Climate Savvy Restoration Workshop

Sensitivity to Climate + Exposure to Climate Change +/- Adaptive Capacity = Vulnerability
➔ Then, evaluate and select restoration strategy(s) and technique(s) that address vulnerability

Workshop participants will find in the six sections that follow information ranging from publications to communication networks to datasets and tools, all intended to supplement other workshop materials and to serve as a resource for your use afterwards.

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I. Species Sensitivity Analyses

The online Climate Change Sensitivity Database summarizes climate change sensitivities for species and habitat systems throughout the Pacific Northwest. The database is intended to be an applied tool for conservation planning and design and relies on input from experts, with a peer review process.

Learning to populate the database is a great first step in understanding the vulnerability of a species or a habitat to climate change.

The project, led and hosted by the University of Washington, provides hands-on experience quantifying climate sensitivity. At the end of process you will rank the relative climate change vulnerability of species and habitat systems of interest. These skills will be transferable to restoration and conservation planning and design, threats analysis for listing determinations, recovery planning, Section 7 consultations, and many other management and planning applications.

II. Biological and Ecosystem Response to Climate Change

Aquatic Resources/Ecosystems Synthesis Documents (and a few key articles)

Climate-Aquatics Blog: This is a fantastic site sponsored by the USFS Rocky Mountain Research Station. The intent of the **Climate-Aquatics Blog** is to "provide a means for the field biologists, hydrologists, students, managers, and researchers to more broadly and rapidly discuss topical issues associated with aquatic ecosystems and climate change. Messages periodically posted to this blog highlight peer-reviewed research and science tools that may be useful in addressing climate change."

Climate change, aquatic ecosystems, and fishes in the Rocky Mountain West: implications and alternatives for management (Reiman and Isaak, 2010, U.S. Forest Service, Rocky Mountain Research Station, Note: the hotlink launches a 4.1MB pdf file). The report addresses three questions: 1) What is changing in the climate and related physical processes that may affect aquatic species and their habitats? 2) What are the implications for aquatic species and related conservation values; and 3) What can we do about it?

A NOAA literature review and synthesis on the effects of climate change on salmon and steelhead can be found in the *Federal Columbia River Power System 2010 Annual ESA Progress Report: Section 2, Pages 148-202,* ***Attachment 1, Literature review for 2010 citations for BIOP: Biological effects of climate change*** ***(hotlink launches 3.5 MB pdf file)*** This provides several sections that would apply to other aquatic species, and many principles from salmon-specific research may apply to other species.

Climate Change Effects on Freshwater Aquatic and Riparian Habitats in Washington State (WA Dept of Fish and Wildlife, National Wildlife Federation, May 28, 2010). This paper is intended as a reference document—a "science summary.

Climate Change Effects and Adaptation Approaches in Freshwater Aquatic and Riparian Ecosystems in the North Pacific Landscape Conservation Cooperative Region: A Compilation of Scientific Literature. Phase 1 Draft Final Report. (August, 2011) Full Report

Role of climate and invasive species in structuring trout distributions in the Interior Columbia Basin Wenger, S.J., Isaak, D.J., Dunham, J.B., Fausch, K.D., Luce, C.H., Neville, H.M., Rieman, B.E., Young, M.K., Nagel, D.E., Horan, D.L., Chandler, G.L., 2011, USA: Canadian Journal of Fisheries and Aquatic Sciences, v. 68, p. 988-1008. Catalog No: 2508

Flow regime, temperature and biotic interactions drive differential declines of trout species under climate change Wenger, S.J., Isaak, D.J., Luce, C.H., Neville, H.M., Fausch, K.D., Dunham, J.B., Dauwalter, D.C., Young, M.K., Elsner, M.M., Rieman, B.E., Hamlet, A.F., Williams, J.E., 2011, Proceedings of the National Academy of Sciences, p. online. [Highlight] [FullText] Catalog No: 2652

Shrub-Steppe and Grassland Ecosystems Synthesis Document (East of the Cascades)

Climate Change Effects on Shrub-Steppe and Grassland Habitats in Washington State
(WA Dept of Fish and Wildlife, National Wildlife Federation, January, 2011). This paper is intended as a reference document—a "science summary.

Climate Change and Natural Resources Management in the Great Basin and Mojave Desert: This publication synthesizes the outcomes of a recent climate change workshop. Federal and state natural resources managers, scientists, and stakeholders outlined potential impacts, recommendations, and collaborative opportunities related to climate change throughout much of the Intermountain West. A report entitled "Natural resource mitigation, adaptation and research needs related to climate change in the Great Basin and Mojave Desert" is also available as a result of the workshop. The workshop and publication were sponsored by FWS, USGS, NPS, BLM, EPA, and the Desert Research Institute.

Forest, Alpine and Western Prairie Ecosystems Synthesis Documents

Climate Change Effects on Forest, Alpine, and Western Prairie Habitats in Washington State (WA Dept of Fish and Wildlife, National Wildlife Federation, July, 2010). This paper is intended as a reference document—a "science summary.

Assessing species and area vulnerability to climate change for the Oregon Conservation Strategy: Willamette Valley Ecoregion. Conservation Management Program. Steel, Z. L., Wilkerson, M., Grof-Tisza, P., and Sulzner, K. 2011. University of California, Davis. Prepared for the Oregon Dept. of Fish and Wildlife and the Defenders of Wildlife. (Email David Patte to receive a copy.)

Climate Change Impacts on Western Pacific Northwest Prairies and Savannas. Bachelet, Dominique, Johnson, B.R, Bridgham, S.D., Dunn, P.V., Anderson, H.E and Rogers, B.M. 2011. Northwest Science, 85(2):411-429. 2011. DOI: 10.3955/046.085.0224 http://www.bioone.org/doi/full/10.3955/046.085.0224

Marine/Coastal Ecosystems Synthesis Documents

Climate Change Effects and Adaptation Approaches in Marine and Coastal Ecosystems of the North Pacific Landscape Conservation Cooperative Region: A Compilation of Scientific Literature. Phase 1 Draft Final Report. (August, 2011) Full Report Executive Summary and Table of Contents

Climate Change Effects on Marine and Coastal Habitats in Washington State (WA Dept of Fish and Wildlife, National Wildlife Federation, April, 2010). This paper is intended as a reference document—a "science summary.

III. Understanding Historical Trends for Climate, Stream Flow, Stream Temperature

Climate change is occurring and trend information is a good place to start an analysis of exposure. Locally depicted annual and seasonal trend information is available from a number of sources. For the Pacific Northwest, temperature and precipitation have been increasing, while snowpack and stream flows have been declining.

1. PRISM on ClimateWizard.org

The Parameter-elevation Regressions on Independent Slopes Model (PRISM) generates gridded estimates of historic precipitation and temperature at monthly and daily time scales (Daly 2002; Daly et al. 2008; http://www.prism.oregonstate.edu/). The method interpolates between point data from thousands of weather stations across the U.S. using a digital elevation model and many other geographic data sets. The model accounts for spatial variations in climate caused by elevation, terrain orientation, effectiveness of terrain as a barrier to flow, coastal proximity, moisture availability, atmospheric inversions, and topographic position (valley, mid-slope, ridge). Because of the complete geographic coverage, PRISM can provide estimates of climate data for remote areas where there is often little or no data available. PRISM does not provide projections of future climate, just estimates of past and current climate at a very fine resolution. [Please note that the ClimateWizard website defaults to projections, not trends. Select "Past 50 Years" in the "Time Period" menu, top left side of the page. And zoom in on your state, top left side of the page. Customized time periods and geographic areas of interest can be requested at: http://climatewizardcustom.org/]

2. United States Historical Climatology Network data

FWS has developed an Excel spreadsheet application that charts climate trends from the 1920's to the present using United States Historical Climatology Network data. This allows you to focus on an observation station (or series of stations) of interest and produce 18 charts of annual and seasonal temperature and precipitation trends.

3. Climate Maps of the Pacific Northwest

The University of Washington's Climate Impacts Group provides maps that show climate anomalies – irregularities in climate – associated with different patterns of climate variability compared to average conditions during 1915-2003.

4. Journal Articles

See the following publications on historical analyses of trends over the past half century in air temperature (rising), precipitation (rising), snowpack (declining) and stream flow (declining). [Contact David Patte for copies of these publications—many are not available via the NCTC E-Journal portal….]

Fu, G. B., M. E. Barber, and S. L. Chen. 2010. Hydro-climatic variability and trends in Washington State for the last 50 years. Hydrological Processes 24:866-878.

Ryu, J. H., M. D. Svoboda, J. D. Lenters, T. Tadesse, and C. L. Knutson. 2010. Potential extents for ENSO-driven hydrologic drought forecasts in the United States. Climatic Change 101:575-597.

Bumbaco, K. A., and P. W. Mote. 2010. Three Recent Flavors of Drought in the Pacific Northwest. Journal of Applied Meteorology and Climatology 49:2058-2068.

Guthrie, R. H., S. J. Mitchell, N. Lanquaye-Opoku, and S. G. Evans. 2010. Extreme weather and landslide initiation in coastal British Columbia. Quarterly Journal of Engineering Geology and Hydrogeology 43:417-428.

Grundstein, A., and T. L. Mote. 2010. Trends in average snow depth across the western United States. Physical Geography 31:172-185.

Jones, J. A., and R. M. Perkins. 2010. Extreme flood sensitivity to snow and forest harvest, western Cascades, Oregon, United States. Water Resources Research 46.

Zedler, J. B. 2010. How frequent storms affect wetland vegetation: a preview of climate change impacts. Frontiers in Ecology and the Environment 8:540-547.

IV. Pacific Northwest Regional Downscaled Climate Models

Physically based models of the ocean, atmosphere, land, and ice, often called global climate models (GCMs), are used to project changes in temperature, precipitation and other aspects of the climate system in relation to increases in greenhouse gasses. A common set of simulations using 21 GCMs was coordinated through the Intergovernmental Panel on Climate Change (IPCC). These GCMs produce course-scale outputs requiring regional "downscaling" techniques and methods for localized application and use. Two commonly used and cited approaches for the Pacific Northwest (and beyond) have been developed by the University of Washington Climate Impacts Group.

Climate Impacts Group Statistical Downscaling Modeling Changes in mean annual temperature and precipitation for the Pacific Northwest (and beyond) are projected based on "statistical downscaling" of an ensemble of 20 global climate models and two carbon emissions scenarios for each model run. The emissions scenarios are the A1B scenario, which assumes moderate greenhouse gas emissions in the future, and the B2 scenario, which assumes low greenhouse gas emissions in the future (Mote and Salathé, 2009 and 2010). The downscaling methodology uses empirically-based relationships between observed features (e.g, temperature, precipitation) and correlates these to coarse-scale climate model output to provide fine-scaled projections (see Mote and Salathé, 2010 for more on downscaling methods).

Climate Impacts Group Dynamic Downscaling Modeling Regional climate simulations (Salathé et al., 2010) are performed using a dynamic downscaling method that specifies regional boundary climate conditions in two global climate models (CCSM3 and ECHAM5). Regional climate models account for local geographic features and their affect on regional climate patterns, such as the strong influence of maritime climate and the Cascade Mountain Range in the Pacific Northwest, and produce fine-scale weather patterns consistent with the coarse-resolution features (Salathe et al 2010).

Maps and Graphs Available Depiction of data sets from the two modeling approaches described above are now available (new Feb, 2012). For Oregon and Washington, maps and graphs are available by Hydrologic Unit Code (HCU) and by ecoregion: http://cses.washington.edu/data/usfs_orwa.shtml
For Idaho, only larger Pacific Northwest maps and charts are available:
http://cses.washington.edu/data/met30s.shtml

> How to use these maps and charts? Not an easy task! A step-by-step guide is being developed by FWS for the class.

Citations Mote, P.W., Salathé E.P. 2010. Future climate in the Pacific Northwest. Climatic Change 102(1-2): 29-50, doi: 10.1007/s10584-010-9848-z

Mote, P.W. Salathé, E.P. 2009. Future Climate in the Pacific Northwest. Chapter 1 in: The Washington Climate Change Impacts Assessment. [Littell, J., M. M. Elsner,L. W. Binder, A. Snover (eds)]. Climate Impacts Group, University of Washington, Seattle, WA.

Other Downscaling Methods/Products ClimateWizard.org downscaling methodologies are not as robust for regional and local applications (correspondence with authors). Other approaches have been developed, but results may not be as readily available and/or methodology and results have not been reported in peer-reviewed publications and/or made available. (This is an ever changing field: please let us know if you have other suggested sources.)

For example, results of the North American Regional Climate Change Assessment Program (NARCCAP), an international program producing high resolution regional climate change simulations, will be used for the Northwest chapter of the 2013 National Climate Assessment, but are not yet widely available. NARCCAP modelers are running a set of regional climate models driven by a set of atmosphere-ocean general circulation models over a domain covering the conterminous United States and most of Canada.

V. Hydrologic Modeling

Variable Infiltration Capacity (VIC) Hydrologic Model

The Climate Impacts Group's [Variable Infiltration Capacity (VIC) hydrologic model] provides a suite of historical (1916-2006) and future (2020s, 2040s, 2080s) hydrologic model simulations for 297 streamflow locations in the Pacific Northwest. Data were calibrated and validated for the Columbia Basin and the Pacific Northwest. Results are shown in hydrographs comparing historic to projected changes. The Columbia Basin/Pacific Northwest project produced three different statistical downscaling methods using two global greenhouse gas emissions scenarios, generating 76 possible realizations of future streamflows for each streamflow location. These were developed with the following partnering agencies and entities: Bonneville Power Administration, British Columbia Ministry of Environment, Northwest Power and Conservation Council, Oregon Depart of Water Resources, and Washington State Department of Ecology. Citations: The weblink above includes citations for VIC methodology and results.

Technical reports by the U.S. Army Corps of Engineers, the Bureau of Reclamation and the Bonneville Power Administration using these data evaluated how water supply changes due to climate change could impact the Columbia River Basin and the operation of federal dams. These three reports were finalized in 2011 and the summary report is available here.

Also, the U.S. Forest Service provided funding to make VIC data more available and they can be viewed here.

How to use these maps and charts? Usefulness? Limitations? A step-by-step guide is being developed for the class.

Figure 1. Station Locations—Charted VIC Model Hydrographs Available for These Locations

Western U.S. Stream Flow Metric Dataset The USFS Rocky Mountain Research Station developed this dataset with Trout Unlimited, building on the VIC model (described above). This provides modeled flow metrics for small and medium streams in the continental Pacific Region (and beyond) under historical conditions and forecast, or projected, climate change scenarios. The data are a merger of National Hydrography Dataset stream reaches and climate change projections developed by Wenger *et al.* for 2040 and 2080 based on A1B emissions scenarios. When imported into a geographic information system the dataset can serve as a decision support and visualization tool showing forecasted comparisons in stream flow between historic and future periods.

For each stream in each temporal scenario, the dataset includes:

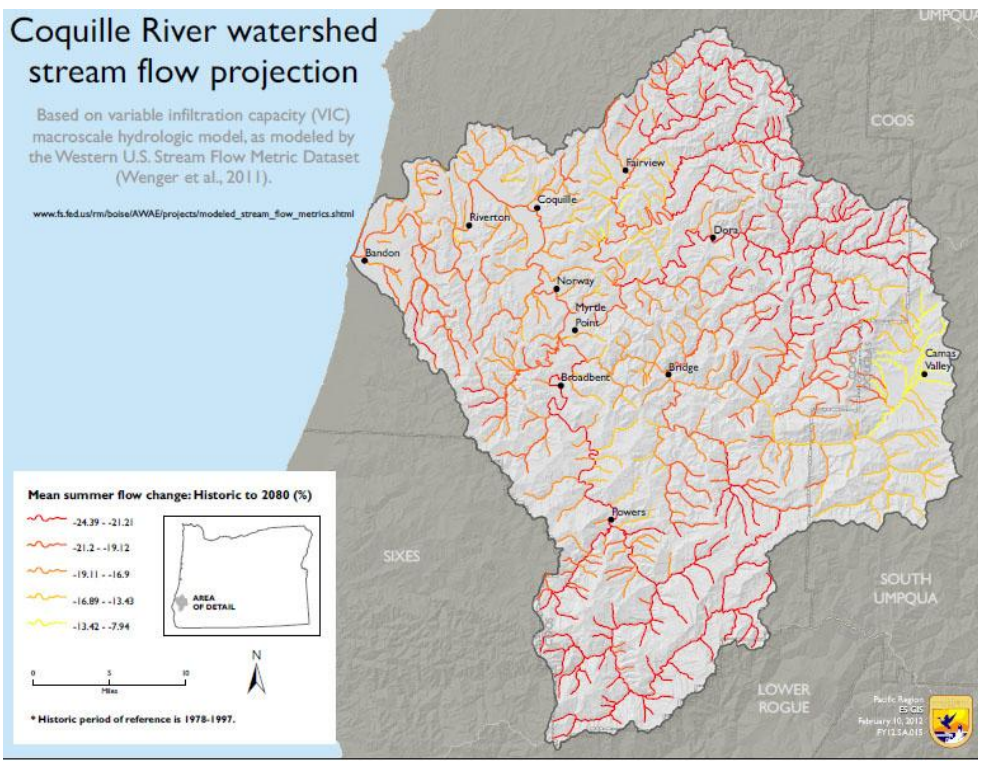
- Mean annual flow (also referred to as daily mean)
- Probabilities of 1.5- or 2-year flow events occurring in the winter
- Number of days in winter in which flows are among the highest 1% or 5% for the year 1.5-year flow, sometimes referred to as channel-forming flow
- Mean summer flow
- 7-day low flow with 10-year return interval (also referred to as 7q10)

(Other data have limitations or are not recommended by the authors.)

Citations: The weblink above includes citations for methodology and results.

How to access these maps? Usefulness? Limitations? The dataset requires GIS manipulation. Results are available by HUC (or aggregation of several HUCs)—and/or more detailed views. Sample pdfs are available. If you have GIS resources, contact Dan Uthman, GIS Specialist, ES RO (dan_uthman@fws.gov). He can walk through his methods for displaying the data. If you do not have source resources, contact David Patte (david_patte@fws.gov) and we'll arrange support from the regional office.

Figure 2. Sample map of modeled summer stream flow for small and medium streams in the Coquille, OR, Watershed



Stream Temperatures

A new regional stream temperature modeling project has been initiated by the USFS Rocky Mountain Research Station with funding from the Great Northern LCC. One of the goals of the project is to compile existing stream temperature data from federal, state, tribal, and private sources across the five state regions that comprise the US portion of the GNLCC. These data will be developed into a comprehensive, integrated regional database that is made available to all interested parties. The stream temperature database will also be used with new spatial statistical models for river networks to develop an accurate regional model capable of predicting stream temperatures for all fish-bearing streams. The model will be used to simulate a variety of historic and future climate scenarios and to assess effects on the distributions of thermal habitat for multiple aquatic species. Spatially continuous maps of stream temperature predictions and thermal habitats will be made available as GIS layers at the end of this project to assist in conservation and management planning.