Climate Change Vulnerability

Climate change has the potential to alter the North Pacific landscape in many complex ways that are not yet fully understood, but these changes are expected to greatly affect the health and distribution of native plant and wildlife species, particularly native freshwater fish that are adapted to cold water (USFWS 2009; Rieman et al. 2007; Mote et al. 2003). Because of this uncertainty, we have focused on identifying the vulnerability of North Pacific watersheds to the direct effects of climate change: alterations in air temperature and precipitation. Additionally, we summarized recently available, regional-scale data on resulting changes in stream flow parameters and climate niche changes for selected species.

We were unable to identify any comprehensive, downscaled data on temperature and precipitation changes caused by climate change for the entire North Pacific. However, two major data-mapping efforts supplement each other to cover the region: Climate Impacts Group (CIG), of the University of Washington, and the Scenarios Network for Alaska & Arctic Planning (SNAP) have created downscaled datasets modeling the effects of climate change for the greater Columbia River Basin and Alaska and British Columbia, respectively. Stream flow data from CIG, Trout Unlimited, and the USDA Forest Service are available within the same region as CIG's temperature and precipitation data as well. Additionally, species-specific climate niche data are available for the entire North Pacific region. Each metric was summarized to the watershed level using hydrologic boundary data from Wild Salmon Center (WSC 2008).

Climate data for the greater Columbia Basin

We originally summarized Columbia-Basin climate data for the Regional Aquatic Prioritization and Mapping tool with the U.S. Fish and Wildlife Service (2012). Because of the resolution of the input data (6,097 meters), we ran the summarization at the sub-basin, rather than the watershed level. For this tool, we assigned a sub-basin's temperature and precipitation values to all watersheds contained within that sub-basin.

Temperature

We chose to summarize summer high air temperature, which is likely to be an important pressure point, particularly for fish in the Pacific Northwest (N. Mantua, Tohver, and Hamlet 2010). For each sub-basin, we calculated the change in monthly-average maximum daily summer air temperature between A1B warming scenario projections for 2099 and historic values using 6,097-meter raster spatial data[1] (CIG 2009a). Because the air temperature data did not cover our entire focal area and the range of temperature change was so limited (4.9 – 5.3^{o}C), we averaged the surrounding sub-basin values to each missing sub-basin in the Oregon portion of the Klamath River Basin.

Hydrologic regime flow change

We classified historic and projected 2080 sub-basin runoff as snowmelt, rainfall, or transient (a mix of snow and rain) following the approach in Mantua et al. (2010; 2009) and with further clarification by Mayer and Norheim (2011). Using 6100-meter raster spatial data of maximum snow water equivalent (SWE)(CIG 2009b) and October-March precipitation (CIG 2009c), we summed SWE and precipitation

[1] For more information on all input datasets, please see the bibliography below, or the data dictionary available at http://nplcc.apps.ecotrust.org/news/about/.

values for each sub-basin, and then calculated the ratio of the former to the latter for historic and 2080 conditions. Ratio classification ranges are listed in Table 1. We then identified those sub-basins where the flow regime would shift from one classification to another.

Table 1: Sub-basin classification

SWE:PCP	Sub-basin classification
< 0.1	Rainfall dominant
0.1 - 0.4	Transient
> 0.4	Snowmelt dominant

Stream Flow Metrics

Flow regime is fundamentally important to North Pacific hydrology, freshwater species, and in determining the physical and ecological characteristics of a river or stream (Wenger and Luce 2011b). We used stream flow data for Oregon and Washington modeled under a Variable Infiltration Capacity (VIC) macro-scale hydrologic model that estimates stream flow at a daily time-step under historical and forecasted future climate conditions (Wenger and Luce 2011a). These data were attached to spatial National Hydrography Dataset stream data (US EPA and USGS 2005) as recommended by the authors.

We chose three flow metrics to include in our analysis to describe hydrological changes that would have the most direct impact on ecological value and would be easily understood when summarized to the watershed level. All projected data were for 2080, under the A1B scenario using a 10-model ensemble representing the lowest bias in simulating observed climate for the region. We calculated the average percent change in mean summer flow, from 2080 to present values; summer was determined for each stream segment and year as beginning the first day after June 1 when flows fell below the mean annual value, to avoid including snowmelt, and ending on September 30th.

We measured the average change in timing of the center of the mass of flow, or the day of the water year at which 50% of the year's flow has passed, to shed light on changes in snowmelt timing. The data were corrected with the following relationship, as suggested by the authors, to avoid underestimating the projected rate of change in snowmelt timing.

$$CFM_{Actual} = (1.25 * CFM_{Predicted}) - 44$$

Finally, we calculated the absolute value of length-averaged change in probability of a 2-year flow event occurring in the winter. As snowmelt occurs earlier, or more winter precipitation falls as rain rather than snow, this metric would be expected to increase.

Climate data for Alaska and British Columbia

The Scenarios Network for Alaska & Arctic Planning (2011a) provides a variety of spatial climate data at various scales and geographic extents to the public. We used the 2 kilometer data historical and projected raster data that covers Alaska and five Canadian Provinces (YT, BC, AB, SK, MB) for the most consistent coverage of the NPLCC area.

Temperature

To determine temperature change, we compared historical monthly temperature data from 2009 (SNAP 2012a) and 5-model average, under the A1B scenario, of AR4 global climate models that perform best across Alaska and the Arctic, downscaled to 2km via the delta method for 2100 (SNAP 2011b). In keeping with our approach using the CIG data, which we established in an earlier project, we identified the highest summer temperature for each cell on the landscape, selecting from July and August temperatures, for both historic and projected datasets. We then calculated the difference between each projected and historic 2km cell, and the resulting absolute value of the average temperature difference for each watershed.

Precipitation

We determined the change in precipitation levels in a similar manner. We compared total historical monthly precipitation data from 2009 (SNAP 2012b) and 5-model average, under the A1B scenario, of AR4 global climate models, downscaled to 2km via the delta method for 2100 (SNAP 2011c). We determined the absolute value of the mean difference in total annual precipitation for each watershed to illustrate the magnitude, but not direction, of precipitation change.

Climate Change data for the entire NPLCC region

Species Climate Response

We used modeled shifts in twelve rainforest focal species climate niches (Table 2) to determine the number of species predicted to be lost from each watershed (DellaSala et al. 2012; Geos Institute and Leuphana University Lueneburg 2012). We used projected climate niches modeled for 2080 under the A1B scenario using the HADCM3 general circulation model. For each watershed, we calculated the number of species lost in the 2080 projection. We did not include measures of habitat gain for species or watersheds.

Table 2. Focal species for which climate niche was calculated.

Common Name	Scientific Name
Pacific silver fir	*Abies amabilis*
Grand fir	*Abies grandis*
Witch's beard	*Alectoria somentosa*
Lettuce lichen	*Lobaria oregana*
Marbled murrelet	*Brachyramphus marmoratus*
Northern spotted owl	*Strix occidentalis caurina*
Sitka Spruce	*Picea sitchensis*
Coastal redwood	*Sequoia sempervirens*
Sitka black-tailed deer	*Odocoileus hemionus sitkensis*
Western redcedar	*Thuja plicata*
Western hemlock	*Tsuga heterophylla*
Mountain hemlock	*Tsuga mertensiana*

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