A Stream-Based Survey of Oregon Watershed Health:

Using GIS to Examine Aquatic Connectivity, Hydrology, Biology, Geomorphology, and Water Quality

Kristina Rissetto, Tobyn Peterson
Instructor Geoffrey Duh, Ph.D.
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Abstract

We applied methods based on the Minnesota DNR's Watershed Health Assessment Framework (WHAF) to examine the overall health of Oregon's watersheds. The objective of this survey is to rate each Oregon watershed (HUC8) using GIS-based methods on the following parameters: biology, geomorphology, aquatic connectivity, hydrology, and water quality.

We focused on the stream-based methods from the WHAF to analyze watershed health in Oregon; our methods could be expanded upon to identify Oregon watersheds in greatest need of stream and riparian area restoration. As anthropogenic pressures increase across the state, restoration efforts should increase as well; in the last century, rivers and entire watersheds have been severely altered by river and land management actions such as interrupted fluxes of water, sediment, and nutrients (Beechie et al. 2010).

Introduction

Watershed health can be gauged by measurable ecological indicators which relate to overall watershed conditions (OR BES 2016). Hydrology, biology, geomorphology, stream connectivity, and water quality are all indicators of watershed health (MN DNR 2016). Changes in land use--especially increases in impervious surface area--can alter the natural hydrology of a watershed by increasing the rate of runoff that is delivered to streams; even small increases of impervious surface area can account for a major increase in non-point pollution in streams (Weber and Bannerman 2004). The health of Portland's watersheds is also closely related to the abundance and distribution of fish populations within our streams; aquatic organisms and communities reflect the cumulative conditions of the other watershed components (OR BES 2016). Additionally dams and other stream barriers can have a negative impact on stream health; uninterrupted flow is essential for the exchange of water, energy, sediments, nutrients, and organisms (MN DNR 2016). Water quality is another essential element for sustaining life; when our streams meet current water quality standards, the environment can support a higher diversity of plant and animal species. In addition, erosion is another possible limiting factor for watershed health; elevated levels of turbidity, sedimentation, and erosion can decrease overall aquatic health. Combined, these five health indicators can provide a useful, holistic view of watershed health, in addition to aiding the process of ultimate restoration site selection.

Study Area

We utilized the National Hydrography Dataset (USGS) in order to divide the state of Oregon into 92 watersheds at the HUC8 (4th order stream network) level. Watersheds are areas of land in which all surface water drains to a single point location at lower elevation (Kolok et al. 2009); these boundaries can provide a valuable spatial framework from which to examine the relationship between human health and environmental health. Eight watersheds from the HUC8 boundary dataset were excluded from the final analysis, due to insufficient data in one or more health indicator categories.

Data Sets Used

Oregon Boundary: Oregon Department of Transportation
Watershed Boundaries: United States Geological Survey, Environmental Protection Agency, USDA Forest Service
Oregon Fish Passage Barriers: Oregon Department of Fish and Wildlife, Oregon Department of Transportation, Bureau of Land Management
Oregon Rivers: Oregon Department of Energy
Land Cover: Multi-Resolution Land Characteristics Consortium
Fish Distribution: Oregon Department of Fish and Wildlife
Oregon Streams: Oregon Department of Environmental Quality

Methods

For each of the five components, a health score ranging from 0-100 was calculated for each watershed. Subsequently, the five health scores for each watershed were averaged together to yield the combined watershed health score.

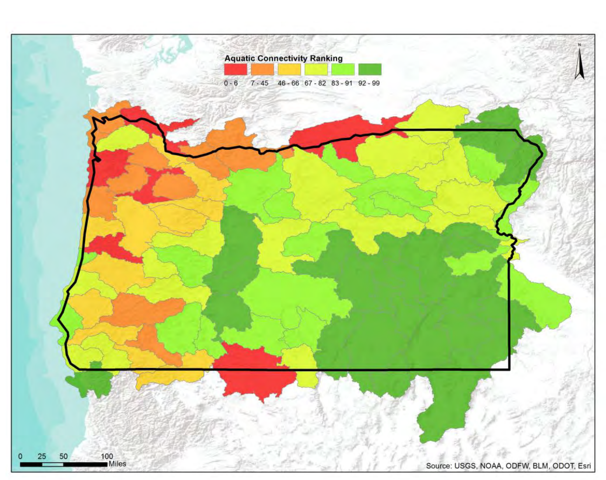


Figure 1: Aquatic Connectivity of Oregon Streams

Aquatic Connectivity

For each watershed, the total count of stream barriers per watershed was calculated by joining the stream barriers layer to the HUC8 watershed layer. The ratio of barriers to total stream length (feet) was calculated by dividing the total barrier count per watershed by the total stream length per watershed. Densities above the threshold value (greater than or equal to the 95th percentile of density values) automatically received a health score of zero. The remaining watersheds were then scored from 0-100 using the equation:
Aquatic Connectivity Health Score = (1-((Barriers per Stream Length/Threshold Value))*100

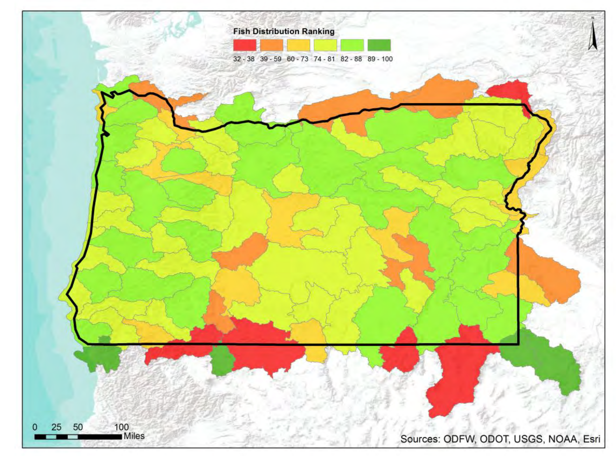


Figure 2: Fish Species Distribution

Biology

The biological input layer represents Oregon rivers that are believed to be suitable habitat or habitat that is used currently (within the past five reproductive life cycles) by native fish populations. The information is based on sampling, modeling, and the best professional opinion of ODFW staff biologists (ODFW 2016). All fish species distribution data was first merged into a single layer, and this combined distribution layer was then spatially joined to the watersheds layer and the original Oregon streams layer. A density of fish distribution per watershed was calculated by dividing the total length of fish-populated stream length (feet) in each watershed by the total stream length (feet) within each watershed. Densities above the threshold value (greater than or equal to the 95th percentile) were automatically assigned a health score of zero. The remaining watersheds were scaled from 0-100 using the equation:
Biological Integrity Health Score = (1-((Fish Distribution Density)/Threshold Value))*100

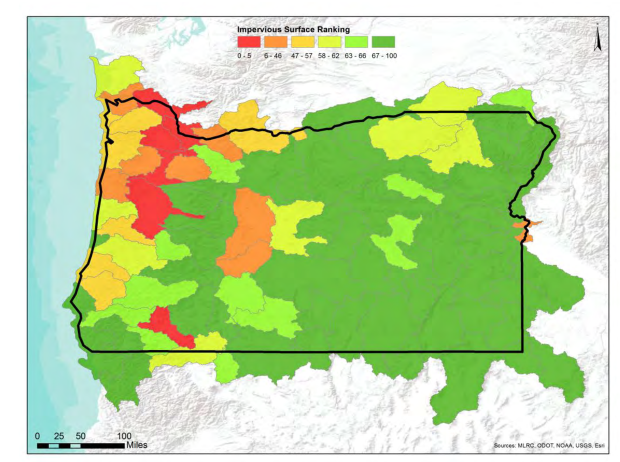


Figure 3: Percent Impervious Surface Cover Per Watershed

Hydrology

Impervious surfaces were extracted from a NLCD 2011 raster (Percent Imperviousness) using the reclassify tool, then a zonal statistics table was created to show the area (miles squared) of impervious surfaces per watershed. Density was calculated by dividing the area of impervious surfaces (miles squared) in each watershed by the total area of each watershed (miles squared). Watersheds with an impervious surface value above the 95th percentile were automatically assigned a health score of 0. An additional threshold (less than or equal to 4% impervious surface area of each watershed) was identified and utilized based on the Minnesota DNR study; watersheds of less than or equal to 4% impervious surface cover were deemed "natural" based on ecological and hydrological factors, and received scores of 100. The remaining values were scaled from 0-100 using the equation:
Hydrology Health Score = (1-((Percent Impervious Surface)/Threshold Value))*100

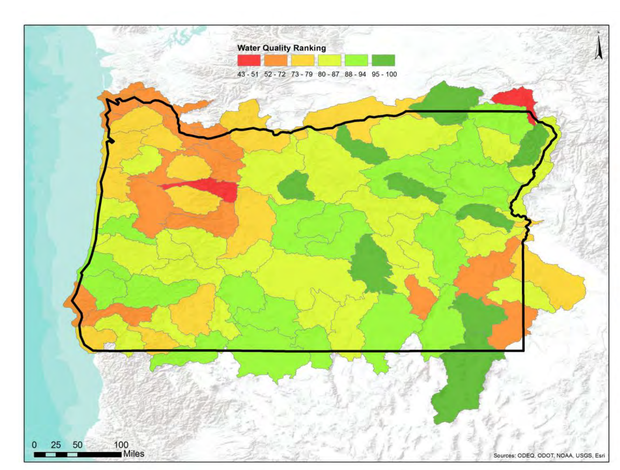


Figure 4: Water Quality Limited Stream Segments vs. Attaining Stream Segments

Water Quality

Water quality layers were created from the Oregon Department of Environmental Quality's 2010 Integrated Water Quality Report. Two separate layers were created by isolating stream segments (miles) that were classified Water Quality Limited or Attaining. A number of segments were classified as both WQL and Attaining, indicating that certain water quality standards were met, while others were not. Both layers were joined to the HUC8 layer and summed per watershed. WQL sums were then divided by Attaining sums of each watershed (canceling out segments which partially or completely fell into both categories), and the resulting values were scaled from 0-100 using the equation:
Water Quality Health Score = (1-((Percent WQL/Att.)/Threshold Value))*100

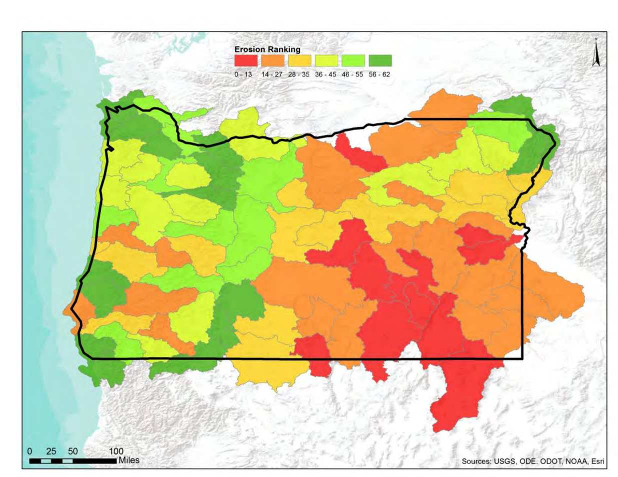


Figure 5: Stream Erosion Classification

Geomorphology

Stream erosion was examined by reclassifying the Oregon Department of Energy's A, B, or C letter rankings to numeric values; this was completed by multiplying the summed stream lengths (feet) for each category by the following coefficients: A(0.5), B(1), and C(1.5). These values were summed on a watershed-by-watershed basis, and then divided by the actual sum stream length (feet) per watershed. Watersheds with an erosion value above the 95th percentile were automatically assigned a health score of 0. The remaining values were scaled from 0-100 using the equation:
Geomorphology Health Score = (1-((Erosion Value)/Threshold Value))*100

Results

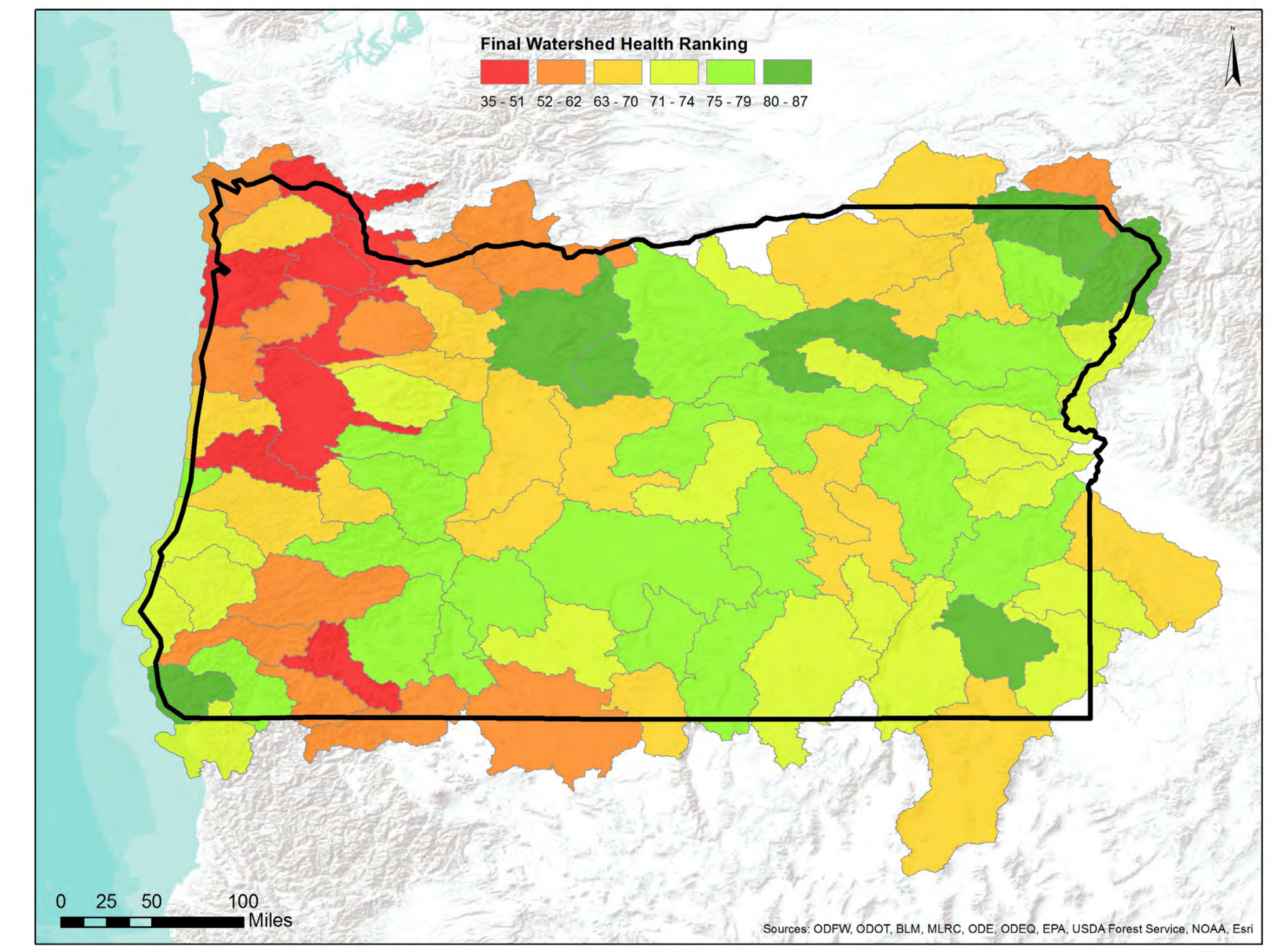


Figure 6: Combined Watershed Health Score

Watersheds that received the lowest combined health score were centered in the Willamette Valley and Lower Columbia regions (Lower Columbia-Clatskanie, Lower Willamette, Tualatin, and Middle Willamette), with one additional watershed in Southern Oregon (Middle Rogue). Watersheds that received the highest combined health score were more dispersed, with two in extreme Northeastern Oregon (Lower Grande Ronde, Imnaha), Central-Northern Oregon (Lower Deschutes, Trout), and extreme Southeastern Oregon (Crooked-Rattlesnake). Combined health scores tended to decline as proximity to urban and/or agricultural regions increased, though the middle 50% of health scores were widely dispersed throughout the state.

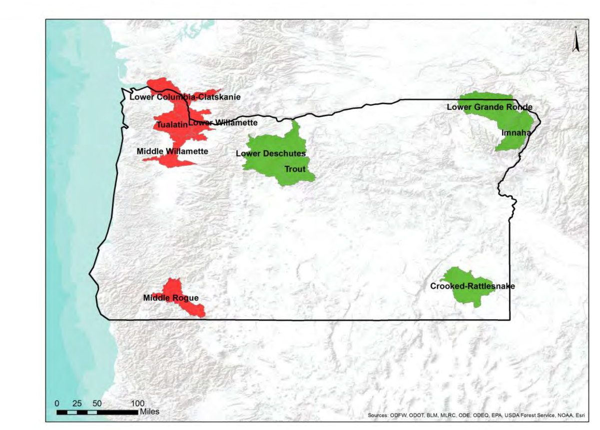
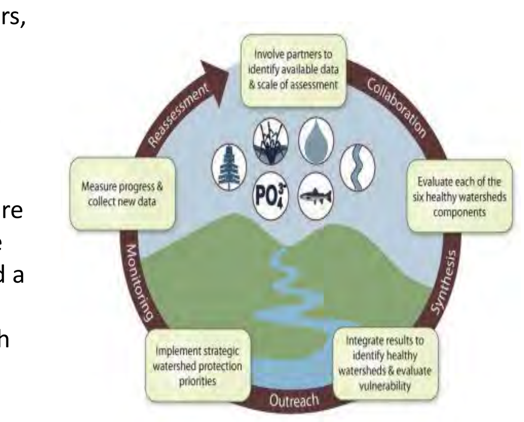


Figure 7: Highest and Lowest Final Health Scores

Conclusion

Calculating stream-based health scores for each watershed provided a brief glimpse of statewide hydrologic health. The Willamette Valley and Lower Columbia regions received low scores on three of the five health indicators, as well as on the combined watershed health assessment. Though anthropogenic factors are linked to some of these low scores, to some degree these results could also be a by-product of populated areas being more closely monitored, or Western Oregon simply having a more extensive stream network. Additionally, most regions of Oregon received low ratings on one or more health indicators, illustrating the fact that there is room for improvement in watershed health across the entire state. The watershed health assessment conducted by the Minnesota DNR provided a far more thorough examination, as data were utilized from well, aquifer, lake, soil, and atmospheric sources, in addition to stream sources. Though combined health scores in Oregon can perhaps identify large areas in greatest need of restoration, many additional factors would need to be taken into account for actual site selection. Each of the health indicators utilized in this survey would also ideally be analyzed with multiple tests and criteria to give more comprehensive results.



References

Beechie TJ, et al. 2010. Process-based Principles for Restoring River Ecosystems. *BioScience*. 60(3): 209-222.
MN Department of Natural Resources. 2016. Watershed Health Assessment Framework. Web. <http://www.dnr.state.mn.us/whaf/index.html>
Kolok AS, et al. 2009. The Watershed as a Conceptual Framework for the Study of Environmental and Human Health. *Environmental Health Insights*. 3: 1-10.
Weber D, Bannerman R. 2004. Relationships Between Impervious Surfaces within a Watershed and Measures of Reproduction in Fathead Minnows. *Hydrobiologia*. 525(1): 215-228.
United States EPA. 2016. Healthy Watersheds: Developing a Watershed Health Sub-Index for Water Quality. Web. <https://www.epa.gov/hwp/healthy-watersheds-developing-watershed-health-sub-index-water-quality>