Aquatic Life

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Introduction

This section evaluates effects of the alternative scenarios on the biota and habitat of Willamette Basin streams, specifically all 2nd to 4th order streams (Fig. 146, also p. 17). In general, these are the streams that are small enough to safely wade across during summer, yet big enough to maintain year-round flow. There are 4,024 miles (6,476 km) of 2nd to 4th order streams, accounting for 30% of the total length of streams and rivers in the basin. First order streams, averaging 3 m in width, are the smallest of the wadeable streams, and are not included in these evaluations. They are so numerous (almost 8,000 miles, or 60% of the basin total stream network length) that the logistics of evaluating them were beyond the scope of this study.

The characteristics of streams in the basin vary widely, from the low-gradient, slow-moving streams with fine, clay-sand substrate common in the Lowlands (Fig. 147) to those in the Uplands that typically have steeper gradients, faster flow, colder temperatures, and larger (gravel, boulder) substrates (Fig. 148). Different types of biota have adapted to live in these very different physical environments. As a result, our analyses generally distinguish between Lowland and Upland streams (Fig. 146).

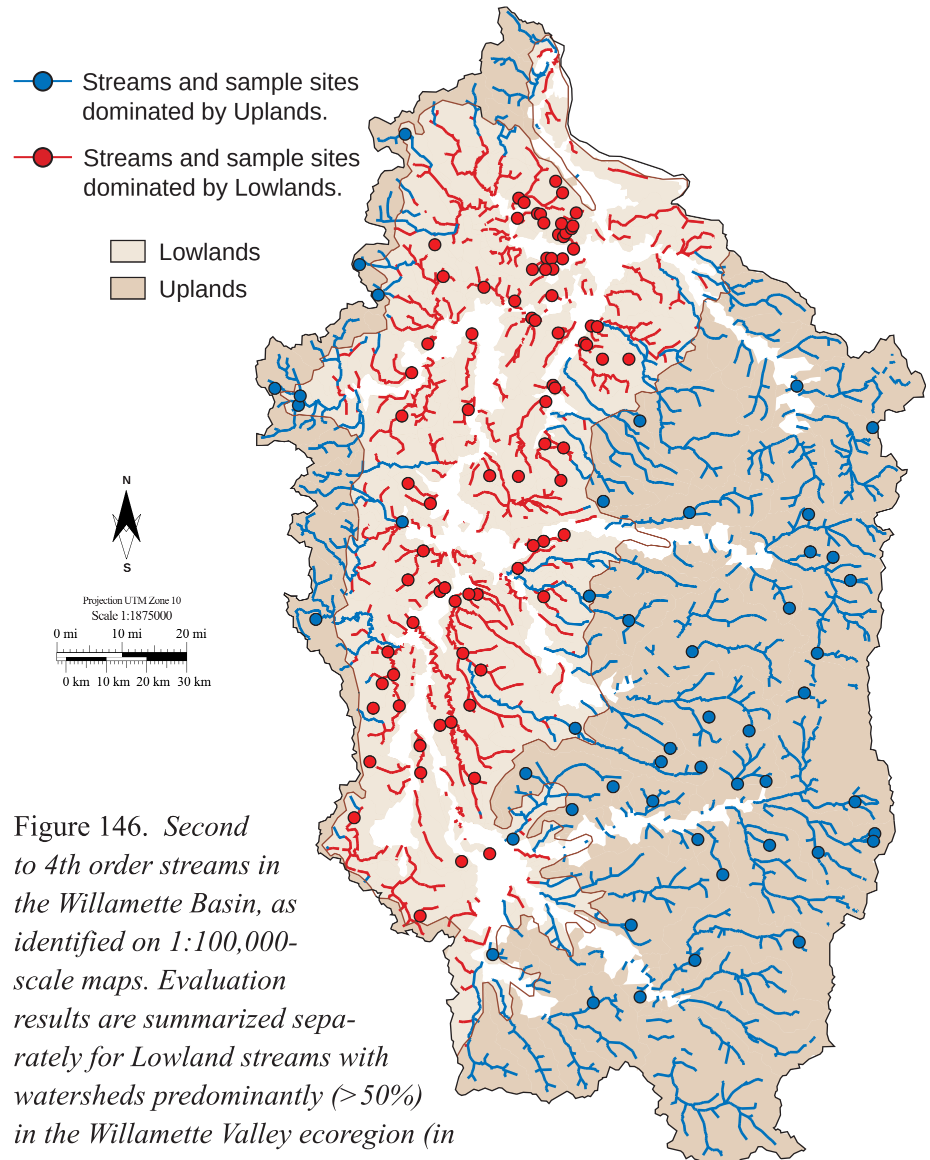

Figure 146. *Second to 4th order streams in the Willamette Basin, as identified on 1:100,000-scale maps. Evaluation results are summarized separately for Lowland streams with watersheds predominantly (>50%) in the Willamette Valley ecoregion (in red) versus those with watersheds predominantly in Upland areas (Cascades and Coast Range ecoregions, in blue). Closed circles indicate locations of stream surveys that provided data for model development. Land areas draining into 2nd to 4th order streams are shaded, with light tan indicating areas within the Willamette Valley ecoregion and darker tan areas in the Cascades and Coast Range ecoregions (p. 49).*

Effects of Land and Water Use on Streams

People affect streams and stream biota in many ways. Water withdrawals for agriculture, municipal, and other uses reduce in-stream flows. Lower stream flows mean less habitat for stream biota and, frequently, increased water temperatures during summer. Conversion of lands for agriculture and residential and urban development is generally accompanied by higher peak flows, lower summer flows, higher stream temperatures, and increased amounts of fine sediments, nutrients, and contaminants. Forestry land use can cause similar, although generally less severe, impacts. These changes in important habitat features alter the types, abundance, and diversity of biota that live in streams. For example, cutthroat trout prefer colder, clear streams with gravel substrates. Human activities that decrease stream flow, increase summer temperatures, and increase loadings of fine sediments may make streams less suitable for this widespread sportfish.

Figure 147. *Lowland stream in the Willamette Valley.*
Photo: T. Moser.

Figure 148. *Upland stream.*
Photo: A. Herlihy.

Indicators of Stream Condition

How do we decide if a stream is "healthy," that is, in good condition? As for humans, there is no single measurement that describes the overall ecological health of streams. We rely on several different indicators of ecological health, based on evaluating the biological communities in streams and the quality and quantity of their habitats. Taken together, these indicators provide an assessment of stream condition.

Habitat Quantity and Quality. Stream biota require water. Thus, more water means more habitat, or simply space available for stream biota. We focus on the season when habitat quantity is likely to be most limited, late summer (August and September) of a moderately dry year (defined as a flow that is exceeded 80% of the time in recent decades). Our indicators of habitat quantity are stream flow, channel width, and channel cross-section area (width x depth) during this summer low-flow period. The latter two measures are then summed across all 2nd to 4th order streams to estimate the *total surface area* (width x stream length) and *total volume* (cross-section area x length) of stream habitat.

The ability of a stream habitat to support a sustainable population of fish or other biota depends on the characteristics of the habitat, as well as its total amount. Examples of important habitat characteristics are stream temperature, stream bed composition (e.g., clay, sand, gravel, boulders), the frequency and depth of pools, and the availability of cover (e.g., undercut banks or large wood) in which fish and other biota can hide from predators. Rather than evaluating each of these features individually, we developed a *Habitat Suitability Index* (HSI) as a composite indicator of habitat condition for cutthroat trout.

Fish Communities. We also evaluated the condition of biological communities in streams. Field crews measured the numbers and types of fish caught in selected stream reaches during summer using standard sampling protocols.[140-143] Based on these results, we assessed two indicators of fish community condition: native fish richness and the fish Index of Biotic Integrity.

Native fish richness (number of native species) reflects the overall biodiversity of the aquatic ecosystem. Human disturbances that introduce toxic contaminants or non-native fish species, increase temperatures, siltate stream beds, or produce other changes in stream habitats frequently result in the loss of one or more native fish species.

We also assessed an *Index of Biotic Integrity* (IBI), which measures the degree to which the composition, diversity, and functional organization of the fish community matches that expected in the stream in the absence of human disturbance, expressed on a scale of 0 to 100. The lower the IBI, the greater the alteration of the fish community, presumably as a result of human-caused impacts. We use an IBI formulated specifically for Willamette Valley streams.[144] IBI formulations for Upland streams have not yet been developed.

Stream Invertebrates. Field crews also measured the numbers and types of invertebrates in Willamette Basin streams during summer (Fig. 149). In some ways, invertebrates are better indicators of stream condition than fish. Invertebrates are much less mobile than fish and thus more accurately reflect the condition of the stream reach in which they are found. There are also hundreds of species of invertebrates in the basin, in contrast to the comparatively small number of fish species. Different types of species tend to respond to different types of stresses and habitat features. Thus, the greater numbers of invertebrate species make invertebrate indicators sensitive to a wider array of human impacts. We use two indicators of invertebrate community condition.

EPT richness is the number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa found in a stream reach. Mayflies, stoneflies, and caddisflies are typically used in biomonitoring because they are generally intolerant of silt, warm temperatures, and water quality degradation. As with native fish richness, stream degradation tends to result in the loss of species and a decline in EPT richness. However, because there are many more EPT taxa than fish species, EPT richness is likely to be more sensitive to disturbance than is native fish richness.

The *Willamette Invertebrate Observed/Expected (WINOE) index* measures the degree to which the overall composition of the invertebrate community is similar to that observed in sites with minimal human disturbance (reference sites). WINOE is scored between 0 (no matching) and 1 (complete matching) to indicate how closely the list of taxa found at a site matches the reference taxa list. A WINOE value near zero indicates a community that is quite altered from reference conditions, presumably due to human disturbance. The WINOE index was developed specifically for this project, but is based on an invertebrate assessment method that has been widely applied and tested in other areas.[145]

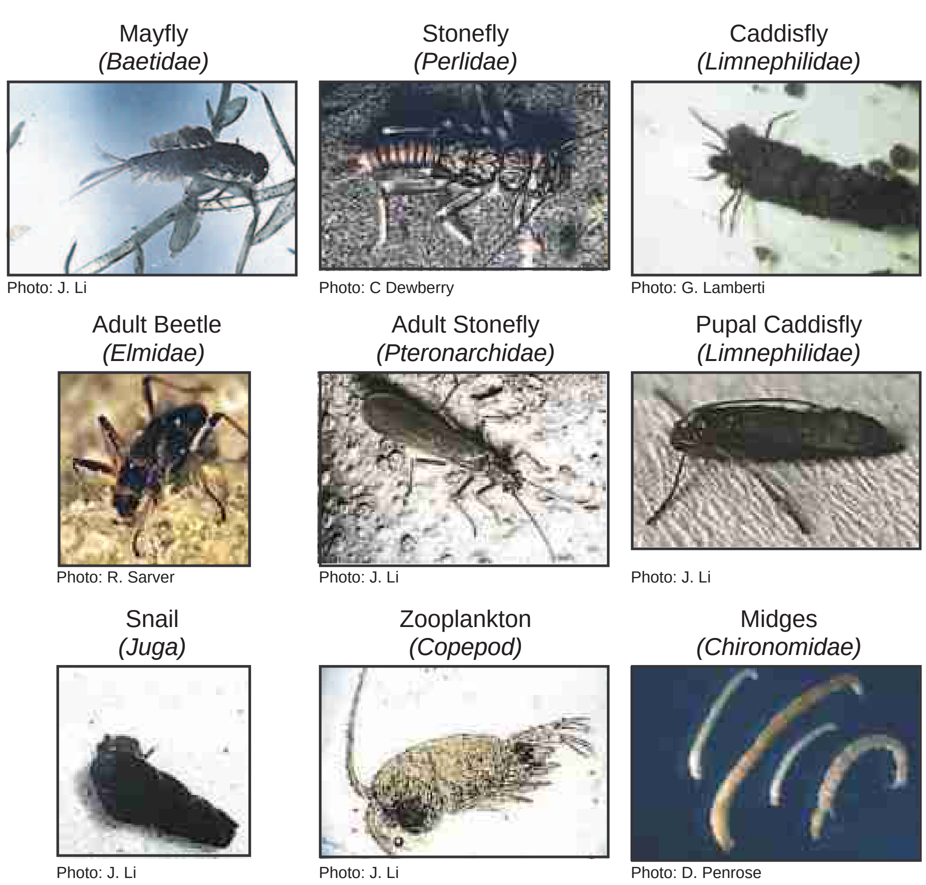

Figure 149. *Common stream invertebrates in the Willamette Basin. The top row depicts examples of EPT taxa.*

Methods, Data Sources, and Assumptions

Ideally, we would like to evaluate the effects of the alternative landscape scenarios using a mathematical model that carefully simulates all the major processes and functional relationships that link human use of land and water to changes in stream habitat and biological communities. Unfortunately, no such model exists. In fact, the processes involved are so complex that, even if such a model were available, it would be difficult to obtain the data needed to apply the model to all streams in the Willamette Basin.

Thus, we took a simpler approach, in which mathematical models are built to represent the quantitative associations between land use and stream condition that can be observed in sample data. Measurements of stream biota and habitat indicators were available for 130 stream reaches distributed around the basin (Fig. 146), collected by the U.S. Environmental Protection Agency,[140] U.S. Geological Survey,[141] and Oregon Departments of Fish and Wildlife [142] and Environmental Quality. [143] We characterized land use and land cover within four *areas of influence* for each site (Fig. 150): (1) the entire contributing watershed, (2) the riparian network, a zone 390 ft (120 m) wide on both sides of the stream over the entire upstream network, (3) a narrower riparian network, a zone 100 ft (30 m) wide extending only 10 km upstream of the stream reach, and (4) a 390-ft wide riparian area immediately adjacent to the stream reach. We then looked for relationships between the stream condition indicators and land use/land cover in each area of influence. For example, Figure 151 illustrates a negative relationship between fish IBI and the percent of the riparian network used for agriculture, in 45 Lowland watersheds with little or no urban or residential development. The statistical relationship between IBI and agricultural land use (represented by the dashed line in Fig. 151) can be used to predict how changes over time in agricultural extent are likely to affect IBI. The fundamental assumption is that if non-agricultural watersheds are subsequently converted to agricultural uses, the streams that drain those watersheds will, given time, become similar to those that currently have substantial agriculture in their watersheds.

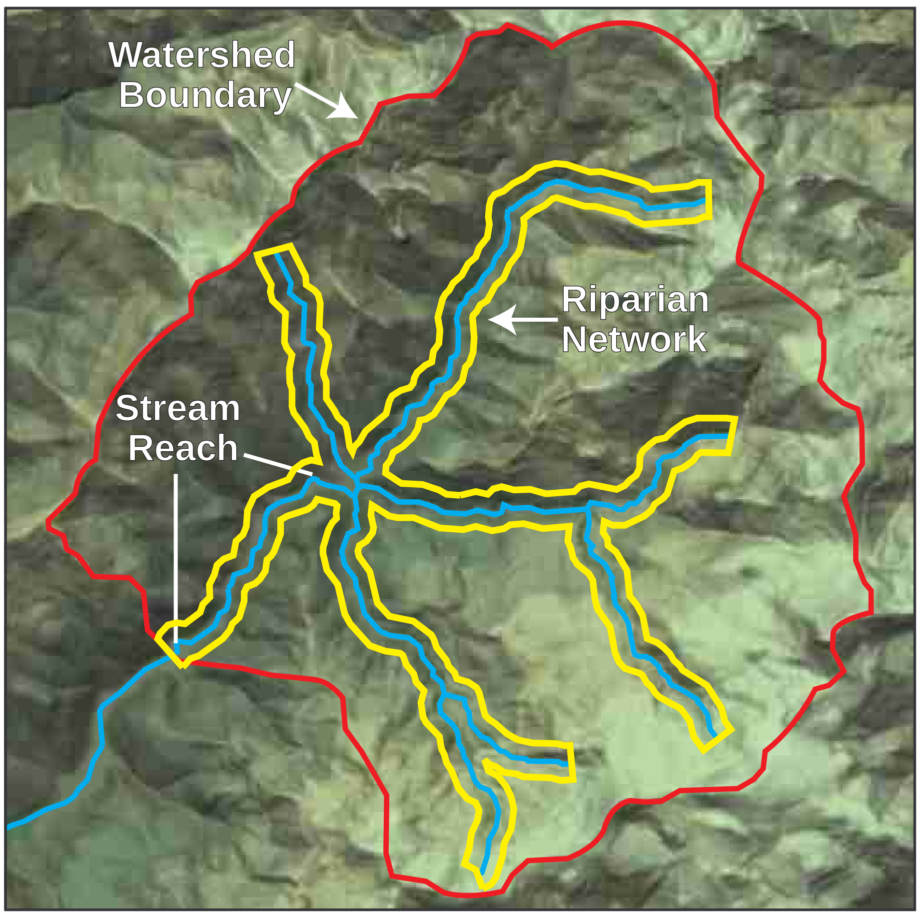

Figure 150. *Areas of influence considered in evaluating the effects of land use / land cover on stream condition: (1) the entire watershed (red), (2) 393-ft (120-m) wide riparian zone on both sides of the stream over the entire upstream riparian network (yellow), (3) 100 ft (30 m) on both sides of the stream for 10 km upstream of the stream reach (not shown), and (4) 393-ft wide riparian zone immediately adjacent to the stream reach.*

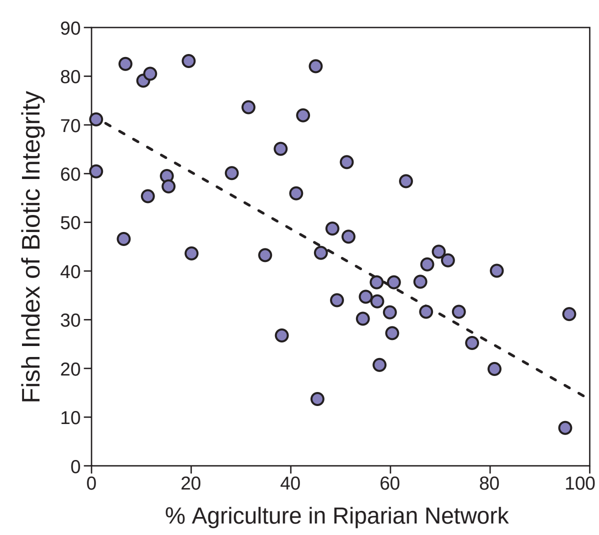

Figure 151. *Relationship between the fish Index of Biotic Integrity (IBI) and percent of 393-ft riparian network used for agriculture, in sampled Lowland watersheds with little area (<10%) in urban or residential development. The dashed line shows the statistical model relating IBI to agricultural land use.*

Of course it is not quite that simple, because not all streams are alike to begin with (natural variations in condition indicators), not all respond in exactly the same way to land use changes, and land use is not the only way in which human activities affect stream biota. To try to account for these complexities, we examined the statistical association between stream condition and a wide variety of physical, land use / land cover, and water use variables. Those most strongly and consistently correlated with each condition indicator were included in the final models. The final models were applied to predict stream condition in every 2nd to 4th order stream reach in the basin (Fig. 152) for each scenario: Pre-EuroAmerican Scenario, circa 1990, and the three alternative futures. Predictions for each reach were then combined across all streams to provide summary statistics for the Lowlands, Uplands, and overall basin. In particular, we define the predicted regional *median* to be the indicator level such that there are an equal number of stream miles in the region above the level as below. The box below provides a more detailed discussion of the assumptions and uncertainties of our modeling approach.

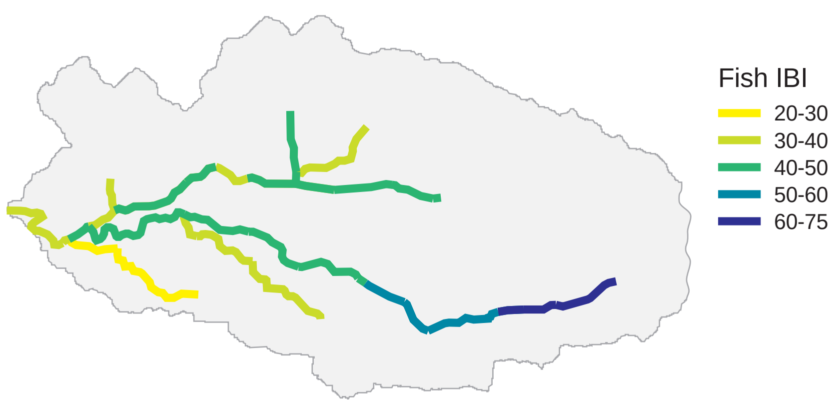

Figure 152. *Model predictions of the fish Index of Biotic Integrity (IBI) for each stream reach LULC ca. 1990, in an example stream network.*

Uncertainty in Stream Model Predictions.

There are three major sources of uncertainty in our model predictions, only the first of which can be quantified and incorporated into our results.

1. Model Incompleteness (Unexplained Variability) — Our models explain only a portion of the observed variation in stream condition indicators (Table 42, Fig. 151). Many factors contribute to this unexplained variation, including errors in our source data (for example, in the characterization of 1990 land use/land cover, in locating the boundaries of watersheds and riparian areas, and in the measurement of the stream condition indicators) and local factors that affect stream condition, such as the occurrence of springs, major point sources of pollutants, etc. In our statistical models, we quantified this unexplained variation and, in essence, "added" it back in to our estimates of stream response (as random variation in Monte Carlo simulations), so that the range and variation in our predictions approximate what was observed in the sample data. Because of this random noise component, model predictions for a single, specific stream reach are very uncertain. However, the overall distribution of stream condition, across all stream reaches in the basin, is estimated with much greater reliability. This approach assumes that these other causes of indicator variability (not explained by the model) are independent of the land use effects and do not change with time.

2. Uncertainties in Model Structure — Did we select the right variables to predict stream condition and the correct form of the relationship (e.g., linear, logarithmic, sigmoidal)? To help evaluate this, we divided our sample data into two parts. The first portion was used to select the predictor variables; the remaining data to test and help validate our models. However, many of the possible predictor variables (different land use/land cover classes and different areas of influence) were highly correlated with each other in our sample watersheds. For example, watersheds with a high percent of the 393-ft riparian network used for agriculture also tended to have a high percent of the 100-ft riparian network used for agriculture. As a result, alternative models, with different predictors and often different forms of the relationship, in some cases fit our test subset almost as well as our final "best" statistical models. Because we have no measurements of changes in stream condition over time, we cannot be certain which model structure provides the most accurate predictions of past and future stream condition. In some cases, we evaluated the sensitivity of our conclusions to the selection of the final model structure, as discussed later in this section.

3. Basic Predictive Assumptions — Fish and stream invertebrates do not respond directly to changes in land use. Rather, land use serves as a surrogate for the human impacts and changes in habitat that generally accompany changes in land use. Our approach assumes that the nature of this surrogate relationship is the same historically, in the future, and in 1990. We assume that differences among streams today can be used to predict how any one stream would change over time (referred to as a "space for time substitution"). We assume that the only things that change in each scenario are land use/land cover and water use, and all the accompanying indirect effects for which land use/land cover and water use serve as a surrogate. Everything else is assumed constant over time. Finally, all of our analyses are based on a static stream network as represented at 1:100,000-scale. These types of assumptions are inherent in almost all model predictions of large-scale environmental change.

Statistical models were developed that predict changes in stream biota (native fish richness, fish IBI, EPT richness, and the WINOE index) in response to changes in land use / land cover, changes in habitat width and cross-section area as a function of stream flow, and natural (historical) stream flow as a function of watershed area and precipitation (Table 42). Current and future estimates of stream flow were calculated as natural stream flow minus water consumed by agriculture, municipal, and other uses, estimated from the WATERMASTER model (p. 114), plus any summer releases from upstream reservoirs (based on data from the US ACE). The water rights database was adequate to estimate "typical" water withdrawals in a dry year, but not actual water withdrawals in the particular years that our sites were sampled. Perhaps for this reason, biological condition was not significantly related to water consumption or summer low flow in any of our statistical models.

We also developed a model derived from our conceptual understanding of how stream ecosystems function. This expert-based model estimates the Habitat Suitability Index (HSI) for cutthroat trout. For example, studies have shown that large wood in streams enhances the quality of habitat for cutthroat trout. We used existing models to estimate potential input rates of stream wood from riparian forest composition, as one component metric of the HSI. In all, 10 metrics were defined (Table 43), representing 10 factors expected to affect the quality of stream habitat for cutthroat trout. Each metric was weighted by its expected relative importance to overall habitat quality. The 10 weighted metrics were combined into the final HSI, which is scored on a 0 to 1 scale, with low values indicating poor cutthroat trout habitat. We cannot quantify the uncertainty in our estimates of HSI.

Table 42. *Statistical models of stream condition.*

Stream Condition Indicator	Region	Predictor Variables[a]	Percent of Variability Explained[b]
Native Fish Richness	Lowland and Upland	% Agriculture in 390-ft riparian network % Development in 390-ft riparian network Distance to divide (indicator of watershed area) Elevation, Strahler order, Slope	70
Fish Index of Biotic Integrity	Lowland	% Agriculture in 390-ft riparian network % Development in 390-ft riparian network	36
EPT Richness	Lowland	% Agriculture in 390-ft riparian network % Development in 390-ft riparian network Stream power	61
WINOE Index	Lowland	% Agriculture in 390-ft riparian network % Development in 390-ft riparian network Stream power, Longitude	52
Natural Stream Flow	Lowland and Upland	Watershed area Average annual precipitation	82
Habitat Width	Lowland Upland	Watershed area Summer low stream flow	72 82
Habitat Cross-Section Area	Lowland Upland	Watershed area Summer low stream flow	84 85

[a]Additional predictor variables considered but not included in final models: % land area naturally vegetated, in closed forest, with mature conifers > 80 years age, with hardwoods; land use / land cover in other areas of influence (Fig. 150); road density; annual average flow; % of natural stream flow consumed; latitude; and distance to 5[th] order river.
[b]Percent of variability in stream condition explained by the model (model R-square).

Table 43. *Cutthroat trout habitat suitability index: metrics and metric weights.*

Metric	Weight Lowland Streams	Weight Upland Streams
Stream gradient	0.065	0.050
Annual mean flow	0.065	0.100
Valley floor width index		0.100
Wood potential	0.200	0.250
Closed forest in riparian network		0.350
% Natural vegetation in riparian network	0.340	
Road density in the watershed	0.065	0.050
Closed forest in the watershed	0.065	0.025
% Human development in riparian network	0.100	0.050
% Agriculture in riparian network	0.100	0.025

Projected Effects of Water Use on Stream Flow and Habitat Quantity

Of the water consumed by all water rights in the basin in August and September of a dry year circa 1990, 38% was withdrawn from 2nd to 4th order streams (and upstream watersheds). Because these streams tend to have fairly low natural flows during summer, even small water withdrawals can have major impacts on the quantity of stream habitat. Sixty-five % of the water consumed from 2nd to 4th order streams circa 1990 was used for agriculture, and the remainder was consumed by municipal, industrial, and domestic uses. As expected, these water withdrawals occur predominately in the Lowlands. Only 10% of the stream miles draining Uplands had more than 10% of their estimated natural stream flow consumed circa 1990. In the Lowlands, by contrast, 47% of stream miles had more than 10% of their natural stream flow consumed and 12% had more than 50% of their natural stream flow consumed.

Water releases from federal reservoirs during summer increase stream flow and the amount of stream habitat. However, only a very small portion (less than 1%) of 2nd to 4th order stream reaches occur downstream of the 11 federal reservoirs. In these reaches, summer flows have increased dramatically. On average, summer flows circa 1990 below the federal reservoirs were estimated to be 24 times greater than historical flows.

Because large decreases in flow from water withdrawals and large increases from reservoir releases occur in only a small portion of the total network, the projected total amount of stream habitat in the alternative scenarios differs by less than 8% from circa 1990 habitat (Fig. 153). Our model results suggest there was 7.4% more habitat volume in Lowland streams historically than there is today in a dry summer. Under Plan Trend 2050, increases in agricultural, municipal, industrial, and domestic consumption would result in loss of an additional 7.7% of current habitat volume. Conservation 2050 measures would moderate, but not eliminate, future habitat loss, with a projected decline of 4.6% from 1990 habitat volume in Lowland streams. In Upland streams, there was 2.3% less total habitat volume historically than circa 1990, reflecting the influence of the reservoirs. Slight declines (about 1%) in Upland stream habitat volume are projected under all future scenarios.

Localized impacts of water use on habitat quantity can be more dramatic. For example, in the Mid-Willamette subbasin (p. 16), model results suggest there was 36% more stream habitat volume historically than circa 1990, and under Plan Trend 2050, habitat volume would decline an additional 19% (Table 44). While all 2nd to 4th order streams in the basin maintained some flow historically, according to our models, an estimated 82 miles of stream went completely dry as a result of water withdrawals circa 1990

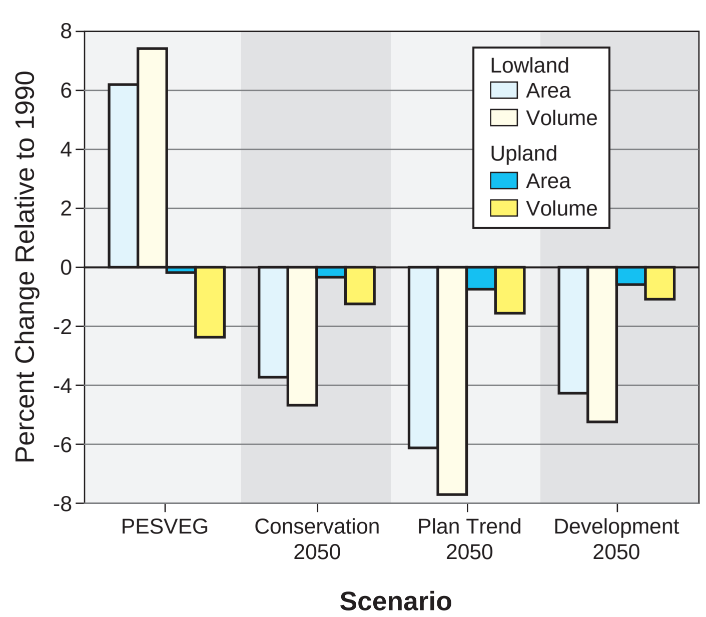

Figure 153. *Percent change in total stream habitat area and volume during August and September of a dry year, relative to conditions LULC ca. 1990, for Pre-EuroAmerican scenario (PESVEG), and the three future scenarios, for Lowland and Upland streams.*

Area	Volume 1990	Percent Change Relative to Circa 1990			
		PESVEG	Conservation	Plan Trend	Development
Whole Basin	1007.5	-0.1	-2.0	-2.9	-2.0
By Region:					
Lowland	227.5	7.4	-4.6	-7.7	-5.2
Upland	780.0	-2.3	-1.2	-1.5	-1.0
By Subbasin:					
MF Willamette	137.5	-8.1	-0.8	0.2	0.0
CF Willamette	47.4	-10.4	-0.1	-0.3	0.0
Upper Willamette	191.4	2.6	0.5	0.1	0.6
McKenzie	135.1	-6.5	-1.5	0.1	-0.2
N Santiam	68.4	0.2	-0.2	-0.2	0.0
S Santiam	107.2	-1.4	-1.4	-3.1	-2.2
Middle Willamette	22.2	36.0	-5.9	-18.6	-14.3
Yamhill	63.8	2.8	-3.3	-2.6	-2.3
Mollala-Pudding	93.1	4.6	-4.3	-7.4	-6.7
Tualatin	55.9	8.2	-10.5	-17.1	-10.4
Clackamas	73.1	1.7	-0.6	-1.9	-1.0
Lower Willamette	13.4	7.9	-3.7	-6.9	-3.2

Table 44. *Percent change in the total volume of small stream habitat, relative to LULC ca. 1990. Volume estimates for LULC ca. 1990 in million cubic feet.*

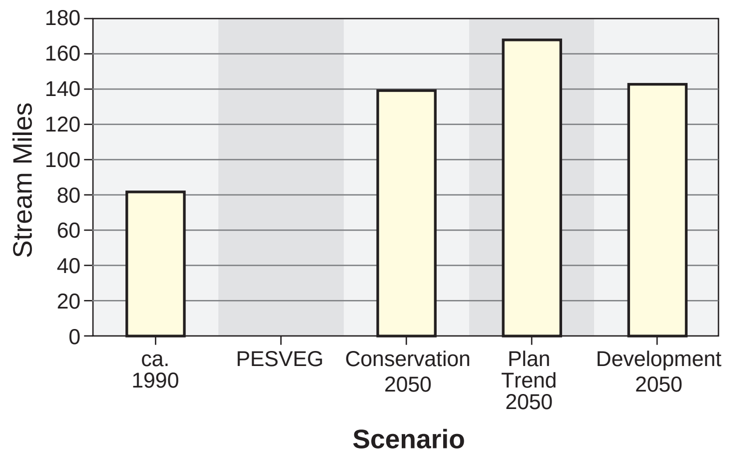

Figure 154. *Miles of stream expected to go completely dry in August and September of a moderately dry year.*

(Fig. 154). This number doubles to 169 miles under Plan Trend 2050. Conservation 2050 limits the length of dry stream to 139 miles, still 57 miles more than ca. 1990.

Importance of Riparian Vegetation

Land use activities anywhere in the upstream watershed can affect stream condition. In general, however, the closer the human activity is to the stream, the greater the impact, which is one reason why riparian vegetation can play such a critical role in conservation strategies. Vegetation immediately adjacent to the stream provides shading (and thus affects stream temperature and light availability), bank stability, and a source of large wood debris, and can moderate non-point source loadings of nutrients, sediments, and contaminants.

Consistent with earlier studies, our statistical analyses found that the best models (strongest relationships) predict stream biota from land use within the entire upstream riparian network (Table 42). Land use within the riparian network predicted stream condition distinctly and consistently better than did land use within the entire watershed or within just the riparian zone immediately adjacent to the sampled reach. Models based on the 390-ft wide riparian network were only slightly better than (and not statistically different from) those based on the 100-ft network or models incorporating multiple areas of influence with differential weightings. Present-day correlations between land use within the 100-ft and 390-ft buffers made it impossible to quantify more complex relationships with varying contributions as a function of distance from the stream. Thus, our final models use land use within the 390-ft riparian network to predict stream condition for alternative scenarios.

Effects of Agriculture and Development

Agriculture and human development (urban and residential land use) in the riparian network were major predictors of all the biological indicators of stream condition (Table 42). For each of these models, the responses estimated for agriculture and development were not statistically different from each other. These results suggest that a given amount of land used for agriculture will have about the same effect on stream biota as an equivalent amount of land used for urban or residential development. Thus, our models suggest that conversion of agricultural lands to urban/residential (or vice versa) results in little change in stream condition. The major impacts on Willamette streams predicted by our models occur when land is converted from natural vegetation to either agriculture or urban/residential development.

For some of the indicators, we also evaluated models that allowed for differential effects from different types of agriculture and different densities of human development. Such models resulted in little if any improvement in our ability to predict stream condition. We suspect that the management practices employed are more important than what specific types of crops are grown or the density of houses built. For example, if runoff is carefully managed and physical alteration of streams minimized, it is possible to increase urban densities with relatively little additional adverse effect. Unfortunately, basinwide data bases with these types of details do not exist. Thus, the models used in the scenario evaluations predict stream condition based on simply the percent of the land area within the riparian network used for agriculture (all types) and development (all densities).

Effects of Forest Type and Age

In none of the statistical models were we able to detect differences in stream biota due to variations in the type of natural vegetation or forest age. From this, we conclude that effects on stream biota from forest harvest in general have not been as severe or straightforward as those from agriculture and urban/residential development. Only the HSI model incorporates expected influences of forest management on stream condition (Table 43) and, thus, is the primary model applied to evaluate changes in Upland streams.

Historical Changes in Stream Biota and Habitat Quality

All of the models suggest that Lowland streams have been impacted fairly dramatically as a result of the extensive conversion of lands to agricultural, residential, and urban uses from Pre-EuroAmerican times to ca. 1990 (Figs. 155, 156). As expected, the largest change occurred in invertebrate EPT richness, due to that indicator's sensitivity to human disturbance. The estimated median EPT richness across all Lowland streams was 90% higher historically than circa 1990. For all other indicators, medians historically were 30-50% higher than those in 1990. These changes represent a loss of 5.2 species of EPT invertebrates (mayflies, stoneflies, and caddisflies) and 1.8 species of native fish, and declines of 21 units for the fish Index of Biotic Integrity (on a scale of 0 to 100) and 0.25 and 0.19 for the cutthroat trout Habitat Suitability Index (HSI) and invertebrate WINOE index, respectively (on scales of 0 to 1).

By contrast, changes in Upland streams have been more moderate (Fig. 155). The decline in median cutthroat HSI in Upland streams (0.14) was about half that estimated for Lowland streams (0.25). The median number of fish species lost was 0.1 in Upland streams, compared to 1.8 species in Lowland streams.

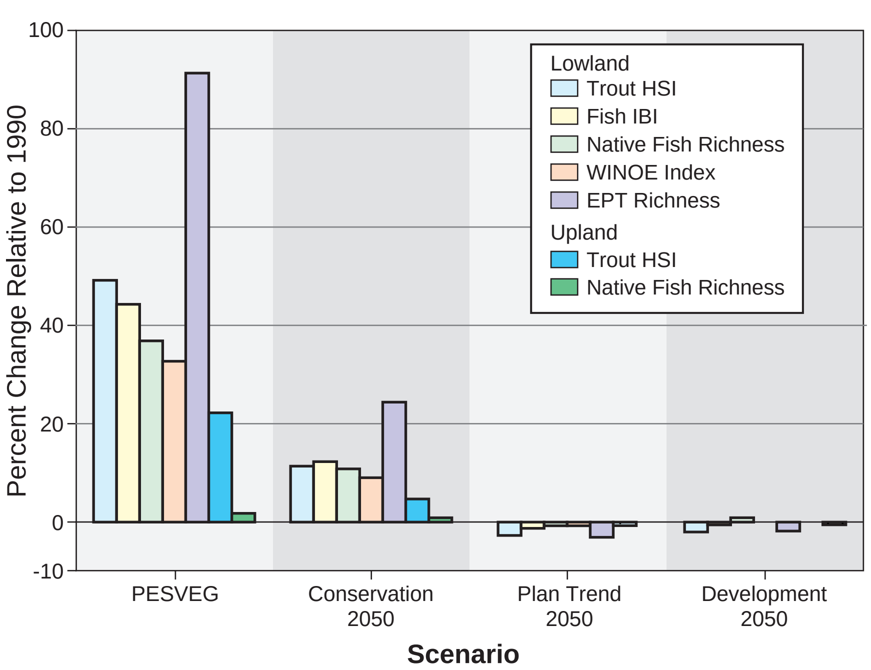

Figure 155. *Percent change in median stream condition, comparing historical and future scenarios to LULC ca. 1990.*

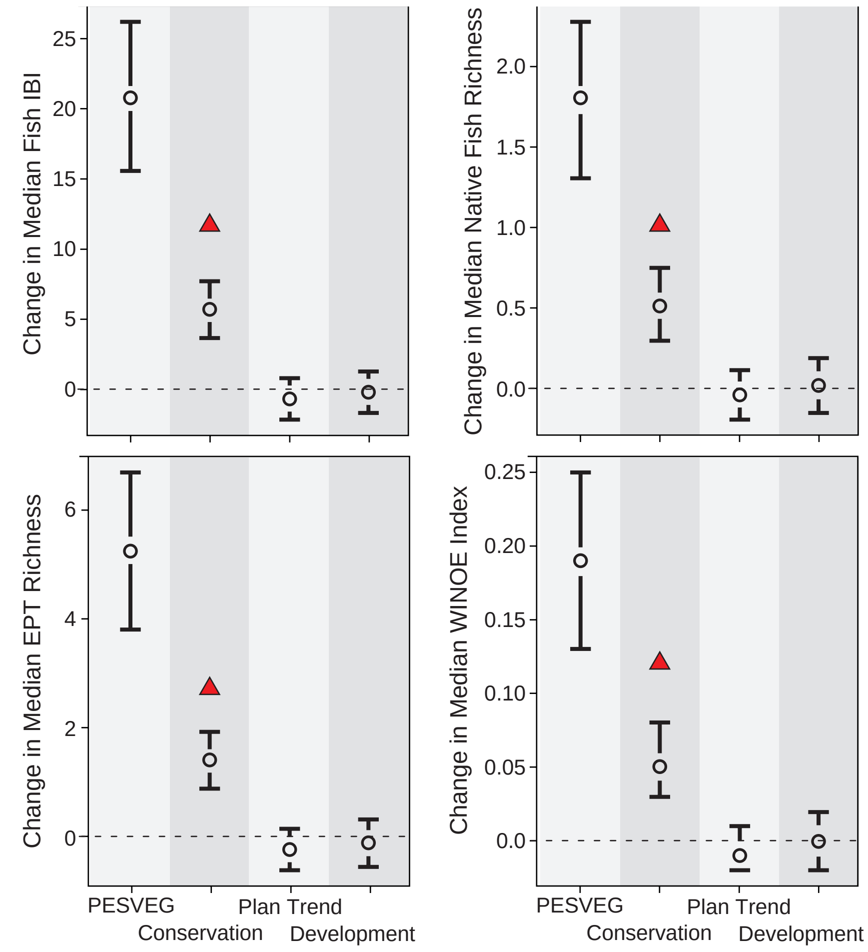

Figure 156. *Change in median Lowland stream condition (circle) and associated 90% confidence bounds (bars) comparing Pre-EuroAmerican (PESVEG) and future scenarios to LULC ca. 1990. For Conservation 2050, triangles denote the change estimated from alternative models employing 100-foot riparian widths.*

Not all streams historically were equally well-suited for cutthroat trout or had the same number of fish or EPT species, because of natural variations in stream condition. Thus, changes in average or median conditions do not fully express the results. In Figure 157, the distribution of indicator values historically is used to define reference values for four classes of streams: those in relatively poor condition (the lowest 10% historically), fair condition (10-25th percentile historically), moderate condition (25-75th percentile historically), and high-quality streams (top 25th percentile historically). Applying these same reference levels in 1990, the proportion of Lowland streams in relatively poor condition has increased sharply for each condition indicator. The change has been most dramatic for cutthroat HSI in Lowland streams. While only 10% of Lowland streams historically had HSI less than 0.66, by 1990 about 80% of Lowland streams had HSI below this same value, indicative of relatively poor cutthroat trout habitat. In Upland streams, by contrast, the proportion of streams in relatively poor condition has changed very little. However, in 1990 many more Upland streams were classified as having only fair cutthroat trout habitat and the number of high quality trout streams has declined sharply, relative to historical conditions.

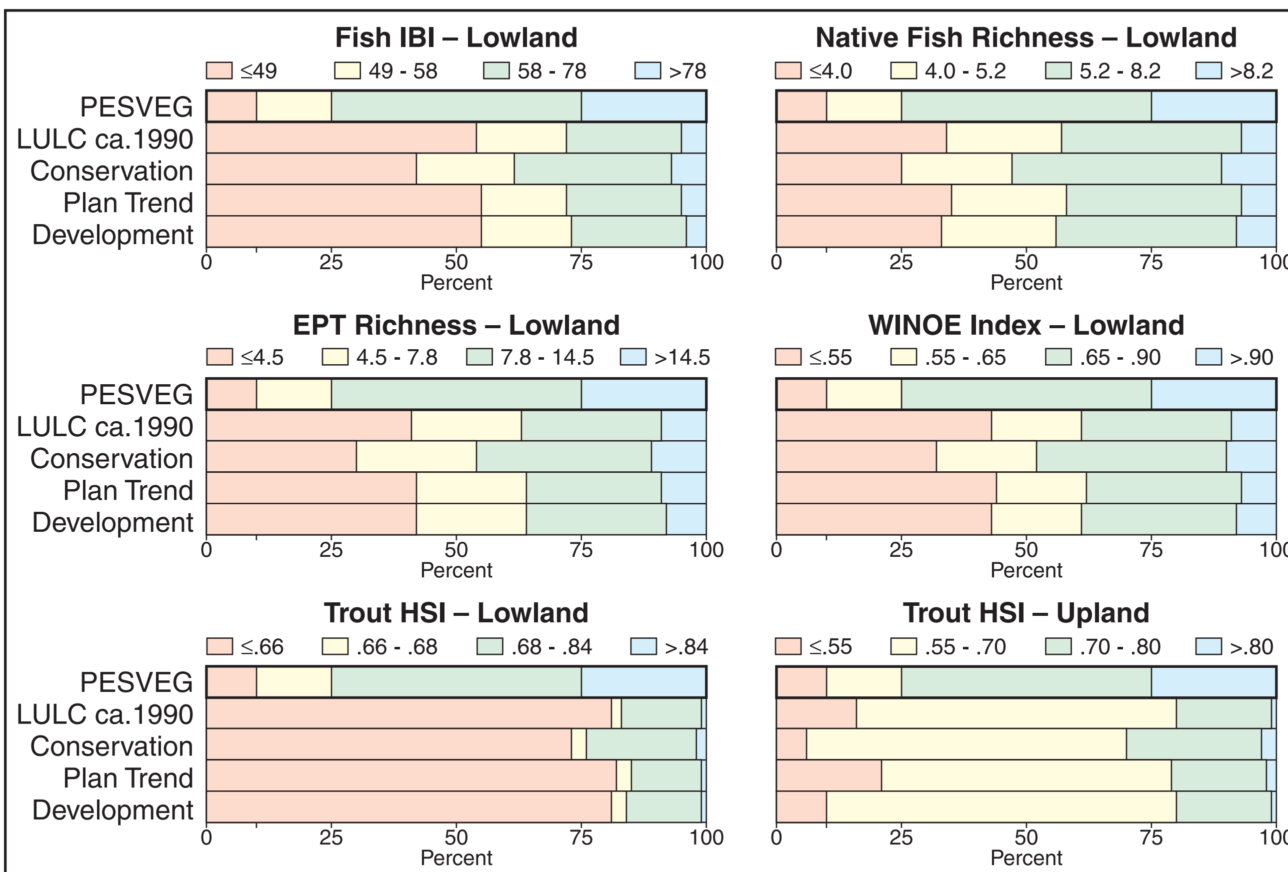

Figure 157. *Percent of Willamette Basin streams (Lowland or Upland) in relatively poor (red), fair (yellow), moderate (green), or high-quality (blue) condition, under each scenario. Condition classes are defined by the 10th, 25th, and 75th percentile of the distribution predicted for the Pre-EuroAmerican scenario (PESVEG). Color legend denotes the range, in original indicator units, of each condition class.*

Alternative Futures

Changes in stream condition, projected for all three alternative futures, are distinctly less than the changes that occurred between Pre-EuroAmerican times and today (Figs. 155 - 157). In fact, projected values for Plan Trend 2050 and Development 2050 are virtually indistinguishable from those for ca. 1990 for all indicators of stream condition in both the Lowland and Upland regions. Most of the land converted to urban and residential use under Plan Trend 2050 and Development 2050 was in agriculture ca. 1990. Even under Development 2050, the amount and types of natural vegetation in riparian zones is fairly similar to levels in LULC ca. 1990 (pp. 98-101). As noted earlier, our analyses indicate that, on average, the impacts of agriculture and urban/residential use on stream condition are similar in magnitude. Thus, converting agriculture to urban/residential uses will not, by itself, cause additional stream degradation, beyond levels observed today. Specific management practices employed on either agriculture or urban/residential lands are likely to be more important in determining stream condition than the type of land use.

While changes between 1990 and Plan Trend 2050 and Development 2050 are also quite small for Upland streams overall, differences are apparent by land ownership (Fig. 158). Under Plan Trend 2050, the cutthroat trout HSI would improve slightly, relative to 1990, in streams draining federally managed forest lands, but continue to decline in streams draining privately managed and state managed forest lands. Smaller changes in HSI are projected under Development 2050 than under Plan Trend 2050, primarily because of the smaller changes in the amount of riparian closed forest in Development 2050 (pp. 98-101). Subbasin differences in HSI (Table 45) reflect both land ownership patterns and the relative proportion of the subbasin in the Lowland and Upland regions.

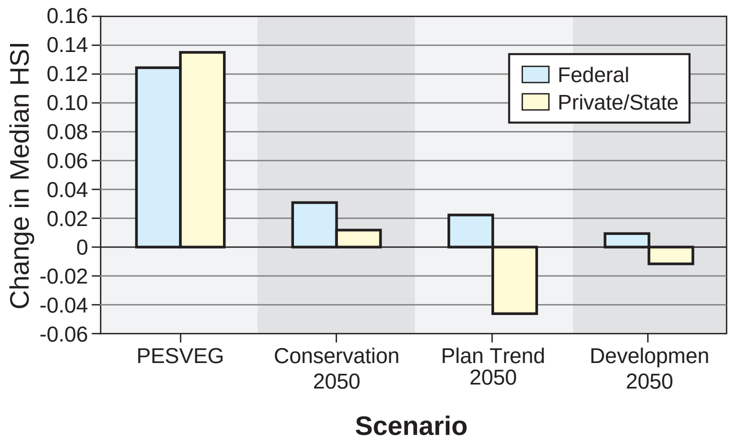

Figure 158. *Change in median HSI for Upland streams draining federally managed forest lands and draining privately and state-managed forest lands, comparing Pre-EuroAmerican and future scenarios to LULC ca. 1990.*

Only for Conservation 2050 does stream condition measurably improve relative to 1990. The estimated increases in the Lowlands are statistically significant for all indicators for which prediction uncertainty can be quantified (Fig. 156). The exact magnitude of recovery is less certain, however. Under Conservation 2050, our models (Table 42) predict recovery of 23-29% of the loss in condition between Pre-EuroAmerican times and LULC ca. 1990 (Fig. 156). An alternative model based on a narrower (100-ft) riparian network predicts recoveries of 60-63% in the Lowlands. While the wider riparian network used in the Table 42 models provided a slightly better fit to existing survey data, the differences were small and not statistically significant. However, we are reasonably confident that Lowland recovery lies within the range of 20-65% predicted by the two model formulations. Conclusions for all other scenarios were relatively unaffected by the choice of riparian network width.

In the Uplands, Conservation 2050 is projected to recover 21% of the loss in median HSI that occurred between Pre-EuroAmerican times and LULC ca. 1990 (Table 45). However, native fish richness shows no significant change in the Uplands either between the Pre-EuroAmerican scenario and LULC ca. 1990, or between LULC ca. 1990 and Conservation 2050 (Fig. 155).

Area	Median HSI 1990	Change in Median HSI, Relative to LULC ca.1990			
		PESVEG	Conservation	Plan Trend	Development
Whole Basin	0.62	0.16	0.03	-0.01	-0.00
By Region:					
Lowland	0.51	0.25	0.06	-0.02	-0.01
Upland	0.64	0.14	0.03	-0.00	-0.00
By Subbasin:					
MF Willamette	0.65	0.14	0.03	0.02	0.02
CF Willamette	0.61	0.15	0.02	-0.02	0.01
Upper Willamette	0.54	0.16	0.04	-0.02	0.01
McKenzie	0.66	0.12	0.02	0.00	0.01
N Santiam	0.67	0.11	0.02	0.00	0.00
S Santiam	0.60	0.17	0.02	-0.02	0.00
Middle Willamette	0.45	0.22	0.06	-0.02	-0.02
Yamhill	0.60	0.08	0.01	-0.04	-0.01
Mollala-Pudding	0.61	0.18	0.03	-0.03	-0.00
Tualatin	0.62	0.19	0.04	-0.03	-0.02
Clackamas	0.66	0.12	0.04	0.03	0.00
Lower Willamette	0.50	0.26	0.04	-0.03	-0.01

Table 45. *Change in cutthroat habitat suitability index (HSI), relative to LULC ca. 1990.*

Summary and Conclusions

- Changes in stream habitat quality and biota from Pre-EuroAmerican times to circa 1990 are greater than those projected to occur over the next 50 years under any of the future scenarios.
- Relative to Pre-EuroAmerican scenario conditions, Willamette Basin Lowland streams have been significantly degraded by conversion of lands to agriculture and urban/residential uses. Median values for indicators of stream condition were estimated to be 30-90% higher historically than LULC ca. 1990. Changes in Upland streams have been more moderate.
- Within the limits of our modeling, it appears that Plan Trend 2050 and Development 2050 would not result in any measurable worsening of stream biota and habitat quality in the basin, overall. Most of the land converted to urban and residential uses in these scenarios is used for agriculture today. Our models predict that converting agriculture to urban/residential uses will not, by itself, cause significant additional stream degradation, beyond levels observed today.
- The conservation measures implemented under Conservation 2050 would partially (by 20-65%) but not completely restore Lowland stream biota and habitat quality to Pre-EuroAmerican conditions.
- Water withdrawals have had major impacts on habitat quantity in some streams. As a result, total habitat quantity in Lowland streams was estimated as being about 7% greater in Pre-EuroAmerican than LULC ca. 1990. Total habitat quantity in Lowland streams is projected to further decline 4 to 8% by 2050, depending on the future scenario.
- The above conclusions apply to overall trends in stream condition within the basin, not to individual stream reaches. Changes in individual streams may be substantially greater or less than those estimated for the basin as a whole.
- The above conclusions are based only on projected changes in land use/land cover and stream water withdrawals. In our models, these few factors act as inclusive surrogates for many, but not all, human impacts on streams. Thus, our models do not account for all possible future changes that might occur. Furthermore, our conclusions cannot be safely applied to any single specific human impact, such as chemical contamination or reduced infiltration.