subbasin ranked near the middle of the 12 Willamette subbasins with 95% of the stream extent with excellent or good OWQI scores. The most extensive water quality stressor in the subbasin was warm water temperature impairing 46% of the extent of stream length.



Stonefly

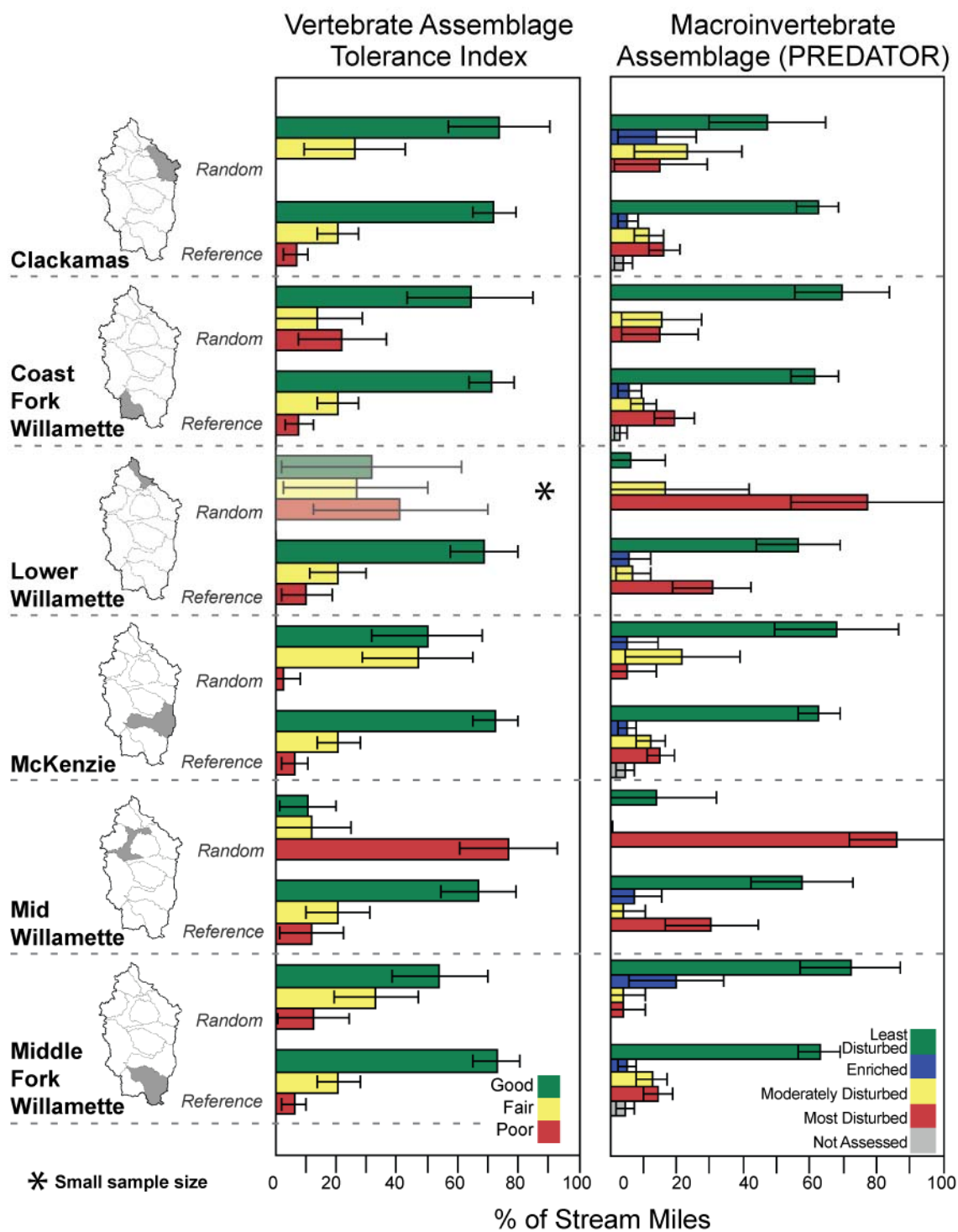


Figure 31. Biological conditions of subbasins: ATI and PREDATOR.

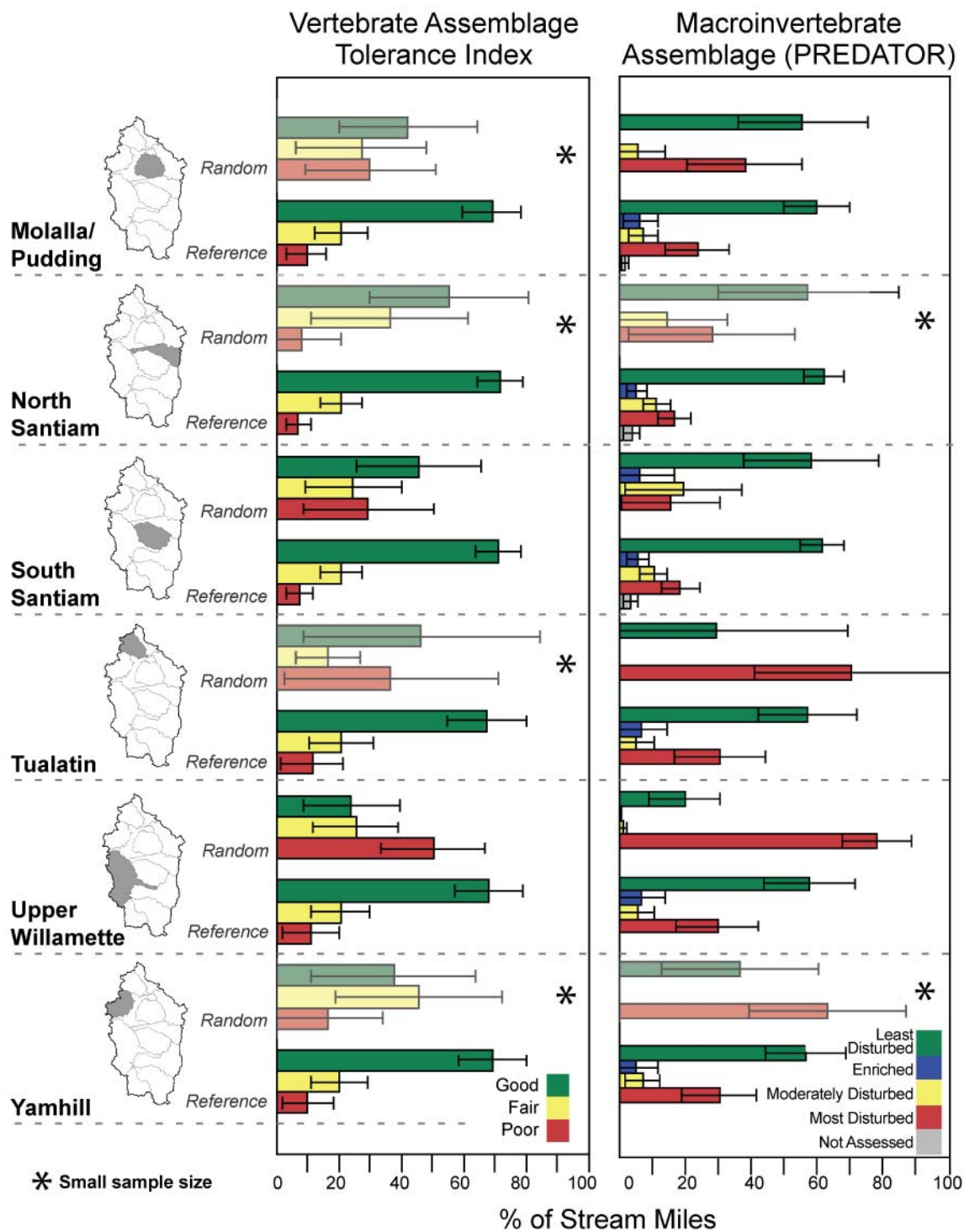


Figure 32. Biological conditions of subbasins: ATI and PREDATOR, continued.

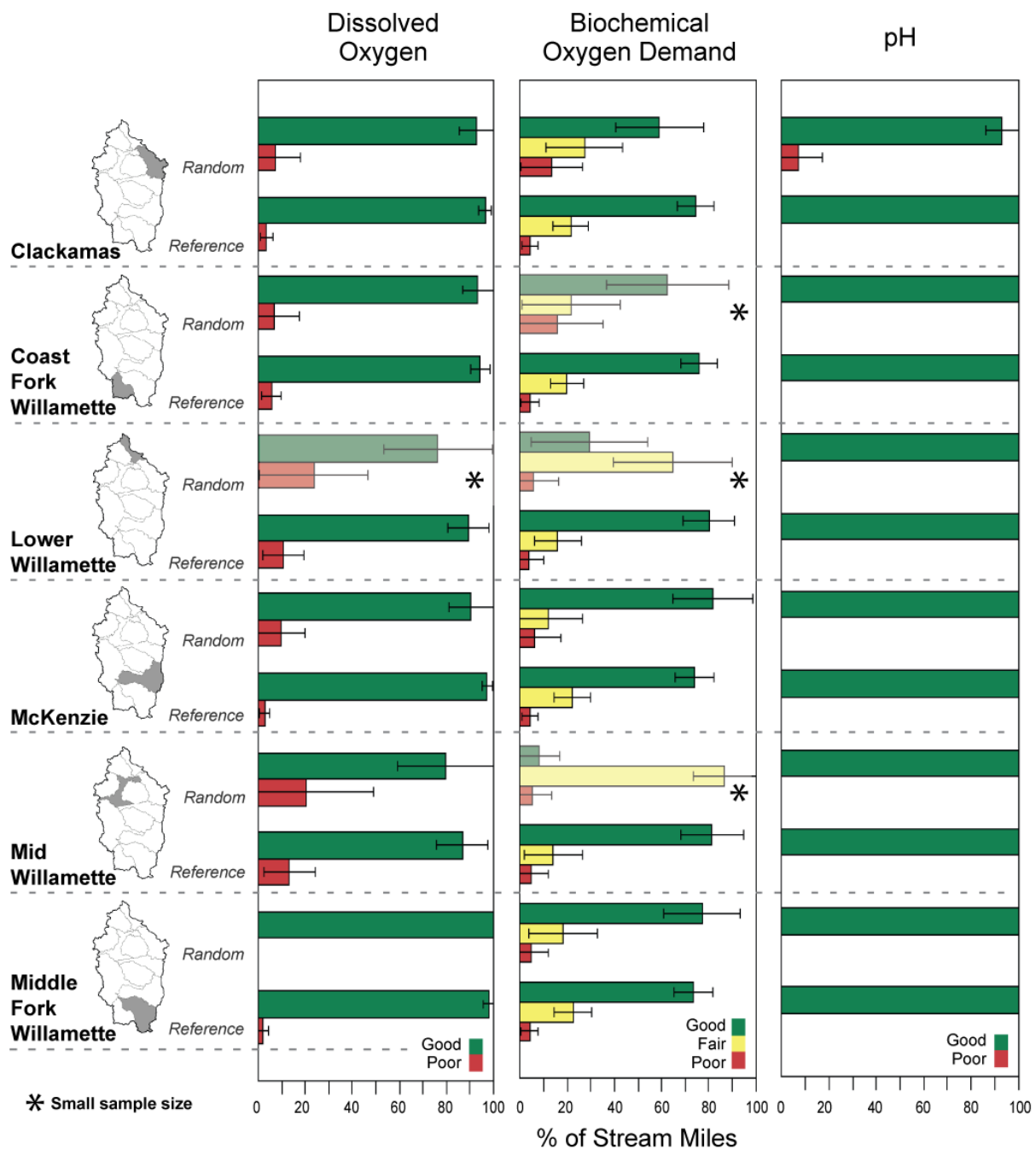


Figure 33. Water quality conditions of subbasins: dissolved oxygen, biochemical oxygen demand, pH.

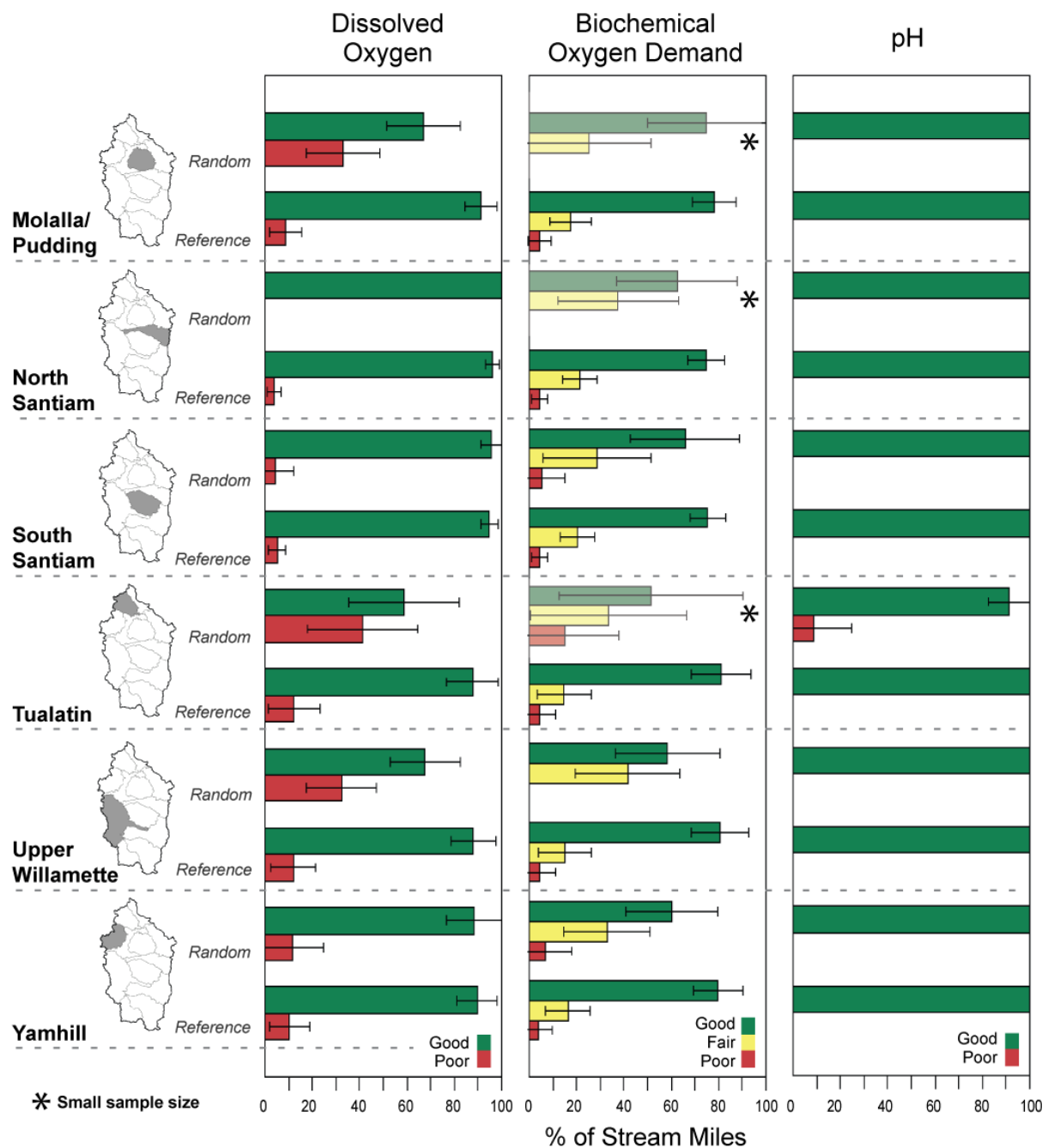


Figure 34. Water quality conditions of subbasins: dissolved oxygen, biochemical oxygen demand, pH, continued.

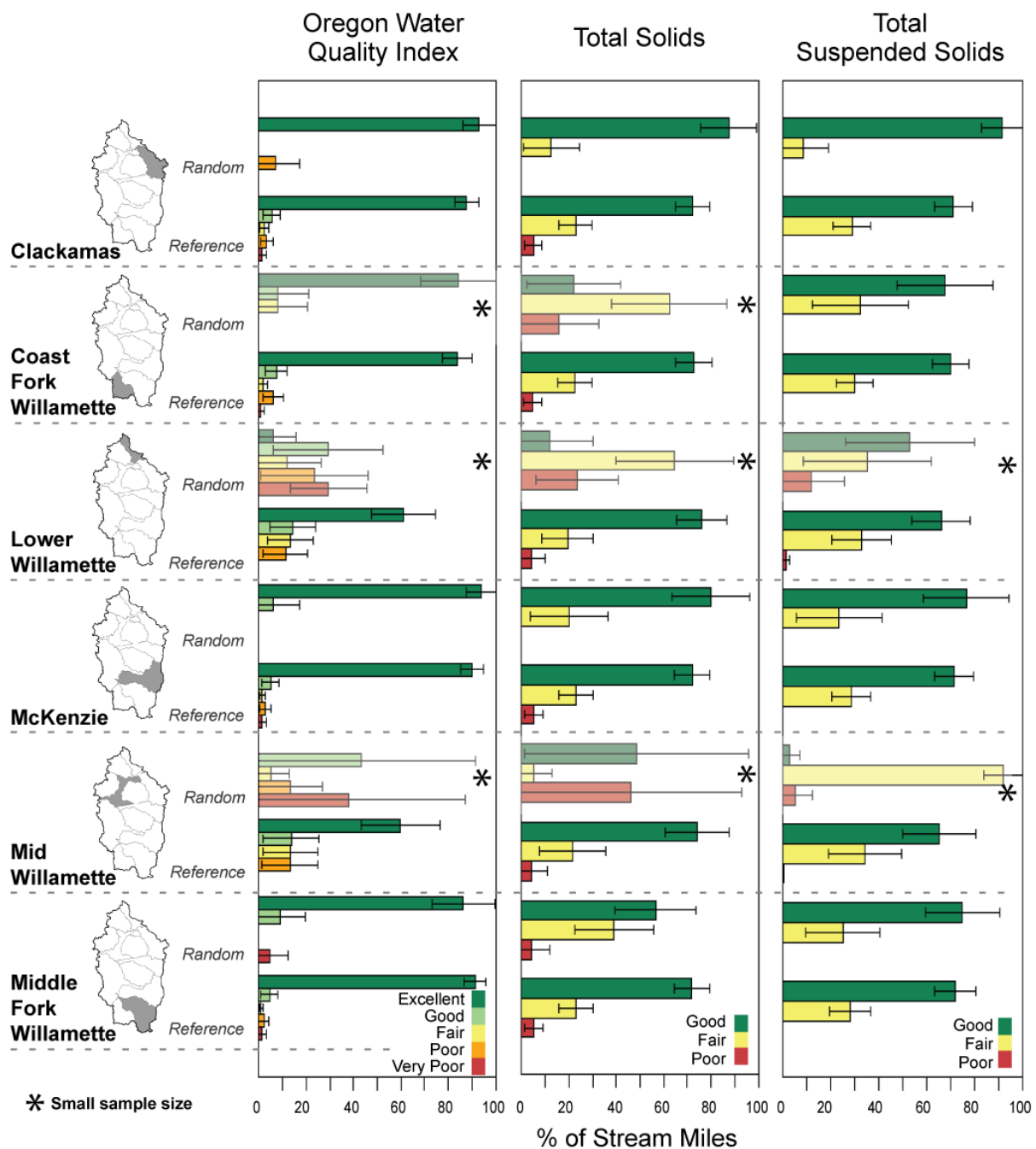


Figure 35. Water quality conditions of subbasins: Oregon Water Quality Index, total solids, total suspended solids.

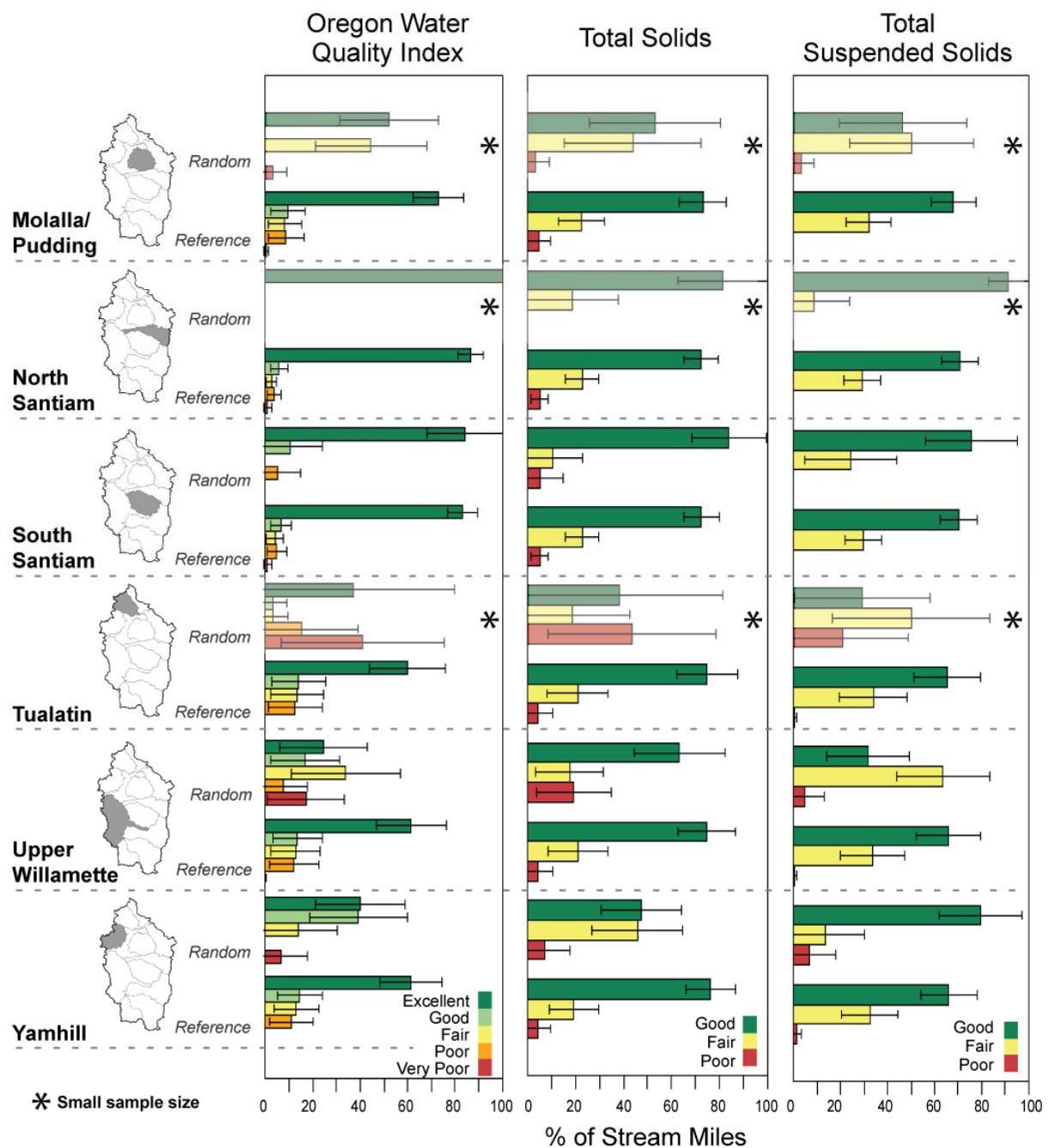


Figure 36. Water quality conditions of subbasins: Oregon Water Quality Index, total solids, total suspended solids, continued.

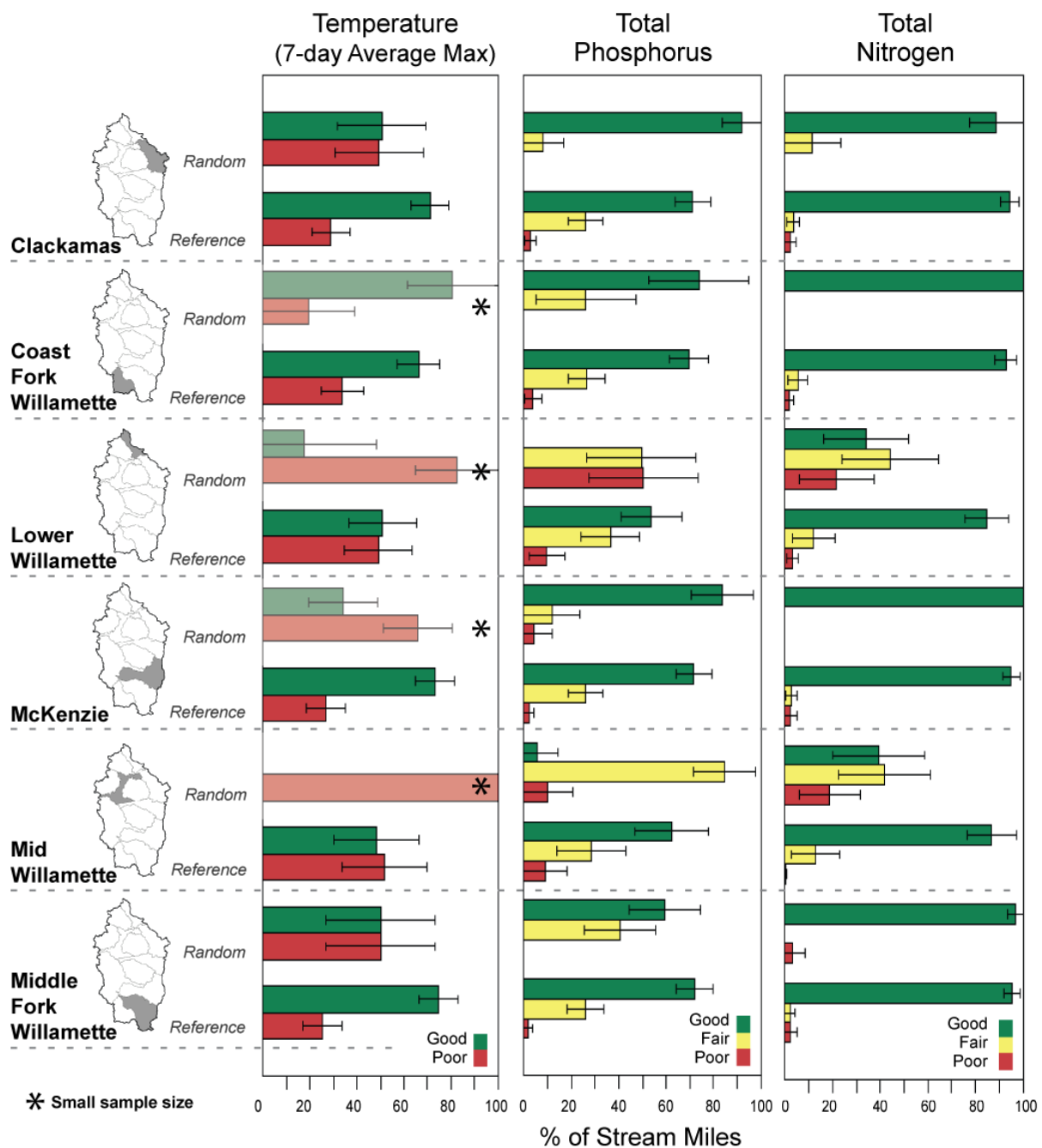


Figure 37. Water quality conditions of subbasins: temperature, total phosphorus, total nitrogen.

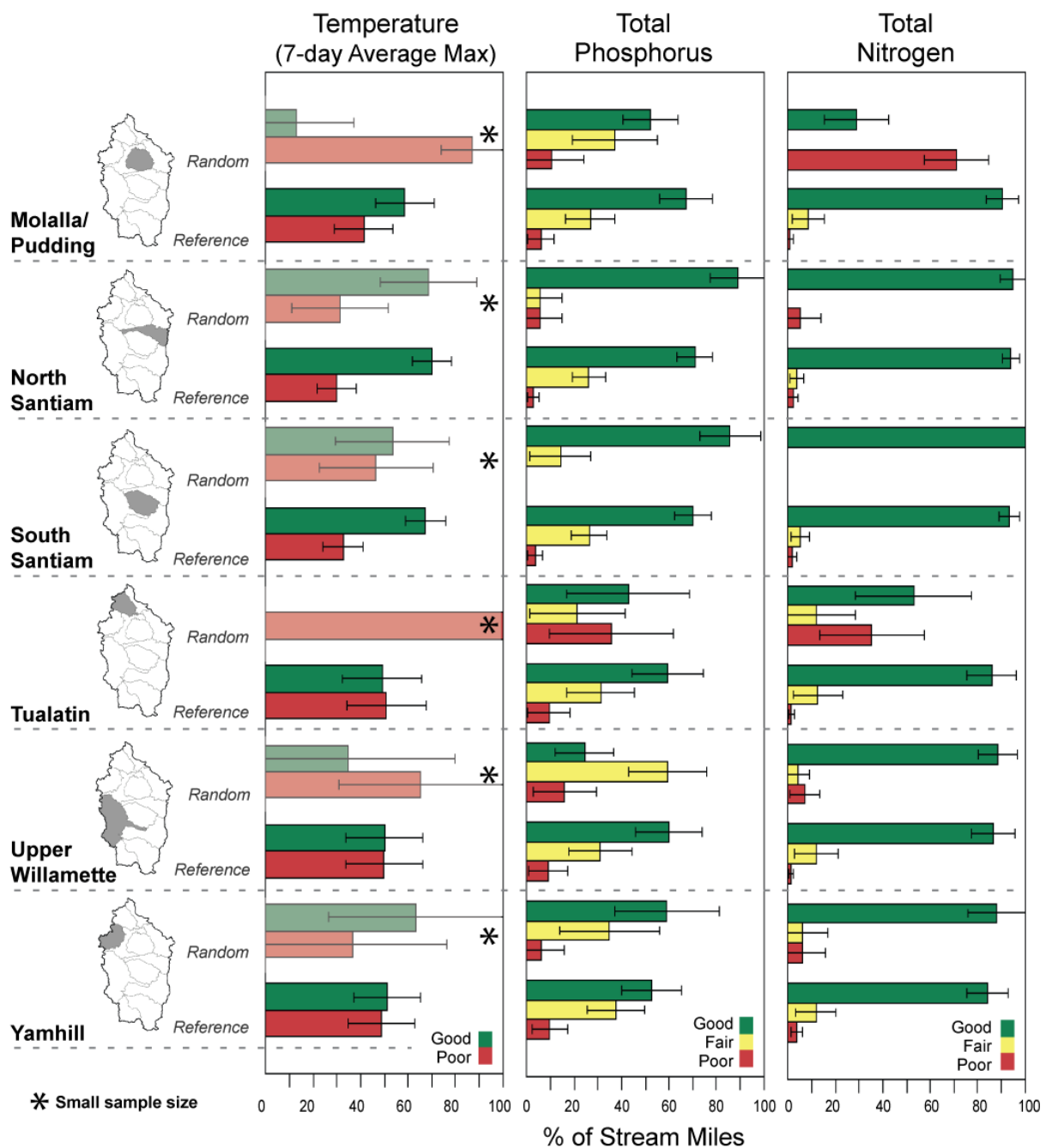


Figure 38. Water quality conditions of subbasins: temperature, total phosphorus, total nitrogen, continued.

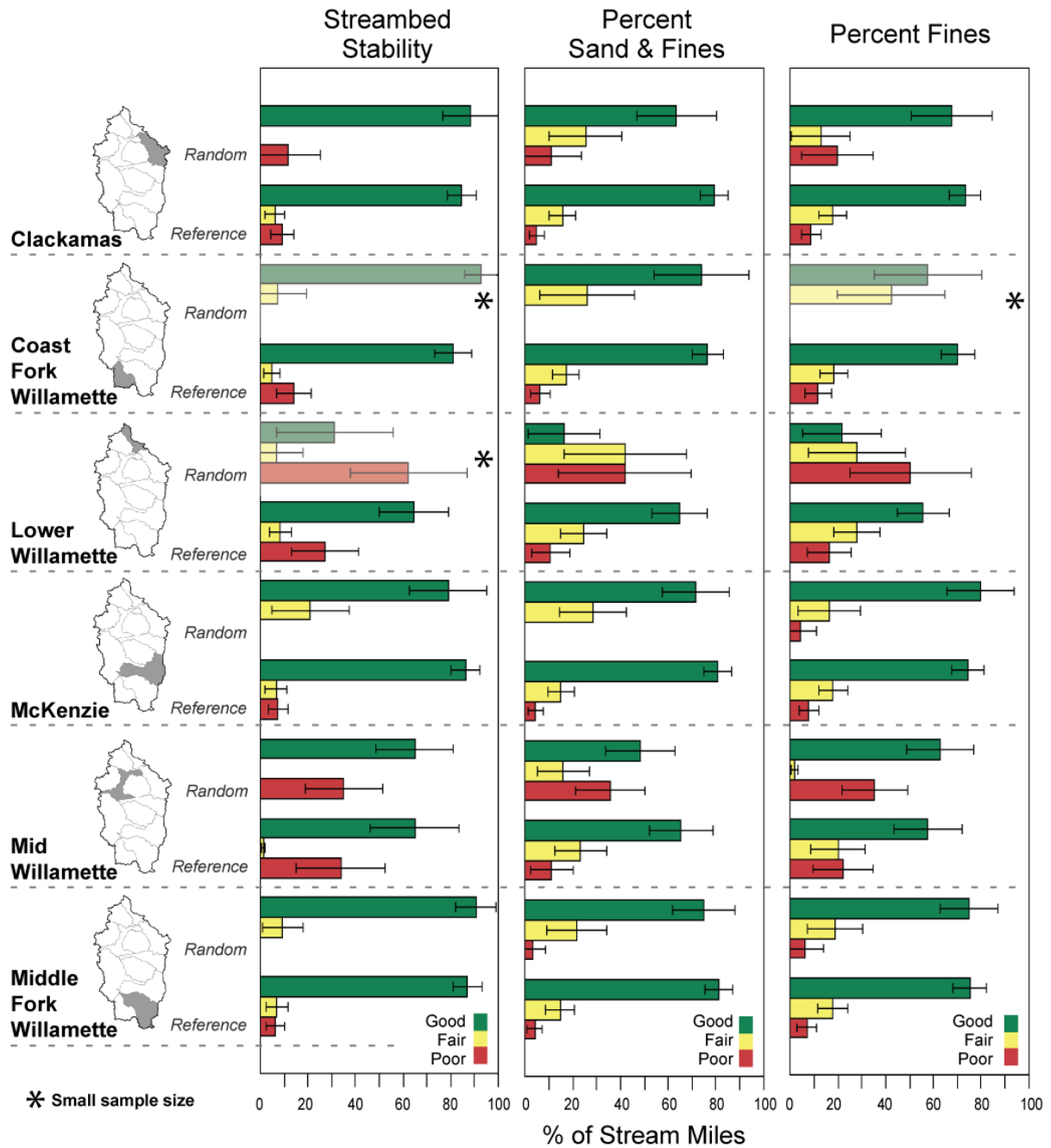


Figure 39. Water quality conditions of subbasins: streambed stability, percent sand and fine sediment, percent fine sediment.

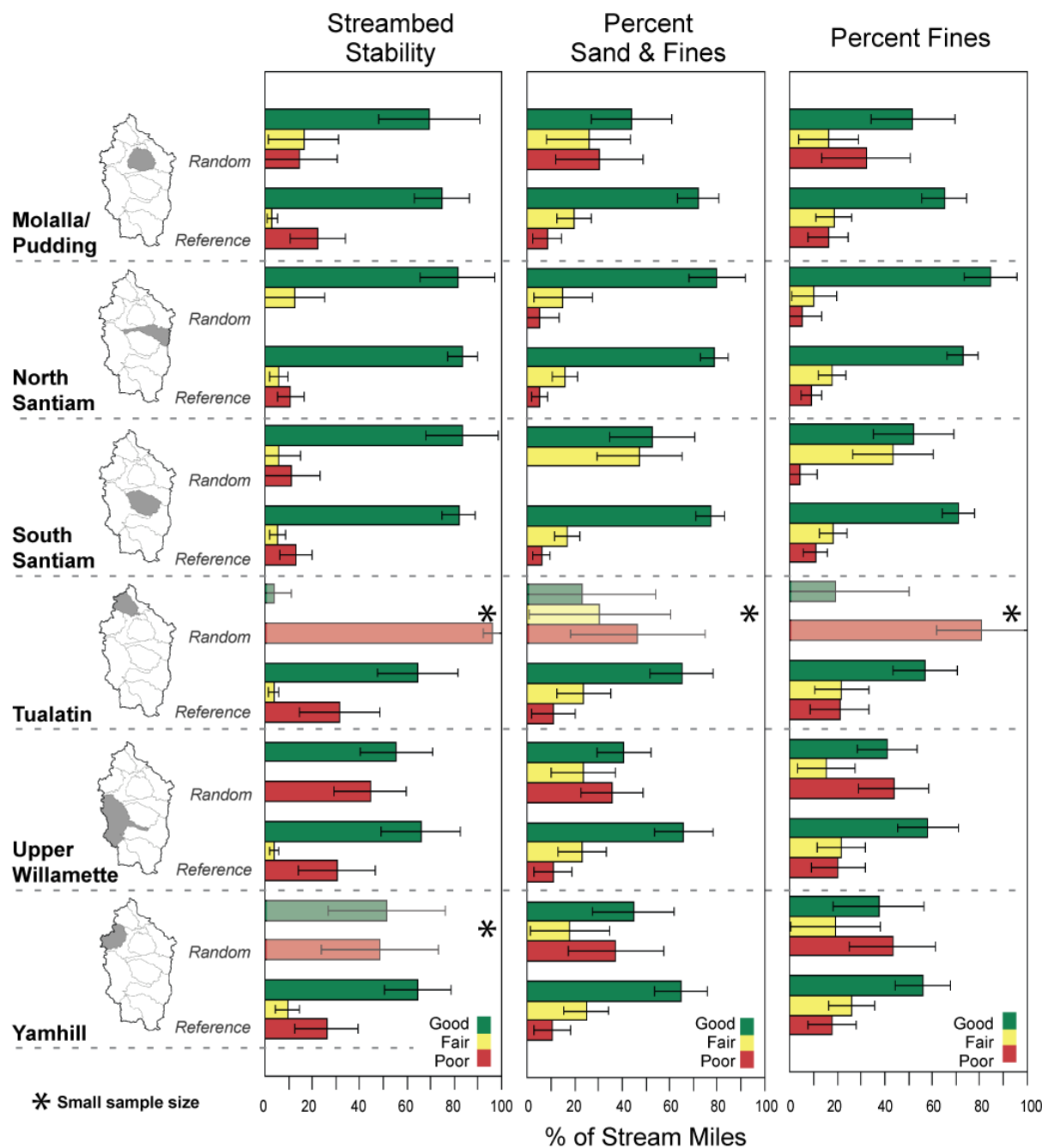


Figure 40. Water quality conditions of subbasins: streambed stability, percent sand and fine sediment, percent fine sediment, continued.

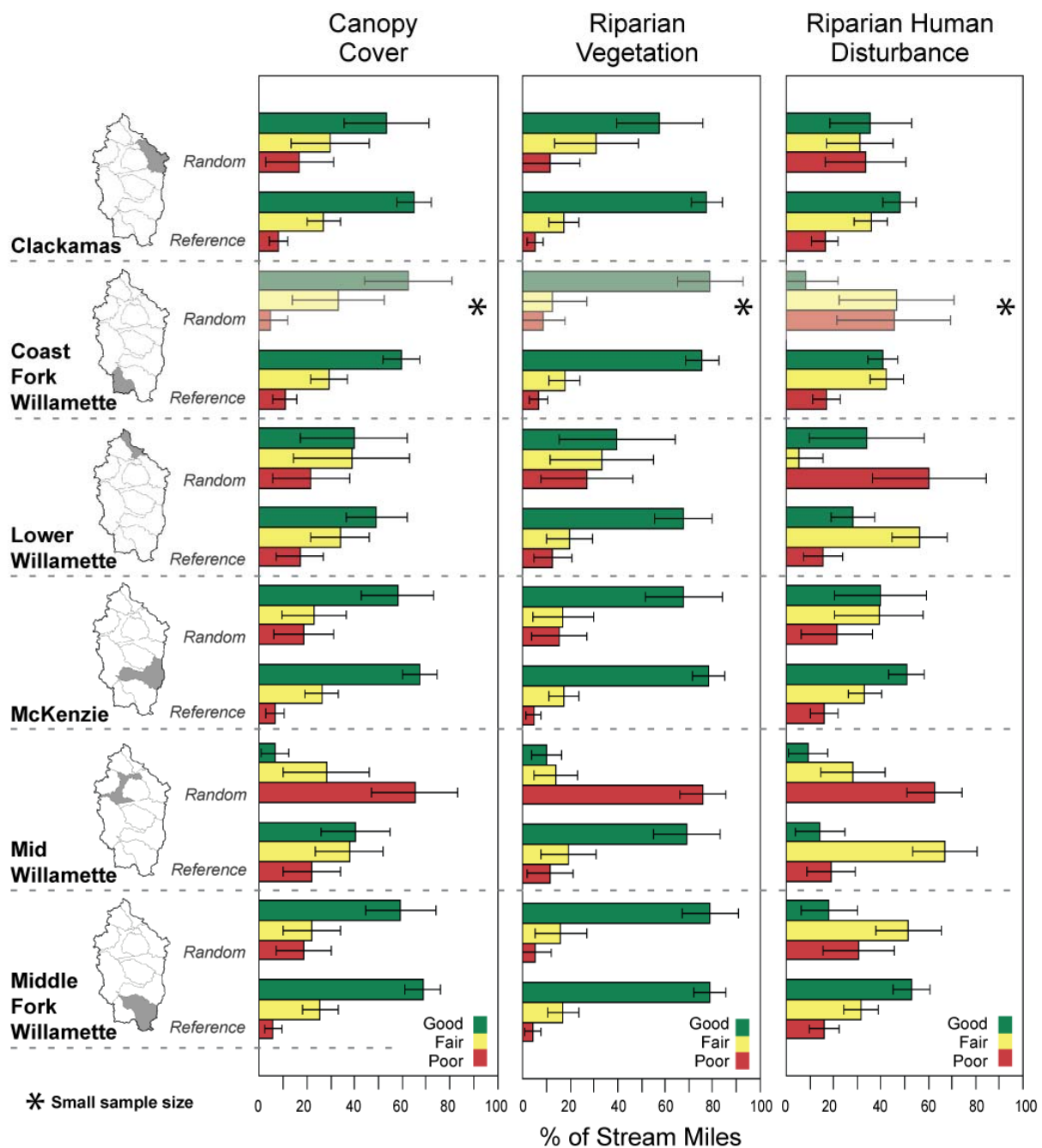


Figure 41. Habitat conditions of subbasins: canopy cover, riparian vegetation, riparian human disturbance.

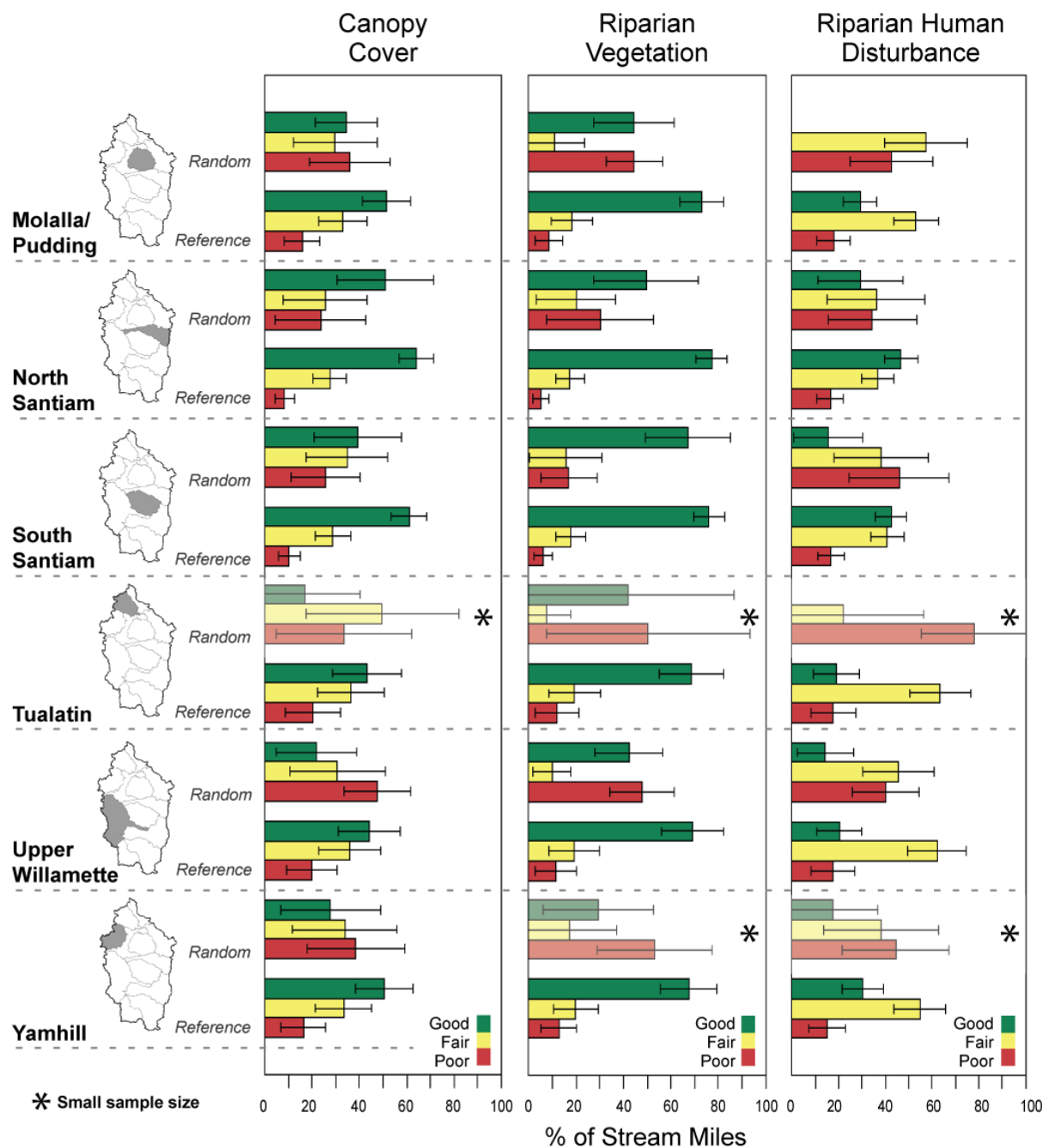


Figure 42. Habitat conditions of subbasins: canopy cover, riparian vegetation, riparian human disturbance, continued.

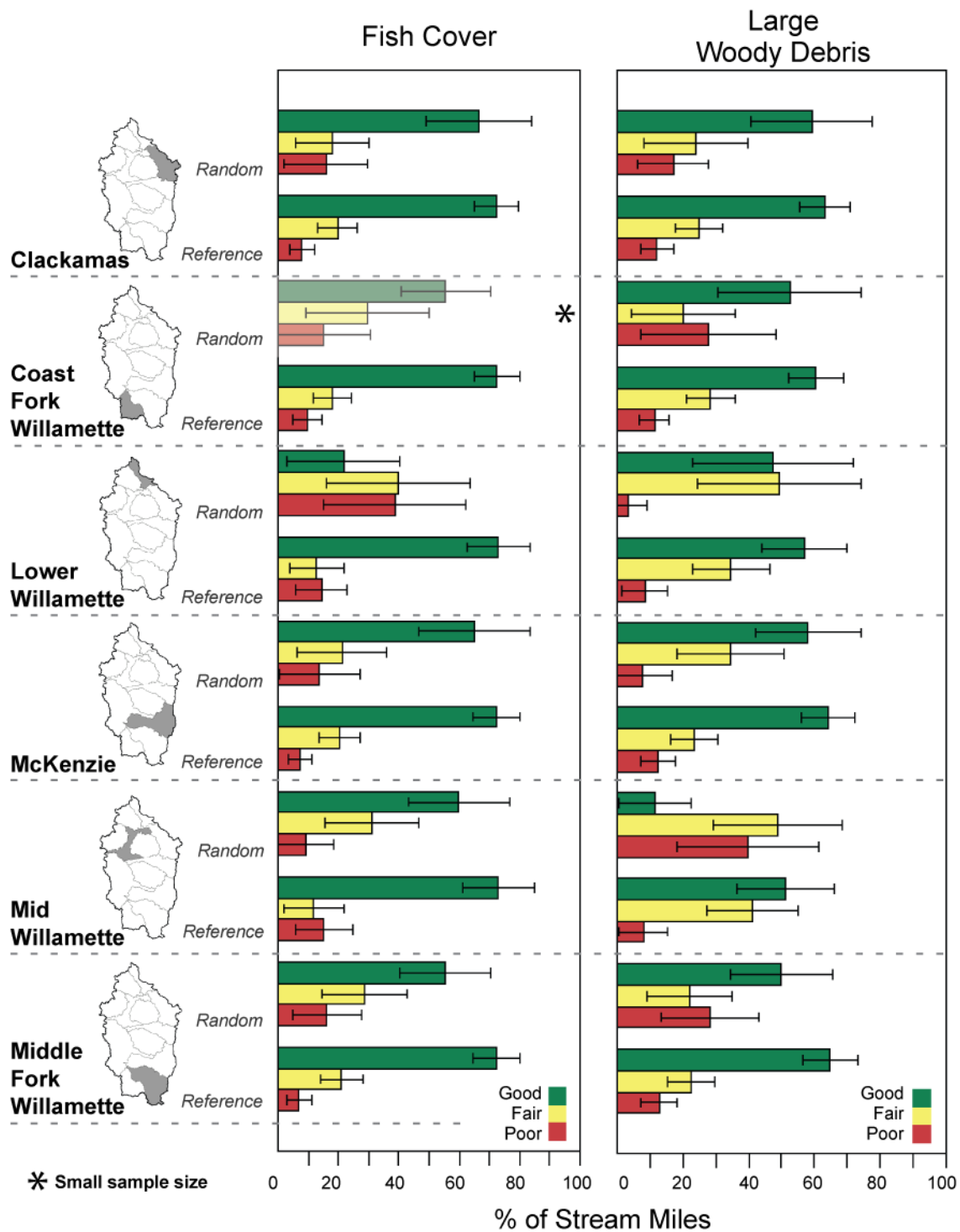


Figure 43. Habitat conditions of subbasins: fish cover, large woody debris.

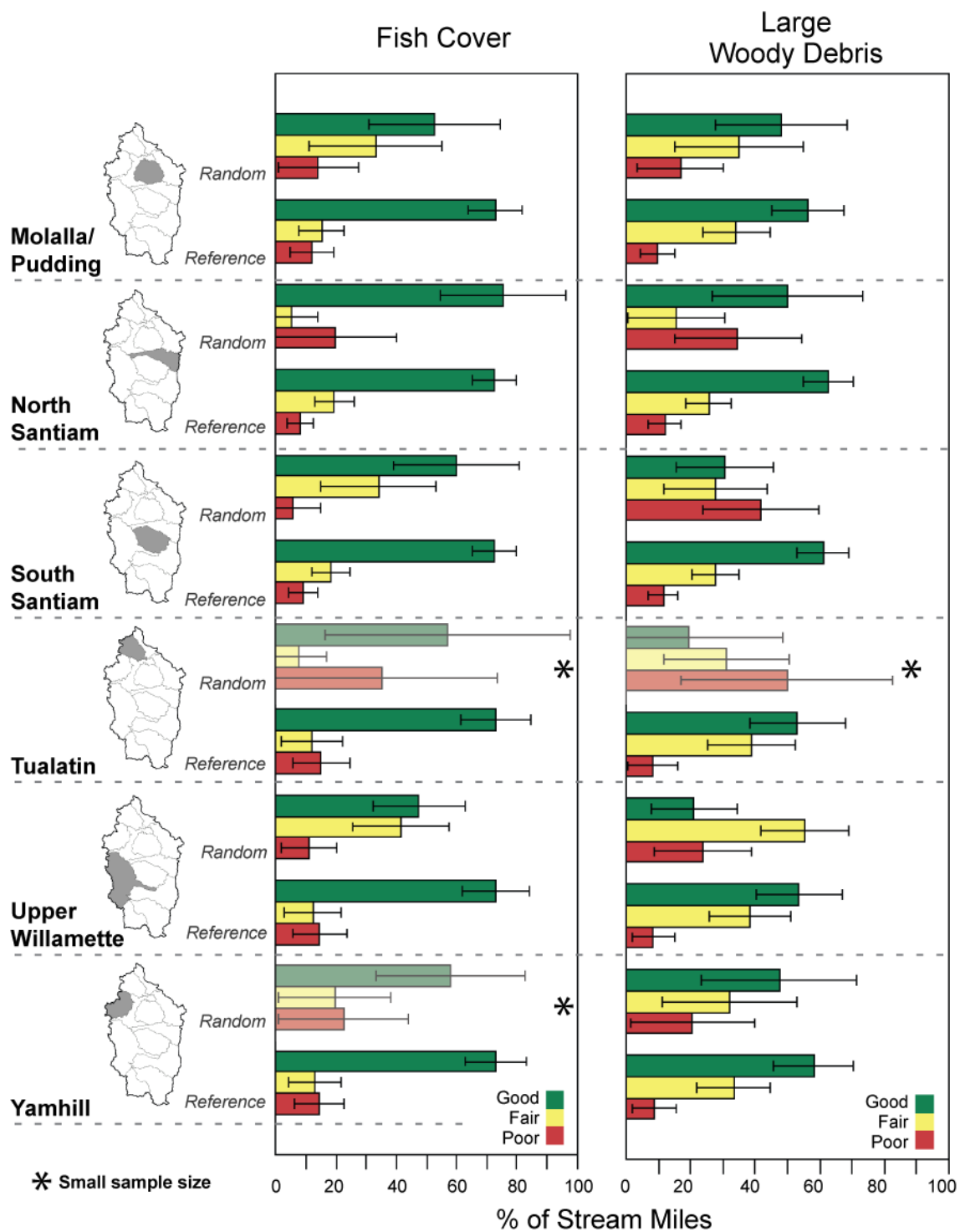


Figure 44. habitat conditions of subbasins: fish cover, large woody debris, continued.

References

- Drake, Douglas. 2004. *Selecting Reference Condition Sites: An Approach for Biological Criteria and Watershed Assessment*. Technical Report WAS04-002. Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Division. 3150 NW 229th, Suite 150, Hillsboro, OR 97124.
- Hubler, Shannon. 2008. *Predator: Development and use of RIVPACS-type macroinvertebrate models to assess the biotic condition of wadeable Oregon streams*. DEQ08-LAB-0048-TR. Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Division, 3150 NW 229th, Suite 150, Hillsboro, OR 97124.
- Thorsens, T.D., S.A. Bryce, D.A. Lammers, A.J. Woods, J.M. Omernik, J. Kagan, D.E. Pater, and J.A. Comstock. 2003. *Ecoregions of Oregon* (color poster with descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale: 1:1,500,000).
- DEQ. 2009. *Water Monitoring and Assessment Mode of Operations Manual, version 3.2*. DEQ03-LAB-Lab-0036-SOP. Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Division, 3150 NW 229th, Suite 150, Hillsboro, OR 97124.
- Kaufmann, P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck. 1999. Quantifying Physical Habitat in Wadeable Streams. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, DC.
- Peck, D.V., D.K. Averill, A.T. Herlihy, R.M. Hughes, P.R. Kaufmann, D.J. Klemm, J.M. Lazorchak, F.H. McCormick, S.A. Peterson, M.R. Cappaert, T. Magee, and P.A. Monaco. 2005. *Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operations Manual for Non-Wadeable Streams*. EPA/620/R-05/xxx. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.
- Peck, D.V., A.T. Herlihy, B.H. Hill, R.M. Hughes, P.R. Kaufmann, D.J. Klemm, J.M. Lazorchak, F.H. McCormick, S.A. Peterson, P.L. Ringold, T. Magee, and M.R. Cappaert. 2006. *Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operations Manual for Wadeable Streams*. EPA/620/R-06/003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.
- Proehl, Rita S. 2009. 2008 Oregon Population Report. Population Research Center, College of Urban and Public Affairs, Portland State University, Portland, OR 97207.
- Van Sickle, J., J. L. Stoddard, S.G. Paulsen, and A.R. Olsen (2006). Using relative risk to compare the effects of aquatic stressors at a regional scale. *Environmental Management* 38, 1020-1030
- Whittier, T.R., R.M. Hughes, G.A. Lomnický, and D.V. Peck. 2007. Fish and Amphibian Tolerance Values and Assemblage Tolerance Index for Streams and Rivers in the Western USA. *Transactions of the American Fisheries Society*. 136:254-271.

Appendix A: Setting Expectations: The Reference Condition Approach

From: Hubler, Shannon. 2007. *Wadeable Stream Conditions in Oregon. Pages 14-15.* DEQ07-LAB-0081-TR. Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Division, 3150 NW 229th, Suite 150, Hillsboro, OR 97124.

Selecting Reference Sites:

In order to make an assessment of stream condition, one must define what constitutes acceptable conditions for each indicator. The reference condition approach has been widely used to identify least-disturbed conditions and set expected values or benchmarks for specific parameters, especially for parameters without clearly defined standards or criteria. Least-disturbed conditions represent “the best of what’s left” for any given region. In some parts of Oregon much of the landscape is relatively undisturbed, while in other regions the landscape has been altered more extensively by human activities. Our expectations of what constituted a natural range for an indicator of stress were based on regional reference sites within Level III Ecoregions (Omernik 2004). Ecoregions combine elements of geology, climate, elevation, and vegetative communities. Similar physiographic and biological characteristics make Level III Ecoregion a useful scale for deriving benchmarks based on reference condition.

To achieve an adequate sample size within each Level III Ecoregion, we aggregated reference sites across Oregon, Washington, and Idaho where ecoregions crossed state boundaries. Each state used slightly different protocol for selecting reference sites, however each protocol was based on a set of defined criteria for identifying the lowest levels of human disturbance in a region. ODEQ methods screen prospective reference sites at the local (reach) and watershed scales for the lowest levels of human activities (Drake 2004). USEPA methods employed aerial photos at the watershed scale, as well as including chemical and physical screens for reference identification (Stoddard et al. 2005a). Idaho DEQ (Grafe 2004) and Washington DOE (Plotnikoff 2001) combine reference selection procedures similar to both ODEQ and USEPA. Besides hand-picked reference sites, random W-EMAP sites that met reference site screening criteria were also used as reference sites. The hand-picked reference sites were not used in making population estimates.

A total of 319 reference sites were used to establish indicator benchmarks (Table 1A) for the assessment of perennial wadeable streams in Oregon. We aggregated some Level III Ecoregions due to the low number of available reference sites in the individual Ecoregions and the basic similarity of the aggregated Ecoregions. The Columbia Plateau, Snake River Planes and Northern Basin and Range Ecoregions were aggregated.

Setting Assessment Benchmarks:

Oregon and other states set water quality standards and criteria to protect the beneficial uses of streams and rivers. For this assessment we used Oregon’s water quality standards to evaluate statewide conditions for those indicators with established numeric standards (dissolved oxygen, temperature, and pH; Table 1A).

When the standard was met, the water quality condition was considered “least disturbed”, and when the standard was not met, the water quality was considered “most disturbed”. For water quality and physical habitat indicators without a standard, we used reference site values to establish three classes of stream condition. Where increasing indicator values were associated with a declining biological indicator response, the upper 75th and 95th percentiles of reference values were used to distinguish “least disturbed” (<75th), “moderately disturbed” (75th -95th), and “most disturbed” (>95th) classes. Where decreasing indicator values were associated with a declining biological indicator response, the lower 5th and 25th percentiles of reference values were used to distinguish “least disturbed” (>25th), “moderately disturbed” (5th -25th), and “most disturbed” (<5th) classes. The 5th /25th and 75th /95th benchmarks are consistent with the benchmarks used in USEPA’s EMAP-West report (Stoddard et al. 2005).

References

- Drake, Doug. 2004. Selecting Reference Condition Sites – An Approach for Biological Criteria and Watershed Assessment. ODEQ Technical Report WASO4-002. Portland, OR
- Grafe, C.S. 2004. Selection of Reference Condition for Small Streams in Idaho: a Systematic Approach. Idaho Department of Environmental Quality. Boise, ID.
- Omernik J., T. Thorson, S.A. Bryce, D.A. Lammers, A.J. Woods, J. Kagan, D.U. Pater, and J.A.Comstock. (In press 2004) Ecoregions of Oregon.
- Plotnikoff, R.W. and C. Wiseman. 2001. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams. Washington State Department of Ecology. Publication: 01-03-028.
<http://www.ecy.wa.gov/biblio/0103028.html>
- Stoddard, J. L., D. V. Peck, S. G. Paulsen, J. Van Sickle, C. P. Hawkins, A. T. Herlihy, R. M. Hughes, P. R. Kaufmann, D. P. Larsen, G. Lomnický, A. R. Olsen, S. A. Peterson, P. L. Ringold, and T. R. Whittier. 2005a. An Ecological Assessment of Western Streams and Rivers. EPA 620/R-05/005, U.S. Environmental Protection Agency, Washington, DC.
- Stoddard, J. L., D. V. Peck, A. R. Olsen, D. P. Larsen, J. Van Sickle, C. P. Hawkins, R. M. Hughes, T. R. Whittier, G. Lomnický, A. T. Herlihy, P. R. Kaufmann, S. A. Peterson, P. L. Ringold, S. G. Paulsen, and R. Blair. 2005b. Environmental Monitoring and Assessment Program (EMAP): Western Streams and Rivers Statistical Summary. EPA 620/R-05/006, U.S. Environmental Protection Agency, Washington, DC.

Table 1A: Benchmarks

Ecoregion	Coast Range N=82		Willamette Valley + Puget Lowlands (pre 2009) N=8 WV + 2 PLL		Willamette Valley (2009) N=24		Cascades N=110		East Cascades N=21		Blue Mountains N=47		Klamath Mountains N=28		Columbia Plateau + Northern Basin and Range + Snake River Plains N=7		Basis
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor	
Conductivity	< 94	> 160	< 102	> 235	< 93	> 137	< 58	> 102	< 101	> 195	< 75	> 212	< 174	> 217	< 104	> 136	75th and 95th reference percentile
Turbidity	< 1	> 6	< 5	> 30	< 6	> 22	< 1	> 2	< 1	> 2	< 1	> 2	< 1	> 3	< 4	> 13	75th and 95th reference percentile
Total Suspended Solids	< 2	> 9	< 4	> 26	< 6	> 21	< 1	> 66	< 3	> 9	< 2	> 5	< 1	> 10	< 7	> 23	75th and 95th reference percentile
Total Solids (mg/L)	< 69.9	> 116.4			< 94.6	> 152.0	< 52.0	> 76.5	< 90.3	> 108.6	< 95.5	> 307.5	< 94.1	> 139.2	< 103.0	> 118.5	75th and 95th reference percentile
Sulfate	< 6.5	> 10.6	< 2.8	> 9.4	< 2.3	> 5.7	< 2.5	> 17.2	< 1.2	> 3.5	< 3.1	> 5.4	< 4.8	> 23.2	< 2.1	> 4.1	75th and 95th reference percentile
Total Phosphorus	< 0.020	> 0.040	< 0.040	> 0.110	< 0.053	> 0.129	< 0.030	> 0.066	< 0.040	> 0.100	< 0.031	> 0.065	< 0.030	> 0.060	< 0.044	> 0.069	75th and 95th reference percentile
Dissolved Ortho Phosphorus (mg/L)	< 0.016	> 0.047			< 0.037	> 0.068	< 0.019	> 0.037	< 0.033	> 0.063	< 0.042	> 0.054	< 0.013	> 0.025	< 0.043	> 0.054	75th and 95th reference percentile
Chloride	< 5.9	> 14.0	< 5.3	> 6.1	< 4.08	> 5.93	< 1.1	> 3.3	< 1.0	> 3.0	< 0.5	> 1.5	< 3.3	> 36.0	< 1.5	> 3.8	75th and 95th reference percentile
Total Nitrogen (mg/L)	< 0.570	> 0.855	< 0.429	> 0.646	< 0.344	> 0.505	< 0.260	> 0.318	< 0.260	> 0.524	< 0.244	> 0.284	< 0.261	> 0.340	< 0.255	> 0.399	75th and 95th reference percentile
Total Inorganic Nitrogen (mg/L)	< 0.340	> 0.914			< 0.251	> 0.356	< 0.250	> 0.356	< 0.047	> 0.107	< 0.045	> 0.093	< 0.054	> 0.190	< 0.218	> 0.283	75th and 95th reference percentile
Biological Oxygen Demand (mg/L)	< 1.00	> 1.88			< 1.01	> 3.00	< 0.50	> 1.20	< 1.00	> 1.13	< 0.53	> 1.10	< 0.60	> 1.32	< 0.61	> 0.96	75th and 95th reference percentile
Vertebrate Assemblage Tolerance Index	< 2.66	> 3.28			< 3.31	> 3.65	< 1.77	> 2.90	< 2.00	> 2.60	< 2.10	> 2.30	< 1.91	> 2.74	< 2.47	> 3.69	75th and 95th reference percentile
Macroinvertebrate Assemblage	Benchmarks based on Level 2 Ecoregions provided in Hubler, 2008.																
pH	pH standard Oregon Administrative Rules, OAR 340-041-0021: Good = 6.5 to 8.5, Poor = < 6.5 or > 8.5																numeric standards
Temperature	Temperature standard based on fish use. See Oregon Administrative Rules: OAR 340-041-0025. 12° C for bull trout spawning and juvenile rearing habitat; 13° C for salmon and steelhead spawning habitat; 16° C for core cold water habitat; 18° C for salmon																numeric standards
Dissolved Oxygen	Dissolved oxygen standard based on fish use. See Oregon Administrative Rules: OAR 340-041-0016. 8.0mg/L or 90% of saturation in most waters, 11.0 mg/L or 95% of saturation in bull trout spawning habitat (upper McKenzie and upper Middle Fork Willamette).																numeric standards
Vegetative Cover (XPCMG)	1.00	< 0.73	> 0.96	< 0.95	> 0.97	< 0.92	> 0.95	< 0.68	> 0.91	< 0.77	> 0.8	< 0.05	1.00	< 0.32	> 0.55	0.00	5th and 25th reference percentile
Canopy Cover, mid (XDCENMID)	> 80	< 30	> 95	< 69	> 98	< 92	> 71	< 48	> 63	< 37	> 22	< 3	> 71	0	> 47	< 1	5th and 25th reference percentile
Canopy Cover, bank-large rivers only (XDCENBK)	> 85	< 70			> 91	< 77	> 89	< 77	> 86	< 68	> 57	< 26	> 85	< 68	> 70	< 40	5th and 25th reference percentile
Habitat Complexity (FC_BIG)	> 0.25	< 0.14	> 0.15	< 0.05	> 0.14	< 0.04	> 0.35	< 0.2	> 0.25	< 0.12	> 0.22	< 0.04	> 0.41	< 0.05	> 0.2	< 0.08	5th and 25th reference percentile
Relative Bed Stability (LRBS_BW5)	> -0.8	< -1.8	> -0.7	< -0.7	> -0.9	< -3.4	> -0.9	< -1.7	> -1.2	< -1.8	> -1.3	< -1.5	> -0.4	< -0.6	> -2	< -2.9	5th and 25th reference percentile
Large Woody Debris (VT1_100)	> 6.7	0.0	> 13.9	< 0.4	> 3.8	< 0.6	> 18	< 4.7	> 8.4	0.0	> 3	0.0	> 0.1	0.0	> 0.4	0.0	5th and 25th reference percentile
Fast Water Habitat	> 35	< 25	> 51	< 23			> 47	< 19	> 64	< 36	> 59	< 27	> 57	< 12	> 55	< 20	5th and 25th reference percentile
Embeddedness	< 51	> 82	< 55	> 78			< 39	> 65	< 63	> 81	< 47	> 70	< 49	> 52	< 63	> 87	75th and 95th reference percentile
All Disturbances (W1HALL)	< 0.7	> 1.6	< 1.3	> 2.3	< 1.5	> 2.7	< 0.1	> 0.9	< 0.7	> 1.1	0.0	> 1.8	< 1.2	> 1.4	< 1	> 1.5	75th and 95th reference percentile
Agricultural Disturbances	0.0	> 0	0.0	> 0.4			0.0	> 0	0.0	> 0.7	0.0	> 0.5	0.0	> 0	< 0.7	> 1.5	75th and 95th reference percentile
% Fines (PCT_FN)	< 7	> 38	< 11	> 18	< 18	> 90	< 5	> 17	< 13	> 19	< 11	> 22	< 3	> 7	< 23	> 63	75th and 95th reference percentile
% Sand/Fines (PCT_SAFN)	< 24	> 45	< 27	> 50	< 33	> 90	< 13	> 45	< 28	> 44	< 22	> 31	< 7	> 31	< 30	> 71	75th and 95th reference percentile
Slow Water Habitat	< 63	> 75	< 49	> 77			< 51	> 68	< 36	> 64	< 41	> 73	< 41	> 49	< 45	> 80	75th and 95th reference percentile
Residual Pools	> 5	< 2.1	> 9.4	< 4.5			> 4.5	< 1.1	> 4	< 2.5	> 4.6	< 0.6	> 4	< 0.3	> 6.4	< 0.9	5th and 25th reference percentile

Appendix B: Sample Size

	Sub Basins												Land Use												Willamette Basin Total
	Clackamas	CF_Willamette	Lwr_Willamette	McKenzie	Mid_Willamette	WF_Willamette	Molalla_Pudding	N_Santiam	S_Santiam	Tualatin	Up_Willamette	Yamhill	Agriculture: All	Agriculture: Cultivated Crops	Agriculture: Pasture Hay	Forest: All	Public Forest	Private Forest	Private Industrial Forest	Private Non-Industrial Forest	Urban: All	Urban: Med/High Intensity	Urban: Low Intensity	Urban: Open Space	
Macroinvertebrates	23	15	33	19	66	27	16	12	21	25	124	14	93	23	70	155	97	58	41	17	147	26	58	63	395
Vertebrates	19	16	14	18	22	24	13	12	21	12	37	10	59	23	36	113	81	32	26	6	46	8	18	20	218
Chemistry																									
Biochemical Oxygen Demand	22	13	14	15	13	22	12	10	16	12	19	15	30	12	18	109	75	34	26	8	44	7	18	19	183
Oregon Water Quality Index	22	13	14	16	13	22	12	10	16	12	19	15	30	12	18	110	76	34	26	8	44	7	18	19	184
Total Solids	22	13	14	15	13	23	12	10	17	12	20	15	32	12	20	110	76	34	26	8	44	7	18	19	186
Total Suspended Solids	23	15	14	17	14	24	13	11	17	12	22	15	37	13	24	116	82	34	26	8	44	7	18	19	197
Dissolved Oxygen	25	17	14	22	15	29	16	17	21	15	27	18	49	15	34	142	102	40	30	10	45	7	19	19	236
Total Nitrogen	25	16	15	22	26	32	17	18	21	15	40	17	73	29	44	140	100	40	30	10	51	7	24	20	264
Total Phosphorus	24	16	15	23	26	32	17	17	21	15	40	17	73	29	44	139	99	40	30	10	51	7	24	20	263
pH	25	16	15	23	26	31	17	18	21	15	40	17	73	29	44	140	100	40	30	10	51	7	24	20	264
Temperature	15	8	5	12	7	15	6	12	12	4	5	6	17	6	11	75	62	13	10	3	15	1	6	8	107
Habitat																									
Streambed Stability	21	12	13	19	59	23	15	15	18	9	30	12	51	21	30	112	81	31	25	6	83	17	37	29	246
Fish Cover	22	13	15	23	68	29	17	18	19	10	33	14	61	24	37	130	94	36	28	8	90	20	40	30	281
Human Disturbance	22	14	15	23	68	29	18	18	19	10	35	14	65	25	40	130	97	36	28	8	90	20	40	30	285
Riparian Vegetation	22	14	15	23	68	29	18	18	19	10	35	14	65	25	40	130	94	36	28	8	90	20	40	30	285
Percent Sand and Fine Sediment	23	15	15	24	68	33	20	18	23	12	38	15	67	27	40	147	103	44	35	9	90	20	40	30	304
Canopy Cover	23	14	15	25	69	33	20	18	23	12	38	15	68	27	41	147	103	44	35	9	90	20	40	30	305
Percent Fine Sediment	23	14	15	24	68	33	19	18	23	12	36	15	63	26	37	147	103	44	35	9	90	20	40	30	300
Large Woody Debris	23	15	15	25	69	33	20	18	23	12	38	15	68	27	41	148	104	44	35	9	90	20	40	30	306

Appendix C: Relative Risk: evaluating stressor importance

The extent (% of stream miles) to which an indicator of stream condition exceeds certain benchmarks or standards is one way to assess what parameters are degrading stream condition. Another way is to evaluate the risk a parameter poses to different biological assemblages, in this case macroinvertebrates or fish and amphibians. How can we assess the relative importance of the impairment created by a given stressor? To assess the risk a parameter poses to these assemblages, we have calculated the “relative risk” of specific habitat and chemistry parameters. It measures the likelihood that the biological condition will be impaired if the condition of an indicator is also poor.

Relative risk is an approach commonly used to communicate medical and health information such as the risk of smokers versus non-smokers of getting lung cancer. It is a useful tool for summarizing complex information and relationships in an easy to understand format. Relative risk can be defined as the probability of some poor outcome (getting a disease or degraded biological assemblage) when a poor stressor is present (smoking or poor streambed stability), divided by the probability of the poor outcome when the poor stressor condition is absent (Van Sickle, et al, 2006).

In the following hypothetical example calculation of the risk of poor streambed stability to the macroinvertebrate community the fair stressor condition and moderately disturbed macroinvertebrate condition are not used.

Estimated Stream Length (kilometers)		Stressor = Streambed Stability		Total
		Good condition	Poor Condition	
Macroinvertebrate Community Response	Most disturbed	2,000	8,000	10,000
	Least Disturbed	9,000	1,000	10,000
Total		11,000	9,000	20,000

$$\begin{aligned}\text{Relative Risk} &= \frac{\text{Probability of Most Disturbed Biological Condition with Poor Streambed Stability}}{\text{Probability of Most Disturbed Biological Condition with Good Streambed Stability}} \\ &= \frac{8,000/9,000}{1,000/10,000} = \frac{0.89}{0.10} = 8.9\end{aligned}$$

This means that streams with poor streambed stability are nearly 9 times more likely to have most disturbed aquatic macroinvertebrates than streams with good streambed.

Large relative risk values for a parameter mean that the chances of having poor biotic condition are high when that parameter exceeds a certain threshold. For these analyses parameters with a relative risk value greater than 1.5, and where the 95% confidence interval is greater than 1.0, are considered significant. Relative risk values of 1.0 or less indicate no parameter effect or risk.