Glimpses

A non –scientific series of observations made during a
3400 miles road trip along the Pacific West Coast of the USA



The Olympic Mountains



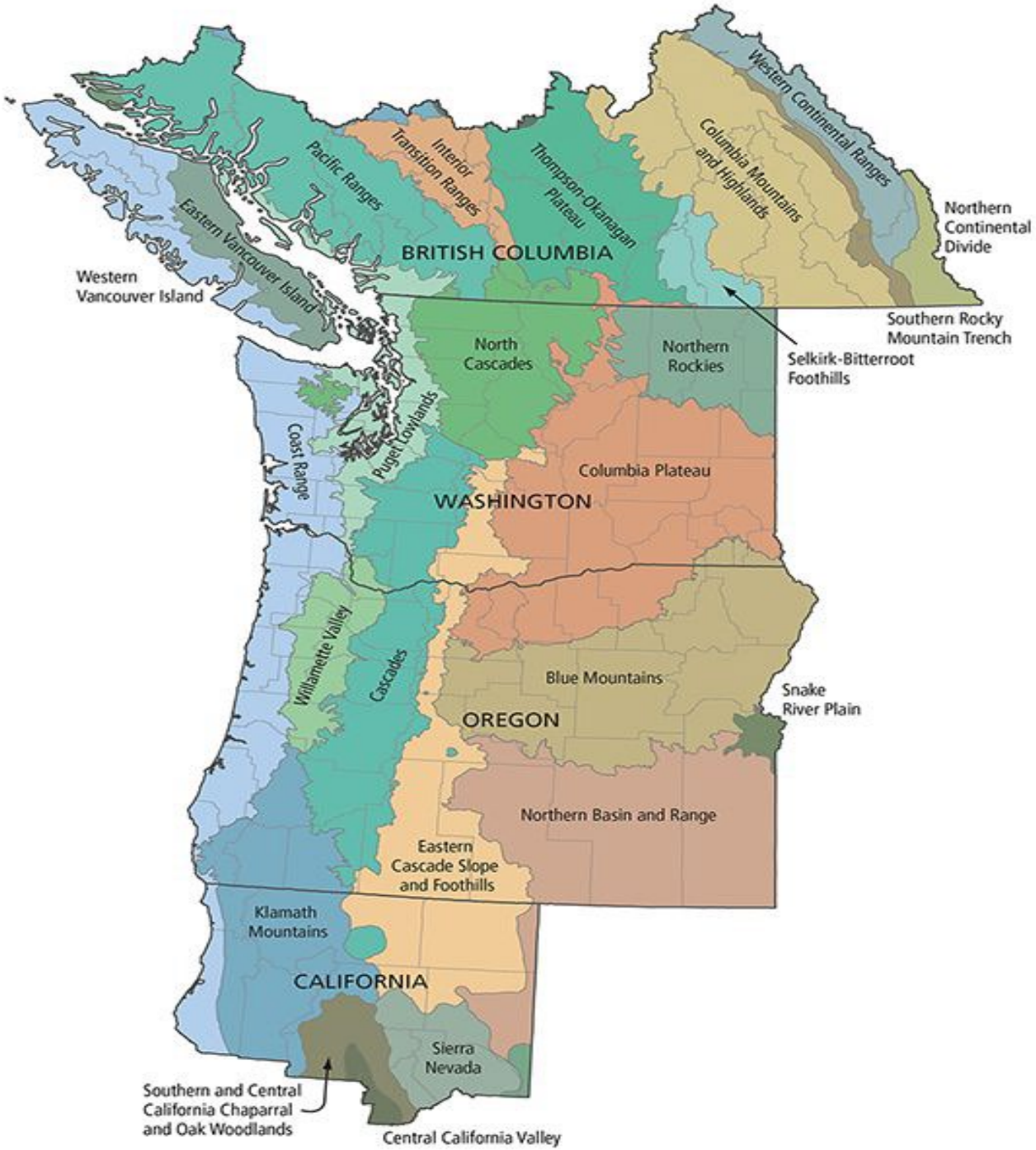
Rainforest ecosystem

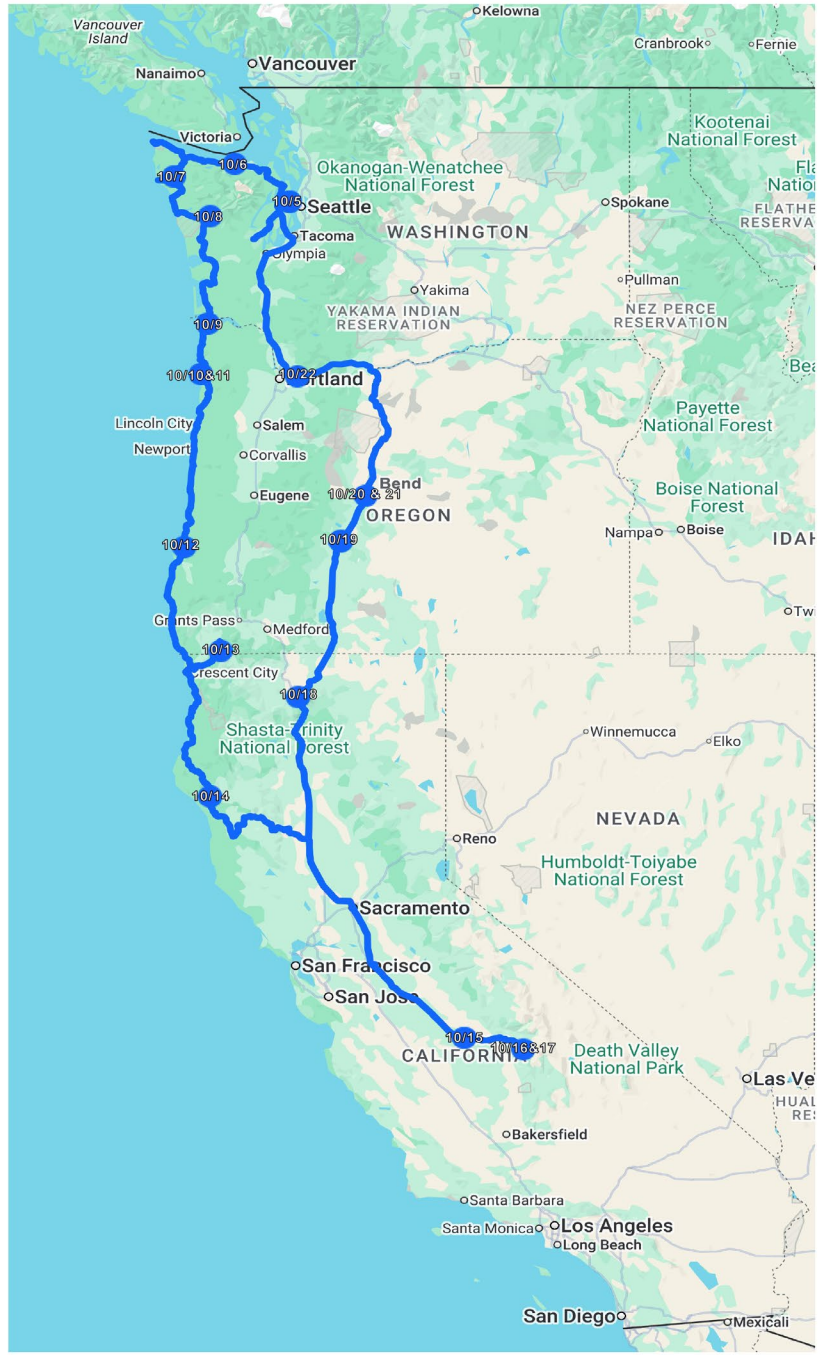
Keith Sacre



The Route and glimpses of the PRESENT







The route took us through seven highly varied and distinct Eco-regions each challenged in different ways by climate change yet inextricably linked to each other.

These Eco-regions were:

Coastal Range
Klamath Mountains
Sierra Nevada
Willamette Valley
Cascades
Columbia Plateau (Just)
Puget Lowlands



Coastal Range

Running the length of the region the Coast Range is characterised by high rainfall.

Along the coast and in adjacent valleys, summer fog and relatively cool temperatures affect the climate.

The coastal range can be as much as 20 miles wide and is composed of glacially deposited sediment and rock.

Redwoods *(Sequoia sempervirens)* dominate near the coast in the southern portion of the coast range.

Much of the forest area is productive conifer plantation dominated by Sitka Spruce *(Picea sitchensis),* Western Hemlock *(Tsuga heterophylla),* Western Red Cedar *(Thuja plicata),* Alaska Yellow Cedar *(Chamaecyparis nootkatensis)* and Douglas Fir *(Pseudotsuga menziesii)*.

Wetlands are common.



Coastal Range continued



Fallen Coastal Redwood.
The next generation emerging



Tree debris on the beach



Coastal Redwood with people for scale


At play !!!!!!!


Two playing!!!!

Understory plants associated with coastal redwood



Asuram caudatum (wild ginger)



Prosartes hookeri (Hooker's fairybells),



Maianthemum racemosum (false solomon seal),



Scoliopus bigelovii (fetid adder's tongue),



Viola sempervirens (redwood violet);

Klamath Mountains

In southern Oregon the Coastal Range transitions into the biologically diverse Klamath Mountains.

A dominantly east-west range of mountains.

Considerably drier than the adjacent Coastal Range and experiences a lengthy summer drought.

A transition zone with a mix of northern California and Pacific Northwest conifers and a high number of endemic species reliant on serpentine soils which are nutrient-poor, metal-rich soils derived from ultramafic rocks, creating extreme conditions that support unique plant communities and high endemism.

Has the largest number of cone bearing tree species of any like-sized area in the world.



Pinus ponderosa (ponderosa pine)



Juniperus occidentalis (Western Juniper)



Chamaecyparis lawsoniana, Port Orford Cedar



Arctostaphylos klamathensis
Klamath manzanita



Ericameria ophitidis
(Serpentine goldenbrush)



Perideridia erythrorhiza
western yampah



Phlox hirsuta (Yreka phlox)



Picea breweriana (Brewer's spruce)

Some endemic species of the ecoregion dependent on the serpentine soils

Sierra Nevada

A region of rugged mountains and deep valleys which is reported to have the greatest biological diversity in California.

Much of the range is granite as opposed to the mostly sedimentary formations in the Klamath.

Ponderosa Pine on the west side and Lodgepole pine on the east side dominate the lower slopes.

At higher altitude *Sequoiadendron giganticum* is dominant in size and stature.

Again, there are a large number of endemic species within the ecoregion.









Sequoiadendron giganticum



Endemic plants of the high Sierra Nevada Region

The high Sierra Nevada region is home to a variety of endemic plants th atare unique to this area. These plants are adapted to the specific conditions of the region and are not found in other parts of the United States or even within California. Here are some examples of endemic plants in the high Sierra Nevada region:



Polemonium eximium
skypilot or showy sky pilot



Allium validum
mountain onion



Oreonana clementis
clements mountain parsley



Podistera Nevadensis
Sierra podistera

Pines

•Grey Pine - Digger Pine (Pinus sabiniana)
•Foxtail Pine - (Pinus balfouriana)
•Knobcone Pine - (Pinus attenuata)
•Ponderosa Pine - (Pinus ponderosa)
•Limber Pine (Pinus flexilis)
•Jeffrey Pine (Pinus jeffreyi)
•Sugar Pine (Pinus lambertiana)
•Western White Pine (Pinus monticola)
•Single-leaf Pinyon Pine (Pinus monophylla)
•Whitebark Pine (Pinus albicaulis)

Other Conifers

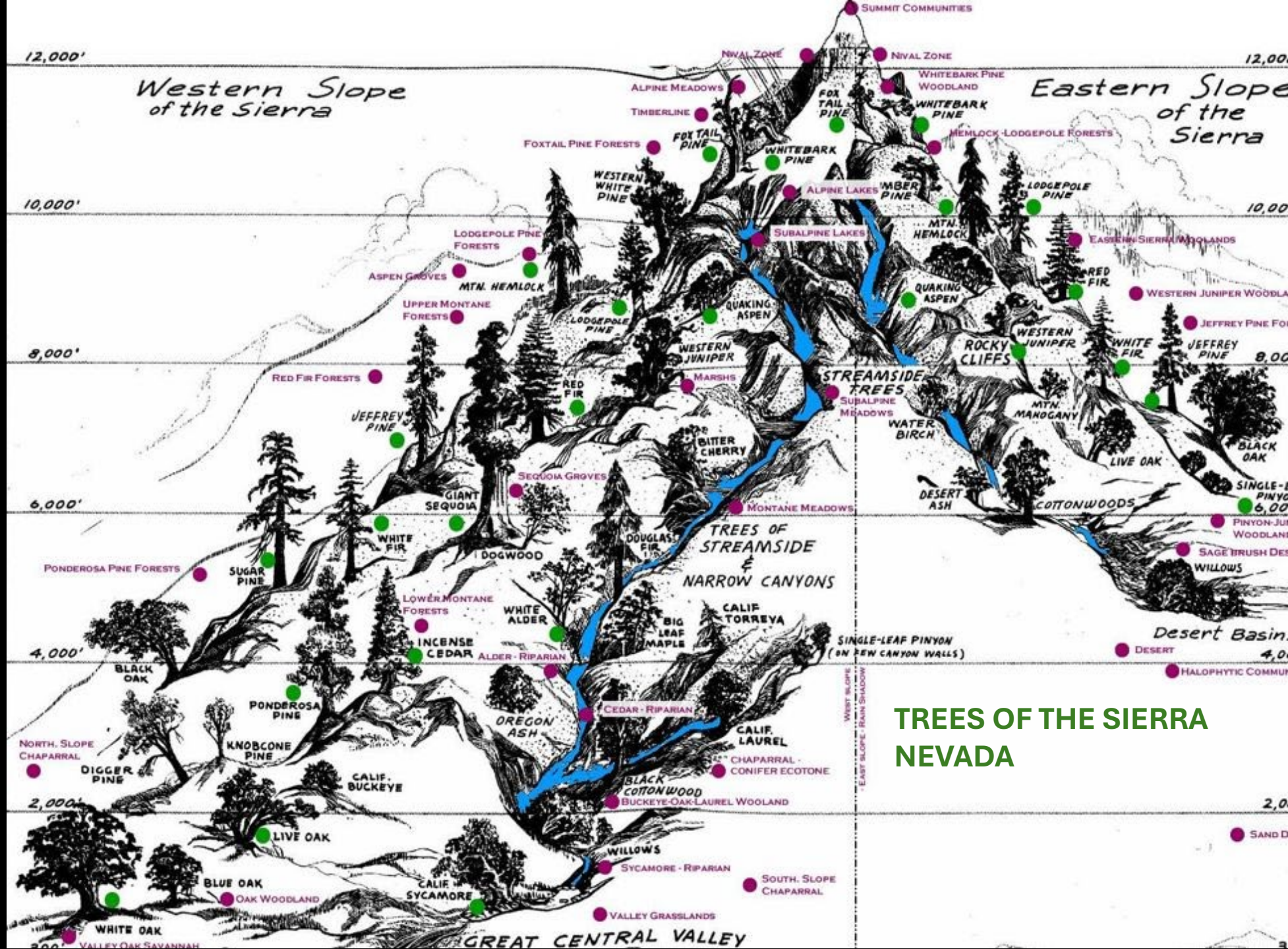
•Douglas-Fir (Pseudotsuga menziesii)
•Incense Cedar (Calocedrus decurrens)
•White Fir (Abies concolor)
•Mountain Hemlock (Tsuga mertensiana)
•Giant Sequoia (Sequoiadendron giganteum)
•Western Juniper (Juniperus occidentalis)
•Red fir (Abies magnifica)

Riparian Trees

•California Sycamore (Platanus racemosa)
•White Alder (Alnus rhombifolia)
•Quaking Aspen (Populus tremuloides)
•Fremont Cottonwood (Populus fremontii)
•Arroyo Willow (Salix lasiolepis)
•Water Birch (betula occidentalis)
•Bigleaf Maple (Acer macrophyllum)

Oaks

•California Black Oak (Quercus kelloggii)
•Canyon Live Oak (Quercus chrysolepis)
•Valley Oak (Quercus lobata)
•Coast Live Oak (Quercus agrifolia)



Willamette Valley

Situated between the Coast range and the Cascades.

Fairly level alluvial plain with scattered basalt hills.

Mild and wet winters with warm dry summers.

Historically the area was the home to rolling prairies and mixed, deciduous/coniferous forests and extensive wetlands.

Forests were concentrated on the edges of the ecoregion with Douglas Fir, Grand Fir and Western Red Cedar the major tree species.

Much of the Willamette Valley has been agriculture and urban environment with only fragments of the original vegetation remaining.





Cascades

Rain shadow of the Cascades is a dominant influence on this ecoregion.

Experiences greater temperature extremes than the mountainous regions to the west.

Receives less precipitation than the mountainous regions to the west.

At higher elevations moist areas typically host subalpine Fir, Mountain Hemlock, or Pacific Silver Fir.

Mid to low–elevation areas usually have a combination of Douglas Fir, Ponderosa Pine and Western Larch.

Garry Oak woodlands appear in the southern half of the eco-region at lower elevations.



Quercus garryana (Garry Oak)







Columbia Plateau

A vast and relatively flat ecoregion dominating central and Eastern Washington State.

The Columbia Plateau is the result of millennia of basalt flows which has produced an underlying layer of basalt nearly two miles deep.

Soils are mainly derived from wind-deposited material.

The driest part of the Northwest - the Columbia Plateau - receives as little as six inches of precipitation annually.

Vegetation is predominantly sagebrush and bunchgrasses.



Sagebrush *(Artemesia tridentata)*







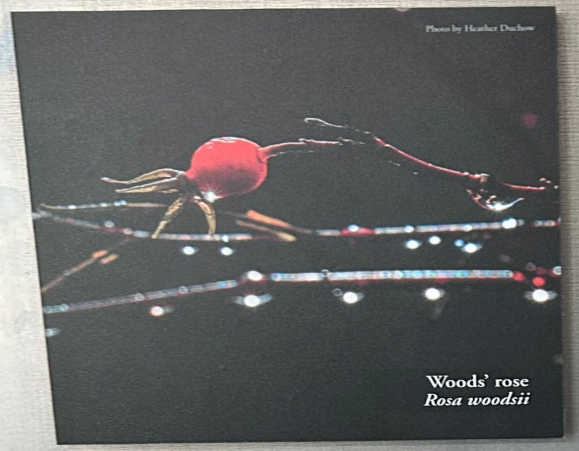
Smith Rock State Park





Western Juniper *(Juniperus occidentalis)*

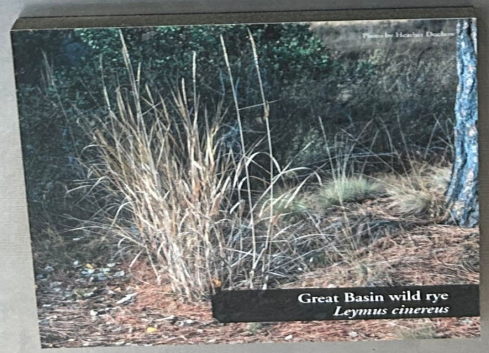
Fall—Winter







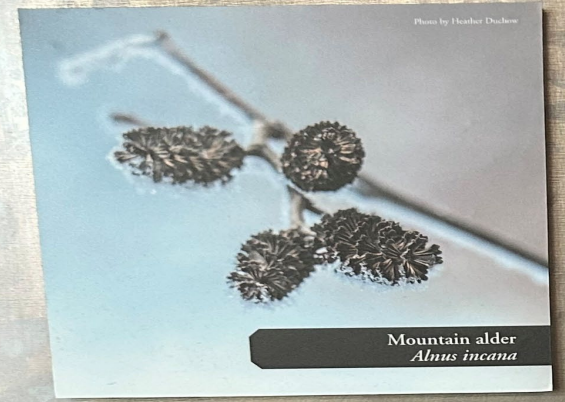






RIPARIAN COMMUNITY

Fall—Winter













AGEBRUSH STEPPE COMMUNITY

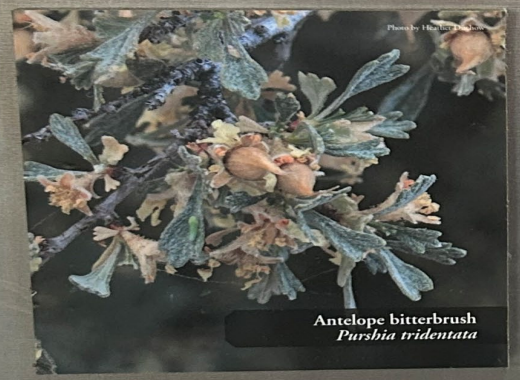
Fall—Winter



Western juniper
Juniperus occidentalis



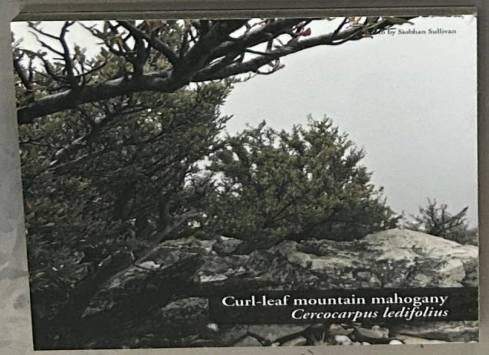
Green rabbitbrush
Chrysothamnus viscidiflorus



Antelope bitterbrush
Purshia tridentata



Big sagebrush
Artemesia tridentata



Curl-leaf mountain mahogany
Cercocarpus ledifolius



Bluebunch wheatgrass
Pseudoroegneria spicata

MONTANE FOREST COMMUNITY

Fall—Winter



Ponderosa pine
Pinus ponderosa



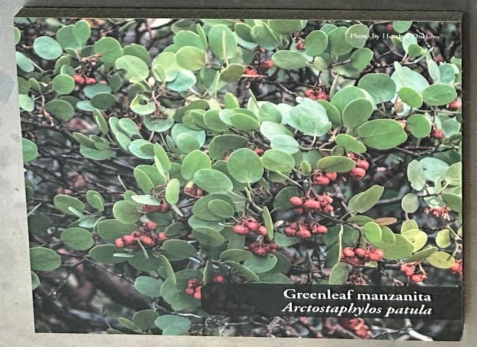
Lodgepole pine
Pinus contorta



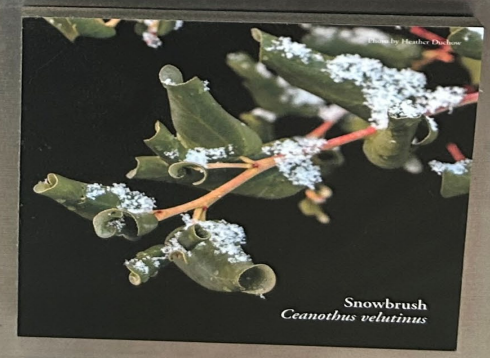
Oregon grape
Mahonia aquifolium



Western serviceberry
Amelanchier alnifolia



Greenleaf manzanita
Arctostaphylos patula



Snowbrush
Ceanothus velutinus

Puget Lowlands

Much of this ecoregion lies in the rain shadow of the Olympic Mountains and Vancouver Island and rainfall varies accordingly.

The climate is mild the year round due to the maritime influence.

A majority of the ecoregion was once dominated by Douglas Fir and Western Hemlock.

Region now predominantly urbanised or agricultural with many non-native species found.

Common tree species in forested areas near the shoreline are Madrone *(Arbutus menziesii)* and Shore Pine (*Pinus contorta)*.

Prairie systems dominated by herbaceous species, once common are now rare.



Pinus contorta

Glimpses: The Past

Some 6000 years ago the area in central Oregon known as the Lava Cast Forest, a part of the Newbury National Volcanic Monument, was covered in forest. The forest was composed of *Pinus ponderosa* (Ponderosa Pine), *Pinus contorta* (Lodgepole Pine), *Abies concolor* (White Pine) coupled with a wide range of native shrubs and grasses.

Unfortunately for the forest as it stood all those years ago, the site is situated in the Cascade Mountains volcanic arc. High volcanic peaks of the Cascade Range mark the axis of the Cascades volcanic arc which extends from Canada to Lassen Peak (also known as Mount Lassen), a 3,187m lava dome volcano in northern California. The arc is about 60 miles wide and includes the off-axis Newbury Volcano. Volcanos erupt periodically producing lava flows, with the most recent major eruption being 6000 years ago wiping out the forest. There was a smaller eruption 1000 years ago and the landscape currently shows that clearly.



So, the forest below was subsumed by lava. Interestingly the shallow lava flow did not cover the whole area evenly but surrounded 11 forested habitat islands known as kipukas. The kipukas range in area from 0.3 to 113 ha and retain conditions - although individual trees obviously have not survived the passage of time - which are unaltered by human activity beyond recent fire suppression activity and other management activities in the surrounding forest.

The past is etched into the landscape with the forest of the past preserved in what are known as the lava cast forests. The lava cast forest area includes cinder cones, which are small steep, conical volcanoes made of volcanic fragments called cinders. They are formed from explosive eruptions around a single vent and moulds created around pre-existing tree trunks when the lava flowed around them. The moulds were created when the hot lava met trees which chilled the lava creating a protective covering or mould. The trees then burnt out completely leaving a hollow interior.



So, with a degree of imagination, it is possible to construct a mental visualisation of what the forest looked like some 6000 years ago. It is possible to estimate the density of the trees at the time of the last lava flow, the size of fallen trees reflected in some of the well-preserved casts and to picture what the landscape might have looked like given that the species mix is likely to have been the same.





A glimpse, perhaps, back in time and certainly a reminder of how current arboricultural and forestry debate is couched in unrealistic and artificial, single human lifetime time frames.





The list of associations between the indigenous peoples and the Western Red Cedar are endless and cannot be discussed at any real length here, but it is a seemingly inescapable fact life for the indigenous peoples of the Pacific Northwest have been inextricably linked to the Western Red Cedar for generations - probably going back thousands of years.

It was these indigenous peoples who managed the forest, sustainability, entering into an unwritten contract with nature based on taking only what was needed and a shared and equitable distribution of the resources available.

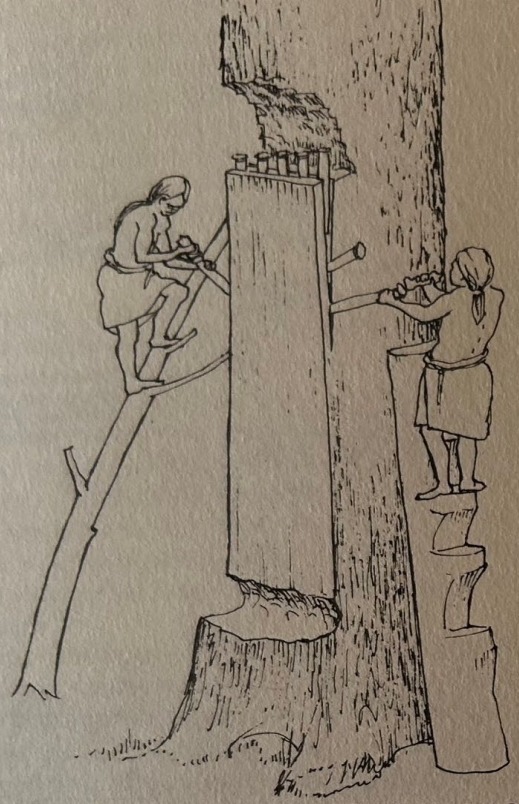



MAKAH CULTURAL AND RESEARCH CENTE
MUSEUM OF
THE MAKAH INDIAN NATION

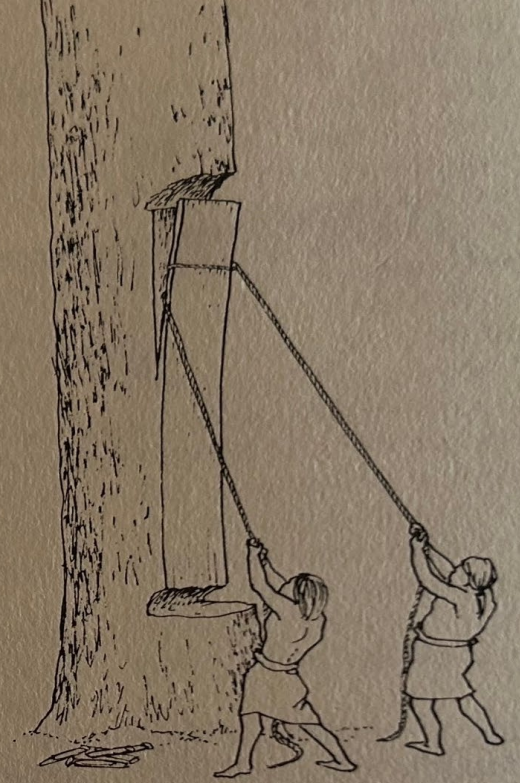


Indigenous people

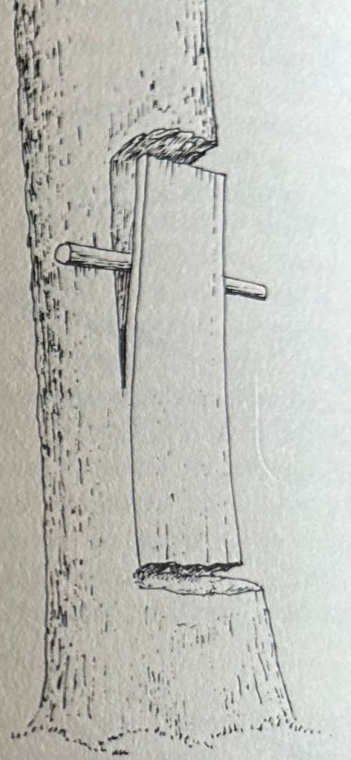
Working and managing Western Red Cedar



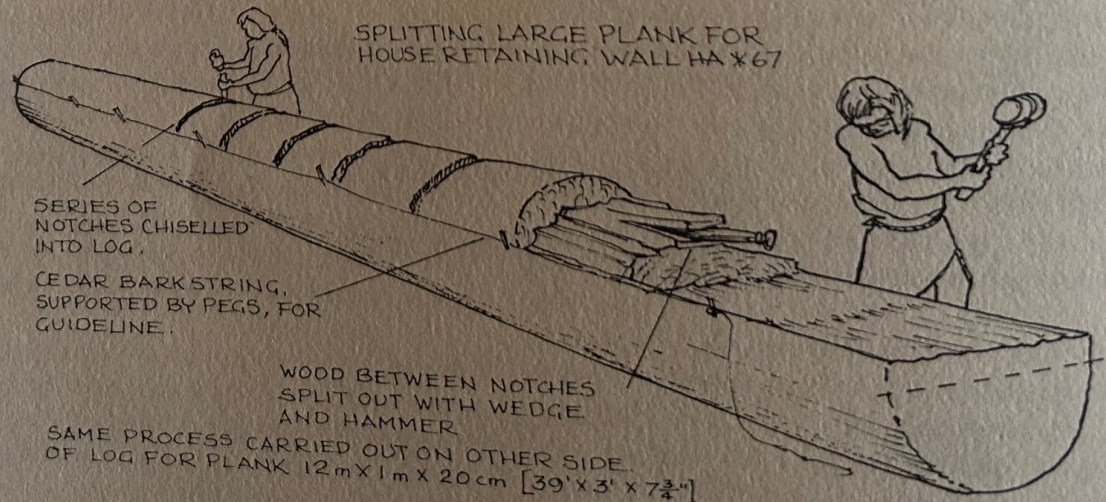
CHISELLED CAVITIES IN TREE TRUNK ALLOWED FOR WEDGES TO BE DRIVEN IN AT TOP, PLANK TO COME AWAY AT BASE. KW*34



PULLING ON ROPE HELPED TO SPLIT PLANK AWAY FROM TRUNK. WC* PERS. COMM. RON HAMILTON.

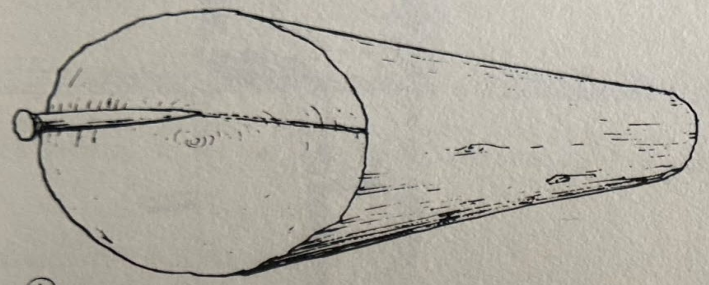


SLOW, BUT ENERGY-SAVING, METHOD OF SPLITTING PLANK: AFTER INITIAL WEDGING, CROSSPIECE WAS INSERTED AND LEFT. WIND AND WEATHER COMPLETED WORK OF SPLITTING OFF PLANK. WC*59

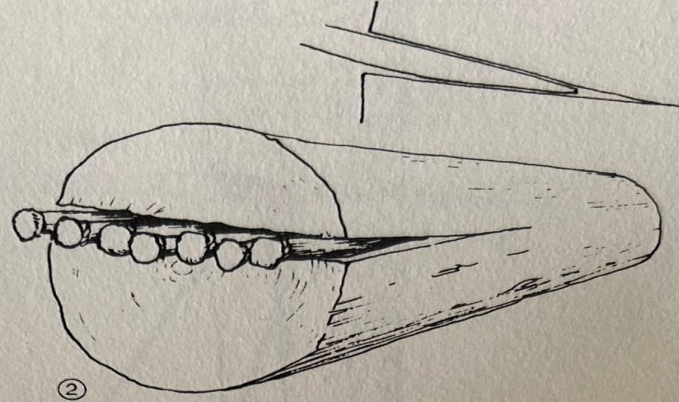


SPLITTING LARGE PLANK FOR HOUSE RETAINING WALL HA*67

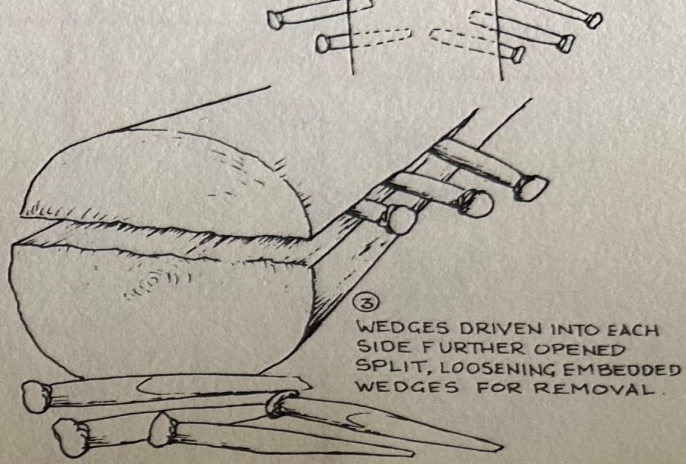
SAME PROCESS CARRIED OUT ON OTHER SIDE OF LOG FOR PLANK 12m X 1m X 20cm [39' X 3' X 7¾"]



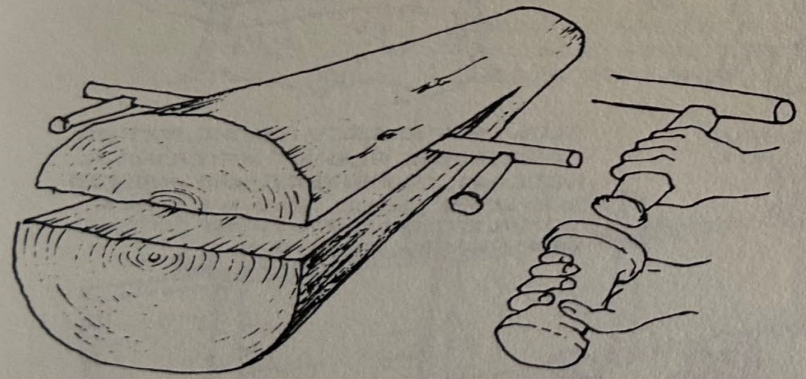
① MARKER WEDGE POUNDED IN ACROSS FACE OF LOG END TO MAKE GROOVED LINE.



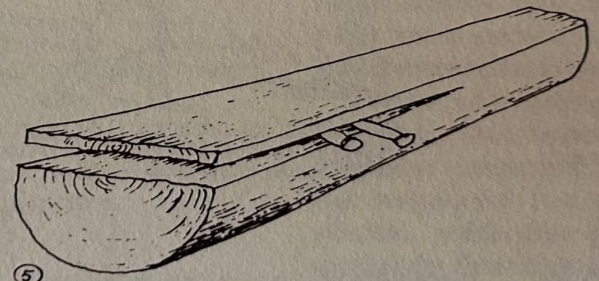
② WEDGES DRIVEN DEEPLY INTO LOG ALONG GROOVE CAUSED WOOD TO SPLIT.



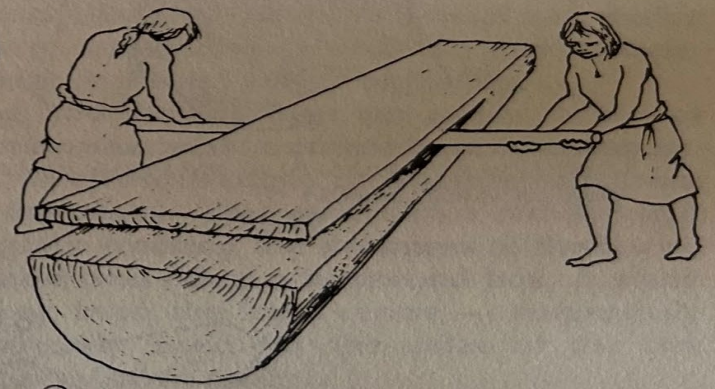
③ WEDGES DRIVEN INTO EACH SIDE FURTHER OPENED SPLIT, LOOSENING EMBEDDED WEDGES FOR REMOVAL.



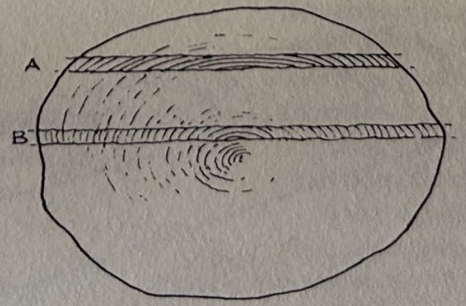
④ SPREADING STICK, DRIVEN ALONG WITH CONCAVE TIPPED WEDGES, FACILITATED SPLITTING.



⑤ WITH TOP SPLIT OFF, PROCESS WAS REPEATED TO MAKE PLANKS OF DESIRED THICKNESS.



⑥ IN ANOTHER METHOD, TWO MEN LEVERED OFF PLANK WITH CROSSBAR.



A. TANGENTIALLY SPLIT PLANK, PREFERRED FOR BOX SIDES.

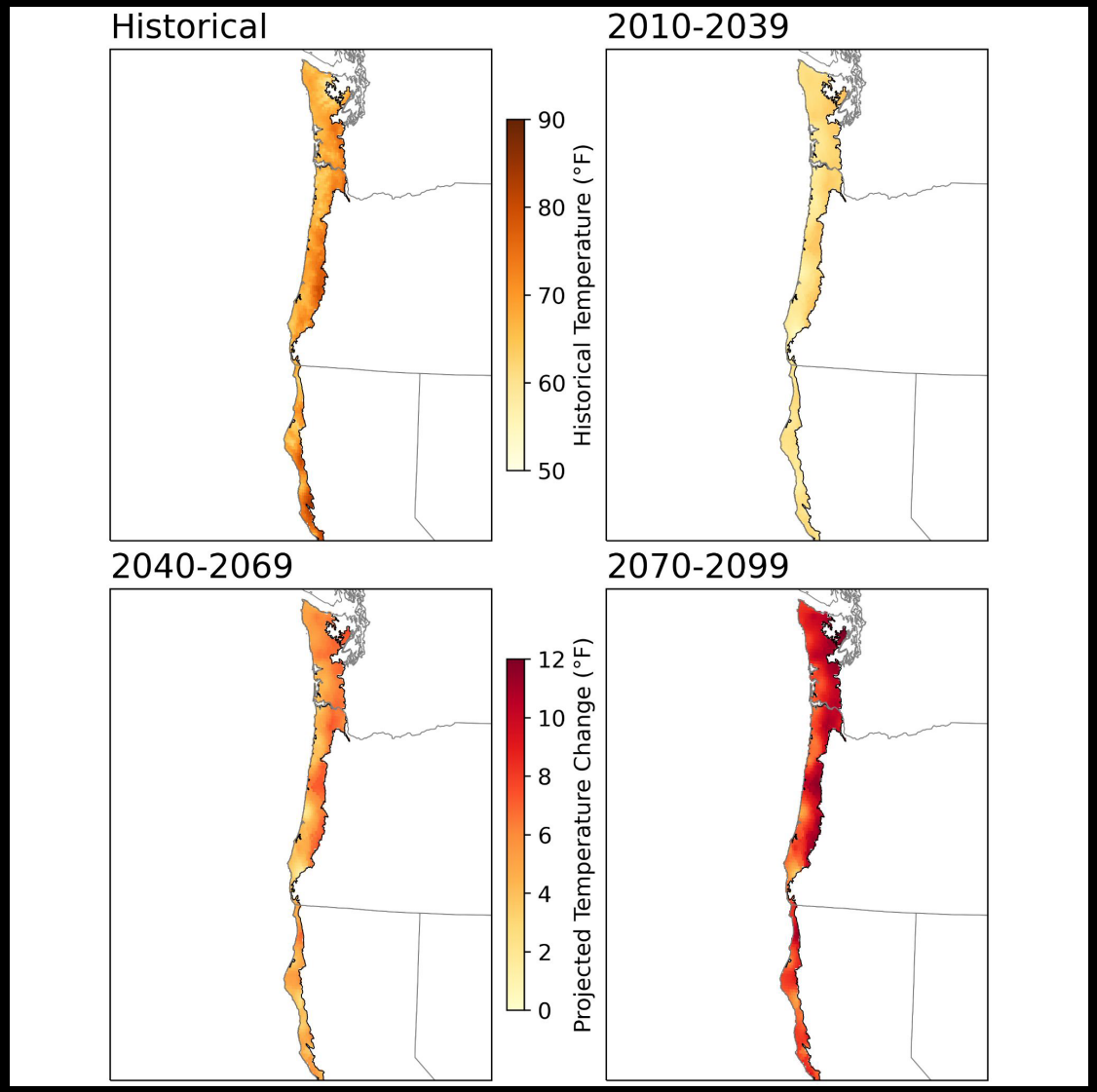
B. RADIALLY SPLIT PLANK, OFTEN USED FOR BOX AND BOWL BASES.


CANADA
VANCOUVER
PACIFIC OCEAN
Marietta Band of Nooksack Tribe
Lummi Nation
Nooksack Indian Tribe
BELLINGHAM
Samish Indian Nation
Upper Skagit Indian Tribe
Swinomish Indian Tribal Community
Kikiallus Nation
Makah Tribe
Lower Elwha Klallam Tribe
PORT ANGELES
Quileute Nation
Tulalip Tribes
Sauk-Suiattle Tribe
Stillaguamish Tribe of Indians
Snoqualmoo Nation
Hoh Tribe
Jamestown S'Klallam Tribe
Snohomish Tribe
Port Gamble S'Klallam Tribe
Suquamish Nation
SEATTLE
Quinault Nation
Snoqualmie Tribe
Duwamish Tribe
Skokomish Tribe
TACOMA
Muckleshoot Indian Tribe
Squaxin Island Tribe
Steilacoom Tribe
OLYMPIA
Puyallup Tribe
Nisqually IndianTribe
Shoalwater Bay Tribe
Chinook Nation
The Confederated Tribes of the Chehalis Reservation
Colville Confederated Tribes
Kalispel Tribe of Indians
Spokane Tribe of Indians
WASHINGTON
SPOKANE
IDAHO
YAKIMA
Yakama Nation
Nez Perce Tribe
Cowlitz Indian Tribe
Confederated Tribes of the Umatilla Indian Reservation
OREGON
Confederated Tribes of Warm Springs
Federally Recognized Nations
Not Federally Recognized Nations
Pacific Coast Region
Puget Sound Region
Columbia River/Plateau Region

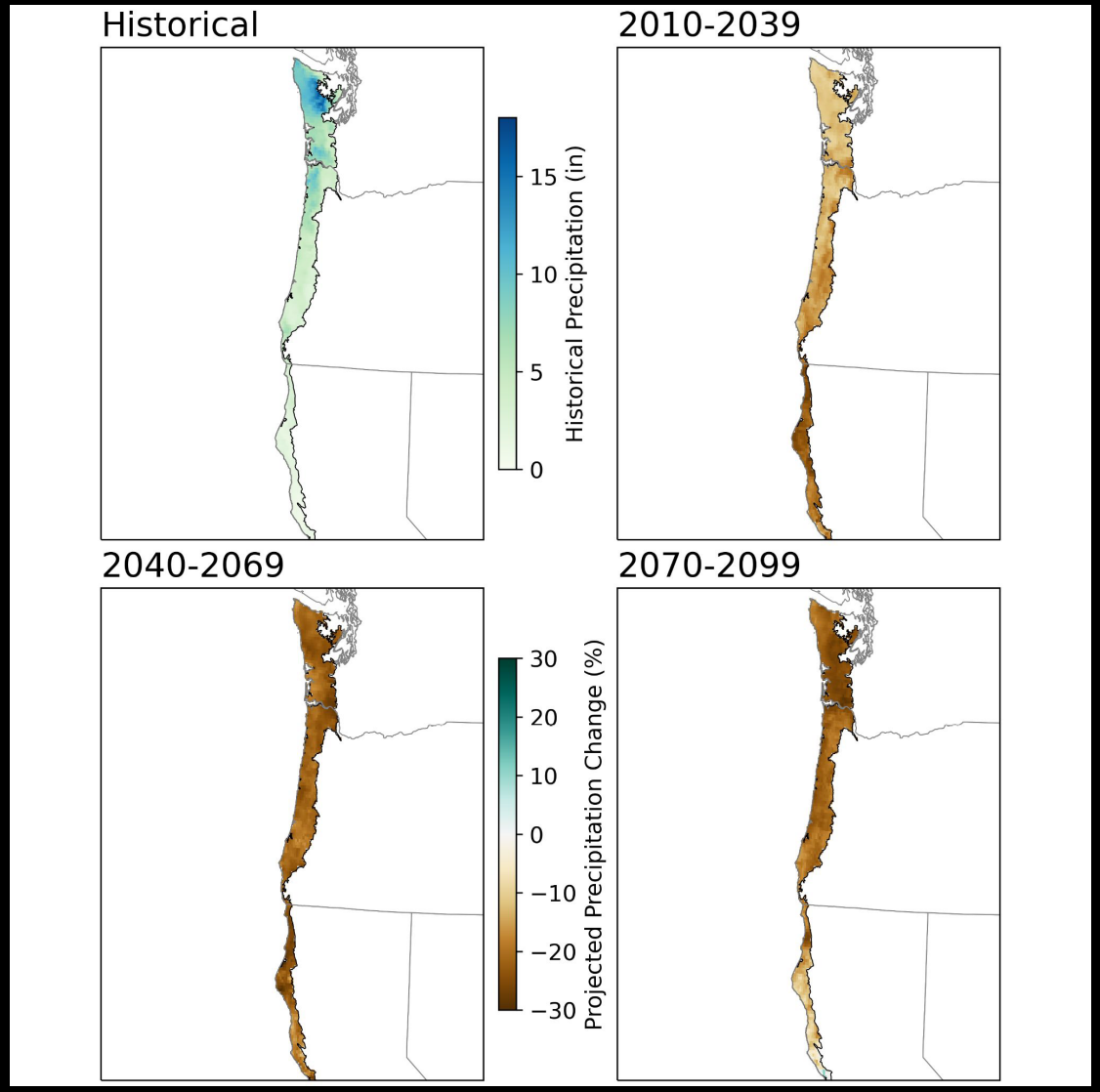
Glimpses, the Future



Coastal Range



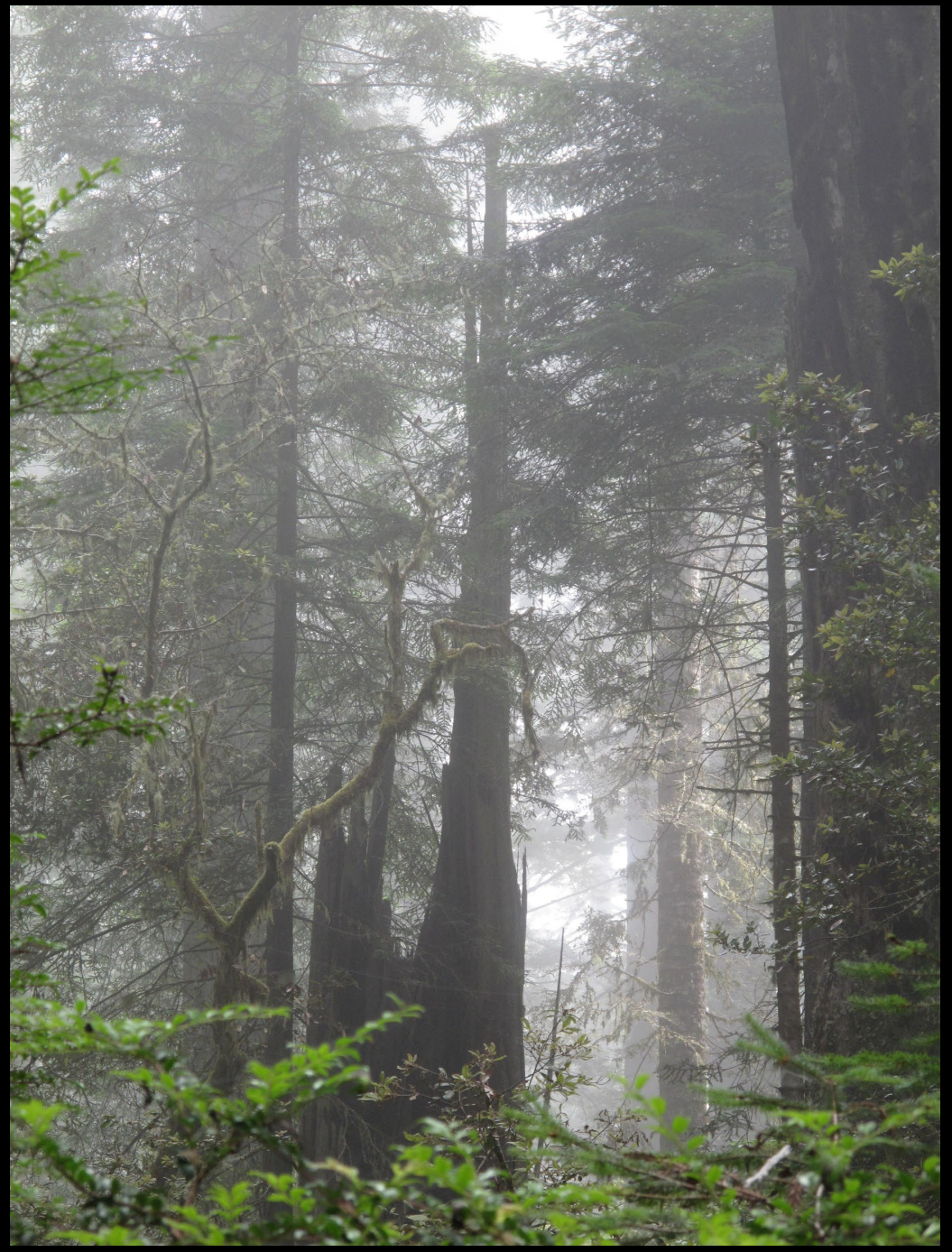
Temperature



Rainfall

This ecoregion receives substantial precipitation and is dominated by highly productive wet forests. Major tree species in wet forests include Sitka spruce, Douglas-fir, western hemlock and western redcedar. Historically, Sitka Spruce dominated the coast with Western Redcedar, Western Hemlock and Douglas-Fir present in inland areas.
Fog is an important climatic factor for Redwood forests that dominate the Californian portion of the ecoregion.
It is reported that these sea mists are gradually moving north leaving the Redwood forest vulnerable to partial desiccation.





Extreme Heat

More frequent and intense heat waves with climate change are expected to further increase forest exposure to extreme heat. The summer 2021 PNW heat wave caused foliar damage of tree canopies on more than 90,000 ha. Coastal Douglas-Fir and Western Hemlock plantations had the most extensive impacts. Phenological characteristics, water availability, and acclimation all influenced tree susceptibility to scorch.

Yellow-Cedar Decline

Yellow-Cedar growth is limited by warm and dry winters that have lower than average snowpack. Warmer winters in recent decades appear to be contributing to the stress and decline of Yellow-Cedar.

Shallow roots of Yellow-Cedars are especially susceptible to damage without a persistent snowpack for insulation.



Callitropsis nootkatensis formerly known as Cupressus nootkatensis (syn. Xanthocyparis nootkatensis, Chamaecyparis nootkatensis),

Douglas-Fir Beetle

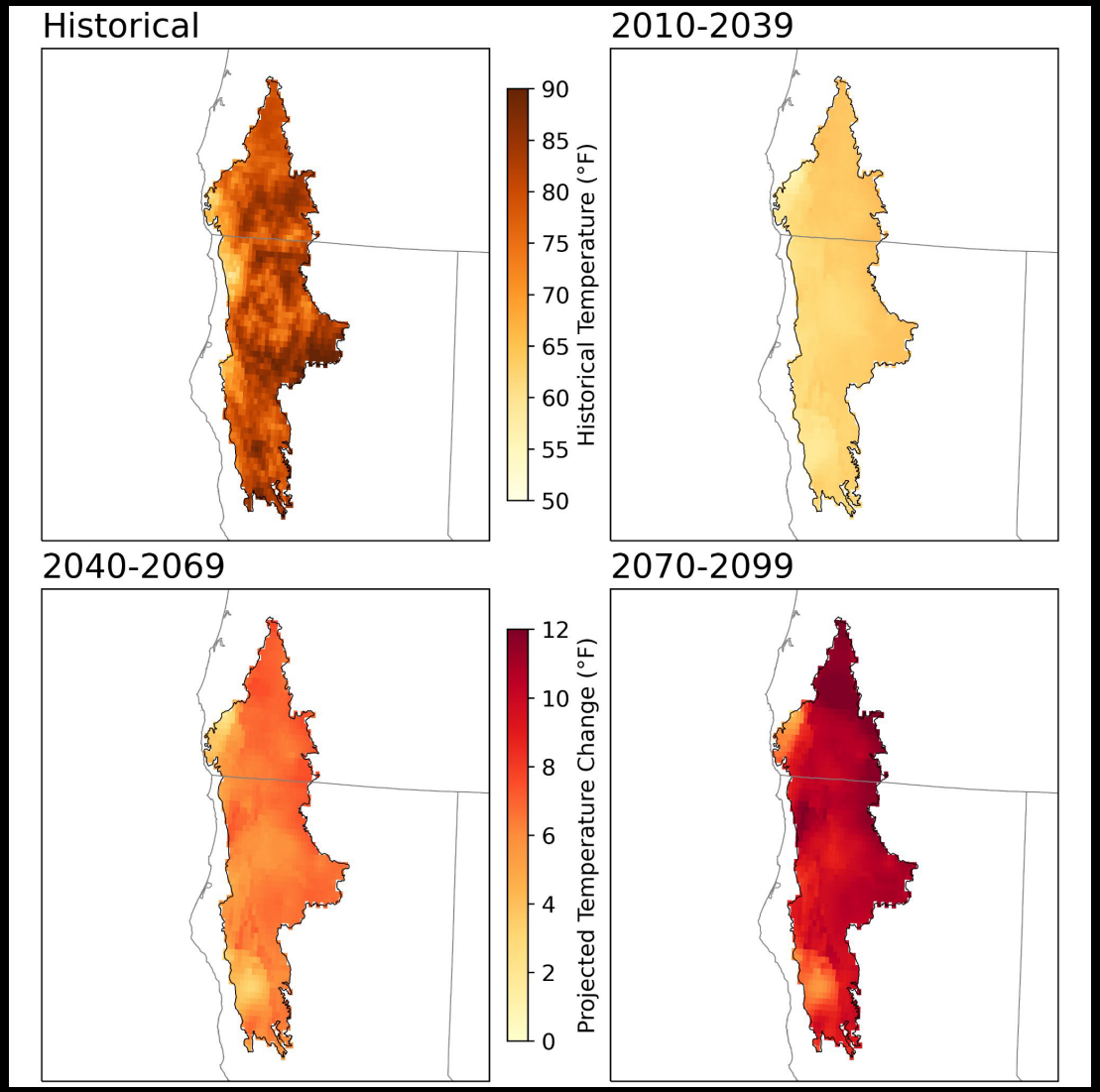
Douglas-Fir Beetle, a native bark beetle, feeds on vascular tissue of stressed Douglas-Fir and causes tree mortality. Host resistance typically keeps beetle populations at endemic levels, and small diameter trees are rarely attacked. Douglas-Fir Beetle is associated with windthrow and drought events, as well as localised areas of root disease. Increased host tree stress from hotter drier summers is expected to increase outbreak severity.
Warmer winters may accelerate beetle development.



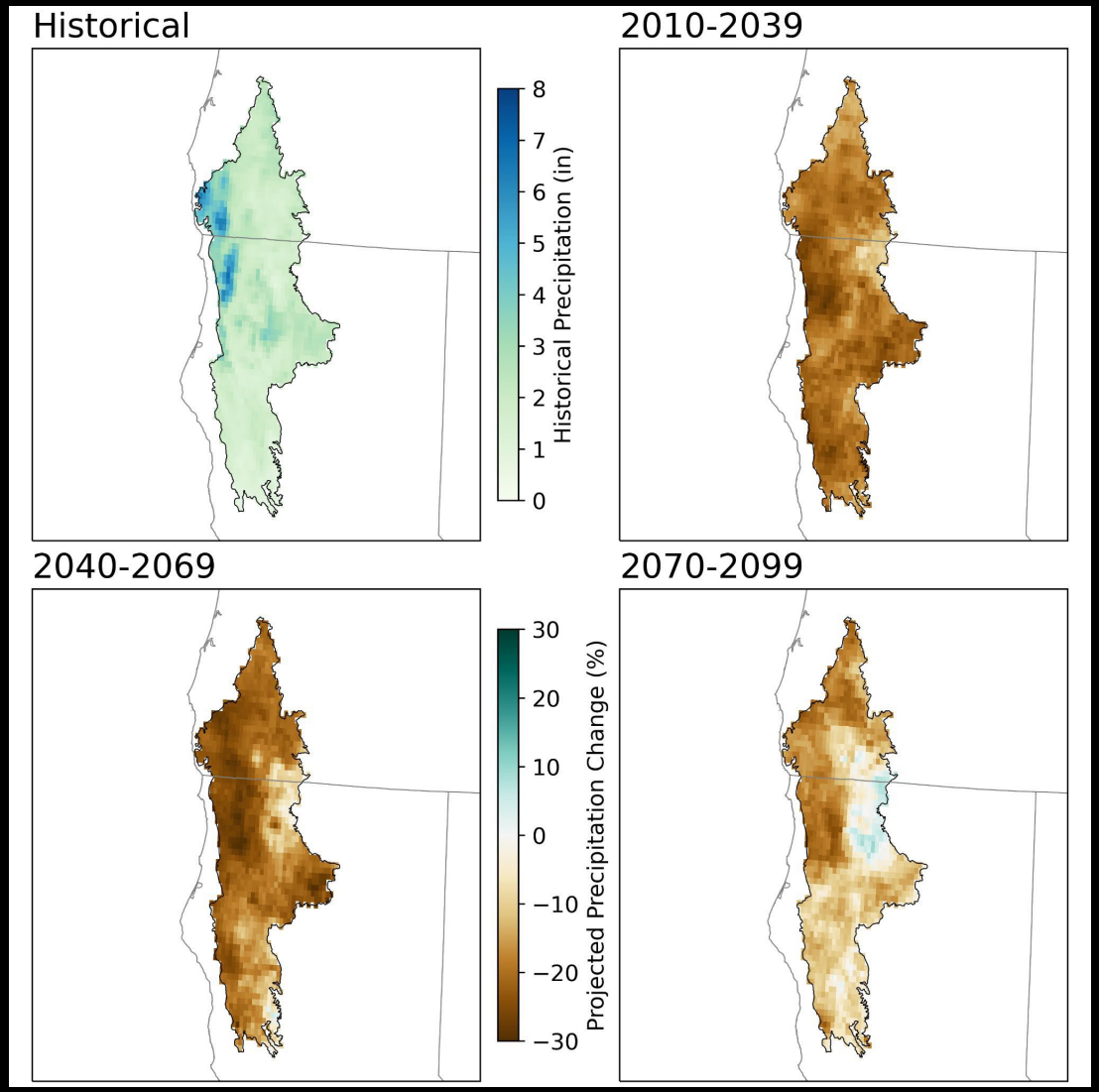




Klamath Mountains



Temperature



Rainfall

Topography

Topography of this ecoregion is dissected ridges, foothills, and valleys of the Klamath and Siskiyou mountains, with substantial relief.

The climate is mild, characterized by lengthy summer drought.

Dry mixed-conifer forests and dry warm forests and woodlands dominate the ecoregon, with some moist mixed-conifer forest. Oregon White Oak, Tanoak, and Black Oak (to the south) are common hardwoods in the dry-mixed conifer forests and dry warm forests and woodlands.

Common conifer species include Ponderosa Pine, Douglas-Fir, Sugar Pine, Incense-Cedar, White Fir and Red Fir.



Shift to Non-Forest Vegetation

Projected increases in aridity and more frequent and severe fire are expected to reduce post-fire forest recovery by reducing conifer recruitment. Dry areas of the ecoregion may exceed a threshold for which intervals between severe fires are too short to allow for conifer recruitment.

Post-fire regeneration is expected to be low in patches of high-severity fire where seed sources are limited.

The vulnerability of conifer forests to conversion to shrub or grass-dominated systems is expected to increase.



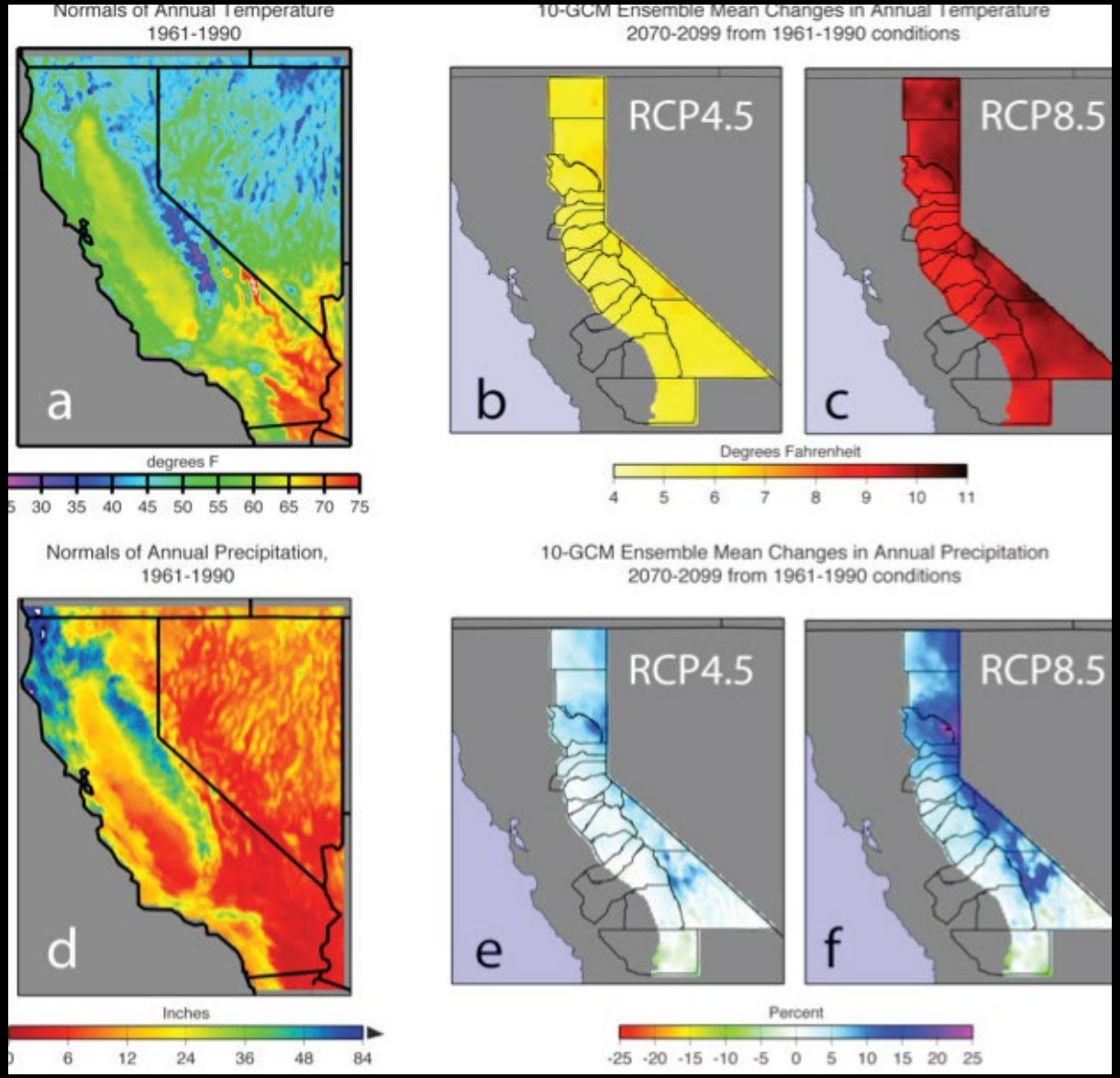
Drought and Biotic Disturbance Interactions

Douglas-Fir mortality in the Klamath Mountains ecoregion has increased in recent decades due to interacting climatic conditions and bark beetle (e.g., Flatheaded Fir Borer) disturbance, with harsh site conditions predisposing trees to mortality. Drought has been identified as an "inciting" factor for this recent mortality. Flatheaded Fir Borer, a native bark beetle, contributes to mortality on predisposed hot and dry sites. Flatheaded Fir Borer is expected to be an increasingly important disturbance agent in this ecoregion as drought frequency and severity increase with climate change.

Sudden Oak Death

Sudden Oak Death is a non-native protist pathogen that currently occurs in Tanoak vegetation in coastal Oregon and California. Black Oak and Tanoak may become more susceptible to Sudden Oak Death with climate change, constraining oak survival and regeneration, and driving changes in canopy cover and vegetation composition. Warmer, wetter springs favour the expansion of Sudden Oak Death eastward in the region (Standiford and Purcell 2015).

Sierra Nevada





Sequoia & Kings Canyon National Parks

National Park Service
U.S. Department of the Interior

A Burning Threat

Giant sequoias are icons of resilience, adapted to survive thousands of years in a landscape visited by regular fire. However, a shifting climate combined with fuel buildup is driving a rise in severe wildfire in sequoia groves.

Don't sequoias need fire?

Yes! Sequoias grow in fire-adapted ecosystems. Periodic fires reduce fuel buildup, preventing destructive, high-severity blazes.

After over a century of fire suppression, many groves had become choked with dead wood and small trees, shading out young sequoias and creating dangerous fire conditions. Today, we are bringing fire back into the groves—helping protect both the new generation and the old.

Confronting a New Challenge

Scientific research is an important tool to help us understand the conditions sequoias need to survive. Prescribed burns and fuel reduction projects are used to restore groves to a more resilient condition. But perhaps the most powerful defenders of sequoias are all those who learn, teach others, and take steps to create a world where sequoias can thrive for thousands of years into the future.





What's behind the trend?

Wildfire is a complex process that depends on many factors: previous fire patterns, forest management practices, and temperature and precipitation.

Rising temperatures and earlier snowmelt lead to longer fire seasons. Warmer and drier conditions are also linked to higher-severity fire. Scientists studying these trends have found that climate change is a significant force behind the rise in fire we are seeing today.

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13–19%

of the world's large giant sequoias.

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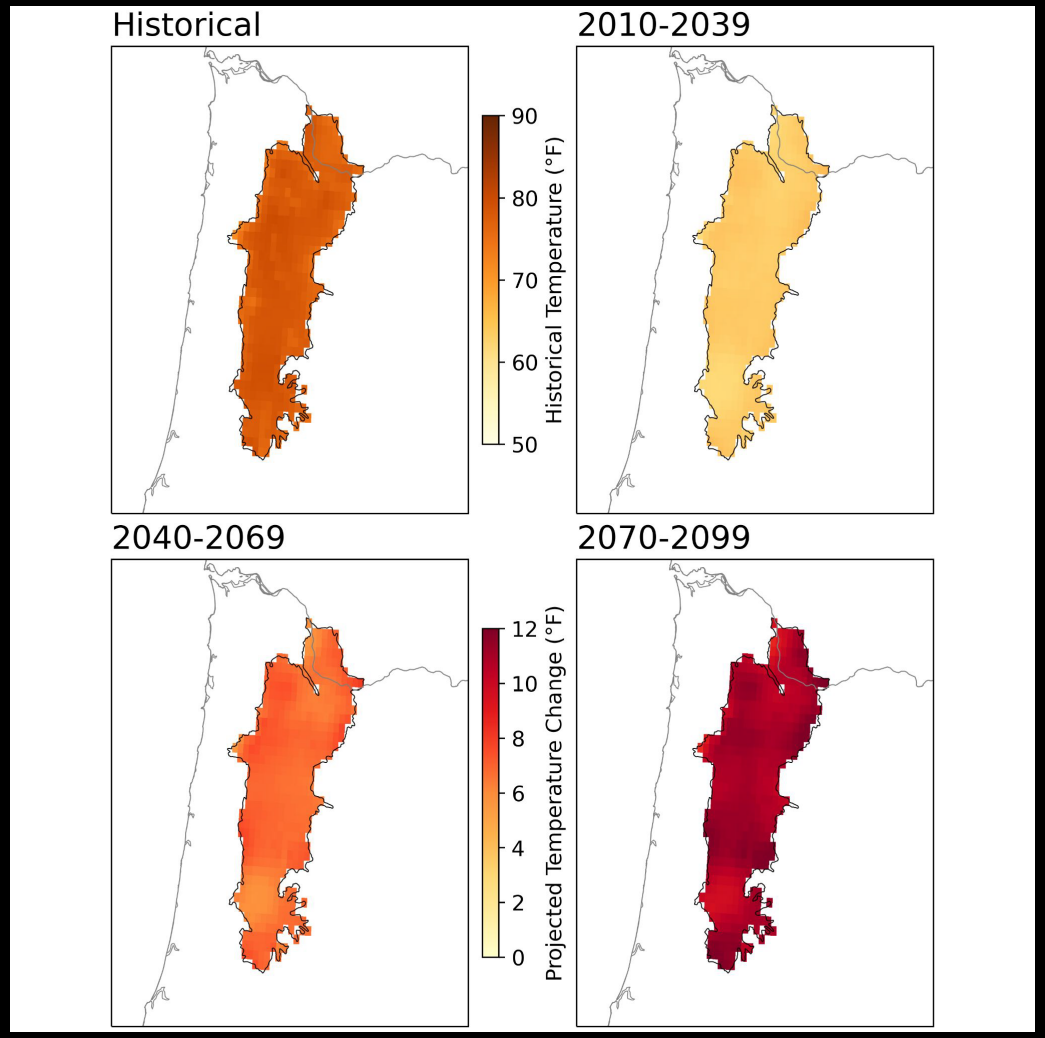
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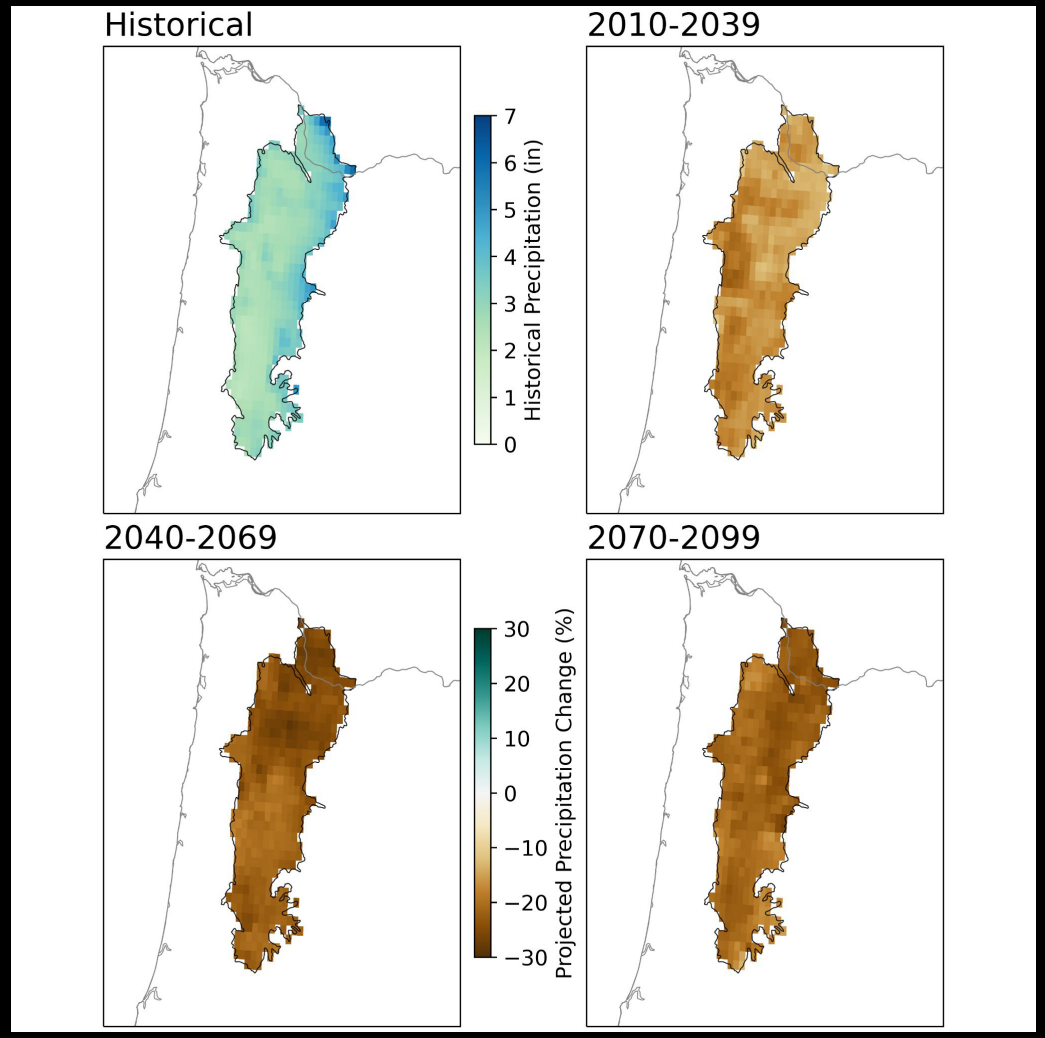




Willamette Valley



temperature



rainfall

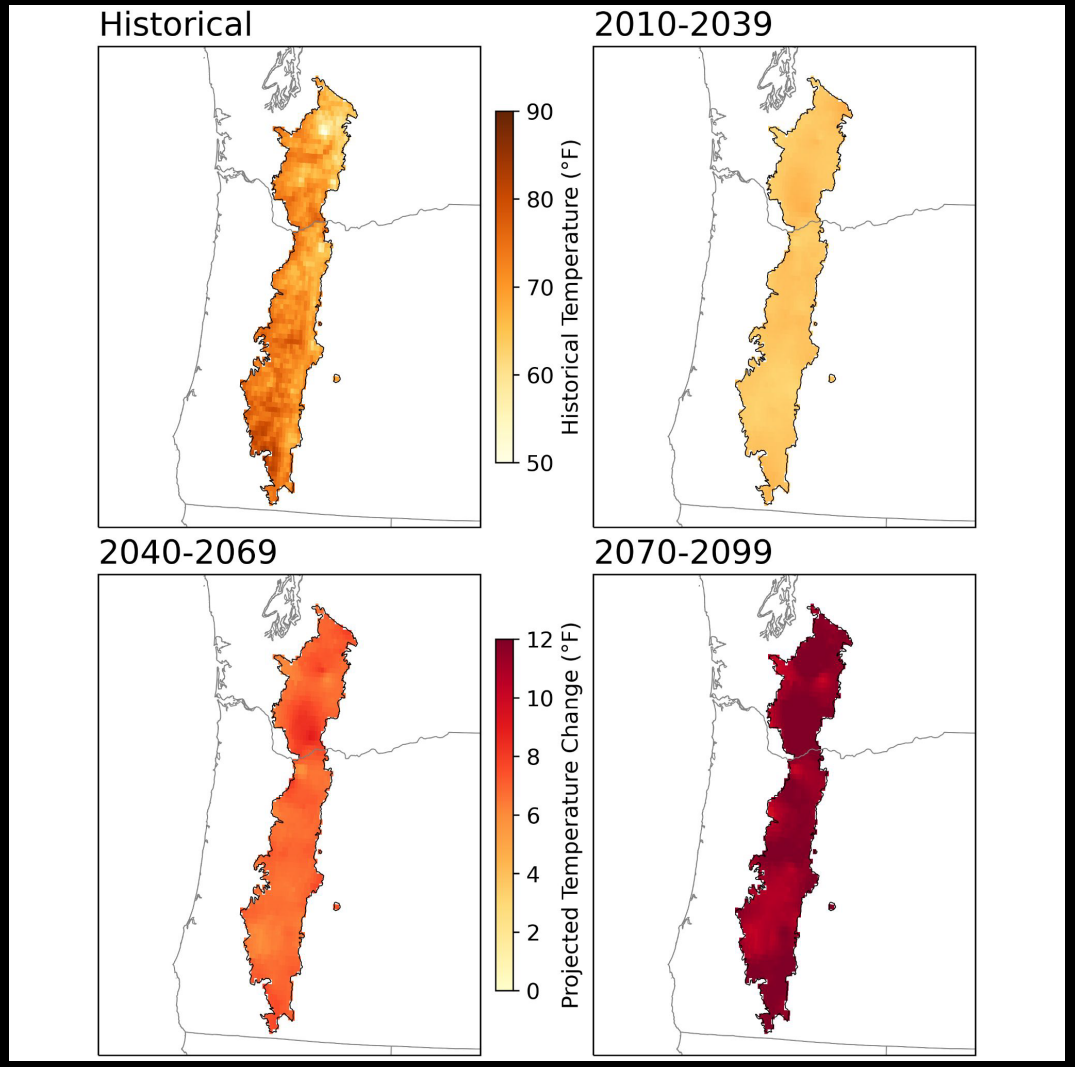
The Willamette Valley ecoregion receives less precipitation than the Coast Range to the west and and the Cascades to the east and has much less relief, leading to dry warm forests and woodlands as the dominant forest. Major tree species in dry warm forests and woodlands include Oregon white Oak (north), California Black Oak (south), Pacific Madrone and Douglas-Fir, with minor components of Oregon Ash, Bigleaf Maple, Black Cottonwood and Red Alder.

Following Euro-American colonisation, more than 95% of native oak woodlands have been lost, and many remaining woodlands are declining due to urbanisation and development, conversion to agriculture, conifer encroachment, exclusion of indigenous burning practices, and invasives.

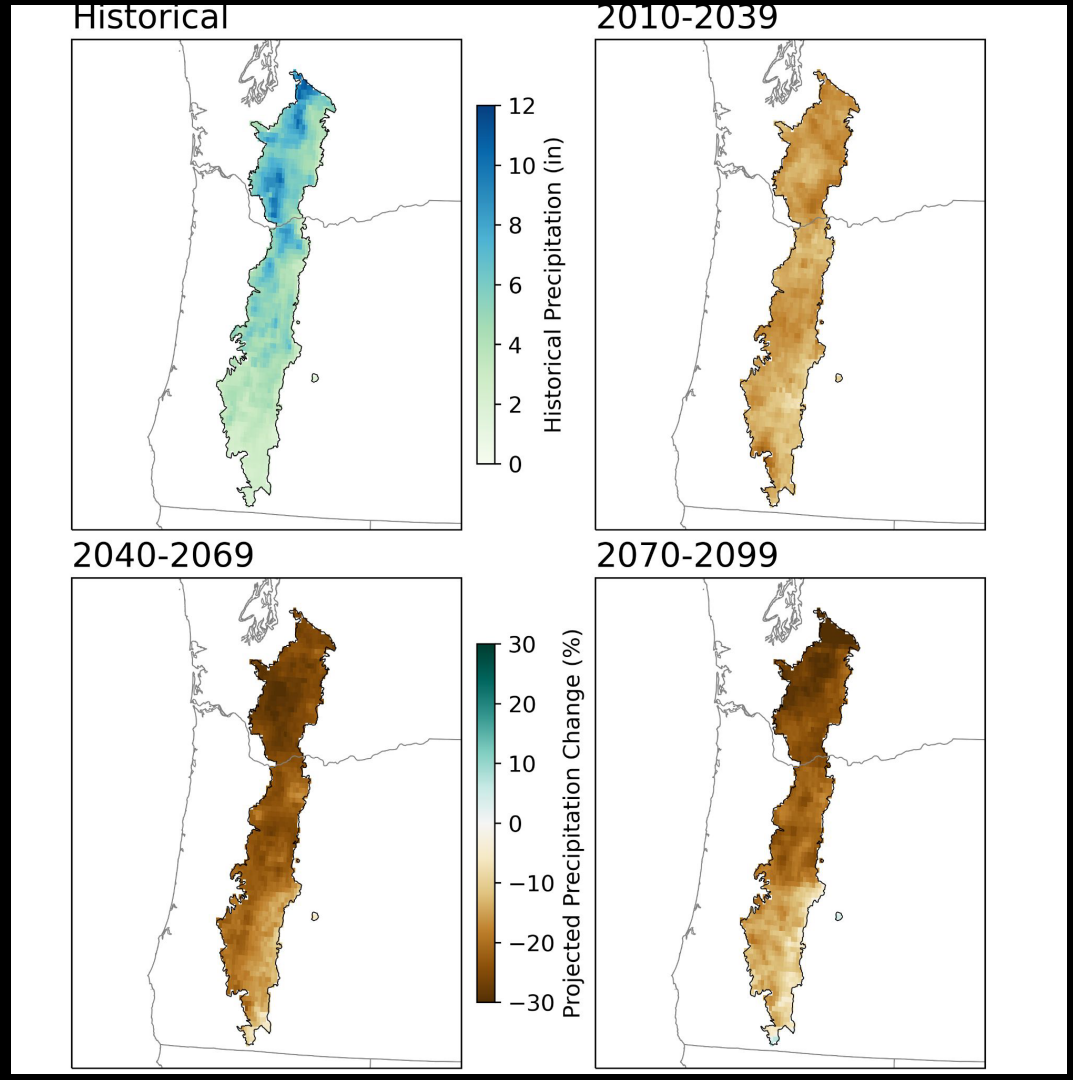


Oregon White Oak in the Willamette Valley

Cascades



temperature



rainfall

Drought-Related Decline and Mortality

Warmer, drier conditions are reducing growth and contributing to the mortality of drought-intolerant species, such as Bigleaf Maple, Yellow-Cedar, Western Hemlock, and Western Redcedar. Parasitic plants, e.g., dwarf mistletoe, reduce vigour and intensify the direct effects of climatic stress on the growth and mortality of infected trees. Future warming and drought are expected to accelerate these declines.

Short-Interval Reburns

Reburns can produce abrupt shifts in forest structure and composition, including transition to non-forest vegetation, when they occur over shortened intervals.

Pest and Disease

Douglas-Fir beetles attack stressed and recently fallen trees and are more common in forests affected by wind and fire. It is unknown how climate change will affect the Douglas-Fir Beetle directly, but moisture stress is expected to increase tree susceptibility to beetle attacks.

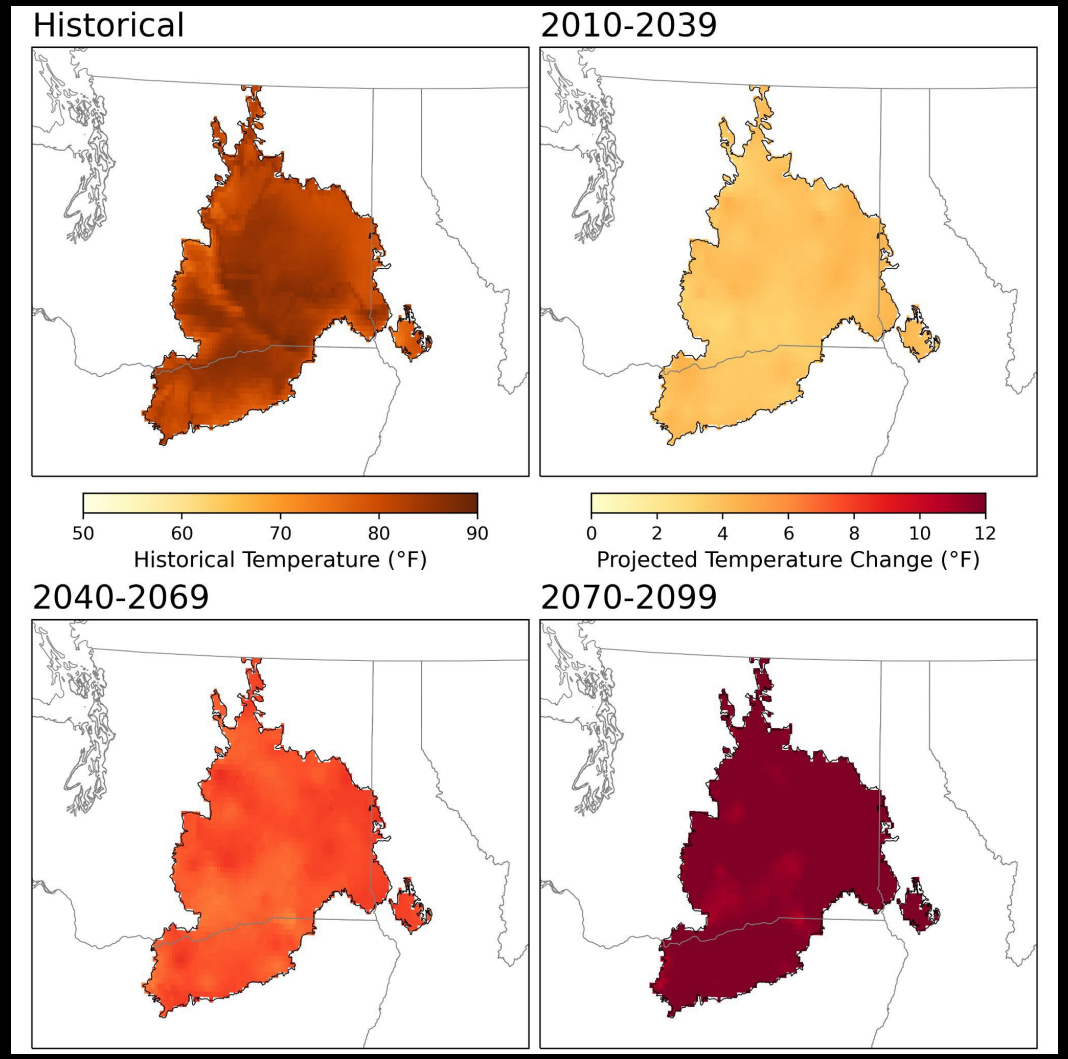


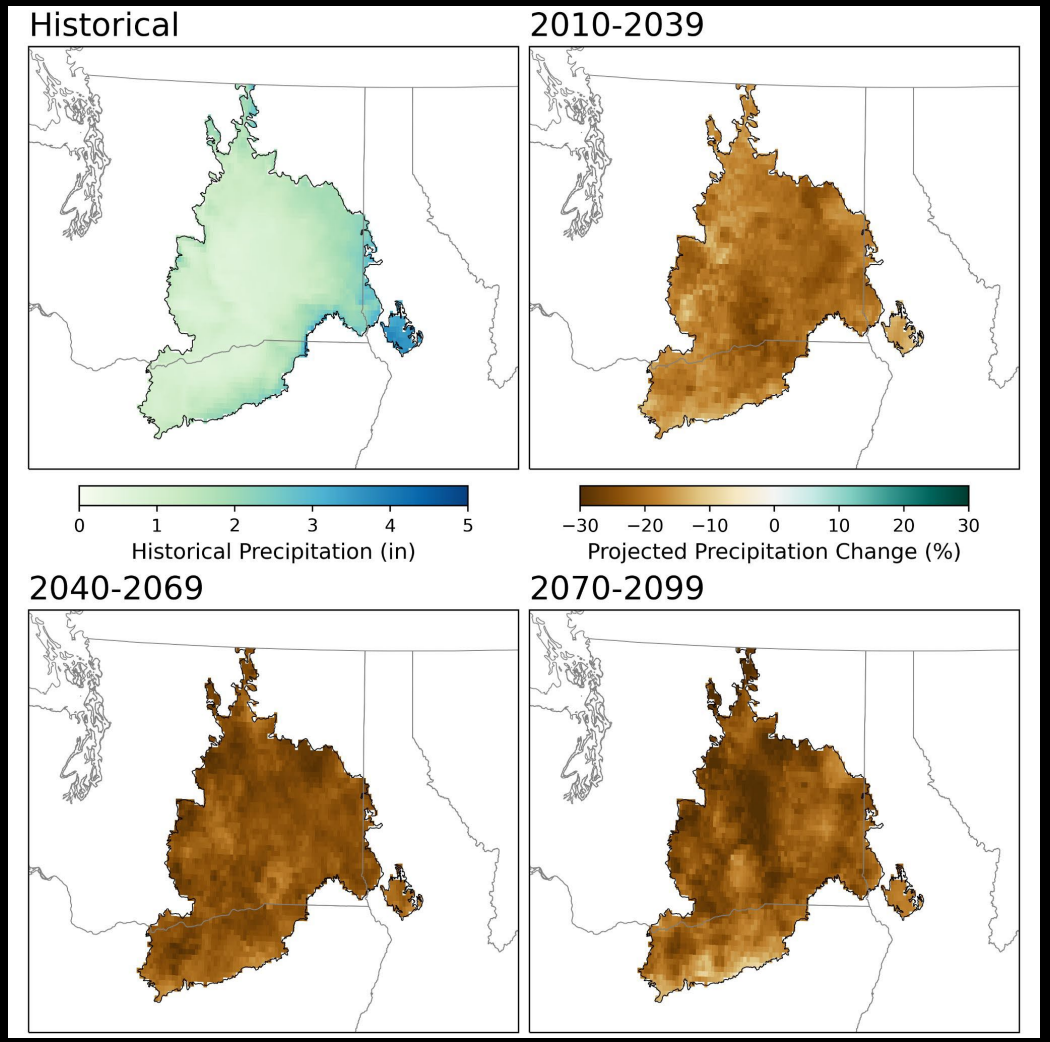
Big Leaf maple *(Acer macrophyllum)*



Douglas-Fir Beetle (*Dendroctonus pseudotsugae)*

Columbia Plateau



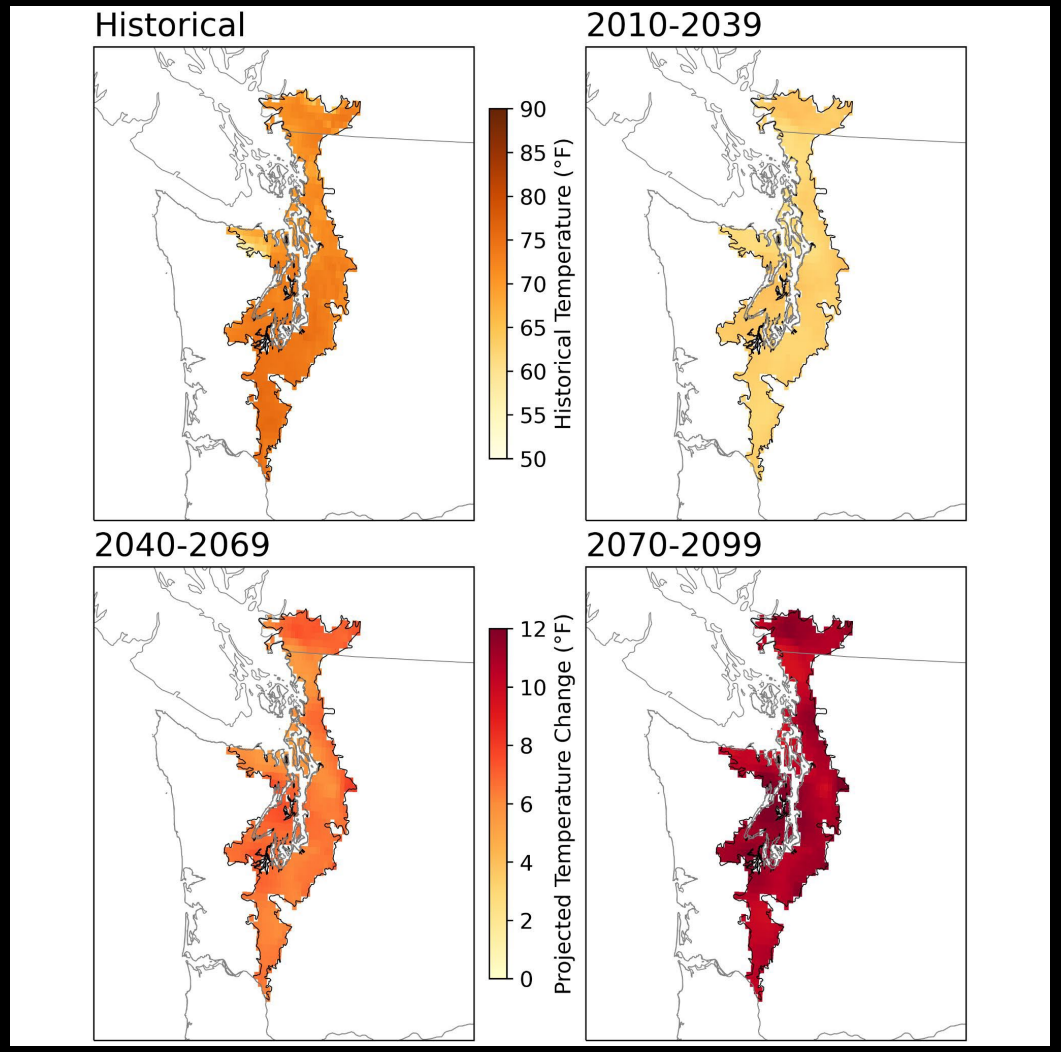


temperature

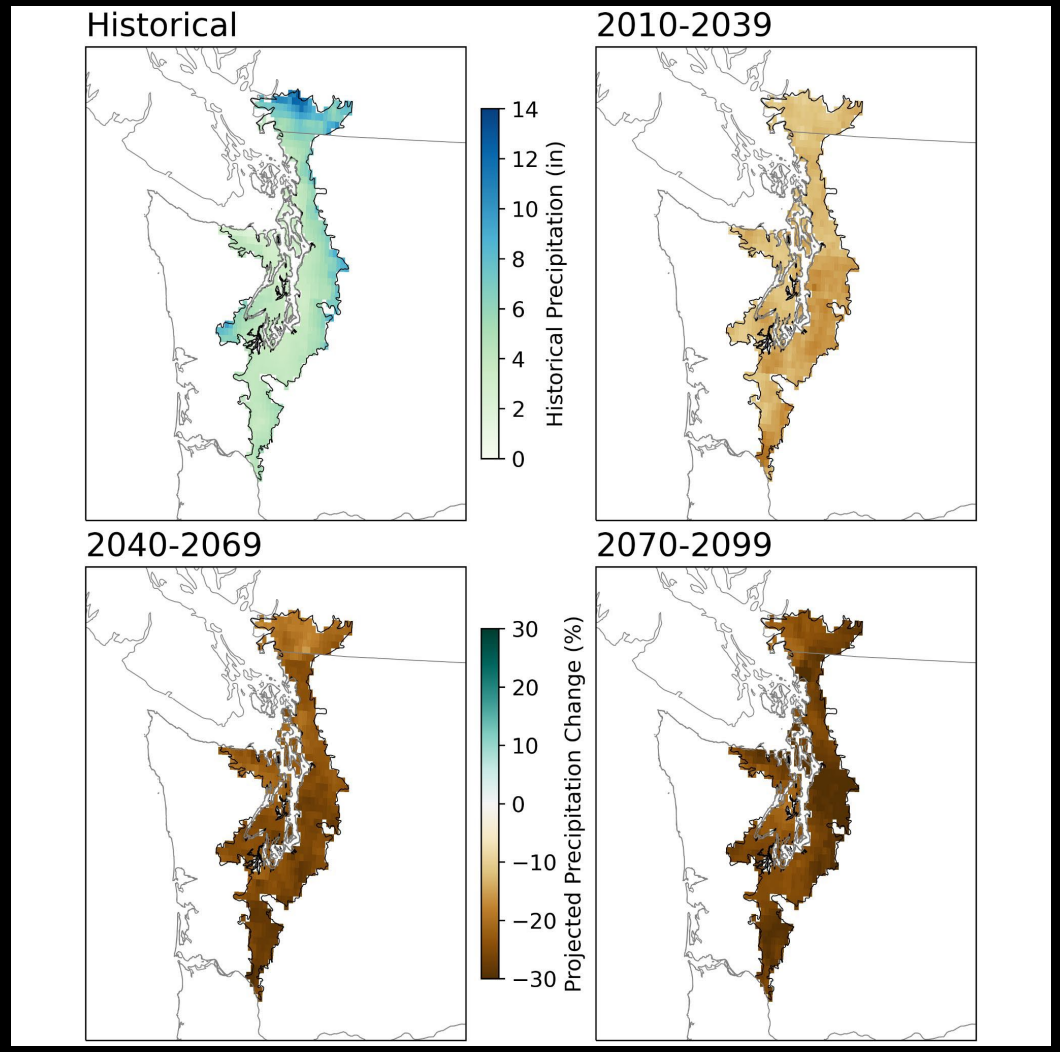
rainfall



Puget Lowlands



temperature



rainfall

Shift to Non-Forest Vegetation

Oak woodlands in this ecoregion have been in decline over the last century due to fire exclusion, removal of Indigenous Peoples and their burning practices, conifer encroachment, development and other widespread changes in land use. Oak species in the woodlands of this Puget Lowlands ecoregion are vulnerable to climate change due to high sensitivity to changing disturbance regimes (e.g., more severe fire), low adaptive capacity (e.g. limited dispersal ability due to land-use change and short annual dispersal distance), and vulnerability to invasive pathogens.



Bigleaf Maple Decline

Bigleaf Maple is thought to have low vulnerability to climate change because of overall low sensitivity to expected changes in the climate and high adaptive capacity.
However, recent declines in Bigleaf Maple in parts of its range suggest it may be more vulnerable than previously thought. Bigleaf Maple is showing evidence of decline (loss of vigor, loss of transpiration, reduced photosynthesis, leaf loss) that has been associated with warmer summers, in combination with development and urbanisation. These abiotic stressors are killing trees directly or predisposing trees to biotic agents.



Acer macrophyllum (Bigleaf Maple)

Summary and Conclusions

DIRECT EFFECTS OF CHANGES IN THE CLIMATE

The physiological sensitivity of forest vegetation to the direct effects of increasing temperatures and changes in precipitation patterns partially depends on species-specific vulnerability to climate change.

Climate change is affecting plant phenology primarily through earlier onset of spring phenological events, such as flowering and bud break, and delayed autumn phenological events, such as leaf colouring and senescence.

Forest ecosystems demonstrate varying sensitivity to ecological drought as a function of species-specific tolerance of dry conditions, stand composition, and landscape characteristic.

Globally, widespread tree mortality in response to drought and heat is well established. In the NW, recent ecological droughts have reduced forest productivity and tree growth, increased mortality rates, and contributed to diebacks and declines in some species.

The effect of higher atmospheric concentrations of carbon dioxide (CO 2) on forest productivity (i.e. CO 2 fertilisation) remains poorly understood; most evidence indicates that the increase is likely to be limited, site specific, and depend on available moisture and nutrients.

Regeneration and recruitment are sensitive life stages that will influence the trajectory of species range shifts and forest conversion to non-forest vegetation.

Climate change effects on recruitment processes will vary by forest type and the associated climatic factors that limit recruitment.

INDIRECT EFFECTS

Climate change will influence NW forest ecosystems indirectly by altering disturbance regimes.

CHANGES IN FIRE REGIMES

Climate change will promote wildfire activity in NW forests, but changes in fire regimes will be variable.

In forests where fire is limited by available fuel (dry warm forests and woodlands, mixed-conifer forests), climate change is highly likely to increase fire frequency, extent, and severity especially in the wildland-urban interface.

In forests where fire is limited by flammability (wet and cold forests), future fire activity is less certain due to limited historical data on fire-climate relationships.

Changing fire regimes are expected to alter postfire forest structure, composition and function. Fire effects will be compounded by legacies of past management, particularly in mixed-conifer forests where fire exclusion and suppression have led to anomalously high fuel amounts.

CHANGES IN INSECTS AND PLANT PATHOGENS

Climate change will alter the potential for biotic disturbance outbreaks in NW forests through interacting effects on both biotic agents and their host trees. Effects will vary by site, species and climate scenario.

Shifts in temperature and precipitation will affect the virulence of biotic agents directly through effects on fitness, fecundity and phenology. Adaptation to local conditions may limit the extent to which biotic agents can respond to climate variation.

Climate change will influence biotic outbreak dynamics indirectly by influencing host tree susceptibility to insects and plant pathogens.

CHANGES IN INVASIVE SPECIES DISTRIBUTION AND ABUNDANCE

Climate change will promote opportunities for expanded distribution, rate of spread and abundance of invasive species in NW forests.

Shifts in temperature and precipitation will have direct effects on invasive species via climate controls on physiology.

Increasing insect and plant pathogen activity will promote biotic disturbance hotspots — areas where multiple biotic disturbances overlap — with potential for compounded effects on forest recovery. Effects of biotic disturbance interactions depend on species, time since outbreak and outbreak severity and extent.

DISTURBANCE AND CLIMATE DRIVER INTERACTIONS

Interactions between direct and indirect climate effects will drive shifts in NW forest structure and function.

Climate conditions following disturbance can influence forest recovery through effects on regeneration processes.

VEGETATION RANGE SHIFTS

Changes in tree recruitment, growth, and mortality will culminate in changes in species dominance and composition and ultimately the distribution, or range, of some tree species. Species ranges are shifting in the NW due to the direct effects of changes in temperature, precipitation and atmospheric CO 2 on these demographic processes, catalysed by more frequent and severe disturbance.

Thanks for listening

